# Appendix G: Emission Inventory Development for Mobile Sources and Agricultural Dust Sources for the Central States (Sonoma Technology, Inc.)

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# EMISSION INVENTORY DEVELOPMENT FOR MOBILE SOURCES AND AGRICULTURAL DUST SOURCES FOR THE CENTRAL STATES

**DRAFT FINAL REPORT**
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## QUALITY ASSURANCE STATEMENT

**This report was reviewed and approved by the project Quality Assurance (QA) Officer or his delegated representatives, as provided in the project QA Plan (Sullivan, 2004).**

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# EXECUTIVE SUMMARY

The Central States Regional Air Planning Association (CENRAP) is researching visibility-related issues for its region and is developing a regional haze plan in response to the U.S. Environmental Protection Agency's (EPA) mandate to protect visibility in Class I areas. Mobile sources (both on- and off-road) and agricultural dust sources contribute to episodes of impaired visibility in the CENRAP region. Therefore, in support of the CENRAP's need to develop a regional haze plan, Sonoma Technology, Inc. (STI) developed emission inventories for on-road and off-road mobile sources and agricultural fugitive dust.

Appendix A, Emission Estimation Methods for Mobile Sources and Agricultural Dust Sources in the Central States, details the methods used throughout inventory development. Methods were based on EPA-accepted emissions models (e.g., NONROAD, SMOKE, and MOBILE6), emission factors gathered from EPA guidance documents or published literature, and geographic information systems (GIS) databases. Activity data sets were prepared using bottom-up methods or region-specific information whenever possible. Examples of bottom-up and region-specific data include the following:

- Facility-level estimates of cattle populations for confined animal feeding operations (CAFOs)
- Activity data gathered through telephone surveys to describe recreational boating and agricultural tilling activities
- Local activity data for commercial marine vessels and locomotives gathered directly from local agencies and industry sources, such as individual port operators and rail lines
- MOBILE6 inputs and vehicle activity data acquired from state and local information sources, including vehicle miles traveled (VMT), fleet characteristics, regulatory controls, and fuels characteristics (see Appendix C)
- Fuels characteristics acquired from state and local information sources and used as inputs for NONROAD 2004 when appropriate (see Appendix C)

**Figures ES-1 and ES-2** illustrate highlights of the resultant emission inventories for on-road mobile sources, non-road mobile sources, and agricultural fugitive dust. The inventories are also tabulated in Appendix B, provided in electronic form in Appendix D, and illustrated in greater detail throughout the body of the report. In many respects, the CENRAP inventories represent substantial improvements and differ significantly from existing inventories, such as the 1999 National Emissions Inventory (NEI) and preliminary 2002 NEI, which were prepared with default guidance, national average activity data, or top-down disaggregation techniques. Some of the most important improvements include the spatial and temporal allocations of the CENRAP inventories, which are more representative and could significantly enhance efforts to perform photochemical modeling. In addition, the use of bottom-up data will lend credibility to any scientific conclusions that may be based on the CENRAP's emission inventories.

Figure ES-1 compares the CENRAP inventory to the preliminary 2002 NEI. Emissions totals of selected pollutants are plotted for the entire CENRAP region. Large revisions to the region-wide annual emissions for specific source categories produced only minor *apparent*

changes in the region-wide annual totals for all source categories. However, the use of region-wide annual totals as the basis of comparison masks the importance of large changes in state-level inventories and spatial and temporal distributions. It also underrates the disproportionate influences of certain source types on visibility in Class I areas. Class I areas are often remote and far removed from the urban areas that contribute most to region-wide inventories. Sources that tend to concentrate away from urban areas—e.g., recreational boating, agricultural activities, etc.—are likely to affect visibility in Class I areas to a greater degree than might be expected if only the relative magnitudes of their emissions are considered.

The most significant revision to the $PM_{2.5}$ emission inventory—a 22% reduction in estimated annual emissions for agricultural fugitive dust sources—was due mostly to improvements in the activity data for tilling operations. As a result of this and other more modest revisions, total $PM_{2.5}$ emissions in the CENRAP inventory are 4% less than those estimated for the preliminary 2002 NEI. Annual $NO_x$ emissions from commercial marine vessels were estimated to be 69% less than those estimated for the preliminary 2002 NEI; and primarily as a result of this, total $NO_x$ emissions estimated for the CENRAP are 4% less than those recorded in the preliminary 2002 NEI. Annual VOC emissions estimated for the CENRAP were 8% greater than those estimated for the preliminary 2002 NEI—a difference mostly due to improved activity data for recreational boating. The CENRAP's VOC inventory for recreational boating is more than a factor of two larger than that incorporated in the preliminary 2002 NEI. Total $SO_x$ emissions estimated for the CENRAP are 2% less than those estimated for the preliminary 2002 NEI. This difference was due to the use of region-specific measurements of fuel sulfur contents rather than default guidance assumptions, and it corresponds primarily to 42% and 85% reductions in $SO_x$ emissions from commercial marine vessels and "other" non-road mobile sources, respectively.[1]

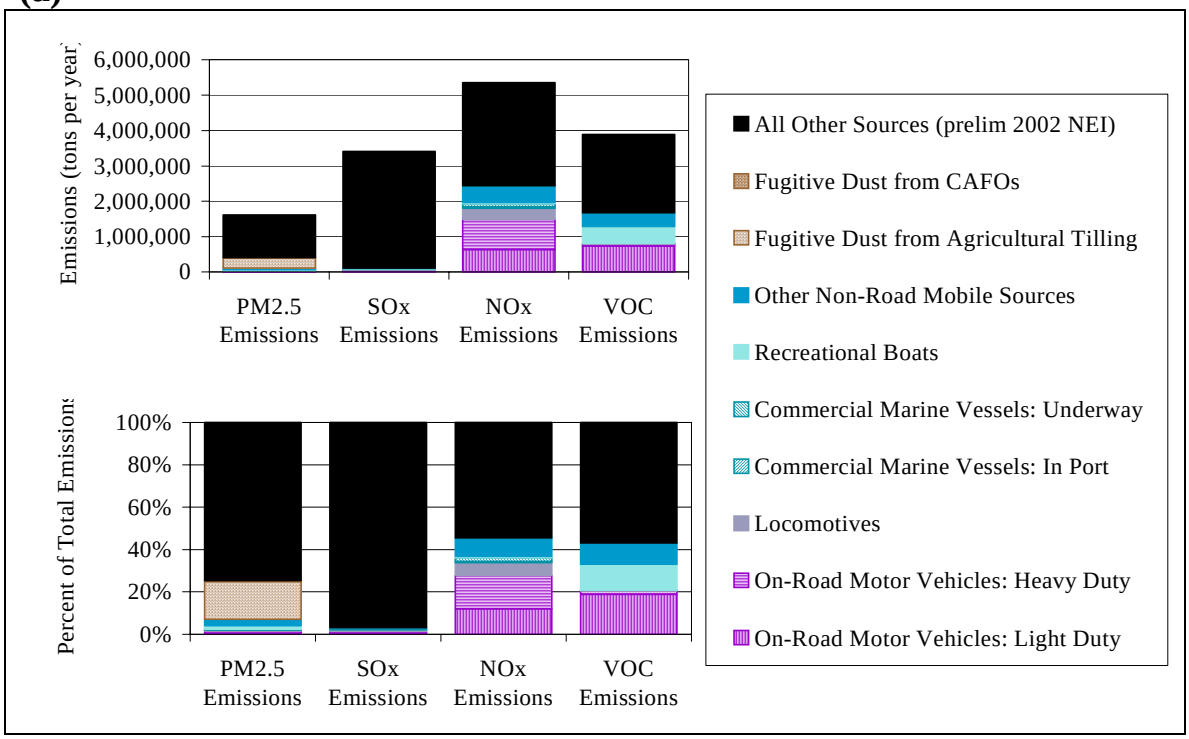
Figure ES-2 illustrates selected temporal profiles developed for or applied to the CENRAP inventories. Recent research has demonstrated that emissions from on-road mobile sources follow dramatically different patterns on weekend days than on weekdays, that patterns for light-duty vehicles are unique compared to those of heavy-duty vehicles, and that activities in rural areas differ from those in urban areas (Chinkin et al., 2003; Lawson, 2003; Croes et al., 2003). The CENRAP inventories reflect this latest understanding of weekday-weekend activity patterns for on-road mobile sources. The weekday-weekend activity patterns for recreational boating, which were based on surveys of representative groups of recreational boat owners in the CENRAP region, are even more dramatic than those of on-road mobile sources. Recreational boating activities tend to be extremely concentrated on weekends (whereas the reverse is true for on-road mobile sources and to a more moderate degree) and to vary diurnally and seasonally by type of boat and geographic area. Seasonal patterns for commercial marine vessels and agricultural tilling operations—also based on bottom-up data collection efforts—are related to the climates and crop types prevalent in different geographic areas.

In summary, the CENRAP inventories of mobile sources and agricultural fugitive dust are highly region-specific, or even county-specific, and adhere closely to EPA's recommended guidance for inventory development. Additional refinements and improvements should be

[1] "Other" non-road mobile sources include all non-road mobiles sources other than locomotives, commercial marine vessels, recreational boats, and aircraft.

incorporated as better information become available. Recommended areas for future efforts and further research include (1) development of information to support day-of-week inventories (i.e., Sunday, Monday, Tuesday, etc.), rather than weekday-weekend inventories; (2) development and/or acquisition of local data as they become available (e.g., metropolitan VMT data, fuels testing programs); (3) investigation of state motor vehicle departments' records of vehicle registrations, including duplicate records and unusual age distributions; (4) use of vehicle registration records to adjust and refine VMT distributions by vehicle type; (5) continuation of bottom-up activity data acquisition for additional types of non-road mobile sources and sources of agricultural fugitive dust (such as agricultural equipment, construction and mining equipment, recreational all-terrain vehicles (ATVs), lawn and garden equipment, cotton ginning operations, and/or crop transport); and (6) development of process-based methods or emission factors to improve inventories of agricultural fugitive dust emissions.

**(a)**




**(b)**

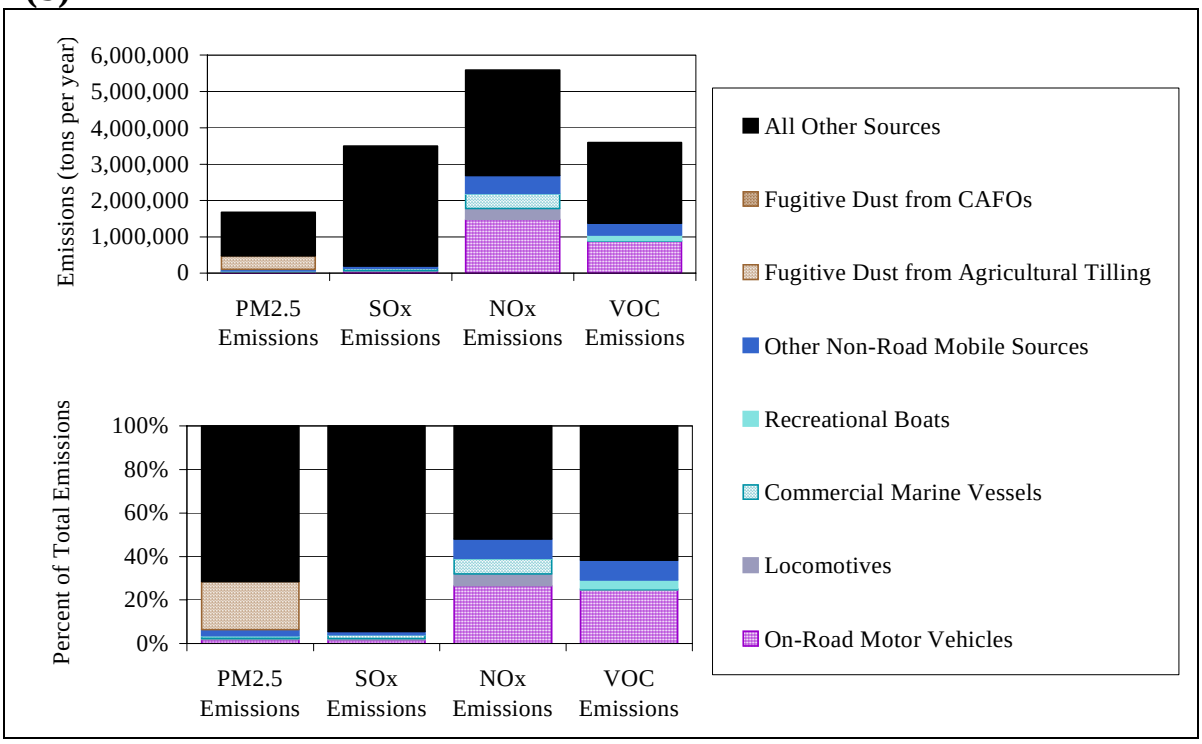



Figure ES-1. Annual emissions in the CENRAP region of selected pollutants as (a) calculated for the CENRAP for year 2002, and (b) recorded in the 1999 NEI or 2002 preliminary NEI.

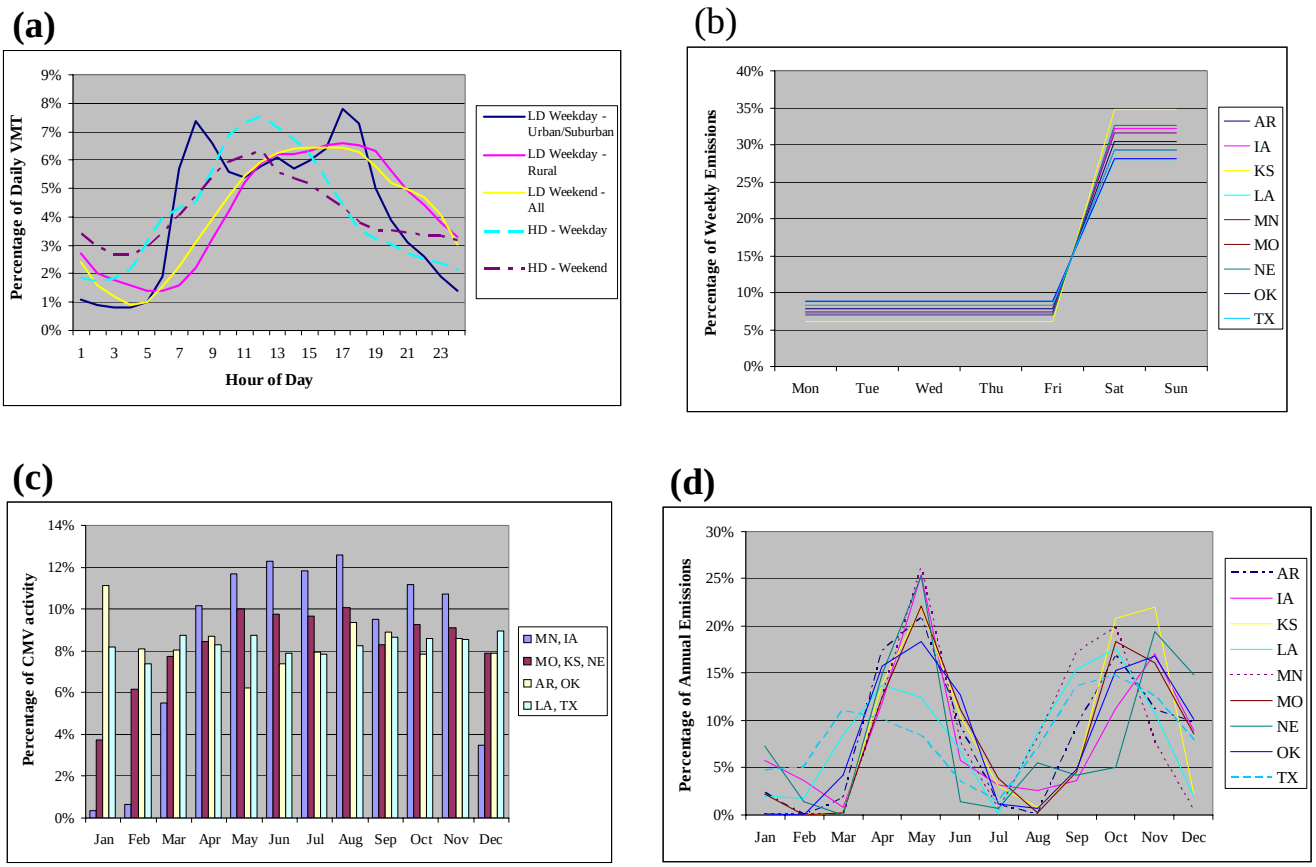



Figure ES-2. Selected temporal patterns, including (a) diurnal patterns for on-road mobile sources, (b) day-of-week patterns for recreational boats, (c) monthly patterns for commercial marine vessels by state, and (d) monthly patterns for agricultural tilling dust.

# 1. INTRODUCTION

The Central States Regional Air Planning Association (CENRAP) is developing a regional haze plan in response to the U.S. Environmental Protection Agency's (EPA) mandate to protect visibility in Class I areas.[2] To develop an effective regional haze plan, the CENRAP ultimately must develop a conceptual model of the phenomena that lead to episodes of low visibility in the CENRAP region. Thus, the CENRAP is researching visibility-related issues for its region, which includes Texas, Oklahoma, Louisiana, Arkansas, Kansas, Missouri, Nebraska, Iowa, and Minnesota. Both primary particulate matter (which is emitted directly to the atmosphere in particulate form) and the formation of secondary particulate matter (which is generated from chemical transformations in the atmosphere of gaseous precursor species such as ammonia, nitrogen oxides, sulfur oxides, and volatile organic compounds) contribute to regional haze issues in the CENRAP region. In recognition of these issues, the CENRAP sponsored the development of improved emission inventories for mobile sources and sources of agricultural dust.

In support of the CENRAP's need to develop a regional haze plan, Sonoma Technology, Inc. (STI) conducted CENRAP Work Assignment Number 03-0214-RP-003-004, "Mobile Source and Agricultural Dust Emission Inventory Development for the Central States." Consistent with the project goals presented in the Work Plan and Methods Document (Sullivan, 2004; Reid et al., 2004b), emissions were calculated for on-road mobile sources, off-road mobile sources, and sources of fugitive agricultural dust throughout the CENRAP region. Bottom-up or region-specific activity data were developed to model emissions from these source categories. These data were developed for compatibility with the MOBILE6 and NONROAD models; SMOKE 1.5 (which runs MOBILE6 internally); and the latest version of the National Emission Inventory Input Format (NIF).

## 1.1 BACKGROUND AND KEY ISSUES

### 1.1.1 Prior Status of the Emission Inventories

As a whole, few areas of the CENRAP region have experienced significant air quality problems in the past. Therefore, emission inventories and regionally representative activity data are relatively incomplete or scarce. In most areas of the CENRAP, existing emission inventories are based on the EPA's nationally representative defaults, which could be greatly improved with local or region-specific data, such as region-specific or state-specific fleet characteristics and improved vehicle miles traveled (VMT) estimates for rural areas. Prior to the completion of this project, the most comprehensive source of emissions estimates available for the CENRAP region was the EPA's National Emissions Inventory (NEI), which is used as the basis of the EPA's National Emission Trends (NET) document series and analyses (U.S. Environmental Protection Agency, 2003a, 2004a). In the NEI, estimates of emissions from mobile sources and sources of agricultural dust in the CENRAP region amount to 4% to 49% of the total inventories of nitrogen

[2] Class I areas include national parks, wilderness areas, and national monuments. These areas have been granted special air quality protections under the federal Clean Air Act.

oxides ($NO_x$), volatile organic compounds (VOC), particulate matter of 2.5 microns aerodynamic diameter or less ($PM_{2.5}$), sulfur dioxide ($SO_2$), and ammonia ($NH_3$) for the region (see **Table 1-1**). The NEI indicates that fugitive dust from agricultural tilling operations is a significant $PM_{2.5}$ source, particularly in of Iowa, Kansas, and Nebraska. Mobile sources are a significant source of $NO_x$ and VOC, particularly in Minnesota and Missouri.

The most significant sources of uncertainties in the NEI are associated with the national-scale representativeness and top-down methods that were applied to generate the inventory (approaches that were dictated by resource constraints). The results of this project substantially address these weaknesses of the NEI for the CENRAP region. As a result, the emission inventories produced through this project differ significantly from the emissions estimates in the NEI in a number of areas.

Table 1-1. Estimates of emissions in the CENRAP region from the preliminary 2002 NEI (U.S. Environmental Protection Agency, 2004a).



| State | $NO_x$ | | VOC | | $PM_{25}$ | | $SO_2$ | | $NH_3$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | tons/year | percent | tons/year | percent | tons/year | percent | tons/year | percent | tons/year | percent |
| Arkansas | | | | | | | | | | |
| On-road Mobile | 88,781 | 38% | 49,525 | 9% | 1,869 | 2% | 3,610 | 2% | 3,005 | 2% |
| Non-road Mobile | 63,117 | 27% | 30,343 | 5% | 4,068 | 5% | 6,665 | 3% | 41 | 0% |
| Ag Dust (Tilling) | 0 | 0% | 0 | 0% | 26,577 | 32% | 0 | 0% | 0 | 0% |
| Stationary Sources | 83,253 | 35% | 484,229 | 86% | 50,494 | 61% | 201,450 | 95% | 129,188 | 98% |
| All Sources | 235,151 | 100% | 564,098 | 100% | 83,008 | 100% | 211,725 | 100% | 132,234 | 100% |
| Iowa | | | | | | | | | | |
| On-road Mobile | 91,840 | 29% | 50,816 | 23% | 1,894 | 2% | 3,520 | 1% | 3,065 | 1% |
| Non-road Mobile | 85,277 | 27% | 34,771 | 16% | 7,125 | 6% | 8,735 | 4% | 77 | 0% |
| Ag Dust (Tilling) | 0 | 0% | 0 | 0% | 53,054 | 44% | 0 | 0% | 0 | 0% |
| Stationary Sources | 135,678 | 43% | 135,757 | 61% | 57,649 | 48% | 233,916 | 95% | 223,502 | 99% |
| All Sources | 312,796 | 100% | 221,344 | 100% | 119,722 | 100% | 246,171 | 100% | 226,644 | 100% |
| Kansas | | | | | | | | | | |
| On-road Mobile | 82,475 | 23% | 48,692 | 25% | 1,680 | 1% | 3,192 | 2% | 2,889 | 2% |
| Non-road Mobile | 81,868 | 23% | 24,426 | 13% | 6,048 | 4% | 7,598 | 5% | 65 | 0% |
| Ag Dust (Tilling) | 0 | 0% | 0 | 0% | 67,217 | 42% | 0 | 0% | 0 | 0% |
| Stationary Sources | 198,667 | 55% | 120,478 | 62% | 85,377 | 53% | 146,752 | 93% | 135,475 | 98% |
| All Sources | 363,010 | 100% | 193,595 | 100% | 160,322 | 100% | 157,542 | 100% | 138,429 | 100% |
| Louisiana | | | | | | | | | | |
| On-road Mobile | 119,067 | 16% | 72,130 | 22% | 2,488 | 2% | 4,868 | 1% | 4,220 | 6% |
| Non-road Mobile | 230,407 | 31% | 55,827 | 17% | 11,342 | 10% | 33,028 | 9% | 52 | 0% |
| Ag Dust (Tilling) | 0 | 0% | 0 | 0% | 12,649 | 11% | 0 | 0% | 0 | 0% |
| Stationary Sources | 398,375 | 53% | 193,623 | 60% | 87,899 | 77% | 347,159 | 90% | 61,320 | 93% |
| All Sources | 747,849 | 100% | 321,581 | 100% | 114,379 | 100% | 385,054 | 100% | 65,591 | 100% |
| Minnesota | | | | | | | | | | |
| On-road Mobile | 153,145 | 35% | 87,926 | 23% | 3,010 | 2% | 4,168 | 3% | 5,482 | 3% |
| Non-road Mobile | 113,288 | 26% | 97,023 | 25% | 9,469 | 5% | 12,395 | 8% | 99 | 0% |
| Ag Dust (Tilling) | 0 | 0% | 0 | 0% | 50,009 | 25% | 0 | 0% | 0 | 0% |
| Stationary Sources | 171,536 | 39% | 196,362 | 51% | 136,045 | 69% | 135,908 | 89% | 160,447 | 97% |
| All Sources | 437,969 | 100% | 381,311 | 100% | 198,534 | 100% | 152,471 | 100% | 166,028 | 100% |

Table 1-1. Estimates of emissions in the CENRAP region from the preliminary 2002 NEI (U.S. Environmental Protection Agency, 2004a).



| State | $NO_x$ | | VOC | | $PM_{25}$ | | $SO_2$ | | $NH_3$ | |
|---|---|---|---|---|---|---|---|---|---|---|
| | tons/year | percent | tons/year | percent | tons/year | percent | tons/year | percent | tons/year | percent |
| Missouri | | | | | | | | | | |
| On-road Mobile | 188,404 | 36% | 109,927 | 31% | 3,877 | 2% | 6,845 | 2% | 6,958 | 6% |
| Non-road Mobile | 117,011 | 22% | 55,279 | 15% | 7,363 | 4% | 12,034 | 3% | 71 | 0% |
| Ag Dust (Tilling) | 0 | 0% | 0 | 0% | 27,251 | 14% | 0 | 0% | 0 | 0% |
| Stationary Sources | 216,722 | 42% | 193,867 | 54% | 163,294 | 81% | 353,408 | 95% | 112,354 | 94% |
| All Sources | 522,137 | 100% | 359,073 | 100% | 201,784 | 100% | 372,287 | 100% | 119,383 | 100% |
| Nebraska | | | | | | | | | | |
| On-road Mobile | 55,284 | 25% | 31,291 | 24% | 1,131 | 1% | 2,094 | 2% | 1,850 | 1% |
| Non-road Mobile | 89,946 | 41% | 18,882 | 15% | 5,323 | 5% | 7,394 | 8% | 49 | 0% |
| Ag Dust (Tilling) | 0 | 0% | 0 | 0% | 38,068 | 38% | 0 | 0% | 0 | 0% |
| Stationary Sources | 73,046 | 33% | 77,809 | 61% | 55,683 | 56% | 83,563 | 90% | 133,536 | 99% |
| All Sources | 218,276 | 100% | 127,982 | 100% | 100,204 | 100% | 93,051 | 100% | 135,435 | 100% |
| Oklahoma | | | | | | | | | | |
| On-road Mobile | 126,710 | 30% | 77,579 | 30% | 2,615 | 2% | 5,756 | 3% | 4,468 | 4% |
| Non-road Mobile | 51,962 | 12% | 30,513 | 12% | 3,940 | 3% | 4,736 | 2% | 45 | 0% |
| Ag Dust (Tilling) | 0 | 0% | 0 | 0% | 27,732 | 19% | 0 | 0% | 0 | 0% |
| Stationary Sources | 242,264 | 58% | 150,107 | 58% | 111,473 | 76% | 182,502 | 95% | 110,303 | 96% |
| All Sources | 420,937 | 100% | 258,199 | 100% | 145,759 | 100% | 192,994 | 100% | 114,815 | 100% |
| Texas | | | | | | | | | | |
| On-road Mobile | 577,082 | 25% | 349,211 | 30% | 11,778 | 2% | 23,343 | 1% | 22,340 | 7% |
| Non-road Mobile | 377,155 | 16% | 153,570 | 13% | 21,998 | 4% | 42,373 | 3% | 210 | 0% |
| Ag Dust (Tilling) | 0 | 0% | 0 | 0% | 67,342 | 12% | 0 | 0% | 0 | 0% |
| Stationary Sources | 1,377,264 | 59% | 661,726 | 57% | 453,992 | 82% | 1,622,787 | 96% | 278,886 | 93% |
| All Sources | 2,331,502 | 100% | 1,164,507 | 100% | 555,111 | 100% | 1,688,503 | 100% | 301,436 | 100% |
| All States | | | | | | | | | | |
| On-road Mobile | 1,482,789 | 27% | 877,097 | 24% | 30,342 | 2% | 57,397 | 2% | 54,277 | 4% |
| Non-road Mobile | 1,210,032 | 22% | 500,634 | 14% | 76,677 | 5% | 134,957 | 4% | 708 | 0% |
| Ag Dust (Tilling) | 0 | 0% | 0 | 0% | 369,899 | 22% | 0 | 0% | 0 | 0% |
| Stationary Sources | 2,896,806 | 52% | 2,213,958 | 62% | 1,201,905 | 72% | 3,307,446 | 95% | 1,345,010 | 96% |
| All Sources | 5,589,626 | 100% | 3,591,689 | 100% | 1,678,823 | 100% | 3,499,799 | 100% | 1,399,995 | 100% |

### 1.1.2 Current Status of the CENRAP Emission Inventories

As detailed in the attached Methods Document (Appendix A), emissions estimates were prepared for mobile sources and sources of agricultural dust throughout the CENRAP region. These emission inventories were prepared with EPA-accepted emissions models (e.g., NONROAD, SMOKE, and MOBILE6), emission factors gathered from EPA guidance documents or published literature, and geographic information systems (GIS) databases of land cover. All activity data sets were prepared using bottom-up methods or region-specific information whenever possible.

The MOBILE6 emissions model, the EPA's approved emission factor model for on-road mobile sources, was operated within SMOKE 1.5 to produce emission factors for January and July at the county level. Spatially and temporally distributed MM5 temperature fields for each day in January and July 2002 were averaged and used as inputs for these MOBILE6 runs so that outputs would represent an entire month rather than a specific episode date. The MOBILE6 outputs were matched with region-specific, county-level estimates of VMT, which also were distributed seasonally and by day of week according to temporal profiles, to estimate county-level emissions for the winter and summer runs. January and July emissions were averaged to estimate annual emissions at the county level. MOBILE6 inputs were prepared at the county level to represent region-specific fleet distributions, fuels characteristics (which can also vary by season), and local regulations (e.g., inspection and maintenance programs, etc.).

The latest version of the NONROAD emissions model (NONROAD 2004), the EPA's approved emission factor model for most off-road mobile sources, was used to produce emissions estimates at the county level for most off-road sources. In addition, EPA guidance documents were consulted for emissions estimation methods for locomotives and commercial marine vessels (U.S. Environmental Protection Agency, 1999c, 1998b, 2000, 2003b, 1999a, 1997, 1992). Bottom-up activity data were gathered for recreational boats, locomotives, and commercial marine vessels—considered to be the most important or uncertain off-road mobile sources affecting regional haze in the CENRAP region. For other source categories, NONROAD default activity data were used in conjunction with region-specific fuels information to estimate emissions. Emissions from aircraft were considered to be a lower priority than other nonroad mobile sources and were not included in the scope of this project.

The Emission Inventory Improvement Program and recent research findings from the University of California at Davis and Texas A&M University were consulted for emission factors and emissions estimation methods for agricultural fugitive dust sources (U.S. Environmental Protection Agency, 2004b; Goodrich et al., 2002; Flocchini and James, 2001). County-level annual emission inventories were prepared for agricultural tilling operations and confined animal feeding operations (CAFOs). Bottom-up activity data included facility-specific animal populations developed for CAFOs in the CENRAP region (Coe and Reid, 2003), agricultural tilling activity information developed through systematic telephone surveys of county agricultural extension services (AES) throughout the CENRAP region (Reid et al., 2004a), and county-level estimates of crop-acreages in 2002 from the National Agricultural Statistics Service (NASS).

The resulting emission inventories are illustrated in **Figures 1-1 through 1-6** and tabulated in Appendix B. In all cases, the inventories were based on generally accepted emission factors and the most complete and up-to-date activity data sets that could be identified and acquired. However, we recognize that available emission factors are uncertain and continue to be the subject of research. In anticipation of future efforts to improve emissions estimation techniques and to further develop or improve the CENRAP's inventories, the deliverables of this project include systems of data files that can be updated with revised emission factors, activity data, and/or emissions estimates as new information becomes available (see Appendix D).

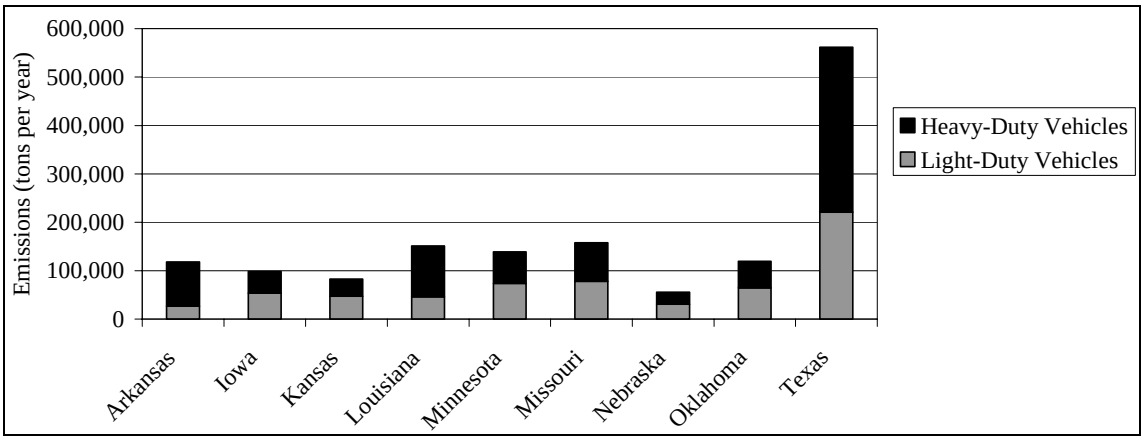



Figure 1-1. Year-2002 emissions of $NO_x$ from on-road mobile sources in the CENRAP region.

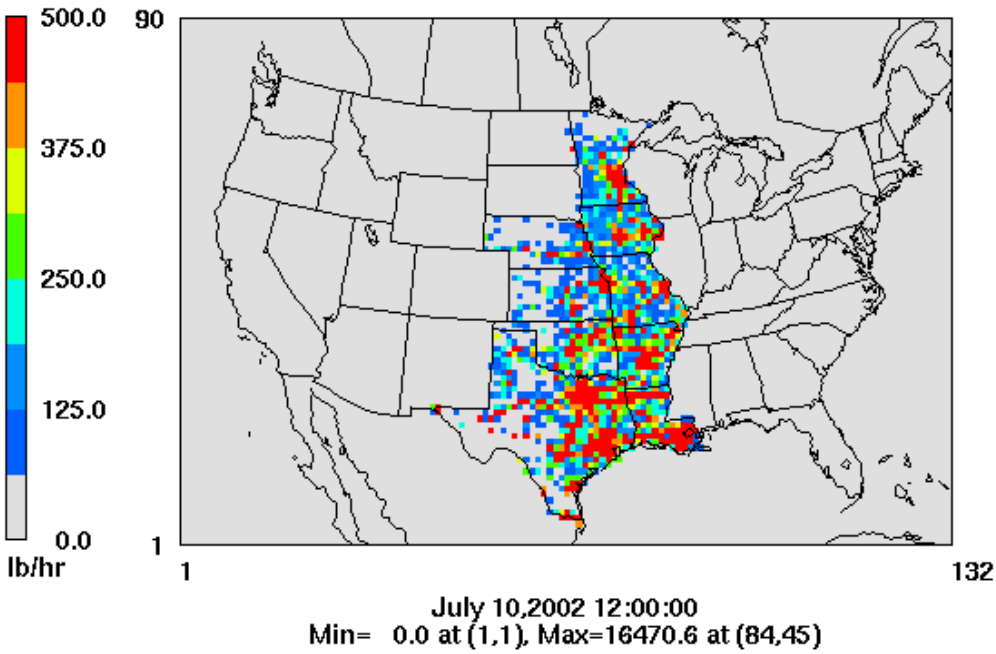



Figure 1-2. Geographic distribution of on-road mobile source emissions of $NO_x$ in the CENRAP states on July 10, 2002.

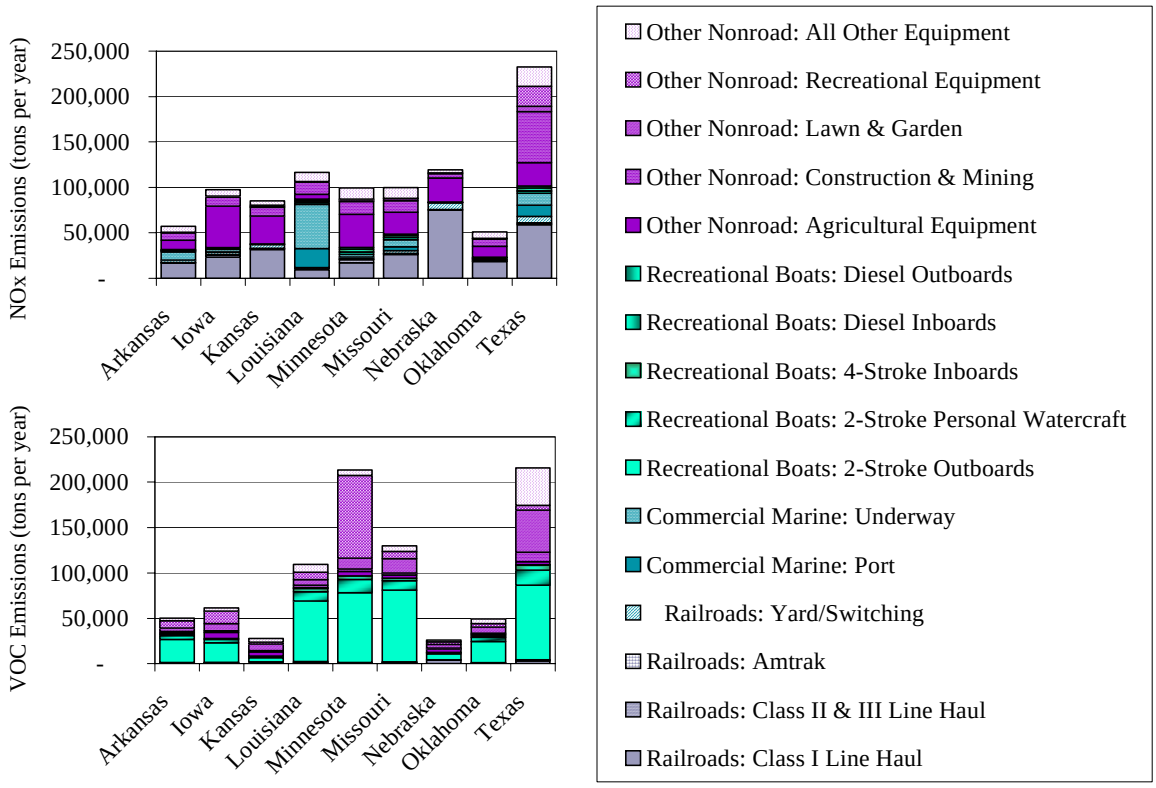



Figure 1-3. Year-2002 emissions of $NO_x$ and VOC from non-road mobile sources in the CENRAP region.

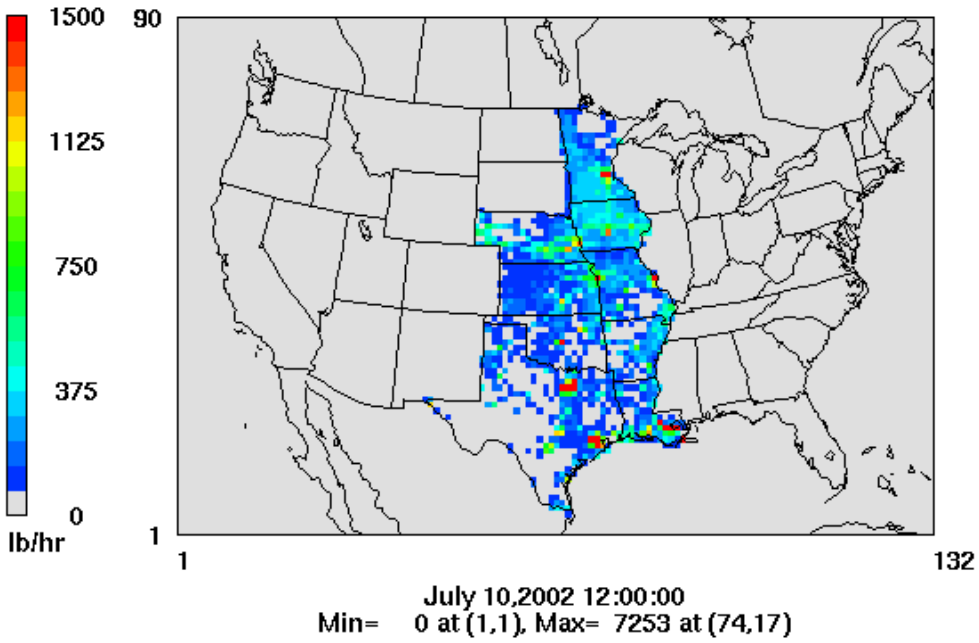



Figure 1-4. Geographic distribution of non-road mobile source $NO_x$ in the CENRAP states on July 10, 2002.

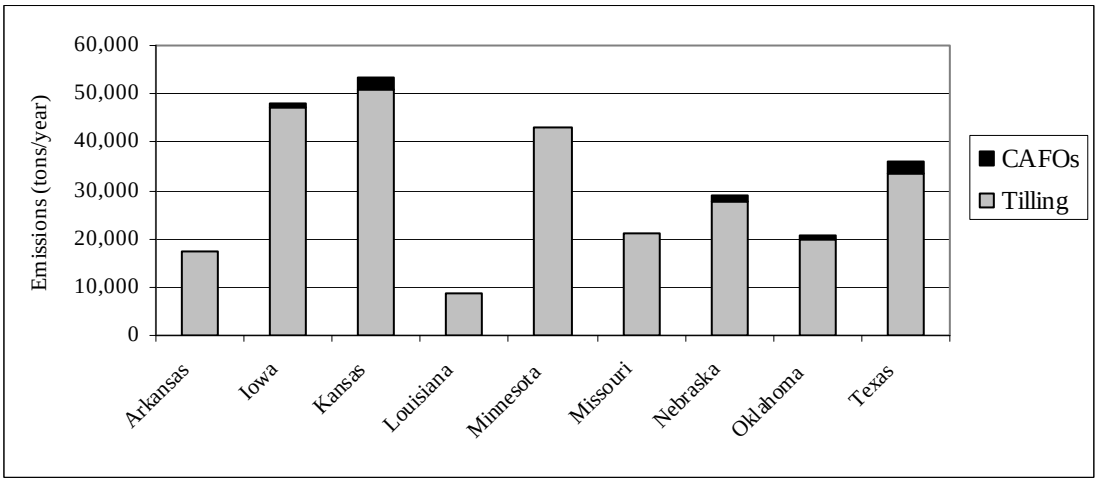



Figure 1-5. Year-2002 emissions of $PM_{2.5}$ from sources of fugitive agricultural dust in the CENRAP region.

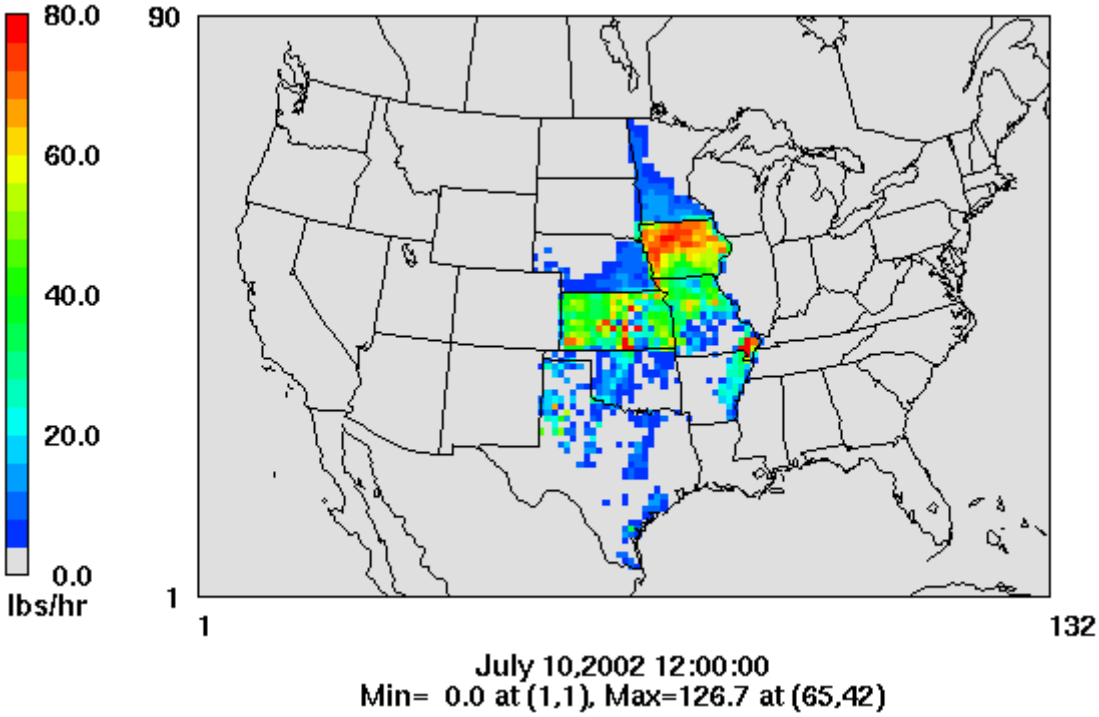



Figure 1-6. Geographic distribution of $PM_{2.5}$ emissions from sources of agricultural fugitive dust in the CENRAP states on July 10, 2002.

Of the mobile and agricultural fugitive dust sources discussed throughout this report, those that we qualitatively consider to contribute the greatest degrees of uncertainty to the emissions for the CENRAP region are agricultural fugitive dust sources and "other" non-road mobile sources.[3] The most effective strategies to improve these components of the inventory in the future would be to develop process-based emissions estimation techniques for agricultural fugitive dust sources and to prioritize and gather bottom-up activity data for "other" non-road mobile sources (as was done through this project for recreational boating). These recommendations are discussed in more detail in Section 3.

[3] "Other" non-road mobile sources include all non-road mobiles sources other than locomotives, commercial marine vessels, recreational boats, and aircraft.

# 2. SUMMARY AND ASSESSMENT OF THE INVENTORIES

STI calculated emissions as detailed in Appendix A, Emission Estimation Methods for Mobile Sources and Agricultural Dust Sources in the Central States, with results tabulated in Appendix B, Annual Emissions by State and Source Category. In addition, STI carried out quality assurance procedures as provided in the Quality Assurance Project Plan (QAPP) (Sullivan, 2004) and as detailed in this section. In summary, emissions from on-road mobile sources were estimated to contribute 20% and 28% of total annual emissions of VOCs and $NO_x$ in the CENRAP region, while non-road mobile sources were estimated to contribute 23% and 18%, respectively. Agricultural dust sources were estimated to contribute 17% of total annual $PM_{2.5}$ emissions. Emissions for many of these source categories vary seasonally, daily, and hourly. Emissions of $NO_x$ and VOC from on-road mobile sources peak in the summer with somewhat increased vehicle activity (VMT); however, emissions of CO from on-road mobile sources peak in the winter due to colder ambient temperatures. In addition, diurnal and day-of-week patterns of emissions from on-road mobile sources vary. On-road mobile emissions are generally greater on weekdays than on weekend days; and weekday driving activities track the morning and afternoon commute patterns, while weekend driving activities do not. The variation of seasonal, diurnal, and day-of-week patterns for recreational boats is even more pronounced than that for on-road mobile sources. Emissions from recreational boats are highly concentrated in the summer months (except in the warmest, most southern states) and on weekend days. Recreational boating activities peak sharply between 0700 and 1000 and decline gradually throughout the day. Emissions from commercial marine vessels also follow a seasonal pattern (except in the warmest, most southern states). Emissions from locomotives vary minimally or negligibly by season, day of week, and hour of day. Emissions from agricultural tilling operations follow seasonal patterns that are unique to each state and dependent on the climatic conditions and types of crops grown in each state.

## 2.1 EMISSIONS FROM ON-ROAD MOBILE SOURCES

### 2.1.1 Summary of Emissions from On-Road Mobile Sources

Over 525 billion VMT were estimated to have occurred in 2002 in the CENRAP region, with consequent emissions as shown in **Table 2-1** and **Figure 2-1**. **Figure 2-2** illustrates the geographic distribution of on-road mobile source emissions for a selected date.

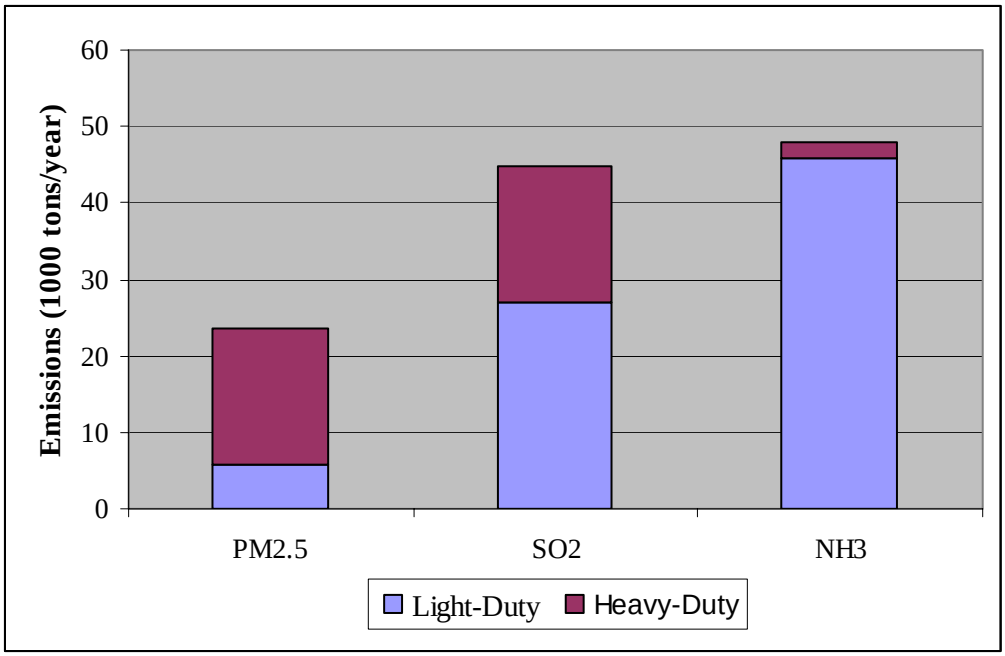
Appendix C provides graphical and tabular summaries of the activity data that were prepared for the emission inventories of on-road mobile sources, including VMT, fleet distributions, fuels characteristics, and regulatory controls. Whenever possible, VMT were acquired from local air quality agencies or metropolitan planning organizations and HPMS data were used as defaults for areas without local VMT estimates. VMT data were provided by local agencies for approximately 25% of the counties in the CENRAP region, while the remainder are from the HPMS data. Areas that were able to provide local estimates of VMT included Houston/Galveston, Texas; Beaumont/Port Arthur, Texas; Dallas-Ft. Worth, Texas; Baton Rouge, Louisiana; New Orleans, Louisiana; St. Louis, Missouri; and Lincoln, Nebraska. Metropolitan areas that have recently produced local estimates of VMT (or will do so very

shortly) include Kansas City, Minneapolis-St. Paul, and Little Rock. In the future, these locally generated VMT estimates should be used to improve the emission inventories for the CENRAP region.

Fleet distributions were developed by acquiring records of vehicle registrations from the departments of motor vehicles in each CENRAP state. These records were decoded using the Eastern Research Group (ERG) Vehicle Identification Number (VIN) Decoder program. Fleet distributions by vehicle type, vehicle age, and fuel type were calculated on the basis of the ERG VIN Decoder outputs. In several states, the fleet distributions differed significantly from national average distributions, which correspond to MOBILE6 model defaults.

Table 2-1. 2002 VMT and emissions (tons) for on-road mobile sources in CENRAP states.

| State | Annual VMT ($10^6$ miles) | $PM_{2.5}$ | CO | $NO_x$ | $SO_2$ | $NH_3$ | VOC |
|---|---|---|---|---|---|---|---|
| Arkansas | | | | | | | |
| Light-Duty | 19,224 | 235 | 502,991 | 27,137 | 1,383 | 1,971 | 29,752 |
| Heavy-Duty | 9,955 | 2,076 | 102,247 | 90,833 | 2,163 | 313 | 9,786 |
| Iowa | | | | | | | |
| Light-Duty | 27,664 | 381 | 973,854 | 53,702 | 2,113 | 2,755 | 67,501 |
| Heavy-Duty | 3,701 | 931 | 30,853 | 44,607 | 884 | 107 | 2,993 |
| Kansas | | | | | | | |
| Light-Duty | 25,424 | 345 | 930,039 | 47,210 | 1,938 | 2,528 | 61,867 |
| Heavy-Duty | 3,401 | 855 | 29,686 | 35,520 | 758 | 98 | 2,979 |
| Louisiana | | | | | | | |
| Light-Duty | 34,246 | 416 | 824,585 | 45,929 | 2,396 | 3,485 | 57,283 |
| Heavy-Duty | 9,049 | 2,272 | 74,770 | 105,449 | 2,257 | 263 | 7,361 |
| Minnesota | | | | | | | |
| Light-Duty | 46,880 | 595 | 1,285,076 | 73,656 | 1,274 | 4,771 | 75,663 |
| Heavy-Duty | 6,271 | 1,577 | 43,160 | 65,290 | 1,314 | 182 | 5,255 |
| Missouri | | | | | | | |
| Light-Duty | 53,030 | 680 | 1,375,126 | 77,916 | 3,120 | 5,356 | 76,004 |
| Heavy-Duty | 7,238 | 1,841 | 52,065 | 79,607 | 1,787 | 209 | 5,491 |
| Nebraska | | | | | | | |
| Light-Duty | 15,957 | 246 | 581,402 | 30,649 | 1,229 | 1,581 | 38,788 |
| Heavy-Duty | 2,449 | 624 | 18,626 | 25,037 | 589 | 71 | 2,115 |
| Oklahoma | | | | | | | |
| Light-Duty | 39,569 | 509 | 1,194,649 | 64,504 | 2,989 | 3,968 | 81,676 |
| Heavy-Duty | 5,293 | 1,331 | 48,382 | 54,812 | 1,265 | 154 | 5,062 |
| Texas | | | | | | | |
| Light-Duty | 190,132 | 2,339 | 3,653,523 | 220,819 | 10,555 | 19,365 | 248,680 |
| Heavy-Duty | 25,989 | 6,276 | 113,949 | 340,992 | 6,667 | 692 | 14,057 |
| Total | 525,473 | 23,529 | 11,834,984 | 1,483,668 | 44,678 | 47,870 | 792,310 |



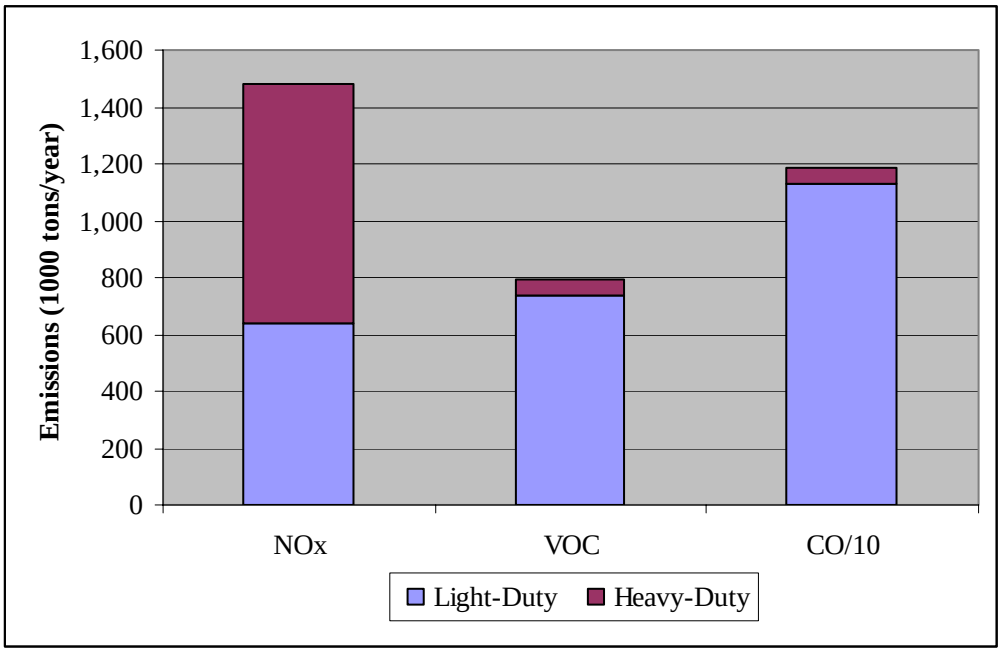




Figure 2-1. Annual on-road mobile emissions by pollutant and vehicle type (note: CO emissions have been divided by 10 for scaling purposes).

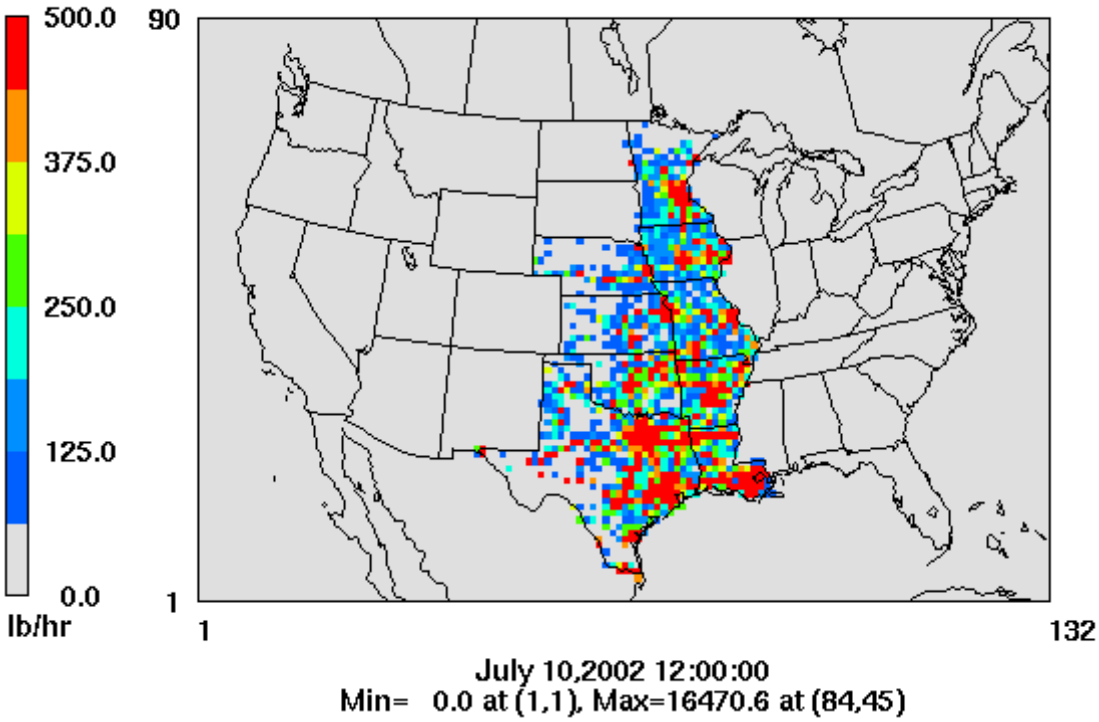



Figure 2-2. Geographic distribution of on-road mobile source emissions of $NO_x$ in the CENRAP states on July 10, 2002.

Fuels characteristics (e.g., sulfur content, volatility, and oxygenate content) required by MOBILE6 were acquired for most CENRAP states from Northrop Grumman. However, for Kansas, Minnesota, and Missouri, data from state departments of agriculture were used because they proved to be more extensive than the Northrop Grumman data. Information on regulatory programs (such as inspection and maintenance programs) was acquired by contacting the state and local personnel involved with these programs.

MOBILE6 was run in SMOKE using gridded, hourly temperature data from meteorological files created by the Meteorology Chemistry Interface Processor (MCIP), a mesoscale model (MM5) post-processing program. Meteorological data files for all of January and July, 2002 were provided by the CENRAP Modeling Work Group, and these files were used to derive monthly average temperatures by hour so that MOBILE6 runs would be representative of entire months rather than specific episode dates.

On-road mobile source emissions were temporally allocated using temporal profiles derived from a variety of sources (see **Figures 2-3 through 2-5**). The monthly profiles for light-duty vehicles and heavy-duty vehicles were derived from national-level sales of gasoline and diesel fuels during 2002 (Energy Information Administration, 2003). SMOKE default weekly temporal profiles were used for light-duty vehicles because they were considered to be consistent with the latest research on weekday-weekend activity patterns. The weekly profile for heavy-duty vehicles was derived from traffic counts conducted in California's South Coast Air Basin

(Coe et al., 2004). County-specific data obtained from the Texas Transportation Institute and the East-West Gateway Coordinating Council were used to develop diurnal profiles for light-duty vehicles in Texas and five counties in the St. Louis area of Missouri. For the remainder of Missouri and all other states, a default SMOKE/EPA diurnal profile for weekdays was used for light-duty vehicles in urban and suburban areas, and a weekday rural profile was developed from the Texas data and applied to counties not associated with a Metropolitan Statistical Area (MSA). A weekend diurnal profile for light-duty vehicles and both a weekend and weekday profile for heavy-duty vehicles were derived from traffic counts conducted in California's South Coast Air Basin (Coe et al., 2004) and used for all CENRAP states. **Figure 2-5** shows all diurnal profiles used except county-specific profiles used for Texas and Missouri, which are detailed in Appendix C.

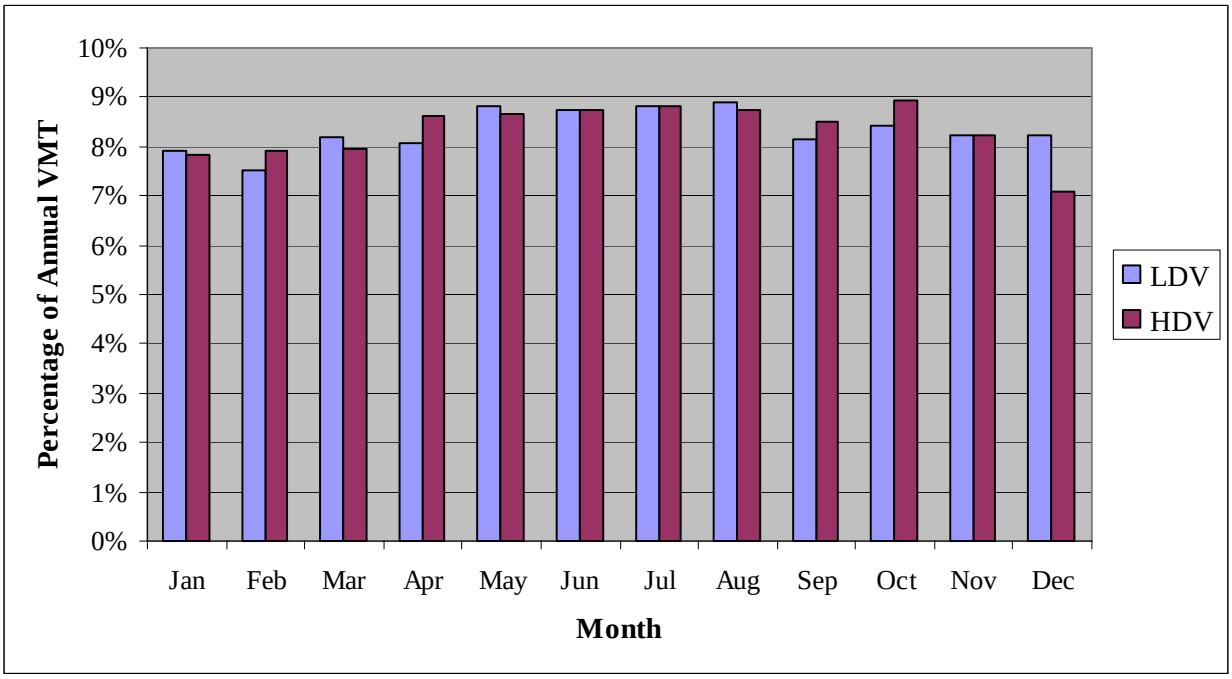



Figure 2-3. Monthly variation in on-road mobile source activity by vehicle type.

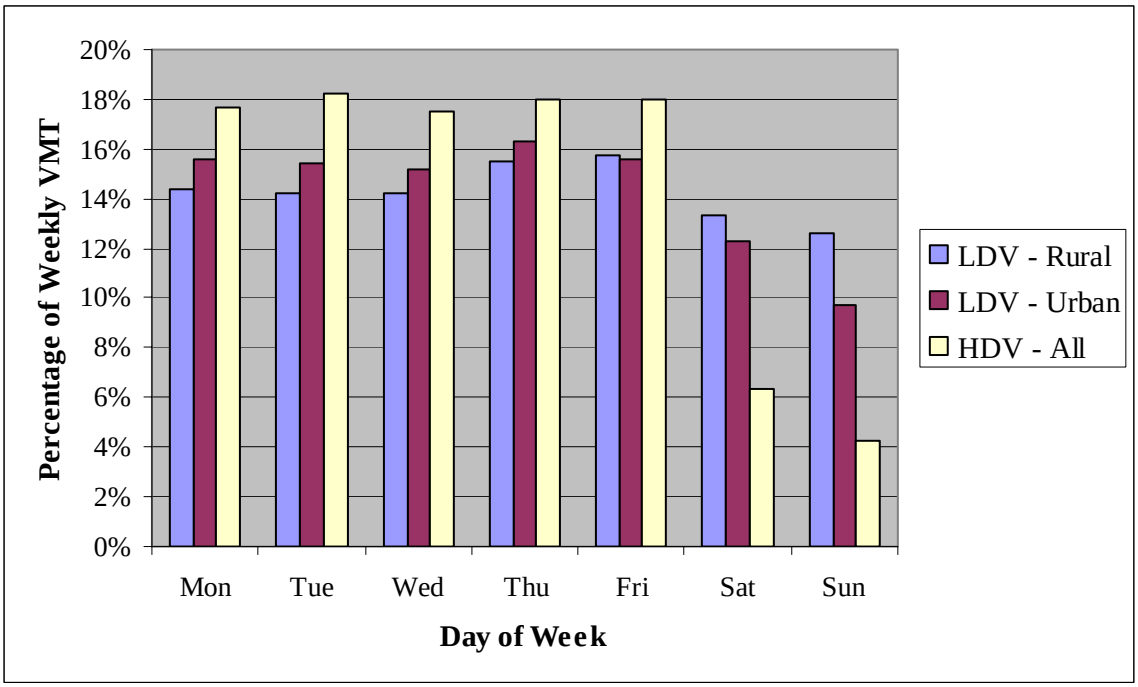



Figure 2-4. Weekly variation in on-road mobile source activity by vehicle type.

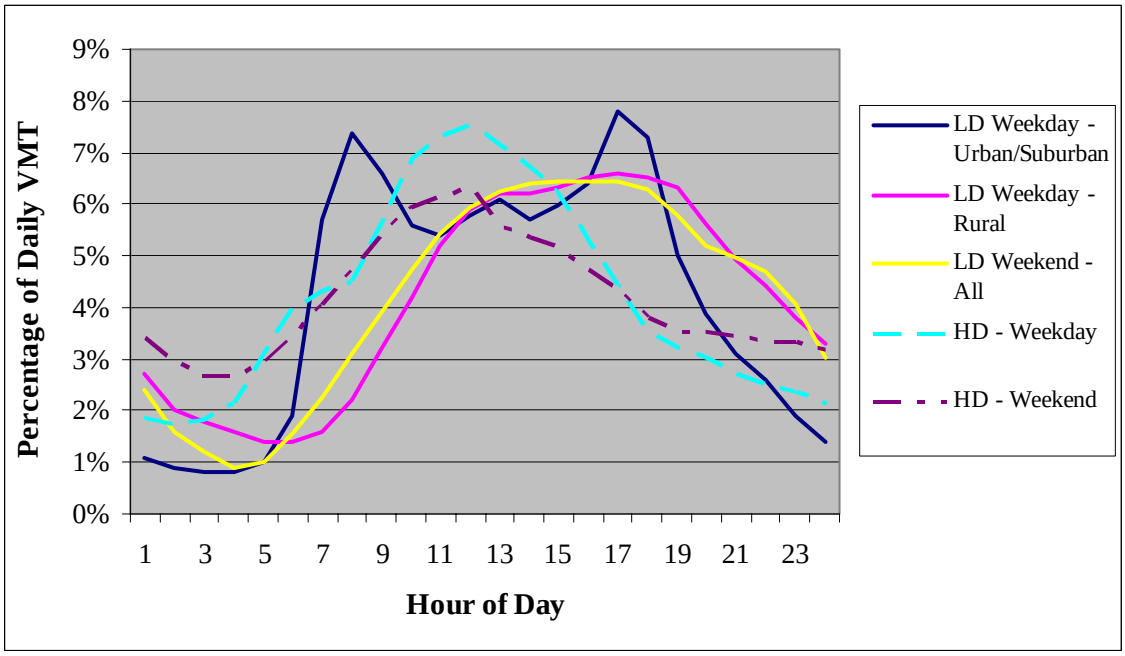



Figure 2-5. Diurnal variation in on-road mobile source emissions by vehicle type.

### 2.1.2 Assessment of On-Road Mobile Source Emissions

The emission inventories for on-road mobile sources are based on extensive region-specific information, including VMT data, fleet characteristics, temporal distributions, and regulatory program descriptions. These estimates were also strengthened by the use of gridded, hourly temperature data. The importance of using state and county-specific data can be seen in a comparison of the CENRAP's inventory with the preliminary 2002 NEI. As **Figure 2-6** shows, both inventories estimate 1.5 million tons of $NO_x$ from on-road mobile sources for the CENRAP region as a whole. However, significant differences exist at the state level. For example, Louisiana's $NO_x$ emissions are 27% higher than the estimates from the NEI, while Missouri's $NO_x$ emissions are 16% lower. Differences are apparent at the CENRAP region-wide scale for VOC emissions, which are about 10% lower than those in the NEI, while region-wide $PM_{2.5}$ and $SO_2$ estimates are about 20% lower. These differences seem to arise primarily from the use of more localized temperature data, fuel volatility data, and fuel sulfur contents. For example, the 2002 NEI assumes an across-the-board diesel sulfur content of 500 ppmw (the regulatory limit), whereas the state-specific data used in this inventory ranged from 330-390 ppmw for the various CENRAP states. Further improvements could be made by continuing to acquire and incorporate local data. For example, improved VMT data are now available for the Kansas City metropolitan area and should be incorporated into future inventory efforts.

Further improvements to the VMT distributions for light-duty vehicle types may be feasible by applying vehicle registration data in novel ways. Many light-duty and/or diesel trucks (e.g., SUVs) are driven for similar purposes as passenger vehicles—a trend that was established in the 1990s and that continues to strengthen. Therefore, the ratio of registered SUVs to registered light-duty autos is likely to be proportional to the VMT traveled by these vehicle types. Alternatively, the VMT mix could be calculated from registration data using vehicle type-specific assumptions about annual mileage accumulation rates (AMAR), which are inherent to the MOBILE6 model. Such adjustments to the VMT distributions may be beneficial because emission factors vary significantly by light-duty vehicle class and fuel type and because MOBILE6 default VMT distributions may be out-of-date due to the rapidly increasing popularity of SUVs and light trucks.

Finally, it should be noted that an "annualized" on-road mobile source inventory was assembled as an average of SMOKE/MOBILE6 runs performed for January and July—a necessity given the current availability of meteorological data. The inventory could be improved by performing runs for all 12 months of the year as new meteorological inputs become available. However, this would likely produce only minor or insignificant changes in annual total emissions.

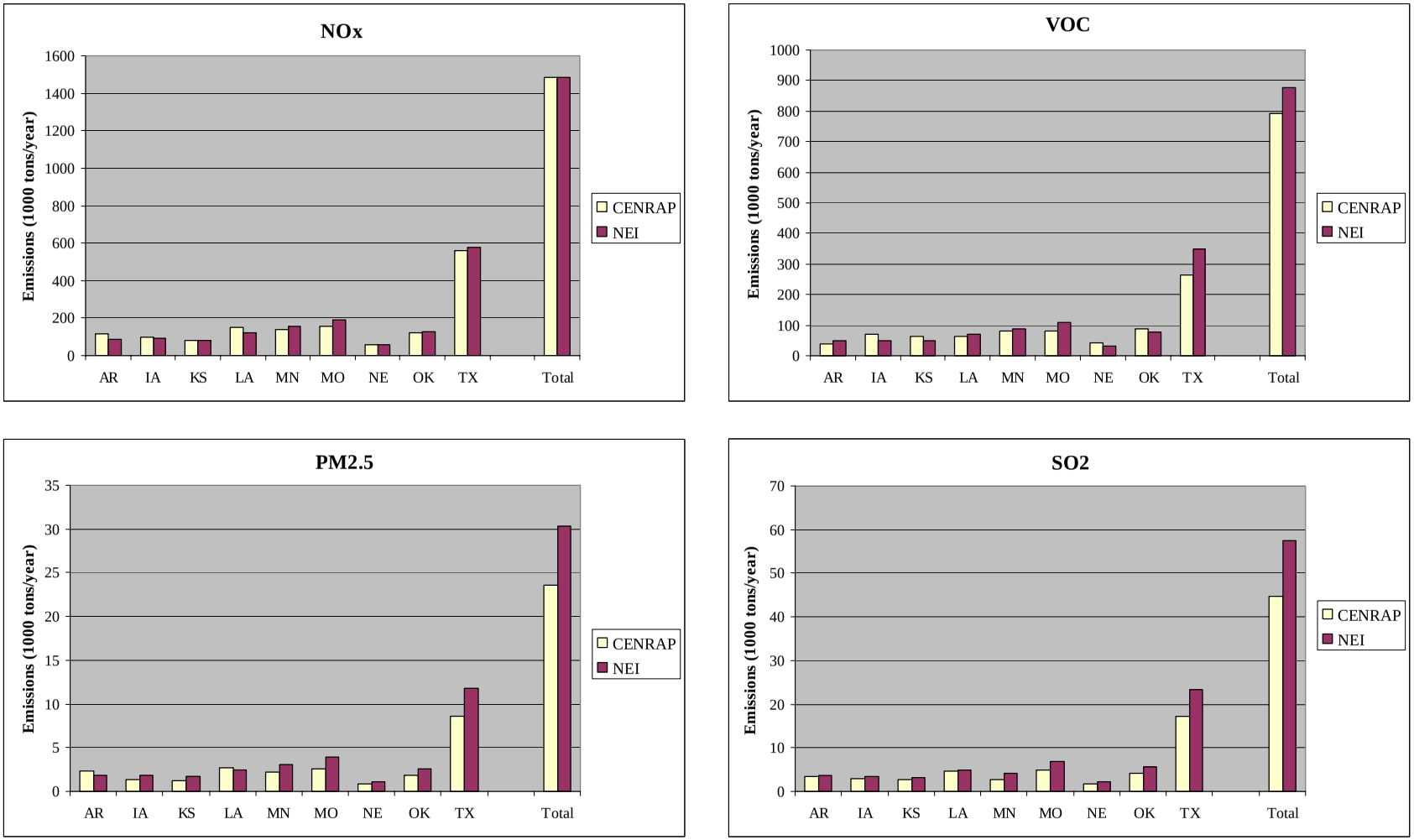



Figure 2-6. Comparison of CENRAP's emission inventories for on-road mobile source to the 2002 preliminary NEI.

## 2.2 EMISSIONS FROM NON-ROAD MOBILE SOURCES

### 2.2.1 Summary of Emissions from Locomotives

Emission estimates were generated for Class I line haul, Class II and III[4] line haul, and yard (or switching) locomotives throughout the CENRAP region using fuel consumption and traffic density data obtained from individual railroads, federal agencies, and other sources. Almost 1.5 billion gallons of diesel fuel were estimated to have been consumed by locomotives in the CENRAP region in 2002, with consequent emissions as shown in **Table 2-2** and **Figure 2-7**. **Figure 2-8** illustrates the geographic distribution of locomotive emissions for a selected date, and **Figure 2-9** shows the monthly variability in locomotive activity, which is based on weekly summaries of carloads of freight moved nationally during 2002.

Table 2-2. 2002 fuel consumption and emissions (tons) for locomotives in CENRAP states.

Page 1 of 2

| State | Fuel Consumption (1000 gallons) | $PM_{2.5}$ | CO | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|---|
| Arkansas | | | | | | | |
| Class I Line Haul | 79,645 | 530 | 2,334 | 16,769 | 1,434 | 880 | 7 |
| Class II & III Line Haul | 2,058 | 14 | 60 | 433 | 37 | 23 | 0 |
| Amtrak | 1,050 | 7 | 32 | 221 | 20 | 12 | 0 |
| Yard/Switching | 7,912 | 73 | 333 | 2,408 | 200 | 184 | 0 |
| Iowa | | | | | | | |
| Class I Line Haul | 110,685 | 738 | 3,243 | 23,304 | 1,992 | 1,224 | 10 |
| Class II & III Line Haul | 11,186 | 74 | 328 | 2,355 | 201 | 124 | 1 |
| Amtrak | 1,050 | 7 | 31 | 221 | 20 | 12 | 0 |
| Yard/Switching | 9,283 | 86 | 389 | 2,825 | 235 | 216 | 0 |
| Kansas | | | | | | | |
| Class I Line Haul | 150,063 | 1,000 | 4,397 | 31,596 | 2,702 | 1,659 | 14 |
| Class II & III Line Haul | 6,518 | 43 | 191 | 1,372 | 117 | 72 | 1 |
| Amtrak | 1,050 | 6 | 31 | 221 | 20 | 11 | 0 |
| Yard/Switching | 12,594 | 115 | 529 | 3,832 | 318 | 293 | 0 |
| Louisiana | | | | | | | |
| Class I Line Haul | 45,878 | 305 | 1,345 | 9,659 | 826 | 507 | 4 |
| Class II & III Line Haul | 576 | 4 | 17 | 121 | 10 | 6 | 0 |
| Amtrak | 1,500 | 10 | 43 | 315 | 27 | 16 | 0 |
| Yard/Switching | 5,556 | 50 | 233 | 1,691 | 139 | 129 | 0 |
| Minnesota | | | | | | | |
| Class I Line Haul | 80,483 | 536 | 2,358 | 16,946 | 1,449 | 890 | 7 |
| Class II & III Line Haul | 17,646 | 118 | 517 | 3,715 | 318 | 195 | 2 |
| Amtrak | 1,050 | 8 | 31 | 221 | 19 | 12 | 0 |
| Yard/Switching | 3,499 | 31 | 147 | 1,065 | 87 | 82 | 0 |

[4] Class I railroads operate over large areas of the country, serving many states. Class II railroads are regional in scope and serve only a few states, while Class III railroads are local and typically operate in only one state.

Table 2-2. 2002 fuel consumption and emissions (tons) for locomotives in CENRAP states.



| State | Fuel Consumption (1000 gallons) | $PM_{2.5}$ | CO | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|---|
| Missouri | | | | | | | |
| Class I Line Haul | 124,524 | 830 | 3,649 | 26,218 | 2,241 | 1,376 | 11 |
| Class II & III Line Haul | 3,352 | 22 | 98 | 706 | 60 | 37 | 0 |
| Amtrak | 2,400 | 15 | 70 | 504 | 42 | 25 | 0 |
| Yard/Switching | 9,463 | 86 | 398 | 2,880 | 239 | 220 | 0 |
| Nebraska | | | | | | | |
| Class I Line Haul | 357,167 | 2,379 | 10,465 | 75,201 | 6,429 | 3,948 | 33 |
| Class II & III Line Haul | 1,379 | 9 | 40 | 290 | 25 | 15 | 0 |
| Amtrak | 750 | 4 | 22 | 158 | 13 | 8 | 0 |
| Yard/Switching | 24,553 | 225 | 1,032 | 7,471 | 618 | 572 | 1 |
| Oklahoma | | | | | | | |
| Class I Line Haul | 86,879 | 578 | 2,545 | 18,293 | 1,564 | 961 | 8 |
| Class II & III Line Haul | 1,826 | 12 | 54 | 384 | 34 | 20 | 0 |
| Amtrak | 1,050 | 7 | 31 | 221 | 19 | 12 | 0 |
| Yard/Switching | 5,276 | 48 | 222 | 1,606 | 134 | 123 | 0 |
| Texas | | | | | | | |
| Class I Line Haul | 279,022 | 1,858 | 8,176 | 58,748 | 5,023 | 3,084 | 25 |
| Class II & III Line Haul | 5,539 | 37 | 162 | 1,166 | 100 | 61 | 1 |
| Amtrak | 5,250 | 34 | 155 | 1,105 | 94 | 57 | 0 |
| Yard/Switching | 23,723 | 220 | 996 | 7,217 | 600 | 551 | 1 |
| Total | 1,481,435 | 10,118 | 44,703 | 321,460 | 27,402 | 17,616 | 126 |

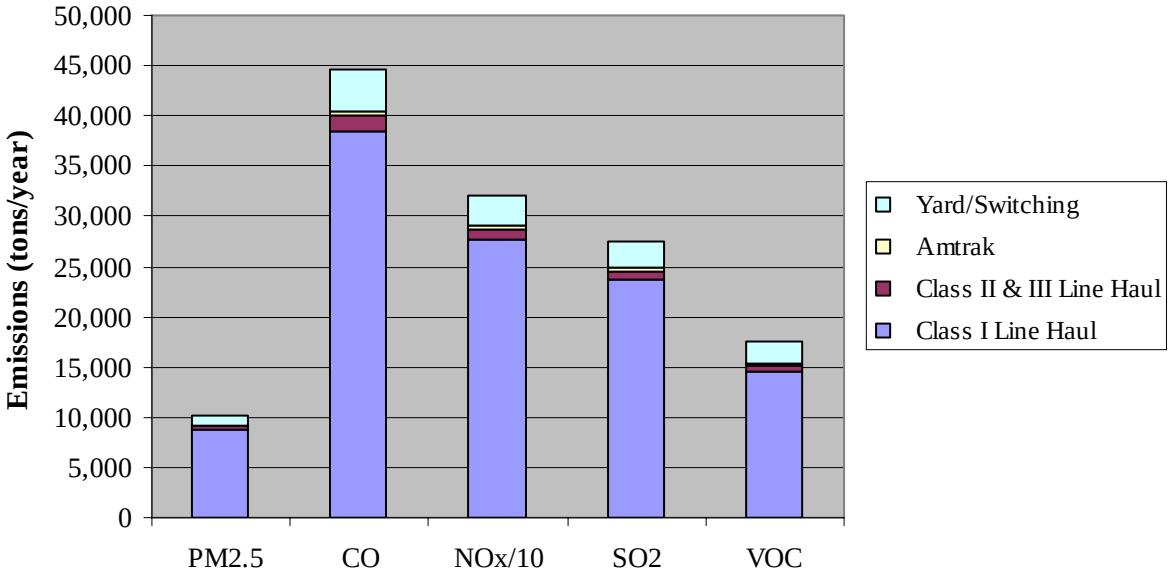



Figure 2-7. Annual locomotive emissions by pollutant and locomotive type for the CENRAP region (note: $NO_x$ emissions have been divided by 10 for scaling purposes).

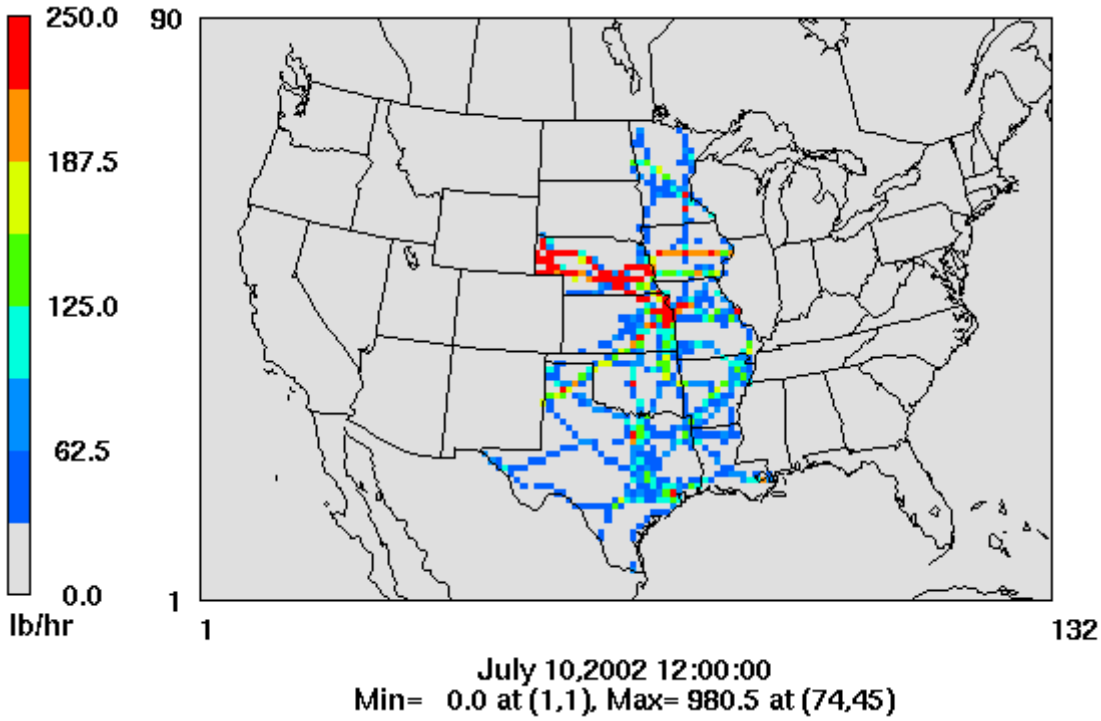



Figure 2-8. Geographic distribution of locomotive emissions of $NO_x$ on July 10, 2002.

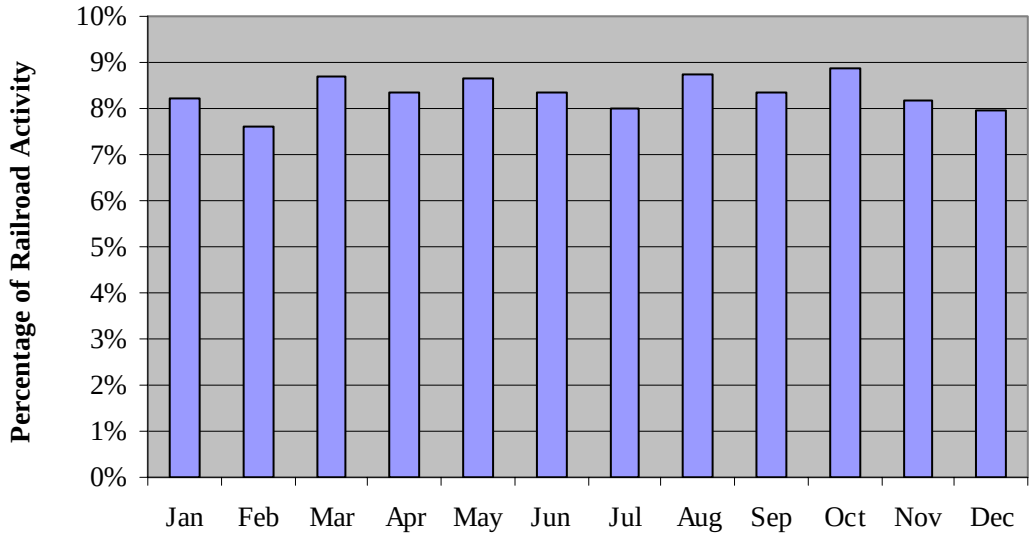



Figure 2-9. Monthly variability in locomotive activity.

### 2.2.2 Assessment of Emissions from Locomotives

Most of the effort of emission inventory development for locomotives was directed toward Class I railroads, which, though small in number, typically account for over 90% of the annual fuel consumption by railroads in the United States (U.S. Environmental Protection Agency, 1998a). Fuel consumption and traffic density data for 2002 were obtained for all eight Class I railroads operating in the CENRAP states, and this information was used to generate county-level emission estimates. Although less effort was expended on smaller railroads, representative bottom-up data sets were collected, including 2002 fuel consumption data for six of the 14 Class II railroads, and either fuel consumption data or yard locomotive fleet sizes for 35 of the 113 Class III and switching railroads that operate in the CENRAP region. Overall, of 1.48 billion gallons of fuel consumed by railroads in the CENRAP region for 2002, 1.44 billion gallons (or 97%) were directly reported by individual railroads, while the remainder were extrapolated from activity patterns. Therefore, the vast majority of the emission inventory for locomotives is based on directly reported, bottom-up activity data.

**Figure 2-10** compares the CENRAP's inventory with the 2002 preliminary NEI inventory. CENRAP's emission estimates for most pollutants are about 50% higher than those in the NEI with the exception of $NO_x$, for which the CENRAP and NEI emission estimates are roughly equal. "Uncontrolled" emission factors were applied across the board for the 2002 NEI, which offset a corresponding underestimate of locomotive activity levels in the CENRAP area. CENRAP's $NO_x$ inventory for locomotives reflects existing federal emission standards for locomotives. These emission standards, which took effect with the 1973 model year, predominately affect $NO_x$ emissions. Therefore, although activity levels estimated for the CENRAP inventory were higher than those estimated for the NEI, the resultant $NO_x$ emissions are about the same.

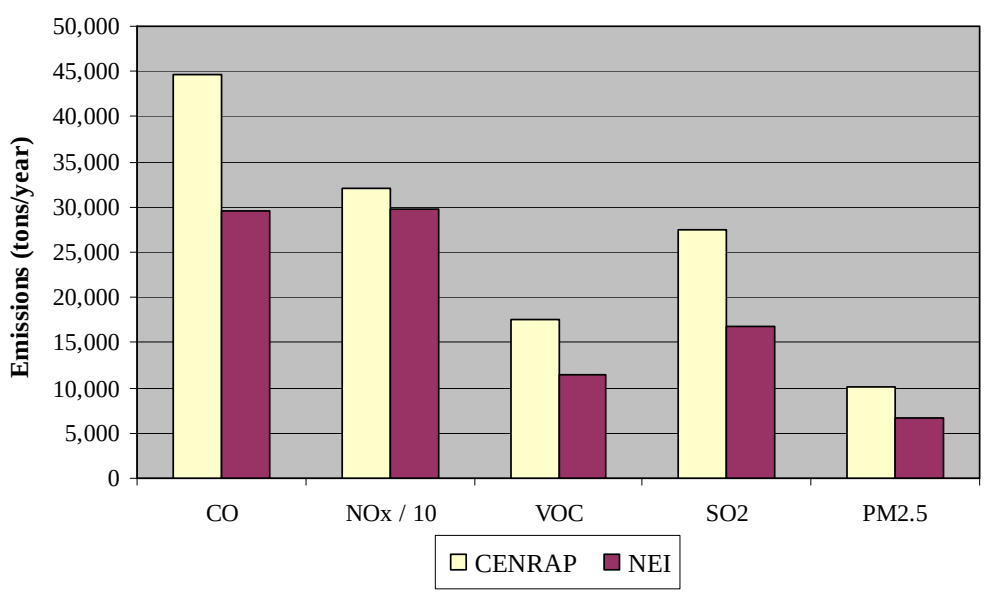



Figure 2-10. Comparison of locomotive emissions estimates with results from the 2002 preliminary NEI (note: $NO_x$ emissions have been divided by 10 for scaling purposes).

Use of 2002 railroad-specific fuel consumption estimates and emission factors reflective of existing emissions standards greatly improved the degree of certainty in the CENRAP region-wide emission inventory above that associated with the preliminary 2002 NEI. Additional survey work could improve the accuracy of the inventory, but this improvement would likely be significant only at county or metropolitan scales where railroad activities are dominated by Class II or III railroads. In addition, local data would likely be more representative of variances in local activity patterns than the national-level data that were used to create a monthly temporal profile.

### 2.2.3 Summary of Emissions from Commercial Marine Vessels

Emission estimates were generated for commercial marine vessels operating in commercially active waterways in the CENRAP region, including inland river systems, Lake Superior, and the Gulf Intracoastal Waterway (GIWW). County-level emissions were designated as either "in-port" or "underway", as shown in **Table 2-3** and **Figure 2-11**. **Figure 2-12** illustrates the geographic distribution of commercial marine emissions for a selected date, and **Figure 2-13** shows the monthly variability in commercial marine activity by state, with profiles based on monthly summaries of freight movements through selected locks and ports for 2002.

Table 2-3. 2002 commercial marine vessel emissions (tons) in CENRAP states.

| State | Type | CO | NOx | VOC | SO2 | PM2.5 | $NH_3$ |
|---|---|---|---|---|---|---|---|
| Arkansas | Port | 13 | 68 | 1 | 6 | 1 | 0 |
| | Underway | 1,783 | 9,274 | 193 | 889 | 197 | 4 |
| Iowa | Port | 55 | 286 | 6 | 27 | 6 | 0 |
| | Underway | 534 | 2,776 | 58 | 266 | 59 | 1 |
| Kansas | Port | 2 | 9 | 0 | 1 | 0 | 0 |
| | Underway | 4 | 22 | 0 | 2 | 0 | 0 |
| Louisiana | Port | 2,719 | 20,772 | 739 | 5,369 | 693 | 6 |
| | Underway | 6,912 | 48,574 | 999 | 7,082 | 1,221 | 7 |
| Minnesota | Port | 211 | 1,533 | 57 | 230 | 37 | 1 |
| | Underway | 492 | 2,822 | 65 | 484 | 79 | 1 |
| Missouri | Port | 585 | 4,281 | 170 | 443 | 84 | 2 |
| | Underway | 1,472 | 7,656 | 159 | 734 | 163 | 3 |
| Nebraska | Port | 1 | 3 | 0 | 0 | 0 | 0 |
| | Underway | 5 | 27 | 1 | 3 | 1 | 0 |
| Oklahoma | Port | 1 | 5 | 0 | 0 | 0 | 0 |
| | Underway | 97 | 505 | 10 | 48 | 11 | 0 |
| Texas | Port | 1,613 | 12,300 | 423 | 4,315 | 526 | 3 |
| | Underway | 1,882 | 13,009 | 300 | 5,778 | 686 | 3 |
| Total | | 18,381 | 123,922 | 3,182 | 25,677 | 3,764 | 32 |

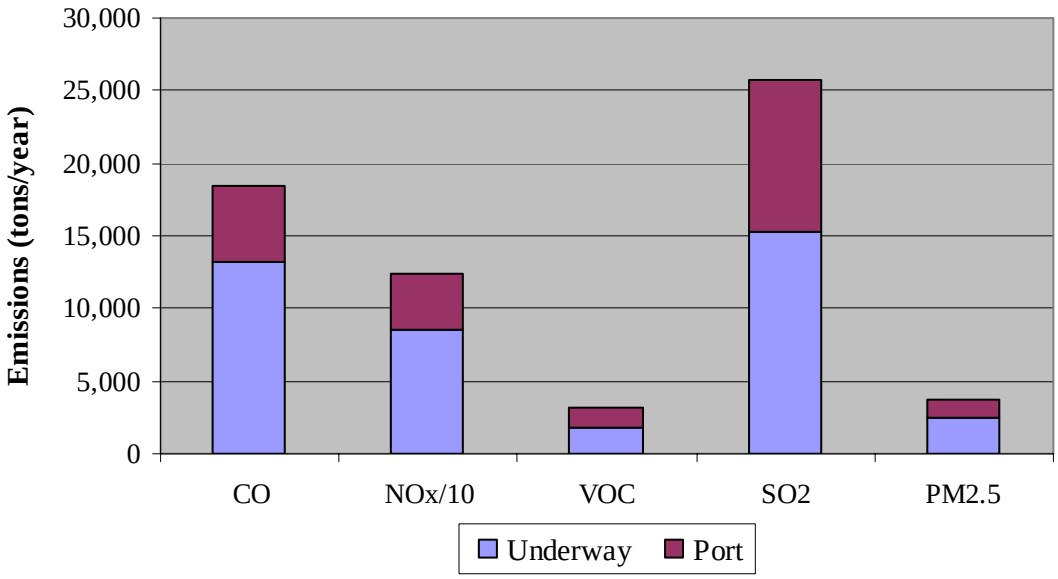



Figure 2-11. Annual commercial marine vessel emissions by pollutant and source type for the CENRAP region (note: $NO_x$ emissions have been divided by 10 for scaling purposes).

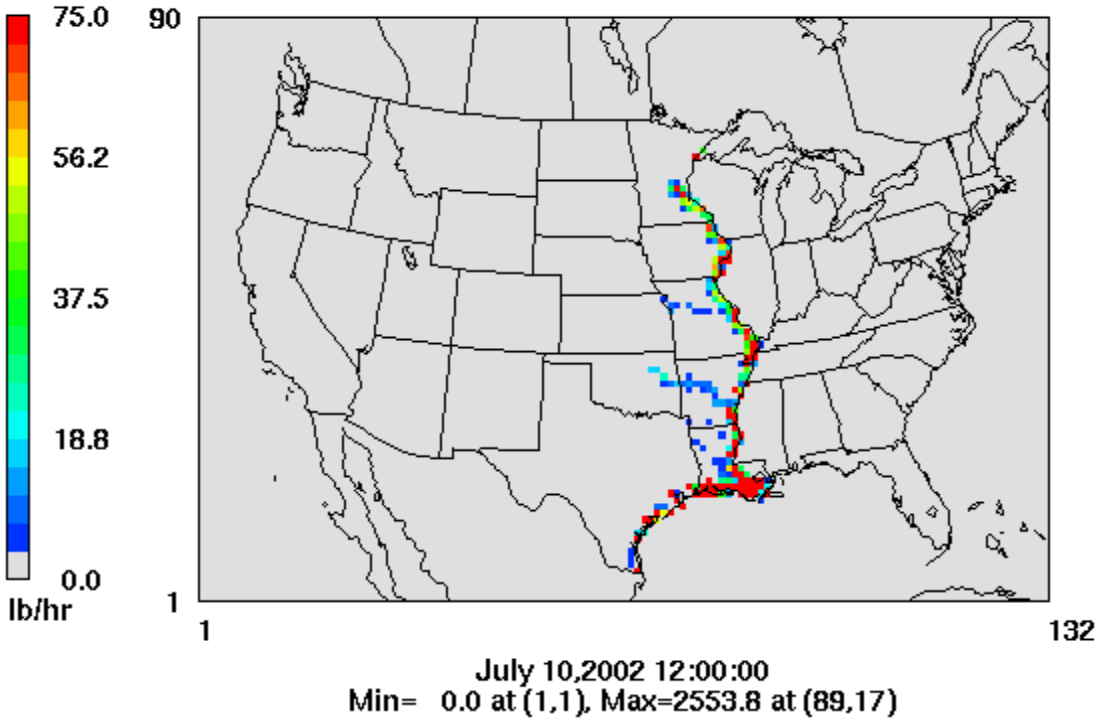



Figure 2-12. Geographic distribution of commercial marine emissions of $NO_x$ in the CENRAP states on July 10, 2002.

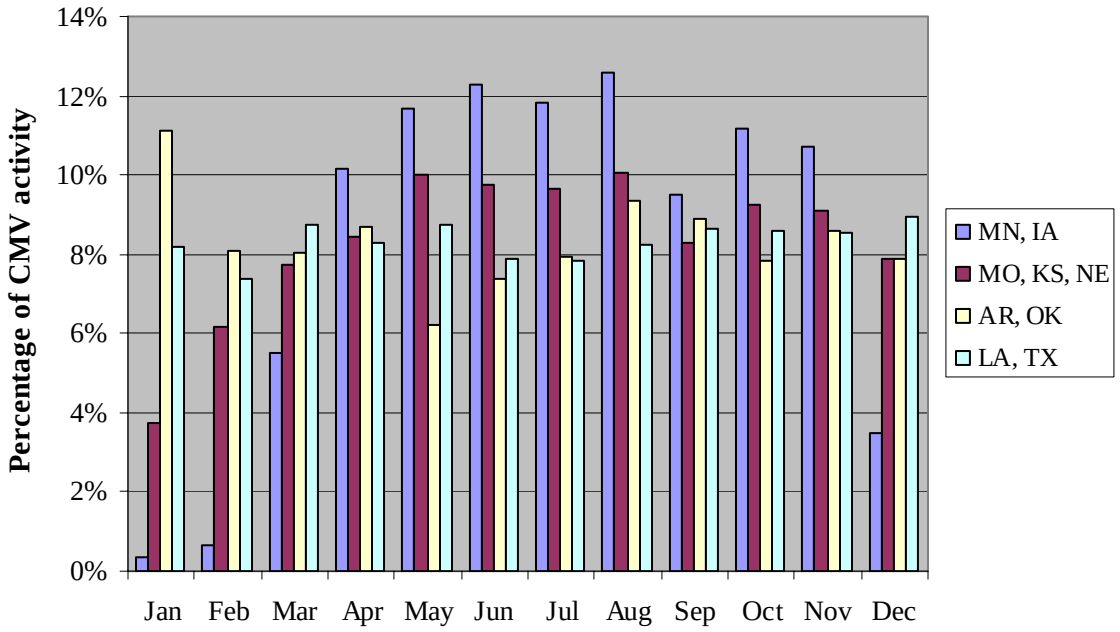



Figure 2-13. Monthly variability in commercial marine vessel activity.

### 2.2.4 Assessment of Emissions from Commercial Marine Vessels

Emission estimates for this inventory differ significantly from those found in the preliminary 2002 NEI. CENRAP's emissions are lower by approximately a factor of 3 for all pollutants (see **Figure 2-14**). Emissions in Louisiana and Texas account for most of the emissions and much of the overall difference, as seen in **Figure 2-15**.

For inland river systems in the CENRAP region, emission estimates were based on bottom-up fuel consumption data derived from the Tennessee Valley Authority (TVA) Barge Costing Model. This model was developed to estimate fuel usage by inland river segment for fuel tax purposes, and annual model results have varied from actual tax receipts by an average of only 1.5% since 1996. The results indicate that the activity data used to estimate emissions for most of the CENRAP region (including all of Arkansas, Iowa, Kansas, Missouri, Nebraska, and Oklahoma) have a high degree of certainty.

However, the TVA model does not cover fuel consumption by "deep-draft" (oceangoing) vessels, harbor tugs, and other vessels that operate around ports in the Great Lakes or the Gulf Inland Waterway of Louisiana and Texas. In these cases, emission estimates were prepared using work-based (rather than fuel-based) emission factors and a complex array of activity data, including the number of vessel calls at specific ports, vessel speeds, and vessel characteristics (such as engine horsepower, load factors, etc.). Although detailed information was available for several important ports in the CENRAP region, including St. Louis, Baton Rouge, New Orleans, South Louisiana, and Corpus Christi, a complete survey of ports in Louisiana, Texas, and Minnesota was not possible within the scope of this project. Therefore, data from "known" ports were extrapolated to "unknown" ports using techniques outlined in a two-volume report produced by ARCADIS on behalf of the EPA (U.S. Environmental Protection Agency, 1999a).

Improvements to the inventory could be made at local scales by gathering more detailed data on individual ports within a county or region.

The difference between the CENRAP inventory and the preliminary 2002 NEI is most likely due to the use of top-down methods to develop the 2002 NEI, for which national-level emissions were calculated from estimated annual hours of operation and fuel consumption for the U.S. commercial marine fleet, then disaggregated to port and underway emissions based on the simplifying assumption that 75% of distillate fuel and 25% of residual fuel is consumed "in-port". National-scale, in-port emissions were then assigned to the largest 150 ports in the country based on the amount of freight handled by each, and the remaining "underway" emissions were assigned to active shipping lanes based on traffic density patterns (U.S. Environmental Protection Agency, 1999b). These methods seem to have resulted in significantly overestimated emissions at large ports, as seen in **Table 2-4**, which compares "in-port" emissions from the 2002 NEI for the counties containing the Port of Baton Rouge and the Houston-Galveston Port with other estimates of emissions for these same ports. CENRAP's emission inventories for these ports are more closely aligned with previous estimates prepared by Booz Allen Hamilton (1991) and Eastern Research Group & Starcrest (2003), both of whom also applied bottom-up activity data to prepare their inventories.

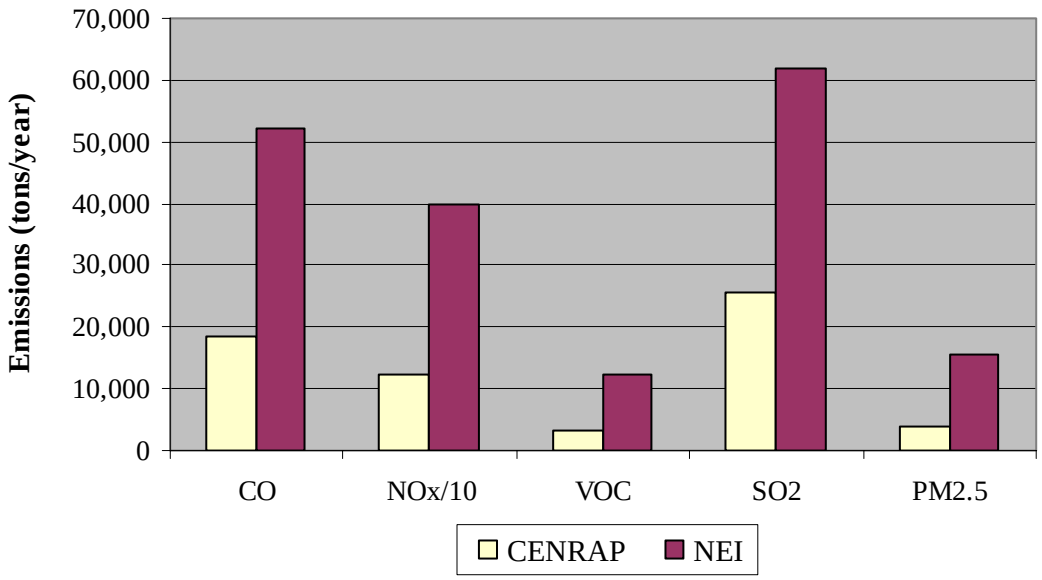



Figure 2-14. Comparison of commercial marine emissions estimates with results from the 2002 preliminary NEI (note: $NO_x$ emissions have been divided by 10 for scaling purposes).

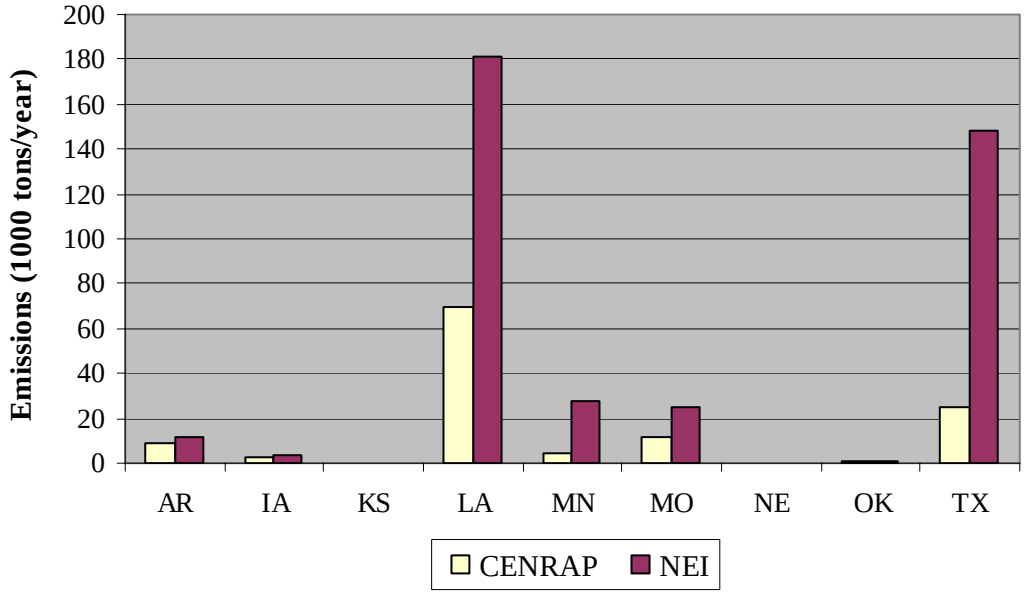



Figure 2-15. State-by-state comparison of commercial marine NOx emissions.

Table 2-4. Comparison of inventories for selected ports in the CENRAP region (emissions in tons/year).

| Port | Inventory | $PM_{2.5}$ | $NO_x$ | CO | VOC | $SO_2$ |
|---|---|---|---|---|---|---|
| Baton Rouge | 1991 Booz-Allen Hamilton | 129 | 2,187 | 449 | 203 | 928 |
| | 2002 CENRAP | 196 | 5,355 | 737 | 170 | 1,562 |
| | 2002 NEI | 1,407 | 36,088 | 4,756 | 1,128 | 5,291 |
| | | | | | | |
| Houston-Galveston | 1991 Booz-Allen Hamilton | 887 | 14,977 | 2,131 | 1,391 | 6,554 |
| | 2000 Starcrest | ----- | 7,336 | 1,022 | 219 | ----- |
| | 2002 CENRAP | 318 | 7,232 | 943 | 245 | 2,610 |
| | 2002 NEI | 2,955 | 75,787 | 9,989 | 2,370 | 11,111 |

### 2.2.5 Summary of Emissions from Recreational Boats

Emissions from recreational boats were calculated with the latest version of the EPA's NONROAD model (NONROAD 2004). NONROAD produces county-level emission estimates for several categories of recreational boats using national equipment populations, which are disaggregated to the county level on the basis of the total water surface area in a given county. NONROAD also relies on broad assumptions related to boating activity (such as annual hours of operation, engine load factors, and temporal variations in activity). These assumptions vary by equipment type but not geographic area. The activity data files used by the NONROAD model were updated for the CENRAP inventory with information gathered through a bottom-up survey of representative groups of recreational boat owners. The survey was designed to gather data on vessel characteristics, hours of use, fuel consumption, engine loads, and temporal and geographic

usage patterns in each of the CENRAP states. Data assembled through this survey were then incorporated into the NONROAD model, along with state-specific data on temperatures and fuels characteristics.[5] The more significant survey results showed that boating activities varied substantially by state in most respects, including types of boats used, diurnal patterns of boating, seasonal patterns of boating, and hours of boat use.

One of the challenges associated with conducting the recreational boating survey and analyzing results was the tendency of survey respondents to generally over-report their use of recreational boats. This phenomenon, called "reporting bias", often occurs when survey respondents have non-neutral attitudes about the behaviors they report. Under-reporting of illicit behaviors (such as use of illegal drugs or driving above posted speed limits) and over-reporting of positive behaviors (such as exercising regularly or volunteering for charity) are commonly observed, unless surveys are designed to control or eliminate these biases. The CENRAP recreational boating survey was designed to control for reporting bias. Respondents were asked about their "typical" usage pattern, but they were also asked about their specific usage pattern for the preceding week—information that is much more likely to be reported accurately. The average usage pattern for the preceding week was used to adjust reported "typical" usage patterns, which greatly reduced the effects of over-reporting by factors of 1.5 to 2.0. In addition, respondents were asked about the quantities of fuel purchased for their recreational boats—information that could be used as a second check of reporting bias. On the basis of reported fuel consumptions, recreational boating usage was further reduced for over-reporting bias by a factor of 0.3 (with a range of uncertainty from 0.0 to 0.5). The resulting database of activity levels in the CENRAP region indicates greater usage of recreational boats than the NONROAD 2004 defaults by a factor of approximately 2. In spite of this large difference, the uncertainty in the overall survey results is judged to be approximately only ±25%. Notably, geographic areas in which subsistence fishing is prevalent exhibited the least evidence of over-reporting bias, while owners of personal watercraft over-reported usage to a greater extent than owners of other types of watercraft. This is consistent with the theory that recreational activities tend to be over-reported more often than non-recreational activities.

Emission estimates for recreational boating vary widely from state to state, as shown in **Table 2-5** and **Figures 2-16 and 2-17**. Louisiana, Minnesota, Missouri, and Texas account for almost 80% of the annual $NO_x$ emissions from recreational boating in the CENRAP region, while Nebraska and Kansas combined contribute less than 4% of the total $NO_x$ emissions. Emissions also vary widely across the months of the year, days of the week, and hours of the day, as shown in **Figures 2-18 through 2-20**. Recreational boating activity peaks during the summer months for each state, and this peak is more pronounced for the four northern states of Minnesota, Nebraska, Kansas, and Iowa. Activity peaks also occur on the weekends and during morning to midday hours.

[5] See Section 2.1.1 for a discussion of sources of information on fuels characteristics.

Table 2-5. Recreational boating emissions (tons) by state and boat type.



| State | Category | PM2.5 | NOx | VOC | SO2 | CO | NH3 |
|---|---|---|---|---|---|---|---|
| Arkansas | 2-Stroke Outboards | 1,662 | 803 | 25,604 | 63 | 69,155 | 6 |
| | 2-Stroke Personal Watercraft | 204 | 115 | 4,253 | 10 | 11,469 | 1 |
| | 4-Stroke Inboards | 8 | 785 | 1,430 | 21 | 19,809 | 1 |
| | Diesel Inboards | 10 | 570 | 21 | 10 | 90 | 0 |
| | Diesel Outboards | 0 | 2 | 0 | 0 | 1 | 0 |
| | Total | 1,884 | 2,274 | 31,309 | 103 | 100,524 | 8 |
| Iowa | 2-Stroke Outboards | 1,418 | 682 | 21,346 | 54 | 58,835 | 5 |
| | 2-Stroke Personal Watercraft | 192 | 108 | 3,944 | 9 | 10,777 | 1 |
| | 4-Stroke Inboards | 7 | 738 | 1,000 | 20 | 18,380 | 1 |
| | Diesel Inboards | 9 | 536 | 20 | 9 | 85 | 0 |
| | Diesel Outboards | 0 | 2 | 0 | 0 | 1 | 0 |
| | Total | 1,626 | 2,066 | 26,310 | 92 | 88,079 | 7 |
| Kansas | 2-Stroke Outboards | 266 | 123 | 4,581 | 10 | 10,940 | 1 |
| | 2-Stroke Personal Watercraft | 72 | 41 | 1,495 | 3 | 4,069 | 0 |
| | 4-Stroke Inboards | 3 | 293 | 431 | 7 | 6,919 | 0 |
| | Diesel Inboards | 3 | 202 | 8 | 3 | 32 | 0 |
| | Diesel Outboards | 0 | 1 | 0 | 0 | 0 | 0 |
| | Total | 345 | 660 | 6,515 | 24 | 21,962 | 2 |
| Louisiana | 2-Stroke Outboards | 4,341 | 2,107 | 66,542 | 165 | 180,909 | 15 |
| | 2-Stroke Personal Watercraft | 509 | 286 | 10,608 | 24 | 28,589 | 2 |
| | 4-Stroke Inboards | 20 | 1,928 | 3,598 | 52 | 49,469 | 3 |
| | Diesel Inboards | 25 | 1,420 | 53 | 26 | 225 | 1 |
| | Diesel Outboards | 0 | 5 | 1 | 0 | 3 | 0 |
| | Total | 4,895 | 5,746 | 80,803 | 267 | 259,196 | 21 |
| Minnesota | 2-Stroke Outboards | 5,113 | 2,462 | 77,086 | 69 | 211,905 | 17 |
| | 2-Stroke Personal Watercraft | 710 | 402 | 14,580 | 12 | 39,829 | 3 |
| | 4-Stroke Inboards | 27 | 2,807 | 3,666 | 26 | 67,462 | 4 |
| | Diesel Inboards | 34 | 1,982 | 74 | 34 | 314 | 1 |
| | Diesel Outboards | 1 | 6 | 2 | 0 | 5 | 0 |
| | Total | 5,886 | 7,659 | 95,409 | 142 | 319,514 | 26 |
| Missouri | 2-Stroke Outboards | 5,397 | 2,671 | 79,005 | 207 | 226,163 | 18 |
| | 2-Stroke Personal Watercraft | 502 | 283 | 10,360 | 23 | 28,213 | 2 |
| | 4-Stroke Inboards | 19 | 1,892 | 2,899 | 51 | 48,478 | 3 |
| | Diesel Inboards | 25 | 1,401 | 52 | 26 | 222 | 1 |
| | Diesel Outboards | 0 | 4 | 1 | 0 | 3 | 0 |
| | Total | 5,943 | 6,251 | 92,318 | 308 | 303,079 | 24 |

Table 2-5. Recreational boating emissions (tons) by state and boat type.



| State | Category | PM2.5 | NOx | VOC | SO2 | CO | NH3 |
|---|---|---|---|---|---|---|---|
| Nebraska | 2-Stroke Outboards | 414 | 198 | 6,366 | 16 | 17,146 | 1 |
| | 2-Stroke Personal Watercraft | 60 | 34 | 1,243 | 3 | 3,382 | 0 |
| | 4-Stroke Inboards | 2 | 247 | 355 | 6 | 5,727 | 0 |
| | Diesel Inboards | 3 | 168 | 6 | 3 | 27 | 0 |
| | Diesel Outboards | 0 | 1 | 0 | 0 | 0 | 0 |
| | Total | 479 | 648 | 7,971 | 28 | 26,282 | 2 |
| Oklahoma | 2-Stroke Outboards | 1,462 | 695 | 23,269 | 55 | 60,589 | 5 |
| | 2-Stroke Personal Watercraft | 226 | 127 | 4,709 | 11 | 12,702 | 1 |
| | 4-Stroke Inboards | 9 | 874 | 1,588 | 23 | 21,922 | 1 |
| | Diesel Inboards | 11 | 631 | 24 | 11 | 100 | 0 |
| | Diesel Outboards | 0 | 2 | 0 | 0 | 1 | 0 |
| | Total | 1,708 | 2,330 | 29,590 | 100 | 95,314 | 7 |
| Texas | 2-Stroke Outboards | 5,095 | 2,422 | 81,866 | 192 | 211,147 | 17 |
| | 2-Stroke Personal Watercraft | 795 | 447 | 16,620 | 37 | 44,684 | 3 |
| | 4-Stroke Inboards | 31 | 2,947 | 5,890 | 81 | 78,276 | 5 |
| | Diesel Inboards | 39 | 2,219 | 83 | 39 | 352 | 1 |
| | Diesel Outboards | 1 | 7 | 2 | 0 | 5 | 0 |
| | Total | 5,960 | 8,043 | 104,461 | 350 | 334,464 | 26 |
| All States | 2-Stroke Outboards | 25,167 | 12,166 | 385,666 | 832 | 1,046,790 | 84 |
| | 2-Stroke Personal Watercraft | 3,270 | 1,843 | 67,812 | 131 | 183,714 | 14 |
| | 4-Stroke Inboards | 126 | 12,511 | 20,858 | 288 | 316,441 | 19 |
| | Diesel Inboards | 159 | 9,128 | 342 | 162 | 1,447 | 6 |
| | Diesel Outboards | 3 | 29 | 7 | 0 | 21 | 0 |
| | Total | 28,725 | 35,676 | 474,685 | 1,413 | 1,548,413 | 122 |

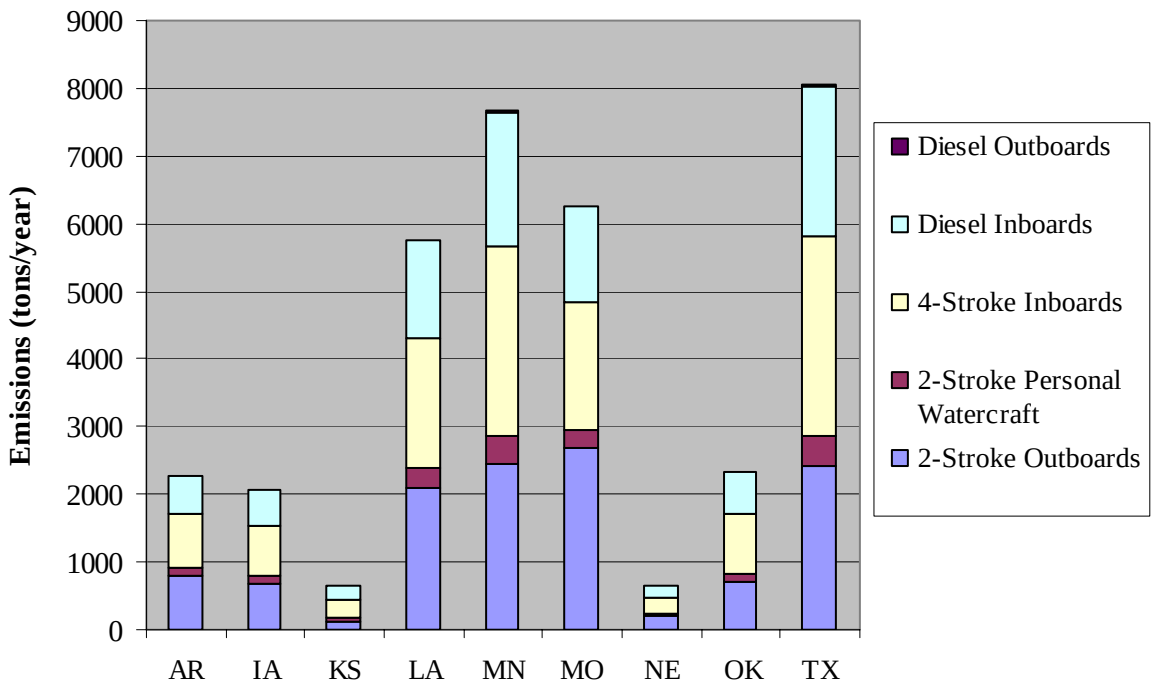



Figure 2-16. Annual $NO_x$ emissions from recreational boating activities by state and boat type.

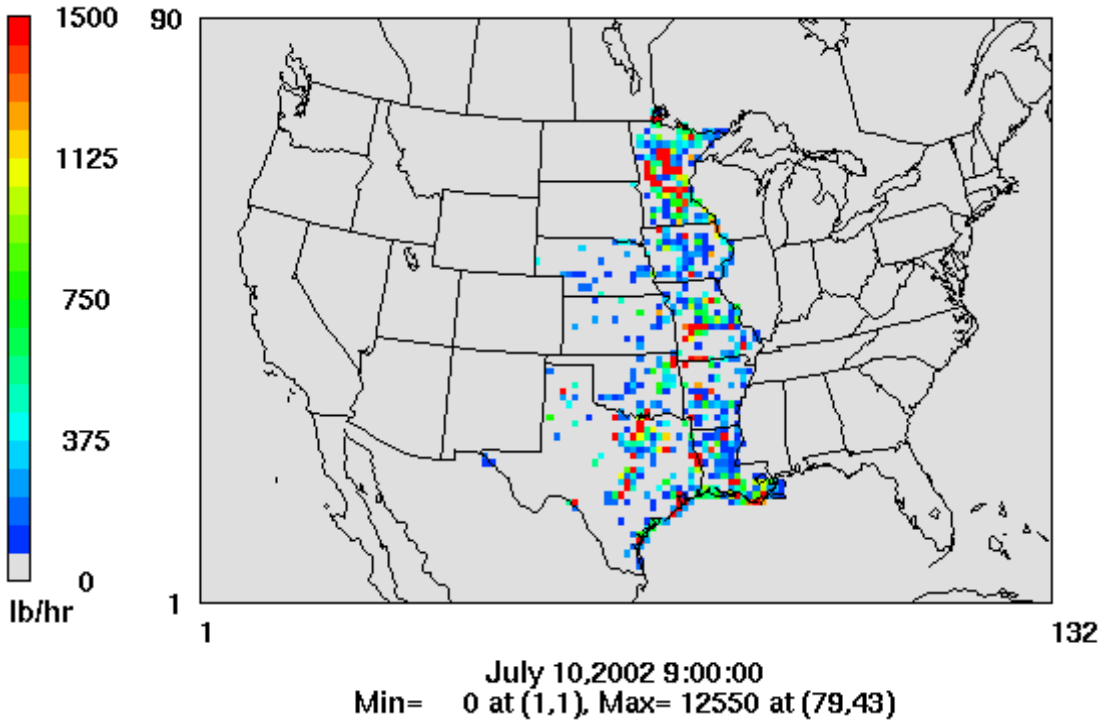



Figure 2-17. Geographic distribution of recreational boating emissions of $NO_x$ in the CENRAP states on July 10, 2002.

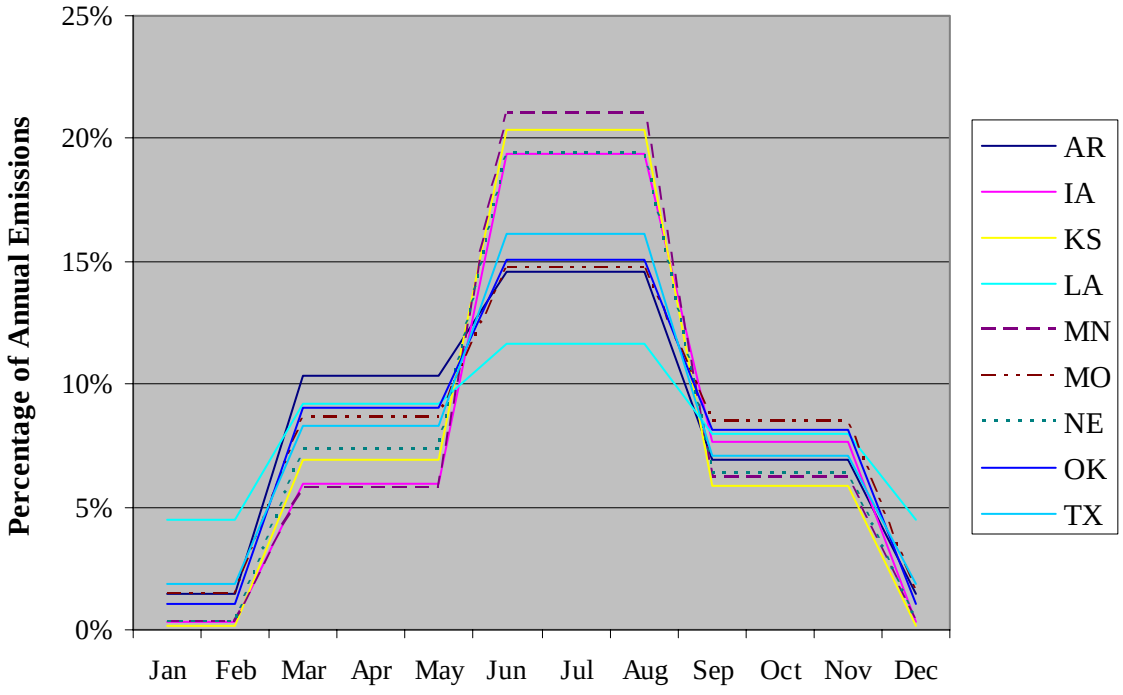



Figure 2-18. Monthly variability in recreational boating emissions by state.

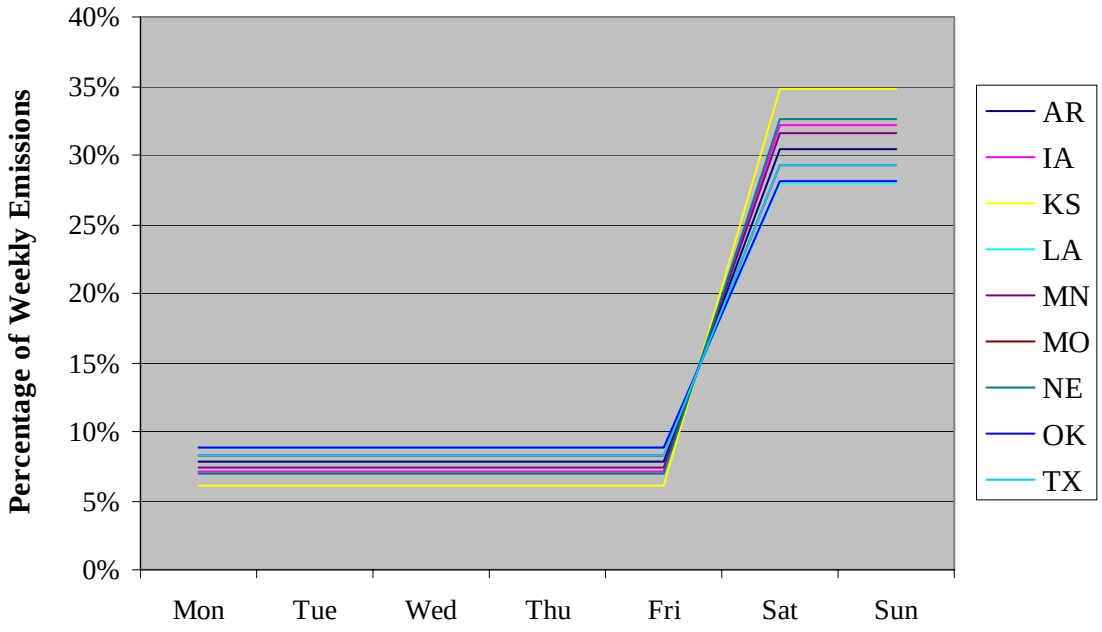



Figure 2-19. Day-of-week variability in recreational boating emissions by state.

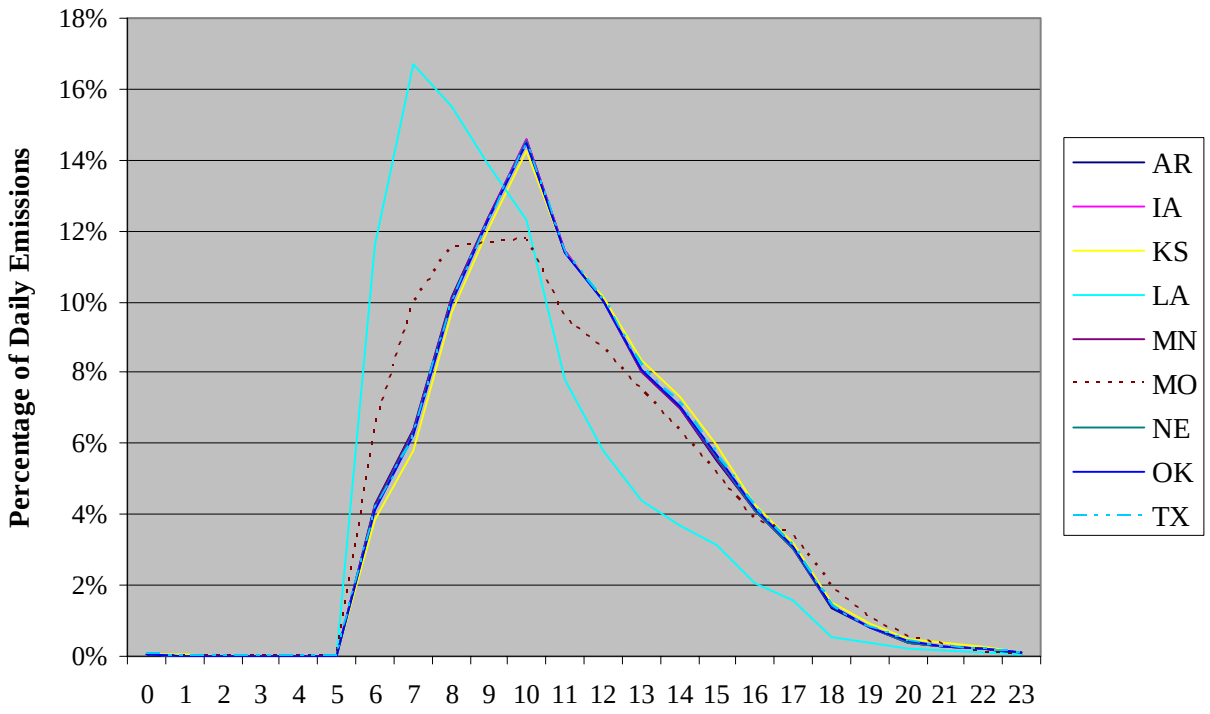



Figure 2-20. Diurnal variability in recreational boating emissions by state.

### 2.2.6 Assessment of Emissions from Recreational Boats

The CENRAP's emission inventory for recreational boating represents a significant improvement over existing inventories and NONROAD default activity data. Surveys of representative groups of boat owners in each of the CENRAP states made possible the replacement of NONROAD default data with state-specific information that more accurately represents recreational boating activity in the CENRAP region. The improved activity data resulted in emission estimates 2 to 4 times greater than estimates from the preliminary 2002 NEI (see **Figure 2-21**). The scale of the differences may seem surprising; however, we believe that they are reasonably accurate and reliable because care was taken to control over-reporting bias (as discussed in Section 2.2.5) and to ensure the representativeness of the survey results.

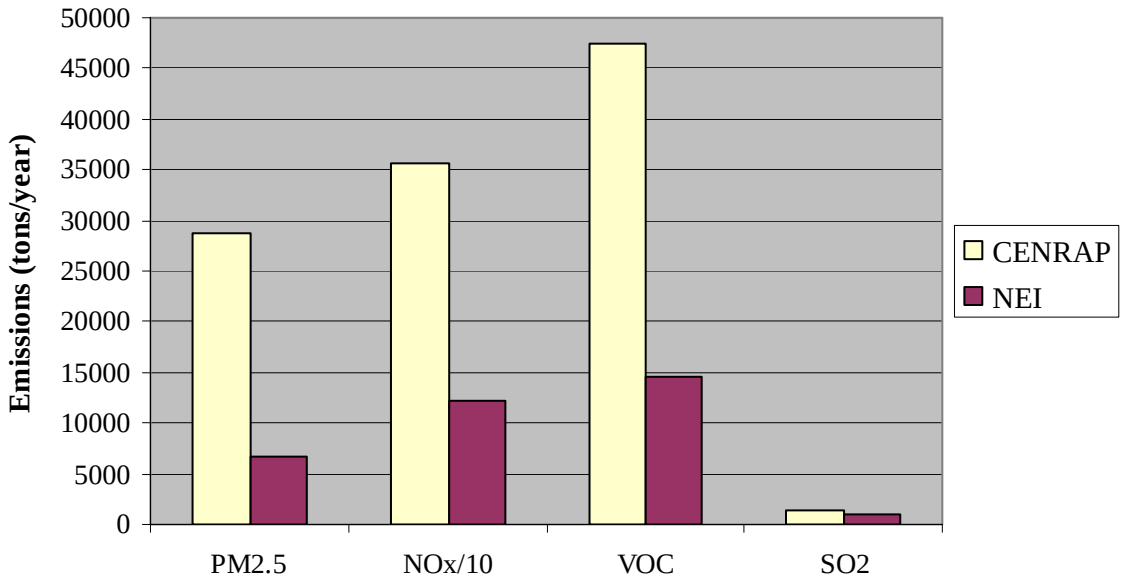



Figure 2-21. Comparison of recreational boating emissions estimates with results from the 2002 preliminary NEI (note: $NO_x$ emissions have been divided by 10 for scaling purposes).

**Figure 2-22** illustrates a county-by-county comparison of the CENRAP emission inventory with an inventory produced by running NONROAD 2004 with default inputs. The inventories differ significantly throughout the CENRAP region with respect to quantities of pollutants emitted and spatial distributions of emissions. The differences are due to the improved activity data, which were more representative of the scale and geographic distribution of recreational boating activities than NONROAD 2004 defaults. **Figure 2-23** provides a side-by-side comparison of the spatial distributions that resulted from NONROAD 2004 defaults and from the CENRAP recreational boating survey results. The CENRAP spatial allocation represents the usage patterns reported by survey respondents and is, therefore, highly representative of real-world behavior. The NONROAD spatial allocation was achieved by allocating statewide emissions proportionally to each county's water surface area. This technique overallocates emissions to areas that are unpopular with recreational boaters due to boating restrictions, remoteness from population centers, or other reasons.

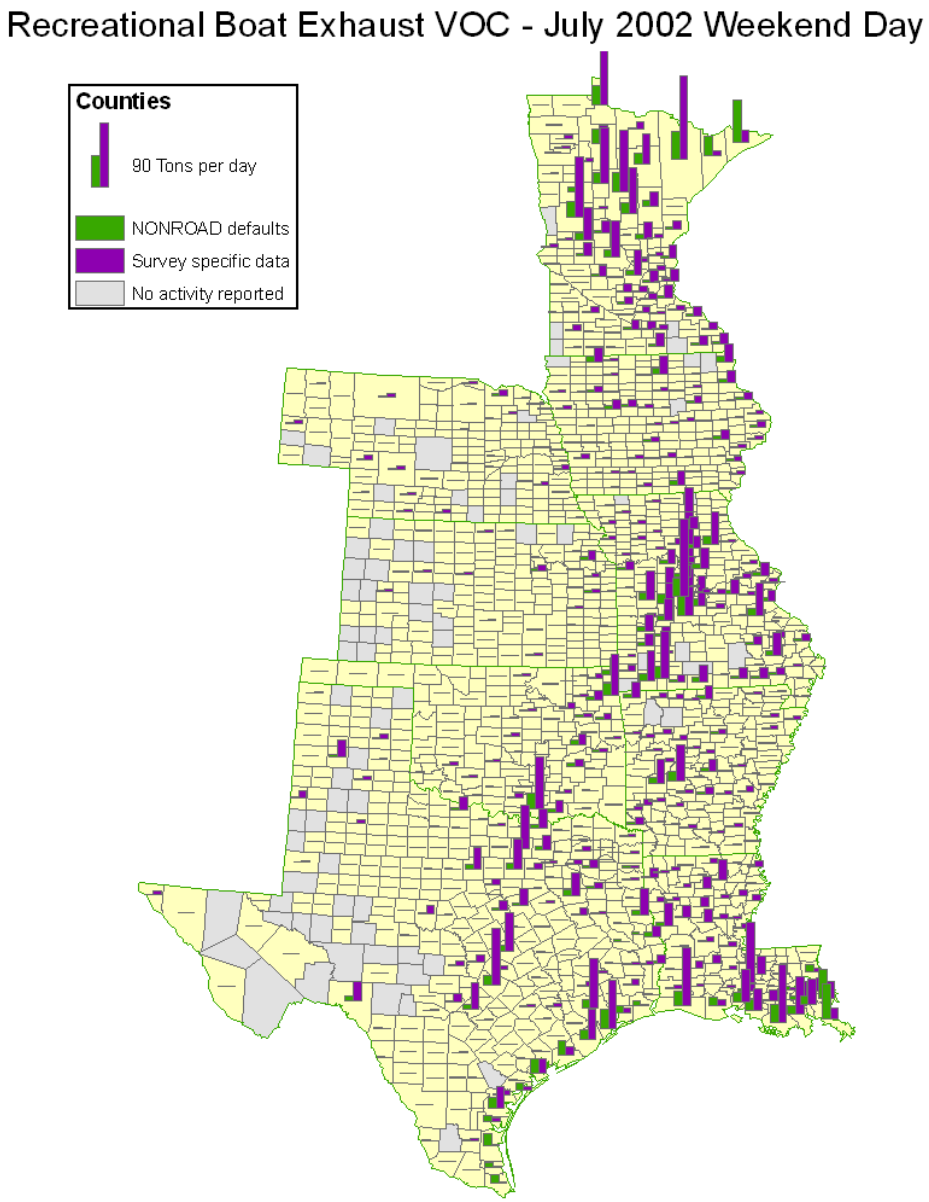



Figure 2-22. Comparison of county-level exhaust VOC emissions estimates with results obtained using NONROAD model defaults.

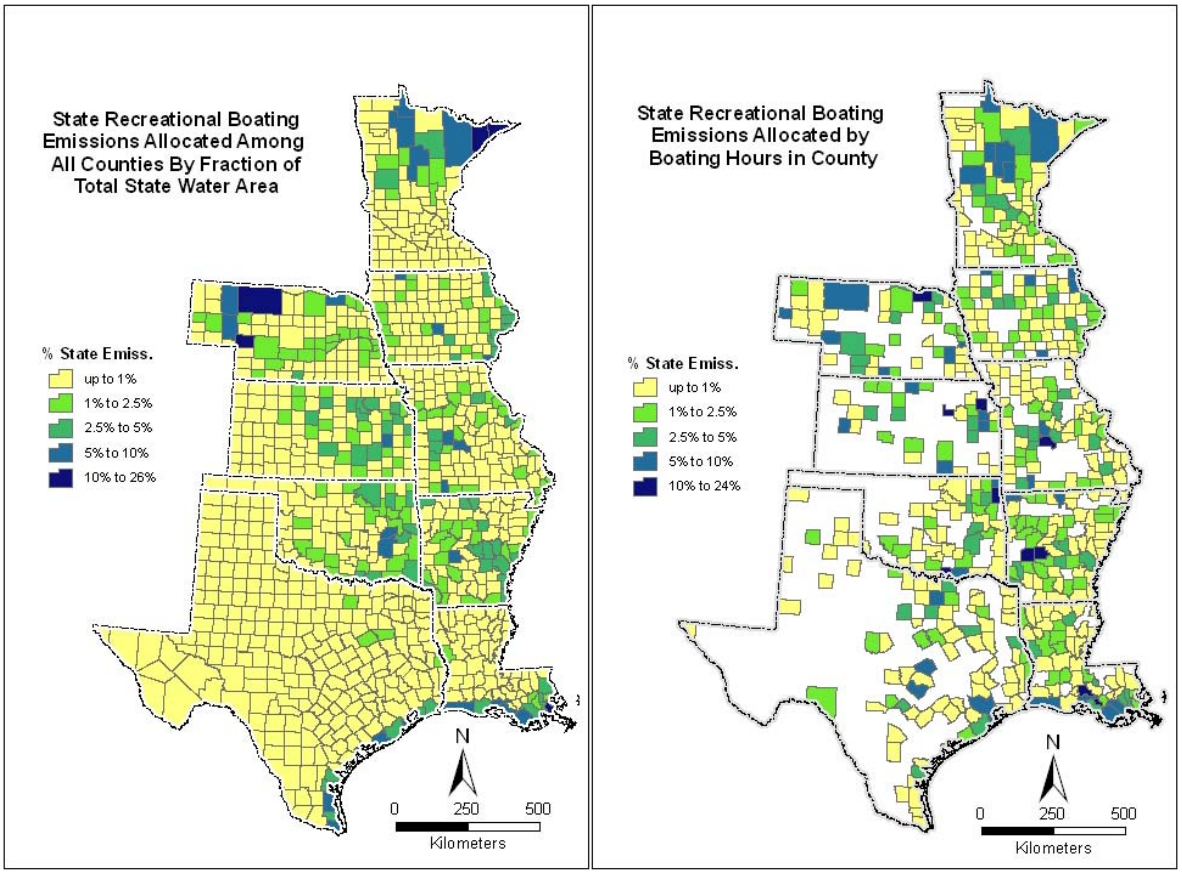



Figure 2-23. Comparison of county-level spatial allocation factors with NONROAD model defaults.

### 2.2.7 Summary of Emissions from Other Non-Road Mobile Sources

An initial prioritization of efforts related to non-road mobile sources indicated that commercial marine vessels, locomotives, and recreational boats represent at least two-thirds of the non-road primary and precursor emissions in counties containing or adjacent to Class I areas in the CENRAP region.[6] Therefore, these source categories were selected for bottom-up treatment, and emissions from remaining non-road mobile sources were estimated with the best available top-down methods. The EPA's NONROAD model is the approved method for estimating emissions from these sources, and the latest version of the model was run with default activity data, but with region-specific fuels characteristics and temperatures as appropriate.

**Table 2-6** lists emissions for non-road mobile source categories not previously treated in earlier sections of this report—i.e., excluding emissions from locomotives, commercial marine vessels, recreational boats, and aircraft. The table lists the five largest $PM_{2.5}$ sources in each state. Agricultural equipment and construction and mining equipment, which are largely fueled

[6] The final CENRAP inventory indicates that these sources are even more substantial contributors to emissions in these areas than the initial prioritization first indicated.

by diesel fuel, tend to be the largest sources of $NO_x$, $SO_2$, and $PM_{2.5}$ for the CENRAP states, whereas recreational and lawn and garden equipment (predominantly gasoline-powered) are the largest sources of VOC. A geographic distribution of emissions for a selected date can be seen in **Figure 2-24**.

Table 2-6. "Other" non-road mobile source emissions (tons) by state and equipment type (not including emissions for locomotives, commercial marine vessels, recreational boats, and aircraft).



| State | Category | $PM_{2.5}$ | $NO_x$ | VOC | $SO_2$ | CO | $NH_3$ |
|---|---|---|---|---|---|---|---|
| Arkansas | Agricultural Equipment | 1,127 | 10,344 | 1,480 | 166 | 12,372 | 6 |
| | Construction & Mining | 677 | 8,285 | 1,508 | 152 | 12,639 | 5 |
| | Recreational Equipment | 253 | 177 | 8,041 | 15 | 26,894 | 1 |
| | Industrial Equipment | 132 | 4,954 | 1,222 | 33 | 19,657 | 1 |
| | Lawn & Garden | 92 | 426 | 3,713 | 18 | 57,637 | 1 |
| | Other | 135 | 1,666 | 1,866 | 34 | 41,660 | 9 |
| | Total | 2,415 | 25,852 | 17,830 | 418 | 170,860 | 22 |
| Iowa | Agricultural Equipment | 4,961 | 45,544 | 6,428 | 731 | 53,863 | 26 |
| | Construction & Mining | 808 | 9,893 | 1,789 | 181 | 15,007 | 5 |
| | Recreational Equipment | 322 | 227 | 13,516 | 36 | 51,872 | 3 |
| | Lawn & Garden | 229 | 1,088 | 8,190 | 42 | 127,060 | 2 |
| | Commercial Equipment | 142 | 1,775 | 2,314 | 36 | 58,916 | 1 |
| | Other | 145 | 5,198 | 1,270 | 35 | 20,234 | 1 |
| | Total | 6,607 | 63,725 | 33,506 | 1,062 | 326,950 | 38 |
| Kansas | Agricultural Equipment | 3,337 | 30,673 | 4,346 | 452 | 36,410 | 17 |
| | Construction & Mining | 785 | 9,622 | 1,744 | 161 | 14,608 | 5 |
| | Lawn & Garden | 206 | 909 | 7,155 | 35 | 106,296 | 2 |
| | Commercial Equipment | 124 | 1,535 | 2,033 | 30 | 52,119 | 1 |
| | Industrial Equipment | 112 | 4,024 | 977 | 26 | 15,550 | 1 |
| | Other | 101 | 618 | 3,125 | 13 | 19,689 | 72 |
| | Total | 4,665 | 47,382 | 19,381 | 716 | 244,673 | 98 |
| Louisiana | Construction & Mining | 1,095 | 13,383 | 2,436 | 260 | 20,482 | 8 |
| | Agricultural Equipment | 589 | 5,402 | 773 | 91 | 6,469 | 3 |
| | Recreational Equipment | 261 | 170 | 8,285 | 15 | 26,223 | 1 |
| | Lawn & Garden | 158 | 713 | 6,177 | 31 | 95,753 | 2 |
| | Commercial Equipment | 156 | 1,854 | 2,564 | 40 | 66,691 | 2 |
| | Other | 320 | 8,128 | 5,939 | 98 | 59,742 | 508 |
| | Total | 2,579 | 29,650 | 26,173 | 536 | 275,361 | 525 |
| Minnesota | Agricultural Equipment | 3,954 | 36,320 | 5,125 | 577 | 42,761 | 21 |
| | Recreational Equipment | 2,024 | 924 | 91,180 | 87 | 262,747 | 21 |
| | Construction & Mining | 1,161 | 14,209 | 2,571 | 259 | 21,446 | 8 |
| | Lawn & Garden | 329 | 1,613 | 11,938 | 26 | 184,758 | 4 |
| | Industrial Equipment | 236 | 8,807 | 2,152 | 55 | 34,390 | 2 |
| | Other | 275 | 3,492 | 3,880 | 49 | 94,248 | 4 |
| | Total | 7,979 | 65,365 | 116,847 | 1,052 | 640,351 | 59 |

Table 2-6. "Other" non-road mobile source emissions (tons) by state and equipment type (not including emissions for locomotives, commercial marine vessels, recreational boats, and aircraft).



| State | Category | $PM_{2.5}$ | $NO_x$ | VOC | $SO_2$ | CO | $NH_3$ |
|---|---|---|---|---|---|---|---|
| Missouri | Agricultural Equipment | 2,643 | 24,252 | 3,435 | 421 | 28,831 | 14 |
| | Construction & Mining | 1,045 | 12,766 | 2,314 | 254 | 19,485 | 7 |
| | Lawn & Garden | 439 | 2,031 | 15,731 | 83 | 244,136 | 5 |
| | Recreational Equipment | 256 | 259 | 8,067 | 18 | 39,236 | 1 |
| | Industrial Equipment | 242 | 8,701 | 2,120 | 64 | 33,917 | 2 |
| | Other | 270 | 3,319 | 3,997 | 69 | 101,239 | 4 |
| | Total | 4,895 | 51,328 | 35,664 | 909 | 466,845 | 33 |
| Nebraska | Agricultural Equipment | 2,870 | 26,356 | 3,733 | 423 | 31,201 | 15 |
| | Construction & Mining | 417 | 5,107 | 924 | 93 | 7,728 | 2 |
| | Lawn & Garden | 120 | 533 | 4,219 | 20 | 62,304 | 1 |
| | Recreational Equipment | 83 | 99 | 2,824 | 8 | 17,152 | 0 |
| | Commercial Equipment | 82 | 1,020 | 1,342 | 20 | 34,191 | 1 |
| | Other | 73 | 2,441 | 607 | 18 | 9,401 | 3 |
| | Total | 3,644 | 35,556 | 13,650 | 582 | 161,977 | 23 |
| Oklahoma | Agricultural Equipment | 1,277 | 11,731 | 1,679 | 188 | 14,025 | 6 |
| | Construction & Mining | 655 | 8,016 | 1,459 | 147 | 12,213 | 4 |
| | Lawn & Garden | 172 | 776 | 6,348 | 32 | 97,477 | 2 |
| | Recreational Equipment | 129 | 124 | 4,106 | 9 | 18,720 | 1 |
| | Commercial Equipment | 126 | 1,532 | 2,097 | 31 | 53,592 | 1 |
| | Other | 184 | 5,383 | 3,157 | 53 | 34,267 | 250 |
| | Total | 2,543 | 27,563 | 18,846 | 460 | 230,294 | 265 |
| Texas | Construction & Mining | 4,610 | 56,355 | 10,274 | 1,049 | 86,597 | 36 |
| | Agricultural Equipment | 2,791 | 25,621 | 3,676 | 414 | 30,877 | 14 |
| | Lawn & Garden | 1,393 | 5,908 | 46,403 | 240 | 708,712 | 16 |
| | Commercial Equipment | 794 | 9,459 | 13,202 | 199 | 340,914 | 10 |
| | Industrial Equipment | 671 | 21,938 | 5,264 | 167 | 82,994 | 5 |
| | Other | 983 | 11,728 | 28,062 | 201 | 190,438 | 1,362 |
| | Total | 11,241 | 131,009 | 106,881 | 2,271 | 1,440,533 | 1,444 |
| Total – All States and Sources | | 46,568 | 477,429 | 388,778 | 8,006 | 3,957,843 | 2,507 |

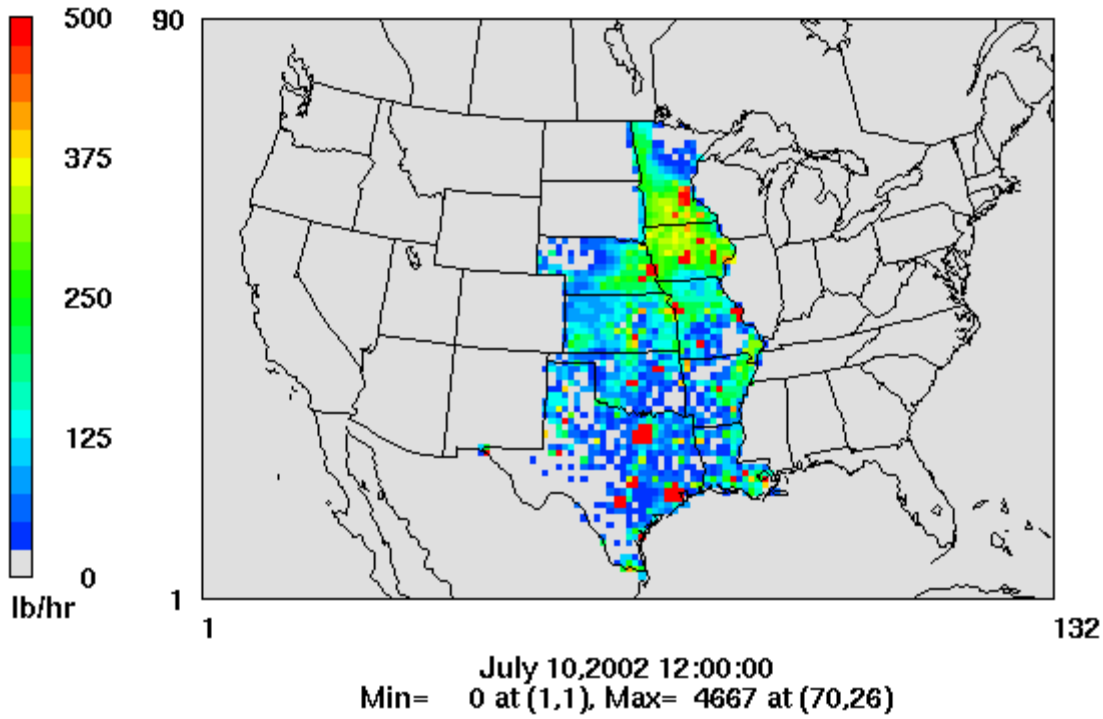



Figure 2-24. Geographic distribution of "other" non-road mobile source emissions of $NO_x$ in CENRAP states on July 10, 2002.

### 2.2.8 Assessment of Emissions from Non-Road Mobile Sources

Emissions estimates for non-road mobile sources represent an improvement over existing inventories due to the use of region-specific fuels characteristics. **Figure 2-25** shows a comparison of the CENRAP inventory and the preliminary 2002 NEI. A significant difference in $SO_2$ emissions and a modest difference in VOC emissions are apparent. These differences are due to the use of state-specific diesel sulfur contents and gasoline volatilities for the CENRAP inventory. However, further improvements could be made by gathering bottom-up activity data (as was done for recreational boating). Based on a review of the emissions totals, the priority categories for further study are agricultural equipment and construction and mining equipment, which account for 75% of the total $NO_x$, $PM_{2.5}$, and $SO_2$ emissions from "other" non-road mobile sources and/or recreational or lawn and garden equipment, which dominate VOC emissions.

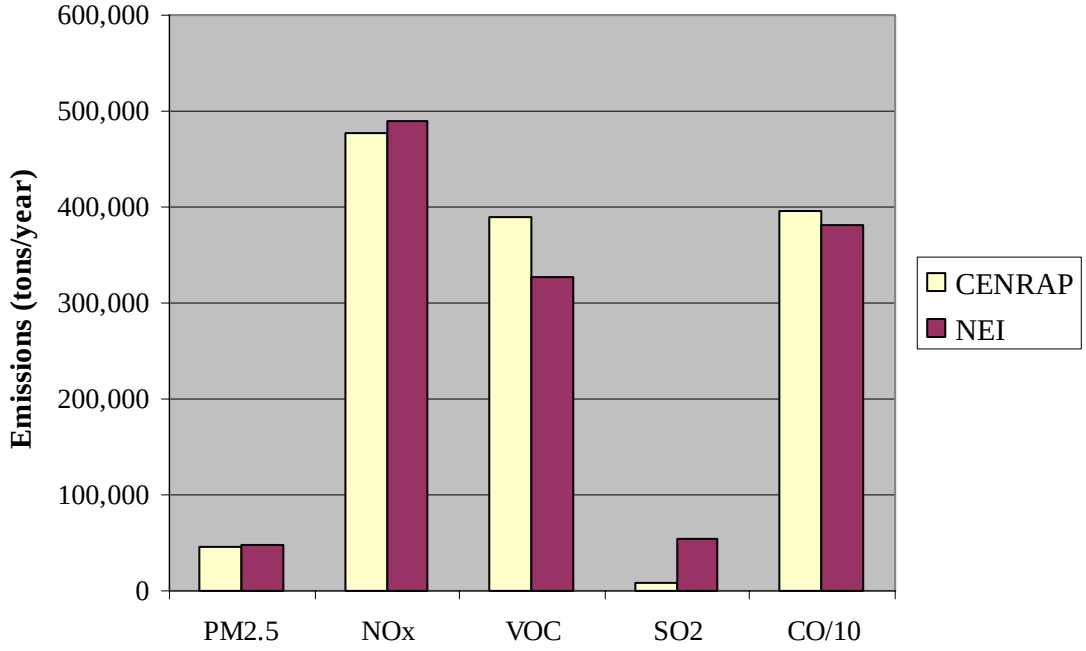



Figure 2-25. Comparison of non-road mobile source emissions with results from the preliminary 2002 NEI (note: CO emissions have been divided by 10 for scaling purposes).

## 2.3 EMISSIONS FROM SOURCES OF AGRICULTURAL DUST

### 2.3.1 Summary of Emissions from Agricultural Tilling Operations

Particulate matter (PM) emissions from agricultural tilling operations in the CENRAP region were estimated combining a constant emission factor with county-level activity data, including the silt content of surface soils, the number of tillings performed in a year for each crop type, the acres of each crop type, and information about conservational tillage practices. (Conservational tilling practices, such as no-till, mulch-till, and ridge-till, reduce the number of tilling passes performed in a year.) Total $PM_{10}$ emissions from agricultural tilling operations in the CENRAP region were estimated to be over 1.3 million tons per year, with $PM_{2.5}$ emissions contributing about 270,000 tons to this total (see **Table 2-7** and **Figure 2-26**). A geographic distribution of county-level $PM_{2.5}$ emissions appears in **Figure 2-27**. Temporal variations in $PM_{2.5}$ emissions by month, day-of-week, and hour-of-day appear in **Figures 2-28 through 2-30**.

Table 2-7. Particulate matter emissions (tons) from agricultural tilling operations by state.

| State | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|
| Arkansas | 87,895 | 17,579 |
| Iowa | 236,520 | 47,304 |
| Kansas | 253,850 | 50,769 |
| Louisiana | 42,443 | 8,489 |
| Minnesota | 215,070 | 43,013 |
| Missouri | 104,530 | 20,905 |
| Nebraska | 138,850 | 27,770 |
| Oklahoma | 100,160 | 20,033 |
| Texas | 167,420 | 33,484 |
| Total | 1,346,738 | 269,346 |

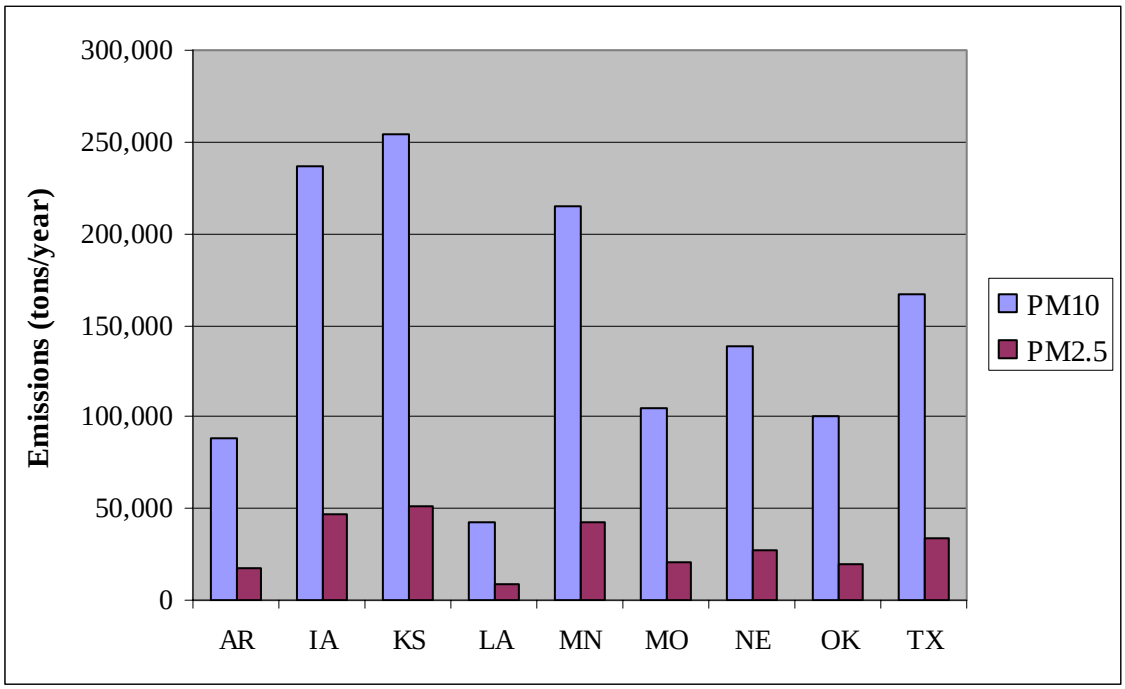



Figure 2-26. Particulate matter emissions from agricultural tilling operations by state.

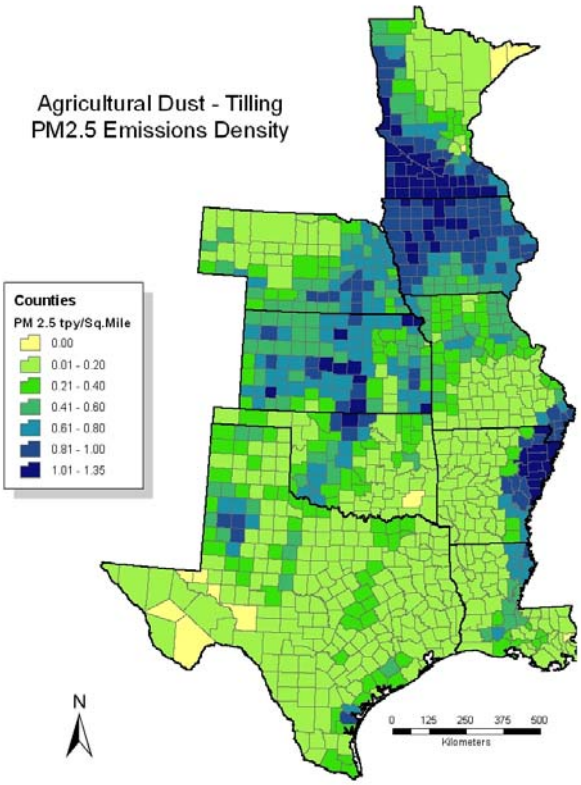



Figure 2-27. County-level $PM_{2.5}$ emission estimates for agricultural tilling operations.

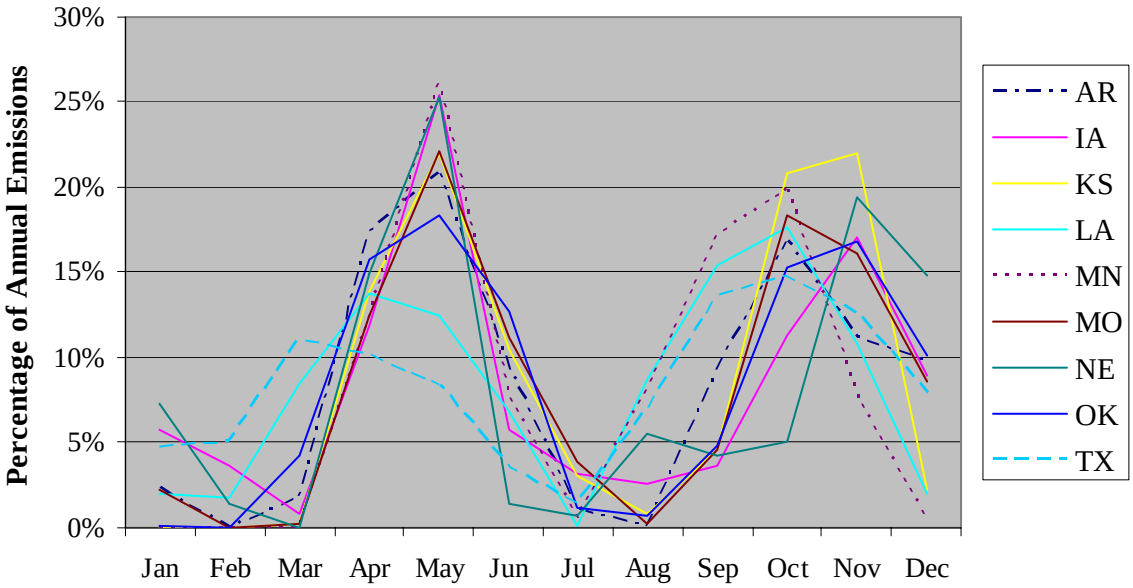



Figure 2-28. Monthly variability in agricultural tilling emissions by state.

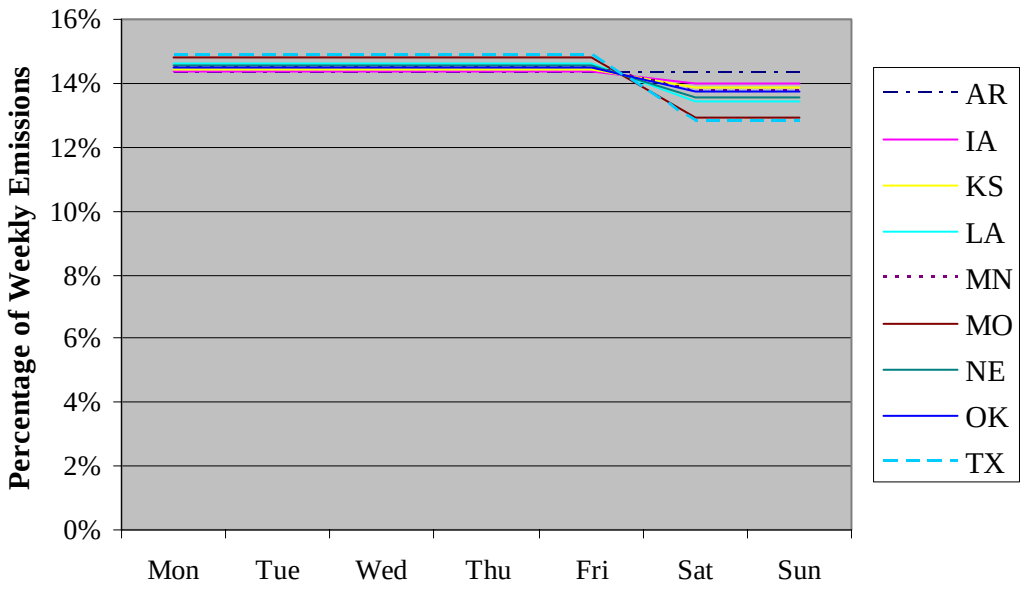



Figure 2-29. Day-of-week variability in agricultural tilling emissions by state.

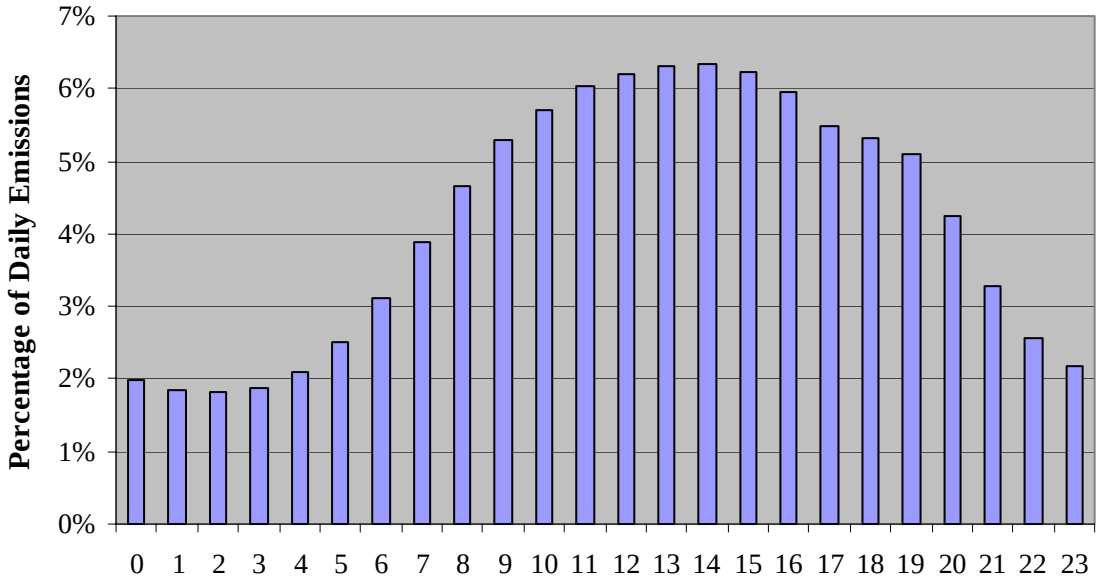



Figure 2-30. Diurnal variability in agricultural tilling emissions (same for all states).

### 2.3.2 Assessment of Emissions from Agricultural Tilling Operations

The use of locally representative activity information in the development of emission inventories for agricultural tilling operations permitted a significant improvement over the inventory compiled for the preliminary 2002 NEI. The most significant improvements included county-level soil silt contents and locally reported tilling practices (reported as the number of

tilling passes completed for each crop type), which were found to correlate with the actual prevalence of conservational tilling practices. Emission estimates from this inventory are generally about 25% to 30% lower than corresponding estimates from the preliminary 2002 NEI, although the comparison varies from state-to-state (see **Figure 2-31**). These reductions seem primarily due to the incorporation of local information on tilling practices because the reported number of tilling passes for each crop type was often less than indicated by EPA guidance. A likely explanation is that conservational tilling practices have become more prevalent in recent years, particularly in Texas, where the most dramatic differences between the preliminary 2002 NEI and the CENRAP inventory are apparent.

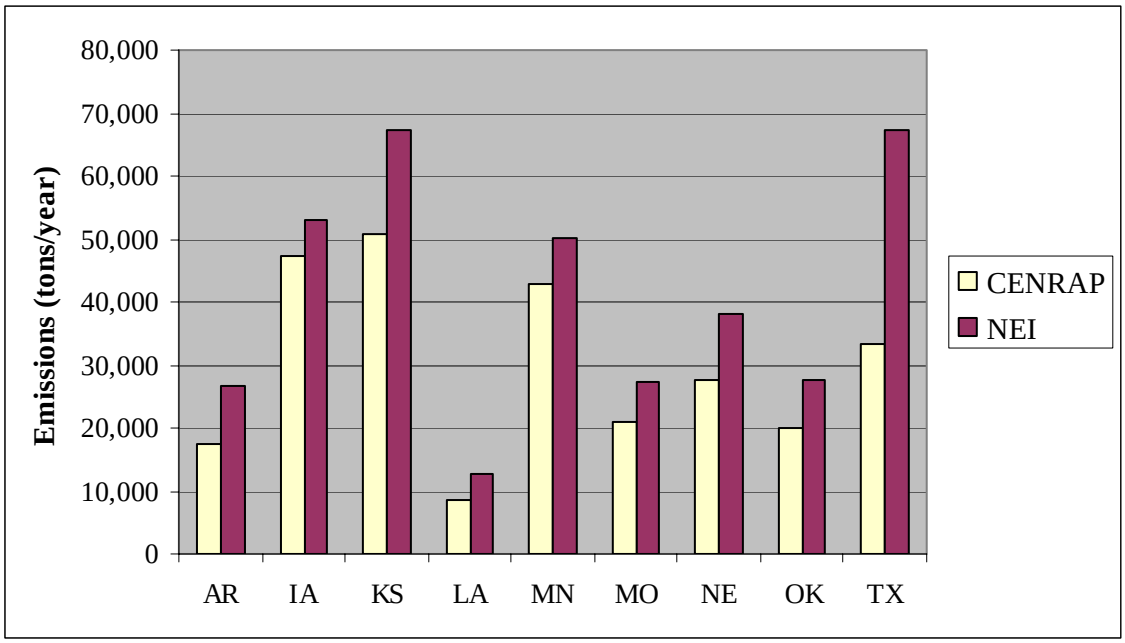



Figure 2-31. State-by-state comparison of $PM_{2.5}$ emissions from agricultural tilling operations.

### 2.3.3 Summary of Emissions from Livestock Operations

PM emissions from livestock operations in the CENRAP region were estimated using a $PM_{10}$ emission factor and a $PM_{2.5}$ size fraction selected after a literature review. These factors were applied to facility-specific annual populations for beef cattle feedlots and dairies. Because facility locations were also acquired, emissions from livestock operations were treated as point sources and assigned to the specific location coordinates of each facility. Total $PM_{10}$ emissions from livestock operations in the CENRAP region were estimated to be 51,000 tons per year, with $PM_{2.5}$ emissions contributing about 7,700 tons to this total (see **Table 2-8** and **Figure 2-32**). A geographic distribution of county-level $PM_{10}$ emissions appears in **Figure 2-33**.

Table 2-8. Particulate matter emissions (tons) from livestock operations by state.

| State | Facility Type | $PM_{10}$ | $PM_{2.5}$ |
|---|---|---|---|
| Arkansas | Beef Cattle Feedlot | 0.0 | 0.0 |
| | Dairy | 3.9 | 0.6 |
| Iowa | Beef Cattle Feedlot | 4,314.0 | 647.1 |
| | Dairy | 40.8 | 6.1 |
| Kansas | Beef Cattle Feedlot | 18,378.5 | 2,756.8 |
| | Dairy | 142.7 | 21.4 |
| Louisiana | Beef Cattle Feedlot | 15.9 | 2.4 |
| | Dairy | 0.0 | 0.0 |
| Minnesota | Beef Cattle Feedlot | 252.6 | 37.9 |
| | Dairy | 35.6 | 5.3 |
| Missouri | Beef Cattle Feedlot | 109.3 | 16.4 |
| | Dairy | 9.7 | 1.5 |
| Nebraska | Beef Cattle Feedlot | 8,732.9 | 1,309.9 |
| | Dairy | 15.4 | 2.3 |
| Oklahoma | Beef Cattle Feedlot | 3,390.4 | 508.6 |
| | Dairy | 22.5 | 3.4 |
| Texas | Beef Cattle Feedlot | 15,673.8 | 2,351.1 |
| | Dairy | 152.2 | 22.8 |
| Total | | 51,290.2 | 7,693.6 |

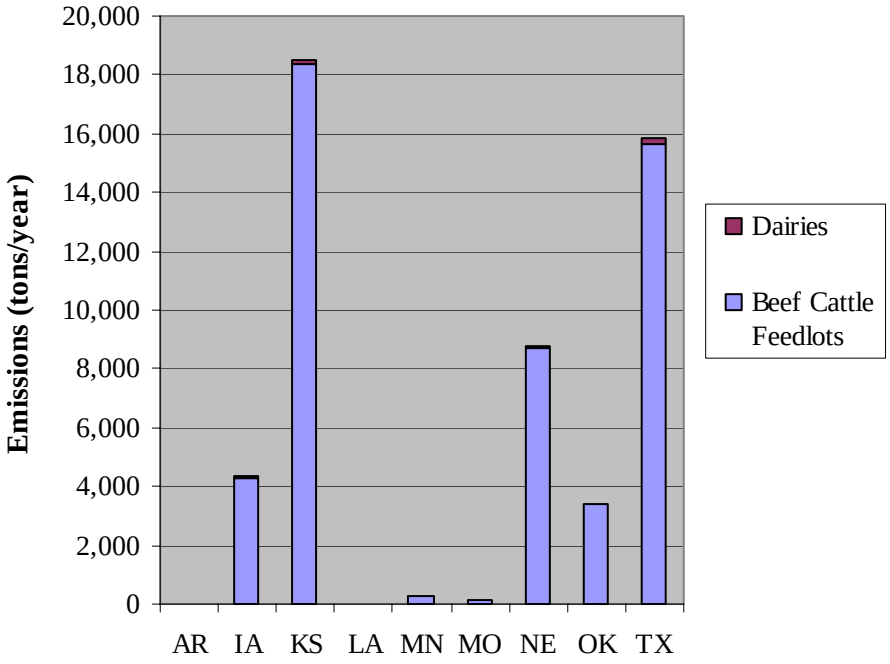



Figure 2-32. $PM_{10}$ emissions from livestock operations by state and facility type.

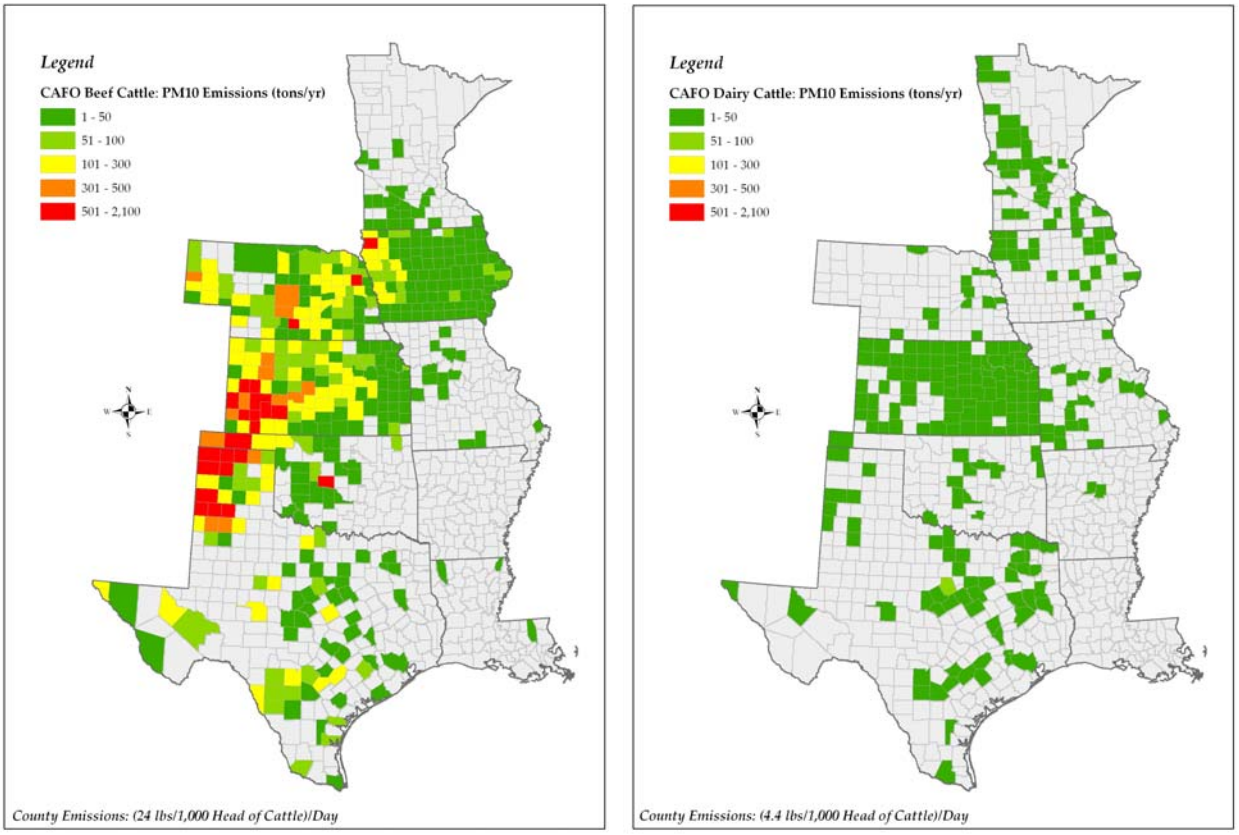



Figure 2-33. County-level $PM_{10}$ emission estimates for beef cattle feedlots (left) and dairies (right).

### 2.3.4 Assessment of Emissions from Livestock Operations

The methods used to develop emission inventories for livestock operations represent a significant improvement over existing inventories, both in terms of the total annual emissions calculated and the geographic distribution of those emissions. The 1999 NEI[7] included an estimated 270,000 tons per year of $PM_{10}$ emissions from CAFOs in the CENRAP region—a figure more than five times higher than that estimated for the CENRAP inventory. A literature search indicated that the emission factor of 17 tons per 1000 animals per year, which was used during development of the 1999 NEI, was too high for this source category. Ultimately, an emission factor of 4.4 tons per 1000 animals per year was selected for beef cattle and an emission factor of 0.8 tons per 1000 animals per year was used for dairy cows.

In addition, the use of facility coordinates greatly enhanced the spatial distribution of emissions. For the 1999 NEI, a simplifying assumption was used that the number of cattle housed at CAFOs is approximately 10% of the total number of beef cattle in each county, regardless of feedlot locations or local animal husbandry practices. As a result, emissions were assigned to many counties in which no feedlots operate, as illustrated by **Figure 2-34**, which

[7] Particulate emissions from animal feedlots are not yet included in the 2002 version of the NEI.

contrasts the geographic distribution of emissions in the 1999 NEI with known feedlot locations and animal populations. Side-by-side comparison of these figures shows that the 1999 NEI registers high emissions densities in eastern Texas, Oklahoma, western Missouri, and northwestern Nebraska—areas where very few CAFOs exist. In reality, most CAFOs in the CENRAP region accumulate in a band that reaches from the Texas panhandle, across Kansas and southeastern Nebraska, and across the state of Iowa.

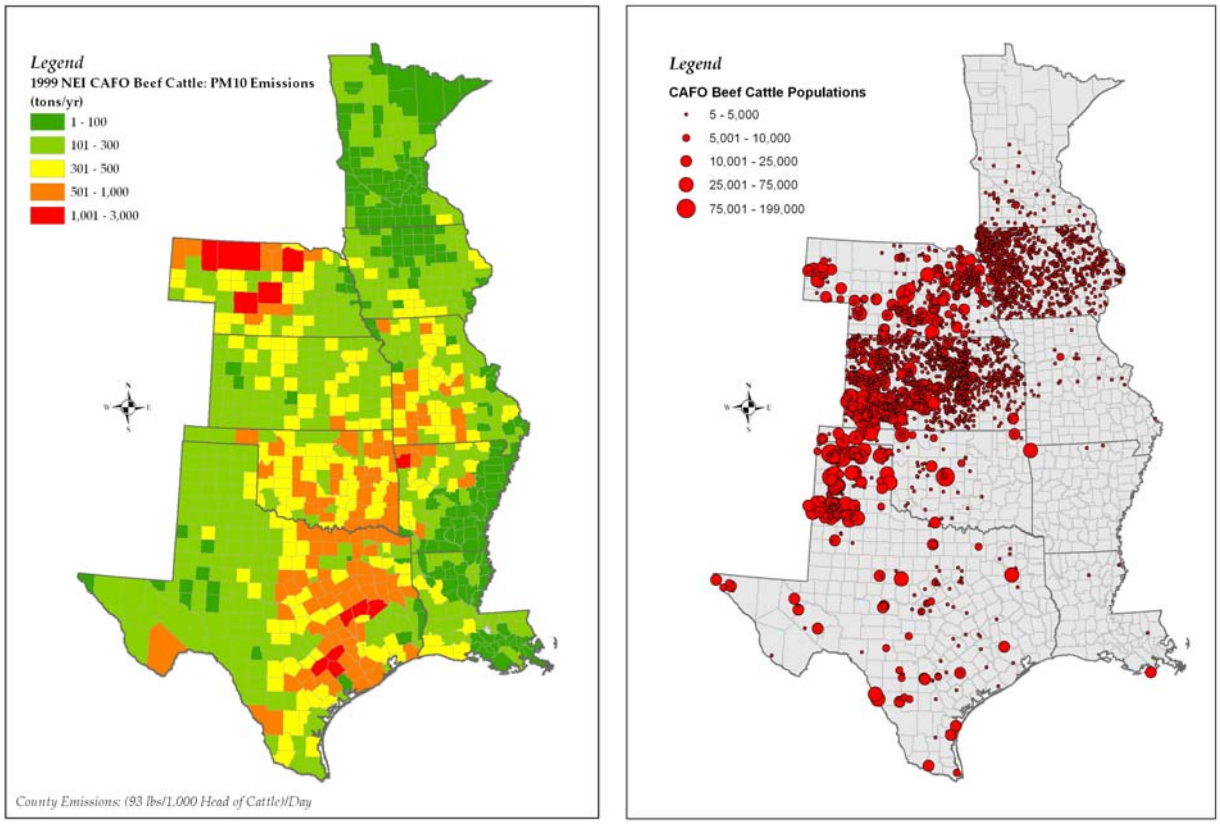



Figure 2-34. NEI county-level $PM_{10}$ emissions for beef cattle feedlots vs. actual beef cattle feedlot locations and populations.

# 3. RECOMMENDATIONS FOR FURTHER RESEARCH

This study resulted in significant improvements to the 2002 emission inventories for on-road and off-road mobile sources and for sources of agricultural fugitive dust in the CENRAP region. Emission inventories were prepared on highly region-specific or even county-specific bases and adhered closely to EPA's recommended guidance for inventory development. Additional refinements and improvements should be incorporated as the products of ongoing research into emission factors and updates to activity data sets become available. Additionally, we identified the following potential sources of uncertainty in the inventories (roughly in order of importance):

1. Unusual vehicle age distributions and duplicate VIN records were observed in DMV databases of vehicle registrations.
2. The inventories of non-road mobile sources could benefit from additional bottom-up data collection efforts.
3. Existing VMT distributions could be refined to better represent the increasing popularity of SUVs and light trucks.
4. Fuels testing programs could be deployed or improved to better represent fuels characteristics.
5. VIN decoding yielded too few records corresponding to alternative-fueled vehicles to allow improvements to this component of the inventory (though this affects future-year projections more than the 2002 inventory).
6. Day-specific inventories (e.g., Monday, Tuesday, etc.) may be superior to assuming all weekdays are the same and both weekend days are the same for photochemical modeling purposes.
7. The inventories of agricultural fugitive dust sources could benefit from additional bottom-up data collection efforts.

This section briefly discusses recommendations for addressing these issues.

## 3.1 RECOMMENDATIONS FOR IMPROVING INVENTORIES OF ON-ROAD MOBILE SOURCES

### 3.1.1 Incorporate New Data and Information as They Become Available

Emission inventories operate best as dynamic databases—subject to continuous refinements, additions, and improvements as research develops and activity data are updated. The electronic file systems of the activity data and emission inventories developed for the CENRAP, which were delivered as products of this project, are likely to be revised and improved as new information becomes available. Examples of recently developed or soon-to-be-available data sets that could be incorporated to further improve the CENRAP's inventories include (1) locally generated VMT estimates for Kansas City, Minneapolis-St. Paul, and Little

Rock; (2) results of the fuels testing program of the Texas Department of Agriculture; and (3) reports of fuels sulfur contents that refiners will be submitting to EPA beginning in February 2005 for diesel and February 2007 for gasoline. In addition, we recommend encouraging fuel testing programs in states where they are not yet planned—Louisiana, Arkansas, Iowa, and Nebraska—and encouraging the Oklahoma Department of Agriculture to archive and maintain records of their existing fuels testing program.

### 3.1.2 Investigate Databases of Vehicle Registrations

Unusual features in several states' databases of vehicle registrations were noted, including (roughly in order of importance) unexpected numbers of duplicate VINs, unusually large proportions of old light-duty vehicles, and unexpectedly small numbers of light-duty vehicles less than 2-3 years in age. High frequencies of duplicate VINs are sources of error in fleet distributions in and of themselves—particularly in Iowa, where the frequency of duplicates could only be reduced to 6%. However, high frequencies of duplicate records may only be one symptom of general database maintenance problems—such as retention of outdated records, mis-assignment of records, etc.—that cannot be easily recognized and remedied without in-depth review and diagnosis. The possibility that unidentified errors in the vehicle registration databases are related to unusual vehicle age distributions in some states is a cause for concern. MOBILE6 models older vehicles with higher emission rates due to their levels of deterioration and outdated emissions control technologies. Therefore, errors in this component of the vehicle population distributions exert significant impacts on the emission inventories of on-road mobile sources. In addition, errors across all age ranges can significantly impact projections of emission inventories to future years.

### 3.1.3 Use Fleet Distributions to Refine VMT Distributions

Patterns of SUVs and light-duty-truck use have been shifting rapidly in recent years. However, for this study, VMT distributions by vehicle type for many areas of the CENRAP were based on EPA defaults, which are based on predictions and data from a number of years ago. Errors in the VMT distributions by vehicle type can be significant because emissions standards vary across the classes of light-duty vehicles, and emissions from gasoline-fueled vehicles differ considerably from those of diesel-fueled vehicles. VMT distributions could be refined or adjusted by using vehicle registration data. This approach is based on an assumption, which we believe is well-founded, that due to recent trends in vehicle ownership and driver behavior, many light-duty trucks (e.g., SUVs) are now driven very similarly like passenger vehicles. Thus, the proportions of VMT that should be assigned to each vehicle type and fuel type are approximately equal to the proportions of vehicles registered in each vehicle- and fuel-type category. (Note that this assumption has already been applied in EPA Region I.) Alternatively, the VMT mix could be calculated from registration data using the vehicle type-specific assumptions about annual mileage accumulation rates that are part of the MOBILE6 model.

### 3.1.4 Prepare Inventories Specific to the Days of the Week

Driving activities for on-road motor vehicles appear to vary with each day of the week. Therefore, a day-specific approach may be preferable to a simple weekday-weekend approach for some photochemical modeling applications. In general, urban VMT declines on Sundays below average weekday levels to an even greater extent than on Saturdays. Friday evening VMT is somewhat higher than on other weekday evenings, and daily total VMT on Mondays is usually somewhat below average for weekdays in urban areas. Day-specific patterns are also likely to occur in rural areas. The 2002 CENRAP inventories reflect the most significant weekday-weekend patterns supported by research results from other areas of the United States. However, further improvements could be made by investing in research projects that investigate region-specific, day-of-week patterns for both rural and urban areas.

### 3.1.5 Improve Inventories for Alternative-Fueled Vehicles

VIN decoding yielded too little information to support improvements to the inventory of alternative-fueled vehicles. In addition, fuels characteristics of alternative fuels are rarely tested, and no region-specific data were identified. While these uncertainties have little effect on the 2002 inventory, they may become more important when future-year emission inventories are projected to 2018 and beyond. Alternative-fueled vehicles may compose significantly larger proportions of vehicle fleets in the future and trace levels of sulfur in alternative fuels may become more important as sulfur levels in diesel and gasoline fuels continue to decline as a result of existing regulations.

## 3.2 RECOMMENDATIONS FOR IMPROVING INVENTORIES OF NON-ROAD MOBILE SOURCES

A survey of representative groups of recreational boat owners in the CENRAP region produced dramatic revisions to the emission inventories for this source category. Emissions estimates were revised by factors of 3 or more, on average. Further improvements in the non-road component of the inventory could be made by gathering bottom-up activity data for the next-largest non-road mobile source categories, including agricultural equipment and construction and mining equipment (which are significant sources of $NO_x$, $PM_{2.5}$, and $SO_2$ emissions) and/or recreational or lawn and garden equipment (which are important sources of VOC emissions).

## 3.3 RECOMMENDATIONS FOR IMPROVING INVENTORIES OF SOURCES OF AGRICULTURAL DUST

### 3.3.1 Research and Develop Process-Based Emissions Estimation Methods

The limited body of research into emission factors and emission processes represents the most significant weakness in the emission inventories of sources agricultural fugitive dust. Investment in the development of emissions measurement programs and process-based

approaches that account for soil moisture, meteorological conditions, and agricultural practices would produce substantial improvements to the accuracy and certainty of this component of the inventory.

### 3.3.2 Prepare Bottom-Up Inventories for Additional Source Categories

A survey of agricultural extension offices and the use of bottom-up animal population data produced significantly altered spatial allocations and emissions estimates for sources of agricultural fugitive dust. State-level emissions estimates were revised by 25% to 50%, and CAFO emissions were displaced to entirely different geographic areas of the CENRAP. Further modest improvements could be made by gathering bottom-up activity data for the next-largest sources of agricultural fugitive dust, including cotton ginning operations and/or crop transport. However, emissions from these types of sources are likely to be dwarfed by emissions from agricultural tilling dust and are likely to be of significance in only a few areas of the CENRAP where cotton ginning occurs.

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# APPENDIX A

## EMISSION ESTIMATION METHODS FOR MOBILE SOURCES AND AGRICULTURAL DUST SOURCES IN THE CENTRAL STATES (STI-903574-2610-MD)

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# EMISSION ESTIMATION METHODS FOR MOBILE SOURCES AND AGRICULTURAL DUST SOURCES IN THE CENTRAL STATES

**METHODS DOCUMENT**
**STI-903574-2610-MD**

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**September 22, 2003**

## QUALITY ASSURANCE STATEMENT

**This report was reviewed and approved by the project Quality Assurance (QA) Officer or his delegated representatives, as provided in the project QA Plan (Sullivan, 2004).**

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**Project QA Officer**

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# 1. INTRODUCTION

The Central States Regional Air Planning Association (CENRAP) is developing a regional haze plan in response to the U.S. Environmental Protection Agency's (EPA) mandate to protect visibility in Class I areas. To develop an effective regional haze plan, the CENRAP ultimately must develop a conceptual model of the phenomena that lead to episodes of low visibility in the CENRAP region. Thus, the CENRAP is researching visibility-related issues for its region, which includes the states of Texas, Oklahoma, Louisiana, Arkansas, Kansas, Missouri, Nebraska, Iowa, and Minnesota. Both primary particulate matter (which is emitted directly to the atmosphere in particulate form) and the formation of secondary particulate matter (which is generated from chemical transformations in the atmosphere of gaseous precursor species such as ammonia, nitrogen oxides, sulfur oxides, and volatile organic compounds [VOCs]) contribute to episodes of regional haze and low visibility in the CENRAP region. Mobile sources and sources of agricultural fugitive dust are thought to be significant sources of these pollutants (as illustrated in **Figure 1-1**). In recognition of these issues, the CENRAP sponsored the development of improved emission inventories for mobile sources and sources of agricultural dust. The project objectives were to improve or develop activity data for off- and on-road mobile sources and sources of agricultural dust throughout the nine CENRAP states; to prepare the activity data in formats compatible for reprocessing and use with MOBILE6, NONROAD, and SMOKE 1.5 (which runs MOBILE6 internally); and/or to prepare the emission inventories in the latest version of the National Emission Inventory Input Format (NIF).

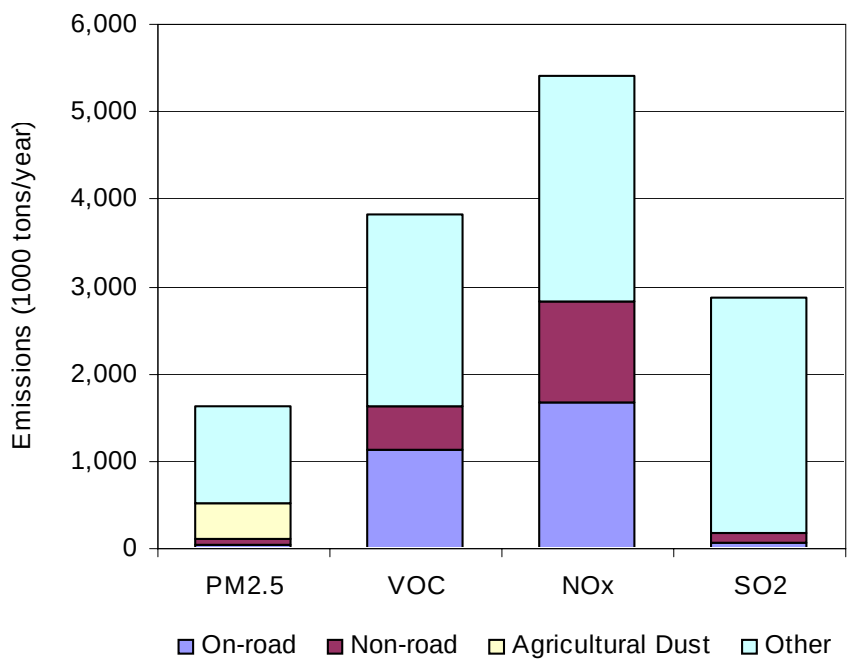


Figure 1-1. Estimated emissions for the CENRAP region. Source: 1999 NEI (U.S. Environmental Protection Agency, 1999c).

## 1.1 BRIEF OVERVIEWS OF EMISSIONS MODELING METHODS

### 1.1.1 Overview of Methods to Prepare Emission Inventories of On-Road Mobile Sources

The EPA's MOBILE6 model—an emission factor model that estimates emission factors for on-road mobile sources—and SMOKE were used to generate and prepare emission inventories of on-road mobile sources for photochemical modeling. SMOKE processes and prepares on-road mobile source emission inventories for photochemical air quality modeling by applying temporal profiles, speciation profiles, and gridding surrogates to county-level emissions estimates. In addition, SMOKE self-contains MOBILE6. Thus, SMOKE has the added capability of generating county-level emission inventories for on-road mobile sources by estimating MOBILE6 emission factors and matching these to county-level activity data. MOBILE6 requires a variety of inputs, including temperatures, fleet distributions, vehicle speeds, regulatory controls settings, and fuels characteristics. **Figure 1-2** illustrates the general processes of using MOBILE6 within SMOKE to generate on-road mobile source emission inventories. Figure 1-2 also illustrates the MOBILE6/SMOKE activity data, input files, and outputs that were prepared as products of this project. The products of these inventory development efforts are highly region-specific, or even county-specific, emission inventories that adhere to EPA's recommended guidance for the development of emission inventories for on-road mobile sources.

### 1.1.2 Overview of Methods to Prepare Emission Inventories of Non-Road Mobile Sources

The EPA's NONROAD model was used to estimate emissions for most non-road mobile sources. The NONROAD model applies equipment populations, activity data (e.g., hours of operation, load factors, etc.), emission factors, and growth factors to estimate emissions for non-road mobile sources. Default input files accompany the model, which are sufficient to estimate emissions for the entire United States at the county level. However, many of the default values are based on national defaults or general assumptions and can be improved with region-specific data, if available. Improved activity data were collected throughout the CENRAP region for recreational boating, which is considered to be one of the most important non-road mobile source categories in the region. These efforts resulted in emission inventories that are much improved over those generated by using the national default values. The most significant improvements included the hours of operation, load factors, spatial distributions, and temporal patterns of recreational boating.

Emissions from locomotives and commercial marine vessels, which are excluded from the NONROAD model, were estimated according to EPA guidance documents and using bottom-up activity data to the extent available. Aircraft emissions, which are also excluded from the NONROAD project, were considered to be a lower priority and were not included in the scope of this project.

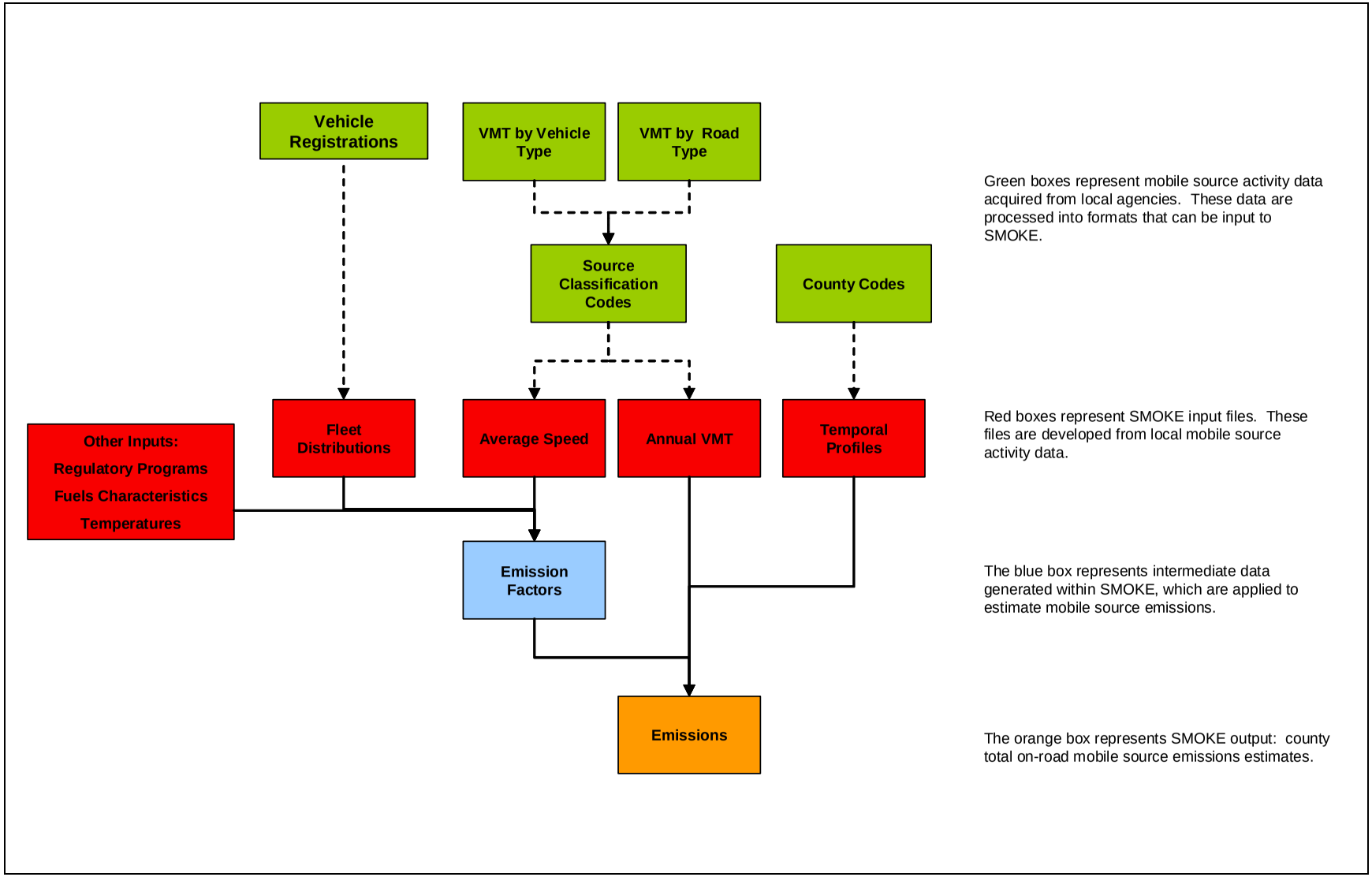


Figure 1-2. General illustration of the overall process and files used by SMOKE to generate on-road mobile source emissions output files.

### 1.1.3 Overview of Methods to Prepare Emission Inventories for Sources of Agricultural Dust

Emissions from agricultural fugitive dust sources were estimated according to EPA guidance documents or published literature. Bottom-up activity data were used to the extent available, including facility-specific animal populations for confined animal feeding operations (CAFOs) and activity data to describe agricultural tilling operations. Up-to-date GIS databases of soil characteristics and crop types were also used to improve the inventories. These activity data represent a significant improvement over inventories developed by applying national default assumptions. The most significant improvements include the CAFO animal populations, the geographic distributions of CAFO populations, the estimates of the number of tilling passes completed for each crop type, the representative soil silt content for each county, and the temporal patterns of agricultural tilling activities.

## 1.2 IMPORTANT ASSUMPTIONS

The methods employed to estimate emissions relied on several fundamental assumptions:

- Monthly fuel consumption data from the Federal Highway Administration (FHWA) and Energy Information Administration are representative of monthly patterns of on-road motor vehicle activity.
- Day-of-week and diurnal patterns of on-road motor vehicle activities observed in rural and urban geographic areas of the United States (such as Texas, California, or the national average) are reasonably representative of urban and rural areas of the CENRAP region.
- Rail link-specific traffic density data (ton-miles of cargo moved) is a reasonable surrogate for allocating locomotive fuel usage to the county level.
- The characteristics and speeds of marine vessels at key ports in the CENRAP region can be extrapolated to other ports for which detailed vessel data are not available.

Surveys were conducted to collect bottom-up information for recreational boating and agricultural dust source categories. In those cases, it was assumed that

- Recreational boat owners were capable of providing survey responses that could be interpreted to reasonably represent recreational boating activities across the CENRAP region. Techniques to eliminate or minimize the effects of over-reporting biases were sufficient.
- County agricultural extension service agents were capable of providing survey responses that reasonably represent agricultural tilling activities in the CENRAP region.
- In some cases, incomplete data were recovered. Thus, extrapolation or aggregation of bottom-up observations was assumed to produce reasonably representative results when data were missing, incomplete, or uncertain. A few examples of affected data sets include age distributions for vehicle types that appear with very low frequencies in the vehicle population, reported numbers of tilling passes for rarely grown crop types,

reported hours of use for recreational boats with inboard motors, and others as discussed in the main body of the Final Report.

- Lastly, we relied on state motor vehicle departments' databases of vehicle registrations to represent the 2002 vehicle populations in each county. In some cases, unusual features in vehicle distributions appeared (e.g., larger than expected populations of old vehicles), but no reasons to discount these phenomena could be determined.

# 2. METHODS TO PREPARE ACTIVITY DATA FOR ON-ROAD MOBILE SOURCES

This section describes the information sources used and the data processing steps followed to prepare activity data for on-road mobile sources, including vehicle miles traveled (VMT), speed distributions, and temporal distributions. VMT, speed distributions of VMT, and temporal distributions of VMT are critical input variables for emission inventories of on-road mobile sources and photochemical air quality models. VMT is a measure of on-road vehicle activity, which is often used as the foundation of emission inventories of on-road mobile sources, including those prepared with MOBILE6. Speed distributions of VMT significantly affect emission rates, while the timing of vehicle activities by season, day, or hour also significantly influences emissions (which vary with temperature).

The SMOKE emissions processor uses VMT, distributions of VMT by speed bin, and temporal distributions of VMT to estimate on-road motor vehicle emissions and to prepare emission inventories for use with photochemical air quality models. The objective of this task was to develop the SMOKE inputs for the CENRAP domain, including county-level VMT, speed distributions, and temporal profiles, which were used to model and prepare emission inventories of on-road mobile sources for the year 2002 (as discussed in Section 8).

## 2.1 BACKGROUND AND TECHNICAL ISSUES

The FHWA maintains the Highway Performance Monitoring System (HPMS) database, which contains estimates of VMT for all U.S. states and counties. The HPMS database is updated periodically with VMT data submitted by states. However, VMT data developed at the local or state level are preferable because they generally better represent regional or local conditions, are often more current than the data in the HPMS database, and, therefore, result in better quality emissions inventories. Therefore, locally or regionally developed mobile source activity data were given preference, were acquired whenever available from state and local transportation or air quality management agencies, and were used preferentially over the national default VMT estimates.

The availability of local- or state-level data varied geographically within the CENRAP domain and depended on the area's attainment status and level of urbanization. **Figure 2-1** depicts non-attainment areas, urban attainment areas, Class I areas, and tribal lands in the CENRAP region. Areas for which data existed at the local level included five non-attainment areas, which had previously performed emissions modeling with MOBILE6 or MOBILE5, as well as some urban attainment areas. Although none of the urban attainment areas had prepared VMT for emissions modeling, most had VMT data for transportation planning purposes. Thus, for all non-attainment and most urban attainment areas, locally developed VMT, speed distributions, and temporal distributions were acquired. For all other areas (i.e., rural attainment areas and some urban attainment areas), data that had been developed at the state level were acquired.

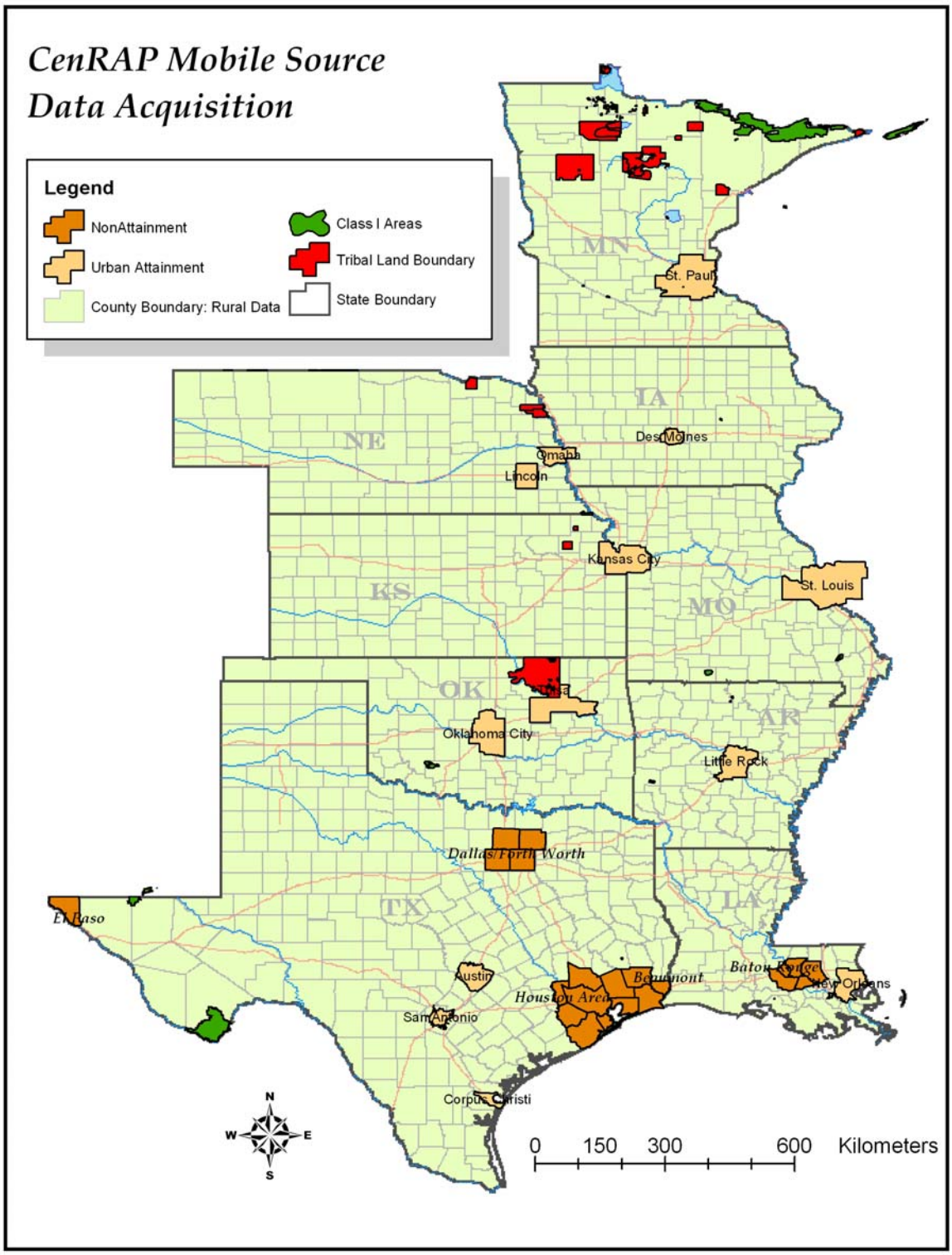


Figure 2-1. Non-attainment areas, urban attainment areas, Class I areas, and tribal lands in the CENRAP region.

To ensure effective use of project resources, we identified areas to be given highest priority according to the following criteria:

1. Magnitude of each region's VMT, population, and proximity to Class I areas.
2. Availability of MOBILE input data.
3. Availability of state or local mobile source activity data to represent the year 2002.

## 2.2 DATA ACQUISITION

Urban areas often maintain state-generated or locally generated VMT and speed or temporal distributions for the purposes of emissions assessments, air quality modeling, or transportation planning. In addition, the FHWA maintains the national Highway Performance Monitoring System (HPMS) database of VMT on major U.S. roadways. The HPMS data are reported at the county or sub-county level by road type (i.e., freeway, highway, major arterial).

Sonoma Technology, Inc. (STI) requested locally developed on-road mobile source activity data for all non-attainment areas in the CENRAP region and for urban attainment areas located near Class I areas. When locally developed mobile source activity data were not available, Metropolitan Planning Organizations (MPOs) and state departments of transportation (DOTs) were contacted with requests for data. For all other areas, state DOTs were contacted for the most up-to-date HPMS data. **Table 2-1** summarizes the mobile source activity data acquired for each area of the CENRAP domain.

Table 2-1. Summary of the on-road mobile source activity data acquired for each area of the CENRAP domain.

Page 1 of 3

| Area | Data Acquired | Year | Source of Data |
|---|---|---|---|
| **Non-Attainment Areas** | | | |
| Houston/Galveston, Beaumont/Port Arthur, and El Paso, Texas | MOBILE6 input files, VMT by vehicle/road type, temporal/speed distributions | 2002 | Texas Transportation Institute (TTI) |
| Dallas/Forth Worth, Texas | VMT by vehicle/road type, temporal/speed distributions | 1999 | Texas Commission on Environmental Quality (TCEQ) |
| Baton Rouge, Louisiana | MOBILE6 input files, VMT by road type | 2002 | Louisiana Department of Environmental Quality (LDEQ) |

Table 2-1. Summary of the on-road mobile source activity data acquired for each area of the CENRAP domain.



| Urban Attainment Areas – Within 500 km of a Class I Area | | | |
|---|---|---|---|
| Attainment counties, Dallas/Ft. Worth, Texas | VMT by vehicle/road type, temporal/speed distributions | 1999 | TCEQ |
| New Orleans, Louisiana | MOBILE6 input files, VMT by road type | 2002 | LDEQ |
| St. Louis, Missouri | VMT by vehicle/road type, temporal distributions | 2004 | East-West Gateway Coordinating Council |
| Kansas City, Missouri -Kansas | VMT by road type | 2002 | Kansas Highway Department (KHD) and Missouri Department of Transportation (MoDOT) |
| Topeka and Wichita, Kansas | VMT by road type | 2002 | KHD |
| Little Rock, Arkansas | VMT by road type | 2002 | Arkansas Highways and Transportation Department (AHTD) |
| Minneapolis/St. Paul, Duluth, and St. Cloud, Minnesota | VMT by road type | 2002 | Minnesota Department of Transportation (MnDOT) |
| Lincoln, Nebraska | VMT by road/vehicle type and speed | 2002 | Lincoln-Lancaster Metropolitan Planning Organization |
| Oklahoma City and Tulsa, Oklahoma | VMT by road type | 2002 | Oklahoma State Highway Department (OSHD) |

Table 2-1. Summary of the on-road mobile source activity data acquired for each area of the CENRAP domain.



| All Other Areas | | | |
|---|---|---|---|
| Texas | MOBILE6 input files, VMT by vehicle/road type, temporal/speed distributions | 2002 | TTI |
| Louisiana | MOBILE6 input files, VMT by road type | 2002 | LDEQ |
| Arkansas | VMT by road type | 2002 | AHTD |
| Iowa | VMT by road type | 2002 | Iowa Department of Transportation |
| Kansas | VMT by road type | 2002 | KHD |
| Minnesota | VMT by road type | 2002 | MnDOT |
| Missouri | VMT by road type | 2002 | MoDOT |
| Nebraska | VMT by road type | 2002 | Nebraska Department of Transportation |
| Oklahoma | VMT by road type | 2002 | OSHD |

### 2.2.1 Details of Data Acquisition for Non-attainment Areas

The CENRAP region currently has five non-attainment areas: four in Texas and one in Louisiana. The El Paso, Texas, non-attainment area (designated as serious) consists of El Paso County and is within about 150 km of the Guadalupe Mountains and Carlsbad Caverns National Parks and within about 400 km of Big Bend National Park. The Dallas-Ft. Worth and Baton Rouge non-attainment areas are located within about 300 kilometers of Class I areas. Houston-Galveston and Beaumont-Port Arthur are at least 500 km distant from any Class I area.

For the non-attainment areas in Texas, MOBILE6-compatible files were acquired from the TTI and the TCEQ. TTI provided hourly and annual VMT and average speed distributions for 2002 by road type and vehicle type. The TCEQ provided MOBILE6-compatible files for 1999, which were grown to 2002 based on additional information provided by the TCEQ. For Baton Rouge, the LDEQ supplied 2002 MOBILE6 input files, as well as 2002 VMT data from the Louisiana Department of Transportation Development (LDOTD).

### 2.2.2 Details of Data Acquisition for Urban Attainment Areas within 500 km of Class I Areas

Several urban attainment areas in the CENRAP domain are within 500 km of Class I areas (identified in Table 2-1). Of these, three provided locally developed activity data for mobile sources: (1) New Orleans, Louisiana; (2) St. Louis, Missouri; and (3) Lincoln, Nebraska. Other urban areas were unable to provide locally developed activity data within the time available for data acquisition; therefore, VMT data were acquired for these areas from state DOTs. Activity data for a few urban attainment areas have become available very recently or will become available soon (e.g., Kansas City, Missouri-Kansas; Minneapolis-St. Paul, Minnesota). These locally developed data are recommended for use during future inventory development projects.

### 2.2.3 Details of Data Acquisition for All Other Areas

Texas and Louisiana provided MOBILE6 inputs and activity data for all counties or parishes within those states. Mobile source activity data for 2002 were acquired from the state DOTs in Arkansas, Missouri, Iowa, Minnesota, Oklahoma, Nebraska, and Kansas. In all cases, the data acquired from the state DOTs contain the same type of information as the national HPMS database. However, in some cases, the data supplied by states were more up to date than the latest version of the national HPMS database.

## 2.3 DATA PREPARATION

A broad array of data types and formats were acquired for this task, which necessitated a strategic data processing scheme to assemble, process, and format the data for use with SMOKE/MOBILE6. The processing scheme was carried out for the following data types:

1. Data acquired for non-attainment areas (MOBILE-compatible inputs)
2. Data acquired for urban attainment areas (MOBILE-compatible inputs or transportation model data)
3. Data acquired for all other areas (HPMS)

Two standardized data processing algorithms were developed to process (1) MOBILE-compatible inputs and transportation demand model data or (2) national HPMS data. **Figure 2-2** illustrates the processing scheme applied to the MOBILE-compatible input data and transportation model data. **Figure 2-3** illustrates the processing scheme applied to the HPMS data. These algorithms included functions to process VMT data into the formats required by SMOKE and to process and calculate average speed distributions and temporal profiles. The outputs of the data processing schemes were SMOKE-ready input files suitable for use with MOBILE6 running within the SMOKE emissions processor.

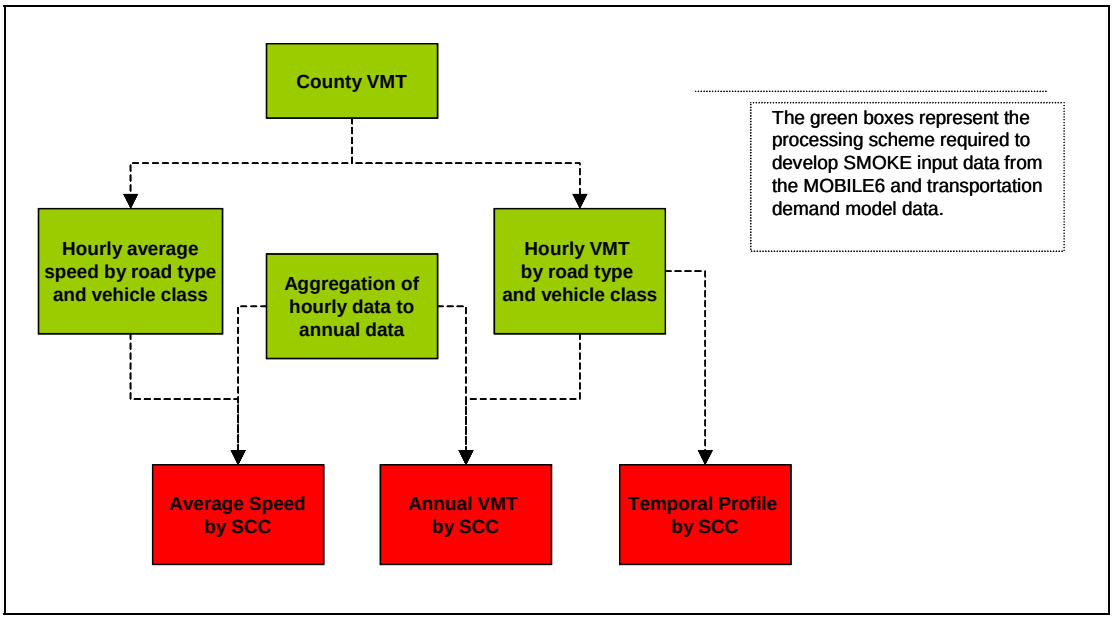


Figure 2-2. Illustration of the processing scheme applied to the MOBILE-compatible input data and transportation model data to develop SMOKE input files.

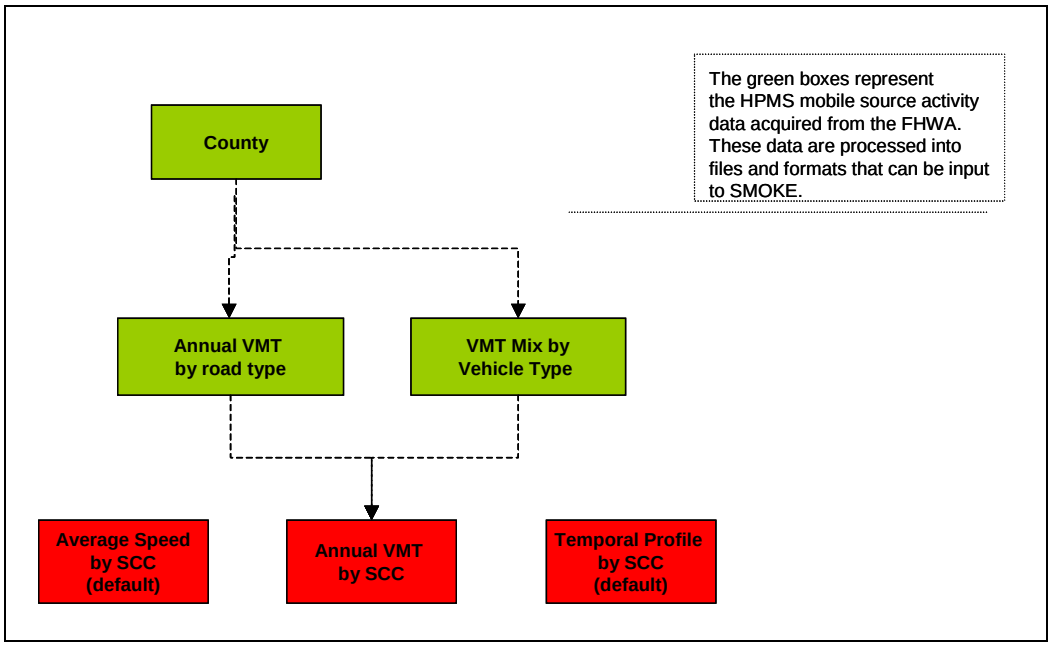


Figure 2-3. Illustration of the processing scheme applied to the national HPMS data.

### 2.3.1 Details of Data Preparation for Mobile Source Activity Data

SMOKE requires VMT data distributed by 96 standard source classification codes (SCC). Each SCC denotes a vehicle type and a road type combination of those listed in **Table 2-2**. For each state in the CENRAP domain, STI compiled SMOKE inputs for the 96 SCCs using the data sets discussed in Section 2-2.

Table 2-2. Definitions of the 8 vehicle types and 12 road types used by SMOKE.

| Vehicle Types | Road Types |
|---|---|
| LDGV - Light Duty Gasoline Vehicles | Rural Interstate |
| LDGT1 - Light Duty Gasoline Trucks 1 | Rural Principal Arterial |
| LDGT2 - Light Duty Gasoline Trucks 2 | Rural Minor Arterial |
| HDGV - Heavy Duty Gasoline Vehicles | Rural Major Collector |
| LDDV - Light Duty Diesel Vehicles | Rural Minor Collector |
| LDDT - Light Duty Diesel Trucks | Rural Local |
| HDDV - Heavy Duty Diesel Vehicles | Urban Interstate |
| MC - Motorcycles | Urban Freeway |
| | Urban Principal Arterial |
| | Urban Minor Arterial |
| | Urban Collector |
| | Urban Local |

### 2.3.2 Details of Data Preparation for Temporal Profiles

SMOKE uses a default library (data file) of monthly, weekly, and diurnal temporal profiles for all emissions source categories. STI reviewed and revised the default SMOKE/EPA profiles to better represent the temporal patterns of on-road mobile emissions in the CENRAP domain. For Texas and parts of Missouri, where locally developed temporal data were available, local temporal profiles were added to the SMOKE profile library. For other areas, representative temporal profiles were selected. Day-of-week temporal profiles were adopted from a recent study of traffic activity patterns (Coe et al., 2004). Monthly temporal profiles were based on the 1995 National Personal Transportation Survey (Federal Highway Administration, 1995). Diurnal profiles were based on the SMOKE/EPA default profiles for counties inside metropolitan statistical areas (MSAs) and other relatively urbanized counties. For other counties, where population densities or urban populations fell below established thresholds, diurnal profiles were based on Texas' profiles for groups of counties sharing similar population characteristics. (Population demographics were acquired from the U.S. Census Bureau.)

## 2.4 QUALITY ASSURANCE

On completion of the development of the VMT data, speed distribution data, and temporal profiles, the following quality assurance/quality control (QA/QC) reviews were

conducted, and graphical illustrations were included as an appendix to the Final Report. In addition, the procedures outlined in the project Quality Assurance Project Plan (QAPP) were followed (Sullivan, 2004).

- Examine county-level total VMT estimates and their relative magnitudes and distributions throughout the domain.
- Examine VMT fractions by road type and vehicle type.
- Examine maps, plots, and graphs of VMT by county, road type, and vehicle type.
- Examine graphs of speed distributions by road type and region.
- Examine graphs of temporal profiles for each region.

# 3. METHODS TO PREPARE FLEET CHARACTERISTICS FOR ON-ROAD MOBILE SOURCES

Emission factors for on-road mobile sources vary with the following fleet characteristics, which are derived from state transportation departments' vehicle registration records.

- *The vehicle age distribution* determines (1) the estimated proportion of the fleet that has been designed to meet certain emissions standards, and (2) the estimated average deterioration level of on-board emissions control devices. Vehicle design standard and deterioration level, in turn, are variables that govern the choice of emission factor.
- The *fractions of the vehicle fleet that are powered by different fuels* (e.g., gasoline or diesel) affect the choice of appropriate emission factors.

Registration distributions vary widely across regions, and Giannelli et al. (2002) indicated that registration distributions exert a major influence (i.e., potentially more than a 20% change) on MOBILE6-modeled emission factors. Therefore, the application of county-specific registration distributions is essential to the development of accurate emission inventories for on-road mobile sources. This section describes the information sources used and the data processing steps followed to prepare fleet characteristics, including vehicle age distributions and vehicle fuel fractions.

## 3.1 DATA ACQUISITION

Seven state DOTs in the CENRAP region provided extracts of their vehicle registration databases, which were decoded and processed to prepare MOBILE6-ready fleet-age distributions and fuel fractions for light-duty vehicles. The DOTs provided vehicle identification numbers (VIN) and county codes for every vehicle registered in their states on a specified date. The VIN records were decoded to yield vehicle ages and fuel types, which were used to calculate county-specific fleet characteristics. **Table 3-1** provides details about each of the acquired vehicle registration databases.

Texas provided ready-made MOBILE6 inputs, including fleet characteristics, for use in this project. Arkansas was excluded from development of fleet characteristics because the state is currently developing an on-road mobile source inventory, which is expected to be available in 2004. Instead, MOBILE6 default fleet characteristics were used for the state of Arkansas. Fleet characteristics were developed for light-duty vehicles only because heavy-duty vehicles are often used for interstate travel; therefore, national average fleet distributions (i.e., MOBILE6 defaults) are reasonably representative.

Table 3-1. Descriptions of acquired vehicle registration databases and related information.

| State | Vehicle Registration Database Characteristics | | Contact Information | Comments |
|---|---|---|---|---|
| | Number of Records | Date Represented | | |
| Texas | n/a | n/a | Mary McGarry-Barber and Chris Kite, Texas Commission on Environmental Quality | Texas provided ready-made fleet characteristics. |
| Louisiana | 2,941,066 | July 1, 2002 | Cecile Bush and Ray Thomas, Louisiana Department of Public Service | |
| Arkansas | n/a | n/a | Mary Pettyjohn, Arkansas Department of Environmental Quality and Charles Beaver, Arkansas Department of Revenue | Arkansas is currently funding a separate project to process VINs and estimate emissions from on-road mobile sources. Results will be made available to CENRAP in 2004. |
| Oklahoma | 5,703,980 | January 9, 2004 | Ray Bishop, Oklahoma Department of Environmental Quality and Chuck Dusenbery, Oklahoma Tax Commission | Oklahoma's database included registrations of non-road vehicles, such as recreational boats, which were eliminated after the automated VIN decoding process. |
| Kansas | 2,568,781 | January 21, 2004 | Donnita Thomas and Leonard Corkill, Kansas Department of Revenue | |
| Missouri | 5,069,888 | February 1, 2004 | John Rustige and Fonda Thomas, Missouri Department of Natural Resources and | |
| Iowa | 2,880,936 | October 31, 2003 | Chad Daniel and Priyanka Painuly, Iowa Department of Natural Resources | |
| Nebraska | 1,850,509 | December 11, 2003 | David Brown, Nebraska Department of Environmental Quality and Deric Bloom, Nebraska Department of Motor Vehicles | Nebraska uses a state-specific system of county identification codes. |
| Minnesota | 4,606,640 | February 1, 2004 | Innocent Eyoh and Chun-Yi Wu, Minnesota Pollution Control Agency and Judith Franklin, Minnesota Department of Public Safety | |

## 3.2 DATA PREPARATION, QUALITY ASSURANCE, AND QUALITY CONTROL

The following steps were carried out to prepare, error-check, and correct the vehicle registration databases as needed before carrying out the process of VIN decoding.

- Load records into a unified database for processing.
- Translate county codes if necessary.
- Eliminate null VIN and county federal information processing standard (FIPS) codes.
- Identify and eliminate duplicate VINs.
- Independently verify the number of records.
- Export files for VIN decoding.

*Load records into a unified database for processing.* All vehicle registration records, including VINs and county FIPs codes, were unified into a structured query language (SQL) database. The unified SQL database supported more efficient preliminary data processing, quality assurance, and quality control procedures and permitted a running record of any changes made to the data sets. Copies of the original data sets from the states were archived before loading them into the unified database.

*Translate county codes.* Each state provided county information for registration records. Iowa's and Louisiana's databases included FIPS county codes. Kansas', Minnesota's, Missouri's, Nebraska's, and Oklahoma's databases contained county names or county codes that were translated to conform to the standard 5-digit FIPS format, "SSCCC", where SS are 2 integers that identify the state and CCC are 3 integers that identify the county or parish. VIN records without valid county names or codes were eliminated. For example, some of the VIN records were classified as state vehicles and were not assigned to any county. Less than one percent of the VIN records received from each state were eliminated due to unavailable county codes.

*Eliminate null VIN and FIPS records.* Null VIN and FIPS entries were identified, and records that contained null entries were eliminated. Less than one percent of the records from each state contained null entries. An additional 6% of the Kansas records were eliminated because they were flagged as representing trailers or mobile homes rather than on-road vehicles.

*Identify and eliminate duplicate VINs.* Each state's database was examined for duplicate VINs. Theoretically, no duplicates should exist because each VIN uniquely identifies a single vehicle. However, duplicate VINs may appear in a vehicle registration database for a variety of administrative reasons, such as failure to update vehicle information associated with changes of owner address or transfers of vehicle ownership. Each state DOT was contacted to discuss any duplicates in their registration databases. Duplicates that occurred within the same county were simply deleted, but cross-county duplicates were retained in most cases. The State of Missouri identified the most recent database entry associated with each duplicate VIN. Therefore, cross-county duplicates were eliminated from Missouri's database by retaining only the most recent duplicate record. The frequencies of duplicate records in the final databases were small for most of the states (i.e., less than one in ten thousand for the Kansas, Louisiana, Minnesota, Nebraska, and Oklahoma data sets). Thus, the potential errors in the vehicle age and fuel type distributions

are expected to be small or negligible. However, a significant number of duplicate records could not be eliminated from Iowa's databases and may represent a source of error in the fleet characteristics for that state. **Table 3-2** summarizes the numbers of duplicate records existing in the vehicle registration databases for each state.

Table 3-2. Summary of null and duplicate VIN record identification and elimination.

| State | Original Database (as received) | | Final Database | |
|---|---|---|---|---|
| | Total No. Records | % Duplicates | Total No. Records | % Duplicates |
| Texas | n/a | n/a | n/a | n/a |
| Louisiana | 2,941,090 | 0.004 | 2,941,066 | 0.004 |
| Arkansas | n/a | n/a | n/a | n/a |
| Oklahoma | 5,704,139 | 0.000 | 5,703,980 | 0.000 |
| Kansas | 2,782,208 | 0.002 | 2,568,781 | 0.002 |
| Missouri | 5,230,782 | 2.960 | 5,069,888 | 3.053 |
| Iowa | 3,111,046 | 19.016 | 2,880,936 | 5.939 |
| Nebraska | 1,863,340 | 0.002 | 1,850,509 | 0.002 |
| Minnesota | 4,611,407 | 0.005 | 4,606,640 | 0.005 |

*Verify the number of records.* The final number of records in each state's database was compared to the number of registered vehicles reported by the FHWA (Federal Highway Administration, 2004) and the state's population as reported for the 2000 Census (U.S. Census Bureau, 2004). The population comparison was performed at a county level to ensure that the most populated counties in each state had the highest numbers of registered vehicles. When large discrepancies were observed, the appropriate state agencies were contacted to resolve the differences. For example, Oklahoma's vehicle registration database includes off-road vehicles. VINs for off-road vehicles were eliminated following VIN decoding, at which time the numbers of records compared better with the figures reported by the FHWA and the 2000 Census. Louisiana's vehicle registration database contained a relatively low number of vehicles (given the state's population and FHWA's reported number of registered vehicles); however, the Louisiana Department of Public Safety confirmed that the number of records in their database was correct.

*Export files for VIN decoding.* The final VIN data sets for each state were exported into separate ASCII text files and formatted for VIN decoding.

## 3.3 VIN DECODING

Eastern Research Group (ERG) developed and maintains VIN decoding software that returns model year, series, gross vehicle weight rating, fuel type, and other vehicle specifications

for all domestic and foreign light duty vehicles sold in the United States from 1972 to 2002.[1] Version 2000.01 of the ERG VIN Decoder was used to decode the VINs received from state registration databases. Before proceeding with VIN decoding, the accuracy of the VIN decoder software was validated by decoding several known VINs and verifying the results and by comparing results to the outputs of other VIN decoders.

After the VINs from each state were decoded, the age of each decoded vehicle was determined by subtracting the model year from the current year, where the current year was defined for each state as the year represented by its VIN data set (see Table 3-1). For each county and each vehicle type, the fractions of vehicles aged <1 through 24 years were calculated. Vehicles of ages greater than 24 years were assigned to age 24. The products of these calculations were county-specific fractional age distributions for light-duty vehicle classes.

In addition, the ERG VIN Decoder returned the type of fuel utilized by each decoded vehicle. The fractions of diesel-fueled vehicles in each county, vehicle class, and age group, from age <1 through 24 or greater were calculated. In some cases, vehicle populations were very small and required extrapolation or aggregation across geographic areas or vehicle classes to calculate representative diesel fractions. The results of these calculations are diesel fractions for each county, light-duty vehicle type, and age group. Too few natural-gas powered vehicles were identified to produce meaningful distributions; therefore, MOBILE6 defaults were used for this fuel type (unless locally developed MOBILE6 inputs were provided).

## 3.4 FINAL QUALITY ASSURANCE, QUALITY CONTROL, AND DATA PREPARATION

On completion of VIN decoding, the following QA/QC reviews and processing steps were conducted to prepare the MOBILE6-ready inputs, and graphical illustrations were included in an appendix to the Final Report. In addition, the procedures outlined in the project QAPP were followed (Sullivan, 2004):

- Verify the number of decoded VIN records.
- Examine the vehicle age fractions and fuel type fractions for reasonableness.
- Independently calculate and verify a vehicle age fraction and a fuel type fraction.
- Parse the vehicle age distributions and fuel type fractions into MOBILE6-ready inputs.
- Verify correct parsing and formatting of the final deliverables.
- Test the use of these files with the SMOKE emissions processor.

*Verify the number of decoded VIN records.* The ERG VIN Decoder appended several fields containing vehicle information and error codes to the original data records containing the VINs and FIPS codes. The number of records contained within each decoded file was verified to be equal to the number of records originally submitted for decoding. The decoded VIN files were loaded into the unified SQL database for the final QA/QC procedures. VINs that were not

[1] A listing of the vehicle manufacturers treated by the software and more information is available online at http://www.ergweb2.com/vindecoder/index.cfm.

decoded by the software remained in the output files and were flagged with error codes for explanation.

*Examine the vehicle age fractions and fuel type fractions for reasonableness.* Two separate files, one containing the age distributions for all vehicle classes and counties and another containing the diesel fractions for all vehicle classes and counties, were loaded into the SQL database in order to examine the calculated fractions. The 25 vehicle fractions for each vehicle class and each county were verified to sum to one. The minimum, maximum, mean, and median fractions for each age class from all the age distributions were examined in order to identify any outlier values and assess their effects. Similarly, the minimum, maximum, mean, and median diesel fractions for each age class from all the vehicle classes and counties were examined. Pivot tables and corresponding pivot charts were also created for the default and calculated age distributions and diesel fractions in order to facilitate quick visual examinations.

*Parse the vehicle age distributions and fuel type fractions into MOBILE6-ready inputs.* The calculated age distributions for each vehicle class and county were contained within a single table in the SQL database that had variable character fields of character length 50 for the FIPS codes and the vehicle classes and 25 numeric fields of precision 0.0001 for the calculated age fractions. The calculated diesel fractions for each vehicle class and county were contained in a similar table in the SQL database. A separate ASCII text file containing 25 age fractions for each of the 5 decoded vehicle classes was exported from the SQL database. The space-delimited text files contained the header REG DIST on the first line followed by rows of 26 fields containing the vehicle class code and the age fractions from zero to age 24. The diesel fractions were exported into similar ASCII text files for each county. The files contained sets of 25 diesel fractions for 14 of the 16 combined MOBILE6 vehicle classes, for a total of 350 fractions. For the remaining 2 vehicle classes, MOBILE6 assumes that all motorcycles (MC) are gasoline-fueled and all urban/transit buses (HDBT) are diesel-fueled. The age distribution files were prepared as external inputs for the MOBILE6 runs, while the diesel fractions were incorporated into the MOBILE6 input files.

*Verify correct parsing and formatting of the final deliverables.* A random sample of registration distribution files and diesel fraction files were examined to ensure that the files were properly exported from the SQL database. The selected registration distribution files were verified to contain the appropriate heading and 25 age fractions for each of the 5 vehicle classes. The selected diesel fraction files were verified to contain 5 sets of 25 fractions with 10 fractions in the first row of each set, 10 fractions in the second row of each set, and 5 fractions in the third row of each set.

*Test the use of these files with the SMOKE emissions processor.* The selected registration distribution files were run through the SMOKE emissions processor using a test MOBILE6 input file with default values to ensure that the files ran properly within the framework of MOBILE6 operating within SMOKE. Similarly, the selected diesel fractions were verified with a test MOBILE6 input file. The diesel fractions were incorporated into the test input file, each in turn, and the files were run through SMOKE to ensure that the diesel fractions were formatted properly to run within the framework of SMOKE.

# 4. METHODS TO PREPARE FUELS CHARACTERISTICS AND IMPACTS OF REGULATORY CONTROLS FOR ON-ROAD AND OFF-ROAD MOBILE SOURCES

Fuel parameters and regulatory controls can significantly impact emission factors predicted by the MOBILE6 model (for on-road sources) and the NONROAD model (for off-road sources). This section describes the information sources used and the data processing steps followed to prepare fuels characteristics and regulatory control settings for use in MOBILE6. When appropriate, fuels characteristics were also prepared for the NONROAD model.

## 4.1 FUELS CHARACTERISTICS

Three characteristics of fuels significantly affect criteria pollutant emission predictions from the MOBILE6 and NONROAD models:

1. Sulfur content
2. Fuel volatility
3. Oxygenate content

Fuel sulfur content directly affects emissions of sulfates (particulate matter) and $SO_2$ from combustion of all fuels. In addition, sulfur's adverse effects on catalytic converters indirectly affect emissions of VOCs, CO, and $NO_x$ from gasoline-fueled vehicles. Fuel volatility and oxygenate content are only necessary for gasoline-fueled vehicles.

EPA found that gasoline volatility can have a major effect on MOBILE6 estimates of VOC and CO emissions (Giannelli et al., 2002), although the influence diminishes at lower temperatures and has no effect at temperatures below 45$^{o}$F (Tang et al., 2003). Oxygenates for gasoline fall into two classes: alcohols and ethers (see **Table 4-1)**. All are assumed to reduce emissions of CO, but ethanol can also increase the gasoline volatility.

Table 4-1. Common types of oxygenates (listed in approximate order of decreasing prevalence).

| Alcohols | Ethers |
|---|---|
| Ethanol | Methyl tert-butyl ether (MTBE) |
| Methanol | Tert-amyl methyl ether (TAME) |
| Butanol | Ethyl tert-butyl ether (ETBE) |
| | Diisopropyl ether (DIPE) |

Both MOBILE6 and NONROAD accept sulfur content information on a weight basis. MOBILE6 requires that sulfur content be specified in parts per million by weight (ppmw or sometimes just ppm), and NONROAD requires that sulfur content be expressed as a percentage by weight (wt. %). Gasoline volatility is expressed in terms of Reid Vapor Pressure (RVP), or pounds per square inch (psi). The extent to which oxygenates are present can be defined either

as the percentage of a specific oxygenate blended by volume (% vol.), or the total weight percentage (% wt.) of oxygen atoms in the blended fuel.

### 4.1.1 Data Acquisition

For gasoline and diesel fuel, a number of information sources exist, including EPA, commercial data sources, state departments of agriculture, and fuel associations. In addition, the American Society for Testing and Materials (ASTM) standards can be used as guidelines for areas where information is missing or incomplete. Each of these sources of information is discussed in greater detail below.

For compressed natural gas (CNG) and liquefied petroleum gas (LPG), only the NONROAD model requires fuels characteristics, and the only information required is the sulfur content. NONROAD only allows entry of a single sulfur content to describe both fuels, although CNG and LPG sulfur contents sometimes differ. However, for both fuels, the sulfur content is very low (often well below specifications), is rarely tested, and currently has a negligible impact on the overall inventory (although it may become more important in the future as sulfur levels in gasoline and diesel fuel drop). Therefore, for NONROAD, a CNG/LPG sulfur content of approximately 0.0007 wt. % was used, which is consistent with the CNG sulfur content assumed by EPA's AP-42 publication for stationary sources (U.S. Environmental Protection Agency, 1998a).[2]

**U.S. Environmental Protection Agency**

EPA maintains a database of reformulated gasoline (RFG) data for those areas that utilize RFG. Also, MOBILE6 allows RFG to be modeled explicitly (i.e., the model chooses appropriate values for sulfur content, volatility, and oxygen content). For future inventories, information for fuels sold in other areas may be available from EPA. Specifically, federal regulations (40 CFR 80.370 and 40 CFR 80.593) will require refiners to submit annual reports of sulfur content to EPA by February 2005 and February 2007 for gasoline and diesel fuel, respectively.

**Commercially available data**

Information about gasoline and diesel fuel compositions is available for purchase from Northrop Grumman and the American Association of Automobile Manufacturers (AAM). These data are the basis for fuel data estimated in EPA's National Emission Inventory (NEI) (E.H. Pechan and Associates, 2004). However, each of these data sets consists of a relatively small number of samples from relatively few areas (e.g., 1-6 cities per state, 1-20 samples per city, and 1-3 locations per city). Data are collected by these entities for winter and summer months only.

AAM can identify specific laboratories and analytical methodologies used, whereas Northrup Grumman's data are reported by a number of private companies and laboratory information cannot be readily tracked down. However, the AAM data are less extensive than the

[2] A sulfur content of 0.0007% (wt.) corresponds to 2000 gr/MMscf = 0.2 gr/100 scf. This factor includes sulfur that is added for safety purposes (odorant).

Northrop Grumman data, and costs are significantly higher. Therefore, Northrup Grumman's data were used rather than AAM's data.

**State departments of agriculture**

Some weights and measures divisions of state departments of agriculture test gasoline and/or diesel fuel on a regular basis and are able to provide these data electronically. These data are often far more extensive (e.g., hundreds or thousands of samples taken, throughout the entire year and the entire state) than the data available from commercial surveys. Thus, they represent a significant improvement over the commercially available data when available.

For 2002, data were available from three of the CENRAP states (Kansas, Minnesota, and Missouri), and it is likely that Texas will have data for future calendar years. Oklahoma conducts tests but currently does not maintain a database of results.[3] Other CENRAP states do not currently test for fuel parameters relevant to mobile source emissions modeling.

**Oxygenated fuel and octane grade data**

In several CENRAP states, blending ethanol into fuel is prevalent, even though no regulatory requirements are in effect. The U.S. Department of Energy's Energy Information Administration (EIA) tracks sales volumes of gasoline and oxygenated gasoline by state; however, these data are tracked at the refinery, whereas blending of ethanol is more likely to occur downstream of the refineries at bulk terminals (due to difficulties associated with sending ethanol-blended fuel through pipelines). For states known to blend significant amounts of ethanol, oxygenated fuel associations were contacted to determine the extent of blending.

EIA data were also collected for the purposes of obtaining information about relative sales of regular and premium gasoline. This information was used to estimate the weighted average sulfur content because sulfur contents are significantly higher for regular gasoline than premium gasoline.

**Standards and existing assumptions**

ASTM standards provide volatility guidelines for every part of the country and every month. ASTM standards, regulations, and assumptions made by state and local agencies/MPOs were collected for the purposes of filling in gaps in fuel sampling data, quality assurance, and consistency with current inventories. However, it should be noted that average values are often below regulatory limits to allow a margin of compliance. In addition, ASTM standards are not regulatory limits, and EPA has found that RVP values can often exceed the ASTM standards (U.S. Environmental Protection Agency, 1992, pp. 25-26).

[3] Oklahoma's Department of Agriculture deferred to the Oklahoma Corporation Commission, which is the lead agency for fuel testing in that state.

### 4.1.2 Data Processing and Quality Assurance

In general, fuels characteristics were defined for various geographic subregions of the CENRAP region, various fuel types, and for on-road or non-road sources. Fuels characteristics were then organized and prepared for use with MOBILE6 and NONROAD. The discussions below provide the relevant factors that were considered when calculating or preparing the fuels characteristics for diesel fuel and gasoline.

**Diesel fuel**

As stated previously, sulfur content is the only parameter of interest for diesel fuel. In 2002, transportation-grade diesel fuel was required to have a sulfur content of no more than 500 ppmw = 0.05 wt. %, and for the 2002 NEI, EPA assumed that sulfur content was approximately 500 ppm for all areas of the United States from 1994 through 2002 (E.H. Pechan and Associates, 2004). However, average sulfur content is likely to be lower than the regulatory standard. Furthermore, EPA regulations require sulfur content to be less than 15 ppmw = 0.0015 wt. % by September 1, 2006. Thus, refineries are likely to be lowering the sulfur content of their diesel fuel already. Therefore, available diesel fuel sulfur content information for 2002 was inspected for statistically significant seasonal or regional differences, and for differences between on-road and off-road fuels.

**Reformulated Gasoline (RFG)**

For areas utilizing RFG (covered areas), little data processing was required because RFG can be modeled explicitly by MOBILE6 with command "FUEL PROGRAM : 2". The only areas of the CENRAP currently utilizing RFG are listed in **Table 4-2**. When RFG is modeled explicitly, user inputs for sulfur content and RVP are overridden by the program. User-supplied oxygenate levels are also overridden, with the exception of user-specified wintertime oxygen contents greater than 2.1 wt. % (U.S. Environmental Protection Agency, 2003a, 2002d). Therefore, in each covered area, the extents to which wintertime oxygen contents are above this level were examined.

Table 4-2. Listing of CENRAP areas utilizing RFG.

| Metropolitan Area | Specific Counties |
|---|---|
| St. Louis, Missouri | Franklin, Jefferson, St. Charles, St. Louis |
| Dallas/Fort Worth, Texas | Collin, Dallas, Denton, Tarrant |
| Houston/Galveston, Texas | Brazoria, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller, Chambers |

Source: 40 CFR 80.70.

When the "FUEL PROGRAM : 2" command is used, the user must also specify whether the RFG is being used in a southern or northern area. These are referred to as "VOC-Control Region 1" and "VOC-Control Region 2", respectively, by federal regulations (40 CFR 80.71); both Missouri and Texas are in VOC-Control Region 1, which corresponds to a MOBILE6 input of "S" (for southern).

**Areas not using RFG – spatial variability and local requirements**

Historically, regional differences in gasoline were modeled by dividing the country into districts on the bases of pipelines and other distribution channels. Northrop Grumman still organizes its gasoline data by these districts. Although the continued appropriateness of these divisions has not been verified (and does not account for RFG usage, localized regulations in metropolitan areas, and regional ethanol blending), the district divisions were utilized to investigate spatial differences among areas that do not have localized requirements. The five districts for various metropolitan areas within CENRAP are identified in **Table 4-3**.

Table 4-3. Gasoline distribution districts identified by Northrop Grumman.

| District | CENRAP Metropolitan Areas |
|---|---|
| 3 (Southeast) | Little Rock, Arkansas<br>New Orleans, Louisiana |
| 5 (North Central) | Minneapolis-St. Paul, Minnesota |
| 7 (Central and Upper Plains) | Kansas City (Kansas/Missouri)<br>Davenport, Iowa<br>Des Moines, Iowa<br>St. Louis, Missouri<br>Omaha, Nebraska |
| 8 (Oklahoma and East Texas) | Tulsa, Oklahoma<br>Dallas-Ft. Worth, Texas<br>Houston, Texas<br>San Antonio, Texas |
| 11 (New Mexico and West Texas) | Amarillo, Texas<br>El Paso, Texas |

Localized regulations restrict summertime fuel volatility, and include requirements and restrictions for oxygenate usage; but currently, there are no localized controls on gasoline sulfur content in the CENRAP region.

**Sulfur content of gasoline (non-RFG)**

MOBILE6 incorporates two elements of gasoline sulfur content data: (1) information about the average sulfur content existing during the calendar year of interest (for purposes of determining $SO_2$ and PM emissions), and (2) information about the maximum sulfur content ever experienced by vehicles in a given model year (for purposes of determining deterioration of catalysts). Available fuel data can only be utilized to modify sulfur contents for the calendar year of interest, not the lifetime maxima of fuel contents ever experienced. Data for regular and premium gasolines were averaged separately, and weighted average sulfur contents were determined based upon relative sales volumes of different grades of gasoline. Given the limited availability of data, the calculated weighted average sulfur contents were only added to MOBILE6 input files if they differed significantly from the MOBILE6 default values.

Default sulfur content data can be different for "western" areas due to a geographic phase-in of gasoline sulfur regulations. However, this only affects Nebraska (of the CENRAP states) and calendar year 2003 and later. A full listing of MOBILE6 default sulfur contents is shown in **Table 4-4**.

Table 4-4. MOBILE6 default sulfur content data for conventional gasoline (i.e., non-RFG).

| Calendar Year | Average Fuel Sulfur Content (ppmw) | | Vehicle Model Year | Maximum Fuel Sulfur Content Experienced (ppmw) | |
|---|---|---|---|---|---|
| | Eastern Areas[a] | Western Areas[b] | | Eastern Areas[a] | Western Areas[b] |
| 2000 | 300 | 300 | 2000[c] | 1000 | 1000 |
| 2001 | 299 | 299 | 2001 | 1000 | 1000 |
| 2002 | 279 | 279 | 2002 | 1000 | 1000 |
| 2003 | 259 | 263 | 2003 | 1000 | 1000 |
| 2004 | 121 | 160 | 2004 | 303 | 325 |
| 2005 | 92 | 160 | 2005 | 303 | 325 |
| 2006 | 33 | 160 | 2006 | 87 | 325 |
| 2007 | 33 | 60 | 2007 | 87 | 142 |
| 2008+ | 30 | 30 | 2008+ | 80 | 80 |

[a] Within CENRAP, this includes all counties except those specifically identified as western areas.
[b] Within CENRAP, this only includes the following counties, all of which are located in western Nebraska: Banner, Box Butte, Cheyenne, Dawes, Deuel, Garden, Keith, Kimball, Morrill, Scotts Bluff, Sheridan, and Sioux (Source: 40 CFR 80.215(a)(2)(i)).
[c] Within MOBILE6, maximum sulfur content does not affect emissions from vehicles of model year 1999 and older.

**RVP and oxygenate content of gasoline (non-RFG) – agriculture department data**

For RVP and oxygenate, the data obtained from state departments of agriculture were analyzed. For regions where data were available, temporal variations in volatilities over the course of the year were compared with the variations in the corresponding ASTM standards for those regions. Within each state, areas known to have local regulatory requirements were examined separately from areas without such requirements, and gasoline blended with ethanol was examined separately from other gasoline. (Methodology documentation for the 2002 NEI indicates that, aside from areas with local requirements, RVP was assumed to be uniform across each state [E.H. Pechan and Associates, 2004].) The limited data obtained from Northrop Grumman were compared to the agriculture departments' data for purposes of gauging the extent to which the Northrop Grumman data are representative.

EPA and local regulations restrict the maximum RVP of some summertime gasolines. For purposes of quality assurance, summertime RVP data were compared to these requirements. However, it should be noted that EPA and many local governments grant a waiver of 1.0 psi to ethanol blends (i.e., the blends are allowed to have RVP values that are 1.0 psi higher than regulatory limits[4]), and in such cases MOBILE6 assumes that the RVP of the ethanol-blended gasoline is 1.0 psi higher than the RVP specified in the model input file. Available data from

[4] EPA's waiver (40 CFR 80.27(d)) only applies if a sufficient quantity of ethanol is used (9-10% vol.)

state agricultural departments were utilized to investigate the extent to which the RVP of ethanol blends is higher than the RVP of conventional gasoline. If differences were found to be considerably smaller than 1.0 psi, the area was modeled as one without a waiver (even if a waiver exists) to prevent MOBILE6 from increasing the RVP of the ethanol blends.

The extent to which a fuel is characterized as an "ethanol blend" depends on how this term is defined. In some cases, the blend is mandated. For example, the State of Minnesota requires that ethanol be blended into all gasoline sold in the state, year-round, to reach a level of 2.7-3.5 wt. % oxygen in the blend.[5] However, in other areas, a variety of levels of oxygenate are in use, and oxygenate analyses show a variety of oxygenate concentrations, which in some cases contain both alcohols and ethers in the same sample. Because MOBILE6 only models one oxygenate type or the other and assumes a single average oxygenate concentration, frequency plots were generated to determine the extent to which different oxygenate concentrations were present, and analytical data were screened to eliminate low data (e.g., near detection limits). It is worth noting that volatility increases due to ethanol tend to be somewhat independent of concentration above approximately 3%. This is important in areas modeled with RVP waivers, for which MOBILE6 will increase RVP by 1.0 psi for all ethanol blends, regardless of the ethanol concentration.

**RVP and oxygenate content of gasoline (non-RFG) – other data**

For states in which agriculture department data were not available, RVP estimates were based primarily on data obtained from Northrop Grumman in the summer and winter. These data were interpolated to different months using ASTM standards—similar to the procedure applied for the 2002 NEI (E.H. Pechan and Associates, 2004). Spatial and temporal variations were also compared to publicly available RVP data from the 1999 NEI (which was generated based upon data from Northrop Grumman and AAM). Areas with specific RVP or oxygenate restrictions were modeled to reflect those restrictions, even if no sampling data were available for those areas.

Although gasoline volatilities are highest in the winter, the extent of wintertime data analysis was tempered by two factors: (1) the effects of volatility are lessened at colder temperatures, and (2) MOBILE6 models any RVP higher than 11.7 psi as equal to 11.7 psi (U.S. Environmental Protection Agency, 2003a, 2002d).

**General quality assurance**

Given the recent court cases involving environmental laboratory fraud (Bureau of National Affairs, 2002a, b), particularly with respect to testing vehicle fuels (McCarthy, 2001; Bureau of National Affairs, 2002c; U.S. Department of Justice, 2002), an effort was made to determine the source of the data collected. Data from fuel testing sources known to have been indicted and/or convicted of laboratory fraud were discarded when appropriate. The methodologies utilized were also examined. For example, it is known that RVP measurements using Grabner equipment are adjusted using a variety of formulas (sometimes season-

[5] The 2.7% minimum oxygen content is identified by Section 239.791 of the Minnesota Statutes, and ethers are specifically excluded from meeting that requirement; Section 239.761 bans the use of ethers (above approximately 0.33%) and limits the maximum ethanol content to 10% vol., which corresponds to approximately 3.5 wt. % oxygen.

dependent), and gas chromatography (GC) results for oxygenates can differ from Fourier-transform infrared (FTIR) results. In addition, the procedures outlined in the project QAPP were followed (Sullivan, 2004).

### 4.1.3 Data Preparation

Fuels characteristics were prepared as a summary data table listing gasoline volatilities as a function of county and month, and the extent to which oxygenated fuel information and fuel sulfur contents differ from MOBILE6 defaults. The tables, which are included in an appendix to the Final Report, show the appropriate MOBILE6 inputs with respect to the commands shown in **Table 4-5**. These command lines were inserted into the SMOKE input files for the complete set of geographic areas within the CENRAP and time periods within calendar year 2002.

Table 4-5. MOBILE6 input commands relevant to fuel composition.

| Command | Meaning | Data |
|---|---|---|
| FUEL PROGRAM[a] | Identifies gasoline sulfur content, and whether RFG is being used | 1 = eastern default sulfur values,<br>2 = RFG,<br>3 = western default sulfur values,<br>4 = user-supplied sulfur data |
| DIESEL SULFUR | Diesel sulfur content | Average diesel sulfur content, in ppmw |
| OXYGENATED FUELS[b] | Extent of oxygenate usage | % of gasoline sold that is blended with alcohols, and that is blended with ethers; average oxygen wt. % in each of those blends |
| FUEL RVP | Gasoline RVP (prior to ethanol addition, if any) | Average RVP, in psi |
| SEASON | For RFG, an identifier of which season's requirements are in effect | 1 = summertime RFG,<br>2 = wintertime RFG |

[a]Optional command; MOBILE6 default is FUEL PROGRAM = 1.
[b]Optional command; MOBILE6 default is no oxygenate.

## 4.2 REGULATORY CONTROLS

Regulatory controls that affect engine emissions and are modeled by MOBILE6 and/or NONROAD include the following:

- Anti-Tampering Programs (ATPs)
- Inspection & Maintenance (I/M) Programs
- Stage II Refueling Controls

Stage II refueling emissions are typically excluded from mobile source emission inventories developed using MOBILE6 because they are considered to be stationary area source

emissions. Thus, refueling emissions were excluded from the CENRAP emission inventory of on-road mobile sources, and associated MOBILE6 settings were not prepared. However, the appropriate MOBILE6 commands were prepared as a table and included in an appendix to the Final Report.

### 4.2.1 Data Acquisition

Environmental regulatory agencies in each of the CENRAP states were contacted for information regarding ATPs, I/M programs, and Stage II controls. These agencies provided the relevant information in the form of MOBILE6 input files.

### 4.2.2 Data Processing and Quality Assurance

Data processing consisted primarily of quality assurance, based in part on EPA technical guidance. Information provided by regulatory agencies was reviewed for consistency with EPA guidance and for reasonableness, and was investigated further if warranted. For example, I/M program compliance rates are often assumed to be 96% prior to implementation (U.S. Environmental Protection Agency, 2002d) but should be based on operating program data after they have been implemented. In addition, if a customized I/M program effectiveness is identified (using the I/M EFFECTIVENESS command), EPA requires that the state or local agency consult with the EPA first (U.S. Environmental Protection Agency, 2002d). For Stage II vapor recovery systems, a working system is assumed to be 95% effective. However, a 95% in-use effectiveness should not be input into MOBILE6 because this does not reflect rule penetration or rule effectiveness (U.S. Environmental Protection Agency, 1991b). Appropriate values for program compliance rates and in-use effectivenesses were selected and reported in a summary data table included in an appendix to the Final Report. In addition, the procedures outlined in the project QAPP were followed (Sullivan, 2004).

### 4.2.3 Data Preparation

Regulatory controls were prepared as a summary data table listing the counties that have ATPs, I/M programs, and/or Stage II vapor recovery, and as an electronic file with the associated MOBILE6 command lines. The tables, which are included in an appendix to the Final Report, show the appropriate MOBILE6 inputs with respect to the commands shown in **Table 4-6**. Command lines were inserted into the SMOKE input files for the geographic areas within the entire CENRAP region. (Note that the I/M commands are provided in external files that will be referenced by MOBILE6 through the “I/M DESC FILE” command.)

Table 4-6. MOBILE6 input commands relevant to non-fuel-related regulatory programs. (Command lines are needed only if programs are in place; some input files may require information for multiple ATPs and I/M programs.)

| Command | Data |
|---|---|
| ANTI-TAMP PROG | Calendar years applied, vehicle model years affected, vehicle types affected, inspection frequency, compliance rate, types of components inspected |
| I/M PROGRAM<br>I/M MODEL YEARS<br>I/M VEHICLES<br>I/M STRINGENCY[a]<br>I/M COMPLIANCE[b]<br>I/M WAIVER RATES[b]<br>I/M CUTPOINTS[c]<br>I/M EXEMPTION AGE[d]<br>I/M GRACE PERIOD[d]<br>NO I/M TTC CREDITS[e]<br>I/M EFFECTIVENESS[f] | Calendar years applied, test frequency, program type, inspection test type, model years affected, vehicle types affected, failure rate, percentage of vehicles that get inspected and either comply or are waived, extent to which inspected vehicles are waived rather than being modified to comply, exempted vehicle ages, number of years that new vehicles are exempted, extent of technician training, customized program effectiveness values (pollutant-specific) |
| STAGE II REFUELING | Calendar year that Stage II program begins to be phased in, number of years of phase-in, in-use efficiency for light-duty vehicles, in-use efficiency for heavy-duty vehicles |

[a] This command is only used for (and required for) exhaust I/M programs.
[b] This command is required for exhaust I/M programs and highly recommended for evaporative I/M programs.
[c] This command is only used (and is required) if I/M PROGRAM is IM240.
[d] This command is optional for exhaust I/M programs and highly recommended for evaporative I/M programs.
[e] This command is optional for exhaust I/M programs and is not used for evaporative I/M programs.
[f] This command is optional.

# 5. ADDITIONAL PARAMETERS FOR ON-ROAD MOBILE SOURCES

Additional optional inputs to MOBILE6 were prepared when readily available. These parameters are of lesser significance than VMT, fleet characteristics, fuels characteristics, or regulatory controls. However, they do have some effects and should be prepared when resources permit. In addition, consistency between the states' and the CENRAP's MOBILE6 inputs is desirable.

Examples included customized annual mileage accumulation rates, relative humidities, and/or natural gas vehicle (NGV) fractions that were provided by environmental regulatory agencies within the CENRAP region in response to other data requests. These data generally were provided in the form of MOBILE5 or MOBILE6 input files. Other inputs were relatively easy to determine. Altitude, which has been identified as having an "intermediate" (5-20%) effect upon VOC and $NO_x$ emissions by EPA (Giannelli et al., 2002, p. iii), is easily determined from regulatory guidance and readily available geographic information systems (GIS) tools.

## 5.1 DATA ACQUISITION

MOBILE input files were requested from environmental regulatory agencies and/or MPOs in each of the CENRAP states, and optional input commands were reviewed and used if appropriate. Topographical GIS databases were used to determine altitudes.

## 5.2 DATA PROCESSING AND QUALITY ASSURANCE

Relatively little data processing was necessary, because data were in MOBILE5 or MOBILE6 format. However, consistency with applicable EPA guidance was checked.

In the case of altitude, MOBILE6 only allows the selection of "high" or "low" altitude. ("Low" is the default setting.) High altitude model outputs are based on conditions representative of approximately 5,500 feet above mean sea level (msl), and low altitude model outputs are based on conditions representative of approximately 500 feet msl (U.S. Environmental Protection Agency, 2003a, 2002d). EPA refers users to 40 CFR 86.091-30(a)(5)(ii) and (iv) for guidance. However, Section (a)(5)(ii) lists no CENRAP areas as "designated high-altitude locations" and Section (a)(5)(iv) names four counties in Nebraska (Banner, Cheyenne, Kimball, and Sioux) as specifically <u>not</u> "designated low-altitude locations." STI utilized GIS tools to determine that substantial portions of these counties <u>are</u> above 4,000 feet msl (see **Figure 5-1**) and that, therefore, they should be modeled as "high" altitude.

## 5.3 DATA PREPARATION

A summary data table listing the additional MOBILE6 input commands was included with an appendix to the Final Report. Command lines were inserted into the MOBILE6/SMOKE input files.

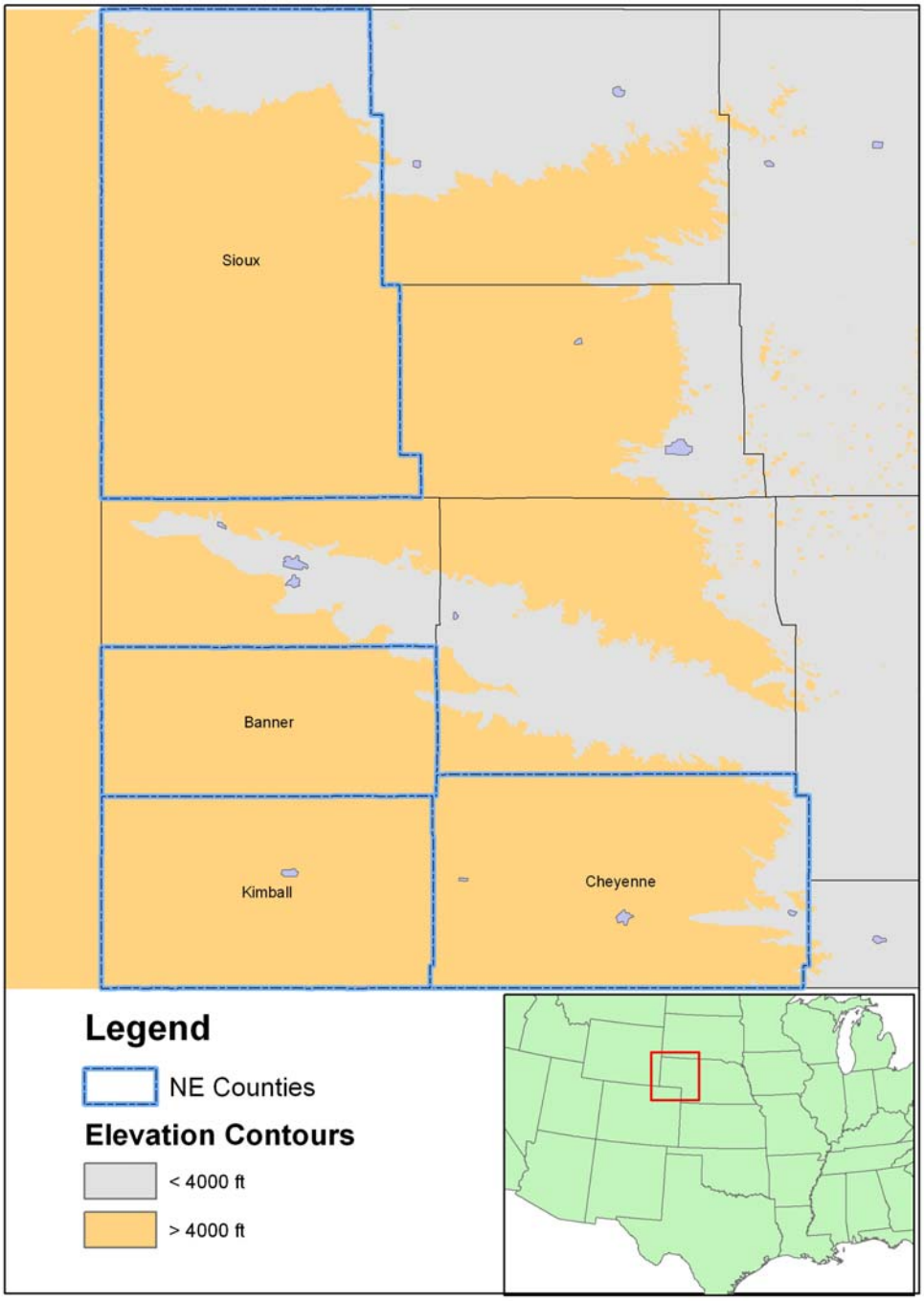


Figure 5-1. Extent to which western Nebraska counties are "high altitude" (above 4000 ft msl).

# 6. METHODS TO ESTIMATE EMISSIONS FOR NON-ROAD MOBILE SOURCES

Non-road mobile sources include equipment and vehicles that have internal combustion engines and are used off-road. Examples include ships, locomotives, aircraft, industrial equipment, recreational boats, and many others. This section describes information sources and methods used to prioritize efforts, gather activity data, and estimate emissions for non-road mobile sources.

## 6.1 PRIORITIZATION

STI reviewed the EPA's 1999 NEI (U.S. Environmental Protection Agency, 1999c) to assess the likely importance of various non-road sources to visibility in Class I areas. **Table 6-1** shows the top five non-road emitters of primary particulates and particulate precursors for counties in the CENRAP region containing or adjoining a Class I area. This review illustrated the likelihood that commercial marine vessels and railroad equipment impact visibility in the CENRAP's Class I areas more than most other non-road mobile sources. However, it also indicated that pleasure craft (recreational boats) are a much more significant source of particulates and particulate precursors than other types of recreational vehicles. It also demonstrated the importance of agricultural equipment, especially in Oklahoma and Missouri. Based on this analysis, an assessment of available resources, and consultation with the CENRAP's Emission Inventory Work Group, a decision was made to give bottom-up treatment to commercial marine vessels, locomotives, and recreational boats. These categories represent at least two-thirds of the non-road primary and precursor emissions in counties containing or adjacent to Class I areas in the CENRAP region.

Table 6-1. 1999 non-road emissions (tons/year) by state and source category for counties in the CENRAP region containing or adjoining a Class I area (U.S. Environmental Protection Agency, 2004b).

Page 1 of 2

| Poll. | Source Category | AR | LA | MN | MO | OK | TX | Total |
|---|---|---|---|---|---|---|---|---|
| $PM_{2.5}$ | Pleasure Craft | 52.3 | 403.5 | 700.3 | 150.4 | 31.1 | 3.2 | 1,340.8 |
| | Commercial Marine Vessels | 0.0 | 151.6 | 771.6 | 151.3 | 0.0 | 0.0 | 1,074.5 |
| | Agricultural Equipment | 71.4 | 1.0 | 27.3 | 404.5 | 280.2 | 8.8 | 793.2 |
| | Construction & Mining Eq. | 49.3 | 45.0 | 56.5 | 73.1 | 58.1 | 16.6 | 298.6 |
| | Railroad Equipment | 24.4 | 0.5 | 5.1 | 57.2 | 9.3 | 127.2 | 223.7 |
| | Other Sources | 52.2 | 9.0 | 144.9 | 56.0 | 32.0 | 2.9 | 297.0 |
| | Total – All Sources | 249.6 | 610.6 | 1,705.7 | 892.5 | 410.7 | 158.7 | 4,027.8 |
| VOC | Pleasure Craft | 1,197.9 | 9,434.0 | 15,418.6 | 3,338.8 | 707.9 | 74.7 | 30,171.9 |
| | Recreational Equipment | 1,102.7 | 250.7 | 5,448.3 | 1,603.8 | 154.5 | 94.4 | 8,654.4 |
| | Lawn & Garden Equipment | 319.8 | 91.5 | 463.5 | 660.3 | 341.9 | 48.1 | 1,925.1 |
| | Agricultural Equipment | 89.9 | 1.2 | 34.4 | 507.5 | 352.3 | 11.1 | 996.4 |
| | Commercial Marine Vessels | 0.0 | 114.5 | 615.9 | 114.2 | 0.0 | 0.0 | 844.6 |
| | Other Sources | 440.0 | 161.8 | 405.4 | 592.9 | 309.9 | 264.7 | 2,174.7 |
| | Total – All Sources | 3,150.3 | 10,053.7 | 22,386.1 | 6,817.5 | 1,866.5 | 493.0 | 44,767.1 |

Table 6-1. 1999 non-road emissions (tons/year) by state and source category for counties in the CENRAP region containing or adjoining a Class I area (U.S. Environmental Protection Agency, 2004b).



| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| $NO_x$ | Commercial Marine Vessels | 0.0 | 3,665.1 | 19,700.1 | 3,657.6 | 0.0 | 0.0 | 27,022.8 |
| | Railroad Equipment | 1,074.9 | 14.0 | 212.5 | 2,533.2 | 399.1 | 5,694.0 | 9,927.7 |
| | Agricultural Equipment | 557.7 | 7.5 | 213.8 | 3,160.6 | 2,188.3 | 69.1 | 6,197.0 |
| | Construction & Mining Eq. | 531.5 | 483.4 | 607.9 | 786.6 | 625.1 | 179.0 | 3,213.5 |
| | Pleasure Craft | 79.4 | 634.9 | 1,119.2 | 229.0 | 47.6 | 4.0 | 2,114.1 |
| | Other Sources | 885.5 | 135.5 | 610.9 | 850.9 | 341.6 | 25.4 | 2,849.8 |
| | Total – All Sources | 3,129.0 | 4,940.4 | 22,464.4 | 11,217.9 | 3,601.7 | 5,971.5 | 51,324.9 |
| $SO_2$ | Commercial Marine Vessels | 0.0 | 714.6 | 2,978.5 | 713.1 | 0.0 | 0.0 | 4,406.2 |
| | Agricultural Equipment | 62.5 | 0.8 | 23.9 | 353.8 | 245.4 | 7.7 | 694.1 |
| | Construction & Mining Eq. | 71.1 | 64.9 | 80.7 | 104.5 | 83.8 | 24.0 | 429.0 |
| | Railroad Equipment | 32.1 | 0.5 | 6.5 | 75.2 | 12.1 | 168.6 | 295.0 |
| | Pleasure Craft | 7.5 | 61.0 | 103.1 | 21.7 | 4.5 | 0.4 | 198.2 |
| | Other Sources | 66.9 | 10.5 | 70.5 | 59.8 | 25.7 | 2.7 | 236.1 |
| | Total – All Sources | 240.1 | 852.3 | 3,263.2 | 1,328.1 | 371.5 | 203.4 | 6,258.6 |

## 6.2 RECREATIONAL BOATS

### 6.2.1 Emissions Modeling with NONROAD

Emissions from recreational boats were modeled with the latest version of the EPA's NONROAD model. NONROAD categorizes equipment types by SCC code, and the codes pertaining to recreational boats are listed in **Table 6-2**.

Table 6-2. NONROAD source categories related to recreational boats.

| SCC code[a] | Equipment Description |
|---|---|
| 22-82-yyy-005 | Pleasure Craft: Inboard Engine |
| 22-82-yyy-010 | Pleasure Craft: Outboard Engine |
| 22-82-yyy-015 | Pleasure Craft: Personal Watercraft |
| 22-82-yyy-025 | Pleasure Craft: Sailboat Auxiliary Engine |

[a] In each code, the letters "yyy" refer to fuel type: 2-stroke gasoline (005), 4-stroke gasoline (010), or diesel (020).

For each of these source categories, the NONROAD model provides exhaust emission factors in units of grams of emissions per horsepower-hour (g/hp-hr) that are a function of engine types and sizes. Activity data include size-dependent engine populations, the load on the engines (hp) while they are in use, and the number of hours that the engines are in use per year. (These data are in turn utilized to calculate fuel consumption, which is needed for the calculation of

evaporative emissions.) Sources of these model inputs are primarily activity data collected by Power Systems Research, Inc. (PSR) and methodological information from a previous EPA non-road engine and vehicle study (U.S. Environmental Protection Agency, 1991a).

NONROAD includes the following default databases of recreational boating activity. Each may be updated with bottom-up or region-specific activity data, if available.

- NONROAD's default engine populations are based on 1998 PSR national surveys of engine manufacturer sales. The national population estimate was disaggregated to the state level by using a fuel consumption distribution developed by the Oak Ridge National Laboratory (ORNL). State-level populations were further disaggregated to the county level by using the total water surface area contained in each county (U.S. Environmental Protection Agency, 2002a).
- Default temporal profiles are based on two sources of information. Monthly allocation factors are derived from a boat usage survey done for the National Marine Manufacturers Association (NMMA) (U.S. Environmental Protection Agency, 2002c). Weekday-weekend allocation factors were derived from a survey of recreational marine use conducted in California during 1993 and 1994. These weekday-weekend factors are specific to equipment type only and do not vary geographically (U.S. Environmental Protection Agency, 1999b).
- Annual equipment usages (hours of use) are based on a 1998 PSR equipment activity database. The application-specific estimates in this database were based on several yearly surveys of equipment owners conducted by PSR (U.S. Environmental Protection Agency, 2002b).
- Default engine load factors were based on a simplifying assumption that the EPA's recreational marine engine test cycle is representative of load factors for engines in use. Although PSR survey results for load factors exist, they are not represented in the NONROAD model because the EPA considered them to be insufficiently documented (U.S. Environmental Protection Agency, 2002b).

Because NONROAD relies primarily on national-level activity data, some regional and/or local equipment population and usage characteristics are likely not properly represented in the model. Moreover, the use of water surface area as a geographic allocation surrogate does not account for the navigability of a given body of water or its popularity. Improving the various types of activity data utilized by NONROAD required gathering additional information about the ownership and use of recreational boats within the CENRAP region.

### 6.2.2 Acquisition of Activity Data

The activity data needed to update the NONROAD inputs for recreational boats were gathered through a bottom-up survey of representative groups of recreational boat owners. The survey was designed to gather data on vessel characteristics, hours of use, fuel consumptions, engine loads, and temporal and geographic usage patterns in each CENRAP state. A representative pool of nearly 1,400 registered boat owners was recruited by telephone to participate in the study. A survey questionnaire and an incentive for participation was mailed to

each participant, followed one week later by a reminder postcard. For the purposes of study design, a 50% return rate was anticipated for the mail survey; however, a significantly better response rate—more than 70%—was actually achieved. Geographic coverage and representativeness of the survey results were considered to be excellent for all states of the CENRAP region. Survey results were analyzed and used to estimate annual hours of use and engine load factors for each state and each type of boat. Survey questionnaires, results, and raw data files are included as an appendix to the Final Report.

### 6.2.3 Spatial Allocation

In order to spatially allocate emissions, the counties where recreational boats are used should be determined (i.e., the county where the boat is registered is not a good spatial surrogate). The survey questionnaire included one or more maps detailing the navigable waterways in the respondents' region, which allowed respondents to easily identify the counties in which they typically operate their boats. (Participants indicated their regions during telephone recruitment.) These responses were converted and used to calculate county-level activity for recreational boats.

### 6.2.4 Temporal Allocation

The survey questionnaire also queried how recreational boat activity is distributed across the months of the year, the days of the week, and the hours of the day. Large variances in climate and boating habits throughout the CENRAP region meant that these temporal patterns were likely to vary greatly from state to state. Responses to these questions were analyzed and used to calculate seasonal, day-of-week, and diurnal temporal profiles for each state and type of boat.

### 6.2.5 Data Preparation

Deliverables for this source category included the updated input files used to run the NONROAD model, as well as county-level emission estimates derived from outputs of the latest version of NONROAD (NONROAD 2004). These emission estimates were provided in both NIF 3.0 format and the IDA format used by the SMOKE emissions model. The temporal allocation profiles and cross-reference files used by SMOKE were also provided.

## 6.3 MARINE VESSELS

Emissions estimates were prepared for commercial marine vessels operating in commercially active waterways in the CENRAP region. This inventory included river barges and other commercial vessels operating in inland waterways, as well as ocean-going ships, harbor tugboats, and other commercial vessels operating in the Gulf Intracoastal Waterway (GIWW). These waterways can be seen in **Figure 6-1** (U.S. Army Corps of Engineers, 1997).

Figure 6-1. Map of commercially active inland and intracoastal waterways in the United States.

### 6.3.1 Emission Factors

In 1999, the EPA released a Regulatory Impact Analysis (RIA) on commercial marine vessel emissions (U.S. Environmental Protection Agency, 1999e). This report estimated emissions for the three categories of marine engines shown in **Table 6-3**:

Table 6-3. EPA marine engine categories.

| Category | Displacement per Cylinder | Description |
|---|---|---|
| 1 | disp. < 5 liters<br>power ≥ 37 kW | Similar to land-based non-road engines. Used in smaller tugboats, ferries, fishing vessels, and dredges. Fueled by marine diesel oil. |
| 2 | 5 ≤ disp. < 30 liters | Similar to engines used in locomotives. Used in smaller ocean-going vessels, as well as large tugboats, towboats, ferries, and fishing vessels. Fueled by marine diesel oil. |
| 3 | disp. ≥ 30 liters | Used primarily for propulsion in large, ocean-going vessels. Usually fueled by residual oil, which has a higher sulfur content than diesel oil. |

In addition to the uses cited in Table 6-3, all three categories of engines can be used for "auxiliary" purposes (such as electrical generation) on larger vessels, though Category 2 engines are used in this way more often than the other types. The EPA RIA estimated emission factors for Category 1 marine engines and cited emission factors for Category 2 and 3 marine engines from a previous EPA report (U.S. Environmental Protection Agency, 1998c). **Tables 6-4 and 6-5** show the emission factors for marine engines in each category.

Table 6-4. Emission factors for Category 1 marine engines.

| Power Range (kW) | HC (g/kW-hr) | $NO_x$ (g/kW-hr) | CO (g/kW-hr) | PM (g/kW-hr) |
|---|---|---|---|---|
| 37 – 75 | 0.27 | 11 | 2.0 | 0.9 |
| 75 – 130 | 0.27 | 10 | 1.7 | 0.4 |
| 130 – 225 | 0.27 | 10 | 1.5 | 0.4 |
| 225 – 450 | 0.27 | 10 | 1.5 | 0.3 |
| 450 – 560 | 0.27 | 10 | 1.5 | 0.3 |
| 560 – 1000 | 0.27 | 10 | 1.5 | 0.3 |
| 1000+ | 0.27 | 13 | 2.5 | 0.3 |

Table 6-5. Emission factors for Category 2 and 3 marine engines.

| Engine Speed[1] | HC (g/kW-hr)[2] | $NO_x$ (g/kW-hr) | CO (g/kW-hr) | PM (g/kW-hr) |
|---|---|---|---|---|
| Medium[2] | 0.5 | 12 | 1.6 | 0.25 |
| Slow[2] | 0.5 | 17 | 1.4 | 1.48 |

[1] Category 2 and smaller Category 3 engines are medium speed (2-stroke). Larger Category 3 engines are slow speed (4-stroke).
[2] Emission factors converted from kilograms per ton of fuel consumed to gram per kilowatt-hour using fuel consumption estimates of 195 g/kW-hr for slow speed engines and 210 g/kW-hr for medium speed engines (Pollack et al., 2004).

Emission factors for $SO_2$ were calculated using Equation 6-1, an algorithm that is based on fuel sulfur content (U.S. Environmental Protection Agency, 2000). **Table 6-6** lists the assumed fuel sulfur content (U.S. Environmental Protection Agency, 2003b) for marine diesel oil and residual oil, as well as the $SO_2$ emission factors calculated for each engine type.

Emission rate (g/kW-hr) =
2.3735* [Fuel Consumption (in g/kW-hr) * Fractional Fuel Sulfur content] **(6-1)**

Table 6-6. $SO_2$ emission factors for marine engines.

| Engine Type | Fuel Sulfur Content | $SO^2$ (g/kW-hr) |
|---|---|---|
| Category 1 | | |
| <1000 hp | 0.25% | 1.29 |
| >1000 hp | 0.25% | 1.25 |
| Category 2 and 3 | | |
| Medium speed | 0.25%/2.70%[a] | 1.25/13.46[a] |
| Slow speed | 2.70% | 12.5 |

[a] The first value is for marine diesel oil, which is used in Category 2 engines, and the second value is for residual oil, which is used in Category 3 engines.

These emission factors can also be converted to fuel-based factors by dividing them by the fuel consumption rate for a given engine type. For example, the $SO_2$ emission factor for slow-speed Category 3 engines can be converted to a fuel basis as follows:

Fuel-based emission rate = (12.5 g/kW-hr / 195 g/kW-hr) * 1000 g/kg = 64.1 g/kg of fuel **(6-2)**

### 6.3.2 Acquisition of Activity Data

Emissions estimates were based primarily on bottom-up fuel usage data for inland river systems in the CENRAP region derived from the Tennessee Valley Authority (TVA) Barge Costing Model. This model was developed to estimate fuel usage by inland river segment for fuel tax purposes.[6] Inputs to the model include engine horsepower and trip characteristics for each vessel that travels on a given waterway segment in a given year. These data are used to estimate fuel consumption for each significant inland waterway segment in the United States.[7] The model uses these data to estimate total fuel consumption, total cargo transported, and average vessel horsepower by waterway segment. Each year, fuel consumption estimates are compared to actual tax receipts, and model errors have averaged only 1.5% per year since 1996.

For the GIWW, however, the TVA model does not provide a complete picture of fuel consumption, as "deep-draft" (oceangoing), harbor tugs, and other vessels not bound for an inland river system are not considered. For these vessels, emission estimates were prepared with work-based emission factors and the following types of activity data (U.S. Environmental Protection Agency, 1999a):

- The number of total trips to and from each port
- The total number of trips passing (but not stopping at) each port

[6] Some "segments" consist of an entire river, such as the Atchafalaya River in Louisiana. Longer rivers, such as the Mississippi, are broken up into multiple segments.
[7] The small rivers and tributaries not considered by the model account for only 1-3% of the total tonnage moved over inland waterways each year (Dager, 2004).

- Vessel characteristics for tugboats and transport ships operating in and through each port
- Speed and time-in-mode data for four operational modes: cruise, slow cruise, maneuvering, and hoteling (or docking)
- Engine load factors for each of the four operational modes listed above

Much of the necessary data on vessel trips can be obtained from the U.S. Army Corps of Engineers (USACE) Waterborne Commerce Statistics Center, which tracks vessel movements and characteristics, as well as barge trips and tonnage. The Maritime Administration of the Department of Transportation also maintains a U.S. waterway database that includes vessel names and ports/waterways visited.

Vessel characteristics, speeds, times-in-mode, and engine load data have been modeled for deep sea, river, and Great Lake ports in the United States in a two-volume report produced by ARCADIS on behalf of the EPA (U.S. Environmental Protection Agency, 1999a, d). These documents provide a detailed analysis of selected ports, as well as a method for extrapolating activity data from these "known" ports to other ports with similar characteristics. Several of the ports chosen for detailed analysis are located within the CENRAP region, including St. Louis, Baton Rouge, New Orleans, Plaquemines, South Louisiana, and Corpus Christi. The techniques described in these reports were used to produce a profile of vessel characteristics and operations for all ports in the CENRAP states. Also, some bottom-up surveys of selected port authorities and/or vessel operators were done to verify the assumptions made in creating these profiles.

### 6.3.3 Spatial Allocation

Emissions occurring in and around a deep sea or Great Lake port area were assigned to the county in which the port is located. If a port spanned multiple counties, the number of port terminals in each county was used to allocate maneuvering and hoteling emissions, and the length of the port area in each county was used to allocate emissions from cruise mode. Data on port terminals and their waterway locations are available from the USACE (2003a).

However, for inland river systems, fuel consumption must first be disaggregated into "in-port" and "underway" components. To accomplish this, fuel consumption at river ports in the CENRAP states was estimated with fuel-based emission factors described in Section 6.3.1 and port-specific data on vessel trips; and characteristics (as outlined in Section 6.3.2) were obtained from USACE data, EPA guidance documents, and surveys of port authorities. Once in-port fuel consumption was estimated, the values were subtracted from Barge Costing Model fuel consumption estimates for the river segment in question. The remaining fuel consumption was considered "underway" and allocated to counties based on the fraction of a river segment's length passing through each county. These county-level river segment fractions were derived from the GIS-based National Waterway Network database produced by the Bureau of Transportation Statistics (BTS).

### 6.3.4 Temporal Allocation

Monthly variations in vessel activity and fuel usage are significant (Dager, 2004). These seasonal variations are influenced by climate (the upper Mississippi is closed during winter) and by the types of commodity being moved (grain shipments, for example, primarily occur in April/May and September/October).

Fuel usage estimates produced by the Barge Costing Model are not currently available on a monthly basis. Therefore, monthly activity patterns were determined from the Lock Performance Monitoring System (LPMS) maintained by the USACE. This database provides USACE operators, planners, and managers with information on the use, performance, and characteristics of the USACE's national system of locks. The LPMS consists of data collected at most USACE-owned and/or -operated locks, including the number of vessels and barges locked, dates of lockages, and the type and tonnage of commodity carried (U.S. Army Corps of Engineers, 2003b). Statistics are published monthly for selected key locks, and these monthly data were used to generate a monthly activity profile for each inland river system, as well as the GIWW.

### 6.3.5 Data Preparation

Deliverables for this source category include the county-level emission estimates in both NIF 3.0 format and the IDA format used by the SMOKE emissions model. The temporal allocation profiles and cross-reference files used by SMOKE were also provided.

## 6.4 LOCOMOTIVES

Railroads can be separated into three class sizes. Class I railroads operate over a large geographic area, serve many states, and maintain fleets of locomotives that number from several hundred to several thousand. These railroads, while few in number, are responsible for about 93% of the annual fuel consumption of all railroads nationwide (U.S. Environmental Protection Agency, 1998d). Class II (or regional) railroads serve only a few states and typically operate about 30 to 200 locomotives. Class III (or local) railroads usually serve only one state and operate only a handful of locomotives. Locomotives in each of these classifications can be used for two types of operation: line haul and yard (or switching) activities. Line haul locomotives generally travel long distances, whereas yard locomotives only move railcars within a local railway yard. Some local railroads do not operate any line haul locomotives, but only provide switching services to other railroads. These "Switching and Terminal" railroads were treated as a fourth classification for emission estimation purposes.

**Table 6-7** shows the total number of railroads operating in the entire CENRAP region by class (Association of American Railroads, 2004). Using the emission factors and activity data described in the following sections, emissions were estimated for all line haul and yard locomotives operated by one of these railroads.

Table 6-7. Railroads operating in the CENRAP region by class.

| Railroad Class | Number of Railroads | Railroad Names |
|---|---|---|
| Class I | 8 | Amtrak<br>Burlington Northern & Sante Fe<br>Kansas City Southern<br>Union Pacific<br>Norfolk Southern<br>CSX Transportation<br>Canadian National<br>Canadian Pacific/Soo Line |
| Class II | 14 | Chicago, Central & Pacific<br>Dakota, Minnesota & Eastern<br>Duluth, Missabe & Iron Range<br>I & M Rail Link<br>Iowa Interstate<br>Kansas City & Oklahoma<br>Kyle<br>Missouri & Northern Arkansas<br>Nebraska, Kansas & Colorado<br>Northern Plains<br>Red River Valley & Western<br>South Kansas & Oklahoma<br>Texas Mexican<br>Texas Pacifico |
| Class III | 80 | Numerous |
| Switching & Terminal | 33 | Numerous |

### 6.4.1 Emission Factors

Emissions from locomotives are calculated based on fuel consumption. The EPA has estimated average emissions rates for locomotives as grams of pollutant emitted per gallon of fuel consumed (g/gal) (U.S. Environmental Protection Agency, 1997). These emission factors vary by the age of the locomotive, as three separate sets of emissions standards have been adopted by the EPA (see **Table 6-8**).

Table 6-8. Locomotive emission factors by model year.

| Locomotive Type | Model Year | Controls | Emission factors (g/gal) | | | |
|---|---|---|---|---|---|---|
| | | | HC | CO | $NO^x$ | PM |
| Line haul | <1973 | Uncontrolled | 10 | 26.6 | 270 | 6.7 |
| | 1973-2001 | Tier 0 | 10 | 26.6 | 178 | 6.7 |
| | 2002-2004 | Tier 1 | 9.8 | 26.6 | 139 | 6.7 |
| | >2004 | Tier 2 | 5.4 | 26.6 | 103 | 3.6 |
| Switch | <1973 | Uncontrolled | 21 | 38.1 | 362 | 9.2 |
| | 1973-2001 | Tier 0 | 21 | 38.1 | 262 | 9.2 |
| | 2002-2004 | Tier 1 | 21 | 38.1 | 202 | 9.2 |
| | >2004 | Tier 2 | 11 | 38.1 | 152 | 4.3 |

For Class I railroads, weighted emission factors were calculated based on locomotive fleet age distribution data available from the Bureau of Transportation Statistics (Bureau of Transportation Statistics, 2003a). The latest BTS locomotive fleet information indicates that 14% of Class I locomotives were built prior to 1973 and 86% were built from 1973 to 2001 (and are, therefore, subject to Tier 1 controls). At the time of data acquisition, no information was available on the number of locomotives built in 2002 that have entered the fleet; so for purposes of the 2002 inventory, it was assumed that the impact of Tier 1 controls is negligible. The weighted emission factors shown in **Table 6-9** were calculated based on the BTS fractions listed above.[8]

Table 6-9. Weighted emission factors for Class I locomotives.

| Locomotive Type | Emission factors (g/gal) | | | |
|---|---|---|---|---|
| | HC | CO | $NO_x$ | PM |
| Line haul | 10 | 26.6 | 191 | 6.7 |
| Switch | 21 | 38.1 | 273 | 9.2 |

For Class II, Class III, and switching railroads, no specific information on fleet age distributions is readily available, and since these railroads use only about 5% of the fuel consumed by all railroads nationwide (U.S. Environmental Protection Agency, 1998d), a simple, conservative approach was applied. Because it is known that these smaller railroads tend to have an older fleet mix than Class I railroads (U.S. Environmental Protection Agency, 1992), uncontrolled emission factors were applied to all Class I, Class II, and switching railroads.

[8] For purposes of this calculation, it was assumed that fuel usage per locomotive does not vary with age, either due to fuel economy changes or the reduced usage of older locomotives.

### 6.4.2 Acquisition of Activity Data

Class I Railroads

Class I line haul locomotives, which operate over large geographic regions, do not burn all their fuel in the same area where the fuel was pumped. Therefore, total annual fuel consumption for each Class I railroad must be estimated at the state (or county) level in order to determine the amount of fuel consumed within the inventory area. Such estimates were made by calculating a system-wide fuel consumption index (expressed in gross ton-miles[9] per gallon or GTM/gal) for each railroad and applying that index to state-level traffic density data (U.S. Environmental Protection Agency, 1992). As a quality assurance check, Class I railroads were contacted individually to see if they track state or county-level fuel consumption data that could be compared to the estimated values.

The data needed to calculate a fuel consumption index can be obtained from the "R-1" reports all Class I railroads are required to file with the Surface Transportation Board (STB) each year. Schedule 755 of this report lists the annual traffic density in gross ton-miles for a given railroad, and Schedule 750 lists the total fuel consumption for line haul operations and switching operations. Copies of these schedules for all Class I railroads were obtained from the STB, and **Table 6-10** lists the 2002 traffic density and fuel consumption data for each Class I railroad operating in the CENRAP region.

Table 6-10. 2002 system-wide activity data for Class I railroads.

| Railroad Name | Traffic Density (1000 ton-miles) | Fuel Consumption (gal) | |
|---|---|---|---|
| | | Line Haul | Switching |
| Amtrak[a] | N/A | 75,000,000 | N/A |
| Burlington Northern and Sante Fe | 958,862,994 | 1,091,248,247 | 57,434,118 |
| Kansas City Southern | 37,563,933 | 51,256,604 | 4,057,180 |
| Union Pacific | 1,085,700,525 | 1,176,963,998 | 137,902,327 |
| Norfolk Southern | 373,281,203 | 433,678,710 | 38,810,939 |
| CSX Transportation | 469,392,729 | 514,107,567 | 56,172,596 |
| Canadian National | 104,578,305 | 108,013,647 | 15,135,382 |
| Canadian Pacific/Soo Line | 45,426,616 | 42,198,000 | 3,060,000 |

[a] Amtrak does not file reports with the STB, so fuel consumption data for that railroad was obtained from the BTS (2003b).

Using these data, a fuel consumption index for each railroad was calculated by dividing the system-wide traffic density by the system-wide fuel usage. For example, the fuel consumption index for the Burlington Northern & Sante Fe (BNSF) railroad was calculated as follows:

$$FCI_{BNSF} = 958{,}862{,}994 \times 10^3 \text{ ton-miles} / 1{,}091{,}248{,}247 \text{ gal} = 878.7 \text{ ton-miles/gal} \quad \textbf{(6-3)}$$

[9] Gross ton-miles include the weight of locomotives, freight cars, etc. rather than the weight of freight only.

State-level traffic density data were obtained from the Federal Railroad Administration (FRA), as Class I railroads are only required to report their traffic density to the STB on an aggregate (or national) basis. The FRA has a rail network model which is used to estimate traffic flows on specific rail lines, and the agency provided state-level traffic density data for all Class I railroads (Kedar, 2004). These data can be used in conjunction with the fuel consumption index calculations described above to estimate fuel usage by state for each Class I railroad. For example, FRA data show that the 2002 gross traffic density for the BNSF Railroad in Arkansas was 8090.66 million ton-miles. Fuel usage for this railroad in Arkansas can then be calculated as follows:

$$\text{Fuel Consumption} = 8090.66 \times 10^6 \text{ ton-miles} / 878.7 \text{ ton-miles/gal} = 9{,}207{,}696 \text{ gal} \qquad \textbf{(6-4)}$$

Class I switching emissions were also calculated based on fuel usage data gathered from Class I railroads or taken from R-1 reports. These data were disaggregated to the state level using procedures similar to those outlined above, with a fuel consumption index generated for each railroad by dividing the railroad's system-wide traffic density by the system-wide fuel usage for switching operations.

Class II and Class III Railroads

Emissions from Class II and III locomotives were calculated based on the amount of fuel consumed in the inventory area. However, these smaller railroad companies are not required to file R-1 reports with the STB, so the only source of fuel consumption information is the railroads themselves. Because there are only 14 Class II (regional) railroads operating in the CENRAP states, each one was surveyed to determine fuel usage by state. In cases where Class II railroads are unable or unwilling to provide data, an average fuel consumption index was calculated for railroads that did supply information and extrapolated to railroads with missing data. This fuel consumption index was based on the total miles of track operated by a railroad and the total carloads of freight transported each year—information gathered through annual surveys conducted by the Association of American Railroads (AAR).

A similar approach was used for Class III railroads. Surveying each of the 80 local railroads in the CENRAP states individually was not feasible within the scope of this project, so a sample of such railroads was contacted in each state. Again, a fuel consumption index was calculated from available data and used to estimate fuel usage for railroads that were not surveyed.

Switching and Terminal Railroads

For yard (or switching) locomotives, the EPA recommends an emission estimation method based on the number of yard locomotives operating within an inventory area. The EPA estimates that the average yard locomotive operates 24 hours per day, 365 days per year, and consumes 228 gallons of diesel fuel per day (U.S. Environmental Protection Agency, 1992). Yard locomotive emissions can be derived by multiplying the number of yard locomotives within the inventory area by this fuel usage factor and applying the switch locomotive emission factors previously cited. However, these assumptions indicate that the typical yard locomotive consumes over 80,000 gallons of fuel per year, and, while this figure may be appropriate for

busy Class I yard locomotives, it is almost certainly too high for local switching operations.[10] Therefore, fuel usage for switching railroads was calculated in a manner similar to that carried out for other Class III railroads. A sample of switching railroads was contacted to obtain annual fuel usage data, and a fuel consumption index was derived and applied to other railroads. This fuel consumption index was based on the number of yard locomotives and total miles of track operated, as well as the number of carloads of freight handled each year—information available from the AAR.

### 6.4.3 Spatial Allocation

For Class I railroads, emissions were apportioned to the county level by using the GIS-based National Rail Network produced by BTS. This network contains traffic density data[11] by railway segment and railroad classification, and the network can be overlaid with county boundaries to estimate the fraction of a given state's Class I rail traffic that passes through each county in that state. These fractions were used to disaggregate emissions from the state to the county level. Similarly, state-level emissions from switching operations were assigned to individual counties based on the number of railroad terminals[12] in a given county.

For Class II and III railroads, emission factors for line haul locomotives[13] were applied to statewide fuel usage estimates for Class II and III railroads, and emissions were apportioned to the county level using the Class II and III traffic density data contained in the National Rail Network. For Class III switching operations, emission factors for switching locomotives were applied to fuel usage estimates, and the emissions were apportioned to the county in which each railroad's yard is located.

### 6.4.4 Temporal Allocation

Movements of freight by rail occur 24 hours per day, 7 days per week, though there are slight variations across the months of the year (Kedar, 2004). The AAR produces an annual report that summarizes weekly carloads of freight shipped in the United States, and these weekly data were used to model monthly variations in locomotive activity (American Association of Railroads, 2003).

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[10] Preliminary data collected for Iowa show that two local switching railroads consume less than 10,000 gallons of diesel fuel per year each.

[11] Each rail segment is assigned to one of seven density groupings (for example, Group 2 represents densities ranging from 5.0 to 9.9 million GTM/mile). The average of each range will be used when apportioning traffic density to the county level.

[12] The BTS National Rail Network contains data on the locations of railroad terminals and junctions in each state.

[13] Class II and III railroads are not as likely as Class I railroads to operate their own switching engines or to track fuel by locomotive type. This assumption was also made by the EPA in a regulatory support document (U.S. Environmental Protection Agency, 1998d).

### 6.4.5 Quality Assurance

For Class I railroads, fuel consumption estimates by state from the FRA rail network model were cross-checked with other readily available estimates of railroad activity as a quality assurance check. For example, the state-level data published by the AAR list the total tons of freight transported through each state annually (Association of American Railroads, 2004). These data show that freight traffic in Nebraska is significantly higher in than any of the other CENRAP states, which corroborates initial fuel estimates performed for Class I railroads from available STB data.

For Class II and III railroads, survey data gathered in 2001 by the American Shortline and Regional Railroad Association (ASRRA) were used as a quality assurance check. This survey included questions related to fuel consumption; and while confidentiality concerns prevent the release of the actual database, a researcher with ASRRA provided an aggregate estimate of fuel consumed by all Class II and III railroads headquartered in CENRAP states for 2001 (Benson, 2004). This estimate of 50,000,000 gallons matches up very well with the results of the CENRAP inventory.

In addition, the procedures outlined in the project QAPP were followed (Sullivan, 2004).

### 6.4.6 Data Preparation

Deliverables for this source category include the county-level emission estimates in both NIF 3.0 format and the IDA format used by the SMOKE emissions model. The temporal allocation profiles and cross-reference files used by SMOKE were also provided.

# 7. METHODS TO ESTIMATE EMISSIONS FOR SOURCES OF AGRICULTURAL FUGITIVE DUST

Agricultural operations, such as crop tilling, crop harvesting, or confined animal feeding operations (CAFOs), release emissions of geologic fugitive dust. This section describes the information sources and methods used to calculate county-level emissions of agricultural fugitive dust for the CENRAP region for calendar year 2002.

## 7.1 PRIORITIZATION

Emissions estimation methodologies and existing emission inventories for the CENRAP region and for other regions of the country were reviewed. The EPA's 1999 NEI includes particulate matter (PM) emissions for the CENRAP region for the following agricultural source categories, as illustrated in **Figure 7-1**: tilling, beef cattle feedlots, cotton ginning, and agricultural crop burning (U.S. Environmental Protection Agency, 2004b). The Western Regional Air Partnership (WRAP) projected emissions from the 1999 NEI to estimate 2002 agricultural PM emissions for the WRAP region (E.H. Pechan and Associates, 2004). The WRAP region's inventories indicated that agricultural tilling and beef cattle feedlots were the largest contributors to agricultural fugitive dust, followed by crop transport and cotton ginning, as illustrated in **Figure 7-2**. Other sources of agricultural PM emissions in the WRAP region included harvesting, crop burning, and other combustion sources.

In the NEI and WRAP inventories, agricultural tilling and CAFOs encompass more than 90% of the PM emissions from agricultural sources. Therefore, agricultural tilling and CAFOs were selected for bottom-up treatment. Emissions of $PM_{10}$ and $PM_{2.5}$[14] for these source categories were estimated by acquiring bottom-up activity data and applying emission factors from EPA guidance or other literature. Activity data for agricultural tilling operations were gathered through a survey of county agricultural extension offices (Reid et al., 2004). Facility-specific population estimates for beef cattle feedlots and dairies were prepared previously (Coe and Reid, 2003).

[14] $PM_{10}$ is PM of less than or equal to 10 microns (μm) aerodynamic matter. $PM_{2.5}$ is PM of less than or equal to 2.5 microns (μm) aerodynamic matter

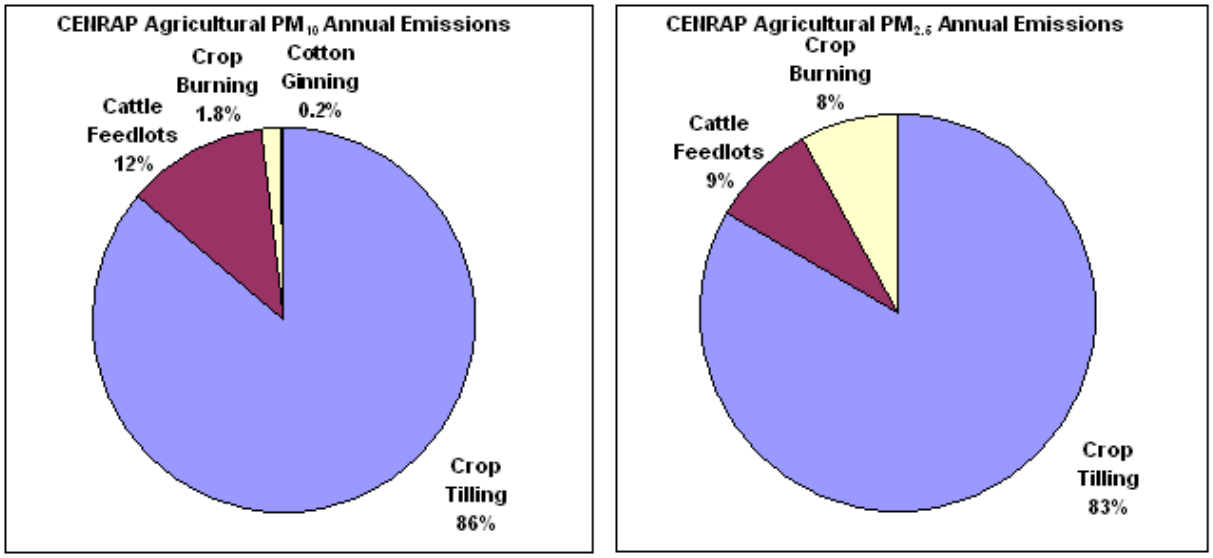


Figure 7-1. 1999 agricultural PM emissions for the CENRAP region.

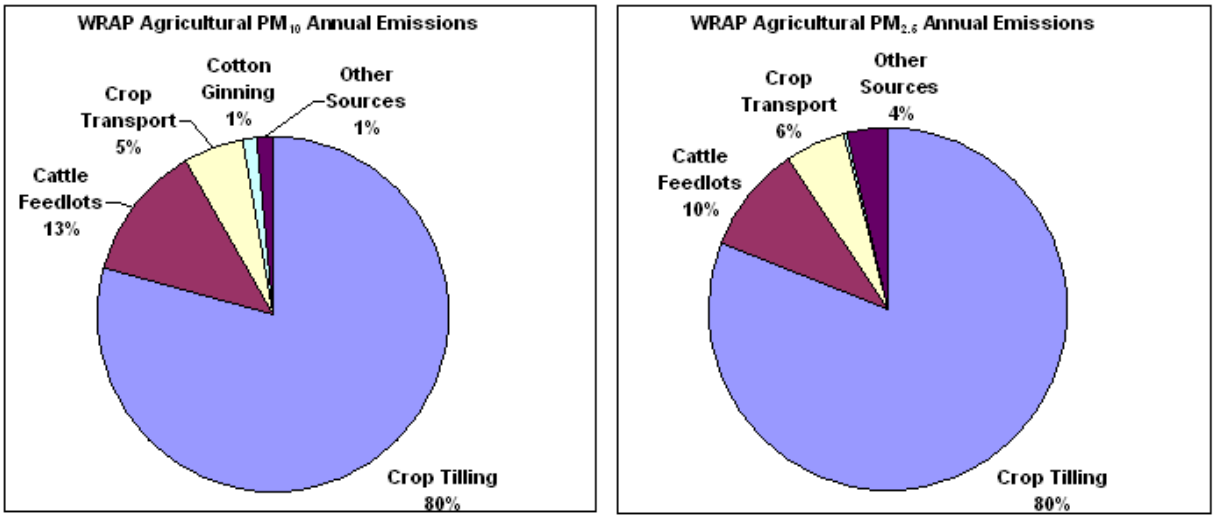


Figure 7-2. Projected 2002 agricultural PM emissions for the WRAP region.

## 7.2 AGRICULTURAL CROP TILLING

EPA's guidance for estimating PM emissions from agricultural crop tilling involves combining a constant emission factor with county-level activity data, including the silt content of surface soils, the number of tillings performed in a year for each crop type, and the acres of each crop type (U.S. Environmental Protection Agency, 2001, 2004c). For conservational tillage practices, such as no till, mulch till, and ridge till, the number of tillings performed in a year is reduced proportionally according to information provided by the Conservation Information

Technology Center (CTIC) (U.S. Environmental Protection Agency, 2004c; Conservation Technology Information Center, 2004). Emissions from agricultural crop tilling are calculated according to Equation 6-1.

$$E = c \times k \times s^{0.6} \times p \times a \qquad \textbf{(6-1)}$$

*E* represents the PM emissions in units of pounds per year, and *c* equals the constant emission factor of 4.8 lbs/acre-tilling. A dimensionless particle size multiplier, *k*, is applied to calculate either $PM_{10}$ ($k$=0.21) or $PM_{2.5}$ ($k$=0.042). The silt content of the soil, *s*, is defined as the mass fraction of particles smaller than 0.75 µm diameter found in soil to a depth of 10 cm, expressed as a percent. The other activity data include *p*, which represents the number of tillings or passes that are performed in a year for each crop type, and *a*, which represents the acres of land tilled for each crop type. In summary, the methodology requires the following information, at county level, as activity data:

- The number of tillings per year by crop.
- The conservational tilling practices.
- The silt content of soils.
- The acres of land planted by crop type .

The EPA's Emissions Inventory Improvement Program suggests that local data for the number of tillings per year for each crop type and the temporal distribution of tilling activities are desirable (U.S. Environmental Protection Agency, 2004c). A survey of tilling practices was conducted by contacting county agricultural extension offices throughout the CENRAP region (Reid et al., 2004). Questionnaires were designed to elicit information about the types of crops in each respondent's county and the tilling practices for each crop type. The survey results were analyzed and extrapolated for each of the CENRAP states to estimate the number of tillings per year by crop type, the temporal distributions of temporal tilling activities, and the prevalences of conservational tilling practices.

The EPA National Air Pollutant Emission Trends Procedures Document provides a cross-reference table with silt contents for various soil types (U.S. Environmental Protection Agency, 1998b). The State Soil Survey Geographic Database (STATSGO) produced by the Natural Resources Conservation Service of the United States Department of Agriculture was used to determine soil types at the county level (National Resources Conservation Service, 1994). County-level silt contents were determined by using the EPA Procedures Document to cross-reference silt contents with STATSGO soil types.

County-level acreages of grown crops were prepared previously (Reid et al., 2004). These acreages were based on 2002 National Agricultural Statistics Service (NASS) data.

## 7.3 CATTLE FEEDLOTS AND DAIRIES

The open surfaces of the pens and/or the manure pack are sources of fugitive dust at cattle feedlots and dairies. The major difference between cattle feedlots and dairies is the proportion of time that herds are in contact with the manure pack, which tends to limit fugitive

dust emissions at dairies to levels much lower than those of beef cattle feedlots (Goodrich et al., 2002).

EPA guidance specifies an emission factor equal to 17 tons of $PM_{10}$ per thousand head of feeding cattle per year (or 93 lbs $PM_{10}$ per thousand head per day), and an assumption that 15% of $PM_{10}$ is emitted as $PM_{2.5}$ (U.S. Environmental Protection Agency, 2004a). However, a literature review indicated that the EPA's guidance results in greatly overestimated emission inventories (Flocchini and James, 2001; Goodrich et al., 2002). Two recent studies performed by the University of California at Davis and Texas A&M University yielded emission factors of 28.9 lbs $PM_{10}$ per thousand head per day (Flocchini and James, 2001) and 19 lbs $PM_{10}$ per thousand head per day (Goodrich et al., 2002) for beef cattle at feedlots. The midpoint—24 lbs $PM_{10}$ per thousand head per day—was selected and used to estimate emissions of $PM_{10}$ for beef cattle feedlots in the CENRAP region. In addition, an emission factor of 4.4 lbs $PM_{10}$ per thousand head per day was selected for use in estimating emissions for dairies. This emission factor is based on sampling conducted at a single central Texas dairy in the summer of 2002 (Goodrich et al., 2002), and is therefore highly uncertain. However, it is the best and most reasonable emission rate that could be identified at this time.

Facility-specific population estimates for beef cattle feedlots and dairies were prepared previously (Coe and Reid, 2003). These population estimates were based primarily on facility-specific animal populations and species available from National Pollutant Discharge Elimination System (NPDES).

No information was identified that could be used to develop temporal patterns for this source category. However, emissions are likely to vary because climate conditions and animal husbandry practices vary seasonally and diurnally.

## 7.4 DATA PREPARATION

Deliverables for this source category include the county-level emission estimates in both NIF 3.0 format and the IDA format used by the SMOKE emissions model. The temporal allocation profiles and cross-reference files used by SMOKE were also provided.

# 8. PREPARATION OF INVENTORIES AND DATA FILE SYSTEMS FOR DELIVERY

## 8.1 ON-ROAD MOBILE SOURCES

Activity data, MOBILE6-ready input files, temporal profiles and cross-references used by SMOKE, and MOBILE6 command files were prepared to allow an independent third party to run MOBILE6 within SMOKE. These deliverables permitted CENRAP to prepare hourly meteorological inputs, estimate emissions, and prepare gridded emission inventories for any 2002 time period. In addition, STI ran MOBILE6 within SMOKE, estimated annual emissions for on-road mobile sources, and prepared NIF 3.0 emission inventories for the entire CENRAP region.

To estimate annual emissions, CENRAP's MM5 meteorological inputs for the months of January and July 2002 were used. Annual emissions were estimated from the average of the emission inventories for January and July 2002.[15] In addition, although SMOKE/MOBILE6 can be used to calculate emissions from refueling, these emissions are better allocated spatially and temporally if they are calculated separately from MOBILE6 runs. Therefore, refueling emissions were not included in the CENRAP emission inventory.

## 8.2 NON-ROAD MOBILE SOURCES

Revised activity data files and fuels characteristics, formatted for use with NONROAD, were prepared to allow an independent third party to run NONROAD and estimate emissions. In addition, STI ran the latest version of NONROAD (NONROAD 2004), estimated annual emissions for non-road mobile sources, and prepared NIF 3.0 and IDA-formatted emission inventories for the entire CENRAP region. The temporal allocation profiles and cross-reference files used by SMOKE were also provided. Emissions for locomotives and commercial marine vessels were estimated externally to the NONROAD model, which does not treat these sources, and were prepared in NIF 3.0 and IDA formats.

## 8.3 SOURCES OF AGRICULTURAL FUGITIVE DUST

STI estimated annual emissions for sources of agricultural fugitive dust, and prepared NIF 3.0 and IDA-formatted emission inventories for the entire CENRAP region. For agricultural tilling dust, the temporal allocation profiles and cross-reference files used by SMOKE were also provided.

[15] Test runs were also completed using representative temperatures for April and October to determine the potential effects on the annual average; however, the effects of including four months in the annual average were negligible.

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# APPENDIX A

## CENTRAL STATES REGIONAL AIR PLANNING ASSOCIATION (CENRAP) PLEASURE CRAFT STUDY

# Central States Regional Air Planning Association (CENRAP) Pleasure Craft Study

## Final Report

*Prepared for*

**Sonoma Technology, Inc.**

Project 1031

July 2004

*Prepared by*

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# Final Report

## Overview

Population Research Systems (PRS), LLC, a subsidiary of Freeman, Sullivan & Co., conducted the Pleasure Craft Survey for the Central States Regional Air Planning Association (CENRAP) Study in July 2004 on behalf of Sonoma Technologies, Inc. The project, which was sponsored by CENRAP, was designed to quantify air pollutant emissions from pleasure craft activities in the states of Nebraska, Kansas, Oklahoma, Arkansas, Texas, Iowa, Minnesota, Missouri and Louisiana.

Sonoma Technology, Inc. and PRS collaborated closely on the development of the mail survey instrument (Appendix B) used for this project. PRS was responsible for printing and mailing of the mail survey, the personalized cover letter (Appendix C), four-color state waterway maps as well as for programming of the telephone recruitment screener used by the PRS computer-assisted telephone interviewing (CATI) laboratory.

All project files and an electronic copy of this report can be found on the enclosed CD-Rom in Appendix D.

## Methods

### *A. Sample*

PRS purchased commercially available sample of registered boat owners in the target states from Dunhill International. Altogether 17,454 records of boat owners were loaded into the CATI system, 2,000 randomly drawn records per state. The only exception was Oklahoma, were the total number of available and loaded sample points was 1,454 records. Out of all records, 16,878 records were attempted, and 577 were not attempted, since some state quota cells were filled

without calling all available records. Table 1. shows the number of sample points available per state.

Table 1. Number of loaded sample points per CENRAP state

| STATE | Frequency |
|---|---|
| AR | 2,000 |
| IA | 2,000 |
| KS | 2,000 |
| LA | 2,000 |
| MN | 2,000 |
| MO | 2,000 |
| NE | 2,000 |
| OK | 1,454 |
| TX | 2,000 |
| Total | 17,454 |

### *B. Telephone Recruit and Survey Package Mailing*

Potential participants for the Pleasure Craft Study were recruited over the phone in a brief 10 minute interview (Appendix A).

Respondents were recruited from May 20, 2004 through June 10, 2004. All recruits were conducted by trained PRS CATI laboratory interviewers on weekdays between 5:00 PM and 9:00 PM Central Standard Time. At a respondent's request, PRS also scheduled callback appointments outside of these interviewing hours.

A maximum of four call attempts were made to each sample point and no refusal conversions were used to convince eligible respondents to participate in the study.

Once a respondent agreed to participate, a survey package containing a personalized letter, a pen-and-paper survey, waterway map(s) for the state respondent is using motorized watercraft, a business reply envelope and a safety whistle on a floating lanyard as incentive were mailed.

About two weeks after the initial survey mailing, a reminder postcard was sent to respondents who had not yet returned their surveys.

### *C. Results*

PRS recruited 1,387 respondents for the mail survey, and 979 completed surveys were returned. Table 2 shows the distribution of recruits and returned surveys per state, as well as the respective

percentage of response rate per state. The response rate varied between 67.4% and 77.1% and averaged at a return rate of 70.6%.

Table 2. Number of recruits and completed interviews per state

| STATE | recruited | returned | % |
|---|---|---|---|
| AR | 158 | 111 | 70.3% |
| IA | 153 | 118 | 77.1% |
| KS | 160 | 107 | 66.9% |
| LA | 153 | 105 | 68.6% |
| MN | 160 | 115 | 71.9% |
| MO | 157 | 113 | 72.0% |
| NE | 152 | 110 | 72.4% |
| OK | 135 | 91 | 67.4% |
| TX | 159 | 109 | 68.6% |
| **Totals** | **1387** | **979** | **70.6%** |

# APPENDIX A

# TELEPHONE RECRUIT SCREENER

**CENRAP Boating Study, Project 1031**
Telephone Recruitment Script

**INTRO1**
Hello, my name is <interviewer>, may I speak with <insert fname, lname>?
1. On the phone (skpto INTRO3)
2. No, respondent is coming to the phone (skpto INTRO2)
3. No, respondent is not at home (schedule callback)
4. No such person (skpto TERM1)

**INTRO2**
Hello, my name is <interviewer> and I'm calling on behalf of CENRAP, the Central States Regional Air Planning Association. CENRAP is an organization of states, tribes, federal agencies, and other interested parties that studies and addresses air pollution, regional haze and visibility issues. Your state is participating in CENRAP and as such, you have been randomly selected to participate in an important air quality study. (Skpto INTRO4)

**INTRO3**
Hi, I'm calling on behalf of CENRAP, the Central States Regional Air Planning Association. CENRAP is an organization of states, tribes, federal agencies, and other interested parties that studies and addresses air pollution, regional haze and visibility issues. Your state is participating in CENRAP and as such, you have been randomly selected to participate in this important air quality study.

**INTRO4**
This telephone interview will take only a few minutes and I can assure you that I am not selling anything. We are conducting a study about recreational boating activities and are interested in learning more about how people use their watercrafts. All of your answers will be confidential and not used for any purpose other than this research.

**Q1**
Do you own a motorized sailboat, a personal watercraft such as a Jet-Ski or Waverunner or a power boat?
1. Yes
2. No (skpto TERM1)
8. Don't know/Refused (skpto TERM1)

**Q2**
Do you own more than one watercraft?
1. Yes
2. No (skpto Q5)
8. Don't know/Refused

**Q3**
What types of watercrafts do you own? Do you own… *(multiple choice, click all that apply)*
1. Powerboats
2. Motorized sail boats
3. Personal watercrafts
8. Don't know/Refused

**Q4**
Which of your watercrafts do you use the most?

1. Powerboat
2. Motorized sail boat
3. Personal watercraft
8. Don't know/Refused

**Q5**
Did you use your (primary) watercraft in the past year?

1. Yes
2. No
8. Don't know/Refused (IF answers = 2 skpto TERM1)

**Q6**
In which states did you use your <Insert Answer from Q4 here> in the past year?
*(multiple choice, click all that apply)*

1. Arkansas
2. Iowa
3. Kansas
4. Louisiana
5. Minnesota
6. Missouri
7. Nebraska
8. Oklahoma
9. Texas
10. Don't know/Refused

**Q7**

We would like to invite you to fill out a short paper survey regarding your boating activities with your watercraft you have used most in the past year, the <Insert Answer from Q5 here>. We would mail you the survey with a business reply envelope, and as a Thank-you gift you will also receive a Kwik Tex Safety whistle with floating Lanyard for your watercraft keys. May I have your address to send you the brief mail survey?

1. Yes
2. No, not interested (skpto TERM1)
3. Not sure (call back)

**Q8**

What is your mailing address?
Name:
Address:
City: / State: / Zip:

**END1**

Thank you very much for your participation in this important air quality study. You will receive the survey together with a business reply envelope and the boating key chain in the next 1-2 weeks in the mail. Please use the provided return envelope to send us back the filled out survey. You do not have to pay for postage. Do you have any other questions about this?

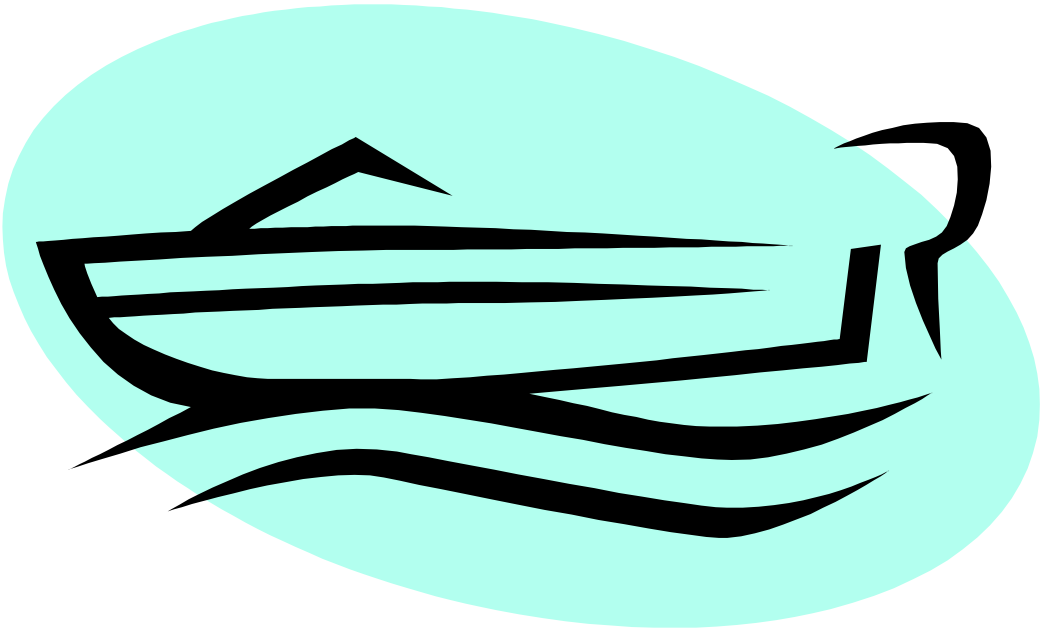
**TERM1**
Then these are all the questions I have for you. Thank you for your time. Good bye.

APPENDIX B

MAIL SURVEY INSTRUMENT

*put sticker w/ boat type here*
*fscid*

# PLEASURE CRAFT SURVEY



**1. Check the one category, which best describes your registered boat.**

- ❑ 1 Sailboat with engine
- ❑ 2 Personal Water Craft (Jetski, Waverunner, etc.)
- ❑ 3 Power boat (bassboat, speedboat, houseboat, etc.)

**2. Which category below describes your primary propulsion engine?**

(*Do not describe any secondary propulsion used for low speed trolling and fishing.)*

- ❑ 1 Two-Stroke Gasoline Engine (requires gasoline and oil fuel mixture)
- ❑ 2 Four-Stroke Gasoline Engine (has an oil sump and dipstick)
- ❑ 3 Diesel (either 2 or 4 Stroke; requires diesel fuel)

**3. Which one of the following is the primary propulsion type for your boat?**
*(Include auxiliary motors for sailboats, but do not include secondary motors for low speed trolling or fishing.)*

- ❑ 1 Outboard
- ❑ 2 Inboard
- ❑ 3 Personal Water Craft Jet (Jetski engine, Waverunner engine, etc.)
- ❑ 4 Other (please specify): _____

**4. What is the horsepower for this boat's primary engine?**
*(If unsure, you might want to check the specifications in the owner's manual. Otherwise, give your best estimate.)*

_____ hp

**5. What year was your engine manufactured?**
*(If unsure, you might want to find the model year in the owner's manual.)*

_____A (enter year)

- ❑ 1 Not sure, but probably before 1997
- ❑ 2 Not sure, but probably 1997 or later
- ❑ 3 Don't know

**6a.** **Typically, how often do you use your boat during the following seasons?**
*(Please choose the answer that best matches your boat usage.)*

**Winter (Dec - Feb):**

- ❑ 1` Practically never
- ❑ 2 1 time per week or less
- ❑ 3 2-3 times per week
- ❑ 4 4-5 times per week
- ❑ 5 6 times per week
- ❑ 6 Practically every day

**Spring (Mar – May):**

- ❑ 7 Practically never
- ❑ 8 1 time per week or less
- ❑ 9 2-3 times per week
- ❑ 10 4-5 times per week
- ❑ 11 6 times per week
- ❑ 12 Practically every day

**6b.** **Summer (Jun - Aug):**

- ❑ 1` Practically never
- ❑ 2 1 time per week or less
- ❑ 3 2-3 times per week
- ❑ 4 4-5 times per week
- ❑ 5 6 times per week
- ❑ 6 Practically every day

**Fall (Sep – Nov):**

- ❑ 7 Practically never
- ❑ 8 1 time per week or less
- ❑ 9 2-3 times per week
- ❑ 10 4-5 times per week
- ❑ 11 6 times per week
- ❑ 12 Practically every day

**7.** **How often did you use your boat <u>during the past week</u>?**

- ❑ 1` Never
- ❑ 2 1 time
- ❑ 3 2 times
- ❑ 4 3 times
- ❑ 5 4 or more times

**8a.** **During each of the following seasons, what percentage of your boat trips occur on weekdays vs. weekends?**
*(Please choose the answer that best matches your boat usage.)*

**Winter (Dec - Feb):**

| | Weekday | Weekend |
|---|---|---|
| ❑ 1 | 0% | 100% |
| ❑ 2 | 25% | 75% |
| ❑ 3 | 50% | 50% |
| ❑ 4 | 75% | 25% |
| ❑ 5 | 100% | 0% |

**Spring (Mar – May):**

| | Weekday | Weekend |
|---|---|---|
| ❑ 6 | 0% | 100% |
| ❑ 7 | 25% | 75% |
| ❑ 8 | 50% | 50% |
| ❑ 9 | 75% | 25% |
| ❑ 10 | 100% | 0% |

**8b.** **Summer (Jun - Aug):**

| | Weekday | Weekend |
|---|---|---|
| ❑ 1 | 0% | 100% |
| ❑ 2 | 25% | 75% |
| ❑ 3 | 50% | 50% |
| ❑ 4 | 75% | 25% |
| ❑ 5 | 100% | 0% |

**Fall (Sep – Nov):**

| | Weekday | Weekend |
|---|---|---|
| ❑ 6 | 0% | 100% |
| ❑ 7 | 25% | 75% |
| ❑ 8 | 50% | 50% |
| ❑ 9 | 75% | 25% |
| ❑ 10 | 100% | 0% |

**9a.** **Typically, how many hours is the engine operating <u>per trip</u> when you use your boat during the following seasons?**
*(Please choose the answer that best matches your boat usage.)*

**Winter (Dec - Feb):**

- ❑ 1` More than 8 hours
- ❑ 2 6 – 8 hours
- ❑ 3 4 – 6 hours
- ❑ 4 2 – 4 hours
- ❑ 5 0 – 2 hours

**Spring (Mar – May):**

- ❑ 6 More than 8 hours
- ❑ 7 6 – 8 hours
- ❑ 8 4 – 6 hours
- ❑ 9 2 – 4 hours
- ❑ 10 0 – 2 hours

**9b.** **Summer (Jun - Aug):**

- ❑ 1` More than 8 hours
- ❑ 2 6 – 8 hours
- ❑ 3 4 – 6 hours
- ❑ 4 2 – 4 hours
- ❑ 5 0 – 2 hours

**Fall (Sep – Nov):**

- ❑ 6 More than 8 hours
- ❑ 7 6 – 8 hours
- ❑ 8 4 – 6 hours
- ❑ 9 2 – 4 hours
- ❑ 10 0 – 2 hours

**10a. At what time do you typically launch your boat during the following seasons?**

**Winter (Dec - Feb):**

- ❑ 1` Before 8:00 AM
- ❑ 2 8:00 AM – 11:00 AM
- ❑ 3 11:00 AM – 1:00 PM
- ❑ 4 1:00 PM – 4:00 PM
- ❑ 5 After 4:00 PM

**Spring (Mar – May):**

- ❑ 6` Before 8:00 AM
- ❑ 7 8:00 AM – 11:00 AM
- ❑ 8 11:00 AM – 1:00 PM
- ❑ 9 1:00 PM – 4:00 PM
- ❑ 10 After 4:00 PM

**10b. Summer (Jun - Aug):**

- ❑ 1` Before 8:00 AM
- ❑ 2 8:00 AM – 11:00 AM
- ❑ 3 11:00 AM – 1:00 PM
- ❑ 4 1:00 PM – 4:00 PM
- ❑ 5 After 4:00 PM

**Fall (Sep – Nov):**

- ❑ 6` Before 8:00 AM
- ❑ 7 8:00 AM – 11:00 AM
- ❑ 8 11:00 AM – 1:00 PM
- ❑ 9 1:00 PM – 4:00 PM
- ❑ 10 After 4:00 PM

11. When your boat engine is in operation, what percentage of time is typically spent at the following power settings? (Please circle an answer for each setting; answers should sum to 100%).

*Example:* 30
+ 60
+ 10 = **100%**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Near Idle/Low Throttle → | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 % | |
| Mid-throttle → | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 % | |
| Full throttle → | | 0 | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 % |
| **Total:** | | | | **100%** (of time when engine is in operation) | | | | | | | | |

**12. Please estimate the amount of fuel you use in your boat <u>each year</u>.**

**Number of gallons purchased:**

- ❑ 1` More than 300 gallons
- ❑ 2 200 – 300 gallons
- ❑ 3 100 – 200 gallons
- ❑ 4 50 – 100 gallons
- ❑ 5 Less than 50 gallons

**13. In which counties do you typically operate your boat? (Use the county codes printed on the enclosed Waterways Map and choose up to three counties.)**

County Code 1: _____

County Code 2: _____

County Code 3: _____

**Thank you for your cooperation.**
**Please use the provided business reply envelope to mail back the survey to**

**Population Research Systems**
**100 Spear St., 17th Floor**
**San Francisco, CA 94105**

**No postage necessary!**

# APPENDIX C

# PERSONALIZED COVER LETTER

Population Research Systems

A Member of the FSC Group

May 2004

«fscid»:

Dear «q8»,

Thank you for agreeing to participate in the Central States Regional Air Planning Association (CENRAP) Pleasure Craft Study. CENRAP is an organization of states, tribes, federal agencies, and other interested parties that studies and addresses air pollution, regional haze and visibility issues. Through your participation, you will help CENRAP learn about factors that affect air quality in your state.

Please complete the enclosed questionnaire about your boat and your boating activities. We have provided a pre-paid business reply envelope to make it simple for you to send back the completed questionnaire. It should only take a few minutes of your time. In appreciation, we are including a safety whistle with floating lanyard for your watercraft keys.

The Central States Regional Air Planning Association has contracted with Population Research Systems (PRS), a research company, to collect this information. Please be assured that your responses and personal information will be kept confidential and will not be used for any purpose other than this study. PRS will combine your responses with hundreds of others and will report only group results, and only to the study sponsors.

If you have any questions about the study, please call Dr. Katrin Ewald of PRS, toll-free at (800) 777-0737. If you are interested in learning more about CENRAP, please visit their website at http://www.cenrap.org.

Thank you once again for participating in this important research.

Sincerely,

Katrin Ewald, Ph.D.
Director

Enclosures:
Waterways Maps

APPENDIX D

WATERWAY MAPS

# Nebraska Waterways

# Nebraska Counties

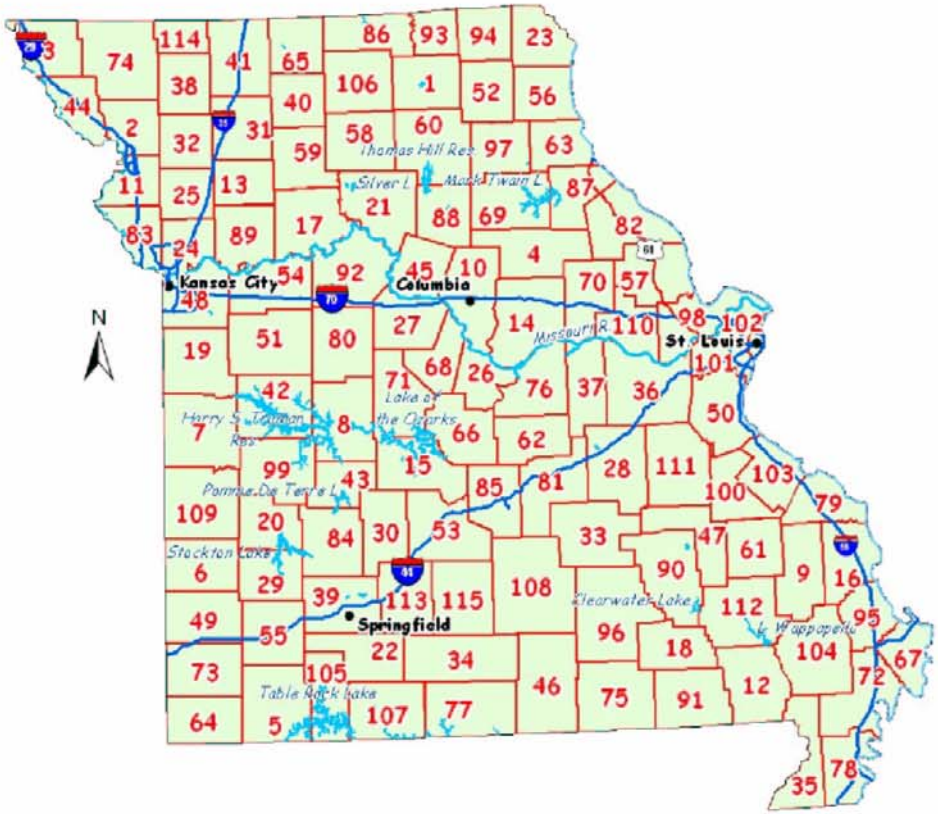
| Number | County Name | Number | County Name | Number | County Name |
|---|---|---|---|---|---|
| 1 | Adams | 32 | Frontier | 63 | Nance |
| 2 | Antelope | 33 | Furnas | 64 | Nemaha |
| 3 | Arthur | 34 | Gage | 65 | Nuckolls |
| 4 | Banner | 35 | Garden | 66 | Otoe |
| 5 | Blaine | 36 | Garfield | 67 | Pawnee |
| 6 | Boone | 37 | Gosper | 68 | Perkins |
| 7 | Box Butte | 38 | Grant | 69 | Phelps |
| 8 | Boyd | 39 | Greeley | 70 | Pierce |
| 9 | Brown | 40 | Hall | 71 | Platte |
| 10 | Buffalo | 41 | Hamilton | 72 | Polk |
| 11 | Burt | 42 | Harlan | 73 | Red Willow |
| 12 | Butler | 43 | Hayes | 74 | Richardson |
| 13 | Cass | 44 | Hitchcock | 75 | Rock |
| 14 | Cedar | 45 | Holt | 76 | Saline |
| 15 | Chase | 46 | Hooker | 77 | Sarpy |
| 16 | Cherry | 47 | Howard | 78 | Saunders |
| 17 | Cheyenne | 48 | Jefferson | 79 | Scotts Bluff |
| 18 | Clay | 49 | Johnson | 80 | Seward |
| 19 | Colfax | 50 | Kearney | 81 | Sheridan |
| 20 | Cuming | 51 | Keith | 82 | Sherman |
| 21 | Custer | 52 | Keya Paha | 83 | Sioux |
| 22 | Dakota | 53 | Kimball | 84 | Stanton |
| 23 | Dawes | 54 | Knox | 85 | Thayer |
| 24 | Dawson | 55 | Lancaster | 86 | Thomas |
| 25 | Deuel | 56 | Lincoln | 87 | Thurston |
| 26 | Dixon | 57 | Logan | 88 | Valley |
| 27 | Dodge | 58 | Loup | 89 | Washington |
| 28 | Douglas | 59 | Madison | 90 | Wayne |
| 29 | Dundy | 60 | McPherson | 91 | Webster |
| 30 | Fillmore | 61 | Merrick | 92 | Wheeler |
| 31 | Franklin | 62 | Morrill | 93 | York |

# Oklahoma Waterways

# Oklahoma Counties

| Number | County Name | Number | County Name | Number | County Name |
|---|---|---|---|---|---|
| 1 | Adair | 27 | Grant | 53 | Nowata |
| 2 | Alfalfa | 28 | Greer | 54 | Okfuskee |
| 3 | Atoka | 29 | Harmon | 55 | Oklahoma |
| 4 | Beaver | 30 | Harper | 56 | Okmulgee |
| 5 | Beckham | 31 | Haskell | 57 | Osage |
| 6 | Blaine | 32 | Hughes | 58 | Ottawa |
| 7 | Bryan | 33 | Jackson | 59 | Pawnee |
| 8 | Caddo | 34 | Jefferson | 60 | Payne |
| 9 | Canadian | 35 | Johnston | 61 | Pittsburg |
| 10 | Carter | 36 | Kay | 62 | Pontotoc |
| 11 | Cherokee | 37 | Kingfisher | 63 | Pottawatomie |
| 12 | Choctaw | 38 | Kiowa | 64 | Pushmataha |
| 13 | Cimarron | 39 | Latimer | 65 | Roger Mills |
| 14 | Cleveland | 40 | Le Flore | 66 | Rogers |
| 15 | Coal | 41 | Lincoln | 67 | Seminole |
| 16 | Comanche | 42 | Logan | 68 | Sequoyah |
| 17 | Cotton | 43 | Love | 69 | Stephens |
| 18 | Craig | 44 | Major | 70 | Texas |
| 19 | Creek | 45 | Marshall | 71 | Tillman |
| 20 | Custer | 46 | Mayes | 72 | Tulsa |
| 21 | Delaware | 47 | McClain | 73 | Wagoner |
| 22 | Dewey | 48 | McCurtain | 74 | Washington |
| 23 | Ellis | 49 | McIntosh | 75 | Washita |
| 24 | Garfield | 50 | Murray | 76 | Woods |
| 25 | Garvin | 51 | Muskogee | 77 | Woodward |
| 26 | Grady | 52 | Noble | | |

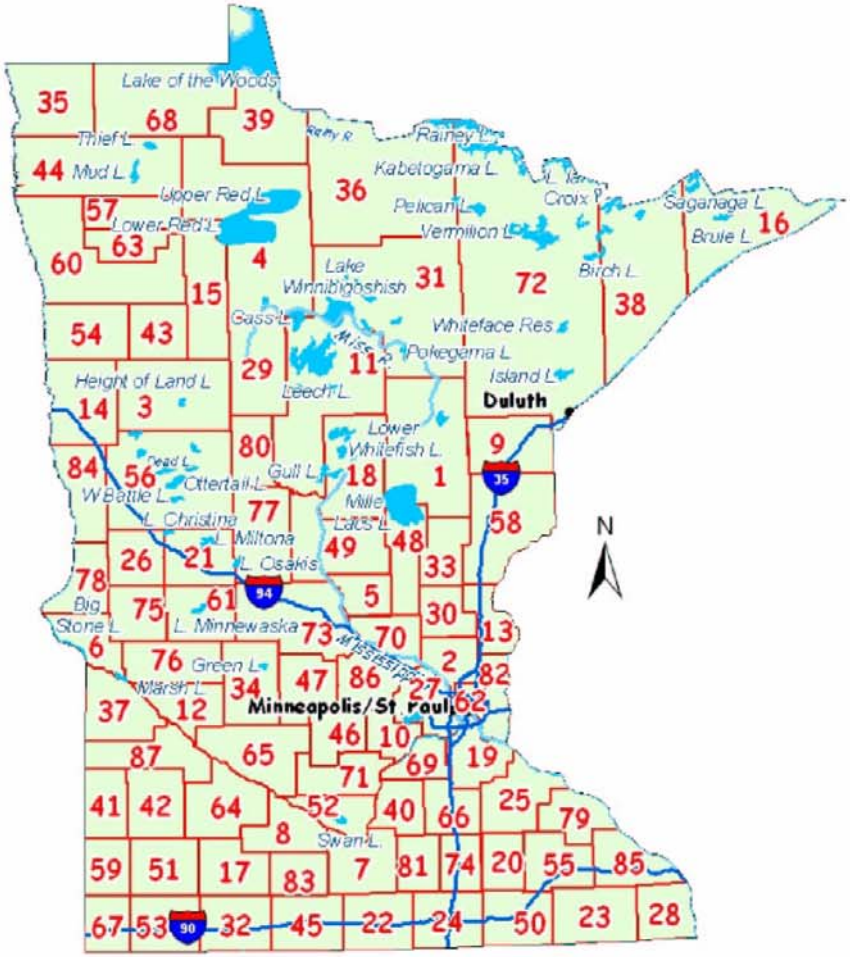
# Missouri Waterways




# Missouri Counties

| Number | County Name | Number | County Name | Number | County Name | Number | County Name |
|---|---|---|---|---|---|---|---|
| 1 | Adair | 30 | Dallas | 59 | Livingston | 88 | Randolph |
| 2 | Andrew | 31 | Daviess | 60 | Macon | 89 | Ray |
| 3 | Atchison | 32 | DeKalb | 61 | Madison | 90 | Reynolds |
| 4 | Audrain | 33 | Dent | 62 | Maries | 91 | Ripley |
| 5 | Barry | 34 | Douglas | 63 | Marion | 92 | Saline |
| 6 | Barton | 35 | Dunklin | 64 | McDonald | 93 | Schuyler |
| 7 | Bates | 36 | Franklin | 65 | Mercer | 94 | Scotland |
| 8 | Benton | 37 | Gasconade | 66 | Miller | 95 | Scott |
| 9 | Bollinger | 38 | Gentry | 67 | Mississippi | 96 | Shannon |
| 10 | Boone | 39 | Greene | 68 | Moniteau | 97 | Shelby |
| 11 | Buchanan | 40 | Grundy | 69 | Monroe | 98 | St. Charles |
| 12 | Butler | 41 | Harrison | 70 | Montgomery | 99 | St. Clair |
| 13 | Caldwell | 42 | Henry | 71 | Morgan | 100 | St. Francois |
| 14 | Callaway | 43 | Hickory | 72 | New Madrid | 101 | St. Louis |
| 15 | Camden | 44 | Holt | 73 | Newton | 102 | St. Louis City |
| 16 | Cape Girardeau | 45 | Howard | 74 | Nodaway | 103 | Ste. Genevieve |
| 17 | Carroll | 46 | Howell | 75 | Oregon | 104 | Stoddard |
| 18 | Carter | 47 | Iron | 76 | Osage | 105 | Stone |
| 19 | Cass | 48 | Jackson | 77 | Ozark | 106 | Sullivan |
| 20 | Cedar | 49 | Jasper | 78 | Pemiscot | 107 | Taney |
| 21 | Chariton | 50 | Jefferson | 79 | Perry | 108 | Texas |
| 22 | Christian | 51 | Johnson | 80 | Pettis | 109 | Vernon |
| 23 | Clark | 52 | Knox | 81 | Phelps | 110 | Warren |
| 24 | Clay | 53 | Laclede | 82 | Pike | 111 | Washington |
| 25 | Clinton | 54 | Lafayette | 83 | Platte | 112 | Wayne |
| 26 | Cole | 55 | Lawrence | 84 | Polk | 113 | Webster |
| 27 | Cooper | 56 | Lewis | 85 | Pulaski | 114 | Worth |
| 28 | Crawford | 57 | Lincoln | 86 | Putnam | 115 | Wright |
| 29 | Dade | 58 | Linn | 87 | Ralls | | |

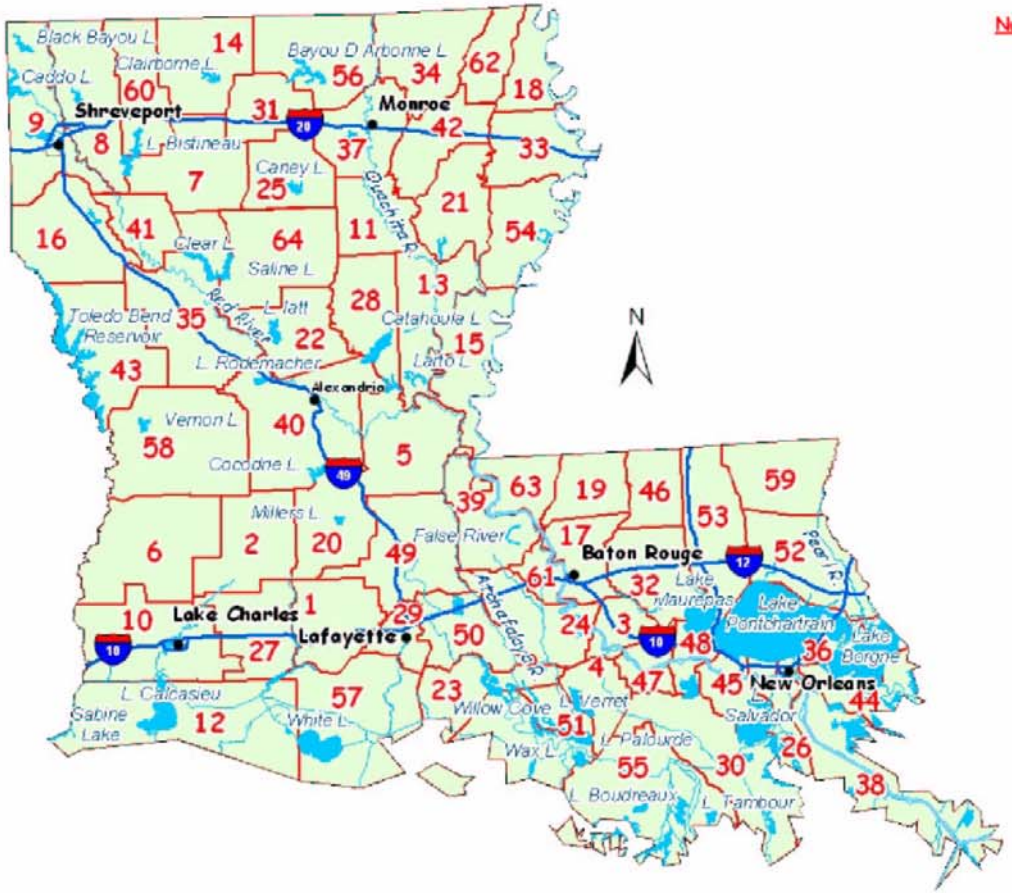
# Minnesota Waterways




# Minnesota Counties

| Number | County Name | Number | County Name | Number | County Name |
|---|---|---|---|---|---|
| 1 | Aitkin | 30 | Isanti | 59 | Pipestone |
| 2 | Anoka | 31 | Itasca | 60 | Polk |
| 3 | Becker | 32 | Jackson | 61 | Pope |
| 4 | Beltrami | 33 | Kanabec | 62 | Ramsey |
| 5 | Benton | 34 | Kandiyohi | 63 | Red Lake |
| 6 | Big Stone | 35 | Kittson | 64 | Redwood |
| 7 | Blue Earth | 36 | Koochiching | 65 | Renville |
| 8 | Brown | 37 | Lac Qui Parle | 66 | Rice |
| 9 | Carlton | 38 | Lake | 67 | Rock |
| 10 | Carver | 39 | Lake of the Woods | 68 | Roseau |
| 11 | Cass | 40 | Le Sueur | 69 | Scott |
| 12 | Chippewa | 41 | Lincoln | 70 | Sherburne |
| 13 | Chisago | 42 | Lyon | 71 | Sibley |
| 14 | Clay | 43 | Mahnomen | 72 | St. Louis |
| 15 | Clearwater | 44 | Marshall | 73 | Stearns |
| 16 | Cook | 45 | Martin | 74 | Steele |
| 17 | Cottonwood | 46 | McLeod | 75 | Stevens |
| 18 | Crow Wing | 47 | Meeker | 76 | Swift |
| 19 | Dakota | 48 | Mille Lacs | 77 | Todd |
| 20 | Dodge | 49 | Morrison | 78 | Traverse |
| 21 | Douglas | 50 | Mower | 79 | Wabasha |
| 22 | Faribault | 51 | Murray | 80 | Wadena |
| 23 | Fillmore | 52 | Nicollet | 81 | Waseca |
| 24 | Freeborn | 53 | Nobles | 82 | Washington |
| 25 | Goodhue | 54 | Norman | 83 | Watonwan |
| 26 | Grant | 55 | Olmsted | 84 | Wilkin |
| 27 | Hennepin | 56 | Otter Tail | 85 | Winona |
| 28 | Houston | 57 | Pennington | 86 | Wright |
| 29 | Hubbard | 58 | Pine | 87 | Yellow Medicine |

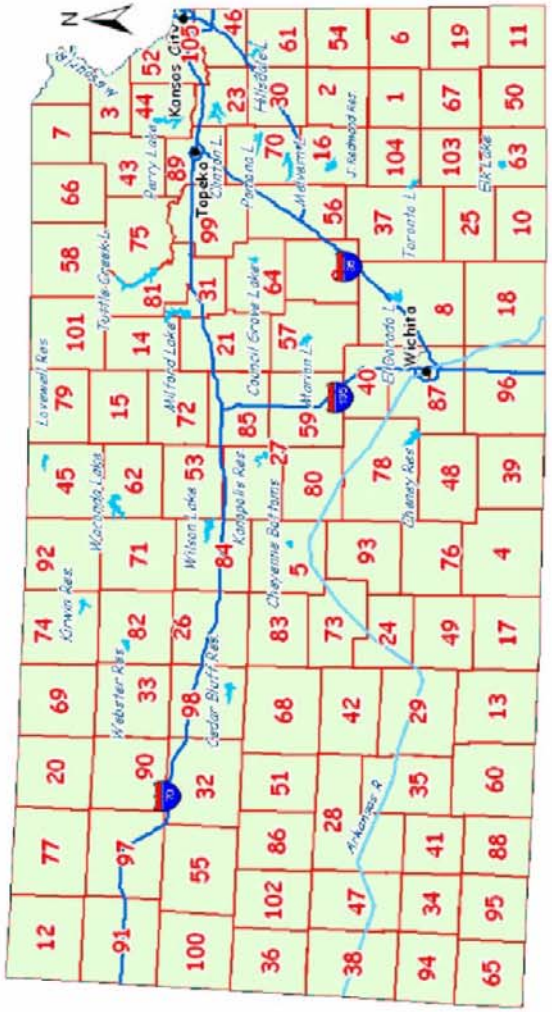
# Louisiana Waterways




# Louisiana Parishes

| Number | County Name | Number | County Name | Number | County Name |
|---|---|---|---|---|---|
| 1 | Acadia | 22 | Grant | 43 | Sabine |
| 2 | Allen | 23 | Iberia | 44 | St. Bernard |
| 3 | Ascension | 24 | Iberville | 45 | St. Charles |
| 4 | Assumption | 25 | Jackson | 46 | St. Helena |
| 5 | Avoyelles | 26 | Jefferson | 47 | St. James |
| 6 | Beauregard | 27 | Jefferson Davis | 48 | St. John the Baptist |
| 7 | Bienville | 28 | La Salle | 49 | St. Landry |
| 8 | Bossier | 29 | Lafayette | 50 | St. Martin |
| 9 | Caddo | 30 | LaFourche | 51 | St. Mary |
| 10 | Calcasieu | 31 | Lincoln | 52 | St. Tammany |
| 11 | Caldwell | 32 | Livingston | 53 | Tangipahoa |
| 12 | Cameron | 33 | Madison | 54 | Tensas |
| 13 | Catahoula | 34 | Morehouse | 55 | Terrebonne |
| 14 | Claiborne | 35 | Natchitoches | 56 | Union |
| 15 | Concordia | 36 | Orleans | 57 | Vermilion |
| 16 | De Soto | 37 | Ouachita | 58 | Vernon |
| 17 | East Baton Rouge | 38 | Plaquemines | 59 | Washington |
| 18 | East Carroll | 39 | Pointe Coupee | 60 | Webster |
| 19 | East Feliciana | 40 | Rapides | 61 | West Baton Rouge |
| 20 | Evangeline | 41 | Red River | 62 | West Carroll |
| 21 | Franklin | 42 | Richland | 63 | West Feliciana |
| | | | | 64 | Winn |

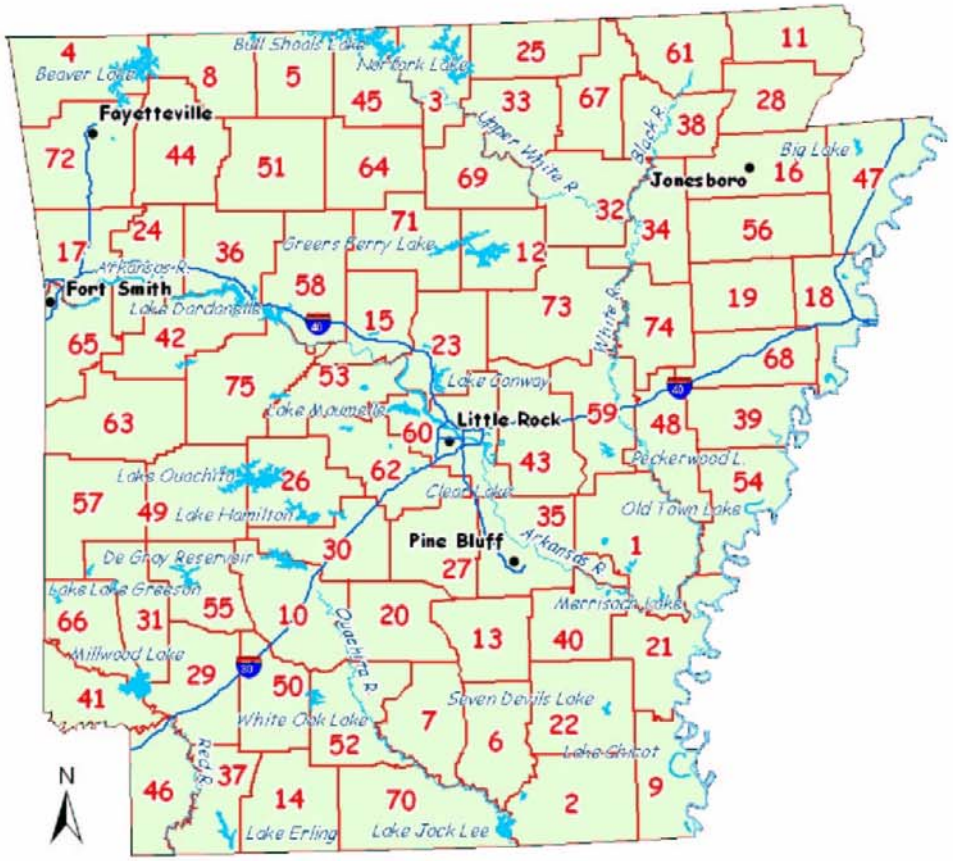
# Kansas Waterways




# Kansas Counties

| Number | County Name | Number | County Name | Number | County Name | Number | County Name |
|---|---|---|---|---|---|---|---|
| 1 | Allen | 27 | Ellsworth | 53 | Lincoln | 79 | Republic |
| 2 | Anderson | 28 | Finney | 54 | Linn | 80 | Rice |
| 3 | Atchison | 29 | Ford | 55 | Logan | 81 | Riley |
| 4 | Barber | 30 | Franklin | 56 | Lyon | 82 | Rooks |
| 5 | Barton | 31 | Geary | 57 | Marion | 83 | Rush |
| 6 | Bourbon | 32 | Gove | 58 | Marshall | 84 | Russell |
| 7 | Brown | 33 | Graham | 59 | McPherson | 85 | Saline |
| 8 | Butler | 34 | Grant | 60 | Meade | 86 | Scott |
| 9 | Chase | 35 | Gray | 61 | Miami | 87 | Sedgwick |
| 10 | Chautauqua | 36 | Greeley | 62 | Mitchell | 88 | Seward |
| 11 | Cherokee | 37 | Greenwood | 63 | Montgomery | 89 | Shawnee |
| 12 | Cheyenne | 38 | Hamilton | 64 | Morris | 90 | Sheridan |
| 13 | Clark | 39 | Harper | 65 | Morton | 91 | Sherman |
| 14 | Clay | 40 | Harvey | 66 | Nemaha | 92 | Smith |
| 15 | Cloud | 41 | Haskell | 67 | Neosho | 93 | Stafford |
| 16 | Coffey | 42 | Hodgeman | 68 | Ness | 94 | Stanton |
| 17 | Comanche | 43 | Jackson | 69 | Norton | 95 | Stevens |
| 18 | Cowley | 44 | Jefferson | 70 | Osage | 96 | Sumner |
| 19 | Crawford | 45 | Jewell | 71 | Osborne | 97 | Thomas |
| 20 | Decatur | 46 | Johnson | 72 | Ottawa | 98 | Trego |
| 21 | Dickinson | 47 | Kearny | 73 | Pawnee | 99 | Wabaunsee |
| 22 | Doniphan | 48 | Kingman | 74 | Phillips | 100 | Wallace |
| 23 | Douglas | 49 | Kiowa | 75 | Pottawatomie | 101 | Washington |
| 24 | Edwards | 50 | Labette | 76 | Pratt | 102 | Wichita |
| 25 | Elk | 51 | Lane | 77 | Rawlins | 103 | Wilson |
| 26 | Ellis | 52 | Leavenworth | 78 | Reno | 104 | Woodson |
| | | | | | | 105 | Wyandotte |

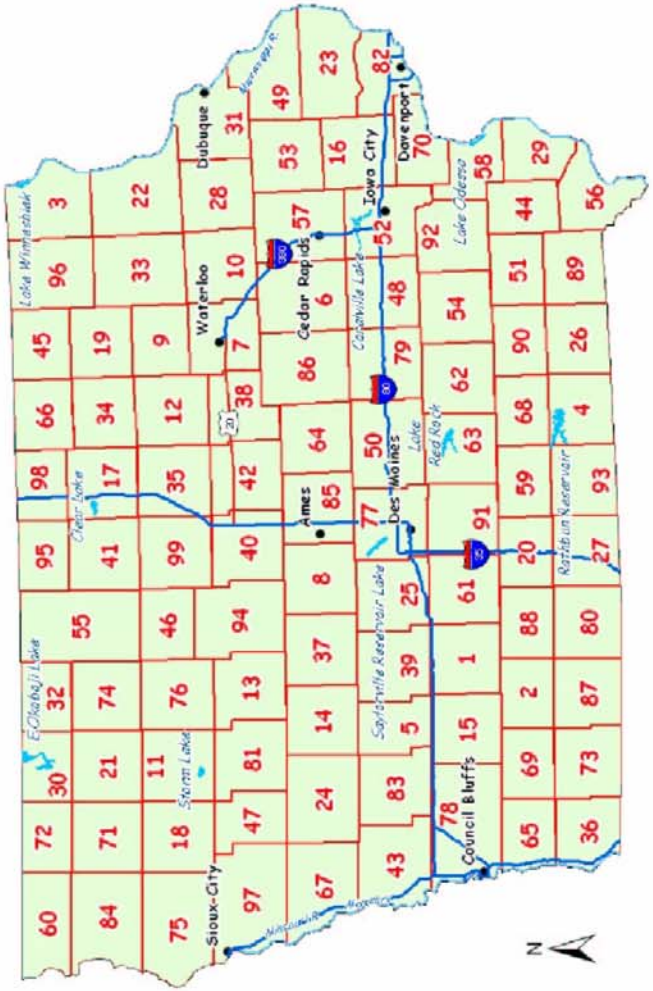
# Arkansas Waterways




# Arkansas Counties

| Number | County Name | Number | County Name | Number | County Name |
|---|---|---|---|---|---|
| 1 | Arkansas | 26 | Garland | 51 | Newton |
| 2 | Ashley | 27 | Grant | 52 | Ouachita |
| 3 | Baxter | 28 | Greene | 53 | Perry |
| 4 | Benton | 29 | Hempstead | 54 | Phillips |
| 5 | Boone | 30 | Hot Spring | 55 | Pike |
| 6 | Bradley | 31 | Howard | 56 | Poinsett |
| 7 | Calhoun | 32 | Independence | 57 | Polk |
| 8 | Carroll | 33 | Izard | 58 | Pope |
| 9 | Chicot | 34 | Jackson | 59 | Prairie |
| 10 | Clark | 35 | Jefferson | 60 | Pulaski |
| 11 | Clay | 36 | Johnson | 61 | Randolph |
| 12 | Cleburne | 37 | Lafayette | 62 | Saline |
| 13 | Cleveland | 38 | Lawrence | 63 | Scott |
| 14 | Columbia | 39 | Lee | 64 | Searcy |
| 15 | Conway | 40 | Lincoln | 65 | Sebastian |
| 16 | Craighead | 41 | Little River | 66 | Sevier |
| 17 | Crawford | 42 | Logan | 67 | Sharp |
| 18 | Crittenden | 43 | Lonoke | 68 | St. Francis |
| 19 | Cross | 44 | Madison | 69 | Stone |
| 20 | Dallas | 45 | Marion | 70 | Union |
| 21 | Desha | 46 | Miller | 71 | Van Buren |
| 22 | Drew | 47 | Mississippi | 72 | Washington |
| 23 | Faulkner | 48 | Monroe | 73 | White |
| 24 | Franklin | 49 | Montgomery | 74 | Woodruff |
| 25 | Fulton | 50 | Nevada | 75 | Yell |

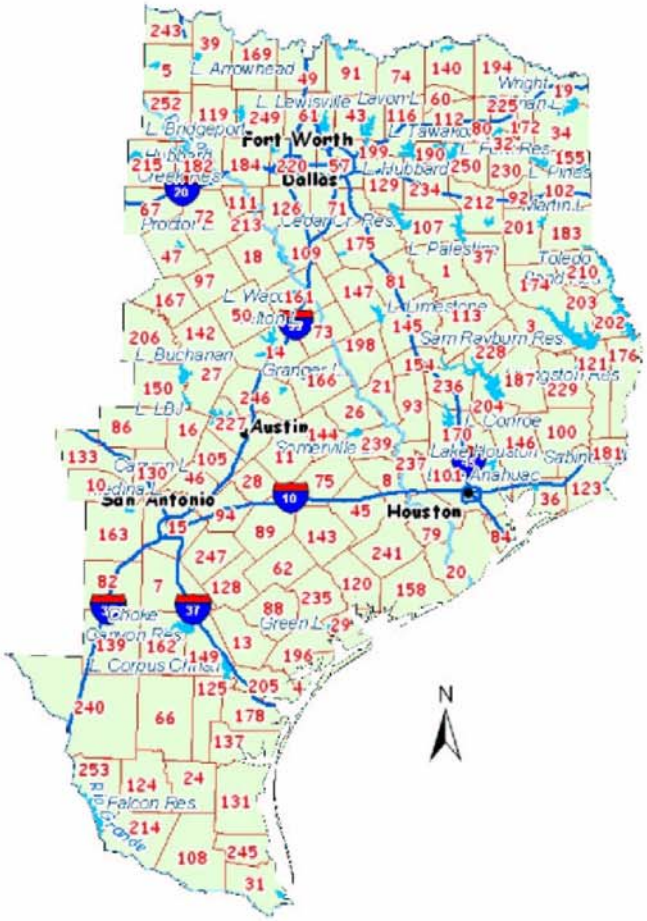
# Iowa Waterways




# Iowa Counties

| Number | County Name | Number | County Name | Number | County Name | Number | County Name |
|---|---|---|---|---|---|---|---|
| 1 | Adair | 26 | Davis | 51 | Jefferson | 76 | Pocahontas |
| 2 | Adams | 27 | Decatur | 52 | Johnson | 77 | Polk |
| 3 | Allamakee | 28 | Delaware | 53 | Jones | 78 | Pottawattamie |
| 4 | Appanoose | 29 | Des Moines | 54 | Keokuk | 79 | Poweshiek |
| 5 | Audubon | 30 | Dickinson | 55 | Kossuth | 80 | Ringgold |
| 6 | Benton | 31 | Dubuque | 56 | Lee | 81 | Sac |
| 7 | Black Hawk | 32 | Emmet | 57 | Linn | 82 | Scott |
| 8 | Boone | 33 | Fayette | 58 | Louisa | 83 | Shelby |
| 9 | Bremer | 34 | Floyd | 59 | Lucas | 84 | Sioux |
| 10 | Buchanan | 35 | Franklin | 60 | Lyon | 85 | Story |
| 11 | Buena Vista | 36 | Fremont | 61 | Madison | 86 | Tama |
| 12 | Butler | 37 | Greene | 62 | Mahaska | 87 | Taylor |
| 13 | Calhoun | 38 | Grundy | 63 | Marion | 88 | Union |
| 14 | Carroll | 39 | Guthrie | 64 | Marshall | 89 | Van Buren |
| 15 | Cass | 40 | Hamilton | 65 | Mills | 90 | Wapello |
| 16 | Cedar | 41 | Hancock | 66 | Mitchell | 91 | Warren |
| 17 | Cerro Gordo | 42 | Hardin | 67 | Monona | 92 | Washington |
| 18 | Cherokee | 43 | Harrison | 68 | Monroe | 93 | Wayne |
| 19 | Chickasaw | 44 | Henry | 69 | Montgomery | 94 | Webster |
| 20 | Clarke | 45 | Howard | 70 | Muscatine | 95 | Winnebago |
| 21 | Clay | 46 | Humboldt | 71 | O'Brien | 96 | Winneshiek |
| 22 | Clayton | 47 | Ida | 72 | Osceola | 97 | Woodbury |
| 23 | Clinton | 48 | Iowa | 73 | Page | 98 | Worth |
| 24 | Crawford | 49 | Jackson | 74 | Palo Alto | 99 | Wright |
| 25 | Dallas | 50 | Jasper | 75 | Plymouth | | |

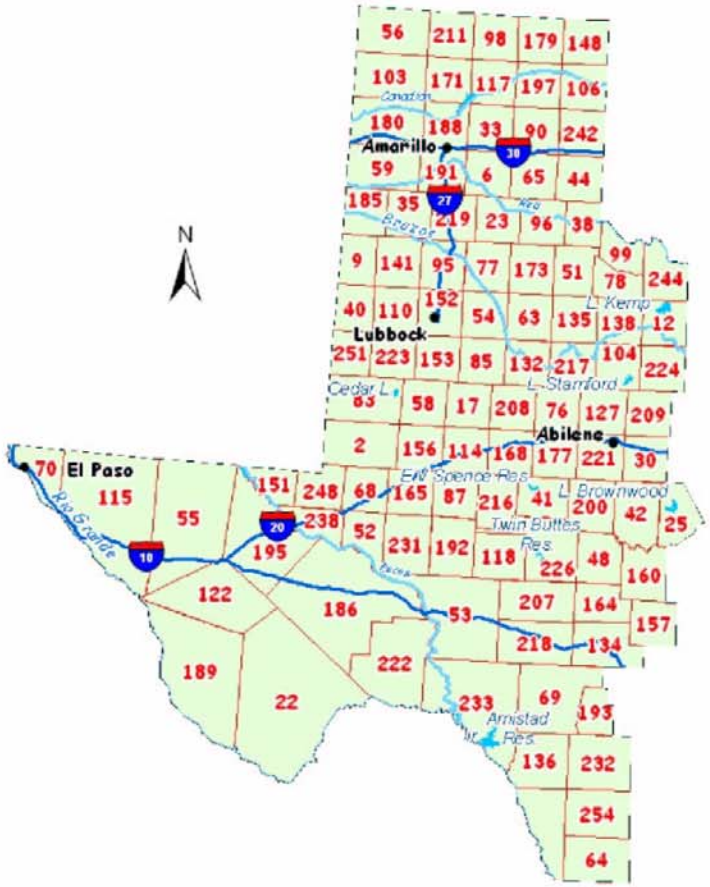
# East Texas Waterways




# East Texas Counties

| Number | County Name | Number | County Name | Number | County Name | Number | County Name | Number | County Name |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Anderson | 47 | Comanche | 105 | Hays | 150 | Llano | 205 | San Patricio |
| 3 | Angelina | 49 | Cooke | 107 | Henderson | 154 | Madison | 206 | San Saba |
| 4 | Aransas | 50 | Coryell | 108 | Hidalgo | 155 | Marion | 210 | Shelby |
| 5 | Archer | 57 | Dallas | 109 | Hill | 158 | Matagorda | 212 | Smith |
| 7 | Atascosa | 60 | Delta | 111 | Hood | 161 | McLennan | 213 | Somervell |
| 8 | Austin | 61 | Denton | 112 | Hopkins | 162 | McMullen | 214 | Starr |
| 10 | Bandera | 62 | DeWitt | 113 | Houston | 163 | Medina | 215 | Stephens |
| 11 | Bastrop | 66 | Duval | 116 | Hunt | 166 | Milam | 220 | Tarrant |
| 13 | Bee | 67 | Eastland | 119 | Jack | 167 | Mills | 225 | Titus |
| 14 | Bell | 71 | Ellis | 120 | Jackson | 169 | Montague | 227 | Travis |
| 15 | Bexar | 72 | Erath | 121 | Jasper | 170 | Montgomery | 228 | Trinity |
| 16 | Blanco | 73 | Falls | 123 | Jefferson | 172 | Morris | 229 | Tyler |
| 18 | Bosque | 74 | Fannin | 124 | Jim Hogg | 174 | Nacogdoches | 230 | Upshur |
| 19 | Bowie | 75 | Fayette | 125 | Jim Wells | 175 | Navarro | 234 | Van Zandt |
| 20 | Brazoria | 79 | Fort Bend | 126 | Johnson | 176 | Newton | 235 | Victoria |
| 21 | Brazos | 80 | Franklin | 128 | Karnes | 178 | Nueces | 236 | Walker |
| 24 | Brooks | 81 | Freestone | 129 | Kaufman | 181 | Orange | 237 | Waller |
| 26 | Burleson | 82 | Frio | 130 | Kendall | 182 | Palo Pinto | 239 | Washington |
| 27 | Burnet | 84 | Galveston | 131 | Kenedy | 183 | Panola | 240 | Webb |
| 28 | Caldwell | 86 | Gillespie | 133 | Kerr | 184 | Parker | 241 | Wharton |
| 29 | Calhoun | 88 | Goliad | 137 | Kleberg | 187 | Polk | 243 | Wichita |
| 31 | Cameron | 89 | Gonzales | 139 | La Salle | 190 | Rains | 245 | Willacy |
| 32 | Camp | 91 | Grayson | 140 | Lamar | 194 | Red River | 246 | Williamson |
| 34 | Cass | 92 | Gregg | 142 | Lampasas | 196 | Refugio | 247 | Wilson |
| 36 | Chambers | 93 | Grimes | 143 | Lavaca | 198 | Robertson | 249 | Wise |
| 37 | Cherokee | 94 | Guadalupe | 144 | Lee | 199 | Rockwall | 250 | Wood |
| 39 | Clay | 97 | Hamilton | 145 | Leon | 201 | Rusk | 252 | Young |
| 43 | Collin | 100 | Hardin | 146 | Liberty | 202 | Sabine | 253 | Zapata |
| 45 | Colorado | 101 | Harris | 147 | Limestone | 203 | San Augustine | | |
| 46 | Comal | 102 | Harrison | 149 | Live Oak | 204 | San Jacinto | | |

# West Texas Waterways




# West Texas Counties

| Number | County Name | Number | County Name | Number | County Name | Number | County Name |
|---|---|---|---|---|---|---|---|
| 2 | Andrews | 65 | Donley | 135 | King | 195 | Reeves |
| 6 | Armstrong | 68 | Ector | 136 | Kinney | 197 | Roberts |
| 9 | Bailey | 69 | Edwards | 138 | Knox | 200 | Runnels |
| 12 | Baylor | 70 | El Paso | 141 | Lamb | 207 | Schleicher |
| 17 | Borden | 76 | Fisher | 148 | Lipscomb | 208 | Scurry |
| 22 | Brewster | 77 | Floyd | 151 | Loving | 209 | Shackelford |
| 23 | Briscoe | 78 | Foard | 152 | Lubbock | 211 | Sherman |
| 25 | Brown | 83 | Gaines | 153 | Lynn | 216 | Sterling |
| 30 | Callahan | 85 | Garza | 156 | Martin | 217 | Stonewall |
| 33 | Carson | 87 | Glasscock | 157 | Mason | 218 | Sutton |
| 35 | Castro | 90 | Gray | 159 | Maverick | 219 | Swisher |
| 38 | Childress | 95 | Hale | 160 | McCulloch | 221 | Taylor |
| 40 | Cochran | 96 | Hall | 164 | Menard | 222 | Terrell |
| 41 | Coke | 98 | Hansford | 165 | Midland | 223 | Terry |
| 42 | Coleman | 99 | Hardeman | 168 | Mitchell | 224 | Throckmorton |
| 44 | Collingsworth | 103 | Hartley | 171 | Moore | 226 | Tom Green |
| 48 | Concho | 104 | Haskell | 173 | Motley | 231 | Upton |
| 51 | Cottle | 106 | Hemphill | 177 | Nolan | 232 | Uvalde |
| 52 | Crane | 110 | Hockley | 179 | Ochiltree | 233 | Val Verde |
| 53 | Crockett | 114 | Howard | 180 | Oldham | 238 | Ward |
| 54 | Crosby | 115 | Hudspeth | 185 | Parmer | 242 | Wheeler |
| 55 | Culberson | 117 | Hutchinson | 186 | Pecos | 244 | Wilbarger |
| 56 | Dallam | 118 | Irion | 188 | Potter | 248 | Winkler |
| 58 | Dawson | 122 | Jeff Davis | 189 | Presidio | 251 | Yoakum |
| 59 | Deaf Smith | 127 | Jones | 191 | Randall | 254 | Zavala |
| 63 | Dickens | 132 | Kent | 192 | Reagan | | |
| 64 | Dimmit | 134 | Kimble | 193 | Real | | |

APPENDIX E

DATA FILES (CD-ROM)

# APPENDIX B

## ANNUAL EMISSIONS BY STATE AND SOURCE CATEGORY FOR THE CENRAP REGION

B-1. Annual emissions (tons) by state and source category for the CENRAP region.



| State | Source Category | $PM_{2.5}$ | CO | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|---|
| Arkansas | On-road Mobile | | | | | | |
| | *Light-Duty* | *235* | *502,991* | *27,137* | *1,383* | *29,752* | *1,971* |
| | *Heavy-Duty* | *2,076* | *102,247* | *90,833* | *2,163* | *9,786* | *313* |
| | Total On-road | 2,311 | 605,238 | 117,970 | 3,545 | 39,537 | 2,284 |
| | Non-road Mobile | | | | | | |
| | *Locomotives* | *624* | *2,759* | *19,831* | *1,690* | *1,099* | *7* |
| | *Commercial Marine* | *198* | *1,796* | *9,341* | *895* | *194* | *4* |
| | *Recreational Boats* | *1,884* | *100,524* | *2,274* | *103* | *31,309* | *8* |
| | *Other Non-road* | *2,415* | *170,860* | *25,852* | *418* | *17,830* | *22* |
| | Total Non-road | 5,121 | 275,939 | 57,298 | 3,107 | 50,432 | 41 |
| | Agricultural Dust | | | | | | |
| | *Animal Feedlots* | *1* | *0* | *0* | *0* | *0* | *0* |
| | *Tilling Operations* | *17,579* | *0* | *0* | *0* | *0* | *0* |
| | Total Ag Dust | 19,937 | 0 | 0 | 0 | 0 | 0 |
| | Arkansas Total | 27,369 | 881,177 | 175,267 | 6,652 | 89,969 | 2,326 |
| Iowa | On-road Mobile | | | | | | |
| | *Light-Duty* | *381* | *973,854* | *53,702* | *2,113* | *67,501* | *2,755* |
| | *Heavy-Duty* | *931* | *30,853* | *44,607* | *884* | *2,993* | *107* |
| | Total On-road | 1,312 | 1,004,707 | 98,308 | 2,997 | 70,494 | 2,863 |
| | Non-road Mobile | | | | | | |
| | *Locomotives* | *905* | *3,992* | *28,705* | *2,447* | *1,575* | *11* |
| | *Commercial Marine* | 65 | 589 | 3,062 | 294 | 64 | 1 |
| | *Recreational Boats* | *1,626* | *88,079* | *2,066* | *92* | *26,310* | *7* |
| | *Other Non-road* | *6,607* | *326,950* | *63,725* | *1,062* | *33,506* | *38* |
| | Total Non-road | 9,203 | 419,610 | 97,558 | 3,895 | 61,455 | 57 |
| | Agricultural Dust | | | | | | |
| | *Animal Feedlots* | *653* | *0* | *0* | *0* | *0* | *0* |
| | *Tilling Operations* | *47,304* | *0* | *0* | *0* | *0* | *0* |
| | Total Ag Dust | 43,694 | 0 | 0 | 0 | 0 | 0 |
| | Iowa Total | 54,209 | 1,424,317 | 195,866 | 6,891 | 131,949 | 2,920 |

B-1. Annual emissions (tons) by state and source category for the CENRAP region.



| State | Source Category | $PM_{2.5}$ | CO | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|---|
| Kansas | On-road Mobile | | | | | | |
| | *Light-Duty* | *345* | *930,039* | *47,210* | *1,938* | *61,867* | *2,528* |
| | *Heavy-Duty* | *855* | *29,686* | *35,520* | *758* | *2,979* | *98* |
| | Total On-road | 1,200 | 959,725 | 82,730 | 2,696 | 64,846 | 2,626 |
| | Non-road Mobile | | | | | | |
| | *Locomotives* | *1,164* | *5,147* | *37,022* | *3,157* | *2,035* | *15* |
| | *Commercial Marine* | *1* | *6* | *32* | *3* | *1* | *0* |
| | *Recreational Boats* | *345* | *21,962* | *660* | *24* | *6,515* | *2* |
| | *Other Non-road* | *4,665* | *244,673* | *47,382* | *716* | *19,381* | *98* |
| | Total Non-road | 6,175 | 271,788 | 85,096 | 3,900 | 27,931 | 115 |
| | Agricultural Dust | | | | | | |
| | *Animal Feedlots* | *2,778* | *0* | *0* | *0* | *0* | *0* |
| | *Tilling Operations* | *50,769* | *0* | *0* | *0* | *0* | *0* |
| | Total Ag Dust | 58,964 | 0 | 0 | 0 | 0 | 0 |
| | Kansas Total | 66,340 | 1,231,513 | 167,825 | 6,595 | 92,777 | 2,740 |
| Louisiana | On-road Mobile | | | | | | |
| | *Light-Duty* | *416* | *824,585* | *45,929* | *2,396* | *57,283* | *3,485* |
| | *Heavy-Duty* | *2,272* | *74,770* | *105,449* | *2,257* | *7,361* | *263* |
| | Total On-road | 2,689 | 899,355 | 151,378 | 4,653 | 64,643 | 3,748 |
| | Non-road Mobile | | | | | | |
| | *Locomotives* | *370* | *1,638* | *11,787* | *1,003* | *658* | *4* |
| | *Commercial Marine* | *1,914* | *9,631* | *69,345* | *12,450* | *1,739* | *14* |
| | *Recreational Boats* | *4,895* | *259,196* | *5,746* | *267* | *80,803* | *21* |
| | *Other Non-road* | *2,579* | *275,361* | *29,650* | *536* | *26,173* | *525* |
| | Total Non-road | 9,757 | 545,825 | 116,528 | 14,256 | 109,373 | 563 |
| | Agricultural Dust | | | | | | |
| | *Animal Feedlots* | *2* | *0* | *0* | *0* | *0* | *0* |
| | *Tilling Operations* | *8,489* | *0* | *0* | *0* | *0* | *0* |
| | Total Ag Dust | 9,542 | 0 | 0 | 0 | 0 | 0 |
| | Louisiana Total | 21,987 | 1,445,180 | 267,906 | 18,908 | 174,016 | 4,311 |

B-1. Annual emissions (tons) by state and source category for the CENRAP region.



| State | Source Category | $PM_{2.5}$ | CO | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|---|
| Minnesota | On-road Mobile | | | | | | |
| | *Light-Duty* | *595* | *1,285,076* | *73,656* | *1,274* | *75,663* | *4,771* |
| | *Heavy-Duty* | *1,577* | *43,160* | *65,290* | *1,314* | *5,255* | *182* |
| | Total On-road | 2,172 | 1,328,236 | 138,946 | 2,588 | 80,918 | 4,954 |
| | Non-road Mobile | | | | | | |
| | *Locomotives* | *693* | *3,053* | *21,947* | *1,873* | *1,179* | *9* |
| | *Commercial Marine* | *116* | *703* | *4,355* | *714* | *122* | *2* |
| | *Recreational Boats* | *5,886* | *319,514* | *7,659* | *142* | *95,409* | *26* |
| | *Other Non-road* | *7,979* | *640,351* | *65,365* | *1,052* | *116,847* | *59* |
| | Total Non-road | 14,673 | 963,621 | 99,327 | 3,781 | 213,557 | 96 |
| | Agricultural Dust | | | | | | |
| | *Animal Feedlots* | *43* | *0* | *0* | *0* | *0* | *0* |
| | *Tilling Operations* | *43,013* | *0* | *0* | *0* | *0* | *0* |
| | Total Ag Dust | 42,307 | 0 | 0 | 0 | 0 | 0 |
| | Minnesota Total | 59,152 | 2,291,857 | 238,272 | 6,369 | 294,474 | 5,049 |
| Missouri | On-road Mobile | | | | | | |
| | *Light-Duty* | *680* | *1,375,126* | *77,916* | *3,120* | *76,004* | *5,356* |
| | *Heavy-Duty* | *1,841* | *52,065* | *79,607* | *1,787* | *5,491* | *209* |
| | Total On-road | 2,521 | 1,427,190 | 157,523 | 4,907 | 81,495 | 5,565 |
| | Non-road Mobile | | | | | | |
| | *Locomotives* | *953* | *4,215* | *30,308* | *2,582* | *1,658* | *12* |
| | *Commercial Marine* | *247* | *2,057* | *11,937* | *1,177* | *329* | *5* |
| | *Recreational Boats* | *5,943* | *303,079* | *6,251* | *308* | *92,318* | *24* |
| | *Other Non-road* | *4,895* | *466,845* | *51,328* | *909* | *35,664* | *33* |
| | Total Non-road | 12,038 | 776,195 | 99,823 | 4,976 | 129,969 | 74 |
| | Agricultural Dust | | | | | | |
| | *Animal Feedlots* | *18* | *0* | *0* | *0* | *0* | *0* |
| | *Tilling Operations* | *20,905* | *0* | *0* | *0* | *0* | *0* |
| | Total Ag Dust | 28,652 | 0 | 0 | 0 | 0 | 0 |
| | Missouri Total | 43,210 | 2,203,386 | 257,347 | 9,883 | 211,464 | 5,639 |

B-1. Annual emissions (tons) by state and source category for the CENRAP region.



| State | Source Category | $PM_{2.5}$ | CO | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|---|
| Nebraska | On-road Mobile | | | | | | |
| | *Light-Duty* | *246* | *581,402* | *30,649* | *1,229* | *38,788* | *1,581* |
| | *Heavy-Duty* | *624* | *18,626* | *25,037* | *589* | *2,115* | *71* |
| | Total On-road | 870 | 600,028 | 55,685 | 1,819 | 40,902 | 1,652 |
| | Non-road Mobile | | | | | | |
| | *Locomotives* | *2,617* | *11,559* | *83,121* | *7,085* | *4,543* | *34* |
| | *Commercial Marine* | *1* | *6* | *31* | *3* | *1* | *0* |
| | *Recreational Boats* | *479* | *26,282* | *648* | *28* | *7,971* | *2* |
| | *Other Non-road* | *3,644* | *161,977* | *35,556* | *582* | *13,650* | *23* |
| | Total Non-road | 6,740 | 199,824 | 119,355 | 7,697 | 26,165 | 59 |
| | Agricultural Dust | | | | | | |
| | *Animal Feedlots* | *1,312* | *0* | *0* | *0* | *0* | *0* |
| | *Tilling Operations* | *27,770* | *0* | *0* | *0* | *0* | *0* |
| | Total Ag Dust | 32,761 | 0 | 0 | 0 | 0 | 0 |
| | Nebraska Total | 40,371 | 799,852 | 175,041 | 9,516 | 67,067 | 1,711 |
| Oklahoma | On-road Mobile | | | | | | |
| | *Light-Duty* | *509* | *1,194,649* | *64,504* | *2,989* | *81,676* | *3,968* |
| | *Heavy-Duty* | *1,331* | *48,382* | *54,812* | *1,265* | *5,062* | *154* |
| | Total On-road | 1,840 | 1,243,032 | 119,317 | 4,253 | 86,738 | 4,122 |
| | Non-road Mobile | | | | | | |
| | *Locomotives* | *645* | *2,853* | *20,505* | *1,750* | *1,116* | *8* |
| | *Commercial Marine* | *11* | *98* | *509* | *49* | *11* | *0* |
| | *Recreational Boats* | *1,708* | *95,314* | *2,330* | *100* | *29,590* | *7* |
| | *Other Non-road* | *2,543* | *230,294* | *27,563* | *460* | *18,846* | *265* |
| | Total Non-road | 4,907 | 328,559 | 50,906 | 2,359 | 49,562 | 280 |
| | Agricultural Dust | | | | | | |
| | *Animal Feedlots* | *512* | *0* | *0* | *0* | *0* | *0* |
| | *Tilling Operations* | *20,033* | *0* | *0* | *0* | *0* | *0* |
| | Total Ag Dust | 21,702 | 0 | 0 | 0 | 0 | 0 |
| | Oklahoma Total | 28,449 | 1,571,590 | 170,223 | 6,612 | 136,300 | 4,402 |

B-1. Annual emissions (tons) by state and source category for the CENRAP region.



| State | Source Category | $PM_{2.5}$ | CO | $NO_x$ | $SO_2$ | VOC | $NH_3$ |
|---|---|---|---|---|---|---|---|
| Texas | On-road Mobile | | | | | | |
| | *Light-Duty* | *2,339* | *3,653,523* | *220,819* | *10,555* | *248,680* | *19,365* |
| | *Heavy-Duty* | *6,276* | *113,949* | *340,992* | *6,667* | *14,057* | *692* |
| | Total On-road | 8,615 | 3,767,472 | 561,811 | 17,222 | 262,737 | 20,057 |
| | Non-road Mobile | | | | | | |
| | *Locomotives* | *2,148* | *9,488* | *68,236* | *5,816* | *3,753* | *26* |
| | *Commercial Marine* | *1,212* | *3,495* | *25,310* | *10,092* | *723* | *6* |
| | *Recreational Boats* | *5,960* | *334,464* | *8,043* | *350* | *104,461* | *26* |
| | *Other Non-road* | *11,241* | *1,440,533* | *131,009* | *2,271* | *106,881* | *1,444* |
| | Total Non-road | 20,561 | 1,787,980 | 232,597 | 18,529 | 215,819 | 1,502 |
| | Agricultural Dust | | | | | | |
| | *Animal Feedlots* | *2,374* | *0* | *0* | *0* | *0* | *0* |
| | *Tilling Operations* | *33,484* | *0* | *0* | *0* | *0* | *0* |
| | Total Ag Dust | 37,012 | 0 | 0 | 0 | 0 | 0 |
| | Texas Total | 66,188 | 5,555,452 | 794,408 | 35,750 | 478,555 | 21,559 |
| All States | All Sources | 389,473 | 17,404,324 | 2,442,155 | 107,177 | 1,676,572 | 50,657 |

# APPENDIX C

## SUMMARIES OF ACTIVITY DATA AND EMISSIONS MODELING INPUTS PREPARED FOR ON-ROAD EMISISON INVENTORIES:

## VEHICLE-MILES OF TRAVEL,
## FLEET DISTRIBUTIONS,
## FUELS CHARACTERISTICS,
## AND
## REGULATORY CONTROLS

Pages C-3 through C-14 (12 pages) illustrate vehicle-miles of travel (VMT) compiled for each CENRAP state. One- to two-page data summary sheets were prepared for each state. Each data summary sheet includes the following elements of information. (The page position of each element is indicated relative to landscape orientation.)

Element of Information (Page Position)

- Sources of information—i.e., specific state agencies or “default”, which indicates EPA guidance defaults (page header)
- CENRAP overview map identifying location of the state of interest (upper left)
- State overview map with interstate freeways (upper center)
- County-specific total annual VMT for 2002 (upper right)
- Distribution of total annual VMT by road type (lower left)
- Distribution of total annual VMT by vehicle type (lower center)
- Average speed by road type (most states: center right; Texas and Louisiana: lower right)
- Weekday diurnal pattern of VMT (most states: lower right; Texas, Louisiana, and St. Louis, Missouri, area: second page of data summary sheet for each state)

Box whisker plots were prepared as follows. The box centerline indicates the median, and the box extents represent the 25$^{th}$ and 75$^{th}$ percentiles with "outliers" plotted above the whiskers.

The whiskers have a maximum length equal to 1.5 times the length of the box (interquartile range). If there are data outside this range, the points are shown on the plot and the whisker ends on the highest or lowest data point within the range of the whisker. The outliers are further identified with asterisks representing the points that fall within 3 times the interquartile range from the end of the box and with squares representing points beyond this range.

Pages C-15 through C-18 (4 pages) illustrate the inputs that were compiled for MOBILE6 and NONROAD 2004 to describe fuel characteristics (such as sulfur content) for areas throughout the CENRAP.

Pages C-19 through C-21 (3 pages) illustrate the inputs that were compiled for MOBILE6 to describe regulatory programs (such as inspection and maintenance, or I/M) for areas throughout the CENRAP.

Pages C-22 through C-24 (3 pages) illustrate the inputs that were compiled for MOBILE6 to describe the IM 240 program of St. Louis, Missouri.

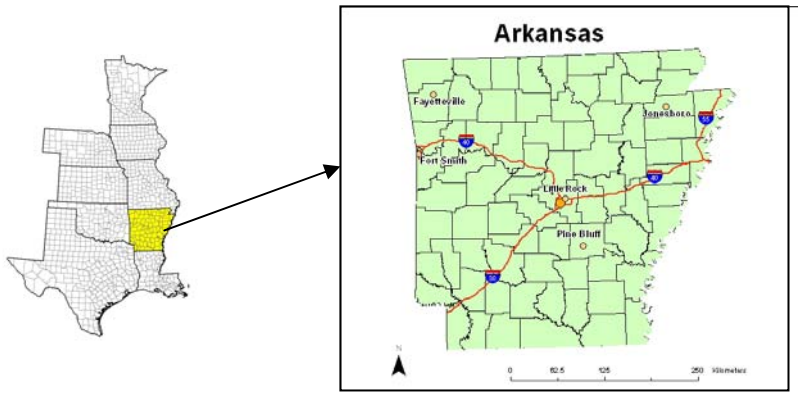
Pages C-25 through C-32 (8 pages) illustrate the MOBILE6 default age distribution of the vehicle fleet (for comparison purposes) and the weighted-average age distribution of the vehicle fleets for each of the CENRAP states. The weighted averages were calculated as the averages of county-level age distributions, weighted by the number of vehicles in each county. Thus, counties with more registered vehicles were weighted proportionally more heavily.

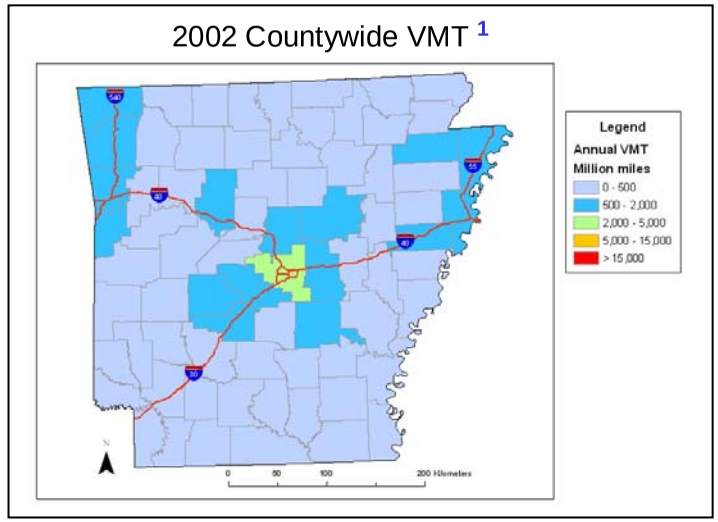
Pages C-33 through C-35 (3 pages) illustrate the fractions of the light-duty vehicle and light-duty truck fleets that are diesel-powered.

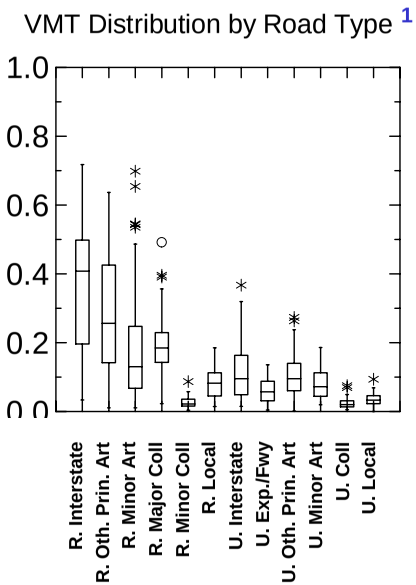
**Data Summary Sheet: Arkansas**

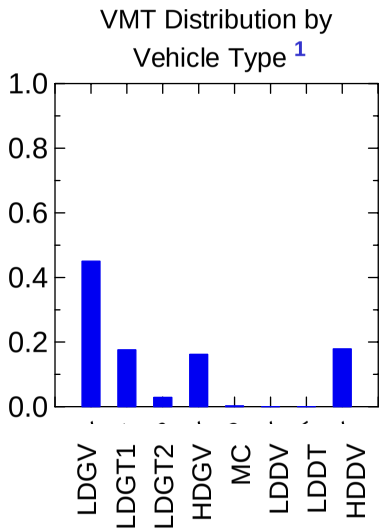
**Data Source: [1] Arkansas Dept. of Transportation & Highways**

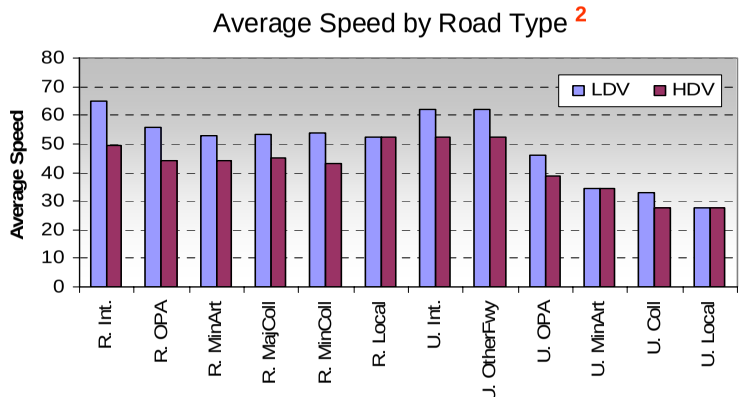
**[2] Default Data**

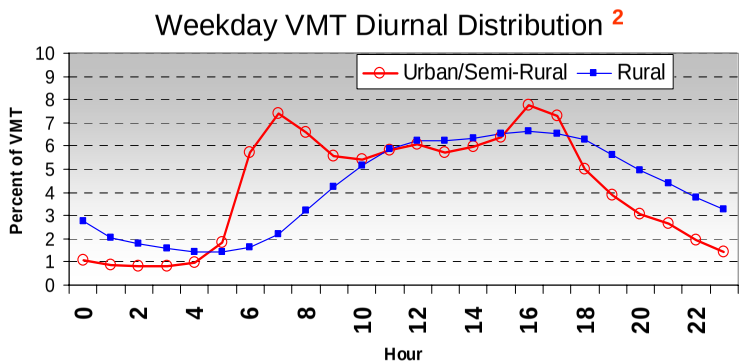


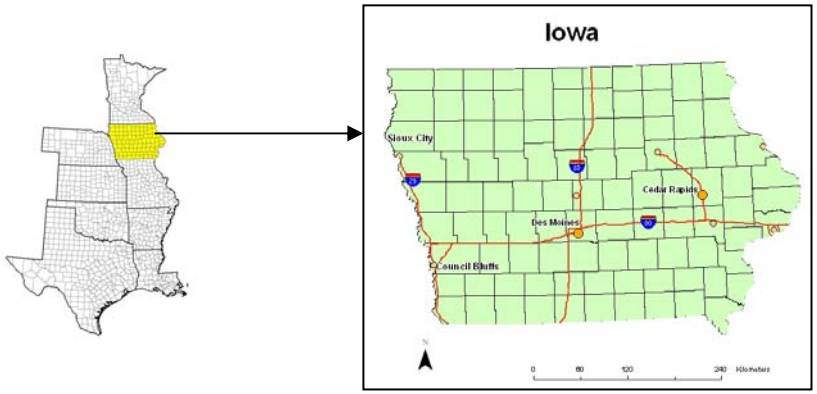



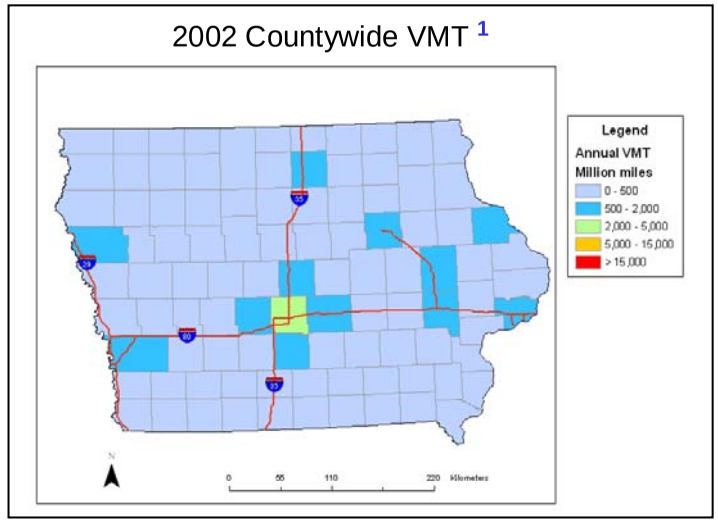



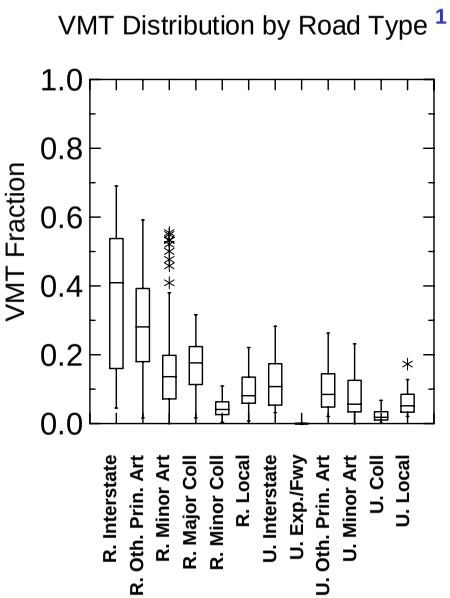
**Data Summary Sheet: Iowa**

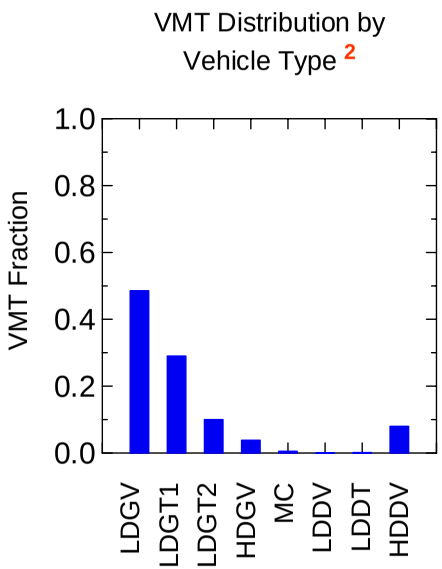
**Data Source: [1] Iowa Dept. of Transportation**

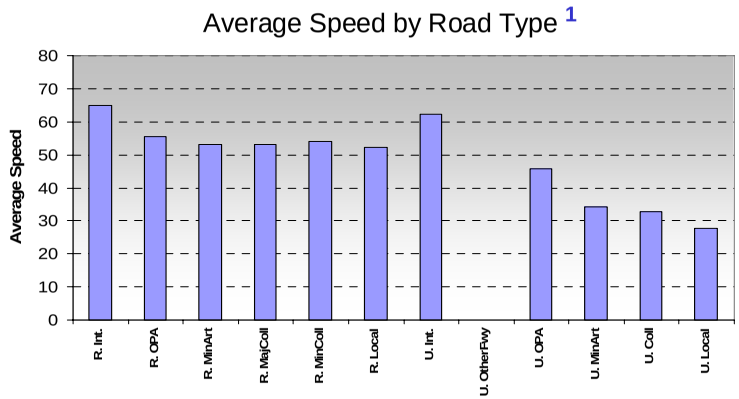
**[2] Default Data**

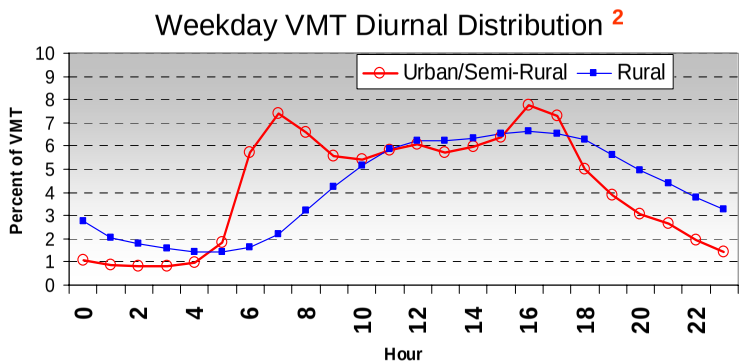


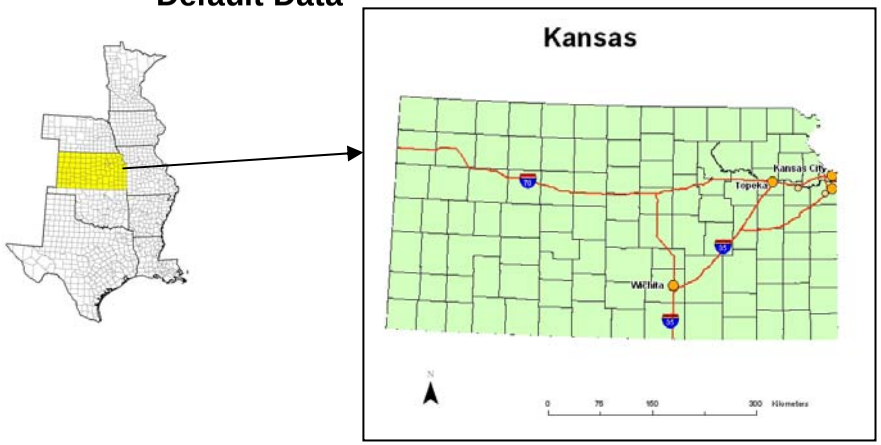



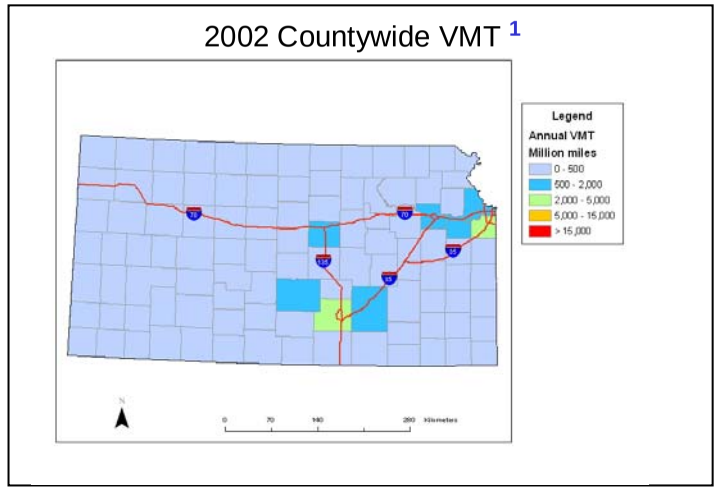



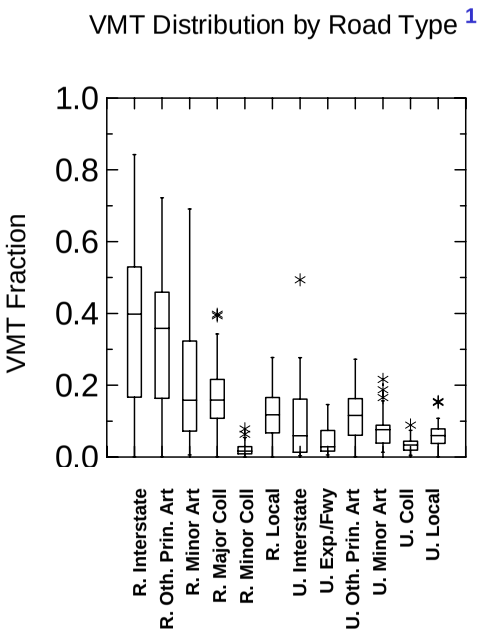
**Data Summary Sheet: Kansas**

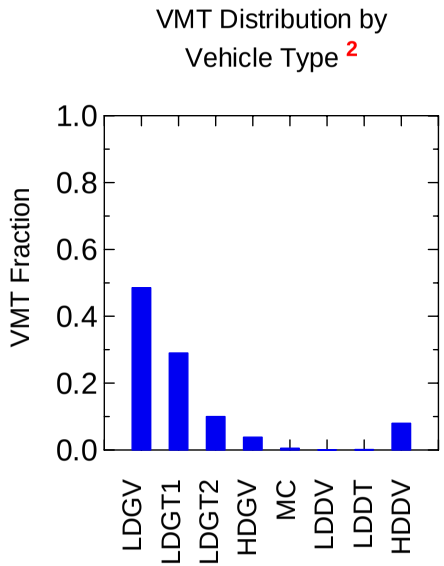
**Data Source: [1] Kansas Highway Dept.**

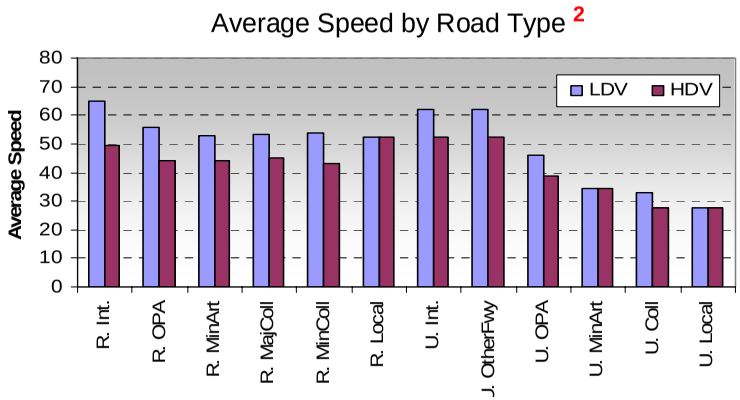
**[2] Default Data**

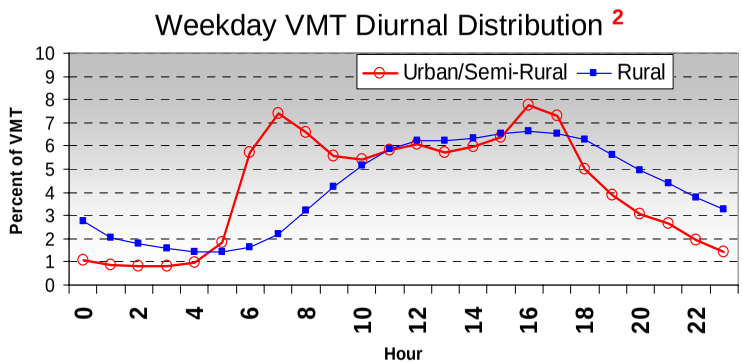


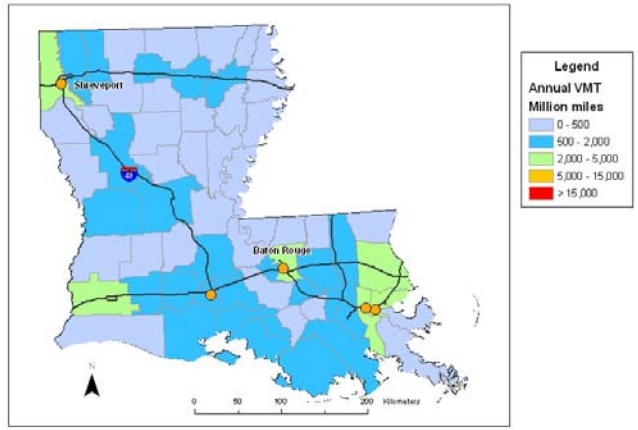



**Data Summary Sheet: Louisiana**

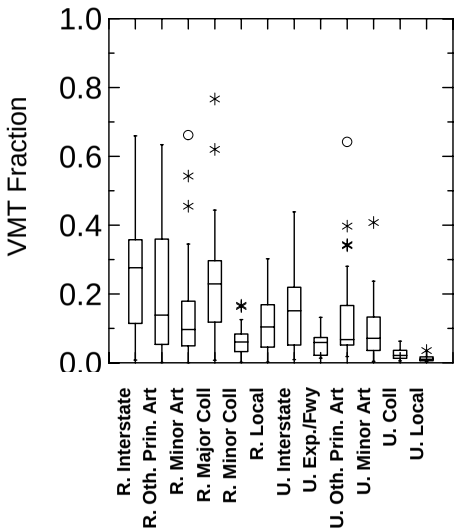
**Data Source: [1] Louisiana Dept. of Environmental Quality**

**[2] Default Data**

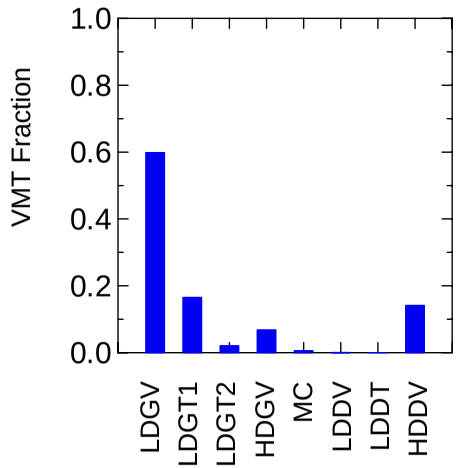
2002 Countywide VMT [1]



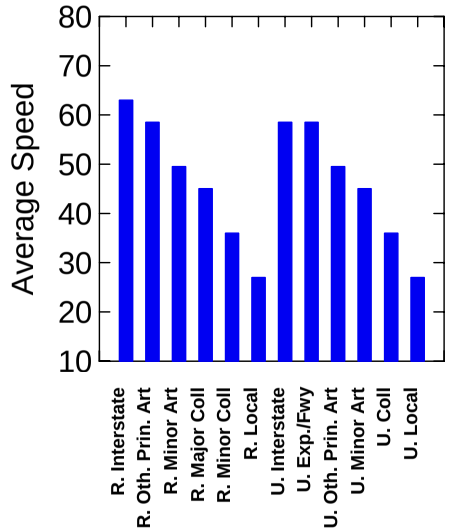

VMT Distribution by Road Type [1]

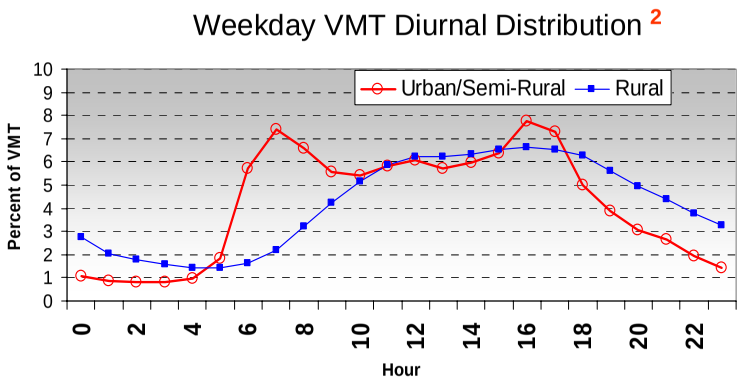



VMT Distribution by Vehicle Type [1]




Average Speed by Road Type [1]



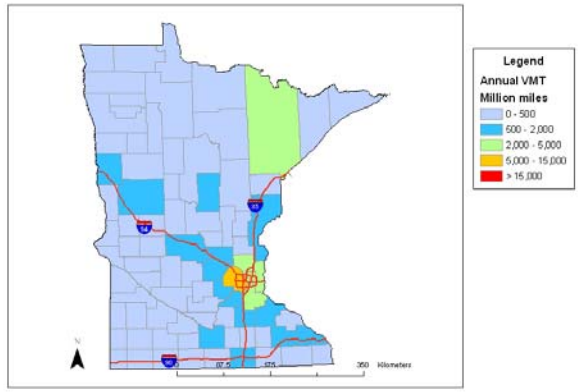

Weekday VMT Diurnal Distribution 2
Urban/Semi-Rural
Rural
Percent of VMT
0
1
2
3
4
5
6
7
8
9
10
0
2
4
6
8
10
12
14
16
18
20
22
Hour

# Data Summary Sheet: Minnesota

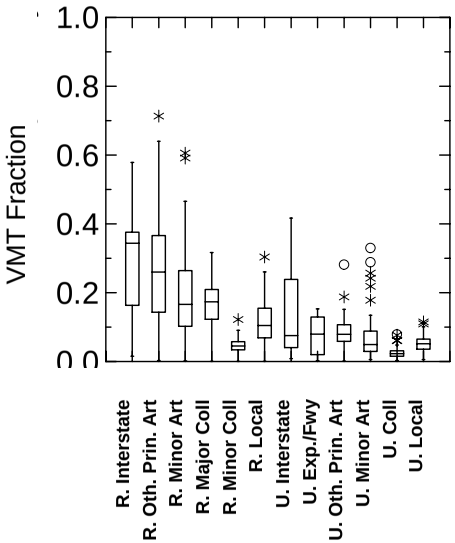
**Data Source: [1] Minnesota Dept. of Transportation**

**[2] Default Data**

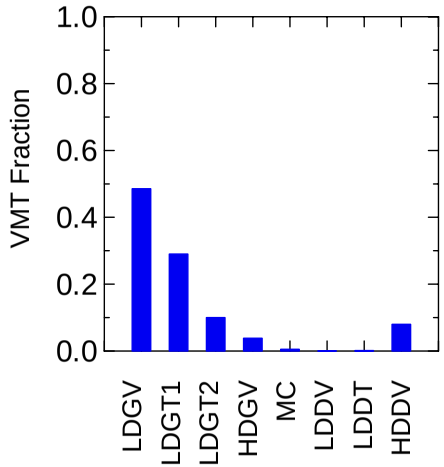
2002 Countywide VMT [1]



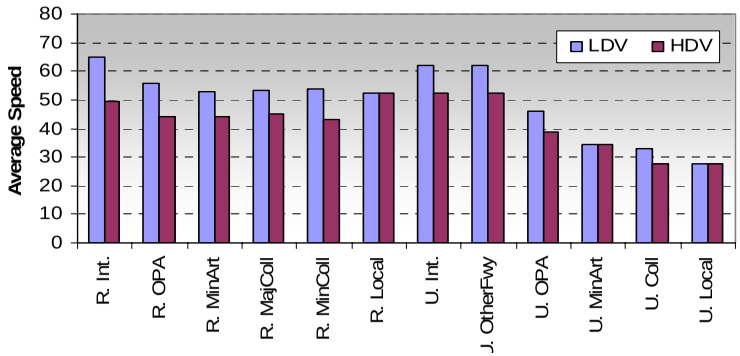

VMT Distribution by Road Type [1]



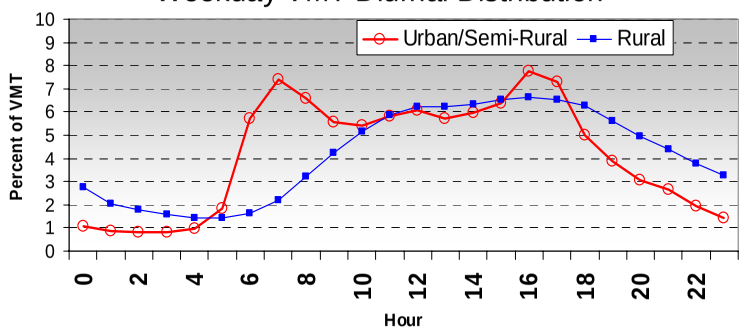

VMT Distribution by Vehicle Type [2]




Average Speed by Road Type [2]




Weekday VMT Diurnal Distribution [2]



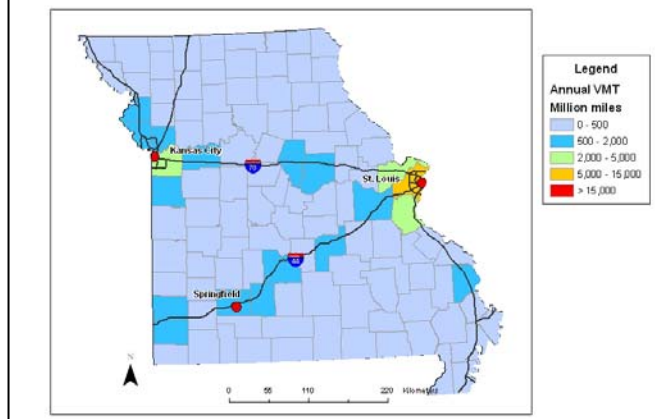
**Data Summary Sheet: Missouri**

**Data Source: [1] Missouri Dept. of Transportation &**

**[2] East-West Gateway Coordinating Council**

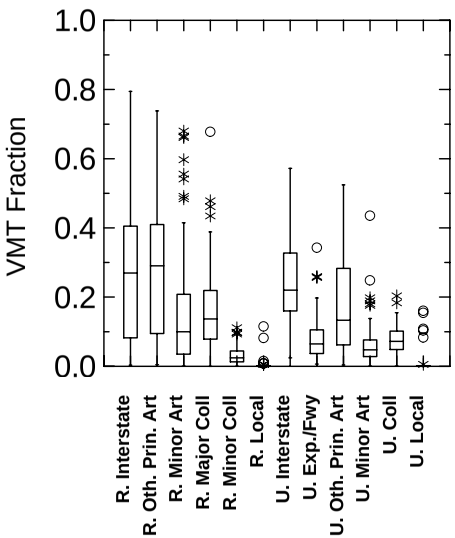
**[3] Default Data**

2002 Countywide VMT [1,2]



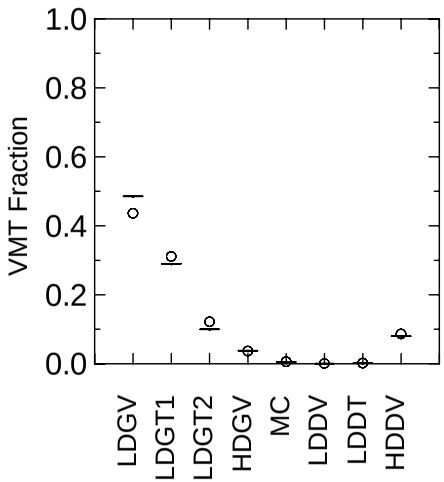

VMT Distribution by Road Type

MoDOT [1] & EWGCC Data [2]

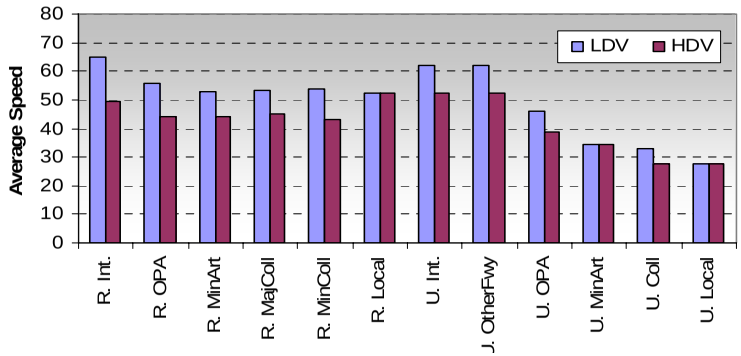



VMT Distribution by Vehicle Type

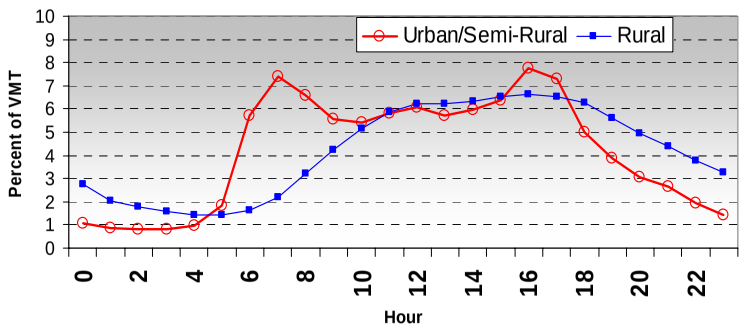
EWGCC Data [2] & Default Data [3]




Average Speed by Road Type [3]

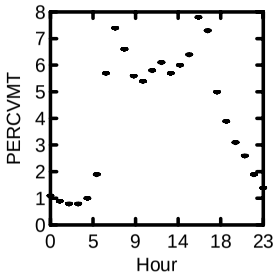



Weekday VMT Diurnal Distribution Outside of St. Louis Area [3]

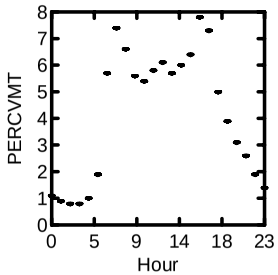


Average of hourly VMT distributions by road type, St. Louis Area**

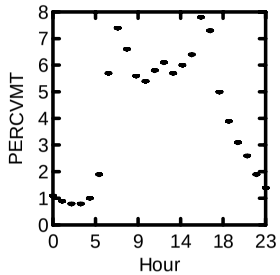
R. Intst



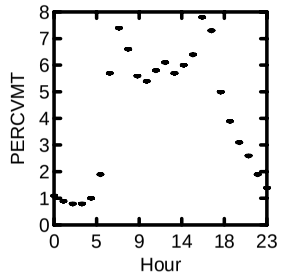

R. OPrArt



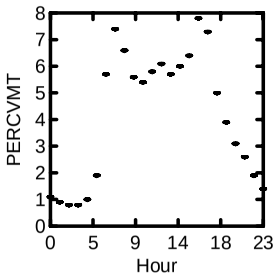

R. MinArt



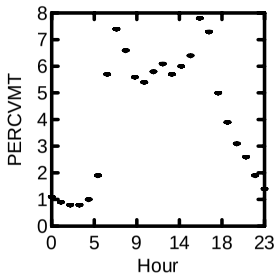

R. MajCol



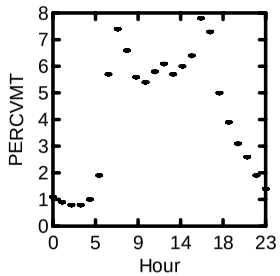

R. MinCol



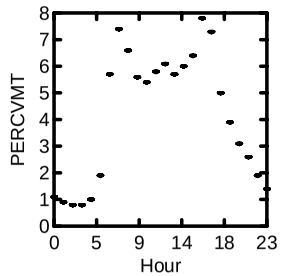

R. Local



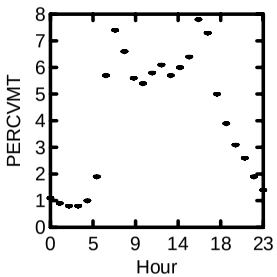

U. Intst



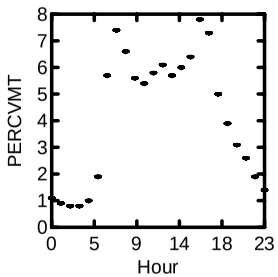

U. ExpFwy



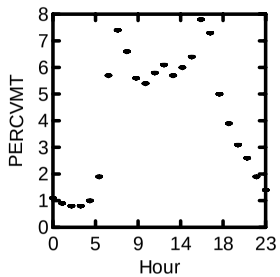

U. OPrArt



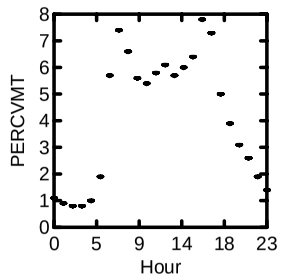

U. MinArt




U. Coll




U. Local




Note that box-whisker plots appear as points because only a small number of counties with negligible variability are plotted.

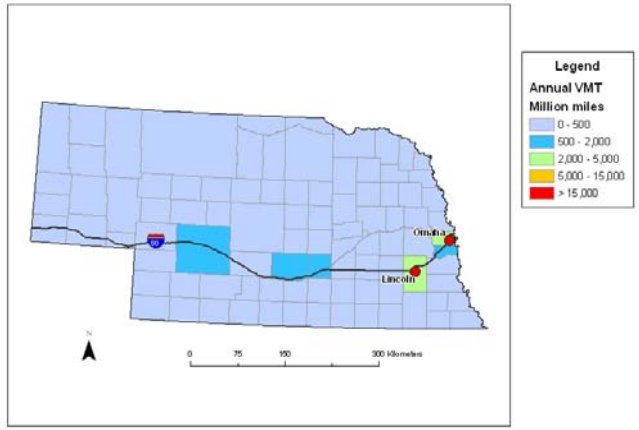
**Data Summary Sheet: Nebraska**

**Data Source: [1] Nebraska Dept. of Transportation &**

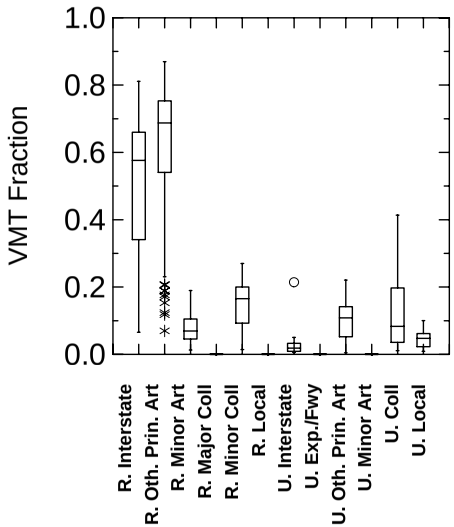
**[2] Lincoln-Lancaster MPO**

**[3] Default Data**

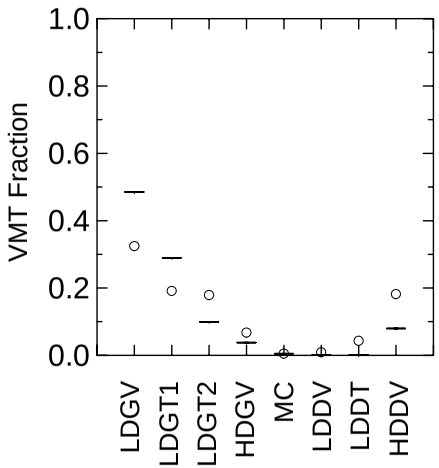
2002 Countywide VMT [1]



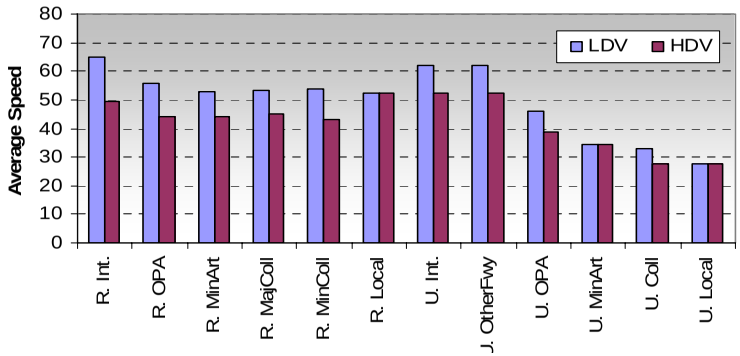

VMT Distribution by Road Type
NeDOT [1] & LLMPO Data [2]



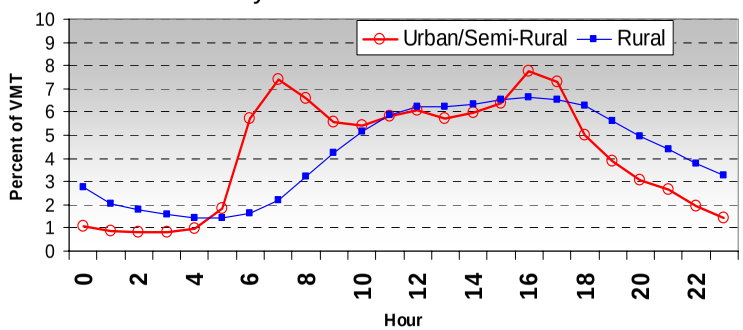

VMT Distribution by Vehicle Type
LLMPO Data [2] & Default Data [3]




Average Speed by Road Type [3]



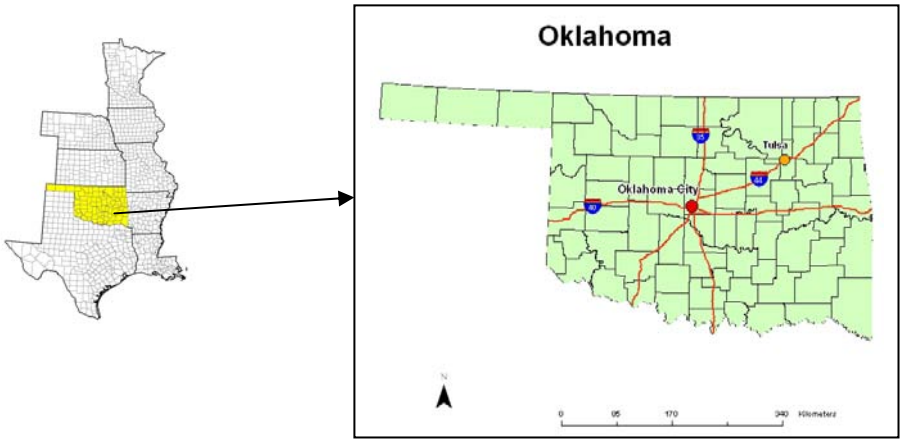

Weekday VMT Diurnal Distribution [3]

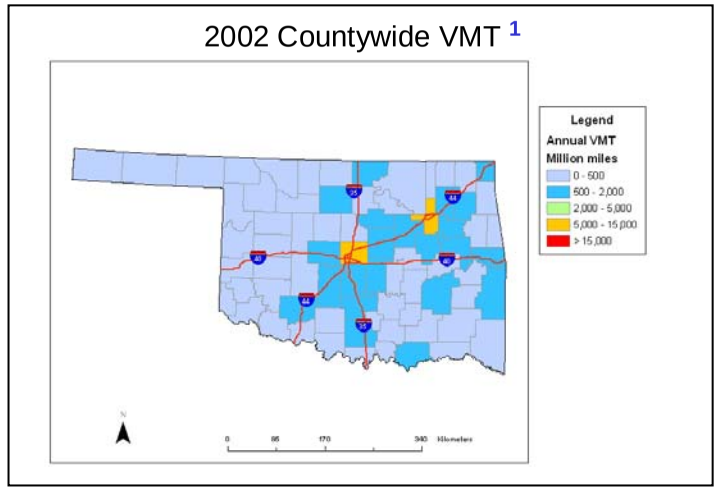


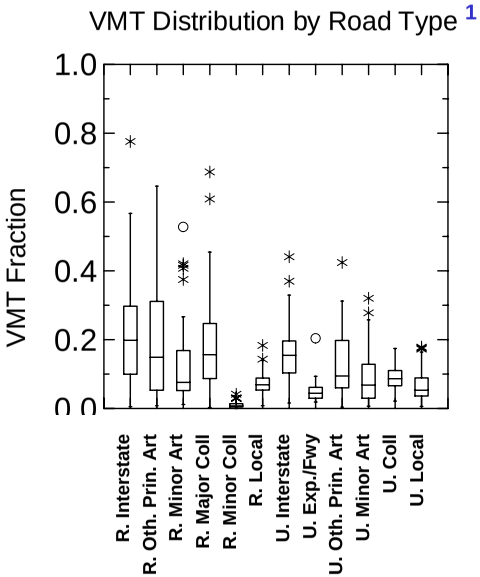
**Data Summary Sheet: Oklahoma**

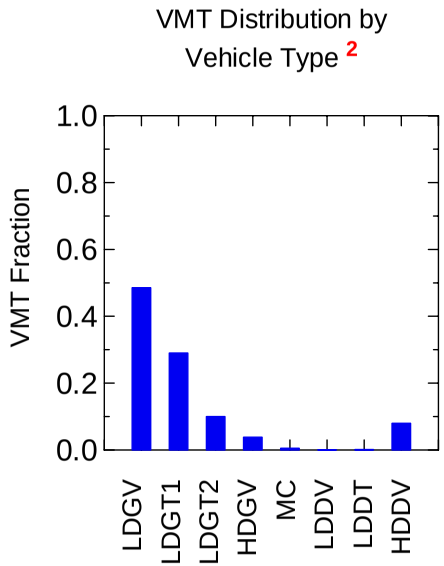
**Data Source: [1] Oklahoma State Highway Dept.**

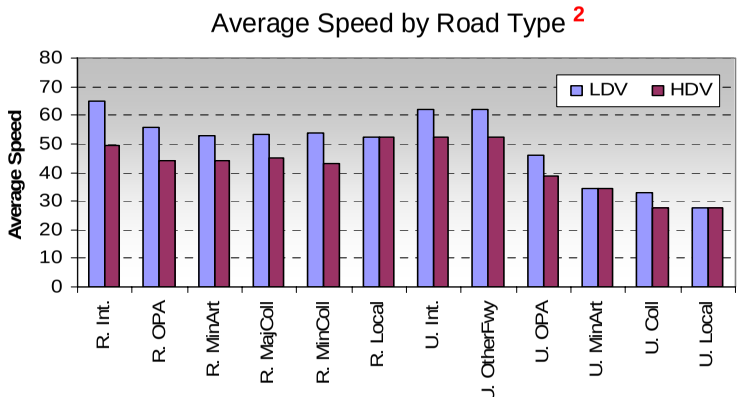
**[2] Default Data**

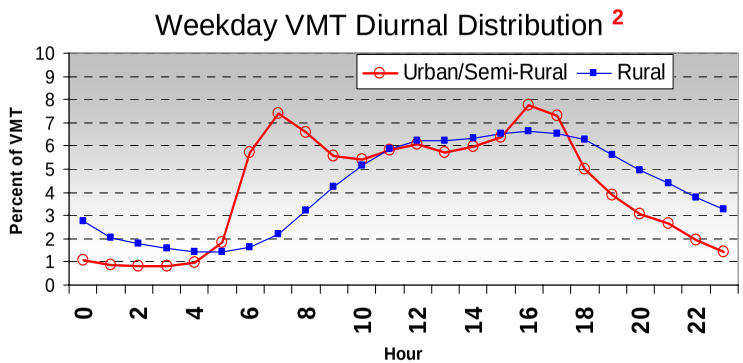


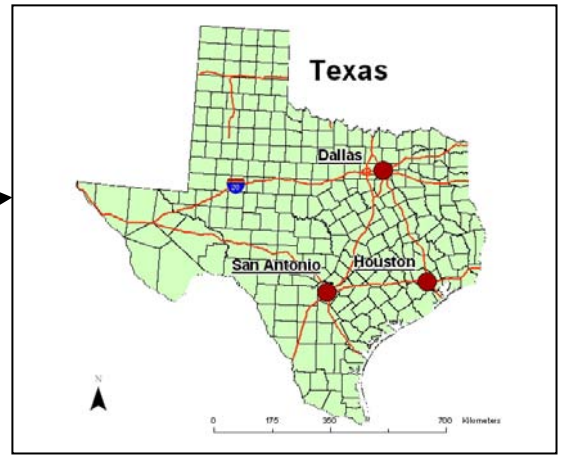



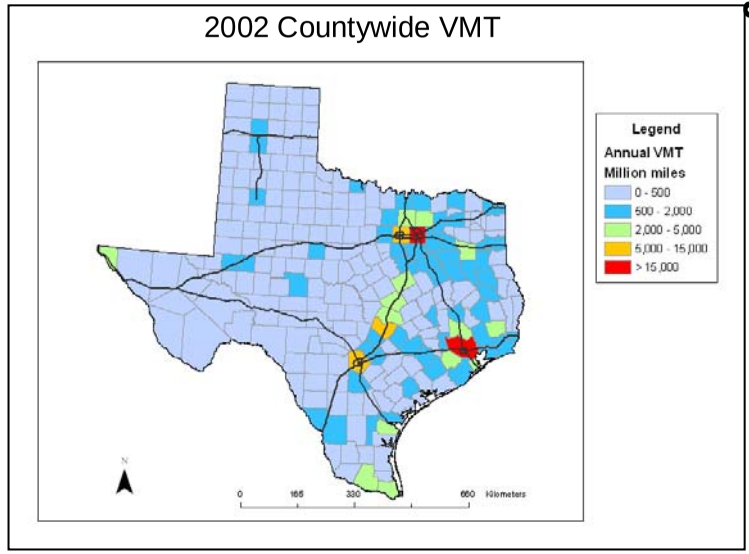



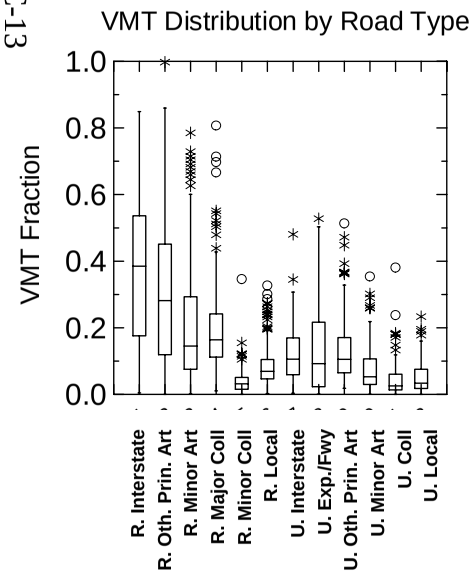



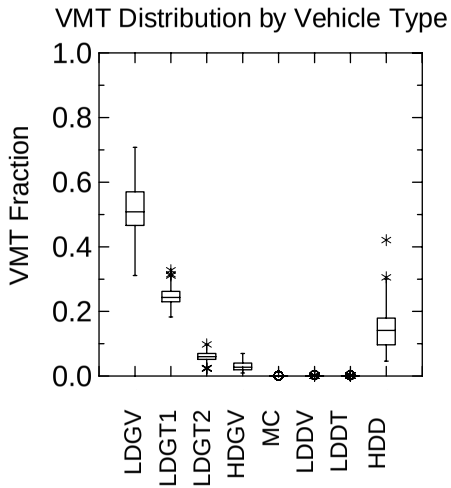
**Data Summary Sheet: Texas**

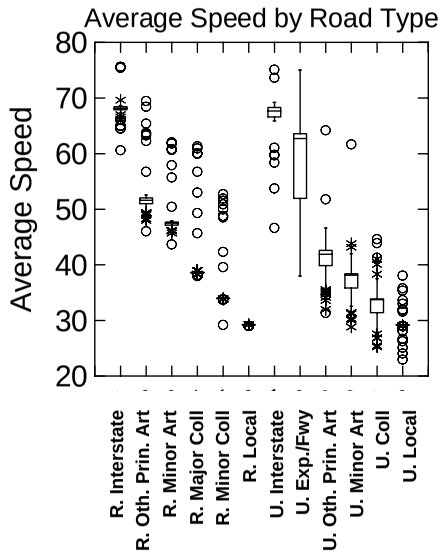
**Data Source: Texas Transportation Institute & TCEQ.**

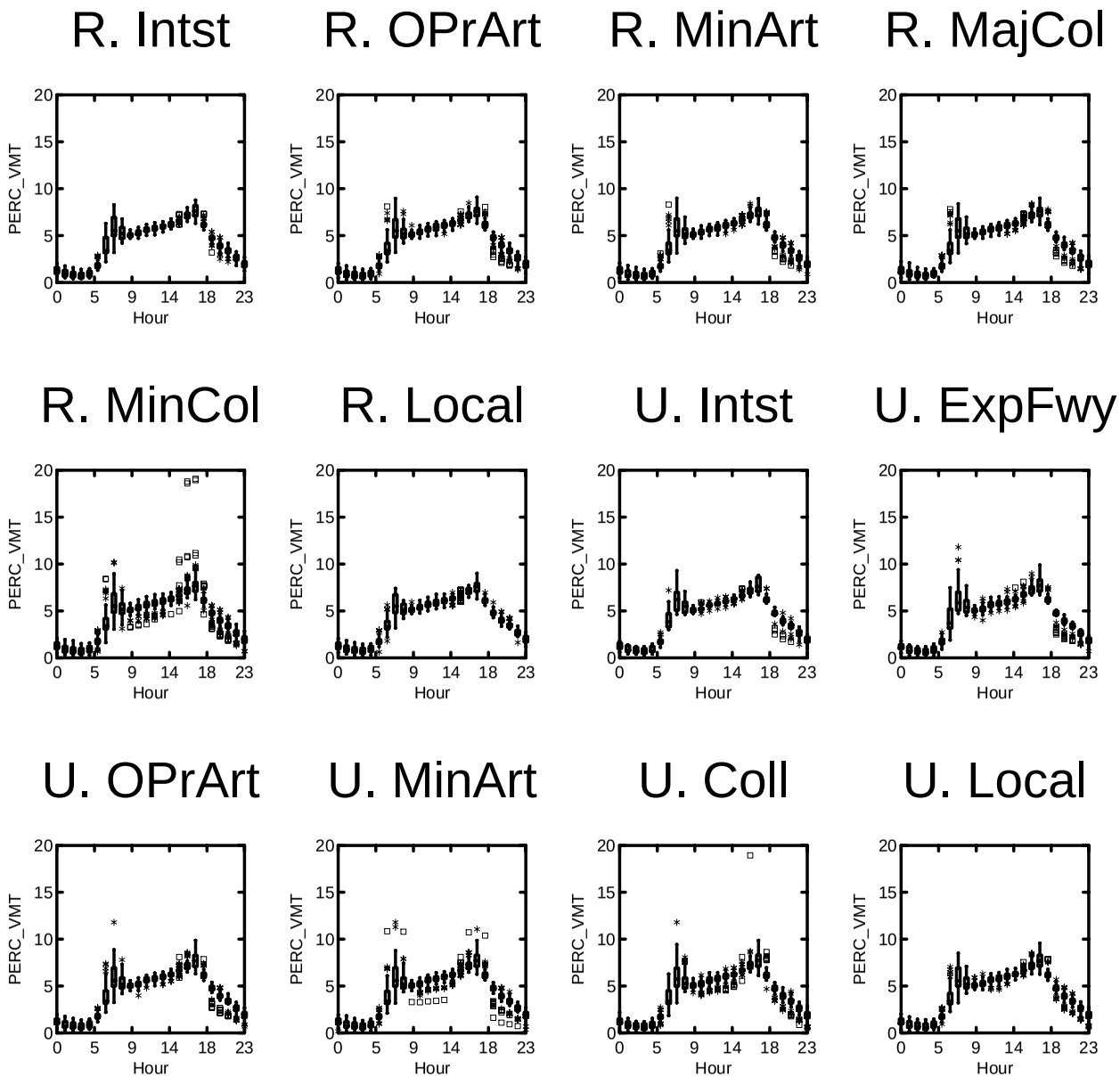





Average of hourly VMT distributions by road type.

(range limited to 20%, 1 outlier was excluded)

## Summary of MOBILE6 Inputs for Fuels Characteristics

| State | County | FUEL PROGRAM command[a] |
|---|---|---|
| AR | All counties | FUEL PROGRAM : 1 |
| IA | All counties | FUEL PROGRAM : 1 |
| KS | All counties | FUEL PROGRAM : 1 |
| LA | All counties | FUEL PROGRAM : 1 |
| MN | All counties | FUEL PROGRAM : 4<br>300.0 299.0 100.0 100.0 100.0 92.0 33.0 33.0<br>30.0 30.0 30.0 30.0 30.0 30.0 30.0 30.0<br>1000.0 1000.0 1000.0 1000.0 303.0 303.0 87.0 87.0<br>80.0 80.0 80.0 80.0 80.0 80.0 80.0 80.0 |
| MO | St. Louis area[b,c] | FUEL PROGRAM : 2 S |
| NE | Western counties[d] | FUEL PROGRAM : 3 |
| | All other counties | FUEL PROGRAM : 1 |
| OK | All counties | FUEL PROGRAM : 1 |
| TX | Dallas/Fort Worth counties[c,e] | FUEL PROGRAM : 2 S |
| | Houston/Galveston counties[c,f] | FUEL PROGRAM : 2 S |
| | All other counties | FUEL PROGRAM : 1 |

[a] If not specified, MOBILE6 assumes FUEL PROGRAM : 1, which corresponds to "Conventional Gasoline East": i.e., an average 2002 fuel sulfur content of 279 ppm and a maximum 2002 fuel sulfur content of 1000 ppm. For areas using Federal Reformulated Gasoline (RFG), the designation "S" or "N" is based upon the classification of regions in 40 CFR 80.71.

[b] Includes Franklin, Jefferson, St. Charles, and St. Louis Counties, and St. Louis City.

[c] All FUEL PROGRAM : 2 S areas should also use the SEASON command. SEASON : 1 applies May 1 through September 15; SEASON : 2 applies for the rest of the calendar year.

[d] Includes the following counties: Banner, Box Butte, Cheyenne, Dawes, Deuel, Garden, Keith, Kimball, Morrill, Scotts Bluff, Sheridan, and Sioux (40 CFR 80.215(a)(2)(i). Although this is the program recommended by EPA for these counties, use of this fuel program command in 2002 is optional, since the 2002 sulfur contents for FUEL PROGRAM : 3 are the same as those for FUEL PROGRAM : 1.

[e] Includes the following counties: Collin, Dallas, Denton, Tarrant.

[f] Includes the following counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller.

Summary of MOBILE6 Inputs for Sulfur Contents of Diesel Fuels

| State | DIESEL SULFUR command[a] |
|---|---|
| AR | DIESEL SULFUR : 360.0 |
| IA | DIESEL SULFUR : 360.0 |
| KS | DIESEL SULFUR : 330.0 |
| LA | DIESEL SULFUR : 380.0 |
| MN | DIESEL SULFUR : 360.0 |
| MO | DIESEL SULFUR : 390.0 |
| NE | DIESEL SULFUR : 360.0 |
| OK | DIESEL SULFUR : 360.0 |
| TX | DIESEL SULFUR : 364.0 |

[a] Value is sulfur content in units of parts per million by weight (ppmw); regulatory limit is 500 ppmw in 2002.

## Summary of MOBILE6 Inputs for Oxygenated Fuels Specifications

| State | Area | Period | Command | Ethers market share (fraction) | Alcohols market share (fraction) | Avg. wt. frac. Oxygen in Ether Blends | Avg. wt. frac. Oxygen in Alcohol Blends | RVP Waiver for Alcohol Blends |
|---|---|---|---|---|---|---|---|---|
| AR | All areas | All Months | OXYGENATED FUELS : | 0.500 | 0.000 | 0.006 | 0.000 | 2 |
| IA | All areas | All Months | OXYGENATED FUELS : | 0.000 | 0.555 | 0.000 | 0.035 | 2 |
| KS | All areas | All Months | OXYGENATED FUELS : | 0.000 | 0.040 | 0.000 | 0.035 | 2 |
| LA | All areas | All Months | OXYGENATED FUELS : | 0.300 | 0.000 | 0.009 | 0.000 | 2 |
| MN | All areas | All Months | OXYGENATED FUELS : | 0.000 | 0.977 | 0.000 | 0.034 | 2 |
| MO | St. Louis area[a] | All Months | (N/A)[b] | | | | | |
| | All other areas | All Months | OXYGENATED FUELS : | 0.000 | 0.095 | 0.000 | 0.033 | 2 |
| NE | All areas | All Months | OXYGENATED FUELS : | 0.000 | 0.420 | 0.000 | 0.035 | 2 |
| OK | All areas | All Months | OXYGENATED FUELS : | 0.000 | 0.000 | 0.000 | 0.000 | 2 |
| TX | Dallas/Fort Worth area[c] | All Months | (N/A)[b] | | | | | |
| | Houston/Galveston area[d] | All Months | (N/A)[b] | | | | | |
| | | All Months | (N/A)[b] | | | | | |
| | El Paso County | Oct to Mar | OXYGENATED FUELS : | 0.000 | 1.000 | 0.000 | 0.027 | 2 |
| | | Apr to Sep | OXYGENATED FUELS : | 0.000 | 0.000 | 0.000 | 0.000 | 2 |
| | All other areas | All Months | OXYGENATED FUELS : | 0.000 | 0.000 | 0.000 | 0.000 | 2 |

[a] Includes Franklin, Jefferson, St. Charles, and St. Louis Counties, and St. Louis City.
[b] The OXYGENATED FUELS command is not specified for these areas (overridden by FUEL PROGRAM : 2 S command).
[c] Includes the following counties: Collin, Dallas, Denton, Tarrant.
[d] Includes the following counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller.

## Summary of MOBILE6 Inputs for Fuel Volatilities

| State | Area | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep 1-15 | Sep 16-30 | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| AR | All areas | 13.0 | 13.0 | 12.0 | 10.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.5 | 11.0 | 12.0 |
| IA | All areas | 13.2 | 12.8 | 11.8 | 10.3 | 9.0 | 8.7 | 8.3 | 8.4 | 8.4 | 8.3 | 9.4 | 11.2 | 12.0 |
| KS | Kansas City area[a] | 13.2 | 12.4 | 11.3 | 10.3 | 7.3 | 7.0 | 7.0 | 7.0 | 7.0 | 8.4 | 9.4 | 11.2 | 12.0 |
| | All other areas | 13.2 | 12.8 | 11.8 | 10.4 | 9.1 | 8.9 | 8.2 | 8.5 | 8.4 | 8.4 | 9.1 | 11.0 | 11.5 |
| LA | Baton Rouge area[b] | 13.0 | 13.0 | 12.0 | 10.0 | 9.0 | 7.8 | 7.8 | 7.8 | 7.8 | 9.0 | 9.5 | 11.0 | 12.0 |
| | Beauregard, Calcasieu, Grant, Lafayette, Lafourche, Pointe Coupee, St. James, and St. Mary Parishes | 13.0 | 13.0 | 12.0 | 10.0 | 9.0 | 7.8 | 7.8 | 7.8 | 7.8 | 9.0 | 9.5 | 11.0 | 12.0 |
| | New Orleans area[c] | 13.0 | 13.0 | 12.0 | 10.0 | 9.0 | 7.8 | 7.8 | 7.8 | 7.8 | 9.0 | 9.5 | 11.0 | 12.0 |
| | All other areas | 13.0 | 13.0 | 12.0 | 10.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.5 | 11.0 | 12.0 |
| MN | All areas | 13.4 | 13.6 | 12.8 | 10.4 | 9.2 | 8.8 | 8.7 | 8.6 | 8.5 | 8.5 | 9.6 | 10.1 | 12.4 |
| MO | Kansas City[a] | 13.1 | 12.4 | 11.3 | 10.3 | 7.3 | 7.0 | 7.0 | 7.0 | 7.0 | 8.4 | 9.4 | 11.2 | 12.0 |
| | St. Louis[d,e] | 13.1 | 12.8 | 11.0 | 7.4 | 6.0 | 6.7 | 6.7 | 6.7 | 6.7 | 6.8 | 9.1 | 10.3 | 12.6 |
| | All other areas | 13.2 | 12.8 | 11.8 | 10.1 | 8.8 | 8.5 | 8.4 | 8.4 | 8.4 | 8.2 | 9.7 | 11.5 | 12.4 |
| NE | All areas | 13.2 | 12.8 | 11.8 | 10.3 | 9.0 | 8.7 | 8.3 | 8.4 | 8.4 | 8.3 | 9.4 | 11.2 | 12.0 |
| OK | Tulsa area[f] | 13.0 | 13.0 | 12.0 | 10.0 | 9.0 | 7.8 | 7.8 | 7.8 | 7.8 | 9.0 | 9.5 | 11.0 | 12.0 |
| | All other areas | 13.0 | 13.0 | 12.0 | 10.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.5 | 11.0 | 12.0 |
| TX | Beaumont/Port Arthur area[g] | 13.0 | 13.0 | 12.0 | 10.0 | 9.0 | 7.5 | 7.5 | 7.5 | 7.5 | 9.0 | 9.5 | 11.0 | 12.0 |
| | Dallas/Fort Worth area[e,h] | 13.1 | 12.8 | 11.0 | 7.4 | 6.0 | 6.7 | 6.7 | 6.7 | 6.7 | 6.8 | 9.1 | 10.3 | 12.6 |
| | Houston/Galveston area[e,i] | 13.1 | 12.8 | 11.0 | 7.4 | 6.0 | 6.7 | 6.7 | 6.7 | 6.7 | 6.8 | 9.1 | 10.3 | 12.6 |
| | Other East Texas counties[j] | 13.0 | 13.0 | 12.0 | 10.0 | 7.8 | 7.5 | 7.5 | 7.5 | 7.5 | 9.0 | 9.5 | 11.0 | 12.0 |
| | El Paso County | 12.3 | 13.0 | 12.0 | 10.0 | 9.0 | 6.8 | 6.8 | 6.8 | 6.8 | 9.0 | 9.5 | 11.0 | 12.0 |
| | All other areas | 13.0 | 13.0 | 12.0 | 10.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.0 | 9.5 | 11.0 | 12.0 |

[a] Includes the following counties: Johnson (KS), Wyandotte (KS), Clay (MO), Jackson (MO), Platte (MO).
[b] Includes the following parishes: Ascension, East Baton Rouge, Iberville, Livingston, West Baton Rouge.
[c] Includes the following parishes: Jefferson, Orleans, St. Bernard, St. Charles.
[d] Includes Franklin, Jefferson, St. Charles, and St. Louis counties, and St. Louis City.
[e] Although the FUEL RVP command must be used, input data will be overridden by the FUEL PROGRAM : 2 S command during May 1 through September 15.
[f] Includes the following counties: Creek, Osage, Rogers, Tulsa, Wagoner.
[g] Includes the following counties: Jefferson, Hardin, Orange.
[h] Includes the following counties: Collin, Dallas, Denton, Tarrant.
[I] Includes the following counties: Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, Waller.
[j] Includes the following counties: Anderson, Angelina, Aransas, Atascosa, Austin, Bastrop, Bee, Bell, Bexar, Bosque, Bowie, Brazos, Burleson, Caldwell, Calhoun, Camp, Cass, Cherokee, Colorado, Comal, Cooke, Coryell, De Witt, Delta, Ellis, Falls, Fannin, Fayeete, Franklin, Freestone, Goliad, Gonzales, Grayson, Gregg, Grimes, Guadalupe, Harrison, Hays, Henderson, Hill, Hood, Hopkins, Houston, Hunt, Jackson, Jasper, Johnson, Karnes, Kaufman, Lamar, Lavaca, Lee, Leon, Limestone, Live Oak, Madison, Marion, Matagorda, McLennan, Milam, Morris, Nacogdoches, Navarro, Newton, Nueces, Panola, Parker, Polk, Rains, Red River, Refugio, Robertson, Rockwall, Rusk, Sabine, San Jacinto, San Patricio, San Augustine, Shelby, Smith, Somervell, Titus, Travis, Trinity, Tyler, Upshur, VanZandt, Victoria, Walker, Washington, Wharton, Williamson, Wilson, Wise, Wood.

# Summary of MOBILE6 Inputs for Anti-tampering Programs

| State | County | | Start Year | Earliest MY | Final MY | Vehicles types covered (1 = exempt, 2 = covered) | | | | | | | | | | | | | | Inspection Frequency (11 = annual, 12 = biennial) | Program Compliance Rate (%) | Inspections (1 = no, 2 = yes) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | LDGV | LDGT1 | LDGT2 | LDGT3 | LDGT4 | HDGV2B | HDGV3 | HDGV4 | HDGV5 | HDGV6 | HDGV7 | HDGV8A | HDGVB | GAS BUS | | | Air pump | Catalyst | Inlet | Lead deposit | EGR system | Evap system | PCV system | Gas cap |
| Louisiana | All | | 00 | 80 | 50 | 2 | 2 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 11 | 072. | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Texas | Harris | Program A | 84 | 78 | 83 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 11 | 096. | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| | | Program B | 84 | 84 | 00 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 11 | 096. | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 |
| | | As modeled | 84 | 78 | 00 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 11 | 096. | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 |
| Texas | El Paso | Program A | 86 | 81 | 83 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 11 | 096. | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| | | Program B | 86 | 84 | 00 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 11 | 096. | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 |
| | | As modeled | 86 | 81 | 00 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 11 | 096. | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 |
| Texas | Dallas, Tarrant | Program A | 86 | 76 | 83 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 11 | 096. | 2 | 1 | 1 | 1 | 2 | 2 | 2 | 2 |
| | | Program B | 86 | 84 | 00 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 11 | 096. | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 |
| | | As modeled | 86 | 76 | 00 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 11 | 096. | 2 | 2 | 1 | 1 | 2 | 2 | 2 | 2 |

# Summary of MOBILE6 Inputs for Inspection and Maintenance Programs

| | | | | | | | Vehicle Model Years, Types, and Ages Covered | | | | | | | | | | | | | | | | | | Compliance Rate | Waiver Rate | | Exhaust I/M Parameters | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Model Years (MY) | | Vehicles types covered (1 = exempt, 2 = covered) | | | | | | | | | | | | | | | | | | | | | TR Effectiveness | | |
| State | Counties | Start Year | End Year | Inspection Frequency (1 = annual, 2 = biennial) | Inspection Facility Type[a] | Inspection Test Type[b] | Earliest | Final | LDGV | LDGT1 | LDGT2 | LDGT3 | LDGT4 | | HDGV2B | HDGV3 | HDGV4 | HDGV5 | HDGV6 | HDGV7 | HDGV8A | HDGV8B | | GAS BUS | EXEMPTION AGE | GRACE PERIOD | | MY 1980 and older | MY 1981 and newer | Stringency (Failure Rate for MY 1980 and older) | Tech. Training? | HC | CO | NOx |
| Louisiana | Ascension, East Baton Rouge, Iberville, Livingston, West Baton Rouge | 2000 | (current) | 1 | TRC | GC | 1980 | (current) | 2 | 2 | 2 | 2 | 2 | | 2 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | (N/A) | 1 | 96.0% | 0% | 0% | (N/A) | (N/A) | (N/A) | (N/A) | (N/A) |
| Missouri | Jefferson, St. Charles, St. Louis, St. Louis City | 1990 | (current) | 2 | T/O | IDLE | 1971 | 1980 | 2 | 2 | 2 | 2 | 2 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | (N/A) | 2 | 96.0% | 25.3% | (N/A) | 18.0% | Yes | (N/A) | (N/A) | (N/A) |
| | | 2000 | (current) | 2 | T/O | IM240 | 1981 | (current) | 2 | 2 | 2 | 2 | 2 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | (N/A) | 2 | 96.0% | (N/A) | 25.3% | (N/A) | Yes | (N/A) | (N/A) | (N/A) |
| | | 2000 | (current) | 2 | T/O | GC | 1981 | (current) | 2 | 2 | 2 | 2 | 2 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | (N/A) | 2 | 96.0% | (N/A) | 0.0% | (N/A) | (N/A) | (N/A) | (N/A) | (N/A) |
| | Franklin | 2000 | (current) | 1 | T/O | IDLE | 1971 | (current) | 2 | 2 | 2 | 2 | 2 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | (N/A) | 2 | 96.0% | 10.9% | 9.9% | 15.2% | Yes | (N/A) | (N/A) | (N/A) |
| | | 2000 | (current) | 1 | T/O | GC | 1981 | (current) | 2 | 2 | 2 | 2 | 2 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | (N/A) | 2 | 96.0% | (N/A) | 0.0% | (N/A) | (N/A) | (N/A) | (N/A) | (N/A) |
| Texas | Harris | 1997 | Apr. 2002 | 1 | TRC | 2500/IDLE | 1978 | 2000 | 2 | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | (N/A) | 2 | 96.0% | 0.0% | 0.0% | 10.0% | Yes | (N/A) | (N/A) | (N/A) |
| | | May 2002 | (current) | 1 | TRC | 2500/IDLE | 1978 | 2000 | 1 | 1 | 1 | 1 | 1 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | (N/A) | 2 | 96.0% | 2.1% | 4.4% | 14.2% | Yes | 100% | 100% | 100% |
| | | May 2002 | (current) | 1 | TRC | ASM 2525/5015 PHASE-IN | 1978 | 1995 | 2 | 2 | 2 | 2 | 2 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | (N/A) | 2 | 96.0% | 1.1% | 0.7% | 27.4% | Yes | 100% | 100% | 100% |
| | | May 2002 | (current) | 1 | TRC | OBD I/M | 1996 | 2000 | 2 | 2 | 2 | 2 | 2 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | (N/A) | 2 | 96.0% | (N/A) | 0.2% | (N/A) | Yes | 100% | 100% | 100% |
| | | 1997 | (current) | 1 | TRC | GC | 1978 | 2000 | 2 | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | (N/A) | 2 | 96.0% | 0.0% | 0.0% | (N/A) | (N/A) | (N/A) | (N/A) | (N/A) |
| Texas | Brazoria, Chambers, Fort Bend, Galveston, Liberty, Montgomery, Waller | 2000 | (current) | 1 | TRC | GC | 1978 | 2000 | 2 | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | (N/A) | 2 | 96.0% | 0.0% | 0.0% | (N/A) | (N/A) | (N/A) | (N/A) | (N/A) |
| Texas | Dallas, Tarrant | 1990 | Apr. 2002 | 1 | TRC | 2500/IDLE | 1975 | 2000 | 2 | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | (N/A) | 2 | 96.0% | 0.3% | 0.0% | 10.0% | Yes | 100% | 100% | 100% |
| Texas | Collin, Denton, Dallas, Tarrant | May 2002 | (current) | 1 | TRC | 2500/IDLE | 1978 | 2000 | 1 | 1 | 1 | 1 | 1 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | (N/A) | 2 | 96.0% | 0.8% | 1.5% | 15.3% | Yes | 100% | 100% | 100% |
| | | May 2002 | (current) | 1 | TRC | ASM 2525/5015 PHASE-IN | 1978 | 1995 | 2 | 2 | 2 | 2 | 2 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | (N/A) | 2 | 96.0% | 2.7% | 1.9% | 28.7% | Yes | 100% | 100% | 100% |
| | | May 2002 | (current) | 1 | TRC | OBD I/M | 1996 | 2000 | 2 | 2 | 2 | 2 | 2 | | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | (N/A) | 2 | 96.0% | (N/A) | 0.3% | (N/A) | Yes | 100% | 100% | 100% |
| Texas | Collin, Denton | May 2002 | (current) | 1 | TRC | GC | 1975 | 2000 | 2 | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | (N/A) | 2 | 96.0% | 0.0% | 0.0% | (N/A) | (N/A) | (N/A) | (N/A) | (N/A) |
| Texas | Dallas, Tarrant | 1996 | (current) | 1 | TRC | GC | 1975 | 2000 | 2 | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | (N/A) | 2 | 96.0% | 0.0% | 0.0% | (N/A) | (N/A) | (N/A) | (N/A) | (N/A) |
| Texas | El Paso | 1987 | (current) | 1 | TRC | 2500/IDLE | 1950 | (current) | 2 | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | (N/A) | 2 | 96.0% | 0.0% | 0.0% | 10.0% | Yes | (N/A) | (N/A) | (N/A) |
| | | 1997 | (current) | 1 | TRC | GC | 1950 | (current) | 2 | 2 | 2 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | | 2 | (N/A) | 2 | 96.0% | 0.0% | 0.0% | (N/A) | (N/A) | (N/A) | (N/A) | (N/A) |

[a] TRC = Test and Repair program, computerized; T/O = Test Only program

[b] GC = gas cap check (evaporative emissions); IDLE = idling only test; 2500/IDLE = idling and 2500 rpm test; ASM 2525/5015 PHASE-IN = testing at 25 mph/25% load and 15 mph/50% load, phased-in cutpoints; OBD I/M = check of malfunction indicator lights; IM240 = transient 240-second test

[c] Default Waiver Rate is 5.0% for evaporative programs, except where an exhaust I/M program is also applicable, in which case the waiver rate for the evaporative program is the same as that for the exhaust program.

Summary of MOBILE6 Inputs for Stage II Vapor Recovery Programs

| State | MSA/CMSA | County | Start Year | Phase In Period (Years) | In-use control efficiency (%) | |
|---|---|---|---|---|---|---|
| | | | | | LDGV/ LDGT | HDGV |
| Louisiana | Baton Rouge | Ascension | 93 | 2 | 77. | 77. |
| Louisiana | Baton Rouge | East Baton Rouge | 93 | 2 | 77. | 77. |
| Louisiana | Baton Rouge | Iberville | 93 | 2 | 77. | 77. |
| Louisiana | Baton Rouge | Livingston | 93 | 2 | 77. | 77. |
| Louisiana | Baton Rouge | West Baton Rouge | 93 | 2 | 77. | 77. |
| Louisiana | Pointe Coupee | Pointe Coupee | 93 | 2 | 77. | 77. |
| Missouri | St. Louis | St. Louis City | 87 | 2 | 89. | 89. |
| Missouri | St. Louis | Jefferson County | 87 | 2 | 89. | 89. |
| Missouri | St. Louis | St. Charles County | 87 | 2 | 89. | 89. |
| Missouri | St. Louis | Franklin County | 87 | 2 | 89. | 89. |
| Missouri | St. Louis | St. Louis County | 87 | 2 | 89. | 89. |
| Texas | Beaumont-Port Arthur | Hardin | 92 | 2 | 84. | 84. |
| Texas | Beaumont-Port Arthur | Jefferson | 92 | 2 | 84. | 84. |
| Texas | Beaumont-Port Arthur | Orange | 92 | 2 | 84. | 84. |
| Texas | Dallas-Ft. Worth | Collin | 92 | 2 | 84. | 84. |
| Texas | Dallas-Ft. Worth | Dallas | 92 | 2 | 84. | 84. |
| Texas | Dallas-Ft. Worth | Denton | 92 | 2 | 84. | 84. |
| Texas | Dallas-Ft. Worth | Tarrant | 92 | 2 | 84. | 84. |
| Texas | El Paso | El Paso | 92 | 2 | 84. | 84. |
| Texas | Houston-Galveston | Brazoria | 92 | 2 | 84. | 84. |
| Texas | Houston-Galveston | Chambers | 92 | 2 | 84. | 84. |
| Texas | Houston-Galveston | Fort Bend | 92 | 2 | 84. | 84. |
| Texas | Houston-Galveston | Galveston | 92 | 2 | 84. | 84. |
| Texas | Houston-Galveston | Harris | 92 | 2 | 84. | 84. |
| Texas | Houston-Galveston | Liberty | 92 | 2 | 84. | 84. |
| Texas | Houston-Galveston | Montgomery | 92 | 2 | 84. | 84. |
| Texas | Houston-Galveston | Waller | 92 | 2 | 84. | 84. |

Summary of MOBILE6 Inputs for the IM240 Program in St. Louis, Missouri (Page 1 of 3)

| Approx. VMT Mix | | | | |
|---|---|---|---|---|
| LDGV | LDGT1 | LDGT2 | LDGT3 | LDGT4 |
| 0.46 | 0.071 | 0.24 | 0.073 | 0.033 |

| Calendar Year |
|---|
| 2002 |

| % Final |
|---|
| 25% |

HC Cutpoints

| | LDGV | | LDGT1 & LDGT2 | | LDGT3 & LDGT4 | |
|---|---|---|---|---|---|---|
| Model Year | Phase-In | Final | Phase-In | Final | Phase-In | Final |
| 1981 | 2.0 | 0.8 | 7.5 | 3.4 | 7.5 | 3.4 |
| 1982 | 2.0 | 0.8 | 7.5 | 3.4 | 7.5 | 3.4 |
| 1983 | 2.0 | 0.8 | 7.5 | 3.4 | 7.5 | 3.4 |
| 1984 | 2.0 | 0.8 | 3.2 | 1.6 | 3.2 | 1.6 |
| 1985 | 2.0 | 0.8 | 3.2 | 1.6 | 3.2 | 1.6 |
| 1986 | 2.0 | 0.8 | 3.2 | 1.6 | 3.2 | 1.6 |
| 1987 | 2.0 | 0.8 | 3.2 | 1.6 | 3.2 | 1.6 |
| 1988 | 2.0 | 0.8 | 3.2 | 1.6 | 3.2 | 1.6 |
| 1989 | 2.0 | 0.8 | 3.2 | 1.6 | 3.2 | 1.6 |
| 1990 | 2.0 | 0.8 | 3.2 | 1.6 | 3.2 | 1.6 |
| 1991 | 1.2 | 0.8 | 2.4 | 1.6 | 2.4 | 1.6 |
| 1992 | 1.2 | 0.8 | 2.4 | 1.6 | 2.4 | 1.6 |
| 1993 | 1.2 | 0.8 | 2.4 | 1.6 | 2.4 | 1.6 |
| 1994 | 1.2 | 0.8 | 2.4 | 1.6 | 2.4 | 1.6 |
| 1995 | 1.2 | 0.8 | 2.4 | 1.6 | 2.4 | 1.6 |
| 1996 | 0.8 | 0.6 | 1.0 | 0.8 | 2.4 | 0.8 |
| 1997+ | same as 1996 | | same as 1996 | | same as 1996 | |

Allowable range in model

| Min | Max |
|---|---|
| 0.80 | 5.0 |

MOBILE6 ages

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | | | | | |

Model year standards applicable to each MOBILE6 age

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1996 | 1996 | 1996 | 1996 | 1996 | 1996 | 1996 | 1995 | 1994 | 1993 |
| 1992 | 1991 | 1990 | 1989 | 1988 | 1987 | 1986 | 1985 | 1984 | 1983 |
| 1982 | 1981 | 1981 | 1981 | 1981 | | | | | |

MOBILE6 Block 1 (LDGV & LDGT1)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 0.800 | 1.247 | 1.247 | 1.247 |
| 1.247 | 1.247 | 1.847 | 1.847 | 1.847 | 1.847 | 1.847 | 1.847 | 1.847 | 2.338 |
| 2.338 | 2.338 | 2.338 | 2.338 | 2.338 | | | | | |

MOBILE6 Block 2 (LDGT2 & LDGT3)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1.195 | 1.195 | 1.195 | 1.195 | 1.195 | 1.195 | 1.195 | 2.200 | 2.200 | 2.200 |
| 2.200 | 2.200 | 2.800 | 2.800 | 2.800 | 2.800 | 2.800 | 2.800 | 2.800 | 5.000 |
| 5.000 | 5.000 | 5.000 | 5.000 | 5.000 | | | | | |

MOBILE6 Block 3 (LDGT4)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.200 | 2.200 | 2.200 |
| 2.200 | 2.200 | 2.800 | 2.800 | 2.800 | 2.800 | 2.800 | 2.800 | 2.800 | 5.000 |
| 5.000 | 5.000 | 5.000 | 5.000 | 5.000 | | | | | |

| Approx. VMT Mix | | | | |
|---|---|---|---|---|
| LDGV | LDGT1 | LDGT2 | LDGT3 | LDGT4 |
| 0.46 | 0.071 | 0.24 | 0.073 | 0.033 |

| Calendar Year |
|---|
| 2002 |

| % Final |
|---|
| 25% |

CO Cutpoints

| | LDGV | | LDGT1 & LDGT2 | | LDGT3 & LDGT4 | |
|---|---|---|---|---|---|---|
| Model Year | Phase-In | Final | Phase-In | Final | Phase-In | Final |
| 1981 | 60.0 | 30.0 | 100.0 | 70.0 | 100.0 | 70.0 |
| 1982 | 60.0 | 30.0 | 100.0 | 70.0 | 100.0 | 70.0 |
| 1983 | 30.0 | 15.0 | 100.0 | 70.0 | 100.0 | 70.0 |
| 1984 | 30.0 | 15.0 | 80.0 | 40.0 | 80.0 | 40.0 |
| 1985 | 30.0 | 15.0 | 80.0 | 40.0 | 80.0 | 40.0 |
| 1986 | 30.0 | 15.0 | 80.0 | 40.0 | 80.0 | 40.0 |
| 1987 | 30.0 | 15.0 | 80.0 | 40.0 | 80.0 | 40.0 |
| 1988 | 30.0 | 15.0 | 80.0 | 40.0 | 80.0 | 40.0 |
| 1989 | 30.0 | 15.0 | 80.0 | 40.0 | 80.0 | 40.0 |
| 1990 | 30.0 | 15.0 | 80.0 | 40.0 | 80.0 | 40.0 |
| 1991 | 20.0 | 15.0 | 60.0 | 40.0 | 60.0 | 40.0 |
| 1992 | 20.0 | 15.0 | 60.0 | 40.0 | 60.0 | 40.0 |
| 1993 | 20.0 | 15.0 | 60.0 | 40.0 | 60.0 | 40.0 |
| 1994 | 20.0 | 15.0 | 60.0 | 40.0 | 60.0 | 40.0 |
| 1995 | 20.0 | 15.0 | 60.0 | 40.0 | 60.0 | 40.0 |
| 1996 | 15.0 | 10.0 | 20.0 | 13.0 | 60.0 | 15.0 |
| 1997+ | same as 1996 | | same as 1996 | | same as 1996 | |

Allowable range in model

| Min | Max |
|---|---|
| 15.00 | 100.0 |

MOBILE6 ages

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | | | | | |

Model year standards applicable to each MOBILE6 age

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1996 | 1996 | 1996 | 1996 | 1996 | 1996 | 1996 | 1995 | 1994 | 1993 |
| 1992 | 1991 | 1990 | 1989 | 1988 | 1987 | 1986 | 1985 | 1984 | 1983 |
| 1982 | 1981 | 1981 | 1981 | 1981 | | | | | |

MOBILE6 Block 1 (LDGV & LDGT1)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15.000 | 15.000 | 15.000 | 15.000 | 15.000 | 15.000 | 15.000 | 23.597 | 23.597 | 23.597 |
| 23.597 | 23.597 | 32.100 | 32.100 | 32.100 | 32.100 | 32.100 | 32.100 | 32.100 | 35.108 |
| 57.848 | 57.848 | 57.848 | 57.848 | 57.848 | | | | | |

MOBILE6 Block 2 (LDGT2 & LDGT3)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 25.363 | 25.363 | 25.363 | 25.363 | 25.363 | 25.363 | 25.363 | 55.000 | 55.000 | 55.000 |
| 55.000 | 55.000 | 70.000 | 70.000 | 70.000 | 70.000 | 70.000 | 70.000 | 70.000 | 92.500 |
| 92.500 | 92.500 | 92.500 | 92.500 | 92.500 | | | | | |

MOBILE6 Block 3 (LDGT4)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 48.750 | 48.750 | 48.750 | 48.750 | 48.750 | 48.750 | 48.750 | 55.000 | 55.000 | 55.000 |
| 55.000 | 55.000 | 70.000 | 70.000 | 70.000 | 70.000 | 70.000 | 70.000 | 70.000 | 92.500 |
| 92.500 | 92.500 | 92.500 | 92.500 | 92.500 | | | | | |

| Approx. VMT Mix | | | | |
|---|---|---|---|---|
| LDGV | LDGT1 | LDGT2 | LDGT3 | LDGT4 |
| 0.46 | 0.071 | 0.24 | 0.073 | 0.033 |

| Calendar Year |
|---|
| 2002 |

| % Final |
|---|
| 25% |

$NO_x$ Cutpoints

| Model Year | LDGV | | LDGT1 & LDGT2 | | LDGT3 & LDGT4 | |
|---|---|---|---|---|---|---|
| | Phase-In | Final | Phase-In | Final | Phase-In | Final |
| 1981 | 3.0 | 2.0 | 7.0 | 4.5 | 7.0 | 4.5 |
| 1982 | 3.0 | 2.0 | 7.0 | 4.5 | 7.0 | 4.5 |
| 1983 | 3.0 | 2.0 | 7.0 | 4.5 | 7.0 | 4.5 |
| 1984 | 3.0 | 2.0 | 7.0 | 4.5 | 7.0 | 4.5 |
| 1985 | 3.0 | 2.0 | 7.0 | 4.5 | 7.0 | 4.5 |
| 1986 | 3.0 | 2.0 | 7.0 | 4.5 | 7.0 | 4.5 |
| 1987 | 3.0 | 2.0 | 7.0 | 4.5 | 7.0 | 4.5 |
| 1988 | 3.0 | 2.0 | 3.5 | 2.5 | 5.0 | 3.5 |
| 1989 | 3.0 | 2.0 | 3.5 | 2.5 | 5.0 | 3.5 |
| 1990 | 3.0 | 2.0 | 3.5 | 2.5 | 5.0 | 3.5 |
| 1991 | 2.5 | 2.0 | 3.0 | 2.5 | 4.5 | 3.5 |
| 1992 | 2.5 | 2.0 | 3.0 | 2.5 | 4.5 | 3.5 |
| 1993 | 2.5 | 2.0 | 3.0 | 2.5 | 4.5 | 3.5 |
| 1994 | 2.5 | 2.0 | 3.0 | 2.5 | 4.5 | 3.5 |
| 1995 | 2.5 | 2.0 | 3.0 | 2.5 | 4.5 | 3.5 |
| 1996 | 2.0 | 1.5 | 2.5 | 1.8 | 4.0 | 2.0 |
| 1997+ | same as 1996 | | same as 1996 | | same as 1996 | |

| Allowable range in model | |
|---|---|
| Min | Max |
| 2.00 | 4.5 |

MOBILE6 ages

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
| 20 | 21 | 22 | 23 | 24 | | | | | |

Model year standards applicable to each MOBILE6 age

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1996 | 1996 | 1996 | 1996 | 1996 | 1996 | 1996 | 1995 | 1994 | 1993 |
| 1992 | 1991 | 1990 | 1989 | 1988 | 1987 | 1986 | 1985 | 1984 | 1983 |
| 1982 | 1981 | 1981 | 1981 | 1981 | | | | | |

MOBILE6 Block 1 (LDGV & LDGT1)

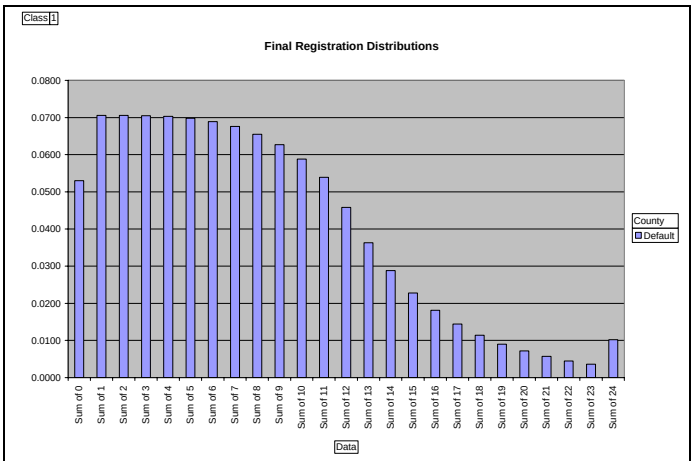
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.000 | 2.442 | 2.442 | 2.442 |
| 2.442 | 2.442 | 2.817 | 2.817 | 2.817 | 3.235 | 3.235 | 3.235 | 3.235 | 3.235 |
| 3.235 | 3.235 | 3.235 | 3.235 | 3.235 | | | | | |

MOBILE6 Block 2 (LDGT2 & LDGT3)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.599 | 2.599 | 2.599 | 2.599 | 2.599 | 2.599 | 2.599 | 3.196 | 3.196 | 3.196 |
| 3.196 | 3.196 | 3.571 | 3.571 | 3.571 | 4.500 | 4.500 | 4.500 | 4.500 | 4.500 |
| 4.500 | 4.500 | 4.500 | 4.500 | 4.500 | | | | | |

MOBILE6 Block 3 (LDGT4)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.500 | 3.500 | 3.500 | 3.500 | 3.500 | 3.500 | 3.500 | 4.250 | 4.250 | 4.250 |
| 4.250 | 4.250 | 4.500 | 4.500 | 4.500 | 4.500 | 4.500 | 4.500 | 4.500 | 4.500 |
| 4.500 | 4.500 | 4.500 | 4.500 | 4.500 | | | | | |




**(a)**

Key to Figures

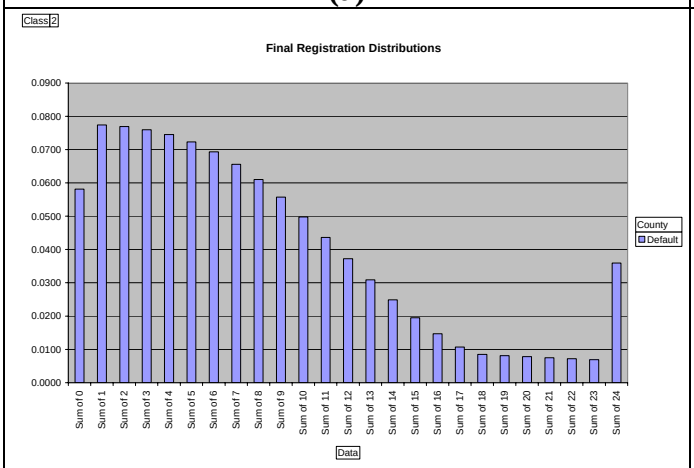
Y-axis: Fraction of total fleet in the indicated age bin

X-axis: Vehicle age from <1 year to ≥ 24 years

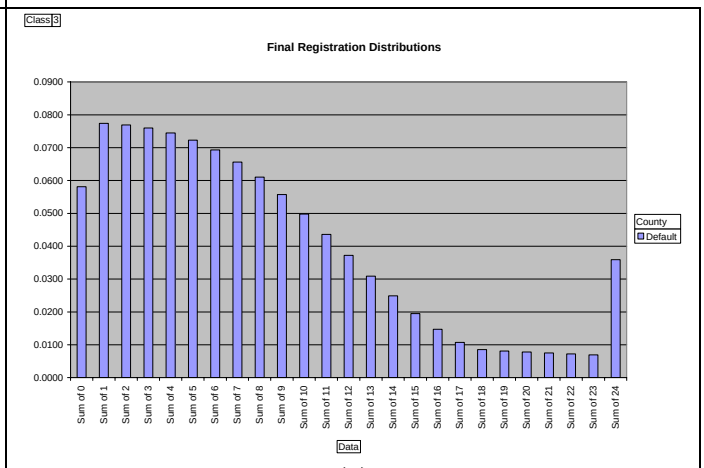
**Gross vehicle weight rating (GVWR)** equals the total weight of the vehicle including its curb (empty) weight, fluids, driver and the maximum recommended payload.

**Adjusted loaded vehicle weight (ALVW)** is the numerical average of the vehicle curb weight and the gross vehicle weight rating (GVWR).

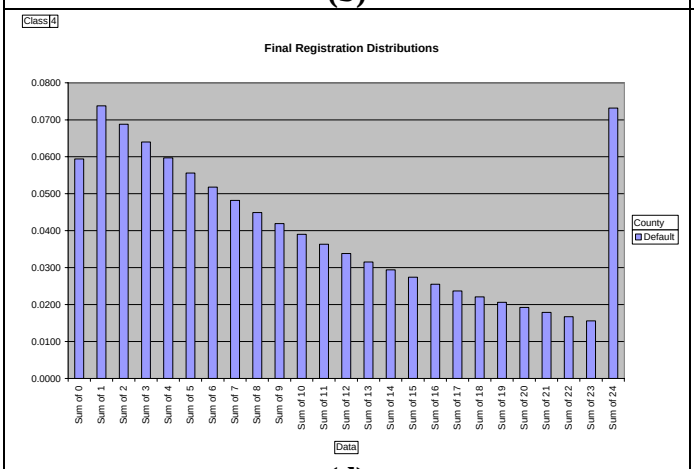
**Loaded vehicle weight (LVW)** is the curb weight of the vehicle plus 300 lbs., which is intended to correspond to the weight of a driver plus incidental payload.



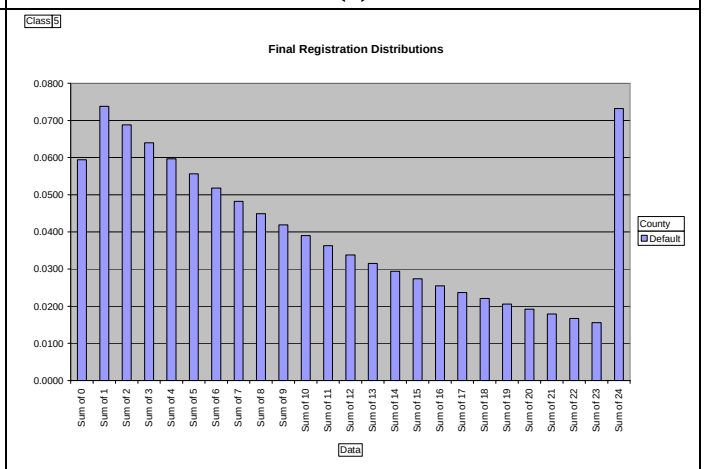

**(b)**




**(c)**



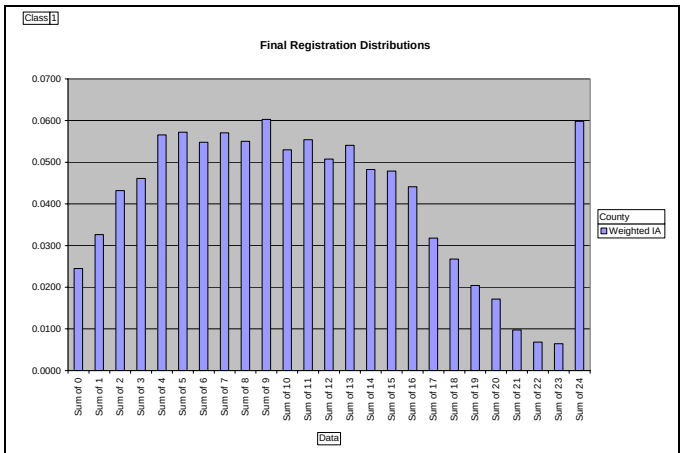

**(d)**




**(e)**

Age distributions of vehicle fleets corresponding to the **MOBILE6 defaults** for:

(a) Light-Duty Vehicles (Passenger Cars)
(b) Light-Duty Trucks, Class 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
(c) Light Duty Trucks, Class 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
(d) Light Duty Trucks, Class 3 (6,001-8500 lbs. GVWR, 0-5750 lbs. ALVW)
(e) Light Duty Trucks, Class 4 (6,001-8500 lbs. GVWR, >5750 lbs. ALVW)



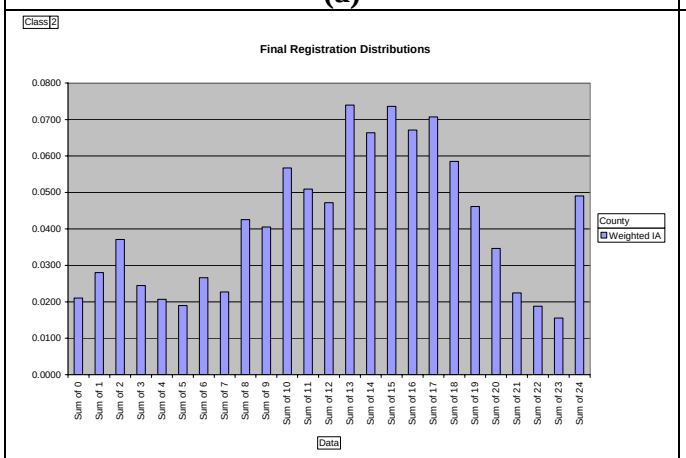

**(a)**

Key to Figures

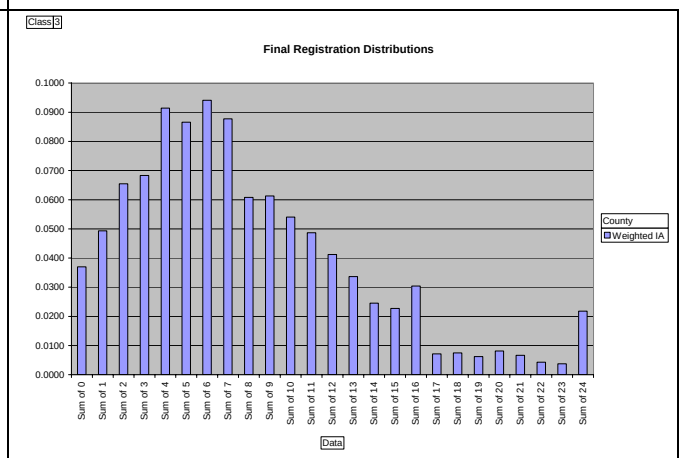
Y-axis: Fraction of total fleet in the indicated age bin

X-axis: Vehicle age from <1 year to ≥ 24 years

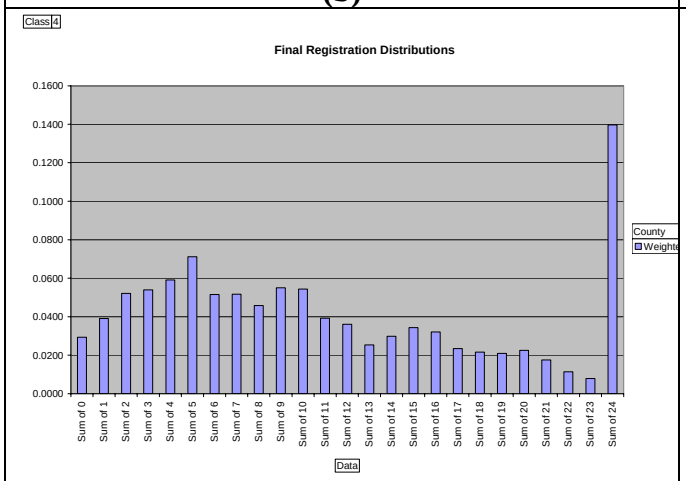
**Gross vehicle weight rating (GVWR)** equals the total weight of the vehicle including its curb (empty) weight, fluids, driver and the maximum recommended payload.
**Adjusted loaded vehicle weight (ALVW)** is the numerical average of the vehicle curb weight and the gross vehicle weight rating (GVWR).
**Loaded vehicle weight (LVW)** is the curb weight of the vehicle plus 300 lbs., which is intended to correspond to the weight of a driver plus incidental payload.



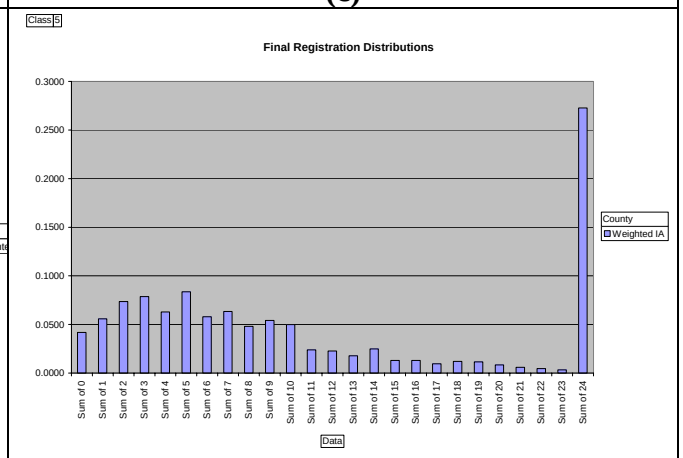

**(b)**




**(c)**



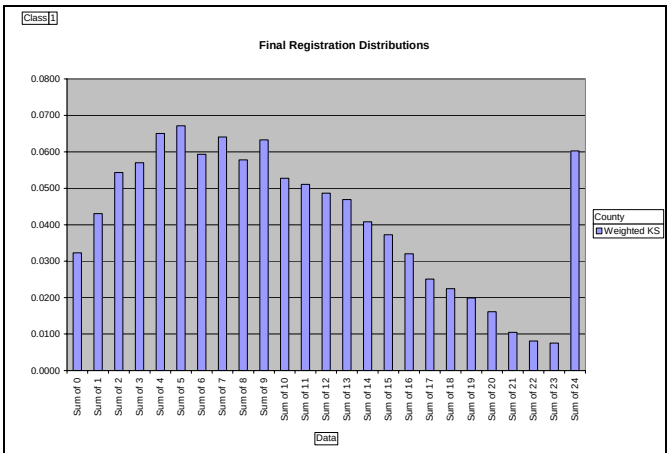

**(d)**




**(e)**

Weighted-average age distributions of vehicle fleets for **<u>Iowa</u>** and for the following vehicle classes:

(a) Light-Duty Vehicles (Passenger Cars)
(b) Light-Duty Trucks, Class 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
(c) Light Duty Trucks, Class 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
(d) Light Duty Trucks, Class 3 (6,001-8500 lbs. GVWR, 0-5750 lbs. ALVW)
(e) Light Duty Trucks, Class 4 (6,001-8500 lbs. GVWR, >5750 lbs. ALVW)



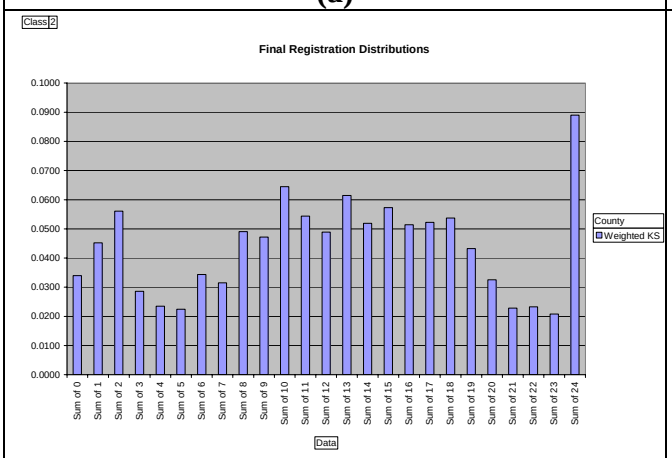

**(a)**

Key to Figures

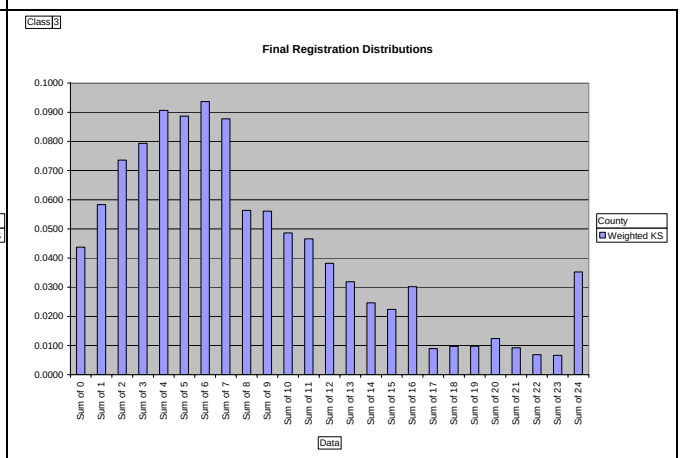
Y-axis: Fraction of total fleet in the indicated age bin

X-axis: Vehicle age from <1 year to ≥ 24 years

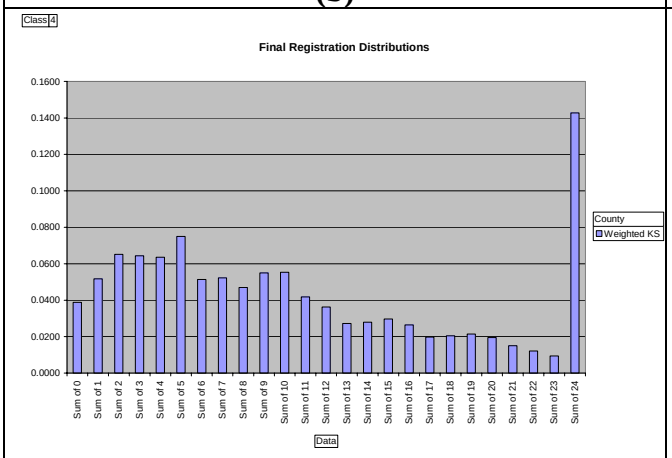
**Gross vehicle weight rating (GVWR)** equals the total weight of the vehicle including its curb (empty) weight, fluids, driver and the maximum recommended payload.
**Adjusted loaded vehicle weight (ALVW)** is the numerical average of the vehicle curb weight and the gross vehicle weight rating (GVWR).
**Loaded vehicle weight (LVW)** is the curb weight of the vehicle plus 300 lbs., which is intended to correspond to the weight of a driver plus incidental payload.



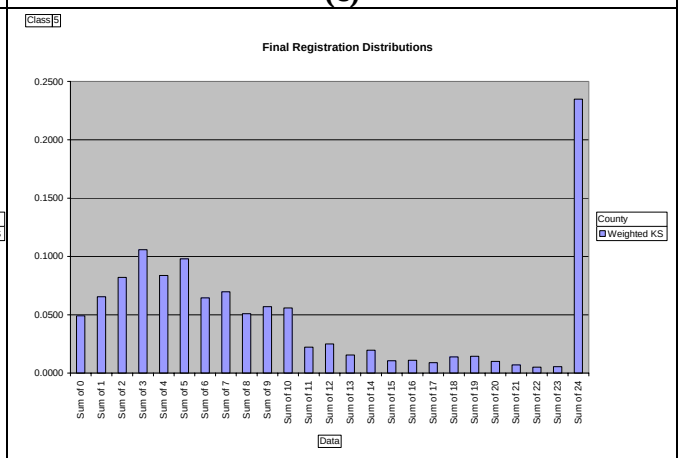

**(b)**




**(c)**



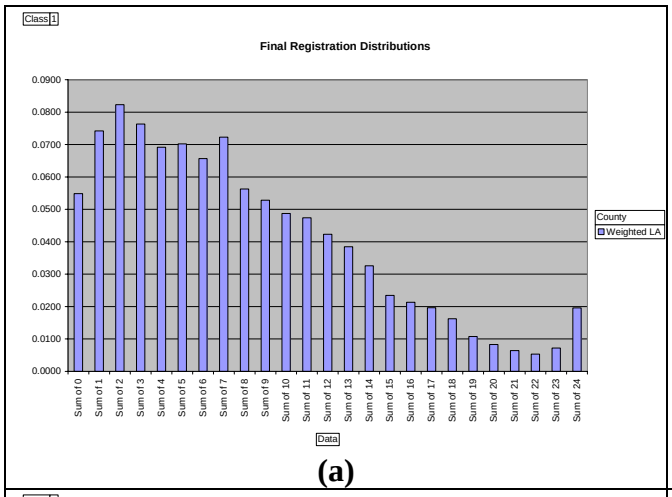

**(d)**




**(e)**

Weighted-average age distributions of vehicle fleets for **Kansas** and for the following vehicle classes:

(a) Light-Duty Vehicles (Passenger Cars)
(b) Light-Duty Trucks, Class 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
(c) Light Duty Trucks, Class 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
(d) Light Duty Trucks, Class 3 (6,001-8500 lbs. GVWR, 0-5750 lbs. ALVW)
(e) Light Duty Trucks, Class 4 (6,001-8500 lbs. GVWR, >5750 lbs. ALVW)




**(a)**

Key to Figures

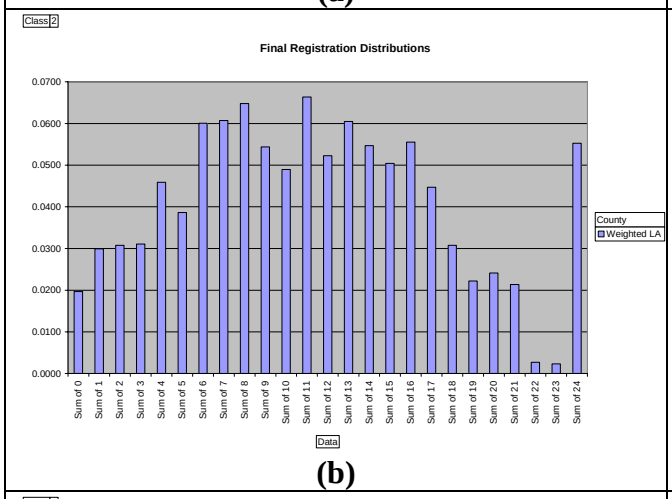
Y-axis: Fraction of total fleet in the indicated age bin

X-axis: Vehicle age from <1 year to ≥ 24 years

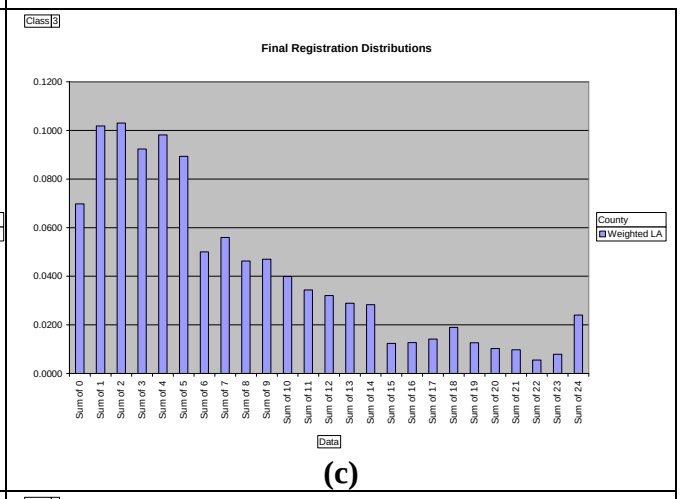
**Gross vehicle weight rating (GVWR)** equals the total weight of the vehicle including its curb (empty) weight, fluids, driver and the maximum recommended payload.

**Adjusted loaded vehicle weight (ALVW)** is the numerical average of the vehicle curb weight and the gross vehicle weight rating (GVWR).

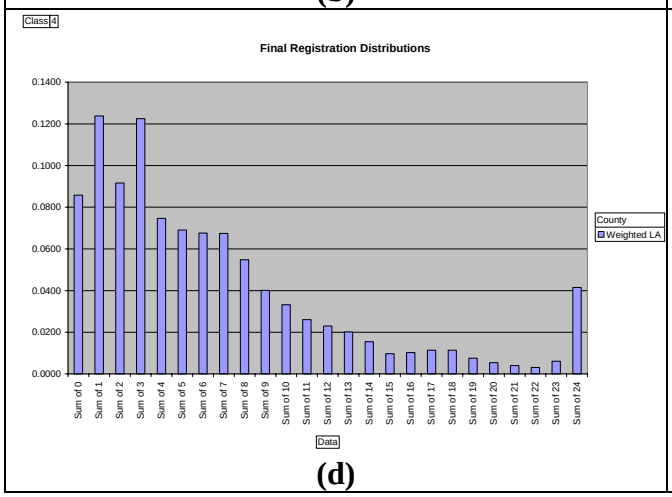
**Loaded vehicle weight (LVW)** is the curb weight of the vehicle plus 300 lbs., which is intended to correspond to the weight of a driver plus incidental payload.



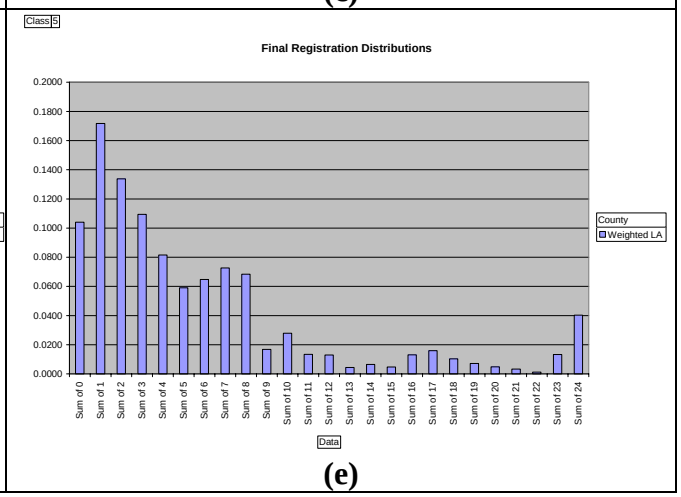

**(b)**




**(c)**



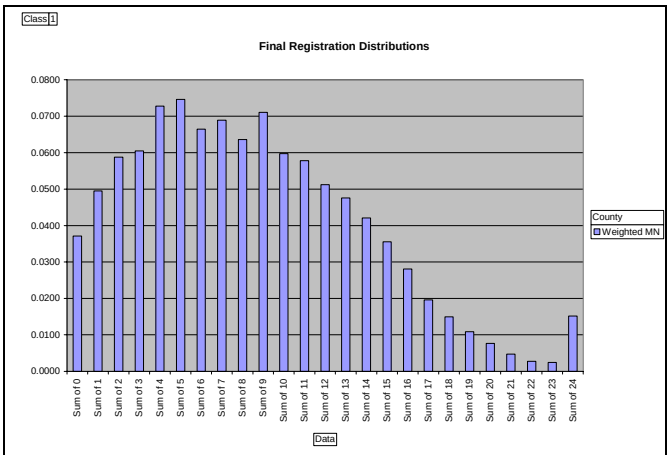

**(d)**




**(e)**

Weighted-average age distributions of vehicle fleets for **Louisiana** and for the following vehicle classes:

(a) Light-Duty Vehicles (Passenger Cars)
(b) Light-Duty Trucks, Class 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
(c) Light Duty Trucks, Class 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
(d) Light Duty Trucks, Class 3 (6,001-8500 lbs. GVWR, 0-5750 lbs. ALVW)
(e) Light Duty Trucks, Class 4 (6,001-8500 lbs. GVWR, >5750 lbs. ALVW)




**(a)**

Key to Figures

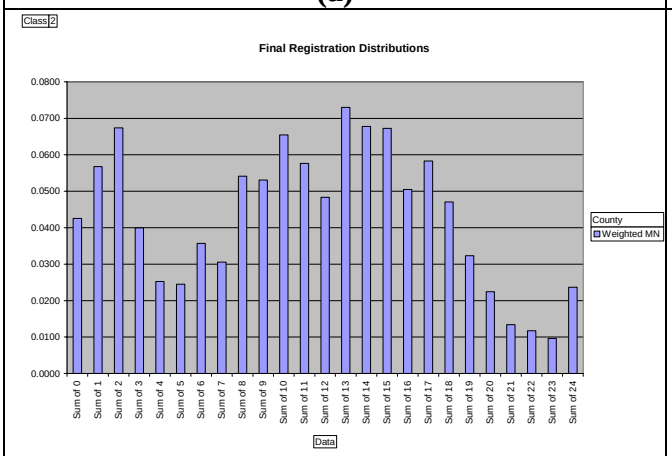
Y-axis: Fraction of total fleet in the indicated age bin

X-axis: Vehicle age from <1 year to ≥ 24 years

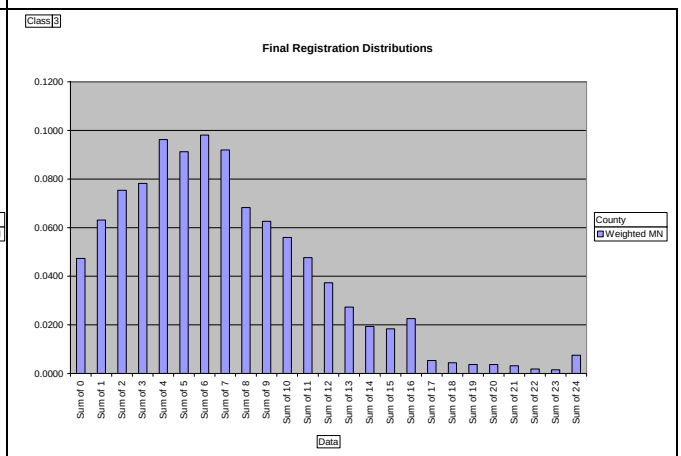
**Gross vehicle weight rating (GVWR)** equals the total weight of the vehicle including its curb (empty) weight, fluids, driver and the maximum recommended payload.

**Adjusted loaded vehicle weight (ALVW)** is the numerical average of the vehicle curb weight and the gross vehicle weight rating (GVWR).

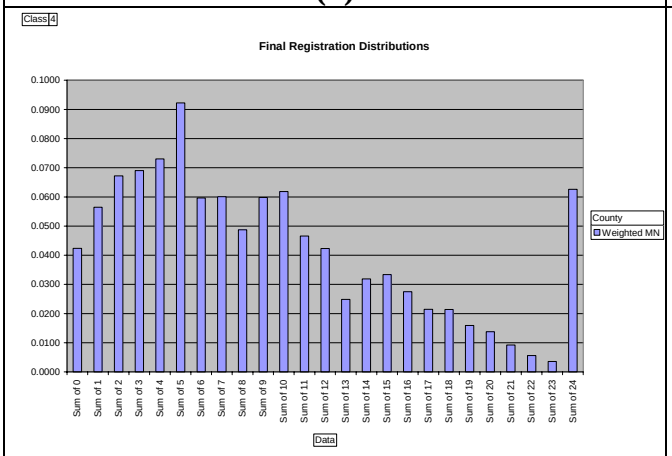
**Loaded vehicle weight (LVW)** is the curb weight of the vehicle plus 300 lbs., which is intended to correspond to the weight of a driver plus incidental payload.



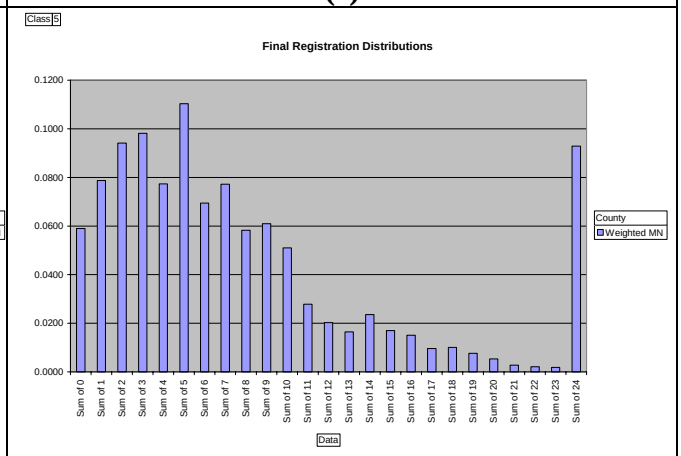

**(b)**




**(c)**



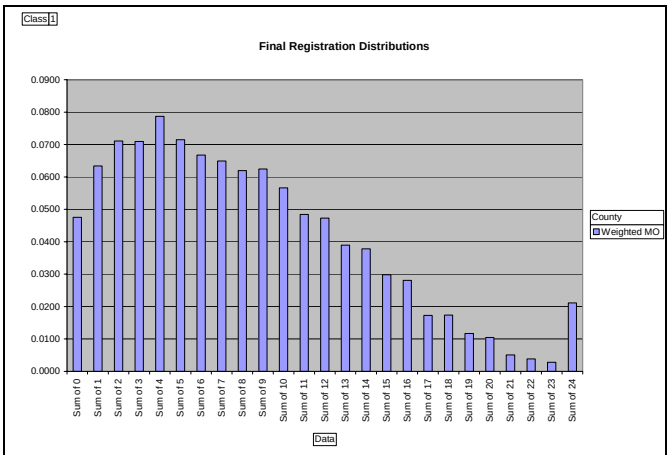

**(d)**




**(e)**

Weighted-average age distributions of vehicle fleets for **Minnesota** and for the following vehicle classes:

(a) Light-Duty Vehicles (Passenger Cars)
(b) Light-Duty Trucks, Class 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
(c) Light Duty Trucks, Class 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
(d) Light Duty Trucks, Class 3 (6,001-8500 lbs. GVWR, 0-5750 lbs. ALVW)
(e) Light Duty Trucks, Class 4 (6,001-8500 lbs. GVWR, >5750 lbs. ALVW)




**(a)**

Key to Figures

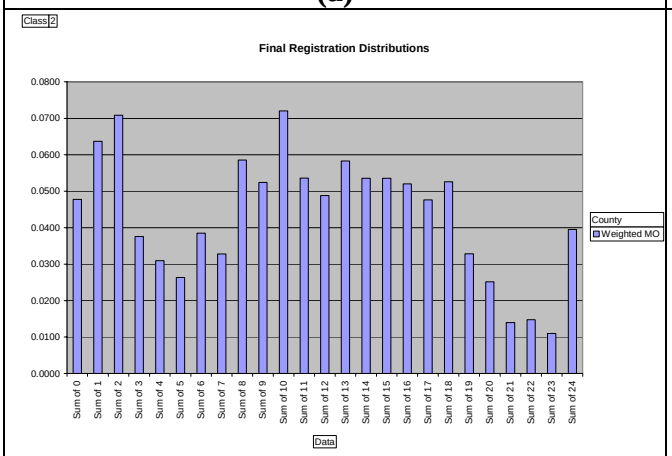
Y-axis: Fraction of total fleet in the indicated age bin

X-axis: Vehicle age from <1 year to ≥ 24 years

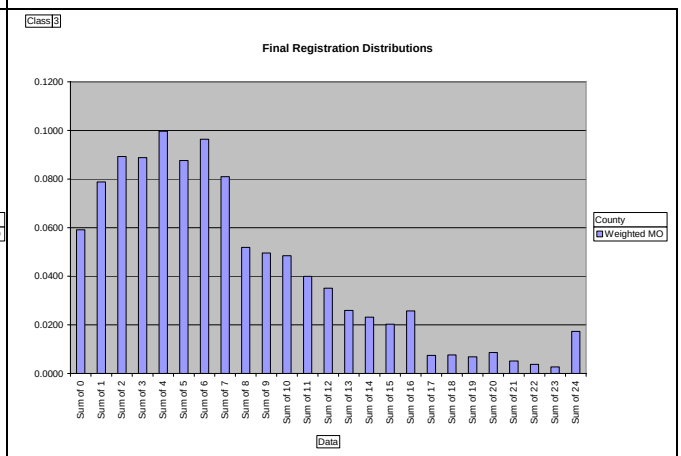
**Gross vehicle weight rating (GVWR)** equals the total weight of the vehicle including its curb (empty) weight, fluids, driver and the maximum recommended payload.

**Adjusted loaded vehicle weight (ALVW)** is the numerical average of the vehicle curb weight and the gross vehicle weight rating (GVWR).

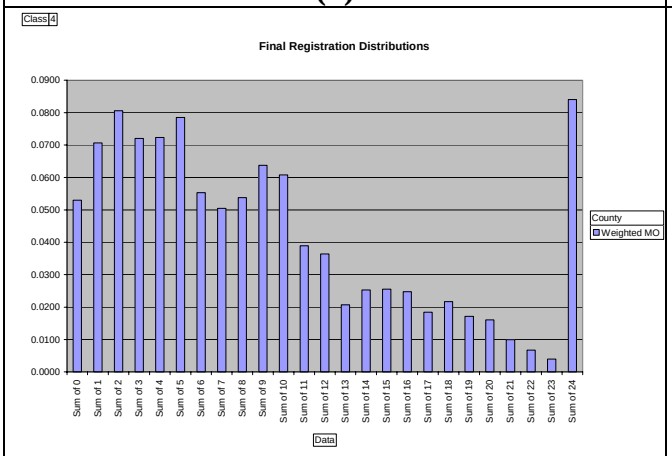
**Loaded vehicle weight (LVW)** is the curb weight of the vehicle plus 300 lbs., which is intended to correspond to the weight of a driver plus incidental payload.



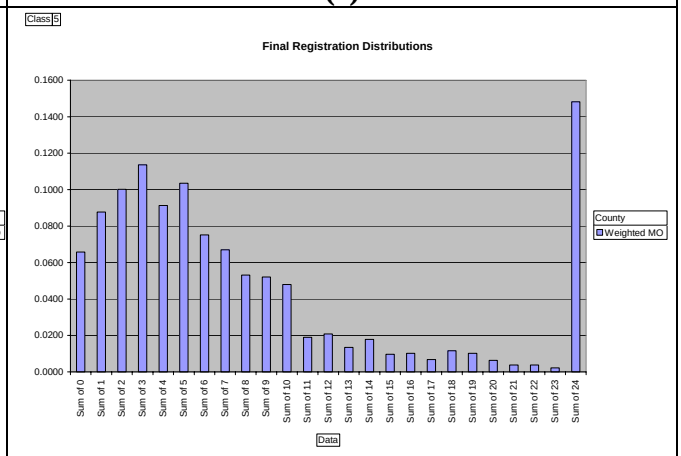

**(b)**




**(c)**



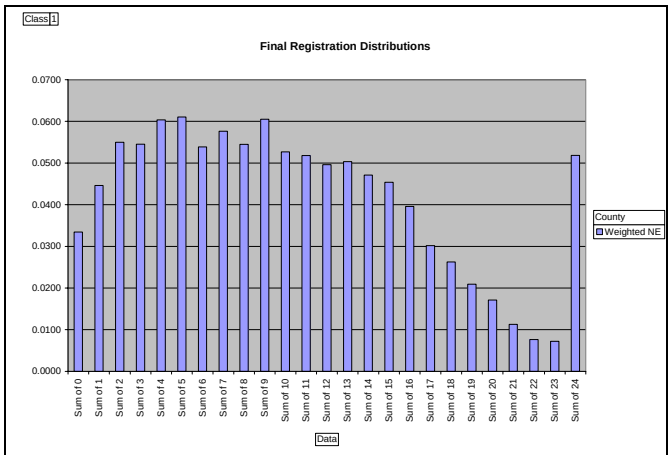

**(d)**




**(e)**

Weighted-average age distributions of vehicle fleets for **Missouri** and for the following vehicle classes:

(a) Light-Duty Vehicles (Passenger Cars)
(b) Light-Duty Trucks, Class 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
(c) Light Duty Trucks, Class 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
(d) Light Duty Trucks, Class 3 (6,001-8500 lbs. GVWR, 0-5750 lbs. ALVW)
(e) Light Duty Trucks, Class 4 (6,001-8500 lbs. GVWR, >5750 lbs. ALVW)



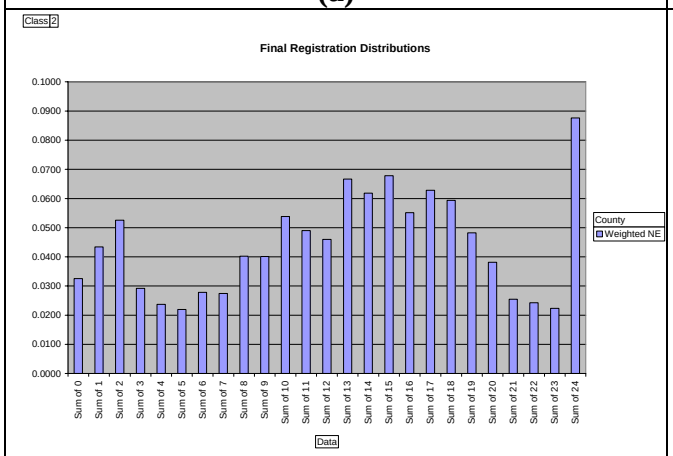

**(a)**

Key to Figures

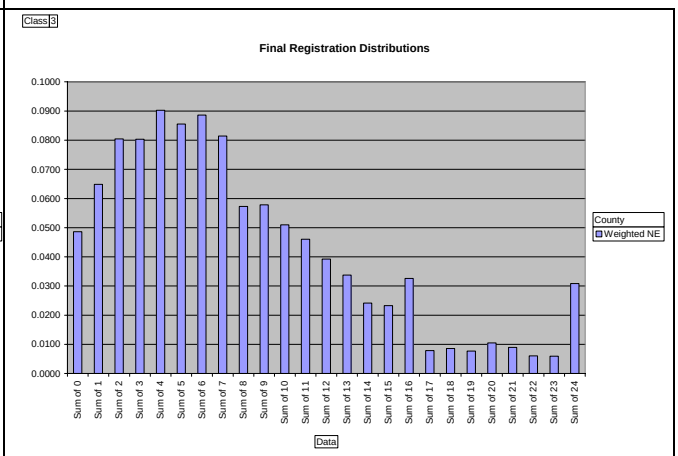
Y-axis: Fraction of total fleet in the indicated age bin

X-axis: Vehicle age from <1 year to ≥ 24 years

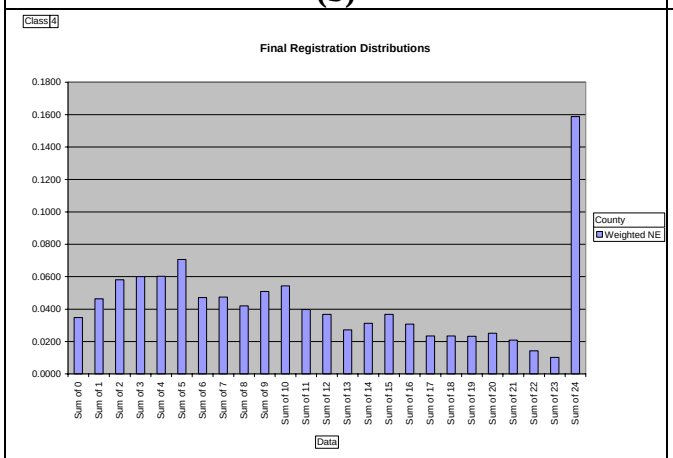
**Gross vehicle weight rating (GVWR)** equals the total weight of the vehicle including its curb (empty) weight, fluids, driver and the maximum recommended payload.
**Adjusted loaded vehicle weight (ALVW)** is the numerical average of the vehicle curb weight and the gross vehicle weight rating (GVWR).
**Loaded vehicle weight (LVW)** is the curb weight of the vehicle plus 300 lbs., which is intended to correspond to the weight of a driver plus incidental payload.



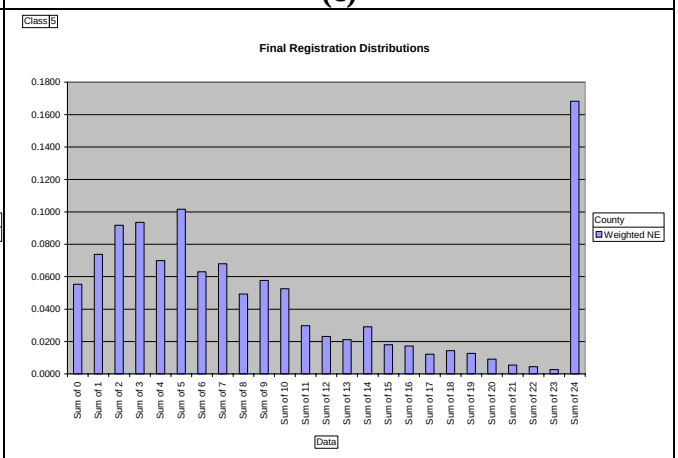

**(b)**




**(c)**



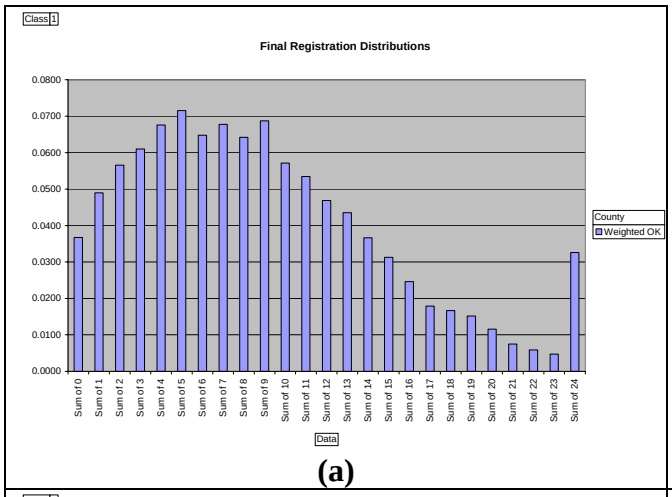

**(d)**




**(e)**

Weighted-average age distributions of vehicle fleets for **Nebraska** and for the following vehicle classes:

(a) Light-Duty Vehicles (Passenger Cars)
(b) Light-Duty Trucks, Class 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
(c) Light Duty Trucks, Class 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
(d) Light Duty Trucks, Class 3 (6,001-8500 lbs. GVWR, 0-5750 lbs. ALVW)
(e) Light Duty Trucks, Class 4 (6,001-8500 lbs. GVWR, >5750 lbs. ALVW)




**(a)**

Key to Figures

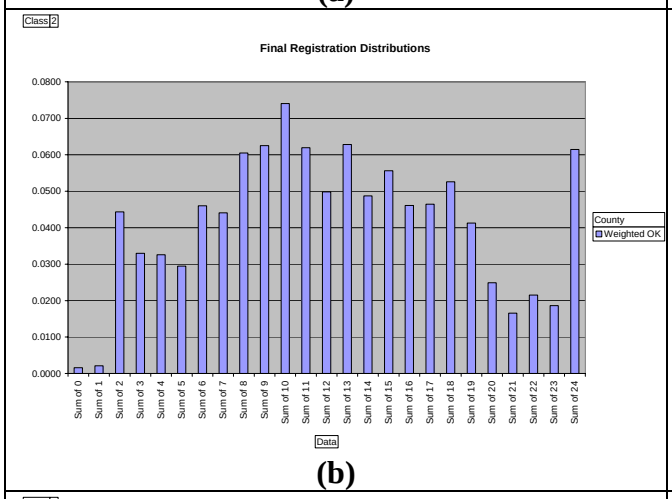
Y-axis: Fraction of total fleet in the indicated age bin

X-axis: Vehicle age from <1 year to ≥ 24 years

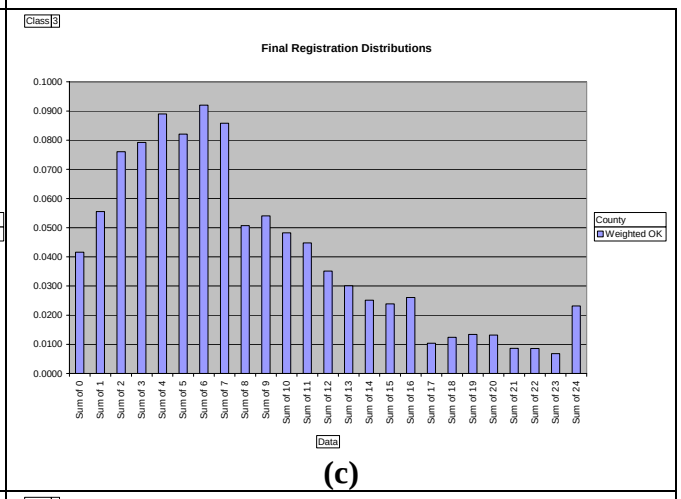
**Gross vehicle weight rating (GVWR)** equals the total weight of the vehicle including its curb (empty) weight, fluids, driver and the maximum recommended payload.

**Adjusted loaded vehicle weight (ALVW)** is the numerical average of the vehicle curb weight and the gross vehicle weight rating (GVWR).

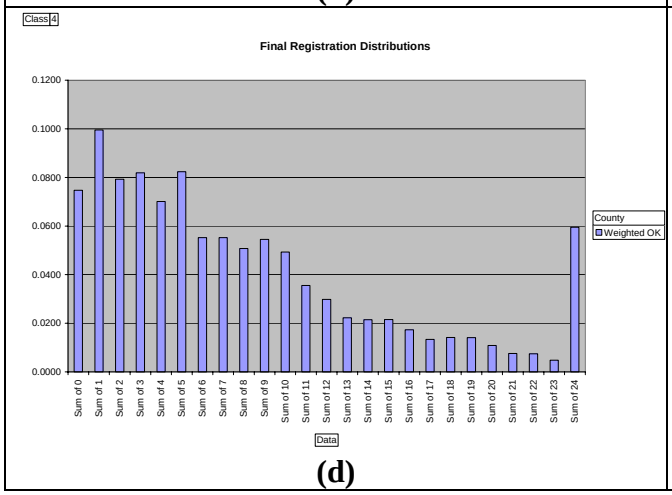
**Loaded vehicle weight (LVW)** is the curb weight of the vehicle plus 300 lbs., which is intended to correspond to the weight of a driver plus incidental payload.



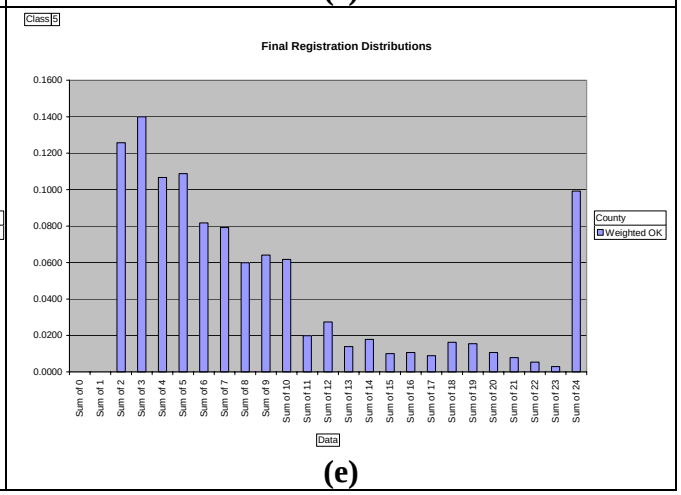

**(b)**




**(c)**



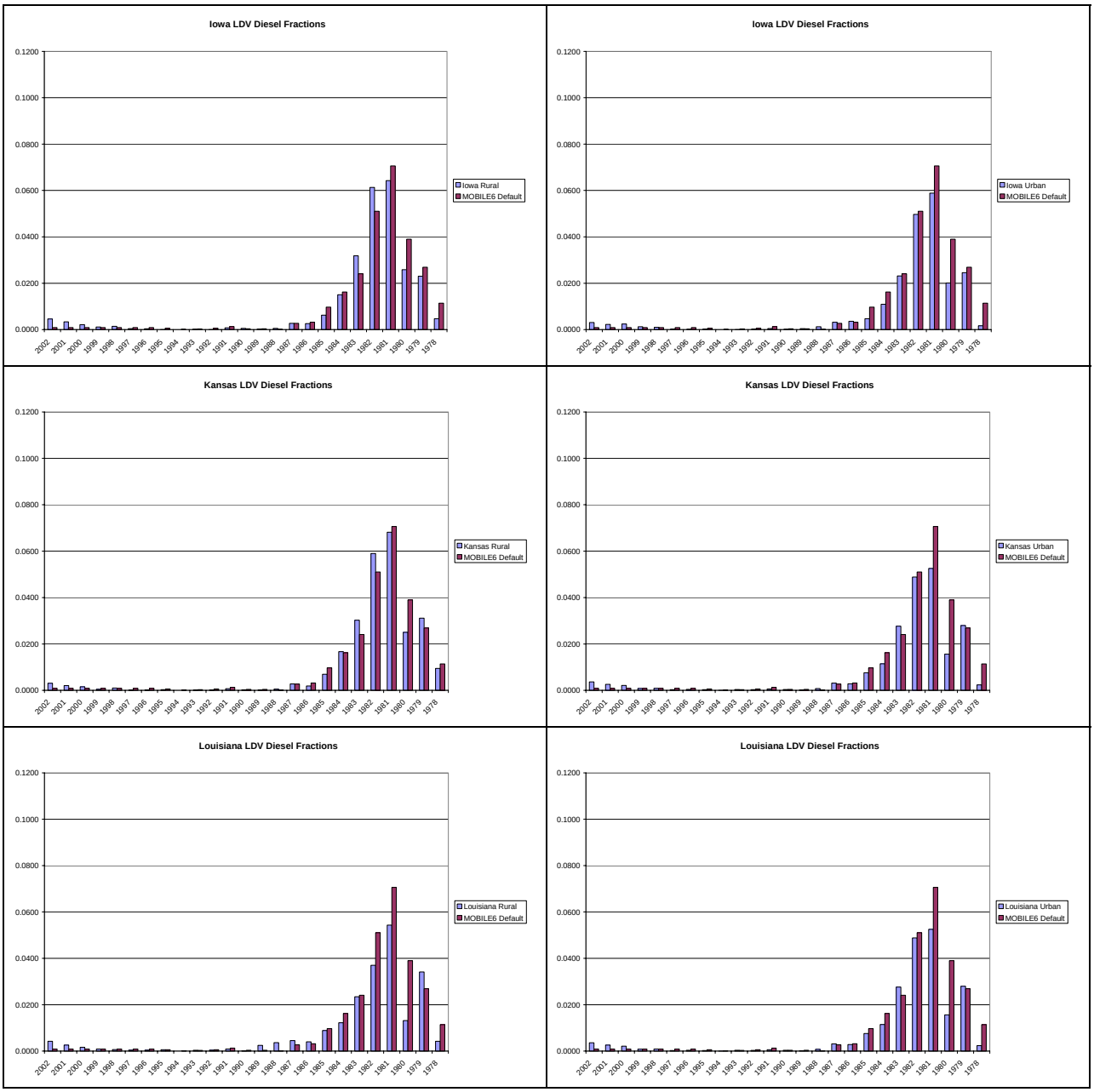

**(d)**




**(e)**

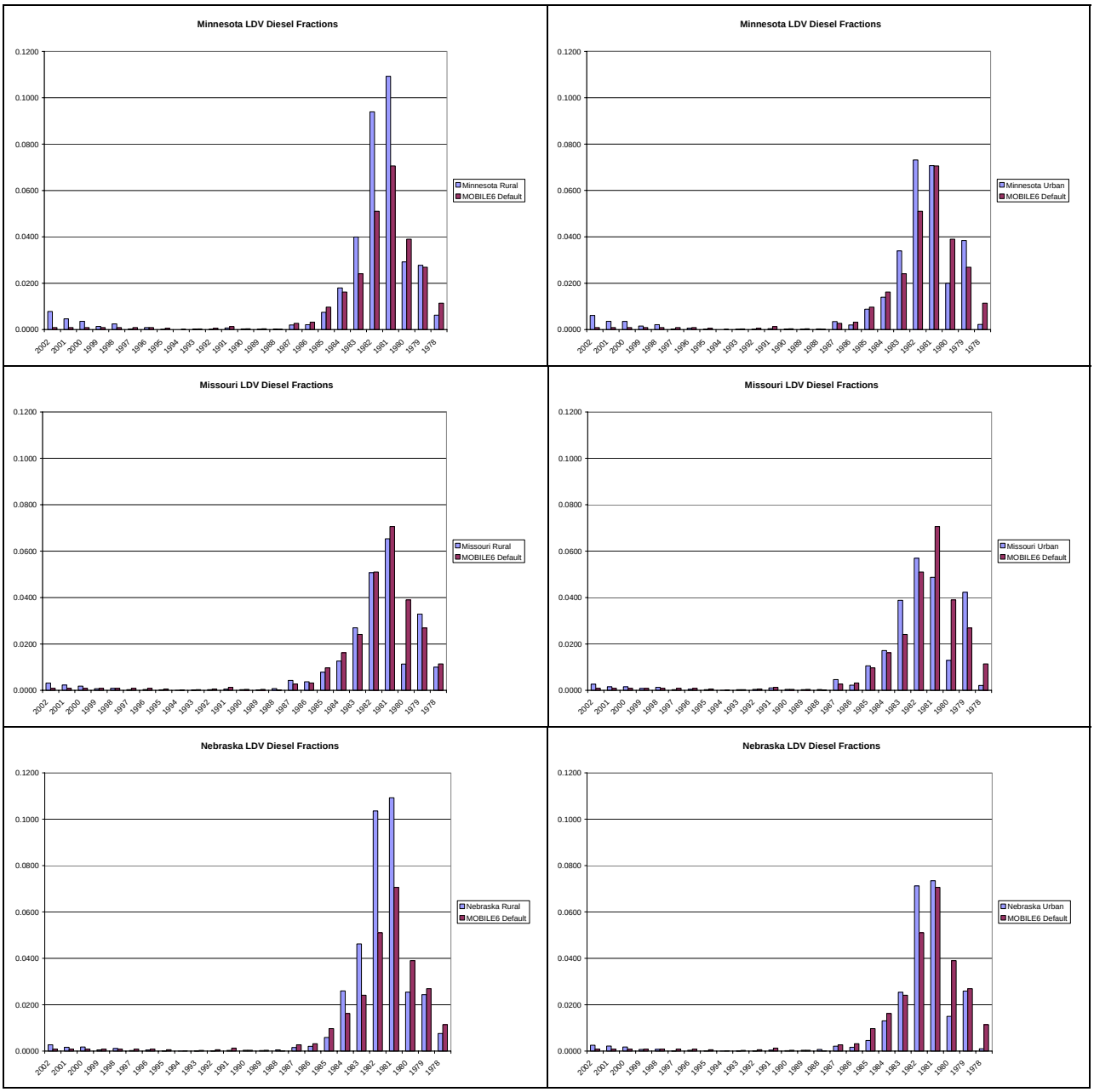
Weighted-average age distributions of vehicle fleets for **Oklahoma** and for the following vehicle classes:

(a) Light-Duty Vehicles (Passenger Cars)
(b) Light-Duty Trucks, Class 1 (0-6,000 lbs. GVWR, 0-3750 lbs. LVW)
(c) Light Duty Trucks, Class 2 (0-6,001 lbs. GVWR, 3751-5750 lbs. LVW)
(d) Light Duty Trucks, Class 3 (6,001-8500 lbs. GVWR, 0-5750 lbs. ALVW)
(e) Light Duty Trucks, Class 4 (6,001-8500 lbs. GVWR, >5750 lbs. ALVW)



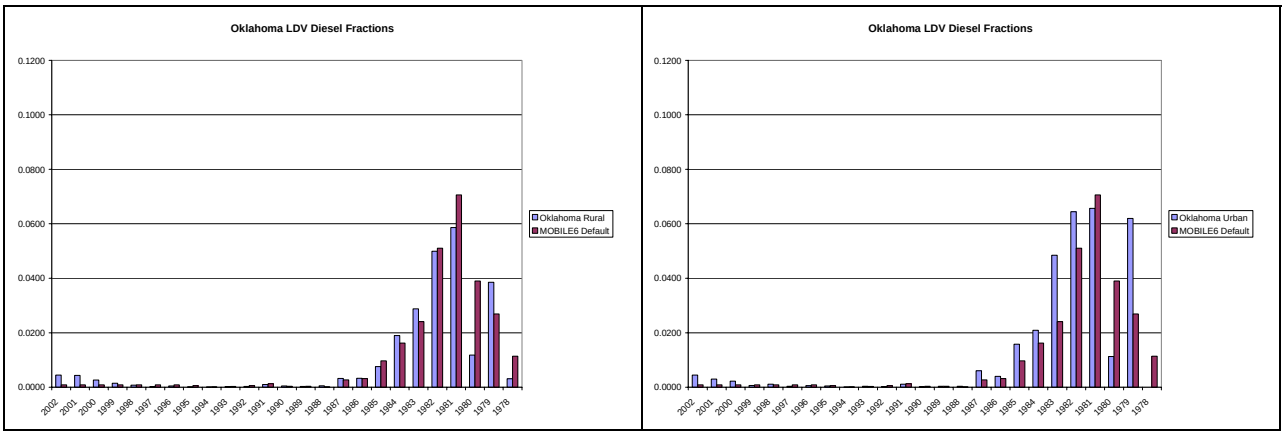

Fractions of the light-duty vehicle fleet that are diesel-powered vehicles for the rural (left) and urban (right) areas of the states of Iowa, Kansas, and Louisiana. The diesel fractions corresponding to MOBILE6 defaults are plotted for comparison on each chart.

<u>Key to Figures:</u>
Y-axis: Fraction of the total fleet that is comprised of diesel-powered vehicles
X-axis: Vehicle age from <1 to ≥24 years

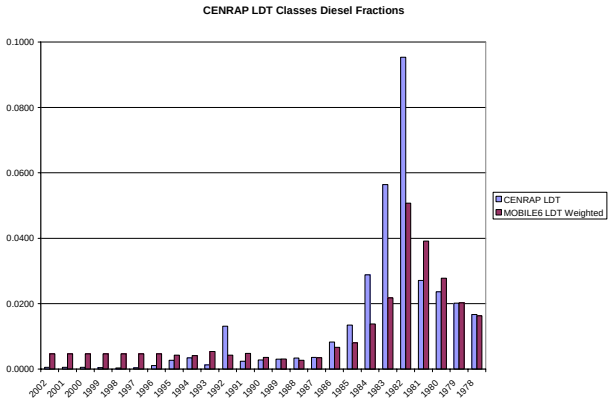



Fractions of the light-duty vehicle fleet that are diesel-powered vehicles for the rural (left) and urban (right) areas of the states of Minnesota, Missouri, and Nebraska. The diesel fractions corresponding to MOBILE6 defaults are plotted for comparison on each chart.

<u>Key to Figures:</u>
Y-axis: Fraction of the total fleet that is comprised of diesel-powered vehicles
X-axis: Vehicle age from <1 to ≥24 years




Fractions of the light-duty vehicle fleet that are diesel-powered vehicles for the rural (left) and urban (right) areas of the state of Oklahoma. The diesel fractions corresponding to MOBILE6 defaults are plotted for comparison on each chart.




Fractions of the light-duty truck fleet that are diesel powered in the CENRAP region. The diesel fractions corresponding to MOBILE6 defaults are plotted for comparison.

<u>Key to Figures:</u>
Y-axis: Fraction of the total fleet that is comprised of diesel-powered vehicles
X-axis: Vehicle age from <1 to ≥24 years