Chapter 1: Health and Welfare Concerns

The engines and vehicles that would be subject to the standards in this final rule generate emissions of HC, NOx, CO, PM and air toxics. They contribute to ozone and CO nonattainment and to adverse health effects associated with ambient concentrations of PM and air toxics. They also contribute to visibility impairment in Class I areas and in other areas where people live, work, and recreate. This chapter presents our estimates of the contribution these engines make to our national air inventory. We include in this chapter estimates of pre- and post-control contributions. These estimates are described in greater detail in Chapter 6.

This chapter also describes the health and environmental effects related to these emissions. These pollutants cause a range of adverse health and welfare effects, especially in terms of respiratory impairment and related illnesses and visibility impairment both in Class I areas and in areas where people live, work and recreate. Air quality modeling and monitoring data presented in this chapter indicate that a large number of our citizens continue to be affected by these emissions.

1.1 Inventory Contributions

1.1.1 Inventory Contribution

The contribution of emissions from the nonroad engines and vehicles that would be subject to the standards to the national inventories of pollutants that are associated with the health and public welfare effects described in this chapter are considerable. To estimate nonroad engine and vehicle emission contributions, we used the latest version of our NONROAD emissions model. This model computes nationwide, state, and county emission levels for a wide variety of nonroad engines, and uses information on emission rates, operating data, and population to determine annual emission levels of various pollutants. A more detailed description of the model and our estimation methodology can be found in the Chapter 6 of this document.

Baseline emission inventory estimates for the year 2000 for the categories of engines and vehicles covered by this rulemaking are summarized in Table 1.1-1. This table show the relative contributions of the different mobile-source categories to the overall national mobile-source inventory. Of the total emissions from mobile sources, the categories of engines and vehicles covered by this rulemaking contribute about 9 percent, 3 percent, 4 percent, and 2 percent of HC, NOx, CO, and PM emissions, respectively, in the year 2000. The results for large SI engines indicate they contribute approximately 2 to 3 percent to HC, NOx, and CO emissions from mobile sources. The results for land-based recreational engines reflect the impact of the significantly different emissions characteristics of two-stroke engines. These engines are estimated to contribute about 6 percent of HC emissions and 2 percent of CO from mobile sources. Recreational CI marine contribute less than 1 percent to NOx mobile source inventories. When only nonroad emissions are considered, the engines and vehicles that would be subject to the standards would account for a larger share.

Our emission projections for 2020 and 2030 for the nonroad engines and vehicles subject to this rulemaking show that emissions from these categories are expected to increase over time if left uncontrolled. The projections for 2020 and 2030 are summarized in Tables 1.1-2 and 1.1-3, respectively. The projections for 2020 and 2030 indicate that the categories of engines and vehicles covered by this rulemaking are expected to contribute approximately 25 percent, 10 percent, 5 percent, and 5 percent of HC, NOx, CO, and PM emissions, respectively. Population growth and the effects of other regulatory control programs are factored into these projections. The relative importance of uncontrolled nonroad engines is higher than the projections for 2000 because there are already emission control programs in place for the other categories of mobile sources which are expected to reduce their emission levels. The effectiveness of all control programs is offset by the anticipated growth in engine populations.

Table 1.1-1
Modeled Annual Emission Levels for
Mobile-Source Categories in 2000 (thousand short tons)

Category	NOx		HC		CO		PM	
	1000 tons	percent of mobile source	1000 tons	percent of mobile source	1000 tons	percent of mobile source	1000 tons	percent of mobile source
Total for engines subject to today's standards*	**351**	**2.6%**	**645**	**8.8%**	**2,860**	**3.8%**	**14.6**	**2.1%**
Highway Motorcycles	8	0.1%	84	1.2%	331	0.4%	0.4	0.1%
Nonroad Industrial SI > 19 kW*	308	2.3%	226	3.1%	1,734	2.3%	1.6	0.2%
Recreational SI*	5	0.0%	418	5.7%	1,120	1.5%	12.0	1.7%
Recreational Marine CI*	38	0.3%	1	0.0%	6	0.0%	1	0.1%
Marine SI Evap	0	0.0%	100	1.4%	0	0.0%	0	0.0%
Marine SI Exhaust	32	0.2%	708	9.7%	2,144	2.8%	38	5.4%
Nonroad SI < 19 kW	106	0.8%	1,460	20.0%	18,359	24.3%	50	7.1%
Nonroad CI	2,625	19.5%	316	4.3%	1,217	1.6%	253	35.9%
Commercial Marine CI	963	7.2%	30	0.4%	127	0.2%	41	5.8%
Locomotive	1,192	8.9%	47	0.6%	119	0.2%	30	4.3%
Total Nonroad	5,269	39%	3,305	45%	24,826	33%	427	60%
Total Highway	7,981	59%	3,811	52%	49,813	66%	240	34%
Aircraft	178	1%	183	3%	1,017	1%	39	6%
Total Mobile Sources	13,428	100%	7,300	100%	75,656	100%	706	100%
Total Man-Made Sources	24,532	--	18,246	--	97,735	--	3,102	--
Mobile Source percent of Total Man-Made Sources	55%	--	40%	--	77%	--	23%	–

Table 1.1-2
Modeled Annual Emission Levels for
Mobile-Source Categories in 2020 (thousand short tons)

Category	NOx		HC		CO		PM	
	1000 tons	percent of mobile source	1000 tons	percent of mobile source	1000 tons	percent of mobile source	1000 tons	percent of mobile source
Total for engines subject to today's standards*	547	8.8%	1,305	24.1%	4,866	5.6%	34.1	5.2%
Highway Motorcycles	14	0.2%	142	2.6%	572	0.7%	0.8	0.1%
Nonroad Industrial SI > 19 kW*	472	7.6%	318	5.9%	2,336	2.7%	2.3	0.4%
Recreational SI*	14	0.2%	985	18.2%	2,521	2.9%	30.2	4.6%
Recreational Marine CI*	61	1.0%	2	0.0%	9	0.0%	1.6	0.2%
Marine SI Evap	0	0.0%	114	2.1%	0	0.0%	0	0.0%
Marine SI Exhaust	58	0.9%	284	5.2%	1,985	2.3%	28	4.3%
Nonroad SI < 19 kW	106	1.7%	986	18.2%	27,352	31.7%	77	11.8%
Nonroad CI	1,791	28.8%	142	2.6%	1,462	1.7%	261	40.0%
Commercial Marine CI	819	13.2%	35	0.6%	160	0.2%	46	7.0%
Locomotive	611	9.8%	35	0.6%	119	0.1%	21	3.2%
Total Nonroad	3,932	63%	2,901	54%	35,944	42%	467	71%
Total Highway	2,050	33%	2,276	42%	48,906	56%	145	22%
Aircraft	232	4%	238	4%	1,387	2%	43	7%
Total Mobile Sources	6,214	100%	5,415	100%	86,237	100%	655	100%
Total Man-Made Sources	16,190	--	15,475	--	109,905	--	3,039	--
Mobile Source percent of Total Man-Made Sources	38%	--	35%	--	79%	--	22%	–

Table 1.1-3
Modeled Annual Emission Levels for
Mobile-Source Categories in 2030 (thousand short tons)

Category	NOx		HC		CO		PM	
	1000 tons	percent of mobile source	1000 tons	percent of mobile source	1000 tons	percent of mobile source	1000 tons	percent of mobile source
Total for engines subject to today's standards*	640	10.0%	1,411	23.5%	5,363	5.4%	36.5	4.8%
Highway Motorcycles	17	0.3%	172	2.9%	693	0.7%	1.0	0.1%
Nonroad Industrial SI > 19 kW*	553	8.6%	371	6.2%	2,703	2.7%	2.7	0.4%
Recreational SI*	15	0.2%	1,038	17.3%	2,649	2.7%	31.9	4.2%
Recreational Marine CI*	72	1.1%	2	0.0%	11	0.0%	1.9	0.3%
Marine SI Evap	0	0.0%	122	2.0%	0	0.0%	0	0.0%
Marine SI Exhaust	64	1.0%	269	4.5%	2,083	2.1%	29	3.8%
Nonroad SI < 19 kW	126	2.0%	1,200	20.0%	32,310	32.4%	93	12.3%
Nonroad CI	1,994	31.0%	158	2.6%	1,727	1.7%	306	40.4%
Commercial Marine CI	1,166	18.1%	52	0.9%	198	0.2%	74	9.8%
Locomotive	531	8.3%	30	0.5%	119	0.1%	18	2.4%
Total Nonroad	4,521	70%	3,242	54%	41,800	42%	557	74%
Total Highway	1,648	26%	2,496	42%	56,303	56%	158	21%
Aircraft	262	4%	262	4%	1,502	2%	43	6%
Total Mobile Sources	6,431	100%	6,000	100%	99,605	100%	758	100%
Total Man-Made Sources	16,639	—	17,020	—	123,983	—	3,319	—
Mobile Source percent of Total Man-Made Sources	39%	—	35%	—	80%	—	23%	–

1.1.2 Baseline Inventory Adjustment

Since we proposed this regulatory program, we revised our baseline inventories for the covered engines to reflect information we received during the comment period. These inventory adjustments are discussed in more detail in Chapter 6, and the changes are reflected in the tables above.

We also revised our national mobile source on-highway and nonroad inventories to reflect additional information and to incorporate routine updates since we finalized our On-Highway Heavy-Duty Engine/Diesel Fuel (HD07) rule. The inventory adjustments to our on-highway and nonroad inventories are of particular importance because the health and visibility results reported in the following sections of this chapter are based on the earlier national mobile source baselines that were used as inputs to the air quality model. We did not perform new

health effects and visibility modeling for this rule; instead, we relied on the ozone and PM modeling performed for the HD07 rule. Because our estimates of baseline national mobile source inventories have increased since the HD07 rule, relying on the earlier inventories would underestimate future PM levels that we would expect if we conducted new modeling with the revised inventory inputs. Thus, the health effects and visibility information would underestimate the size of populations living in counties with air quality above certain levels compared to new modeling.

Table 1.1-4 contains a summary of the changes to the on-highway and nonroad inventories since the HD07 rule, and reports the percent change in the inventory for each pollutant. This table shows that the HD07 inventories used in the health and visibility modeling underestimate 2020 direct PM emissions by 0.3 percent for highway engines and 9.4 percent for nonroad engines. The HD07 inventories underestimate 2030 direct PM emissions by 0.1 percent for on-highway and 11.9 percent for nonroad engines. HC and NOx emissions could also affect predicted ambient PM concentrations via secondary formation in the atmosphere.

While the health effects and visibility analyses in the following section may thus underestimate the extent of health effects and visibility impairment we would predict if we were to model the information with our updated inventories, the HD07 analysis still supports our determination that these engines cause or contribute to such health and welfare concerns.

Table 1.1-4
Comparison of Inventory Projections to Projections Used for Air Quality Modeling in the 2007 Highway Heavy-Duty Engine/Diesel Fuel Rule (thousand short tons)

Category	Comparison	NOx	HC	CO	Direct PM
2020 Highway	HD07 Modeling Inventories	2,022	2,019	48,334	143
	Current Estimates	2,050	2,276	48,906	145
	Difference	28	257	572	2
	Difference as a percent of total mobile inventory	0.5%	4.7%	0.7%	0.3%
2020 Nonroad (including aircraft)	HD07 Modeling Inventories	4,040	1,995	33,938	449
	Current Estimates	4,164	3,139	37,331	510
	Difference	124	1,144	3,393	61
	Difference as a percent of total mobile inventory	2.0%	21.1%	3.9%	9.4%
2030 Highway	HD07 Modeling Inventories	2,181	1,624	55,610	157
	Current Estimates	2,496	1,648	56,303	158
	Difference	315	24	693	1
	Difference as a percent of total mobile inventory	4.9%	0.4%	0.7%	0.1%
2030 Nonroad (including aircraft)	HD07 Modeling Inventories	2,228	4,325	39,223	509
	Current Estimates	3,504	4,783	43,302	600
	Difference	1,276	458	4,079	91
	Difference as a percent of total mobile inventory	19.8%	7.6%	4.1%	11.9%

1.1.2 Inventory Impacts on a Per Vehicle Basis

In addition to the general inventory contributions described above, the engines that would be subject to the standards are more potent polluters than their highway counterparts in that they have much higher emissions on a per vehicle basis. This is illustrated in Table 1.1-5, which equates the emissions produced in one hour of operation from the different categories of equipment covered by the rulemaking to the equivalent miles of operation it would take for a car produced today to emit the same amount of emissions.

Table 1.1-5
Per-Vehicle Emissions Comparison

Equipment Category	Emission Comparison	Miles a Current Passenger Car Would Need to Drive to Emit the Same Amount of Pollution as the Equipment Category Emits in One Hour of Operation
Recreational Marine CI	HC+NOx	2,400
Large SI	HC+NOx	1,340
Snowmobiles	HC	24,300
Snowmobiles	CO	1,520
2-Stroke ATVs	HC	6,470
4-Stroke ATVs	HC	290
2-Stroke off-road motorcycles	HC	9,580
4-Stroke off-road motorcycles	HC	430

The per engine emissions are important because they mean that operators of these engines and vehicles, as well as those who work in their vicinity, are exposed to high levels of emissions, many of which are air toxics. These effects are of particular concern for people who operate forklifts in enclosed areas and for snowmobile riders following a lead rider. These effects are described in more detail in the next sections.

1.2 Ozone

1.2.1 General Background

Ground-level ozone, the main ingredient in smog, is formed by complex chemical reactions of volatile organic compounds (VOC) and NOx in the presence of heat and sunlight. Ozone forms readily in the lower atmosphere, usually during hot summer weather. Volatile organic compounds are emitted from a variety of sources, including motor vehicles, chemical plants, refineries, factories, consumer and commercial products, and other industrial sources. Volatile organic compounds also are emitted by natural sources such as vegetation. Oxides of nitrogen are emitted largely from motor vehicles, off-highway equipment, power plants, and other sources of combustion. Hydrocarbons (HC) are a large subset of VOC, and to reduce mobile source VOC levels we set maximum emissions limits for hydrocarbon as well as particulate matter emissions.

The science of ozone formation, transport, and accumulation is complex. Ground-level ozone is produced and destroyed in a cyclical set of chemical reactions involving NOx, VOC, heat, and sunlight.[1] As a result, differences in weather patterns, as well as NOx and VOC levels, contribute to daily, seasonal, and yearly differences in ozone concentrations and differences from

city to city. Many of the chemical reactions that are part of the ozone-forming cycle are sensitive to temperature and sunlight. When ambient temperatures and sunlight levels remain high for several days and the air is relatively stagnant, ozone and its precursors can build up, resulting in higher ambient ozone levels than typically would occur on a single high temperature day. Further complicating matters, ozone also can be transported into an area from pollution sources found hundreds of miles upwind, resulting in elevated ozone levels even in areas with low local VOC or NOx emissions.

On the chemical level, NOx and VOC are the principal precursors to ozone formation. The highest levels of ozone are produced when both VOC and NOx emissions are present in significant quantities on clear summer days. Relatively small amounts of NOx enable ozone to form rapidly when VOC levels are relatively high, but ozone production is quickly limited by removal of the NOx. Under these conditions, NOx reductions are highly effective in reducing ozone while VOC reductions have little effect. Such conditions are called "NOx limited." Because the contribution of VOC emissions from biogenic (natural) sources to local ambient ozone concentrations can be significant, even some areas where man-made VOC emissions are relatively low can be NOx limited.

When NOx levels are relatively high and VOC levels relatively low, NOx forms inorganic nitrates but relatively little ozone. Such conditions are called "VOC limited." Under these conditions, VOC reductions are effective in reducing ozone, but NOx reductions can actually increase local ozone under certain circumstances. Even in VOC limited urban areas, NOx reductions are not expected to increase ozone levels if the NOx reductions are sufficiently large.

Rural areas are almost always NOx limited, due to the relatively large amounts of biogenic VOC emissions in such areas. Urban areas can be either VOC or NOx limited, or a mixture of both.

Ozone concentrations in an area also can be lowered by the reaction of nitric oxide with ozone, forming nitrogen dioxide (NO_2); as the air moves downwind and the cycle continues, the NO_2 forms additional ozone. The importance of this reaction depends, in part, on the relative concentrations of NOx, VOC, and ozone, all of which change with time and location.

1.2.2 Health and Welfare Effects of Ozone and Its Precursors

Based on a large number of recent studies, EPA has identified several key health effects caused when people are exposed to levels of ozone found today in many areas of the country.[2, 3] Short-term exposures (1-3 hours) to high ambient ozone concentrations have been linked to increased hospital admissions and emergency room visits for respiratory problems. For example, studies conducted in the northeastern U.S. and Canada show that ozone air pollution is associated with 10-20 percent of all of the summertime respiratory-related hospital admissions. Repeated exposure to ozone can make people more susceptible to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as asthma. Prolonged (6 to 8 hours), repeated exposure to ozone can cause inflammation of the lung, impairment of lung

defense mechanisms, and possibly irreversible changes in lung structure, which over time could lead to premature aging of the lungs and/or chronic respiratory illnesses such as emphysema and chronic bronchitis.

Children and outdoor workers are most at risk from ozone exposure because they typically are active outside during the summer when ozone levels are highest. For example, summer camp studies in the eastern U.S. and southeastern Canada have reported significant reductions in lung function in children who are active outdoors. Further, children are more at risk than adults from ozone exposure because their respiratory systems are still developing. Adults who are outdoors and are moderately active during the summer months, such as construction workers and other outdoor workers, also are among those most at risk. These individuals, as well as people with respiratory illnesses such as asthma, especially asthmatic children, can experience reduced lung function and increased respiratory symptoms, such as chest pain and cough, when exposed to relatively low ozone levels during prolonged periods of moderate exertion.

Evidence also exists of a possible relationship between daily increases in ozone levels and increases in daily mortality levels. While the magnitude of this relationship is too uncertain to allow for direct quantification, the full body of evidence indicates the possibility of a positive relationship between ozone exposure and premature mortality.

In addition to human health effects, ozone adversely affects crop yield, vegetation and forest growth, and the durability of materials. Because ground-level ozone interferes with the ability of a plant to produce and store food, plants become more susceptible to disease, insect attack, harsh weather and other environmental stresses. Ozone causes noticeable foliage damage in many crops, trees, and ornamental plants (i.e., grass, flowers, shrubs) and causes reduced growth in plants. Studies indicate that current ambient levels of ozone are responsible for damage to forests and ecosystems (including habitat for native animal species). Ozone chemically attacks elastomers (natural rubber and certain synthetic polymers), textile fibers and dyes, and, to a lesser extent, paints. For example, elastomers become brittle and crack, and dyes fade after exposure to ozone.

Volatile organic compounds emissions are detrimental not only for their role in forming ozone, but also for their role as air toxics. Some VOCs emitted from motor vehicles are toxic compounds. At elevated concentrations and exposures, human health effects from air toxics can range from respiratory effects to cancer. Other health impacts include neurological developmental and reproductive effects. The toxicologically significant VOCs emitted in substantial quantities from the engines that are the subject of this rule are discussed in more detail in Section 1.6, below.

1.2.3 Ozone Nonattainment and Contribution to Ozone Nonattainment

The current primary and secondary ozone National Ambient Air Quality Standard (NAAQS) is 0.12 ppm daily maximum 1-hour concentration, not to be exceeded more than once per year on average. The determination that an area is at risk of exceeding the ozone standard in

the future was made for all areas with current design values grater than or equal to 0.125 ppm (or within a 10 percent margin) and with modeling evidence that exceedances will persist into the future.

Ground level ozone today remains a pervasive pollution problem in the United States. In 1999, 90.8 million people (1990 census) lived in 31 areas designated nonattainment under the 1-hour ozone NAAQS.[4] This sharp decline from the 101 nonattainment areas originally identified under the Clean Air Act Amendments of 1990 demonstrates the effectiveness of the last decade's worth of emission-control programs. However, elevated ozone concentrations remain a serious public health concern throughout the nation.

Over the last decade, declines in ozone levels were found mostly in urban areas, where emissions are heavily influenced by controls on mobile sources and their fuels. Twenty-three metropolitan areas have realized a decline in ozone levels since 1989, but at the same time ozone levels in 11 metropolitan areas with 7 million people have increased.[5] Regionally, California and the Northeast have recorded significant reductions in peak ozone levels, while four other regions (the Mid-Atlantic, the Southeast, the Central and Pacific Northwest) have seen ozone levels increase.

The highest ambient concentrations are currently found in suburban areas, consistent with downwind transport of emissions from urban centers. Concentrations in rural areas have risen to the levels previously found only in cities. Particularly relevant to this rulemaking, ozone levels at 17 of our National Parks have increased, and in 1998, ozone levels in two parks, Shenandoah National Park and the Great Smoky Mountains National Park, were 30 to 40 percent higher than the ozone NAAQS over the last decade.[6]

To estimate future ozone levels, we refer to the modeling performed in conjunction with the final HD07 rule.[7] We performed a series of ozone air quality modeling simulations for nearly the entire Eastern U.S. covering metropolitan areas from Texas to the Northeast.[8] This ozone air quality model was based upon the same modeling system as was used in the Tier 2 passenger vehicle air quality analysis,[9] with the addition of enhanced inventory estimates for 2007 and 2030 based on the state of knowledge at the time the modeling was performed. Emissions from nonroad engines, including the engines subject to this final rule, were included as input to the air quality modeling we describe in this section (as shown in Tables 1.1-2 to 1.1-4 above).

The model simulations were performed for several emission scenarios, and the model outputs were combined with current air quality data to identify areas expected to exceed the ozone NAAQS in 2007, 2020, and 2030.[10] The results of this modeling are contained in Table 1.2-1. Areas presented in Table 1.2-1 exhibit 1997-99 air quality data indicating violations of the 1-hour ozone NAAQS, or are within 10 percent of the standard, are predicted to have exceedance in 2007, 2020, or 2030. An area was considered likely to have future exceedances if exceedances were predicted by the model, and the area is currently violating the 1-hour standard, or is within 10 percent of violating the 1-hour standard. Table 1.2-1 shows that 37 areas with a 1999 population of 91 million people are at risk of exceeding the 1-hour ozone standard in 2007.

These estimates include contributions from the engines subject to this rule.[1]

[1]Additional information about the Regulatory Model System for Aerosols and Deposition (REMSAD) and our modeling protocols can be found in our Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, document EPA420-R-00-026, December 2000. Docket No. A-2000-01, Document No. A-II-13. This document is also available at http://www.epa.gov/otaq/disel.htm#documents.

Table 1.2-1
Eastern Metropolitan Areas with Modeled Exceedances of the 1-Hour Ozone Standard in 2007, 2020, or 2030 (Includes all national emission controls through HD07 standards)

MSA or CMSA / State	2007	2020	2030	pop (1999)
Atlanta, GA MSA	x	x	x	3.9
Barnstable-Yarmouth, MA MSA*	x			0.2
Baton Rouge, LA MSA	x	x	x	0.6
Beaumont-Port Arthur, TX MSA	x	x	x	0.4
Benton Harbor, MI MSA*	x	x	x	0.2
Biloxi-Gulfport-Pascagoula, MS MSA*	x	x	x	0.3
Birmingham, AL MSA	x	x	x	0.9
Boston-Worcester-Lawrence, MA CMSA	x	x	x	5.7
Charleston, WV MSA*	x	x		0.3
Charlotte-Gastonia-Rock Hill, NC MSA	x	x	x	1.4
Chicago-Gary-Kenosha, IL CMSA	x	x	x	8.9
Cincinnati-Hamilton, OH-KY-IN CMSA*	x	x	x	1.9
Cleveland-Akron, OH CMSA*	x	x	x	2.9
Detroit-Ann Arbor-Flint, MI CMSA	x	x	x	5.4
Grand Rapids-Muskegon-Holland, MI MSA*	x	x	x	1.1
Hartford, CT MSA	x	x	x	1.1
Houma, LA MSA*	x	x	x	0.2
Houston-Galveston-Brazoria, TX CMSA	x	x	x	4.5
Huntington-Ashland, WV-KY-OH MSA	x	x	x	0.3
Lake Charles, LA MSA*	x		x	0.2
Louisville, KY-IN MSA	x	x	x	1
Macon, GA MSA	x			0.3
Memphis, TN-AR-MS MSA	x	x	x	1.1
Milwaukee-Racine, WI CMSA	x	x	x	1.7
Nashville, TN MSA	x	x	x	1.2
New London-Norwich, CT-RI MSA	x	x	x	0.3
New Orleans, LA MSA*	x	x	x	1.3
New York-Northern NJ-Long Island, NY-NJ-CT-PA CMSA	x	x	x	20.2
Norfolk-Virginia Beach-Newport News, VA-NC MSA*	x		x	1.6
Orlando, FL MSA*	x	x	x	1.5
Pensacola, FL MSA	x			0.4
Philadelphia-Wilmington-Atlantic City, PA-NJ-DE-MD CMSA	x	x	x	6
Providence-Fall River-Warwick,RI-MAMSA*	x	x	x	1.1
Richmond-Petersburg, VA MSA	x	x	x	1
St. Louis, MO-IL MSA	x	x	x	2.6
Tampa-St. Petersburg, FL MSA*	x	x		2.3
Washington-Baltimore	x	x	x	7.4
Total number of areas	37	32	32	
Population	91.2	88.5	87.8	91.4

* These areas have registered 1997-1999 ozone concentrations within 10 percent of standard.

With regard to future ozone levels, our air quality ozone modeling for 2020 predicts exceedances of the 1-hour ozone standard in 32 areas with a total of 89 million people (1999 census; see Table 1.2-1). We expect that the control strategies contained in this rulemaking will further assist state efforts already underway to attain and maintain the 1-hour ozone standard.

The inventories that underlie this predictive modeling for 2020 and 2030 include reductions from all current and committed to federal control programs, including the recently promulgated NOx and PM standards for heavy-duty vehicles and low sulfur diesel fuel (HD07 rule). The geographic scope of these areas at risk of future exceedances underscores the need for additional, nationwide controls of ozone precursors.

It should be noted that this modeling did not attempt to examine the prospect of areas attaining or maintaining the ozone standard with possible future controls (i.e., controls beyond current or committed controls). Therefore, this information should be interpreted as indicating what areas are at risk of ozone violations in 2007, 2020 or 2030 without federal, State, or local measures that may be adopted and implemented in the future. We expect many of these areas to adopt additional emission reduction programs, but we are unable to quantify or rely upon future reductions from additional State or local programs since they have not yet been adopted.

1.2.4 Public Health and Welfare Concerns from Prolonged and Repeated Exposures to Ozone

In addition to the health effects described above, there exists a large body of scientific literature that shows that harmful effects can occur from sustained levels of ozone exposure much lower than 0.125 ppm. Studies of prolonged exposures, those lasting about 7 hours, showed health effects from exposures to ozone concentrations as low as 0.08 ppm. Prolonged and repeated exposures to ozone at these levels are common in areas that do not attain the 1-hour NAAQS, and also occur in areas where ambient concentrations of ozone are in compliance with the 1-hour NAAQS.

Prolonged exposure to levels of ozone below the NAAQS have been reported to cause or be statistically associated with transient pulmonary function responses, transient respiratory symptoms, effects on exercise performance, increased airway responsiveness, increased susceptibility to respiratory infection, increased hospital and emergency room visits, and transient pulmonary respiratory inflamation. Such acute health effects have been observed following prolonged exposures at moderate levels of exertion at concentrations of ozone as low as 0.08 ppm, the lowest concentration tested. The effects are more pronounced as concentrations increase, affecting more subjects or having a greater effect on a given subject in terms of functional changes or symptoms. A detailed summary and discussion of the large body of ozone health effects research may be found in Chapters 6 through 9 (Volume 3) of the 1996 Criteria Document for ozone.[11] Monitoring data indicates that 333 counties in 33 states exceed these levels in 1997-99.[12]

To provide a quantitative estimate of the projected number of people anticipated to reside in areas in which ozone concentrations are predicted to exceed the 8-hour level of 0.08 to 0.12

ppm or higher for multiple days, we performed regional modeling using the variable-grid Urban Airshed Model (UAM-V) for the HD07 rule.[13] UAM-V is a photochemical grid model that numerically simulates the effects of emissions, advection, diffusion, chemistry, and surface removal processes on pollutant concentrations within a 3-dimensional grid. As with the previous modeling analysis, the inventories that underlie this predictive modeling include reductions from all current and committed to control programs, including the HD07 NOx and PM reductions.

This HD07 ozone modeling forecast that 111 million people are predicted to live in areas that areas at risk of exceeding these moderate ozone levels for prolonged periods of time in 2020 after accounting for expected inventory reductions due to controls on light- and heavy-duty on-highway vehicles; that number is expected to increase to 125 million in 2030.[14] Prolonged and repeated ozone concentrations at these levels are common in areas throughout the country. These concentrations are found both in areas that are exceeding, and areas that are not exceeding, the 1-hour ozone standard. Areas with these high concentrations are more widespread than those in nonattainment for that 1-hour ozone standard.

Ozone at these levels can have other welfare effects, with damage to plants and ecosystems being of most concern. Plant damage affects crop yields, forestry production, and ornamentals. The adverse effect of ozone on forests and other natural vegetation can in turn cause damage to associated ecosystems, with additional resulting economic losses. Prolonged ozone concentrations of 0.10 ppm can be phytotoxic to a large number of plant species, and can produce acute injury and reduced crop yield and biomass production. Ozone concentrations within the range of 0.05 to 0.10 ppm have the potential over a longer duration of creating chronic stress on vegetation that can result in reduced plant growth and yield, shifts in competitive advantages in mixed populations, decreased vigor, and injury. Ozone effects on vegetation are presented in more detail in Chapter 5, Volume II of the 1996 Criteria Document.

1.2.5 Additional Health and Welfare Effects of NOx Emissions

In addition to their role as an ozone precursor, NOx emissions are associated with a wide variety of other health and welfare effects.[15, 16] Nitrogen dioxide can irritate the lungs and reduce resistance to respiratory infection (such as influenza). Nitrogen dioxide and airborne nitrate also contribute to pollutant haze, which impairs visibility and can reduce residential property values and the value placed on scenic views. Elevated levels of nitrates in drinking water pose significant health risks, especially to infants. NOx emissions are an important precursor to acid rain that may affect both terrestrial and aquatic ecosystems. Atmospheric deposition of nitrogen leads to excess nutrient enrichment problems ("eutrophication"). Deposition of nitrogen-containing compounds also affects terrestrial ecosystems.

1.2.3.1 Acid Deposition

Acid deposition, or acid rain as it is commonly known, occurs when SO_2 and NOx react in the atmosphere with water, oxygen, and oxidants to form various acidic compounds that later fall to earth in the form of precipitation or dry deposition of acidic particles.[17] It contributes to damage of trees at high elevations and in extreme cases may cause lakes and streams to become

so acidic that they cannot support aquatic life. In addition, acid deposition accelerates the decay of building materials and paints, including irreplaceable buildings, statues, and sculptures that are part of our nation's cultural heritage. To reduce damage to automotive paint caused by acid rain and acidic dry deposition, some manufacturers use acid-resistant paints, at an average cost of $5 per vehicle--a total of $61 million per year if applied to all new cars and trucks sold in the U.S.

Acid deposition primarily affects bodies of water that rest atop soil with a limited ability to neutralize acidic compounds. The National Surface Water Survey (NSWS) investigated the effects of acidic deposition in over 1,000 lakes larger than 10 acres and in thousands of miles of streams. It found that acid deposition was the primary cause of acidity in 75 percent of the acidic lakes and about 50 percent of the acidic streams, and that the areas most sensitive to acid rain were the Adirondacks, the mid-Appalachian highlands, the upper Midwest and the high elevation West. The NSWS found that approximately 580 streams in the Mid-Atlantic Coastal Plain are acidic primarily due to acidic deposition. Hundreds of the lakes in the Adirondacks surveyed in the NSWS have acidity levels incompatible with the survival of sensitive fish species. Many of the over 1,350 acidic streams in the Mid-Atlantic Highlands (mid-Appalachia) region have already experienced trout losses due to increased stream acidity. Emissions from U.S. sources contribute to acidic deposition in eastern Canada, where the Canadian government has estimated that 14,000 lakes are acidic. Acid deposition also has been implicated in contributing to degradation of high-elevation spruce forests that populate the ridges of the Appalachian Mountains from Maine to Georgia. This area includes national parks such as the Shenandoah and Great Smoky Mountain National Parks.

1.2.3.2 Eutrophication and Nitrification

Nitrogen deposition into bodies of water can cause problems beyond those associated with acid rain. The Ecological Society of America has included discussion of the contribution of air emissions to increasing nitrogen levels in surface waters in a recent major review of causes and consequences of human alteration of the global nitrogen cycle in its Issues in Ecology series.[18] Long-term monitoring in the United States, Europe, and other developed regions of the world shows a substantial rise of nitrogen levels in surface waters, which are highly correlated with human-generated inputs of nitrogen to their watersheds. These nitrogen inputs are dominated by fertilizers and atmospheric deposition.

Human activity can increase the flow of nutrients into those waters and result in excess algae and plant growth. This increased growth can cause numerous adverse ecological effects and economic impacts, including nuisance algal blooms, dieback of underwater plants due to reduced light penetration, and toxic plankton blooms. Algal and plankton blooms can also reduce the level of dissolved oxygen, which can also adversely affect fish and shellfish populations. This problem is of particular concern in coastal areas with poor or stratified circulation patterns, such as the Chesapeake Bay, Long Island Sound, or the Gulf of Mexico. In such areas, the "overproduced" algae tends to sink to the bottom and decay, using all or most of the available oxygen and thereby reducing or eliminating populations of bottom-feeder fish and shellfish, distorting the normal population balance between different aquatic organisms, and in extreme cases causing dramatic fish kills.

Collectively, these effects are referred to as eutrophication, which the National Research Council recently identified as the most serious pollution problem facing the estuarine waters of the United States.[19] Nitrogen is the primary cause of eutrophication in most coastal waters and estuaries.[20] On the New England coast, for example, the number of red and brown tides and shellfish problems from nuisance and toxic plankton blooms have increased over the past two decades, a development thought to be linked to increased nitrogen loadings in coastal waters. We believe that airborne NOx contributes from 12 to 44 percent of the total nitrogen loadings to United States coastal water bodies. For example, some estimates assert that approximately one-quarter of the nitrogen in the Chesapeake Bay comes from atmospheric deposition.

Excessive fertilization with nitrogen-containing compounds can also affect terrestrial ecosystems.[21] Research suggests that nitrogen fertilization can alter growth patterns and change the balance of species in an ecosystem, providing beneficial nutrients to plant growth in areas that do not suffer from nitrogen over-saturation. In extreme cases, this process can result in nitrogen saturation when additions of nitrogen to soil over time exceed the capacity of the plants and microorganisms to utilize and retain the nitrogen. This phenomenon has already occurred in some areas of the U.S.

1.3 Carbon Monoxide

1.3.1 General Background

Unlike many gases, CO is odorless, colorless, tasteless, and nonirritating. Carbon monoxide results from incomplete combustion of fuel and is emitted directly from vehicle tailpipes. Incomplete combustion is most likely to occur at low air-to-fuel ratios in the engine. These conditions are common during vehicle starting when air supply is restricted ("choked"), when vehicles are not tuned properly, and at high altitude, where "thin" air effectively reduces the amount of oxygen available for combustion (except in engines that are designed or adjusted to compensate for altitude). Carbon monoxide emissions increase dramatically in cold weather. This is because engines need more fuel to start at cold temperatures and because some emission control devices (such as oxygen sensors and catalytic converters) operate less efficiently when they are cold. Also, nighttime inversion conditions are more frequent in the colder months of the year. This is due to the enhanced stability in the atmospheric boundary layer, which inhibits vertical mixing of emissions from the surface.

1.3.2 Health Effects of CO

Carbon monoxide enters the bloodstream through the lungs and forms carboxyhemoglobin (COHb), a compound that inhibits the blood's capacity to carry oxygen to organs and tissues.[22] Carbon monoxide has long been known to have substantial adverse effects on human health, including toxic effects on blood and tissues, and effects on organ functions. Although there are effective compensatory increases in blood flow to the brain, at some concentrations of COHb somewhere above 20 percent these compensations fail to maintain sufficient oxygen delivery, and metabolism declines[23]. The subsequent hypoxia in brain tissue then produces behavioral effects, including decrements in continuous performance and reaction

time.[24]

Carbon monoxide has been linked to increased risk for people with heart disease, reduced visual perception, cognitive functions and aerobic capacity, and possible fetal effects. Persons with heart disease are especially sensitive to carbon monoxide poisoning and may experience chest pain if they breathe the gas while exercising. In Ontario, 18 deaths of snowmobilers involved myocardial infarction and 14 involved sudden cardiac death[25]. It is unknown if these deaths are linked to CO exposures.

Infants, elderly persons, and individuals with respiratory diseases are also particularly sensitive. Carbon monoxide can affect healthy individuals, impairing exercise capacity, visual perception, manual dexterity, learning functions, and ability to perform complex tasks. More importantly to many individuals is the frequent exposure of individuals to exhaust emissions from engines operating indoors. The Occupational Safety and Health Administration sets standards regulating the concentration of indoor pollutants, but high local CO levels are still commonplace.

Several recent epidemiological studies have shown a link between CO and premature morbidity (including angina, congestive heart failure, and other cardiovascular diseases). Several studies in the United States and Canada have also reported an association of ambient CO exposures with frequency of cardiovascular hospital admissions, especially for congestive heart failure (CHF). An association of ambient CO exposure with mortality has also been reported in epidemiological studies, though not as consistently or specifically as with CHF admissions. EPA reviewed these studies as part of the Criteria Document review process.[26] There is emerging evidence suggesting that CO is linked with asthma exacerbations.

1.3.3 CO Nonattainment

The current primary NAAQS for CO are 35 parts per million for the one-hour average and 9 parts per million for the eight-hour average. These values are not to be exceeded more than once per year. Air quality carbon monoxide value is estimated using EPA guidance for calculating design values. Over 22.4 million people currently live in the 13 non-attainment areas for the CO NAAQS.[27] As described in Section 1.1, the engines subject to this rule currently account for about 3.8 percent of the mobile source CO inventory; this is expected to increase to 8.8 percent by 2020 without the emission controls in this action.

Emissions from the engines and vehicles covered by this rule contribute to the national CO inventory and to CO levels in several nonattainment areas. Large SI engines are used in forklifts and many types of construction, industrial, and lawn care equipment that are used in urban areas, including nonattainment areas.

ATVs and off-highway motorcycles are also used in counties and cities within CO-nonattainment areas, and are operated on private land and in and around non-attainment areas. This is illustrated by information about ATV use provided by Honda in public comments, which included recent warranty claims for ATVs in three serious CO non-attainment areas: Fairbanks,

AK, in 1998 and 2001, in Phoenix, AZ in 2001, and in Las Vegas, NV in 2000.[28] In our December 7, 2000 notice finding that recreational vehicles cause or contribute to CO nonattainment, we provided information showing CO emissions in six nonattainment areas in 2000. Five of these areas remain in nonattainment.

In addition, Western state studies of off-highway vehicle use in Colorado and Utah both indicate that ATVs and off-highway motorcycles are operated on private land about 20 to 30 percent of the time (22.4 percent for off-highway motorcycles and 27.8 percent for ATVs in Utah, and combined vehicles 22.4 percent of off-highway vehicles are operated on the survey respondent's own private land or ranch).[29] In addition, operation of these vehicles is not limited to established trails. Half of the off-highway motorcyclists and 40 percent of the ATV owners in Utah reported riding off established trails or roads.[30] Furthermore, according to the U.S. Consumer Product Safety Commission, almost three quarters of ATV drivers use ATVs for at least one non-recreational activity; half use ATVs for farming or ranching; 63 percent use ATVs for household chores (e.g., yard work); and about 8 percent use ATVs for occupational or commercial tasks.[31] Another CO nonattainment area, Anchorage, AK, estimates ATVs and motorcycles (on- and off-road) contribute 0.19 tons per day in 2000.[32]

Several states that contain CO nonattainment areas also have large populations of registered off-highway motorcycles, as shown in Table 1.3-1 (similar information was not available for ATVs).

Table 1.3-1
Off-Highway Motorcycle Use in Selected CO Nonattainment Areas

City and State	CO Nonattainment Classification	2001 State off-highway motorcycle population[a]
Anchorage, AK	Serious	5,100[b]
Fairbanks, AK	Serious	
Las Vegas, NV	Serious	15,800
Los Angeles, CA	Serious	175,100
Phoenix, AZ	Serious	20,400
Spokane, WA	Serious	44,800
New York/New Jersey/Long Island, NY, NJ, CT	Moderate > 12.7 ppm	81,300
Provo, UT	Moderate > 12.7 ppm	16,600
El Paso, TX	Moderate	61,600
Fort Collins, CO	Moderate	30,200
Medford, OR	Moderate	28,800
Missoula, MT	Moderate	96,00
Reno, NV	Moderate	15,800[b]

[a] Source: Motorcycle Industry Council, 2001 Motorcycle Statistical Annual, Docket A-2000-01, Document No. II-G.
[b] State has more than one CO nonattainment area.

Snowmobiles, which have relatively high per engine CO emissions, can also be an important source of ambient CO levels in CO nonattainment areas. While some of these areas have experienced improved CO air quality in recent years, an area cannot be redesignated to attainment until it can show EPA that it has had air quality levels within the level required for attainment and that it has a plan in place to maintain such levels. Until areas have been redesignated, they remain non-attainment areas.[33] Snowmobiles contribute to CO nonattainment in more than one of these areas.

The state of Alaska estimated (and a National Research Council study confirmed) that snowmobiles contributed 0.3 tons/day in 2001 to Fairbanks' CO nonattainment area or 1.2

percent of a total inventory of 23.3 tons per day in 2001.[2, 3] There is some indication that Fairbanks' snowmobile population is significantly higher than EPA's estimates.[34] While Fairbanks has made significant progress in reducing ambient CO concentrations, existing climate conditions make achieving and maintaining attainment challenging. Anchorage, AK, reports a similar contribution of snowmobiles to their emissions inventories (0.34 tons per day in 2000). Furthermore, a recent National Academy of Sciences report concludes that "Fairbanks will be susceptible to violating the CO health standards for many years because of its severe meteorological conditions. That point is underscored by a December 2001 exceedance of the standard in Anchorage which had no violations over the last 3 years."[4] There is also a snowmobile trail within the Spokane, WA, CO nonattainment area.

Several states that contain CO nonattainment areas also have large populations of registered snowmobiles. This is shown in Table 1.3-2. A review of snowmobile trail maps and public comments indicate that snowmobiles are used in counties containing these CO nonattainment areas or in adjoining counties.[35] These include the Mt. Spokane and Riverside trails near the Spokane, Washington, CO nonattainment area; the Larimer trails near the Fort Collins, Colorado CO nonattainment area; and the Hyatt Lake, Lake of the Woods, and Cold Springs trails near the Klamath Falls and Medford, Oregon CO nonattainment area. There are also trails in Missoula County, Montana that demonstrate snowmobile use in the Missoula, Montana CO nonattainment area. While Colorado has a large snowmobile population, the snowmobile trails are fairly distant from the Colorado Springs CO nonattainment area.[36]

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[2] Draft Anchorage Carbon Monoxide Emission Inventory and Year 2000 Attainment Projections, Air Quality Program, May 2001, Docket Number A-2000-01, Document II-A-40; Draft Fairbanks 1995-2001 Carbon Monoxide Emissions Inventory, June 1, 2001, Docket Number A-2000-01, Document II-A-39.

[3]National Research Council. The Ongoing Challenge of Managing Carbon Monoxide Pollution in Fairbanks, AK. May 2002. Docket A-2000-01, Document No. IV-A-115.

[4]National Research Council. The Ongoing Challenge of Managing Carbon Monoxide Pollution in Fairbanks, AK. May 2002. Docket A-2000-01, Document IV-A-115.

Table 1.3-2
Snowmobile Use in Selected CO Nonattainment Areas

City and State	CO Nonattainment Classification	2001 State snowmobile population*
Anchorage, AK	Serious	35,576
Fairbanks, AK	Serious	
Spokane, WA	Serious	31,532
Fort Collins, CO	Moderate	32,500
Medford, OR	Moderate	16,809
Missoula, MT	Moderate	23,440

* Source: Letter from International Snowmobile Manufacturers Association to US-EPA, March 14, 2002, Docket A-2000-01, Document No. II-G

While snowmobile trails are often located in rural areas and many are located outside CO nonattainment areas, it is nevertheless the case that snowmobiles are used in urban areas within nonattainment areas. In some northeast cities, "snowmobiles are a common sight in downtown areas [and] are driven in large numbers along streets and recreational paths ... in close proximity to pedestrians, motorists, and those using public parks such as cross-country skiers."[37] A search of the available literature indicates that snowmobiles are ridden in areas other than trails. For example, a report by the Michigan Department of Natural Resources indicates that from 1993 to 1997, of the 146 snowmobile fatalities studied, 46 percent occurred on a state or county roadway (another 2 percent on roadway shoulders) and 27 percent occurred on private lands.[38] Furthermore, accident reports in the CO nonattainment area Fairbanks, AK, document that snowmobiles driven on streets have collided with motor vehicles.[39] On certain days there may be concentrations of snowmobiles operated in non-attainment areas due to public events such as snowmachine races (such as the Iron Dog Gold Rush Classic, which finishes in Fairbanks, AK), during which snowmobiles will be present and operated. There is some indication that Fairbanks snowmobile population is significantly higher than EPA's estimates.[40]

While the operation of snowmobiles alone in an area would not necessarily result in CO nonattainment, emissions from regulated categories need only contribute to, not themselves cause, nonattainment. Concentrations of NAAQS-related pollutants are by definition a result of multiple sources of pollution. The above discussion shows that snowmobiles are operated on snowmobile trails and some are within CO nonattainment areas (e.g., Spokane). Snowmobiles are also used for maintenance operations and other uses in CO nonattainment areas (e.g., Fairbanks and Anchorage), and there is evidence that snowmobiles are operated in town along streets in these and other CO nonattainment areas.

While CO air quality is improving in several northern areas, further reductions may still be required. Exceedances of the 8-hour CO standard were recorded in three of the six CO nonattainment areas located in the northern portion of the country over the five year period from 1994 to 1999: Fairbanks, AK; Medford, OR; and Spokane, WA.[41] Given the variability in CO

ambient concentrations due to weather patterns such as inversions, the absence of recent exceedances for some of these nonattainment areas should not be viewed as eliminating the need for further reductions to consistently attain and maintain the standard. A review of CO monitor data in Fairbanks from 1986 to 1995 shows that while median concentrations have declined steadily, unusual combinations of weather and emissions have resulted in elevated ambient CO concentrations well above the 8-hour standard of 9 ppm. Specifically, a Fairbanks monitor recorded average 8-hour ambient concentrations at 16 ppm in 1988, around 9 ppm from 1990 to 1992, and then a steady increase in CO ambient concentrations at 12, 14 and 16 ppm during some extreme cases in 1993, 1994 and 1995, respectively.[42] Furthermore, a recent National Academy of Sciences report concludes that "Fairbanks will be susceptible to violating the CO health standards for many years because of its severe meteorological conditions. That point is underscored by a December 2001 exceedance of the standard in Anchorage which had no violations over the last 3 years."[43] Fairbanks is located in a mountain valley with a much higher potential for air stagnation than cities within the contiguous United States. Nocturnal inversions that give rise to elevated CO concentrations can persist 24-hours a day due to the low solar elevation, particularly in December and January. These inversions typically last from 2 to 4 days, and thus inversions may continue during hours of maximum CO emissions from mobile sources. While Fairbanks has made significant progress in reducing ambient CO concentrations, existing climate conditions make achieving and maintaining attainment challenging.

In addition to the CO nonattainment areas, there are 6 areas that have not been classified as non-attainment where air quality monitoring indicated a need for CO control. For example, CO monitors in northern locations such as Des Moines, IA, and Weirton, WV/Steubenville, OH, registered levels above the level of the CO standards in 1998.[44]

1.4 Particulate Matter

1.4.1 General Background

Particulate pollution is a problem affecting urban and non-urban localities in all regions of the United States. Nonroad engines and vehicles that would be subject to the standards contribute to ambient particulate matter (PM) levels in two ways. First, they contribute through direct emissions of particulate matter. Second, they contribute to indirect formation of PM through their emissions of organic carbon, especially HC. As shown in Table 1.4-1, organic carbon accounts for between 27 and 36 percent of ambient fine particle mass depending on the area of the country.

Table 1.4-1
Percent Contribution to $PM_{2.5}$ by Component, 1998

	East	West
Sulfate	56	33
Elemental Carbon	5	6
Organic Carbon	27	36
Nitrate	5	8
Crustal Material	7	17

Source: National Air Quality and Emissions Trends Report, 1998, March, 2000, at 28. This document is available at http://www.epa.gov/oar/aqtrnd98/. Relevant pages of this report can be found in Memorandum to Air Docket A-2000-01 from Jean Marie Revelt, September 5, 2001, Document No. II-A-63.

PM represents a broad class of chemically and physically diverse substances. It can be principally characterized as discrete particles that exist in the condensed (liquid or solid) phase spanning several orders of magnitude in size. All particles equal to and less than 10 microns are called PM_{10}. Fine particles can be generally defined as those particles with an aerodynamic diameter of 2.5 microns or less (also known as $PM_{2.5}$), and coarse fraction particles are those particles with an aerodynamic diameter greater than 2.5 microns, but equal to or less than a nominal 10 microns.

Manmade emissions that contribute to airborne particulate matter result principally from combustion sources (stationary and mobile sources) and fugitive emissions from industrial processes and non-industrial processes (such as roadway dust from paved and unpaved roads, wind erosion from crop land, construction, etc.). Human-generated sources of particles include a variety of stationary sources (including power generating plants, industrial operations, manufacturing plants, waste disposal) and mobile sources (light- and heavy-duty on-road vehicles, and off-highway vehicles such as construction, farming, industrial, locomotives, marine vessels and other sources). Natural sources also contribute to particulate matter in the atmosphere and include sources such as wind erosion of geological material, sea spray, volcanic emissions, biogenic emanation (e.g., pollen from plants, fungal spores), and wild fires.

The chemical and physical properties of PM vary greatly with time, region, meteorology, and source category. Particles may be emitted directly to the atmosphere (primary particles) or may be formed by transformations of gaseous emissions of sulfur dioxide, nitrogen oxides or volatile organic compounds (secondary particles). Secondary PM is dominated by sulfate in the eastern U.S. and nitrate in the western U.S.[45] The vast majority (>90 percent) of the direct mobile source PM emissions and their secondary formation products are in the fine PM size range. Mobile sources can reasonably be estimated to contribute to ambient secondary nitrate and sulfate PM in proportion to their contribution to total NOx and SOx emissions.

1.4.2 Health and Welfare Effects of PM

Particulate matter can adversely affect human health and welfare. Discussions of the health and welfare effects associated with ambient PM can be found in the Air Quality Criteria for Particulate Matter.[46]

Key EPA findings regarding the health risks posed by ambient PM are summarized as follows:

a. Health risks posed by inhaled particles are affected both by the penetration and deposition of particles in the various regions of the respiratory tract, and by the biological responses to these deposited materials.

b. The risks of adverse effects associated with deposition of ambient particles in the thorax (tracheobronchial and alveolar regions of the respiratory tract) are markedly greater than for deposition in the extrathoracic (head) region. Maximum particle penetration to the thoracic regions occurs during oronasal or mouth breathing.

c. Published, peer-reviewed studies have reported statistical associations between PM and several key health effects, including premature death; aggravation of respiratory and cardiovascular disease, as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days; changes in lung function and increased respiratory symptoms; changes to lung tissues and structure; and altered respiratory defense mechanisms. Most of these effects have been consistently associated with ambient PM concentrations, which have been used as a measure of population exposure, in a large number of community epidemiological studies. Additional information and insights on these effects are provided by studies of animal toxicology and controlled human exposures to various constituents of PM conducted at higher than ambient concentrations. Although mechanisms by which particles cause effects are not well known, there is general agreement that the cardio-respiratory system is the major target of PM effects.

d. Based on a qualitative assessment of the epidemiological evidence of effects associated with PM for populations that appear to be at greatest risk with respect to particular health endpoints, we have concluded the following with respect to sensitive populations:

    1. Individuals with respiratory disease (e.g., chronic obstructive pulmonary disease, acute bronchitis) and cardiovascular disease (e.g., ischemic heart disease) are at greater risk of premature mortality and hospitalization due to exposure to ambient PM.

    2. Individuals with infectious respiratory disease (e.g., pneumonia) are at greater risk of premature mortality and morbidity (e.g., hospitalization, aggravation of respiratory symptoms) due to exposure to ambient PM. Also, exposure to PM may increase individuals' susceptibility to respiratory infections.

3. Elderly individuals are also at greater risk of premature mortality and hospitalization for cardiopulmonary problems due to exposure to ambient PM.

4. Children are at greater risk of increased respiratory symptoms and decreased lung function due to exposure to ambient PM.

5. Asthmatic individuals are at risk of exacerbation of symptoms associated with asthma, and increased need for medical attention, due to exposure to PM.

e. There are fundamental physical and chemical differences between fine and coarse fraction particles. The fine fraction contains acid aerosols, sulfates, nitrates, transition metals, diesel exhaust particles, and ultra fine particles; the coarse fraction typically contains high mineral concentrations, silica and resuspended dust. It is reasonable to expect that differences may exist in both the nature of potential effects elicited by coarse and fine PM and the relative concentrations required to produce such effects. Both fine and coarse particles can accumulate in the respiratory system. Exposure to coarse fraction particles is primarily associated with the aggravation of respiratory conditions such as asthma. Fine particles are closely associated with health effects such as premature death or hospital admissions, and for cardiopulmonary diseases.

With respect to welfare or secondary effects, fine particles have been clearly associated with the impairment of visibility over urban areas and large multi-State regions. Particles also contribute to soiling and materials damage. Components of particulate matter (e.g., sulfuric or nitric acid) also contribute to acid deposition, nitrification of surface soils and water eutrophication of surface water.

1.4.3 PM Nonattainment

1.4.3.1 PM_{10} Concentrations and Nonattainment

The NAAQS for PM_{10} was established in 1987. According to these standards, the short term (24-hour) standard of 150 $\mu g/m^3$ is not to be exceeded more than once per year on average over three years. The long-term standard specifies an expected annual arithmetic mean not to exceed 50 $\mu g/m^3$ over three years.

PM_{10} monitoring data indicate that 14 designated PM_{10} nonattainment areas with a projected population of 23 million violated the PM_{10} NAAQS in the period 1997-1999. Table 1.4-2 lists the 14 areas, and also indicates the PM_{10} nonattainment classification, and 1999 projected population for each PM_{10} nonattainment area. The projected population in 1999 was based on 1990 population figures which were then increased by the amount of population growth in the county from 1990 to 1999.

Table 1.4-2
PM_{10} Nonattainment Areas Violating the PM_{10} NAAQS in 1997-1999

Nonattainment Area or County	1999 Population (projected, in thousands)
Anthony, NM (Moderate)[b]	3
Clark Co [Las Vegas], NV (Serious)	1,200
Coachella Valley, CA (Serious)	239
El Paso Co, TX (Moderate)[a]	611
Hayden/Miami, AZ (Moderate)	4
Imperial Valley, CA (Moderate)	122
Los Angeles South Coast Air Basin, CA (Serious)	14,352
Nogales, AZ (Moderate)	25
Owens Valley, CA (Serious)	18
Phoenix, AZ (Serious)	2,977
San Joaquin Valley, CA (Serious)	3,214
Searles Valley, CA (Moderate)	29
Wallula, WA (Moderate)[b]	52
Washoe Co [Reno], NV (Moderate)	320
Total Areas: 14	23,167

[a] EPA has determined that continuing PM_{10} nonattainment in El Paso, TX is attributable to transport under section 179(B).

[b] The violation in this area has been determined to be attributable to natural events under section 188(f) of the Act.

In addition to the 14 PM_{10} nonattainment areas that are currently violating the PM_{10} NAAQS listed in Table 1.4-2, there are 25 unclassifiable areas that have recently recorded ambient concentrations of PM_{10} above the PM_{10} NAAQS. EPA adopted a policy in 1996 that allows areas with PM_{10} exceedances that are attributable to natural events to retain their designation as unclassifiable if the State is taking all reasonable measures to safeguard public health regardless of the sources of PM_{10} emissions. Areas that remain unclassifiable areas are not required under the Clean Air Act to submit attainment plans, but we work with each of these areas to understand the nature of the PM_{10} problem and to determine what best can be done to reduce it. With respect to the monitored violations reported in 1997-99 in the 25 areas designated as unclassifiable, we have not yet excluded the possibility that factors such as a one-time monitoring upset or natural events, which ordinarily would not result in an area being designated as nonattainment for PM_{10}, may be responsible for the problem. Emission reductions from today's action will assist these currently unclassifiable areas to achieve ambient PM_{10} concentrations below the current PM_{10} NAAQS.

1.4.3.2 $PM_{2.5}$ Concentrations

Fine particle concentrations contribute to both health effects and visibility impairment. This section presents our assessment of current and future PM2.5 levels. Because monitoring data are not available for all areas, we have modeled PM2.5 levels for those areas using the EPA's Regulatory Model System for Aerosols and Deposition (REMSAD) model. These concentrations are related to both health effects and visibility impairment. After a brief description of the PM air quality model, we present current PM2.5 data, both modeled and

estimated. Then we present projections of PM2.5 levels that were estimated using REMSAD.

1.4.3.2.1 Description of PM Air Quality Modeling

To estimate both current PM2.5 levels in areas for which no monitoring data are available and future $PM_{2.5}$ levels for all areas, we refer to the PM air quality modeling performed in conjunction with EPA's on-highway Heavy Duty Engine/Diesel Fuel (HD07) final rule. This modeling was performed using EPA's Regulatory Model System for Aerosols and Deposition (REMSAD) model.[47] We describe the REMSAD modeling because we use the modeling examine visibility impairment and population exposures related to the PM health effects we would anticipate would occur without the emissions reductions from this rulemaking. The REMSAD modeling was also a key input for the economic benefits transfer technique described in Chapter 10 related to selected PM health effects.

REMSAD simulates every hour of every day of the year and, thus, requires a variety of input files that contain information pertaining to the modeling domain and simulation period. These include gridded, 3-hour average emissions estimates and meteorological fields, initial and boundary conditions, and land-use information. As applied to the contiguous U.S., the model segments the area within the region into square blocks called grids (roughly equal in size to counties), each of which has several layers of air conditions. Using this data, REMSAD generates predictions of 3-hour average PM concentrations for every grid. We then calculated daily and seasonal PM air quality metrics.

REMSAD was peer-reviewed in 1999 for EPA as reported in "*Scientific Peer-Review of the Regulatory Modeling System for Aerosols and Deposition.*" Earlier versions of REMSAD have been employed for the EPA's Prospective CAA Section 812 Report to Congress and for EPA's Analysis of the Acid Deposition and Ozone Control Act (Senate Bill 172). Version 4.1 of REMSAD was employed for the HD07 final rule analysis and is fully described in the air quality technical support documents for that HD07 rulemaking. We focus on the HD07 modeling because it is the most current modeling for mobile sources.

For the HD07 rulemaking, EPA modeled PM air quality in 1996 and in 2030 after those requirements were to take effect using REMSAD. Although we did not undertake new air quality modeling for this rulemaking, the modeling from the HD07 rulemaking can be considered a baseline for this rulemaking. As explained in Section 1.1.2, the emissions inventories that were used in the HD07 REMSAD modeling have been updated and that the HD07 modeling may underestimate the PM2.5 levels that we would expect with revised emissions inventories.

1.4.3.2.2 Current PM Air Quality

The 1999-2000 $PM_{2.5}$ monitored values, which cover about a third of the nation's counties, indicate that at least 82 million people live in areas where long-term ambient fine particulate matter levels are at or above 15 $\mu g/m^3$.[48]

To estimate the current number of people who live in areas where long-term ambient fine particulate matter levels are at or above 16 µg/m^3 but for which there are no monitors, we can use the HD07 REMSAD modeling described above. At the time the HD07 modeling was performed, 1999 PM monitoring data were not yet available, so we conducted 1996 base year modeling to reproduce the atmospheric processes resulting in formation and dispersion of $PM_{2.5}$ across the U.S. and to evaluate operational model performance for $PM_{2.5}$ and its related speciated components (e.g., sulfate, nitrate, elemental carbon) which are important to visibility impairment. This 1996 modeling included emissions from the engines subject to this final rule (although earlier emissions estimates were used). According to our national modeled predictions, there were a total of 76 million people (1996 population) living in areas with modeled annual average $PM_{2.5}$ concentrations at or above 16 µg/m^3 (29 percent of the population).[49]

1.4.3.2.3 Future PM Air Quality

To estimate future year concentrations, we can use the air quality model to predict changes between current and future states. The most reliable information would be to compare future levels in counties for which we have monitoring data. Thus, we estimated future conditions for the areas with current $PM_{2.5}$ monitored data (which covered about a third of the nation's counties at that time).[50] For these counties, REMSAD predicts the current level of 37 percent of the population living in areas where fine PM levels above 15 µg/m3 to increase to 49 percent in 2030.[51] Again, this 2030 modeling included emissions from the engines subject to this final rule (although earlier emissions estimates were used). These emissions are contributing to air quality levels that may result in future PM nonattainment. Nonattainment status is related to both health impacts described above and welfare impacts, such as visibility impairment, soiling, and material damage. Thus, for areas with levels above the NAAQS, unacceptable health and welfare effects are anticipated to be occurring, and emissions from the engines subject to this rulemaking are contributing to these anticipated adverse effects. In Table 1.4-3, we summarize the national PM air quality based on the HD07 REMSAD modeling.

Table 1.4-3
Summary of Anticipated 2030 National PM Baseline Air Quality (μg/m³)

Statistic	2030 Air Quality Value (μg/m³)[a]
PM_{10}	
Minimum Annual Mean[b]	1.49
Maximum Annual Mean[b]	64.29
Average Annual Mean	10.03
Median Annual Mean	7.97
Population-Weighted Average Annual Mean[c]	21.04
$PM_{2.5}$	
Minimum Annual Mean[b]	1.16
Maximum Annual Mean[b]	38.2
Average Annual Mean	7.6
Median Annual Mean	5.79
Population-Weighted Average Annual Mean[c]	14.2

[a] Based on public comment received on the proposed Large SI/Recreational Vehicle rule and other updated information, we revised our emissions estimates in some categories downwards and other categories upwards; however, on net, we believe this modeling would underestimate the baseline PM emissions without regulation.
[b] The minimum (maximum) is the value for the populated grid-cell with the lowest (highest) annual average.
[c] Calculated by summing the product of the projected 2030 grid-cell population and the estimated 2030 PM concentration, for that grid-cell and then dividing by the total population in the 48 contiguous States.

Nonroad engines and vehicles that are subject these standards contribute to ambient fine PM levels in two ways. First, they contribute through direct emissions of fine PM. As shown in Table 1.1-1, these engines emitted 14,600 tons of PM (about 2.1 percent of all mobile source PM) in 2000. As shown in Table 1.1-3, they are modeled to emit 36,500 tons of PM (about 4.8 percent of all mobile source PM) in 2030. Second, these engines contribute to indirect formation of PM through their emissions of gaseous precursors which are then transformed in the atmosphere into particles. For example, these engines emitted about 1,411,000 tons of HC or 23.5 percent of the HC emitted from mobile sources in 2030. Furthermore, recreational vehicles, such as snowmobiles and ATVs emit high levels of organic carbon (as HC) on a per engine basis. Some organic emissions are transformed into particles in the atmosphere and other volatile organics can condense if emitted in cold temperatures, as is the case for emissions from snowmobiles, for example. Organic carbon accounts for between 27 and 36 percent of ambient fine particle mass depending on the area of the country. The relationship between HC and PM have implications for the most efficient controls of ambient PM as discussed in Chapter 4.

Further, as discussed below, the nonroad engines we are regulating contribute to PM levels in areas with PM levels above 15 µg/m3.

1.5 Visibility Degradation

1.5.1 General Background

Visibility can be defined as the degree to which the atmosphere is transparent to visible light.[52] Visibility impairment has been considered the "best understood and most easily measured effect of air pollution."[53] Visibility degradation is often directly proportional to decreases in light transmittal in the atmosphere. Scattering and absorption by both gases and particles decrease light transmittance. It is an easily noticeable effect of fine PM present in the atmosphere, and fine PM is the major cause of reduced visibility in parts of the United States, including many of our national parks and in places where people live, work, and recreate. Fine particles with significant light-extinction efficiencies include organic matter, sulfates, nitrates, elemental carbon (soot), and soil.

Visibility is an important effect because it has direct significance to people's enjoyment of daily activities in all parts of the country. Individuals value good visibility for the well-being it provides them directly, both in where they live and work, and in places where they enjoy recreational opportunities. Visibility is highly valued in significant natural areas such as national parks and wilderness areas, because of the special emphasis given to protecting these lands now and for future generations.

To quantify changes in visibility, the analysis presented in this chapter computes a light-extinction coefficient, based on the work of Sisler, which shows the total fraction of light that is decreased per unit distance.[54] This coefficient accounts for the scattering and absorption of light by both particles and gases, and accounts for the higher extinction efficiency of fine particles compared to coarse particles. Visibility can be described in terms of visual range, light extinction or deciview.[5]

In addition to limiting the distance that one can see, the scattering and absorption of light caused by air pollution can also degrade the color, clarity, and contrast of scenes. Visibility impairment also has a temporal dimension in that impairment might relate to a short-term excursion or to longer periods (e.g., worst 20 percent of days or annual average levels). More

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[5]Visual range can be defined as the maximum distance at which one can identify a black object against the horizon sky. It is typically described in miles or kilometers. Light extinction is the sum of light scattering and absorption by particles and gases in the atmosphere. It is typically expressed in terms of inverse megameters (Mm^{-1}), with larger values representing worse visibility. The deciview metric describes perceived visual changes in a linear fashion over its entire range, analogous to the decibel scale for sound. A deciview of 0 represents pristine conditions. Under many scenic conditions, a change of 1 deciview is considered perceptible by the average person.

detailed discussions of visibility effects are contained in the EPA Criteria Document for PM.

Visibility effects are manifest in two principal ways: (1) as local impairment (e.g., localized hazes and plumes) and (2) as regional haze. The emissions from engines covered by this rule contribute to both types of visibility impairment.

Local-scale visibility degradation is commonly in the form of either a plume resulting from the emissions of a specific source or small group of sources, or it is in the form of a localized haze such as an urban "brown cloud." Plumes are comprised of smoke, dust, or colored gas that obscure the sky or horizon relatively near sources. Impairment caused by a specific source or small group of sources has been generally termed as "reasonably attributable."

The second type of impairment, regional haze, results from pollutant emissions from a multitude of sources located across a broad geographic region. It impairs visibility in every direction over a large area, in some cases over multi-state regions. Regional haze masks objects on the horizon and reduces the contrast of nearby objects. The formation, extent, and intensity of regional haze is a function of meteorological and chemical processes, which sometimes cause fine particulate loadings to remain suspended in the atmosphere for several days and to be transported hundreds of kilometers from their sources.[55]

On an annual average basis, the concentrations of non-anthropogenic fine PM are generally small when compared with concentrations of fine particles from anthropogenic sources.[56] Anthropogenic contributions account for about one-third of the average extinction coefficient in the rural West and more than 80 percent in the rural East.[57] Because of significant differences related to visibility conditions in the eastern and western U.S., we present information about visibility by region. Furthermore, it is important to note that even in those areas with relatively low concentrations of anthropogenic fine particles, such as the Colorado plateau, small increases in anthropogenic fine particle concentrations can lead to significant decreases in visual range. This is one of the reasons Class I areas have been given special consideration under the Clean Air Act.

1.5.2 Visibility Impairment Where People Live, Work and Recreate

Visibility impairment occurs in many areas throughout the country, where people live, work, and recreate. In this section, in order to estimate the magnitude of the problem, we use monitored PM2.5 data and modeled air quality using emissions inventories from the engines subject to this rule. The engines covered by this rule contribute to PM2.5 levels in areas across the country with unacceptable visibility conditions.

1.5.2.1 Areas Affected by Visibility Impairment

The secondary PM NAAQS is designed to protect against adverse welfare effects such as visibility impairment. In 1997, the secondary PM NAAQS was set as equal to the primary (health-based) PM NAAQS (62 Federal Register No. 138, July 18, 1997). EPA concluded that PM can and does produce adverse effects on visibility in various locations, depending on PM

concentrations and factors such as chemical composition and average relative humidity. In 1997, EPA demonstrated that visibility impairment is an important effect on public welfare and that visibility impairment is experienced throughout the U.S., in multi-state regions, urban areas, and remote Federal Class I areas.

In many cities having annual mean PM2.5 concentrations exceeding 17 ug/m3, improvements in annual average visibility resulting from the attainment of the annual PM2.5 standard are expected to be perceptible to the general population (e.g., to exceed 1 deciveiew). Based on annual mean monitored PM2.5 data, many cities in the Northeast, Midwest, and Southeast as well as Los Angeles would be expected to experience perceptible improvements in visibility if the PM2.5 annual standard were attained. For example, in Washington, DC, where the IMPROVE monitoring network shows annual mean PM2.5 concentrations at about 19 ug/m3 during the period of 1992 to1995, approximate annual average visibility would be expected to improve from 21 km (29 deciview) to 27 km (27 deciview). The PM2.5 annual average in Washington, DC, was 18.9 ug/m3 in 2000.

The updated monitored data and air quality modeling presented below confirm that the visibility situation identified during the NAAQS review in 1997 is still likely to exist. Specifically, there will still likely be a broad number of areas that are above the annual PM2.5 NAAQS in the Northeast, Midwest, Southeast and California , such that the determination in the NAAQS rulemaking about broad visibility impairment and related benefits from NAAQS compliance are still relevant. Thus, levels above the fine PM NAAQS cause adverse welfare impacts, such as visibility impairment (both regional and localized impairment).

In addition, in setting the PM NAAQS, EPA acknowledged that levels of fine particles below the NAAQS may also contribute to unacceptable visibility impairment and regional haze problems in some areas, and Clean Air Act Section 169 provides additional authorities to remedy existing impairment and prevent future impairment in the 156 national parks, forests and wilderness areas labeled as Class I areas.

In making determinations about the level of protection afforded by the secondary PM NAAQS, EPA considered how the Section 169 regional haze program and the secondary NAAQS would function together. Regional strategies are expected to improve visibility in many urban and non-Class I areas as well. The following recommendation for the National Research Council, Protecting Visibility in National Parks and Wilderness Areas (1993), addresses this point: “Efforts to improve visibility in Class I areas also would benefit visibility outside these areas. Because most visibility impairment is regional in scale, the same haze that degrades visibility within or looking out from a national park also degrade visibility outside it. Class I areas cannot be regarded as potential islands of clean air in a polluted sea.”

Visibility impairment (localized and regional haze) in Class I areas is discussed in the next section.

1.5.2.1.1 Areas Affected by Visibility Impairment: Monitored Data

The 1999-2000 $PM_{2.5}$ monitored values, which cover only a portion of the nation's counties, indicate that at least 82 million people live in areas where long-term ambient fine particulate matter levels are at or above 15 $\mu g/m^3$.[58] Thus, these populations (plus others who travel to these areas) would be experiencing visibility impairment that is unacceptable, and based on our modeling, emissions of PM and its precursors from engines in these categories contribute to this unacceptable impairment.

Another way to consider this information is to compare the values directly to the PM NAAQS in the format required by regulation. EPA regulations require 3 consecutive years of PM2.5 data in order to make comparisons with the National Ambient Air Quality Standards; see Part 50, Appendix N. In Table 1.5-1, we list areas with 1999 and 2000 monitored annual average PM2.5 levels above 15 ug/m3 in 2000, as represented by design values that can be compared to the PM2.5 NAAQS. There were a total of 129 counties representing 65 million people with levels above the design value for the annual PM2.5 NAAQS based on 1999 and 2000 monitored data. The table also notes areas which have made a note of "exceptional events" in their reporting of the monitored data.

Table 1.5-1.
Areas with Monitored Annual Average PM2.5 Concentrations Above 15 ug/m3.

EPA regulations require 3 consecutive years of PM2.5 data in order to make comparisons with the National Ambient Air Quality Standards; see Part 50, Appendix N. The data represented in this table reflect air quality monitoring from 1999 to 2001, although not all data have been verified by the monitoring agency.

State	County	Population 2000	Annual PM2.5 Standard Design Value	Design Value Data Flagged for Exceptional Events? 1
ALABAMA	CLAY	14,254	15.5	
ALABAMA	COLBERT	54,984	15.3	
ALABAMA	DE KALB	64,452	16.8	
ALABAMA	HOUSTON	88,787	16.3	
ALABAMA	JEFFERSON*	662,047	20.8*	
* Two sites in Jefferson County are encompassed in a Community Monitoring Zone (i.e. utilize spatial averaging); the spatially averaged design value for the CMZ is 20.8, which is the maximum for the county.				
ALABAMA	MADISON	276,700	15.5	
ALABAMA	MOBILE	399,843	15.3	
ALABAMA	MONTGOMERY	223,510	16.8	
ALABAMA	MORGAN	111,064	19.1	
ALABAMA	RUSSELL	49,756	18.4	
ALABAMA	SHELBY	143,293	17.2	
ALABAMA	TALLADEGA	80,321	17.8	
CALIFORNIA	BUTTE	203,171	15.4	yes
CALIFORNIA	FRESNO	799,407	24.0	yes
CALIFORNIA	IMPERIAL	142,361	15.7	
CALIFORNIA	KERN	661,645	23.7	yes
CALIFORNIA	KINGS	129,461	16.6	
CALIFORNIA	LOS ANGELES	9,519,338	25.9	
CALIFORNIA	MERCED	210,554	18.9	yes
CALIFORNIA	ORANGE	2,846,289	22.4	
CALIFORNIA 2	RIVERSIDE	1,545,387	29.8	
CALIFORNIA 2	SAN BERNARDINO	1,709,434	25.8	
CALIFORNIA	SAN DIEGO	2,813,833	17.1	
CALIFORNIA	SAN JOAQUIN	563,598	16.4	yes
CALIFORNIA	STANISLAUS	446,997	19.7	yes

State	County	Population 2000	Annual Std Design Value	DataFlagged for Exc. Events?1
CALIFORNIA	TULARE	368,021	24.7	
CONNECTICUT	NEW HAVEN	824,008	16.8	
DELAWARE	NEW CASTLE	500,265	16.6	
DISTRICT OF COLUMBIA	WASHINGTON	572,059	16.6	yes
GEORGIA	BIBB	153,887	17.6	
GEORGIA	CHATHAM	232,048	16.5	
GEORGIA	CLARKE	101,489	18.6	
GEORGIA	CLAYTON	236,517	19.2	
GEORGIA	COBB	607,751	18.6	
GEORGIA	DE KALB	665,865	19.6	
GEORGIA	DOUGHERTY	96,065	16.6	
GEORGIA	FLOYD	90,565	18.5	yes
GEORGIA	FULTON	816,006	21.2	
GEORGIA	HALL	139,277	17.2	
GEORGIA	MUSCOGEE	186,291	18.0	
GEORGIA	PAULDING	81,678	16.8	
GEORGIA	RICHMOND	199,775	17.4	
GEORGIA	WASHINGTON	21,176	16.5	
GEORGIA	WILKINSON	10,220	18.1	
ILLINOIS	COOK	5,376,741	18.8	
ILLINOIS	DU PAGE	904,161	15.4	
ILLINOIS	MADISON	258,941	17.3	
ILLINOIS	ST CLAIR	256,082	17.4	
ILLINOIS	WILL	502,266	15.9	
INDIANA	CLARK	96,472	17.3	
INDIANA	FLOYD	70,823	15.6	
INDIANA	LAKE	484,564	16.3	
INDIANA	MARION	860,454	17.0	
KENTUCKY	BOYD	49,752	15.5	yes
KENTUCKY	BULLITT	61,236	16.0	yes
KENTUCKY	CAMPBELL	88,616	15.5	yes
KENTUCKY	FAYETTE	260,512	16.8	yes
KENTUCKY	JEFFERSON	693,604	17.1	
KENTUCKY	KENTON	151,464	15.9	yes

State	County	Population 2000	Annual Std Design Value	DataFlagged for Exc. Events?1
KENTUCKY	MC CRACKEN	65,514	15.1	yes
KENTUCKY	PIKE	68,736	16.1	yes
KENTUCKY	WARREN	92,522	15.4	yes
MARYLAND	BALTIMORE (CITY)	651,154	17.8	
MICHIGAN	WAYNE	2,061,162	18.9	
MISSISSIPPI	HINDS	250,800	15.1	
MISSISSIPPI	JONES	64,958	16.6	
MISSOURI	ST LOUIS (CITY)	348,189	16.3	
MONTANA	LINCOLN	18,837	16.4	
NEW JERSEY	HUDSON	608,975	17.5	
NEW JERSEY	UNION	522,541	16.3	
NEW YORK	NEW YORK	1,537,195	17.8	yes
NORTH CAROLINA	ALAMANCE	130,800	15.3	
NORTH CAROLINA	CABARRUS	131,063	15.7	yes
NORTH CAROLINA	CATAWBA	141,685	17.1	yes
NORTH CAROLINA	CUMBERLAND	302,963	15.4	yes
NORTH CAROLINA	DAVIDSON	147,246	17.3	yes
NORTH CAROLINA	DURHAM	223,314	15.3	
NORTH CAROLINA	FORSYTH	306,067	16.2	yes
NORTH CAROLINA	GASTON	190,365	15.3	yes
NORTH CAROLINA	GUILFORD	421,048	16.3	yes
NORTH CAROLINA	HAYWOOD	54,033	15.4	yes
NORTH CAROLINA	MC DOWELL	42,151	16.2	yes
NORTH CAROLINA	MECKLENBURG	695,454	16.8	yes
NORTH CAROLINA	MITCHELL	15,687	15.5	yes
NORTH CAROLINA	WAKE	627,846	15.3	yes
OHIO	BUTLER	332,807	17.4	
OHIO	CUYAHOGA	1,393,978	20.3	

State	County	Population 2000	Annual Std Design Value	DataFlagged for Exc. Events?1
OHIO	FRANKLIN	1,068,978	18.1	
OHIO	HAMILTON	845,303	19.3	
OHIO	JEFFERSON	73,894	18.9	
OHIO	LORAIN	284,664	15.1	
OHIO	MAHONING	257,555	16.4	
OHIO	MONTGOMERY	559,062	17.6	
OHIO	PORTAGE	152,061	15.3	
OHIO	SCIOTO	79,195	20.0	
OHIO	STARK	378,098	18.3	
OHIO	SUMMIT	542,899	17.3	
OHIO	TRUMBULL	225,116	16.2	
PENNSYLVANIA	ALLEGHENY	1,281,666	21.0	
PENNSYLVANIA	BERKS	373,638	15.6	
PENNSYLVANIA	CAMBRIA	152,598	15.3	
PENNSYLVANIA	DAUPHIN	251,798	15.5	
PENNSYLVANIA	LANCASTER	470,658	16.9	
PENNSYLVANIA	PHILADELPHIA	1,517,550	16.6	
PENNSYLVANIA	WASHINGTON	202,897	15.5	
PENNSYLVANIA	WESTMORELAND	369,993	15.6	
PENNSYLVANIA	YORK	381,751	16.3	
SOUTH CAROLINA	GREENVILLE	379,616	17.0	yes
SOUTH CAROLINA	LEXINGTON	216,014	15.6	yes
SOUTH CAROLINA	RICHLAND	320,677	15.4	yes
SOUTH CAROLINA	SPARTANBURG	253,791	15.4	yes
TENNESSEE	DAVIDSON	569,891	17.0	
TENNESSEE	HAMILTON	307,896	18.9	
TENNESSEE	KNOX	382,032	20.4	yes
TENNESSEE	ROANE	51,910	17.0	yes
TENNESSEE	SHELBY	897,472	15.6	
TENNESSEE	SULLIVAN	153,048	17.0	yes

State	County	Population 2000	Annual Std Design Value	DataFlagged for Exc. Events?1
TENNESSEE	SUMNER	130,449	15.7	
VIRGINIA	BRISTOL	17,367	16.0	yes
VIRGINIA	ROANOKE (CITY)	94,911	15.2	yes
WEST VIRGINIA	BERKELEY	75,905	16.0	
WEST VIRGINIA	BROOKE	25,447	17.4	
WEST VIRGINIA	CABELL	96,784	17.8	yes
WEST VIRGINIA	HANCOCK	32,667	17.4	
WEST VIRGINIA	KANAWHA	200,073	18.4	yes
WEST VIRGINIA	MARSHALL	35,519	16.5	
WEST VIRGINIA	OHIO	47,427	15.7	
WEST VIRGINIA	WOOD	87,986	17.6	yes
TOTAL	**129 Counties**	**65,185,812**		

1. Design Values include all valid data. Some valid data were impacted by exceptional events. These special situations are being reviewed by EPA.

2. Sacramento County CA does not exceed the PM2.5 annual standard but does exceed the daily standard.

Source: EPA Trends Reports

1.5.2.1.2 Areas Affected by Visibility Impairment: Modeled Future PM Levels and Visibility Index Estimates

Because the chemical composition of the PM affects visibility impairment, we used REMSAD air quality model to project visibility conditions in 2030 accounting for the chemical composition of the particles and to estimate visibility impairment directly as changes in deciview. Our projections included anticipated emissions from the engines subject to this rule, and although our emission predictions reflected our best estimates of emissions projections at the time the modeling was conducted, we now have new estimates, as discussed above in Table 1.1-4. Based on public comment for this rule and new information, we have revised our emissions estimates in some categories downwards and other categories upwards; however, on net, we believe the HD07 modeling underestimates the PM air quality levels that would be predicted if new inventories were used.

The most reliable information about the future visibility levels would be in areas for which monitoring data are available to evaluate model performance for a base year (e.g., 1996). Accordingly, we predicted that in 2030, 49 percent of the population will be living in areas where fine PM levels are above 15 µg/m3 and monitors are available.[59] This can be compared with the 1996 level of 37 percent of the population living in areas where fine PM levels are above 15 µg/m3 and monitors are available.

Based upon the light-extinction coefficient, we also calculated a unitless visibility index, called a "deciview," which is used in the valuation of visibility. The deciview metric provides a linear scale for perceived visual changes over the entire range of conditions, from clear to hazy. Under many scenic conditions, the average person can generally perceive a change of one deciview. The higher the deciview value, the worse the visibility. Thus, an improvement in visibility is a decrease in deciview value.

As shown in Table 1.5-2, in 2030 we estimate visibility in the East to be about 19 deciviews (or visual range of 60 kilometers) on average, with poorer visibility in urban areas, compared to the visibility conditions without man-made pollution of 9.5 deciviews (or visual range of 150 kilometers). Likewise, in we estimate visibility in the West to be about 9.5 deciviews (or visual range of 150 kilometers) in 2030, compared to the visibility conditions without man-made pollution of 5.3 deciviews (or visual range of 230 kilometers). Thus, in the future, a substantial percent of the population may experience unacceptable visibility impairment in areas where they live, work and recreate.

Table 1.5-2
Summary of 2030 National Visibility Conditions Based on REMSAD Modeling (Deciviews)

Regions[b]	Predicted 2030 Visibility[a] (annual average)	Natural Background Visibility
Eastern U.S.	18.98	9.5
Urban	20.48	
Rural	18.38	
Western U.S.	9.54	5.3
Urban	10.21	
Rural	9.39	

[a] The results incorporate earlier emissions estimates from the engines subject to this rule. We have revised our estimates both upwards for some categories and downwards for others based on public comment and updated information; however, on net, we believe that the results would underestimate future PM emissions.

[b] Eastern and Western Regions are separated by 100 degrees north longitude. Background visibility conditions differ by region.

The emissions from nonroad engines generally, and in particular the engines subject to this rule, contribute to this visibility impairment shown in Table 1.5-2. Nonroad engines emissions contribute a large portion of the total PM emissions from mobile sources and anthropogenic sources, in general. These emissions occur in and around areas with PM levels above the annual PM2.5 NAAQS. The engines subject to the final rule will contribute to these effects. They are estimated to emit 36,500 tons of direct PM in 2030, which is 1.1 percent of the total anthropogenic PM emissions in 2030. Similarly, for PM precursors, the engines subject to this rule will emit 640,000 tons of NOx and 1,411,000 tons HC in 2030, which are 3.8 and 8.3 percent of the total anthropogenic NOx and HC emissions, respectively, in 2030. Recreational vehicles in particular contribute to these levels. In Table I.E-1 through I.E-3, we show that recreational vehicles emitted about 1.7 percent of mobile source PM emissions in 2000. Similarly, recreational vehicles are modeled to emit over 4 percent of mobile source PM in 2020 and 2030. Thus, the emissions from these sources contribute to the visibility impairment modeled for 2030 summarized in the table.

Snowmobiles are operated in and around areas with PM2.5 levels above the level of the secondary NAAQS. For 20 counties across nine states, snowmobile trails are found within or near counties that registered ambient $PM_{2.5}$ concentrations at or above 15 $\mu g/m^3$, the level of the $PM_{2.5}$ NAAQS.[6] These counties are listed in Table 1.5-3. To obtain the information about

[6] Memo to file from Terence Fitz-Simons, OAQPS, Scott Mathias, OAQPS, Mike Rizzo, Region 5, "Analyses of 1999 PM Data for the PM NAAQS Review," November 17, 2000, with attachment B, 1999 PM2.5 Annual Mean and 98th Percentile 24-Hour Average Concentrations.

snowmobile trails contained in the table, we consulted snowmobile trail maps that were supplied by various states.[60] Fine particles may remain suspended for days or weeks and travel hundreds to thousands of kilometers, and thus fine particles emitted or created in one county may contribute to ambient concentrations in a neighboring county.[7]

Docket No. A-2000-01, Document No. II-B-17.

[7]Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment for Scientific and Technical Information, OAQPS Staff Paper, EPA-452\R-96-013, July, 1996, at IV-7. This document is available from Docket A-99-06, Document II-A-23.

Table 1.5-3
Counties with Annual $PM_{2.5}$ Levels Above 16 µg/m3 and Snowmobile Trails

State	$PM_{2.5}$ Exceedances County	County with Snowmobile Trails	Proximity to $PM_{2.5}$ Exceedances County
Ohio	Machining	Machining	Same County
	Trumbull	Trumbull	Same County
	Summit	Summit	Same County
	Montgomery	Montgomery	Same County
	Portage	Portage	Same County
	Franklin	Delaware	Borders North
	Marshall/Ohio (WV)	Belmont	Borders West
Montana	Lincoln	Lincoln	Same County
California	Tulane	Tulane	Same County
	Butte	Butte	Same County
	Fresno	Fresno	Same County
	Kern	Kern	Same County
Minnesota	Washington	Washington	Same County
	Wright	Wright	Same County
Wisconsin	Waukesha	Waukesha	Same County
	Milwaukee	Milwaukee	Same County
Oregon	Jackson	Douglas	Borders NNE
	Klammath	Douglas	Borders North
Pennsylvania	Washington	Layette	Borders East
		Somerset	—
Illinois	Rock Island	Rock Island	Same County
		Henry	Borders East
Iowa	Rock Island (IL)	Dubuque	Borders West

Achieving the annual $PM_{2.5}$ NAAQS will help improve visibility across the country, but it will not be sufficient (64 FR 35722 July 1, 1999 and 62 FR July 18, 1997 PM NAAQS). In setting the NAAQS, EPA discussed how the NAAQS in combination with the regional haze program, is deemed to improve visibility consistent with the goals of the CAA. In the East, there are wide areas above 15 ug/m^3 and light extinction is significantly above natural background. Thus, large areas of the Eastern United States have air pollution that is causing unacceptable visibility problems. In the West, scenic vistas are especially important to public welfare. Although the annual $PM_{2.5}$ NAAQS is met in most areas outside of California, virtually the entire West is in close proximity to a scenic Class I area protected by 169A and 169B of the CAA.

1.5.3 Visibility Impairment in Class I Areas

The Clean Air Act establishes special goals for improving visibility in many national parks, wilderness areas, and international parks. In the 1977 amendments to the Clean Air Act, Congress set as a national goal for visibility the "prevention of any future, and the remedying of any existing, impairment of visibility in mandatory class I Federal areas which impairment results from manmade air pollution" (CAA section 169A(a)(1)). The Amendments called for EPA to issue regulations requiring States to develop implementation plans that assure "reasonable progress" toward meeting the national goal (CAA Section 169A(a)(4)). EPA issued regulations in 1980 to address visibility problems that are "reasonably attributable" to a single source or small group of sources, but deferred action on regulations related to regional haze, a type of visibility impairment that is caused by the emission of air pollutants by numerous emission sources located across a broad geographic region. At that time, EPA acknowledged that the regulations were only the first phase for addressing visibility impairment. Regulations dealing with regional haze were deferred until improved techniques were developed for monitoring, for air quality modeling, and for understanding the specific pollutants contributing to regional haze.

In the 1990 Clean Air Act amendments, Congress provided additional emphasis on regional haze issues (see CAA section 169B). In 1999 EPA finalized a rule that calls for States to establish goals and emission reduction strategies for improving visibility in all 156 mandatory Class I national parks and wilderness areas. In this rule, EPA established a "natural visibility" goal.[61] In that rule, EPA also encouraged the States to work together in developing and implementing their air quality plans. The regional haze program is focused on long-term emissions decreases from the entire regional emissions inventory comprised of major and minor stationary sources, area sources and mobile sources. The regional haze program is designed to improve visibility and air quality in our most treasured natural areas from these broad sources. At the same time, control strategies designed to improve visibility in the national parks and wilderness areas will improve visibility over broad geographic areas. In the PM NAAQS rulemaking, EPA also anticipated the need in addition to the NAAQS and Section 169 regional haze program to continue to address localized impairment that may relate to unique circumstances in some Western areas. For mobile sources, there may also be a need for a Federal role in reduction of those emissions, in particular, because mobile sources are regulated primarily at the federal level.

As described above, regional haze is caused by the emission from numerous sources located over a wide geographic area.[62] Visibility impairment is caused by pollutants (mostly fine particles and precursor gases) directly emitted to the atmosphere by several activities (such as electric power generation, various industry and manufacturing processes, truck and auto emissions, construction activities, etc.). These gases and particles scatter and absorb light, removing it from the sight path and creating a hazy condition. Visibility impairment is caused by both regional haze and localized impairment.

Because of evidence that fine particles are frequently transported hundreds of miles, all 50 states, including those that do not have Class I areas, participate in planning, analysis and, in many cases, emission control programs under the regional haze regulations. Even though a given State may not have any Class I areas, pollution that occurs in that State may contribute to impairment in Class I areas elsewhere. The rule encourages states to work together to determine whether or how much emissions from sources in a given state affect visibility in a downwind Class I area.

The regional haze program calls for states to establish goals for improving visibility in national parks and wilderness areas to improve visibility on the haziest 20 percent of days and to ensure that no degradation occurs on the clearest 20 percent of days. The rule requires states to develop long-term strategies including enforceable measures designed to meet reasonable progress goals toward natural visibility conditions. Under the regional haze program, States can take credit for improvements in air quality achieved as a result of other Clean Air Act programs, including national mobile-source programs.[8]

As noted above, EPA issued regulations in 1980 to address Class I area localized visibility impairment that is "reasonably attributable" to a single source or small group of sources. In 40 CFR Part 51.301 of the visibility regulations, visibility impairment is defined as "any humanly perceptible change in visibility (light extinction, visual range, contrast, coloration) from that which would have existed under natural conditions." States are required to develop implementation plans that include long-term strategies for improving visibility in each Class I area. The long-term strategies under the 1980 regulations should consist of measures to reduce impacts from local sources and groups of sources that contribute to poor air quality days in the class I area. Types of impairment covered by these regulations includes layered hazes and visible plumes. While these kinds of visibility impairment can be caused by the same pollutants and processes as those that cause regional haze, they generally are attributed to a smaller number of sources located across a smaller area. The Clean Air Act and associated regulations call for

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[8] Though a recent case, American Corn Growers Association v. EPA, 291F.3d 1(D.C .Cir 2002) vacated the BART provisions of the Regional Haze rule, the court denied industry's challenge to EPA's requirement that state's SIPS provide for reasonable progress towards achieving natural visibility conditions in national parks and wilderness areas and the "no degradation" requirement. Industry did not challenge requirements to improve visibility on the haziest 20 percent of days. The court recognized that mobile source emission reductions would need to be a part of a long-term emission strategy for reducing regional haze. A copy of this decision can be found in Docket A-2000-01, Document IV- A-113.

protection of visibility impairment in Class I areas from localized impacts as well as broader impacts associated with regional haze.

As part of the HD07 PM air quality modeling described above, we modeled visibility conditions in the Class I areas nationally. The results by region are summarized in Table 1.5-4. In Figure 1.5-1, we define the regions used in this analysis based on a visibility study.[63] These results show that visibility is impaired in most Class I areas and additional reductions from behicles subject to this rule are needed to achieve the goals of the Clean Air Act of preserving natural conditions in Class I areas.

Table 1.5-4
Summary of 2030 Visibility Conditions in Class I Areas Based on REMSAD Modeling (Annual Average Deciview)

Region	Predicted 2030 Visibility	Natural Background Visibility
Eastern		9.5
Southeast	25.02	
Northeast/Midwest	21.00	
Western		5.3
Southwest	8.69	
California	11.61	
Rocky Mountain	12.30	
Northwest	15.44	
National Class I Area Average	14.04	

[a] Regions are depicted in Figure 1-5.1. Background visibility conditions differ by region based on differences in relative humidity and other factors: Eastern natural background is 9.5 deciviews (or visual range of 150 kilometers) and in the West natural background is 5.3 deciviews (or visual range of 230 kilometers).

[b] The results incorporate earlier emissions estimates from the engines subject to this rule. We have revised our estimates both upwards for some categories and downwards for others based on public comment and updated information; however, on net, we believe that the HD07 analyses underestimate future PM emissions.

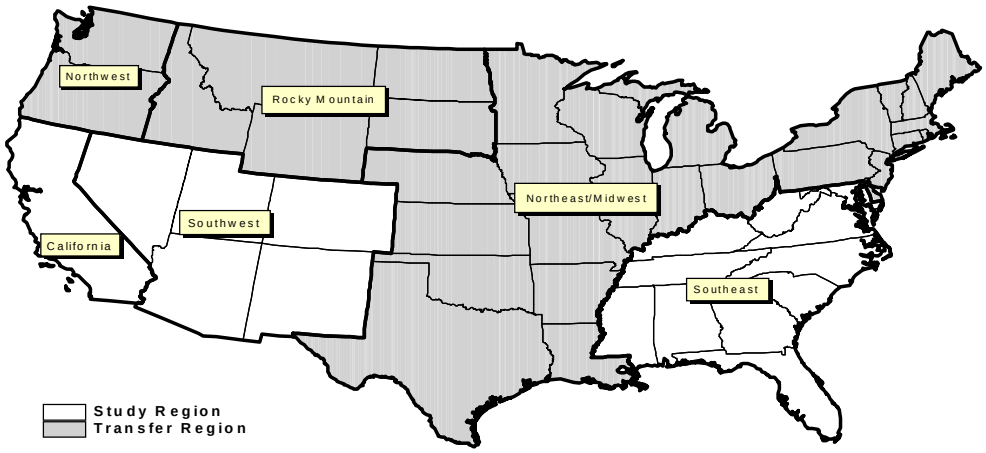

Figure 1.5-1. Visibility Regions for Continental U.S.

Note: Study regions were represented in the Chestnut and Rowe (1990a, 1990b) studies used in evaluating the benefits of visibility improvements.

The overall goal of the regional haze program is to prevent future and remedy existing visibility impairment in Class I areas. As shown by the future deciview estimates in Table 1.5-4, additional emissions reductions will be needed from the broad set of sources that contribute, including the emissions from engines subject to this rule.

1.5.4 Recreational Vehicles and Visibility Impairment in Class I Areas

This section presents information about the contribution of recreational vehicles to visibility impairment in Class I areas. Although this discussion focuses primarily on snowmobiles, we present information on other recreational vehicles as well. We use monitoring data to show that many of the worst 20 percent of days in terms of visibility levels occur in the wintertime, when snowmobiles are used. We also summarize air quality modeling information of future visibility for Class I areas where snowmobiles are operated and a case study of localized impairment in a national park.

1.5.4.1 Snowmobiles Emissions in Class I Areas

Emissions of HC from snowmobiles contribute to direct and secondary formation of fine particulate matter which can cause a variety of adverse health and welfare effects, including visibility impairment discussed above. This section presents snowmobile-related emissions information for Class I areas where snowmobiles are operated as further evidence of their contribution in Class I areas.

Ambient concentrations of fine particles are the primary pollutant responsible for visibility impairment. The classes of fine particles principally responsible for visibility impairment are sulfates, nitrates, organic carbon particles, elemental carbon, and crustal material. Hydrocarbon emissions from automobiles, trucks, snowmobiles, and other industrial processes are common sources of organic carbon. The organic carbon fraction of fine particles ranges from 47 percent in western Class I areas such as Denali National Park, to 28 percent in Rocky Mountain National Park, to 13 percent in Acadia National Park.[64]

The contribution of snowmobiles to elemental carbon and nitrates is relatively small. Their contribution to sulfates is a function of fuel sulfur and is small and will decrease even more as the sulfur content of their fuel decreases due to our recently finalized fuel sulfur requirements. In the winter months, however, hydrocarbon emissions from snowmobiles can be significant, as indicated in Table 1.5-5 and these HC emissions can contribute significantly to the organic carbon fraction of fine particles which are largely responsible for visibility impairment. This is because snowmobiles are typically powered by two-stroke engines that emit large amounts of hydrocarbons. In Yellowstone, a park with high snowmobile usage during the winter months, snowmobile hydrocarbon emissions can exceed 500 tons per year, as much as several large stationary sources. Other parks with less snowmobile traffic are also impacted, though to a lesser extent, by these hydrocarbon emissions.[65]

Table 1.5-5
1999 Winter Season Snowmobile Emissions in Selected Class I Areas (tons)

Class I area	HC	CO	NOx	PM
Denali NP and Preserve	>9.8	>26.1	>0.08	>0.24
Grand Teton NP	13.7	36.6	0.1	0.3
Rocky Mountain NP	106.7	284.7	0.8	2.6
Voyager NP	138.5	369.4	1.1	3.4
Yellowstone NP	492	1311.9	3.8	12

Source: Letter from Aaron J. Worstell, Environmental Engineer, National Park Service, Air Resources Division, to Drew Kodjak, August 21, 2001, particularly Table 1. Docket No. A-2000-01, Document No. II-G-178.

The national park areas outside of Denali in Alaska are open to snowmobile operation in accordance with special regulations (36 CFR Part 7). Denali National Park permits snowmobile operation by local rural residents engaged in subsistence uses (36 CFR Part 13). Emission calculations are based on an assumed 2 hours of use per snowmobile visit at 16 hp with the exception of Yellowstone where 4 hours of use at 16 hp was assumed. The emission factors used to estimate these emissions are identical to those used by the NONROAD model. Two-stroke snowmobile emission factors are: 111 g/hp-hr HC, 296 g/hp-hr CO, 0.86 g/hp-hr NOx, and 2.7 g/hp-hr PM. These emission factors are based on a number of engine tests performed by the International Snowmobile Manufacturers Association (ISMA) and the Southwest Research Institute (SwRI).

1.5.4.2 Air Quality Monitoring Information

To explore whether recreational vehicles, such as snowmobiles, contribute to visibility impairment in Class I areas, we examine current monitored PM levels. Visibility and particulate monitoring data are available for 8 Class I areas where snowmobiles are commonly used. These are Acadia, Boundary Waters, Denali, Mount Ranier, Rocky Mountain, Sequoia and Kings Ganyon, Voyager, and Yellowstone. Monitored fine particle data for these parks are set out in Table 1.5-6. This table shows the number of monitored days in the winter that fell within the 20-percent haziest days for each of these eight parks. Monitors collect data two days a week for a total of about 104 days of monitored values. Thus, for a particular site, a maximum of 21 worst possible days of these 104 days with monitored values constitute the set of 20-percent haziest days during a year which are tracked as the primary focus of regulatory efforts.[66] With the exception of Denali in Alaska, we defined the snowmobile season as January 1 through March 15 and December 15 through December 31 of the same calendar year, consistent with the methodology used in the Regional Haze Rule, which is calendar-year based. For Denali, Alaska, the snowmobile season is October 1 to April 30.

Table 1.5-6
Winter Days That Fall Within the 20 Percent Worst Visibility Days
At National Parks Where Snowmobiles Are Operated

Class I Area	State(s)	Number of Sampled Wintertime Days Within 20 Percent Worst Visibility Days (maximum of 21 out of 104 monitored days)			
		1996	1997	1998	1999
Acadia NP	ME	4	4	2	1
Denali NP and Preserve	AK	10	10	12	9
Mount Rainier NP	WA	1	3	1	1
Rocky Mountain NP	CO	2	1	2	1
Sequoia and Kings Canyon NP	CA	4	9	1	8
Voyager NP (1989-1992)	MN	1989: 3	1990: 4	1991: 6	1992: 8
-- Boundary Waters USFS Wilderness Area (close to Voyaguers with recent data)	MN	2	5	1	5
Yellowstone NP	ID, MT, WY	0	2	0	0

Source: Letter from Debra C. Miller, Data Analyst, National Park Service, to Drew Kodjak, August 22, 2001. Docket No. A-2000-01.

1.5.4.3 Future Visibility Impairment in Class I Areas: Regional Haze

We also examined future air quality information to whether the emissions from recreational vehicles, such as snowmobiles, contribute to regional visibility impairment in Class I areas. We present results from the HD07 future air quality modeling described above for these Class I areas in addition to inventory and air quality measurements. Specifically, in Table 1-5.7, we summarize the expected future visibility conditions in these areas without these regulations.

Table 1.5-7
Estimated 2030 Visibility in Selected Class I Areas

Class I Area	County	State	Predicted 2030 Visibility (annual average deciview)	Natural Background Visibility (annual average deciview)
Eastern areas				
Acadia	Hancock Co	ME	23.42	9.5
Boundary Waters	St. Louis Co	MN	22.07	
Voyager	St. Louis Co	MN	22.07	
Western areas				
Grand Teton NP	Teton Co	WY	11.97	5.3
Kings Canyon	Fresno Co	CA	10.39	
Mount Rainier	Lewis Co	WA	16.19	
Rocky Mountain	Larimer Co	CO	8.11	
Sequoia-Kings	Tulare Co	CA	9.36	
Yellowstone	Teton Co	WY	11.97	

[a] Natural background visibility conditions differ by region because of differences in factors such as relative humidity: Eastern natural background is 9.5 deciviews (or visual range of 150 kilometers) and in the West natural background is 5.3 deciviews (or visual range of 230 kilometers).

[b] The results incorporate earlier emissions estimates from the engines subject to this rule. We have revised our estimates both upwards for some categories and downwards for others based on public comment and updated information; however, on net, we believe that HD07 analysis would underestimate future PM emissions from these categories.

In these areas, snowmobiles represent a signficant part of wintertime visibility-impairing emissions. In fact, as the following discussion shows, snowmobile emissions can even be a sizable percentage of annual emissions in some Class I areas. The snowmobiles thus are a significant contributor to visibility impairment in these areas during the winter. As indicated, winter days can often be among the worst visibility impairment. In addition, as the CAA specifically states a goal of prevention and of remedying of <u>any</u> impairment of visibility in Class I areas, the contribution of snowmobiles to visibility impairment even on winter days that are not among the days of greatest impairment is a contribution to pollution that may reasonably be anticipated to endanger public welfare and is properly regulated in this rule.

The information presented in Table 1.5-6 shows that visibility data supports a conclusion that there are at least 8 Class I areas frequented by snowmobiles with one or more wintertime days within the 20-percent worst visibility days of the year. For example, Rocky Mountain National Park in Colorado was frequented by about 27,000 snowmobiles during the 1998-1999 winter. Of the monitored days characterized as within the 20-percent worst visibility monitored days, 2 of those days occurred during the wintertime when snowmobile emissions such as HC contributed to visibility impairment. The information in Table 1.5-7 shows that these areas also have high predicted annual average deciview levels in the future. According to the National Park Service, "[s]ignificant differences in haziness occur at all eight sites between the averages of the clearest and haziest days. Differences in mean standard visual range on the clearest and haziest days fall in the approximate range of 115-170 km."[67]

1.5.4.4 Localized Visibility Impairment in Class I Areas: Yellowstone National Park

The Class I are with the most detailed analysis of snowmobile contribution is Yellowstone National Park. This provides an example of the extent to which snowmobiles can contribute to emissions that can cause visibility impairment in Class I areas. Annual and particularly wintertime hydrocarbon emissions from snowmobiles are high in the five parks considered in Table 1.5-7, with two parks having HC emissions nearly as high as Yellowstone (Rocky Mountain and Voyageurs). The proportion of snowmobile emissions to emissions from other sources affecting air quality in these parks is likely to be similar to that in Yellowstone.

Inventory analysis performed by the National Park Service for Yellowstone National Park suggests that snowmobile emissions can be a significant source of total annual mobile source emissions for the park year round. Table 1.5-8 shows that in the 1998 winter season snowmobiles contributed 64 percent, 39 percent, and 30 percent of HC, CO, and PM emissions.[68] When the emission factors used by EPA in its NONROAD model are used, the contribution of snowmobiles to total emissions in Yellowstone is still high: 59 percent, 33 percent, and 45 percent of HC, CO and PM emissions. The University of Denver used remote-sensing equipment to estimate snowmobile HC emissions at Yellowstone during the winter of 1998-1999, and estimated that snowmobiles contribute 77 percent of annual HC emissions at the park.[69] The portion of wintertime emissions attributable to snowmobiles is even higher, since all snowmobile emissions occur during the winter months.

Table 1.5-8
1998 Annual HC Emissions (tons per year), Yellowstone National Park

Source	HC		CO		NOx		PM	
Coaches	2.69	0%	24.29	1%	0.42	0%	0.01	0%
Autos	307.17	33%	2,242.12	54%	285.51	88%	12.20	60%
RVs	15.37	2%	269.61	6%	24.33	7%	0.90	4%
Snowmobiles	596.22	64%	1,636.44	39%	1.79	1%	6.07	30%
Buses	4.96	1%	18.00	0%	13.03	4%	1.07	5%
TOTAL	926.4		4190.46		325.08		20.25	

Source: National Park Service, February 2000. Air Quality Concerns Related to Snowmobile Usage in National Parks. Air Docket A-2000-01, Document No. II-A-44.

As part of public comments, Sierra Research conducted modeling of local impairment using EPA's SCREEN3 Model Version 96043. This methodology consists of a single source Gaussian plume model, which provides maximum ground-level concentrations for point, area, flare, and volume sources, as well as concentrations in the cavity zone and concentrations due to inversion break-up and shoreline fumigation.

The Sierra Research modeling demonstrated that there is up to an 8 percent contribution to visibility degradation from snowmobile exhaust based on worst case conditions in Yellowstone national park. It should be noted that SCREEN3 is not an EPA-approved model for conducting visibility modeling. In interpreting the results of this modeling, the International Snowmobile Manufacturers Association (ISMA) notes that the conversion factors used by SCREEN3 are "conservatively high" and meant for worst case conditions, where there is a "pronounced [wind] polarity…such as where a sea breeze exists."[70] Consequently, ISMA appears to believe that data gathered away from a coastline would actually have a lower demonstrated visual impact than the impact determined by the model. Even using this modeling, ISMA presents modeling results that support an 8 percent contribution to visibility impairment. ISMA reasons that by using the same model for automobiles, the impairment contribution is double of what was expected, and therefore, the 8 percent is most likely double of what it should be. As a result, ISMA concludes an up to 4% contribution to visibility impairment from snowmobile emissions in national parks "on best visibility days."[71] Though the contribution levels in this industry-sponsored study are lower than those discussed above, and though we have some concerns with this study, as discussed in the Summary and Analysis of Comments, they still confirm that snowmobiles are indeed a significant contributor to visibility degradation in Yellowstone.

In addition to the national modeling presented in Tables 1.4-3, 1.5-1, and 1.5-6, we also conducted local-scale modeling using an EPA-approved visibility model, VISCREEN Version 1.01, to evaluate whether current emissions from recreational vehicles, such as snowmobiles,

contribute to localized visibility impairment in Class I areas. This analysis focused on localized visibility impairments in Yellowstone National Park.[72] The VISCREEN model is a visibility screening level-I and -II model that characterizes point source plumes and visibility effects at 34 lines of sight. Thus, in this modeling, EPA treated snowmobiles as a synthetic point source in order to determine plume perceptibility effects in a national park.

Using VISCREEN Version 1.01, we determined plume perceptibility from snowmobile usage at four entrances (North, South, East, and West) in Yellowstone National Park as a case study of visibility impairment from recreational vehicles. We conclude that plume perceptibility would be noticeable at all entrances, even at the North entrance where the smallest numbers of snowmobiles enter. Variations in the parameters concluded that perceptibility increased as the observer neared the plume and at smaller plume-offset angles. As well, a sensitivity analysis was conducted in order to demonstrate visibility impairment when the source is located within the Class I boundaries and concluded that visibility impairment increases if the source is located within the boundary. This provides further proof that snowmobile usage can lead to visibility impairment at Yellowstone.

These results all indicate that snowmobiles contribute to visibility impairment concerns in Yellowstone National Park, a Class I area.

1.6 Gaseous Air Toxics

In addition to the human health and welfare impacts described above, emissions from the engines covered by this rulemaking also contain several other substances that are known or suspected human or animal carcinogens, or have serious non-cancer health effects. These include benzene, 1,3-butadiene, formaldehyde, acetaldehyde, acrolein, and toluene. The health effects of these air toxics are highlighted below. Additional information can also be found in the Technical Support Document four our final Mobile Source Air Toxics rule.[73]

1.6.1 Benzene

Benzene is an aromatic hydrocarbon which is present as a gas in both exhaust and evaporative emissions from motor vehicles. Benzene in the exhaust, expressed as a percentage of total organic gases (TOG), varies depending on control technology (e.g., type of catalyst) and the levels of benzene and other aromatics in the fuel, but is generally about three to five percent. The benzene fraction of evaporative emissions depends on control technology and fuel composition and characteristics (e.g., benzene level and the evaporation rate), and is generally about one percent.[74]

EPA has recently reconfirmed that benzene is a known human carcinogen by all routes of exposure.[75] Respiration is the major source of human exposure. Long-term respiratory exposure to high levels of ambient benzene concentrations has been shown to cause cancer of the tissues that form white blood cells. Among these are acute nonlymphocytic leukemia,[76] chronic lymphocytic leukemia and possibly multiple myeloma (primary malignant tumors in the bone marrow), although the evidence for the latter has decreased with more recent studies.[77,78]

Leukemias, lymphomas, and other tumor types have been observed in experimental animals exposed to benzene by inhalation or oral administration. Exposure to benzene and/or its metabolites has also been linked with genetic changes in humans and animals[79] and increased proliferation of mouse bone marrow cells.[80] The occurrence of certain chromosomal changes in individuals with known exposure to benzene may serve as a marker for those at risk for contracting leukemia.[81]

A number of adverse non-cancer health effects, blood disorders such as preleukemia and aplastic anemia, have also been associated with low-dose, long-term exposure to benzene.[82] People with long-term exposure to benzene may experience harmful effects on the blood-forming tissues, especially the bone marrow. These effects can disrupt normal blood production and cause a decrease in important blood components, such as red blood cells and blood platelets, leading to anemia (a reduction in the number of red blood cells), leukopenia (a reduction in the number of white blood cells), or thrombocytopenia (a reduction in the number of blood platelets, thus reducing the ability for blood to clot). Chronic inhalation exposure to benzene in humans and animals results in pancytopenia,[83] a condition characterized by decreased numbers of circulating erythrocytes (red blood cells), leukocytes (white blood cells), and thrombocytes (blood platelets).[84,85] Individuals that develop pancytopenia and have continued exposure to benzene may develop aplastic anemia,[86] whereas others exhibit both pancytopenia and bone marrow hyperplasia (excessive cell formation), a condition that may indicate a preleukemic state.[87] [88] The most sensitive non-cancer effect observed in humans is the depression of absolute lymphocyte counts in the circulating blood.[89]

1.6.2 1,3-Butadiene

1,3-Butadiene is formed in vehicle exhaust by the incomplete combustion of fuel. It is not present in vehicle evaporative emissions, because it is not present in any appreciable amount in fuel. 1,3-Butadiene accounts for 0.4 to 1.0 percent of total organic gas exhaust, depending on control technology and fuel composition.[90]

1,3-Butadiene was classified by EPA as a Group B2 (probable human) carcinogen in 1985.[91] This classification was based on evidence from two species of rodents and epidemiologic data. In the EPA1998 draft Health Risk Assessment of 1,3-Butadiene, that was reviewed by the Science Advisory Board (SAB), the EPA proposed that 1,3-butadiene is a known human carcinogen based on human epidemiologic, laboratory animal data, and supporting data such as the genotoxicity of 1,3-butadiene metabolites.[92] The Environmental Health Committee of EPA's Scientific Advisory Board (SAB) reviewed the draft document in August 1998 and recommended that 1,3-butadiene be classified as a probable human carcinogen, stating that designation of 1,3-butadiene as a known human carcinogen should be based on observational studies in humans, without regard to mechanistic or other information.[93] In applying the 1996 Guidelines for Carcinogen Risk Assessment, the Agency relies on both observational studies in humans as well as experimental evidence demonstrating causality, and therefore the designation of 1,3-butadiene as a known human carcinogen remains applicable.[94] The Agency has revised the draft Health Risk Assessment of 1,3-Butadiene based on the SAB and public comments. The draft Health Risk Assessment of 1,3-Butadiene will undergo the Agency consensus review, during which time

additional changes may be made prior to its public release and placement on the Integrated Risk Information System (IRIS).

1,3-Butadiene also causes a variety of non-cancer reproductive and developmental effects in mice and rats (no human data) when exposed to long-term, low doses of butadiene.[95] The most sensitive effect was reduced litter size at birth and at weaning. These effects were observed in studies in which male mice exposed to 1,3-butadiene were mated with unexposed females. In humans, such an effect might manifest itself as an increased risk of spontaneous abortions, miscarriages, still births, or very early deaths. Long-term exposures to 1,3-butadiene should be kept below its reference concentration of 4.0 microgram/m^3 to avoid appreciable risks of these reproductive and developmental effects.[96] EPA has developed a draft chronic, subchronic, and acute RfC values for 1,3-butadiene exposure as part of the draft risk characterization mentioned above. The RfC values will be reported on IRIS.

1.6.3 Formaldehyde

Formaldehyde is the most prevalent aldehyde in vehicle exhaust. It is formed from incomplete combustion of both gasoline and diesel fuel and accounts for one to four percent of total organic gaseous emissions, depending on control technology and fuel composition. It is not found in evaporative emissions.

Formaldehyde exhibits extremely complex atmospheric behavior.[97] It is formed by the atmospheric oxidation of virtually all organic species, including biogenic (produced by a living organism) hydrocarbons. Mobile sources contribute both primary formaldehyde (emitted directly from motor vehicles) and secondary formaldehyde (formed from photooxidation of other VOCs emitted from vehicles).

EPA has classified formaldehyde as a probable human carcinogen based on limited evidence for carcinogenicity in humans and sufficient evidence of carcinogenicity in animal studies, rats, mice, hamsters, and monkeys.[98] Epidemiological studies in occupationally exposed workers suggest that long-term inhalation of formaldehyde may be associated with tumors of the nasopharyngeal cavity (generally the area at the back of the mouth near the nose), nasal cavity, and sinus. Studies in experimental animals provide sufficient evidence that long-term inhalation exposure to formaldehyde causes an increase in the incidence of squamous (epithelial) cell carcinomas (tumors) of the nasal cavity. The distribution of nasal tumors in rats suggests that not only regional exposure but also local tissue susceptibility may be important for the distribution of formaldehyde-induced tumors.[99] Research has demonstrated that formaldehyde produces mutagenic activity in cell cultures.[100]

Formaldehyde exposure also causes a range of non-cancer health effects. At low concentrations (0.05-2.0 ppm), irritation of the eyes (tearing of the eyes and increased blinking) and mucous membranes is the principal effect observed in humans. At exposure to 1-11 ppm, other human upper respiratory effects associated with acute formaldehyde exposure include a dry or sore throat, and a tingling sensation of the nose. Sensitive individuals may experience these effects at lower concentrations. Forty percent of formaldehyde-producing factory workers

reported nasal symptoms such as rhinitis (inflammation of the nasal membrane), nasal obstruction, and nasal discharge following chronic exposure.[101] In persons with bronchial asthma, the upper respiratory irritation caused by formaldehyde can precipitate an acute asthmatic attack, sometimes at concentrations below 5 ppm.[102] Formaldehyde exposure may also cause bronchial asthma-like symptoms in non-asthmatics.[103] [104]

Immune stimulation may occur following formaldehyde exposure, although conclusive evidence is not available. Also, little is known about formaldehyde's effect on the central nervous system. Several animal inhalation studies have been conducted to assess the developmental toxicity of formaldehyde. The only exposure-related effect noted in these studies was decreased maternal body weight gain at the high-exposure level. No adverse effects on reproductive outcome of the fetuses that could be attributed to treatment were noted. An inhalation reference concentration (RfC), below which long-term exposures would not pose appreciable non-cancer health risks, is not available for formaldehyde at this time.

1.6.4 Acetaldehyde

Acetaldehyde is a saturated aldehyde that is found in vehicle exhaust and is formed as a result of incomplete combustion of both gasoline and diesel fuel. It is not a component of evaporative emissions. Acetaldehyde comprises 0.4 to 1.0 percent of total organic gas exhaust, depending on control technology and fuel composition.[105]

The atmospheric chemistry of acetaldehyde is similar in many respects to that of formaldehyde.[106] Like formaldehyde, it is produced and destroyed by atmospheric chemical transformation. Mobile sources contribute to ambient acetaldehyde levels both by their primary emissions and by secondary formation resulting from their VOC emissions. Acetaldehyde emissions are classified as a probable human carcinogen. Studies in experimental animals provide sufficient evidence that long-term inhalation exposure to acetaldehyde causes an increase in the incidence of nasal squamous cell carcinomas (epithelial tissue) and adenocarcinomas (glandular tissue).[107] [108]

Non-cancer effects in studies with rats and mice showed acetaldehyde to be moderately toxic by the inhalation, oral, and intravenous routes.[109] [110] [111] The primary acute effect of exposure to acetaldehyde vapors is irritation of the eyes, skin, and respiratory tract. At high concentrations, irritation and pulmonary effects can occur, which could facilitate the uptake of other contaminants. Little research exists that addresses the effects of inhalation of acetaldehyde on reproductive and developmental effects. The *in vitro* and *in vivo* studies provide evidence to suggest that acetaldehyde may be the causative factor in birth defects observed in fetal alcohol syndrome, though evidence is very limited linking these effects to inhalation exposure. Long-term exposures should be kept below the reference concentration of 9 $\mu g/m^3$ to avoid appreciable risk of these non-cancer health effects.[112]

1.6.5 Acrolein

Acrolein is extremely toxic to humans from the inhalation route of exposure, with acute exposure resulting in upper respiratory tract irritation and congestion. Although no information is available on its carcinogenic effects in humans, based on laboratory animal data, EPA considers acrolein a possible human carcinogen.[113]

1.6.6 Toluene

Toluene is a known respiratory irritant with central nervous system effects. Reproductive toxicity has been observed in exposed humans and rats.[114] Toluene toxicity is most prominent in the central nervous system after acute and chronic exposure, and that the brain is the principal target organ for toluene toxicity in humans. Specifically, recent studies indicate that toluene and other similar solvents alter the function of ion channels in neuronal membranes, including receptors stimulated by γ-amino butyric acid (GABA), *n*-methyl-D-aspartate (NMDA), nicotinic acetylcholine (nACh), and those sensitive to membrane voltage.[115, 116, 117, 118, 119] Anesthetic agents, ethanol, toluene, and other solvents inhibit the function of receptors that are excitatory in the nervous system (NMDA, nACh), and enhance the function of inhibitory receptors (GABA).[120, 121] Thus, these compounds tend to suppress the activity of the nervous system, yielding slowed reaction times, reduced arousal and, at high concentrations, anesthesia, unconsciousness and respiratory failure.[122]

1.7 Exposure to CO and Air Toxics Associated with Nonroad Engines and Vehicles

The previous section describes national-scale adverse public health effects associated with the nonroad engines and vehicles covered by this rulemaking. This section describes significant adverse health and welfare effects arising from the usage patterns of snowmobiles, large SI engines, and gasoline marine engines on the regional and local scale. Studies suggest that emissions from these engines can be concentrated in specific areas, leading to elevated ambient concentrations of particular pollutants and associated elevated exposures to operators and by-standers. This section describes these exposures.

1.7.1 Large SI Engines

Exhaust emissions from applications with significant indoor use can expose individual operators or bystanders to dangerous levels of pollution. Forklifts, ice-surfacing machines, sweepers, and carpet cleaning equipment are examples of large industrial spark-ignition engines that often operate indoors or in other confined spaces. Forklifts alone account for over half of the engines in this category. Indoor use may include extensive operation in a temperature-controlled environment where ventilation is kept to a minimum (e.g., for storing, processing, and shipping produce). Although our standards are not designed to eliminate occupational exposures, the standards will reduce CO and HC emissions that contribute to those exposures.

The principal concern for human exposure relates to CO emissions. One study showed several forklifts with measured CO emissions ranging from 10,000 to 90,000 ppm (1 to 9 percent).[123] The threshold limit value for a time-weighted average 8-hour workplace exposure set by the American Conference of Governmental Industrial Hygienists is 25 ppm.

One example of a facility that addressed exposure problems with new technology is in the apple-processing field.[124] Trout Apples in Washington added three-way catalysts to about 60 LPG-fueled forklifts to address multiple reports of employee health complaints related to CO exposure. The emission standards are based on the same technologies installed on these in-use engines.

Additional exposure concerns occur at ice rinks. Numerous papers have identified ice-surfacing machines with spark-ignition engines as the source of dangerous levels of CO and NO_2, both for skaters and for spectators.[125] This is especially problematic for skaters, who breathe air in the area where pollutant concentration is highest, with higher respiration rates resulting from their high level of physical activity. This problem has received significant attention from the medical community.

In addition to CO emissions, HC emissions from these engines can also lead to increased exposure to harmful pollutants, particularly air toxics. Since many gasoline or dual-fuel engines are in forklifts that operate indoors, reducing evaporative emissions could have direct health benefits to operators and other personnel. Fuel vapors can also cause odor problems.

1.7.2 Snowmobiles

In addition to their contribution to CO concentrations generally and visibility impairment, snowmobile emissions are of concern because of their potential impacts on riders and on park attendants, as well as other groups of people who are in contact with these vehicles for extended periods of time.

Snowmobile users can be exposed to high air toxic and CO emissions, both because they sit very close to the vehicle's exhaust port and because it is common for them to ride their vehicles in lines or groups on trails where they travel fairly close behind other snowmobiles. Because of these riding patterns, snowmobilers breathe exhaust emissions from their own vehicle, the vehicle directly in front as well as those farther up the trail. This can lead to relatively high personal exposure levels of harmful pollutants. A study of snowmobile rider CO exposure conducted at Grand Teton National Park showed that a snowmobiler riding at distances of 25 to 125 feet behind another snowmobiler and traveling at speeds from 10 to 40 mph can be exposed to average CO levels ranging from 0.5 to 23 ppm, depending on speed and distance. The highest CO level measured in this study was 45 ppm, as compared to the current 1-hour NAAQS for CO of 35 ppm.[126] While exposure levels can be less if a snowmobile drives 15 feet off the centerline of the lead snowmobile, the exposure levels are still of concern. This study led to the development of an empirical model for predicting CO exposures from riding behind snowmobiles.

Hydrocarbon speciation for snowmobile emissions was performed for the State of Montana in a 1997 report.[127] Using the dispersion model for CO from the Grand Teton exposure study with air toxic emission rates from the State of Montana's emission study, average benzene exposures for riders driving at an average speed of 23 mph, 25 feet behind another snowmobile were predicted to be 0.402 ppm, (95% bootstrap confidence intervals = 0.285-0.555). Average toluene concentrations in this scenario were modeled at 10.3 ppm (95% bootstrap CI = 8.1-12.8). With an average speed of 23 mph with a 50 foot space between snowmobiles, average benzene concentrations were estimated to be 0.210 ppm (95% bootstrap CI = 0.154 – 0.271).

The cancer risk posed to those exposed to benzene emissions from snowmobiles must be viewed within the broader context of expected lifetime benzene exposure. Observed monitoring data and predicted modeled values demonstrate that a significant cancer risk already exists from ambient concentrations of benzene for a large portion of the US population. The Agency's 1996 National-Scale Air Toxics Assessment of personal exposure to ambient concentrations of air toxic compounds emitted by outside sources (e.g., cars and trucks, power plants) found that benzene was among the five air toxics appear to pose the greatest risk to people nationwide. This national assessment found that for approximately 50% of the US population in 1996, the inhalation cancer risks associated with benzene exceeded 10 in one million. Modeled predictions for ambient benzene from this assessment correlated well with observed monitored concentrations of benzene ambient concentrations.

Specifically, the draft National-Scale Assessment predicted nationwide annual average benzene exposures from outdoor sources to be 1.4 µg/m3.[128] In comparison, snowmobile riders and those directly exposed to snowmobile exhaust emissions had predicted benzene levels two to three orders of magnitude greater than the 1996 national average benzene concentrations.[129] These elevated levels are also known as air toxic "hot spots," which are of particular concern to the Agency. Thus, total annual average exposures to typical ambient benzene concentrations combined with elevated short-term exposures to benzene from snowmobiles may pose a significant risk of adverse public health effects to snowmobile riders and those exposed to exhaust benzene emissions from snowmobiles.

Toluene concentrations, also elevated in snowmobile plumes, were predicted to be within the concentrations typically observed in occupational settings. While not considered a human carcinogenic hazard, toluene at high concentrations can affect the central nervous system, causing effects similar to intoxication. Weakness, confusion, euphoria, dizziness, and headache are associated with high exposures to toluene. National Institute of Occupational Safety and Health. NIOSH Pocket Guide to Chemical Hazards. NIOSH web site. http://www.cdc.gov/niosh/npg/npgd0619.html. Exposure to constituents of snowmobile exhaust at the levels predicted is anticipated to cause such effects in the human central nervous system.

Since snowmobile riders often travel in large groups, the riders towards the back of the group are exposed to the accumulated exhaust of those riding ahead. This scenario was not modeled, given the lack of data on snowmobile plume concentrations in trains of several vehicles. However, snowmobile trains, consisting of multiple riders in a line, are common riding scenarios. In these conditions, exhaust concentrations are anticipated to be significantly higher

than those predicted here. These exposure levels can continue for hours at a time, depending on the length of a ride. An additional consideration is that the risk to health from CO exposure increases with altitude, especially for unacclimated individuals. Therefore, a park visitor who lives at sea level and then rides his or her snowmobile on trails at high-altitude is more susceptible to the effects of CO than local residents.

In addition to snowmobilers themselves, people who are active in proximity to the areas where snowmobilers congregate may also be exposed to high CO levels. An OSHA industrial hygiene survey reported a peak CO exposure of 268 ppm for a Yellowstone employee working at an entrance kiosk where snowmobiles enter the park. This level is greater than the NIOSH peak recommended exposure limit of 200 ppm. OSHA's survey also measured employees' exposures to several air toxics. Benzene exposures in Yellowstone employees ranged from 67-600 µg/m3, with the same individual experiencing highest CO and benzene exposures. The highest benzene exposure concentrations exceeded the NIOSH Recommended Exposure Limit of 0.1 ppm for 8-hour exposures.

Notes to Chapter 1

1.Carbon monoxide also participates in the production of ozone, albeit at a much slower rate than most VOC and NOx compounds.

2.U.S. EPA, 1996, Review of National Ambient Air Quality Standards for Ozone, Assessment of Scientific and Technical Information, OAQPS Staff Paper, EPA-452/R-96-007. A copy of this document can be obtained from Air Docket A-99-06, Document No. II-A-22.

3.U.S. EPA, 1996, Air Quality Criteria for Ozone and Related Photochemical Oxidants, EPA/600/P-93/004aF. The document is available on the internet at http://www.epa.gov/ncea/ozone.htm. A copy can also be obtained from Air Docket No. A-99-06, Documents Nos. II-A-15, II-A-16, II-A-17.

4.National Air Quality and Emissions Trends Report, 1999, EPA, 2001, at Table A-19. This document is available at http://www.epa.gov/oar/aqtrnd99/. The data from the Trends report are the most recent EPA air quality data that has been quality assured. A copy of this table can also be found in Docket No. A-2000-01, Document No. II-A-64.

5.National Air Quality and Emissions Trends Report, 1998, March, 2000, at 28. This document is available at http://www.epa.gov/oar/aqtrnd98/. Relevant pages of this report can be found in Memorandum to Air Docket A-2000-01 from Jean Marie Revelt, September 5, 2001, Document No. II-A-63.

6.National Air Quality and Emissions Trends Report, 1998, March, 2000, at 32. This document is available at http://www.epa.gov/oar/aqtrnd98/. Relevant pages of this report can be found in Memorandum to Air Docket A-2000-01 from Jean Marie Revelt, September 5, 2001, Document No. II-A-63.

7.Additional information about this modeling can be found in our Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, document EPA420-R-00-026, December 2000. Docket No. A-2000-01, Document No. II-A-13. This document is also available at http://www.epa.gov/otaq/diesel.htm#documents.

8.We also performed ozone air quality modeling for the western United States but, as described further in the air quality technical support document, model predictions were well below corresponding ambient concentrations for out heavy-duty engine standards and fuel sulfur control rulemaking. Because of poor model performance for this region of the country, the results of the Western ozone modeling were not relied on for that rule.

9.U.S. EPA Regulatory Impact Analysis – Control of Air Pollution from New Motor Vehicles: Tier 2 Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements. EPA420-R-99-023. December 1999. A copy of this document is also available in Docket A-97-10, Document No. V-B-01.

10.Additional information about these studies can be found in Chapter 2 of "Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements," December 2000, EPA420-R-00-026. Docket No. A-2000-01, Document Number II-A-13. This document is also available at http://www.epa.gov/otaq/diesel.htm#documents.

11.Air Quality Criteria Document for Ozone and Related Photochemical Oxidants, EPA National Center for Environmental Assessment, July 1996, Report No. EPA/600/P-93/004cF. The document is available on the internet at http://www.epa.gov/ncea/ozone.htm. A copy can also be obtained from Air Docket No. A-99-06, Documents Nos. II-A-15, II-A-16, II-A-17.

12.A copy of this data can be found in Air Docket A-2000-01, Document No.II-A-80.

13.Memorandum to Docket A-99-06 from Eric Ginsburg, EPA, "Summary of Model-Adjusted Ambient Concentrations for Certain Levels of Ground-Level Ozone over Prolonged Periods," November 22, 2000. Docket A-2000-01, Document Number II-B-13.

14.Memorandum to Docket A-99-06 from Eric Ginsburg, EPA, "Summary of Model-Adjusted Ambient Concentrations for Certain Levels of Ground-Level Ozone over Prolonged Periods," November 22, 2000, at Table C, Control Scenario – 2020 Populations in Eastern Metropolitan Counties with Predicted Daily 8-Hour Ozone greater than or equal to 0.080 ppm. Docket A-2000-01, Document Number II-B-13.

15.U.S. EPA, 1995, Review of National Ambient Air Quality Standards for Nitrogen Dioxide, Assessment of Scientific and Technical Information, OAQPS Staff Paper, EPA-452/R-95-005.

16.U.S.EPA, 1993, Air Quality Criteria for Oxides of Nitrogen, EPA/600/8-91/049aF.

17.Much of the information in this subsection was excerpted from the EPA document, *Human Health Benefits from Sulfate Reduction*, written under Title IV of the 1990 Clean Air Act Amendments, U.S. EPA, Office of Air and Radiation, Acid Rain Division, Washington, DC 20460, November 1995. Air Docket A-2000-01, Document No. II-A-32.

18.Vitousek, Peter M., John Aber, Robert W. Howarth, Gene E. Likens, et al. 1997. Human Alteration of the Global Nitrogen Cycle: Causes and Consequences. *Issues in Ecology*. Published by Ecological Society of America, Number 1, Spring 1997.

19. National Research Council, 1993. Protecting Visibility in National Parks and Wilderness Areas. National Academy of Sciences Committee on Haze in National Parks and Wilderness Areas. National Academy Press, Washington, DC. This document is available on the internet at http://www.nap.edu/books/0309048443/html/

20.Much of this information was taken from the following EPA document: *Deposition of Air Pollutants to the Great Waters-Second Report to Congress*, Office of Air Quality Planning and Standards, June 1997, EPA-453/R-97-011.

21.Terrestrial nitrogen deposition can act as a fertilizer. In some agricultural areas, this effect can be beneficial.

22. Coburn, R.F. (1979) Mechanisms of carbon monoxide toxicity. *Prev. Med.* 8:310-322.

23. Helfaer, M.A., and Traystman, R.J. (1996) Cerebrovascular effects of carbon monoxide. In: *Carbon Monoxide* (Penney, D.G., ed). Boca Raton, CRC Press, 69-86.

24. Benignus, V.A. (1994) Behavioral effects of carbon monoxide: meta analyses and extrapolations. *J. Appl. Physiol.* 76:1310-1316. Docket A-2000-01, Document IV-A-127.

25. Rowe, B., Milner, R., Johnson, C. Bota, G. Snowmobile-Related Deaths in Ontario: A 5-Year Review. *Canadian Medical Association Journal*, Vol. 146, Issue 2, pp 147-152. Docket A-2000-01, Document IV-A-194.

26.The CO Criteria Document (EPA 600/P-99/001F) contains additional information about the health effects of CO, human exposure, and air quality. It was published as a final document and made available to the public in August 2000 (www.epa.gov/ncea/co/). A copy of this document is also available in Docket A-2000-01, Document A-II-29.

27.National Air Quality and Emissions Trends Report, 1999, EPA, 2001, at Table A-19. This document is available at http://www.epa.gov/oar/aqtrnd99/. The data from the Trends report are the most recent EPA air quality data that has been quality assured. A copy of this table can also be found in Docket No. A-2000-01, Document No. II-A-64.

28. Information attached to written comments, P. Amette, Vice President, Motorcycle Industry Council, Incorporated. Docket A-2000-01, Document IV-D-214.

29. Economic Contribution of Off-Highway Vehicle Use in Colorado" Prepared for the Colorado Of-Highway Vehicle Coalition, by Hazen and Sawer Environmental Engineers & Scientists. July, 2001. Colorado OHV User Survey" Summary of Results: prepared for State of Colorado OHV Coalition under a contract with the Colorado State Parks OHV Program, prepared by T. Crimins, Trails Consultant. January 1999. Off Highway Vehicle Uses and Owners Preferences in Uta", prepared for Utah DNR, Div. Of Parks and recreation, prepared by Institute for Outdoor recreation and Tourism Department of Forest Resources, Utah State University. July 22, 2001. These documents are available in Docket A-2000-01, Documents IV-A-02, 03, 05.

30. Off Highway Vehicle Uses and Owners Preferences in Uta", prepared for Utah DNR, Div. Of Parks and recreation, prepared by Institute for Outdoor recreation and Tourism Department of Forest Resources, Utah State University. July 22, 2001. This document is available in Docket A-2000-01, Document IV-A-03.

31. All-Terrain Vehicle Exposure, Injury, Death and Risk Studies. U.S. Consumer Product Safety Commission, April, 1998. Docket A-2000-01, Document IV-A-197.

32. Anchorage Carbon Monoxide Emission Inventory and Year 2000 Attainment Projections" Air Quality Program, Environmental Services Division, Department of Health and Human

Services [DRAFT]. May, 2001. Docket A-2000-01, Document II-A-40.

33.Areas with a few years of attainment data can and often do have exceedances following such years of attainment because of several factors including different climatic events during the later years, increases in inventories, etc. Thus, a plan to maintain the NAAQS is critical to showing attainment.

34.Dulla, Robert G. Sierra Research, Inc. "A Review of Vehicle Test Programs Conducted in Alaska in Recent Years and a Summary of the Fairbanks Co. Inventory 1995-2001. June 4, 2001. Docket A-2000-01, Document IV-A-198.

35.St. Paul, Minnesota was recently reclassified as being in attainment but is still considered a maintenance area. There is also a significant population of snowmobiles in Minnesota, with snowmobile trails in Washington County.

36.The trail maps consulted for this rulemaking can be found in Docket No. A-2000-01, Document No. II-A-65.

37. Written comments from J.S. Grumet, Executive Director, Northeast States for Coordinated Use Management (NESCAUM), Docket A-2000-01, Document IV-D-196.

38. Doss, Howard. Snowmobile Safety. Michigan Agricultural Safety Health Center. A copy of this document can be found in Docket A-2000-01, Document IV-A-148 (an attachment).

39. Mauer, Richard. "Snowmobile Perils" Anchorage Daily News. Internet search 7/3/02. Docket A-2000-01, IV-A-184.

40.Dulla, Robert G. Sierra Research, Inc. "A Review of Vehicle Test Programs Conducted in Alaska in Recent Years and a Summary of the Fairbanks Co. Inventory 1995-2001. June 4, 2001. Docket A-2000-01, Document IV-A-198.

41. Technical Memorandum to Docket A-2000-01 from Drew Kodjak, Attorney-Advisor, Office of Transportation and Air Quality, "Air Quality Information for Selected CO Nonattainment Areas," July 27, 2001, Docket Number A-2000-01, Document Number II-B-18.

42. Air Quality Criteria for Carbon Monoxide, US EPA, EPA 600/P-99/001F, June 2000, at 3-38, Figure 3-32 (Federal Bldg, AIRS Site 020900002). Air Docket A-2000-01, Document Number II-A-29. This document is also available at http://www.epa.gov/ncea/coabstract.htm.

43.National Research Council. The Ongoing Challenge of Managing Carbon Monoxide Pollution in Fairbanks, AK. May 2002. Docket A-2000-01, Document IV-A-115.

44. National Air Quality and Emissions Trends Report, 1999, EPA, 2001, at Table A-19. This document is available at http://www.epa.gov/oar/aqtrnd99/. The data from the Trends report are

the most recent EPA air quality data that have been quality assured. A copy of this table can also be found in Docket No. A-2000-01, Document No. II-A-64. See also the air quality update, 1998-2000 Ozone and 1999-2000 Carbon Monoxide, available at www.epa.gov/oar/aqtrnd00. A copy of this document is also available at Docket A-2000-01, Document No. IV-A-141.

45. Air Quality and Emissions Trends Report, 1998, March, 2000. This document is available at http://www.epa.gov/oar/aqtrnd98/. Relevant pages of this report can be found in Memorandum to Air Docket A-2000-01 from Jean Marie Revelt, September 5, 2001, Document No. II-A-63.

46.EPA (1996) Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information OAQPS Staff Paper. EPA-452/R-96-013. Docket Number A-99-06, Documents Nos. II-A-18, 19, 20, and 23. The particulate matter air quality criteria documents are also available at http://www.epa.gov/ncea/partmatt.htm.

47.Additional information about the Regulatory Model System for Aerosols and Deposition (REMSAD) and our modeling protocols can be found in our Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements, document EPA420-R-00-026, December 2000. Docket No. A-2000-01, Document No. A-II-13. This document is also available at http://www.epa.gov/otaq/disel.htm#documents.

48.Memorandum to Docket A-99-06 from Eric O. Ginsburg, Senior Program Advisor, "Summary of 1999 Ambient Concentrations of Fine Particulate Matter," November 15, 2000. Air Docket A-2000-01, Document No. II-B-12.

49.Memorandum to Docket A-99-06 from Eric O. Ginsburg, Senior Program Advisor, "Summary of Absolute Modeled and Model-Adjusted Estimates of Fine Particulate Matter for Selected Years," December 6, 2000. This memo is also available in the docket for this rule. Docket A-2000-01, Document Number II-B-14.

50.The fine particle monitoring network was expanding with more monitors being added between 1996 and 2002.

51. Technical Memorandum, EPA Air Docket A-99-06, Eric O. Ginsburg, Senior Program Advisor, Emissions Monitoring and Analysis Division, OAQPS, Summary of Absolute Modeled and Model-Adjusted Estimates of Fine Particulate Matter for Selected Years, December 6, 2000, Table P-2. Docket Number 2000-01, Document Number II-B-14.

52.National Research Council, 1993 (Ibid); U.S. EPA Criteria for Particulate Matter, 8-3; US EPA Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information OAQPS Staff Paper. EPA-452/R-96-013. 1996. Docket Number A-99-06, Documents Nos. II-A-18, 19, 20, and 23. The particulate matter air quality criteria documents are also available at http://www.epa.gov/ncea/partmatt.htm.

53. Council on Environmental Quality, 1978. Visibility Protection for Class I Areas, the Technical Basis. Washington DC. Cited in US EPA, Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. OAQPS Staff Paper. EPA-452 \ R-96-013. This document is available in Docket

A-99-06, Document II-A-23.

54. Sisler, James F. Spatial and Seasonal Patterns and Long Term Variability of the Composition of Haze in the United States: An Analysis of Data from the IMPROVE Network. 1996. A copy of the relevant pages of this document can be found in Docket A-99-06, Document No. II-B-21.

55. National Research Council, 1993 (Ibid).

56.National Research Council, 1993 (Ibid).

57. National Acid Precipitation Assessment Program (NAPAP), 1991. Office of the Director. Acid Deposition: State of Science and Technology. Report 24, Visibility: Existing and Historical Conditions - Causes and Effects. Washington, DC. Cited in US EPA, Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information. OAQPS Staff Paper. EPA-452 \ R-96-013. This document is available in Docket A-99-06, Document II-A-23. Also, US EPA. Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information, OAQPS Staff Paper. Preliminary Draft. June 2001. Docket A-2000-01, Document IV-A-199.

58.Memorandum to Docket A-99-06 from Eric O. Ginsburg, Senior Program Advisor, "Summary of 1999 Ambient Concentrations of Fine Particulate Matter," November 15, 2000. Air Docket A-2000-01, Document No. II-B-12.

59. Technical Memorandum, EPA Air Docket A-99-06, Eric O. Ginsburg, Senior Program Advisor, Emissions Monitoring and Analysis Division, OAQPS, Summary of Absolute Modeled and Model-Adjusted Estimates of Fine Particulate Matter for Selected Years, December 6, 2000, Table P-2. Docket Number 2000-01, Document Number II-B-14.

60. The trail maps consulted for this rulemaking can be found in Docket No. A-2000-01, Document No. II-A-65.

61.This goal was recently upheld by the US Court of Appeals. American Corn Growers Association v. EPA, 291F.3d 1(D.C .Cir 2002). A copy of this decision can be found in Docket A-2000-01, Document IV- A-113..

62.U.S. EPA Review of the National Ambient Air Quality Standards for Particulate Matter: Policy Assessment of Scientific and Technical Information OAQPS Staff Paper. EPA-452/R-96-013. 1996. Docket Number A-99-06, Documents Nos. II-A-18, 19, 20, and 23. The particulate matter air quality criteria documents are also available at http://www.epa.gov/ncea/partmatt.htm.

63. Chestnut, L.G., and R.D. Rowe. 1990a. *Preservation for Visibility Protection at the National Parks: Draft Final Report*. Prepared for Office of Air Quality Planning and Standards, US Environmental Protection Agency, and Air Quality Management Division, National Park Service; Chestnut, L.G., and R.D. This document is available from Docket A-97-10, Document II-A-33 Rowe. 1990b. A New National Park Visibility Value Estimates. In *Visibility and Fine Particles*, Transactions of an AWMA/EPA International Speciality Conference. C.V. Mathai, ed.,

Air and Waste Management Association, Pittsburg. Docket A-2000-01, IV-A-2000.

64.Letter from Debra C. Miller, Data Analyst, National Park Service, to Drew Kodjak, August 22, 2001. Docket No. A-2000-01, Document Number. II-B-28.

65.Technical Memorandum, Aaron Worstell, Environmental Engineer, National Park Service, Air Resources Division, Denver, Colorado, particularly Table 1. Docket No. A-2000-01, Document Number II-G-178.

66.Letter from Debra C. Miller, Data Analyst, National Park, to Drew Kodjak, August 22, 2001. Docket No. A-2000-01, Document Number. II-B-28.

67.Letter from Debra C. Miller, Data Analyst, National Park Service, to Drew Kodjak, August 22, 2001. Docket No. A-2000-01, Document. Number. II-B-28.

68.National Park Service, February 2000. Air Quality Concerns Related to Snowmobile Usage in National Parks. Air Docket A-2000-01, Document No. II-A-44.

69.G. Bishop, et al., Snowmobile Contributions to Mobile Source Emissions in Yellowstone National Park, Environmental Science and Technology, Vol. 35, No. 14, at 2873. Docket No. A-2000-01, Document No. II-A-47.

70.Memorandum to IV-D-204 at 13

71.Ibid, at 14.

72.Julia Rege, Environmental Scientist, EPA. Memorandum to Docket A-2000-0. Predicted visibility effects from snowmobile exhaust (particulate matter) on or near snowmobile trails in Yellowstone National Park. July, 12, 2002. Docket A-2000-01, Document IV-A-147.

73.See our Mobile Source Air Toxics final rulemaking, 66 FR 17230, March 29, 2001, and the Technical Support Document for that rulemaking. Docket No. A-2000-01, Documents Nos. II-A-42 and II-A-30.

74.U.S. EPA. (1999) Analysis of the Impacts of Control Programs on Motor Vehicle Toxic Emissions and Exposure in Urban Areas and Nationwide: Volume I. Prepared for EPA by Sierra Research, Inc. and Radian International Corporation/Eastern Research Group, November 30, 1999. Report No. EPA420-R-99-029. http://www.epa.gov/otaq/toxics.htm.

75.U.S. EPA (1998) Environmental Protection Agency, Carcinogenic Effects of Benzene: An Update, National Center for Environmental Assessment, Washington, DC. 1998. EPA/600/P-97/001F. http://www.epa.gov/ncepihom/Catalog/EPA600P97001F.html.

76.Leukemia is a blood disease in which the white blood cells are abnormal in type or number. Leukemia may be divided into nonlymphocytic (granulocytic) leukemias and lymphocytic leukemias. Nonlymphocytic leukemia generally involves the types of white blood cells (leukocytes) that are involved in engulfing, killing, and digesting bacteria and other parasites

(phagocytosis) as well as releasing chemicals involved in allergic and immune responses. This type of leukemia may also involve erythroblastic cell types (immature red blood cells). Lymphocytic leukemia involves the lymphocyte type of white bloods cell that are responsible for the immune responses. Both nonlymphocytic and lymphocytic leukemia may, in turn, be separated into acute (rapid and fatal) and chronic (lingering, lasting) forms. For example; in acute myeloid leukemia (AML) there is diminished production of normal red blood cells (erythrocytes), granulocytes, and platelets (control clotting) which leads to death by anemia, infection, or hemorrhage. These events can be rapid. In chronic myeloid leukemia (CML) the leukemic cells retain the ability to differentiate (i.e., be responsive to stimulatory factors) and perform function; later there is a loss of the ability to respond.

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