FINAL

2000/2001 AIR EMISSION INVENTORIES

Grand Canyon National Park

Summary Report for Twenty-One National Park Service Units

December 2003

Yellowstone National Park

Great Smoky Mountains National Park

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SUMMARY REPORT FOR TWENTY-ONE NATIONAL PARK SERVICE UNITS

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CONTENTS

CONTENTS (Continued)

FIGURES

TABLES

ABBREVIATIONS AND ACRONYMS

AAQS	Ambient Air Quality Standards
ARD	Air Resources Division
AST	Aboveground Storage Tank
B20	Biodiesel fuel
Btu	British thermal unit
CH_4	Methane
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
FOFEM	First Order Fire Effects Model
GSA	General Services Administration
kW	Kilowatt
LPG	Liquefied Petroleum Gas
NAAQS	National Ambient Air Quality Standards
N.G.	Natural Gas
NM	National Monument
NO_X	Nitrogen Oxides
NP	National Park
N Pres	National Preserve
NRA	National Recreation Area
NS	National Seashore
NSPS	New Source Performance Standard
O_3	Ozone
Pb	Lead
$PM_{2.5}$	Particulate Matter less than 2.5 micrometers
PM_{10}	Particulate Matter less than 10 micrometers
ROD	Record of Decision
SO_2	Sulfur Dioxide
USEPA	U.S. Environmental Protection Agency
UST	Underground Storage Tank
VMT	Vehicle Miles Traveled

EXECUTIVE SUMMARY

The National Park Service (NPS) Air Resources Division (ARD) had air emissions inventories conducted for calendar years 2000 or 2001[1]. Typical air emission sources within NPS units include stationary, area, and mobile sources. Stationary sources can include fossil fuel-fired space and water heating equipment, generators, fuel storage tanks, and wastewater treatment plants. Area sources may include woodstoves and fireplaces, campfires, and wildfires and prescribed burning. Mobile sources may include vehicles operated by visitors, tour operators, and NPS and concessioner employees, and nonroad vehicles and equipment.

Stationary Sources–Air emissions from stationary sources are summarized in Table ES-1.

Table ES-1: Emissions from Stationary Sources

Park	Pollutant (lbs/yr)					
	PM_{10}	SO_2	NO_X	CO	CO_2	VOC
Badlands NP, SD	10	4	267	42	191,891	1,020
Big Cypress N Pres, FL	12	9	201	38	59,928	1,453
Carlsbad Caverns NP, NM	18	390	657	121	436,028	122
Chiricauha NM, AZ	3	46	106	16	98,601	241
Crater Lake NP, OR	231	6,075	2,866	681	1,873,113	1,215
Craters of Moon NM and Pres, ID	0	0	0	0	0	12
Denali NP and Pres, AK	1,716	9,111	24,158	5,256	3,265,517	2,122
Glacier NP, MT	1,726	5,545	28,832	6,679	9,290,548	2,381
Grand Canyon NP, AZ	1,387	25,284	29,405	5,657	15,918,268	7,536
Grand Teton NP, WY	703	9,447	11,370	2,650	4,468,158	2,234
Great Sand Dunes NM and Pres, CO	7	0	252	36	224,588	29
Great Smoky Mountains NP, NC/TN	113	1,974	2,328	532	1,009,225	3,533
Guadalupe Mountains NP, TX	6	2	184	572	151,350	1,360
Lake Mead NRA, NV/AZ	287	260	4,300	896	518,125	43,422
Lake Meredith NRA, TX	13	1	335	66	324,000	1,185
Mammoth Cave NP, KY	67	1,271	970	200	643,064	906
Mesa Verde NP, CO	37	239	1,069	163	971,175	1,384
Padre Island NS, TX	2	2	24	6	5,801	857
Theodore Roosevelt NP, ND	9	16	284	41	231,902	397

[1] For Denali NP & Pres, the year 2002 was selected since these data were the most recent and available.

Park	Pollutant (lbs/yr)					
	PM_{10}	SO_2	NO_X	CO	CO_2	VOC
Wind Cave NP, SD	16	429	386	78	256,479	549
Yellowstone NP, WY/MT/ID	3,096	55,147	53,876	13,518	21,810,574	19,672
Total	9,459	115,252	161,870	37,248	61,748,335	91,630

- On a Btu basis, 55 percent of fossil fuel consumed for heating is supplied by No. 2 fuel oil, 42 percent by propane or LPG, and only 3 percent by natural gas. Substituting propane for No. 2 fuel oil would generally reduce emissions for most pollutants. In addition, energy conservation and renewable energy sources are the best measures to reduce emissions from heating units.
- On an aggregate basis, generators produced more emissions than fossil-fueled heating units. Denali NP & Pres, Glacier NP, and Yellowstone NP accounted for slightly more than 80 percent of the aggregate emissions from generators included in this study. Therefore, if these units could be replaced by photovoltaic-battery systems, fuel cell systems, or otherwise eliminated, then the majority of air emissions from generators would be eliminated.
- Fuel storage tanks produce considerably more VOC emissions than heating equipment and generators. The public gasoline stations at Lake Mead NRA accounted for more than 50 percent of VOC emissions from all gasoline tanks in the parks studied.

Area Sources–Emissions from woodstoves, campfires, and wildfires/prescribed burning were quantified.

- One of the largest sources of emissions are woodstoves in employee residences. Phasing-out or replacing older woodstoves with modern units that meet the U.S. EPA New Source Performance Standards (NSPS) would reduce these emissions considerably.
- Emissions from campfires are slightly higher than those from woodstoves, but much lower than those from wildfires and prescribed burning.
- Wildfires and prescribed burning are the largest source of emissions at parks, although these emissions are often considered natural in origin and not anthropogenic.

Mobile Sources–Emissions from visitor and NPS highway vehicles and NPS, concessionaire, and visitor nonroad vehicles and equipment, including marine vessels, snowmobiles, and aircraft, were quantified.

- An estimated 14.2 million visitor vehicles traveled approximately 540 million miles within the boundaries of the 21 park units on an annual basis.
- Reducing emissions associated with vehicles operating on park roadways can be accomplished by reducing vehicles miles traveled (VMT), usually by implementing visitor shuttle bus systems; replacing conventional NPS and GSA vehicles with alternative fuel vehicles; and utilizing biodiesel in the existing diesel vehicle fleet, which has been done at about six parks.
- Unlike highway vehicles, emission controls for nonroad vehicles and equipment have evolved only in recent years, and park officials should consider replacing older equipment with low emission units in the near future.
- Visitor snowmobiles are allowed to operate in Crater Lake, Grand Teton, and Yellowstone NPs and Denali NP & Pres. The NPS also operates snowmobiles in these parks, as well as in Grand Canyon NP. Replacing two-stroke gasoline engines with four-stroke or two-stroke direct injection engines in nonroad equipment, such as snowmobiles and marine vessels, would reduce emissions.
- Grand Teton NP has the highest emissions from aircraft since the Jackson Hole Airport, a full service commercial airport, is located within the park's boundary.

Compliance – A review of applicable state air quality regulations for each area found no compliance issues. Parks should continue to interact with these agencies on fire management issues.

1. INTRODUCTION

1.1 BACKGROUND

In August of 1999, the National Park Service (NPS) embarked on the Natural Resource Challenge, a major effort to substantially improve how the NPS manages the natural resources under its care. As part of Natural Resource Challenge, the NPS Air Resources Division (ARD) was tasked with the responsibility of expanding efforts to monitor and understand air quality and related values in the parks. In addition, the NPS Environmental Leadership policy directs the NPS to manage the parks in a manner "that demonstrates sound environmental stewardship by implementing sustainable practices in all aspects of NPS management…." In order to achieve both of these objectives, it is necessary to gain an understanding of air pollution emissions that result from activities within the park. In this regard, development of an in-park air emissions inventory for NPS units serves three functions. First, it provides an understanding of the sources and magnitude of in-park emissions and a basis for contrasting them with emissions from the surrounding area. Second, it identifies existing and potential strategies to mitigate in-park air emissions. Finally, it evaluates and ensures the compliance status of the park relative to state and federal air pollution regulations.

The NPS ARD had air emissions inventories conducted for calendar year 2000 or 2001 for 21 NPS units in 17 states. A list of the 21 park units included in this project is provided in Table 1, and their locations are illustrated in Figure 1. The remainder of this report summarizes the overall findings of the study.

1.2 TYPICAL AIR EMISSION SOURCES

Typical air emission sources within NPS units include stationary, area, and mobile sources. Stationary sources can include fossil fuel-fired space and water heating equipment, generators, fuel storage tanks, and wastewater treatment plants. Area sources may include woodstoves, fireplaces, campfires, and prescribed burning. Mobile sources may include vehicles operated by visitors, tour operators, and NPS and concessionaire employees, and nonroad vehicles and equipment, including aircraft, marine vessels, snowmobiles, and railroads.

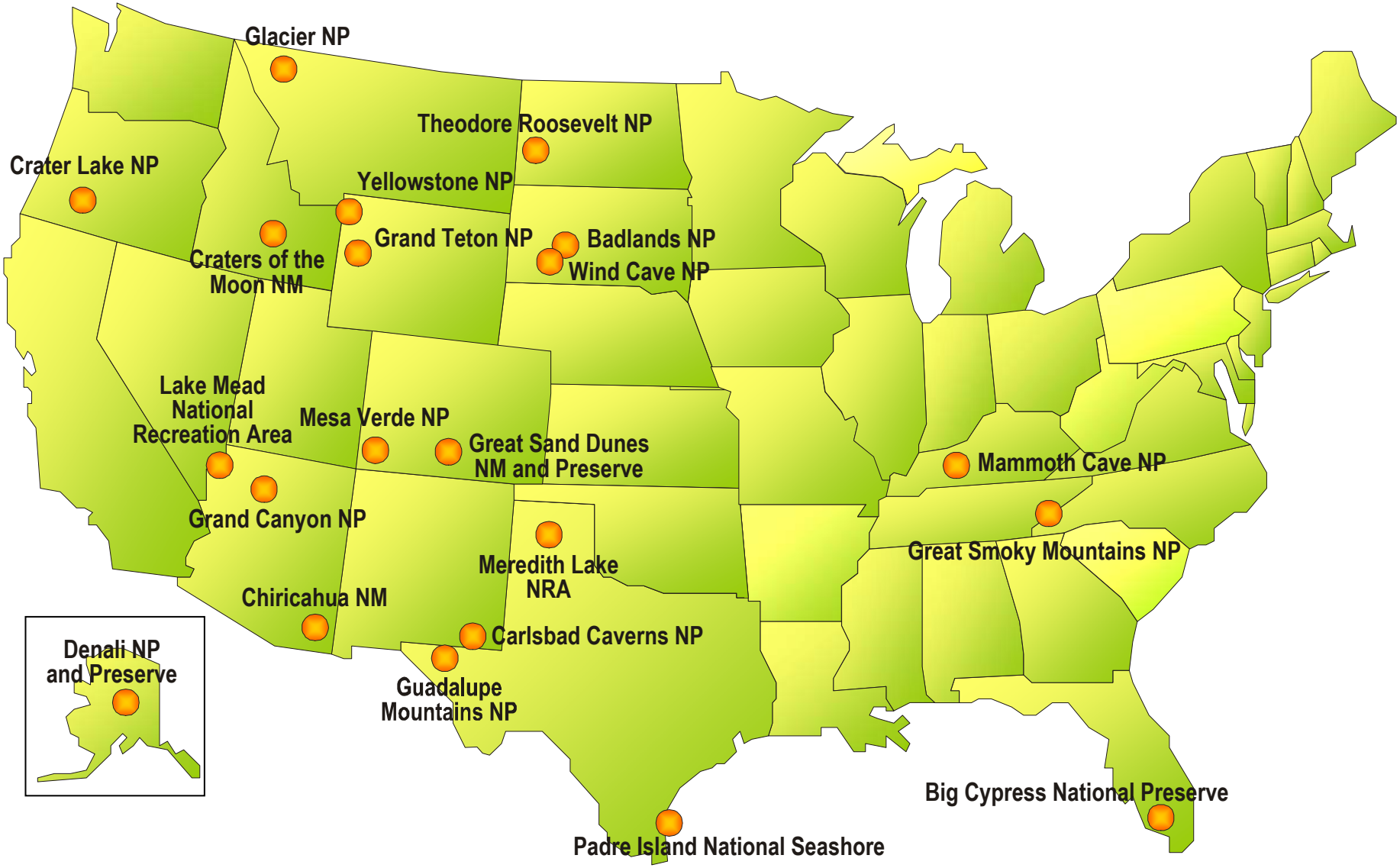

Figure 1. Park Locations

Table 1: National Park Unit Information

National Park Unit	Size (acres)[1]	2000 Visitation[1]
Badlands NP, SD	232,822	1,105,824
Big Cypress N Pres, FL	535,709	505,062
Carlsbad Caverns NP, NM	46,427	469,303
Chiricauha NM, AZ	11,982	85,562
Crater Lake NP, OR	183,223	426,883
Craters of Moon NM and Pres, ID	410,000	211,642
Denali NP and Pres, AK	1,303,972	363,983
Glacier NP, MT	1,013,154	1,728,693
Grand Canyon NP, AZ	1,180,863	4,460,228
Grand Teton NP, WY	307,654	2,590,624
Great Sand Dunes NM and Pres, CO	44,676	260,789
Great Smoky Mountains NP, NC/TN	521,225	10,175,812
Guadalupe Mountains NP, TX	86,190	198,762
Lake Mead NRA, NV/AZ	1,470,328	8,755,005
Lake Meredith NRA, TX	44,978	1,615,751
Mammoth Cave NP, KY	52,003	1,749,268
Mesa Verde NP, CO	51,891	452,287
Padre Island NS, TX	130,355	759,596
Theodore Roosevelt NP, ND	69,702	431,813
Wind Cave NP, SD	28,295	668,507
Yellowstone NP, WY/MT/ID	2,219,789	2,838,233
Total	9,945,239	39,855,627

[1]Source: NPS Pubic Use Statistical Office

The air pollutants that are addressed in this report are summarized in Table 2. Of the pollutants noted, ozone is not produced and emitted directly from stationary, area, or mobile sources, but rather it is formed as a result a chemical reaction of NO_X and VOC emissions in the presence of sunlight. Carbon dioxide historically has not been considered a pollutant. However, in recent years, there has been much interest in its contribution to global climate warming since it is considered a greenhouse gas.

1.2 INVENTORY METHODOLOGY

The methodology to accomplish the air emissions inventory was outlined in a protocol that was prepared at the initiation of the project (EA Engineering 2001). Tasks consisted of:

- site surveys at each park unit during 2001-2003,
- on-site interviews with NPS and where applicable, concessionaire personnel,
- review of applicable equipment, energy, and other applicable records,
- emission calculations,
- review of applicable state air quality regulations,
- assessment of existing and potential air pollutant reduction measures, and
- draft and final report preparation.

Table 2: Air Pollutants and Their Characteristics

Pollutant	Characteristics
Particulates (PM_{10})	• Mixture of solid particles and liquid droplets; fine particles (less than 10 micrometers) produced by fuel combustion, power plants, and diesel buses and trucks • Can aggravate asthma, produce acute respiratory symptoms, including aggravated coughing and difficult or painful breathing, and chronic bronchitis • Impairs visibility
Sulfur Dioxide (SO_2)	• Can cause temporary breathing difficulties for people with asthma • Reacts with other chemicals to form sulfate particles that are major cause of reduced visibility in many parts of the country • Main contributor to acid deposition
Nitrogen Oxides (NO_X)	• High temperature fuel combustion exhaust product • Can be an irritant to humans and participates in the formation of ozone • Reacts with other pollutants to form nitrate particles that are a significant contributor to visibility reduction in many parts of the country • Contributor to acid deposition
Carbon Monoxide (CO)	• Odorless, colorless gas produced by fuel combustion, particularly mobile sources • May cause chest pains and aggravate cardiovascular diseases, such as angina • May affect mental alertness and vision in healthy individuals

Pollutant	Characteristics
Volatile Organic Compounds (VOCs)	• Fuel combustion exhaust product • Consists of a wide variety of carbon-based molecules • Participates in the formation of ozone
Ozone (O_3)	• Not directly emitted by mobile, stationary, or area sources • Formed from complex reactions between NO_X and VOC emissions in the presence of sunlight • Occurs regionally due to multiplicity of sources • Can irritate the respiratory system • Can reduce lung function • Can aggravate asthma and increase susceptibility to respiratory infections • Can inflame and damage the lining of the lungs • Interferes with the ability of plants to produce and store food, which makes them more susceptible to disease, insects, other pollutants, and harsh weather • Damages the leaves of trees and other plants
Carbon Dioxide (CO_2)	• Does not directly impair human health • It is a greenhouse gas that traps the earth's heat and contributes to global warming

The data were used in conjunction with a number of manual and computer software computational tools to calculate emissions. Computational tools included U.S. Environmental Protection Agency (USEPA) emission factors such as the Factor Information Retrieval System (FIRE) database, USEPA *TANKS 4.0* model, U.S. Forest Service *First Order Fire Effects Model (FOFEM) 4.0* model, USEPA *MOBILE6.2* mobile source emissions model, and the Federal Aviation Administration *Emissions and Dispersion Modeling System* for aircraft emissions. The years 2000 and 2001 were selected as the basis for the air emission inventories since data for those years were the most recent available at the parks[2]. It should be noted that emissions are expected to vary from year to year due to fluctuations in visitation, prescribed burning and wildfires, and other activities.

1.4 AIR QUALITY STATUS

1.4.1 Ambient Air Attainment Designations

[2] For Denali NP & Pres, the year 2002 was selected since these data were the most recent and available

The federal Clean Air Act requires that the U.S. EPA establish National Ambient Air Quality Standards (NAAQS) and reassess, at least every five years, whether adopted standards are adequate to protect public health based on current scientific evidence. These NAAQS include ozone (O_3), carbon monoxide (CO), nitrogen oxides (NO_X), sulfur dioxide (SO_2), suspended particulate matter (PM_{10}), and lead (Pb).

Table 3 summarizes the federal ambient air quality designations for PM_{10}, O_3, and CO for the counties in which the park units are located. As the table indicates, all the park units are located in areas that are designated as attainment for the federal NAAQS, with the exception of Flathead County, MT in eastern Glacier NP. Some states also have state AAQS, and all of the counties in which the parks are located were in attainment for the particular state AAQS.

Table 3: NAAQS Designations

National Park Unit	Attainment		
	PM_{10}	**O_3**	**CO**
Badlands NP, SD	Yes	Yes	Yes
Big Cypress N Pres, FL	Yes	Yes	Yes
Carlsbad Caverns NP, NM	Yes	Yes	Yes
Chiricauha NM, AZ	Yes	Yes	Yes
Crater Lake NP, OR	Yes	Yes	Yes
Craters of Moon NM and Pres, ID	Yes	Yes	Yes
Denali NP and Pres, AK	Yes	Yes	Yes
Glacier NP, MT	No	Yes	Yes
Grand Canyon NP, AZ	Yes	Yes	Yes
Grand Teton NP, WY	Yes	Yes	Yes
Great Sand Dunes NM and Pres, CO	Yes	Yes	Yes
Great Smoky Mountains NP, TN/NC	Yes	Yes[1]	Yes
Guadalupe Mountains NP, TX	Yes	Yes	Yes
Lake Mead NRA, NV/AZ	Yes	Yes	Yes
Lake Meredith NRA, TX	Yes	Yes	Yes
Mammoth Cave NP, KY	Yes	Yes	Yes
Mesa Verde NP, CO	Yes	Yes	Yes
Padre Island NS, TX	Yes	Yes	Yes
Theodore Roosevelt NP, ND	Yes	Yes	Yes
Wind Cave NP, SD	Yes	Yes	Yes
Yellowstone NP, WY/MT/ID	Yes	Yes	Yes

[1] Governor has recommended that the area be classified as nonattainment for new 8-hour O_3 standard

1.4.2 Class I Designations

With the exception of Big Cypress N Pres, Padre Island NS, Lake Mead NRA, and Lake Meredith NRA, the park units included in this study have been designated as Class I air quality areas under the Clean Air Act and its Amendments[3]. Class I areas were set aside by Congress for their pristine air quality or other natural, scenic, recreational, or historic values that are potentially vulnerable to air pollution, and Class I area resources receive special protection against air pollution.

Where emissions from new or modified facilities[4] may affect Class I areas, the act imposes special requirements to ensure that the new and existing pollution will not adversely affect such areas. In addition, Congress gave the NPS Superintendents, who are charged with direct responsibility for managing Class I areas, an affirmative responsibility to protect those values of an area that may be affected by changes in air quality. They are also to consider, in consultation with the permitting authority, whether a proposed major emitting facility will have an adverse impact on air quality-related values, which include visibility, odor, flora, fauna, and geological resources; archeological, historical, and other cultural resources; and soil and water resources.

1.4.3 Compliance

A review of applicable state air quality regulatory rules and regulations for each area found no compliance issues for the years evaluated. Stationary sources, such as heating units and generators, are generally exempt from permit requirements based on their relatively small size. There was one source at Lake Mead NRA that was installed in 2002 that may require a permit from the state. This is a 26-kW generator that was installed at Echo Bay and is operated four hours a day.

The principal park interactions with state air quality regulatory agencies relate to prescribed burning activities. These interactions should continue and be incorporated into Fire Management Plans as they are developed or revised. A review of the individual air rules addressing open fires indicated that all areas allow open fires for cooking food for human consumption and for recreational purposes. Some park units also have implemented mitigating measures, such as prohibiting the collection and burning of dead or other wood in the park and making clean, dry wood available through concession services.

[3] There are 49 NPS units that are designated as Class I areas throughout the United States.
[4] Within 100 kilometers of a Class I area.

2. STATIONARY SOURCES

This section summarizes emissions from stationary sources at the 21 NPS units for calendar years 2000 or 2001. The following emissions were calculated for most sources: PM_{10}, SO_2, NO_x, CO, CO_2, and VOCs.

2.1 HEATING EQUIPMENT

Summary–NPS units utilize a variety of space and water heating equipment. Energy sources include propane or LPG, No. 2 fuel oil, natural gas, and electricity. The majority of heating units are residential in size and are explicitly exempt from construction and operating permits by the various state air quality agencies. Table 4 summarizes the heating fuel types and quantities consumed by the park units in 2000 or 2001 and their associated air emissions.

Analysis–On an aggregate basis, total emissions are moderate from fossil fuel heating units. In order to evaluate mitigation opportunities to reduce air emissions from these units, the types and quantities of energy consumed were considered on a Btu basis. As noted at the bottom of Table 4, approximately 45 percent of fossil fuel consumed for heating is either propane (42 percent) or natural gas (3 percent), and 55 percent is supplied by No. 2 fuel oil. Unlike an earlier study of NPS units in California (EA 2000) where over 95 percent of park units utilized natural gas or propane, which are relatively clean heating fossil fuels, many of the park units included in this study are geographically remote and are located in areas where natural gas service is not available. From an air emissions standpoint, energy conservation measures to reduce fuel consumption and utilization of renewable energy sources to substitute for No. 2 fuel oil are the principal measures to reduce air emissions from heating sources.

2.2 GENERATORS

Summary–As noted in Table 5, approximately sixteen of the 21 NPS park units had one or more electrical generators. They ranged in size from 5 kW to 2,750 kW and were powered by diesel fuel (74 units), propane (34 units), and gasoline (15). Most were for emergency backup purposes only and were operated for only a few hours a year for maintenance purposes. However, Yellowstone NP has five units that were operated essentially full time at Beartooth Road Camp, Bechler Ranger Station, and Lamar Ranger Station. A unit at Toklat in Denali NP & Pres operates continuously.

Analysis–On an aggregate basis, generators produced more PM_{10}, NO_X, CO, and VOC emissions than fossil-fueled heating units, but considerably less SO_2 emissions. However, three parks, Denali NP & Pres, Glacier NP, and Yellowstone NP, accounted for slightly more than 80 percent of the aggregate emissions from generators included in this study. Therefore, if these units could be replaced by photovoltaic-battery systems, fuel cell systems, or otherwise eliminated, then the majority of air emissions from generators would be eliminated.

2.3 FUEL STORAGE TANKS

Summary–The number and types of gasoline storage tanks at the park units are summarized in Table 6. Of the approximately 133 tanks, about 92 are underground storage tanks (USTs) and 41 are aboveground storage tanks (ASTs). Gasoline fuel tanks are a source of VOC emissions due to standing and working losses. Standing or breathing losses are considerably less from USTs than ASTs since their temperature remains fairly constant. Diesel, Nos. 1 and 2 fuel oil, and propane tanks were not included in the studies since they produce no or negligible emissions. Only a few parks provided gasoline sales to the public by concessionaires. In order of sales volumes, these include Yellowstone NP, Grand Teton NP, Lake Mead NRA, Grand Canyon NP, and Crater Lake NP.

Analysis–In the aggregate, fuel storage tanks produce considerably more VOC emissions than heating equipment and generators, but less than woodstoves and fireplaces. An examination of the individual units indicates that the gasoline outlets that provide fuel for public boats at Lake Mead NRA constitute approximately one-half of all tank VOC emissions from gasoline tanks. Although Yellowstone NP has greater gasoline sales to the public than Lake Mead NRA, most of Yellowstone NP's tanks are USTs, while most of Lake Mead NRA's tanks are ASTs, which produce considerably greater emissions.

2.4 WASTEWATER TREATMENT PLANTS

Summary–Wastewater at the majority of the park units is typically treated in lagoons or underground septic tanks that remove settable solids and provide for the anaerobic digestion of these solids but generate negligible emissions. Some, such as Mammoth Cave NP, discharge to off-site treatment facilities. Only Grand Canyon and Yellowstone NPs have relatively large capacity municipal wastewater treatment plants. The principal emissions from wastewater treatment plants are VOCs, and these were estimated to be approximately 1,776 and 1,440 lbs/year from Grand Canyon and Yellowstone NPs, respectively.

Analysis–VOC emissions from wastewater treatment plants in Grand Canyon and Yellowstone NPs are very small relative to other VOC stationary and area sources.

Table 4: Heating Equipment Criteria Pollutant Emissions

Park	Fuel Consumption			Pollutants (lbs/yr)					
	Propane (gal/yr)	No. 2 Oil (gal/yr)	N.G. (cu ft/yr)	PM_{10}	SO_2	NO_X	CO	CO_2	VOC
Badlands NP, SD	15,191	--	--	6	0	213	30	189,888	5
Big Cypress N Pres, FL	4,380	--	--	2	0	61	8	54,750	1
Carlsbad Caverns NP, NM	25,476	5,000	--	12	355	447	73	425,950	11
Chiricahua NM, AZ	6,770	650[1]	--	3	46	106	16	98,600	2
Crater Lake NP, OR	1,062	84,447	--	146	5,996	1,674	424	1,828,886	35
Craters of Moon NM and Pres, ID[2]	--	--	--	--	--	--	--	--	--
Denali NP and Pres, AK	12,620	102,734	--	161	7,578	2,243	534	2,452,531	53
Glacier NP, MT	14,236	--	7,089,000	60	4	868	326	8,684,750	43
Grand Canyon NP, AZ	729,058	347,800	--	1,165	24,711	25,096	4,695	15,751,686	564
Grand Teton NP, WY	122,456	122,500	--	257	8,700	4,118	853	4,164,450	87
Great Sand Dunes NM and Pres, CO	17,967	--	--	7	0	252	36	224,588	5
Great Smoky Mountains NP, NC/TN	27,968	19,400	--	45	1,378	774	153	1,009,225	16
Guadalupe Mountains NP, TX	12,000	--	--	5	0	168	23	150,000	4
Lake Mead NRA, NV/AZ	29,951	--	--	12	1	419	60	374,388	9
Lake Meredith NRA, TX	19,240	--	700,000	13	1	335	66	324,000	10
Mammoth Cave NP, KY	20,195	17,591	--	43	1,249	635	128	630,644	12
Mesa Verde NP, CO	69,550	4,700	--	37	239	1,069	163	971,175	22
Padre Island NS, TX	53,613	--	--	0	0	2	1	5,000	0
Theodore Roosevelt NP, ND	18,144	190	--	7	14	257	35	230,885	6
Wind Cave NP, SD	9,934	5,910	--	6	420	245	48	251,240	7
Yellowstone NP, WY/MT/ID	396,570	712,895	1,034,500	1,546	50,623	19,863	4,406	20,297,277	382
Total	1,606,381	1,365,792	8,823,500	3,533	101,315	58,845	12,078	58,119,913	1,274
	10^6 Btus/yr[3]								
Total	146,984	191,211	9,265						

[1] Kerosene
[2] Electric heating equipment only
[3] Heating values: Propane – 91,500 Btu/gal; No. 1 and 2 Fuel Oil – 140,000 Btu/gal; Natural Gas – 1,050 Btu/cubic feet

Table 5: Generator Criteria Pollutant Emissions

Park	Type and Number			Pollutants (lbs/yr)					
	Propane	Diesel	Gasoline	PM_{10}	SO_2	NO_X	CO	CO_2	VOC
Badlands NP, SD	--	1	--	4	4	54	12	2,003	4
Big Cypress N Pres, FL	--	4	--	10	9	140	30	5,178	11
Carlsbad Caverns NP, NM	--	1	--	6	35	210	48	10,078	6
Chiricauha NM, AZ[1]	--	--	--	--	--	--	--	--	--
Crater Lake NP, OR	--	3	--	85	79	1,192	257	44,227	97
Craters of Moon NM and Pres, ID[1]	--	--	--	--	--	--	--	--	--
Denali NP and Pres, AK	--	5	--	1,555	1,533	21,915	4,722	812,986	1,774
Glacier NP, MT	13	3	--	1,666	5,541	27,964	6,353	605,798	1,955
Grand Canyon NP, AZ	6	3	--	222	573	4,309	962	166,582	244
Grand Teton NP, WY	1	22	2	446	747	7,252	1,797	303,708	422
Great Sand Dunes NM and Pres, CO[1]	--	--	--	--	--	--	--	--	--
Great Smoky Mountains NP, TN/NC	2	--	--	68	596	1,554	379	--	85
Guadalupe Mountains NP, TX	2	--	11	1	2	16	549	1,349	28
Lake Mead NRA, NV/AZ	4	4		275	259	3,881	836	143,737	314
Lake Meredith NRA, TX[1]	--	--	--	--	--	--	--	--	--
Mammoth Cave NP, KY	--	2	--	24	22	335	72	12,420	27
Mesa Verde NP, CO[1]	--	--	--	--	--	--	--	--	--
Padre Island NS, TX	1	2	--	2	2	22	5	801	2
Theodore Roosevelt NP, ND	--	1	--	2	2	27	6	1,017	2
Wind Cave NP, SD	--	1	--	10	9	141	30	5,239	11
Yellowstone NP, WY/MT/ID	5	22	2	1,550	4,524	34,013	9,112	1,513,297	1,740
Total	34	74	15	5,926	13,937	103,025	25,170	3,628,420	6,722

[1] No generators

Table 6: Gasoline Storage Tank Emissions[1]

Park	Tank Type and Number[1]		Gasoline Throughput (gal/yr)		VOC Emissions (lbs/yr)
	UST[2]	AST[3]	UST[2]	AST[3]	
Badlands NP, SD	--	3	--	30,000	1,011
Big Cypress N Pres, FL	--	1	--	13,294	1,441
Carlsbad Caverns NP, NM	1	--	15,556	--	105
Chiricauha NM, AZ	--	1	--	9,170	239
Crater Lake NP, OR	2	1	181,000	7,000	1,083
Craters of Moon NM and Pres, ID	1	--	2,535	--	12
Denali NP and Pres, AK	3	3	45,072	5,190	295
Glacier NP, MT	3	--	75,500	--	383
Grand Canyon NP, AZ	5	3	259,200	139,740	4,952
Grand Teton NP, WY	19	1	957,250	750	5,680
Great Sand Dunes NM and Pres, CO	1	--	5,600	--	24
Great Smoky Mountains NP, NC/TN	--	9	--	104,400	3,432
Guadalupe Mountains NP, TX	--	3	--	11,700	1,328
Lake Mead NRA, NV/AZ	15	8	1,634,800	814,160	43,099
Lake Meredith NRA, TX	--	2	15,750	--	1,175
Mammoth Cave NP, KY	3	2	47,383	19,745	867
Mesa Verde NP, CO	3	1	28,232	45,700	1,362
Padre Island NS, TX	--	2	--	16,500	855
Theodore Roosevelt NP, ND	--	2	--	14,600	389
Wind Cave NP, SD		1	--	8,770	531
Yellowstone NP, WY/MT/ID	36	2	2,690,194	4,430	16,110
Total	92	41	5,958,072	1,201,855	84,373

[1] Gasoline tank emissions only since diesel fuel and No. 1 or 2 fuel oil storage tank emissions are negligible
[2] UST – Underground storage tank
[3] AST – Aboveground storage tank

3. AREA SOURCES

This section summarizes emissions from area sources at the 21 NPS units for calendar years 2000 or 2001. The following emissions were calculated for various sources: PM_{10}, SO_2, NO_x, CO, and VOCs.

3.1 WOODSTOVES AND FIREPLACES

Summary–The number of woodstoves and fireplaces at the park units are summarized in Table 7. Of the approximately 400 woodburning appliances at 11 of the 21 park units, about 95 percent are woodstoves that are located in employee residences. Yellowstone NP accounted for over 60 percent of the total woodburning appliances identified in the study. While the number of woodburning appliances at individual parks can be accurately quantified, there are no data on the types of woodstoves, their condition, or the quantity of wood consumed. No data are maintained on wood consumption in personal residences, and personnel provided estimates based on their personal experience.

Analysis–Emissions of PM_{10}, CO, and VOC emissions from woodburning appliances are the highest of any of the stationary source groups discussed in Section 2. However, the accurateness of the emission estimates is questionable due to the lack of data on wood consumption by individual units. A first step to improve this accuracy would be to conduct a survey of woodstove users at each park unit to determine woodstove type, its condition, typical yearly wood consumption, and type of wood burned. Future actions to reduce air emissions include replacing older woodburning stoves with modern units that meet the U.S. EPA New Source Performance Standards (NSPS).

3.2 CAMPFIRES

Summary–The NPS and its concessioners operate campgrounds in 17 of the 21 park units. As the data in Table 8 indicate, there were over a half-million campfires at these campgrounds on an annual basis. Carlsbad Caverns NP has no campground, and Badlands and Guadalupe NPs prohibited campfires in their campgrounds. Although the NPS Public Use Statistics Office gathers data on the number of overnight visitors that utilize these campgrounds, there are no specific data on the number of campfires occurring at these sites. The data provided in Table 8 are based on the number of camp sites at a park and an estimate by park personnel of the number of nights they are

occupied and the percent that may have had a campfire. For comparative purposes, it was assumed that each campfire consumed the same quantity of wood.

Analysis–As noted previously in the discussion of woodstoves, the accuracy of the campfire data is considerably less than for sources for which fuel consumption or other records are available. The aggregate PM_{10}, CO, and VOC emissions are higher than those for woodstoves, but are very much less than those from wildfires and prescribed burning, which are described in the next section. Some parks have implemented mitigating measures, such as prohibiting the collection and burning of dead or other wood in the park and making clean, dry wood available through concession services. Also, campfires may be restricted during "Red Flag" or other designated days when the potential for fires in a park is high. Therefore, there will be seasonal variations in the number of campfires.

3.3 WILDFIRES AND PRESCRIBED BURNING

Summary– Wildland fire consists of both wildfires and prescribed fires. Wildfires are ignited naturally, usually by lightening, are typically unwanted, and therefore suppressed. On the other hand, prescribed burning is a land treatment process to accomplish natural resource management objectives, including reducing the potential for destructive wildfires, eliminating excessive fuel buildup, controlling insects and disease, improving wildlife habitat and forage production, maintaining natural succession of plant communities, and restoring natural processes. Prescribed burning can be for either ecological restoration or ecological maintenance. By policy, only prescribed burning for ecological restoration is considered an anthropogenic source of emissions; however, for the purposes of this emissions inventory, all prescribed burning has been treated as an anthropogenic source.

As noted in Table 9, prescribed burning was conducted at 12 of the 21 parks studied. It should be noted that the data in Table 9 are a one-year snapshot, while annual variation of emissions can be high due to meteorological conditions and/or local air quality levels. Also, actual emissions from prescribed burning occur on a seasonal basis, with fires typically occurring between June and October. These data also include wildfires, which typically occur due to lightning strikes and are aggressively suppressed, at parks where prescribed burning was not conducted.

Analysis–Emissions from prescribed burning are the largest sources of air pollution in the parks. The emission factors used to compute emissions were generated by the *First Order Fire Effects Model* based on the park's typical fuel vegetation, and they vary widely. For example, the table below provides a comparison between emission factors generated for lodgepole pine that is prevalent in Yellowstone NP and sand bluestem found at Padre Island NS.

Vegetation	Emission Factors (lbs/acre)				
	PM_{10}	**$PM_{2.5}$**	**CH_4**	**CO**	**CO_2**
Lodgepole Pine	654	554	335	7,325	33,375
Sand Bluestem	12	11	3	26	7,203

Prescribed burning can be conducted only at NPS units that have approved Fire Management Plans. Basically, these plans guide park personnel in planning prescribed fires so that they occur under favorable conditions of weather, fuel conditions, and resources. Components of the plans address minimization of impacts and measures to mitigate impacts, including alternative treatments such as mechanical fuel removal; coordination with state and local air quality regulatory agencies; public notification and exposure reduction procedures; and air quality monitoring.

Table 7: Woodstove/Fireplace Criteria Pollutant Emissions

Park	Appliance Type and Number		Pollutants (lbs/yr)				
	Woodstove	Fireplace	PM_{10}	SO_2	NO_X	CO	VOC
Badlands NP, SD	10	--	No Data				
Big Cypress N Pres, FL	--	--	--	--	--	--	--
Carlsbad Caverns NP, NM	1	--	17	0	2	129	30
Chiricauha NM, AZ	4	2	137	2	13	1,034	237
Crater Lake NP, OR	--	--	--	--	--	--	--
Craters of Moon NM and Pres, ID	1	--	61	1	5	443	402
Denali NP and Pres, AK	1	--	15	0	1	111	100
Glacier NP, MT	--	3	911	11	68	6,650	6,028
Grand Canyon NP, AZ	55	Lodges	10,269	119	772	74,972	67,967
Grand Teton NP, WY	43	7	10,318	120	775	75,330	68,290
Great Sand Dunes NM and Pres, CO	2	--	304	4	23	2,217	2,009
Great Smoky Mountains NP, TN/NC	--	--	--	--	--	--	--
Guadalupe Mountains NP, TX	1	--	17	0	2	129	30
Lake Mead NRA, NV/AZ	--	--	--	--	--	--	--
Lake Meredith NRA, TX	--	--	--	--	--	--	--
Mammoth Cave NP, KY	--	--	--	--	--	--	--
Mesa Verde NP, CO	8	--	972	11	73	7,093	6,430
Padre Island NS, TX	--	--	--	--	--	--	--
Theodore Roosevelt NP, ND	8	--	486	6	37	3,547	3,215
Wind Cave NP, SD	--	--	--	--	--	--	--
Yellowstone NP, WY/MT/ID	250	--	75,904	878	5,704	554,141	502,369
Total	384	12	99,410	1,152	7,475	725,796	657,107

Table 8: Campfire Criteria Pollutant Emissions

Park	Campfires		Pollutants (lbs/yr)				
	Number/yr	Tons/yr	PM_{10}	SO_2	NO_X	CO	VOC
Badlands NP, SD	Campfires prohibited						
Big Cypress N Pres, FL	Majority of campers are recreation vehicle campers						
Carlsbad Caverns NP, NM	No campgrounds						
Chiricauha NM, AZ	1,823	9	315	4	24	2,303	2,088
Crater Lake NP, OR	13,050	98	3,386	39	254	24,723	22,413
Craters of Moon NM and Pres, ID	Campfires prohibited						
Denali NP and Pres, AK	1,300	10	337	4	25	2,463	2,233
Glacier NP, MT	69,188	520	17,954	208	1,349	131,076	118,830
Grand Canyon NP, AZ	63,712	319	11,022	127	828	80,468	72,950
Grand Teton NP, WY	116,260	870	30,160	350	2,275	220,200	199,630
Great Sand Dunes NM and Pres, CO	7,560	57	1,962	23	147	14,322	12,984
Great Smoky Mountains NP, NC/TN	123,405	617	21,349	247	1,604	155,861	141,299
Guadalupe Mountains NP, TX	Campfires prohibited						
Lake Mead NRA, NV/AZ	34,141	171	5,906	68	444	43,120	39,092
Lake Meredith NRA, TX	6,450	16	558	6	42	4,075	3,694
Mammoth Cave NP, KY	11,700	29	1,012	12	76	7,389	6,698
Mesa Verde NP, CO	18,747	141	4,865	56	366	35,516	32,198
Padre Island NS, TX	2,000[1]	10	346	4	26	2,526	2,290
Theodore Roosevelt NP, ND	180	1.35	47	1	4	341	309
Wind Cave NP, SD	727	4	126	1	9	918	832
Yellowstone NP, WY/MT/ID	72,888	547	18,915	219	1,421	138,087	125,186
Total	543,140	3,419	118,260	1,369	8,894	863,388	782,726

[1] Beach fires

Table 9: Prescribed Burning Criteria Pollutant Emissions

Park	Acres	Fuel Types	Pollutants (lbs/yr)				
			PM_{10}	$PM_{2.5}$	CO	CO_2	VOC[1]
Badlands NP, SD	3,874	Prairie Grassland	11,622	11,620	27,118	7,813,858	3,874
Big Cypress N Pres, FL	29,944	Pine-Grass	3,560,000	3,010,000	37,202,000	331,225,336	1,740,000
Carlsbad Caverns NP, NM	570	Pine Grassland	6,270	5,130	31,920	2,287,410	2,280
Chiricauha NM, AZ	420	Pine Grassland/ Oak Woodland	50,260	42,300	443,470	9,392,140	10,900
Crater Lake NP, OR	8[2]	Western Hemlock-Lodgepole Pine	13,880	11,760	7,124	155,960	681,116
Craters of Moon NM and Pres, ID	200[2]	Mountain Sagebrush-Sage	2,200	1,800	11,200	802,600	800
Denali NP and Pres, AK	2,856[2]	Black & White Spruce	3,938,710	3,338,378	42,886,410	274,142,870	1,983,778
Glacier NP, MT	95	Douglas Fir	43,795	37,145	488,205	2,344,885	22,420
Grand Canyon NP, AZ	1,634	Pondarosa & Pinyon Pine-Juniper	308,523	262,476	3,281,130	24,510,000	153,085
Grand Teton NP, WY	9,657[2]	Lodgepole Pine	6,315,351	5,349,701	70,733,863	322,285,688	3,234,928
Great Sand Dunes NM and Pres, CO	30	Ponderosa Pine Shrub	5,880	4,980	63,360	449,520	2,940
Great Smoky Mountains NP, NC/TN	668	Fescue Grass-Poplar-Oak	6,412	5,019	1,540	5,907,124	16,448
Guadalupe Mountains NP, TX	135	Sagebrush-Mesquite Oak	3,185	2,643	1,084	15,516	1,269,763
Lake Mead NRA, NV/AZ	100[2]	Sagebrush-Salt Desert Shrub	1,450	1,250	500	7,400	574,100
Lake Meredith NRA, TX	1,120	Bluestem-Grama Prairie	5,040	4,480	1,120	10,640	2,993,760
Mammoth Cave NP, KY	No prescribed burning or wildfires						
Mesa Verde NP, CO	48	Mesquite-Juniper	576	432	2,784	219,600	192
Padre Island NS, TX	3,500[2]	Bluestem Grass	21	19	46	12,605	5
Theodore Roosevelt NP, ND	1,500	Blue Gamma-Buffalo Grass	4,500	4,500	10,500	3,025,500	1,500
Wind Cave NP, SD	1,000[2]	Buffalo Grass-Ponderosa Pine	78,300	66,900	835,900	6,736,000	39,100
Yellowstone NP, WY/MT/ID	4,342[2]	Lodgepole Pine	2,840,000	2,405,468	31,805,150	144,914,250	1,454,570
Total	53,996		17,184,353	14,566,001	187,834,424	1,136,258,902	14,185,559
		Total (tons/yr)	8,592	7,283	93,917	568,129	7,093

[1] As methane (CH_4)
[2] Wildfires; no prescribed burning

4. MOBILE SOURCES

This section summarizes emissions from mobile sources at the 21 NPS units. Mobile sources include visitor and NPS highway vehicles and nonroad vehicles and equipment. The following emissions were calculated: PM_{10}, SO_2, NO_X, CO, and VOCs.

4.1 HIGHWAY VEHICLES

Summary–As summarized in Table 10, an estimated 14.2 million visitor vehicles traveled approximately 540 million miles within the boundaries of the 21 park units on an annual basis. Concessionaires also operate extensive visitor shuttle bus systems in Denali NP & Pres and Grand Canyon NP. The NPS and concessionaires operate administrative, maintenance, law enforcement and other highway vehicles within the parks. As the data in Table 10 indicate, the average NPS/General Service Administration (GSA) vehicle travels approximately 6,770 miles/year within a park. This compares to an average 5,800 miles/year traveled by NPS/GSA in 21 parks in California that were analyzed in a previous study (EA 2000).

Analysis–Reducing emissions associated with vehicles operating on park roadways can be accomplished by reducing vehicles miles traveled (VMT) and by replacing conventional NPS and GSA vehicles with alternative fuel vehicles. Several parks have accomplished the former by operating visitor shuttle bus systems, and others are looking at shuttle bus or other transit options. Grand Canyon NP operates a fleet of natural gas-powered visitor shuttle buses on the South Rim, while Denali NP & Pres operates a shuttle bus system in the park entrance area and a mandatory bus system on the Park Road beyond mile 15.

Mesa Verde NP provides limited shuttle bus services to several area attractions, and Mammoth Cave NP provides bus service from the Visitor Center to the primary cave entrance. Glacier NP has a fleet of nostalgic Red Buses that have been converted to operate on propane fuel and that carry visitors across the Going-to-the-Sun Road. At Chiricahua NM, the park has some interest in investigating a possible commercial shuttle bus operation for visitors from the town of Wilcox, AZ, a gateway community located directly off Interstate 10 approximately 35 miles due west of the monument, in order to reduce emissions associated with visitor vehicles.

Several parks also operate limited shuttle bus service for employees. For example, Yellowstone NP operates a commuter bus from Livingston, MT to the Mammoth administrative area, which displaces the private vehicles of approximately 35 employees. The concessionaire at Crater Lake

NP has an internal van system for its employees who are not permitted to have private vehicles in the park. In addition to reducing park vehicle congestion, it also reduces vehicle emissions.

With respect to alternative fuels, several parks have acquired alternative fuel vehicles for the park's fleet. Biodiesel fuel, generally B20, is the most widely used alternative fuel in the parks studied. B20, a blend of 20 percent vegetable oils and 80 percent diesel fuel, is a fuel that can be used in unmodified diesel engines with the existing diesel fuel infrastructure. Parks that are utilizing B20 exclusively or partially include:

- Yellowstone NP
- Grand Teton NP
- Glacier NP
- Crater Lake NP
- Grand Canyon NP
- Mammoth Cave NP

In addition to the natural gas visitor shuttle buses operated by Grand Canyon NP, Yellowstone and Grand Teton NPs extensively utilize alternative fuel vehicles. In addition to B20, alternative fuels used in these parks include B100, E85 (85 percent ethanol/15 percent gasoline mixture), and E10. E10 also is sold at all the public service stations in Yellowstone NP since 2001. Lake Mead NRA operates nine compressed natural gas (CNG) bi-fuel vehicles, including eight pickups and one sedan, and in 2002, the park opened a slow-fill CNG refueling facility that can refuel six vehicles simultaneously. In addition to utilizing B20 in its small diesel-powered equipment, Mammoth Cave NP is utilizing E85 on a limited basis.

4.2 NONROAD VEHICLES AND EQUIPMENT

Nonroad vehicles and equipment operating in parks varies from large diesel nonroad vehicles such as snowplows, bulldozers, and graders to small gasoline lawn mowers. In addition to common groundskeeping and other equipment, the category of nonroad vehicles includes marine vessels, snowmobiles, and aircraft operated by the NPS, concessionaires, and visitors.

4.2.1 NPS Nonroad Vehicles and Equipment

Summary–The NPS operates a variety of vehicles and motorized equipment to maintain its structures and grounds. Data on the number a pieces of equipment at each park unit and their

estimated emissions are summarized in Table 11. This table also includes emissions from locomotives that operate in within Grand Canyon NP and Denali NP & Pres, as well as visitor and NPS-operated all-terrain vehicles and airboats in Big Cypress N Pres.

Analysis–When park officials consider replacing or adding new nonroad vehicles and equipment to their fleet, they should consider the availability of lower emission substitutes. In addition, use of ethanol blends in gasoline vehicles and equipment and bio-based and synthetic lubricants in two-stroke engines also reduces emissions. For example, bio-based fuels and lubricants are used in NPS vehicles and equipment at Yellowstone NP specifically to reduce emissions, and park officials are working to have them available for public sale within the park and in gateway communities.

Replacing two-stroke gasoline engines with four-stroke or two-stroke direct injection engines also would lower emissions. Since two-stroke engines also produce relatively large quantities of unburned fuel, their replacement reduces the release of unburned fuel in other media, such as surface recreational waters where two-stroke engine marine vessels operate.

4.2.2 Marine Vessels

A number of parks provide boating recreational opportunities, and emissions from these motorized units are summarized in Table 12. In terms of visitor and NPS-related boating activities, Lake Mead NRA accounts for over 90 percent of all criteria pollutants estimated to be generated by boating activities in the parks included in this study. The majority of the marine vessels operated by the NPS and its concessionaires at the time of this study were equipped with 2-stroke engines. As these engines and vessels are replaced, models with 4-stroke engines should be procured. Four-stroke engines produce significantly lower PM_{10} and VOC emissions compared to 2-stroke models; however, NO_X and CO emissions would increase.

4.2.3 Snowmobiles

Recreational snowmobiles are allowed to operate in Yellowstone, Grand Teton, and Crater Lake NPs and Denali NP & Pres. In addition, park staff operate snowmobiles in these parks. Data in Table 13 provide estimates of emissions associated with both visitor-operated and park staff-operated snowmobiles, as well as concessionaire-operated snowcoaches, which is a form of oversnow mass transit. Visitation and other data indicate that Yellowstone NP is the most popular snowmobiling site.

Winter use in Yellowstone and Grand Teton National Parks has been a significant issue for the past decade and has generated extensive interest. In recent years, that attention has been even more focused, controversial, and contentious. A November 2000 Record of Decision (ROD) for the Winter Use Final Environmental Impact Statement (FEIS) that called for the elimination of recreational snowmobile and snowplane use by the winter of 2003-2004 resulted in a lawsuit brought by the snowmobile industry and others asking that the decision be set aside. A settlement agreement resulted in the NPS undertaking a Supplemental Environmental Impact Statement (SEIS) to solicit more public comment and consider any new or updated substantive information not available at the time of the earlier decision, especially as it related to new snowmobile technology.

The new 2003 ROD strikes a balance between phasing out all snowmobile use, as required under the November 2000 ROD, and allowing for the unlimited snowmobile use of the park. The critical elements of the decision are a package that must be carried forward completely, with all components inextricably tied together. The principle components of the package are:

- Reduced numbers of snowmobiles with the establishment of daily limits
- Implementing Best Available Technology (BAT) requirements for snowmobiles
- Implementation of an Adaptive Management Program
- Access by trained guides will be required for both snowmobiles and snowcoaches
- A new generation of snowcoaches is to be developed as a key to winter transportation.

4.2.4 Aircraft

Aircraft are operated in and out of several of the parks, and emissions data from these aircraft are provided in table 14. The most significant are commercial and general aviation aircraft operated out of Jackson Hole Airport, which is located inside the boundary of Grand Teton NP. The aircraft emissions associated with Grand Canyon NP are actually generated from the Grand Canyon Airport, which is located just south of Tusayan approximately five miles south of the park boundary. The aircraft operating out of Big Cypress N Pres is an NPS owned general aviation aircraft, while aircraft operating on two maintained airstrips are general aviation aircraft as well. Emissions associated with Badlands NP are generated by a sightseeing helicopter that is located just outside the east entrance to the park.

Table 10: Highway Vehicle Criteria Pollutant Emissions

Park	No. Vehicles		VMT[1]		Pollutants (lbs/yr)			
	Visitor	NPS/GSA	Visitor	NPS/GSA	PM_{10}	NO_X	CO	VOC
Badlands NP, SD	405,975	49	10,962,000	533,672	287,178	32,445	432,996	22,549
Big Cypress N Pres, FL	165,850	50	6,634,000	500,000	13,697	19,260	225,462	14,613
Carlsbad Caverns NP, NM	162,720	33	2,148,000	264,012	16,628	23,643	76,653	4,582
Chiricauha NM, AZ	26,740	40	427,850	164,400	1,204	5,463	18,703	1,082
Crater Lake NP, OR[2]	197,785	59[2]	7,452,090	458,936[2]	15,250	22,914	310,900	14,754
Craters of Moon NM and Pres, ID	66,355	16	498,000	60,000	1.074	1,641	22,496	1,126
Denali NP and Pres, AK	111,600	253[2]	1,412,000	1,865,050[2]	554,604	51,630	99,213	5,830
Glacier NP, MT	490,440	247	23,600,400	1,640,430	50,520	52,380	599,940	60,580
Grand Canyon NP, AZ[2]	1,378,485	368[2]	38,137,654	2,536,125[2]	80,927	100,039	998,035	99,739
Grand Teton NP, WY[2]	929,667	160[2]	55,780,030	1,110,000[2]	112,341	179,050	2,396,788	117,299
Great Sand Dunes NM and Pres, CO	83,000	25	829,130	104,870	13,686	2,639	36,735	1,840
Great Smoky Mountains NP, NC/TN	3,931,606	234	177,239,603	747,600	356,331	370,174	3,483,280	373,729
Guadalupe Mountains NP, TX	18,913[3]	48	128,655[3]	246,706	12,742	2,567	12,695	698
Lake Mead NRA, NV/AZ	2,658,359	231	38,993,362	1,247,945	82,620	434,080	1,138,560	74,360
Lake Meredith NRA, TX	500,000	49	1,000,000	530,900	20,348	10,209	69,586	3,445
Mammoth Cave NP, KY	657,686	51	6,576,860	360,000	13,886	14,624	137,922	14,617
Mesa Verde NP, CO	454,000	89[2]	12,644,840	463,113[2]	25,285	40,303	496,673	29,664
Padre Island NS, TX	233,930	54	3,508,930	213,848	7,158	9,563	118,093	7,976
Theodore Roosevelt NP, ND	55,751	57	2,007,000	327,654	4,487	6,455	98,090	4,749
Wind Cave NP, SD	289,260	33	2,002,620	176,889	4,202	6,195	81,983	4,154
Yellowstone NP, WY/MT/ID	1,371,345	474	147,419,134	4,186,200	291,610	425,125	6,071,130	297,457
Total	14,189,467	2,620	539,402,158	17,738,350	1,964,705	1,810,399	16,925,933	1,154,843
				Total (tons/yr)	982	905	8,463	577

1 VMT – Vehicle miles traveled within the park unit
2 Includes concessionaire vehicles
3 Majority of visitors went to the Visitor Center that is just a hundred feet from the main highway

Table 11: Nonroad Vehicle and Equipment Criteria Pollutant Emissions

Park		Number	Hours	Pollutant (lbs/yr)			
				PM_{10}	NO_X	CO	VOC
Badlands NP, SD		9	905	104	817	364	1,201
Big Cypress N Pres, FL[1]		30	1,548	3,933	14,188	2,582,541	359,490
Carlsbad Caverns NP, NM		12	1,015	116	691	316	141
Chiricauha NM, AZ		9	660	87	352	198	96
Crater Lake NP, OR		9	625	112	357	220	141
Craters of Moon NM and Pres, ID		8	650	137	667	468	158
Denali NP and Pres, AK	Nonroad	25	18,750	3,328	22,935	47,127	17,505
	Railroad	--	--	3,524	142,386	14,023	5,274
Glacier NP, MT		41	2,603	1,482	8,945	7,507	2,275
Grand Canyon NP, AZ	Nonroad	31	5,295	738	4,553	2,218	862
	Railway	--	--	525	20,767	2,067	765
Grand Teton NP, WY		24	1,216	727	5,120	2,670	845
Great Sand Dunes NM and Pres, CO		2	110	39	20	44	42
Great Smoky Mountains NP, NC/TN		57	5,300	628	2,140	1,248	714
Guadalupe Mountains NP, TX		14	1,675	202	1,305	626	241
Lake Mead NRA, NV/AZ		138	31,000	3,629	20,170	9,651	4,405
Lake Meredith NRA, TX		20	2,400	447	3,060	1,770	536
Mammoth Cave NP, KY		20	1,600	166	293	248	185
Mesa Verde NP, CO		5	1,900	198	518	344	226
Padre Island NS, TX		4	1,565	258	1,277	665	302
Theodore Roosevelt NP, ND		19	1,591	297	1,197	685	1,420
Wind Cave NP, SD		15	1,760	217	336	325	1,345
Yellowstone NP, WY/MT/ID		42	7,233	3,450	22,110	16,425	4,130
	Total	534	89,401	24,344	274,204	2,691,750	402,299
			Total (tons/yr)	12.17	137.10	1345.88	201.15

1 Emissions include visitor off-road vehicles

Table 12: Marine Vessel Criteria Pollutant Emissions

Park	Pollutants (lbs/yr)				
	PM_{10}	SO_2	NO_X	CO	VOC
Big Cypress N Pres, FL	5	--	403	10,860	434
Crater Lake NP, OR	9	--	587	26,760	1,232
Glacier NP, MT	136	35	1,088	12,457	2,481
Grand Canyon NP, AZ	41	--	5,022	228,436	10,050
Grand Teton NP, WY	702	--	11,608	280,700	12,070
Lake Mead NRA, NV/AZ	240,500	--	313,700	19,744,800	4,155,050
Lake Meredith NRA, TX	14,700	--	8,335	689,100	206,720
Mammoth Cave NP, KY	189	100	2,552	1,400	790
Padre Island NS, TX	61	--	870	40,790	2,540
Yellowstone NP, WY/MT/ID	7,620	--	7,237	439,900	122,925
Total	263,963	135	351,402	21,475,203	4,514,292

Table 13: Snowmobile Criteria Pollutant Emissions

Park	Pollutants (lbs/yr)			
	PM_{10}	NO_X	CO	VOC
Crater Lake NP, OR[1]	118	48	21,673	8,081
Denali NP and Pres, AK[1]	513	195	58,444	21,878
Grand Canyon NP, AZ[2]	582	185	64,627	23,700
Grand Teton NP, WY[1]	825	272	119,120	45,210
Yellowstone NP, WY/MT/ID[1]	19,060	8,200	3,460,000	1,298,000
Total	21,098	8,900	3,723,864	1,396,869

[1] Pubic and NPS snowmobiles

[2] NPS snowmobiles only; public snowmobiles prohibited

Table 14: Aircraft Criteria Pollutant Emissions

Park	Pollutants (lbs/yr)				
	PM_{10}	SO_2	NO_X	CO	VOC
Badlands NP, SD	--	168	1,895	3,668	396
Big Cypress N Pres, FL	--	--	138	4,620	130
Denali NP and Pres, AK	--	--	10	2,756	10
Grand Canyon NP, AZ	--	890	8,348	32,630	4,550
Grand Teton NP, WY	360	1,506	47,500	97,550	6,870
Lake Mead NRA, NV/AZ	--	--	28	8,610	210
Total	360	2,564	57,919	149,834	12,166

5. MITIGATION MEASURES AND RECOMMENDATIONS

5.1 MITIGATION MEASURES

Actions to promote sustainable development in the design, retrofit, and construction of park facilities have associated air quality benefits. These include actions that reduce or replace consumption of conventional fossil fuels and/or reduce the consumption of other resources. Reductions in potable and non-potable water consumption also achieve concurrent reductions in energy consumption and associated air emissions. Acquisition of energy efficient appliances whenever possible also is an incremental energy saving measure that has associated air quality benefits.

- Energy substitution measures include switching from No. 2 fuel oil to propane, solar energy systems such as passive heating and photovoltaics, and water-powered microturbines
- Water conservation measures include waterless urinals in rest rooms and reductions in irrigation activities
- Replacement of remote diesel generators that operate nearly full-time with photovoltaic/ battery hybrid systems and fuel cells
- Woodstove phase-out or replacement with cleaner burning units
- Vehicle alternative fuels, such as biodiesel, propane, and natural gas
- Replacement of two-stroke engine-powered boats, snowmobiles, and other equipment with four-stroke engine units

5.2 RECOMMENDATIONS

An analysis of measures that may reduce air emissions at the individual parks resulted in some specific recommendations. These include:

- Replacement of woodstoves in Yellowstone and Theodore Roosevelt NPs with clean-burning EPA certified stoves
- Replacement of two-stroke engine-powered snowmobiles owned and operated by the NPS in Yellowstone, Grand Teton, and Crater Lake NPs and Denali NP & Pres with four-stroke engine-powered snowmobiles
- Replacement of two-stroke engine powered boats owned and operated by the NPS and concessionaires in Yellowstone, Grand Teton, Glacier, and Crater Lake NPs and Lake Mead and Lake Meredith NRAs with four-stroke powered boats

- Utilization of biodiesel fuels in NPS road vehicles and nonroad equipment where biodiesel fuel is regionally available and cost-effective, such as Great Smoky Mountains NP
- Expand utilization of E85 in NPS gasoline vehicles beyond current 15 percent level in Mammoth Cave NP
- Expand application of stabilizing dust palliative on remainder of the unpaved Park Road in Denali NP & Pres
- Improve energy consumption data collection and reporting at Lake Mead and Lake Meredith NRA

6. REFERENCES

EA Engineering, Science, and Technology. 2000. *1998 Air Emissions Inventories. Summary Report for California National Park Service Units*. Prepared for the National Park Service. October.

EA Engineering, Science, and Technology. 2001. *Air Emission Inventory Preparation Plan*. Prepared for the National Park Service. November.

National Park Service, 2000. *Winter Use Plans, Final Environmental Impact Statement for Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr., Memorial Parkway*. August

National Park Service, 2003. *Winter Use Plans, Final Supplemental Environmental Impact Statement for Yellowstone and Grand Teton National Parks and the John D. Rockefeller, Jr., Memorial Parkway*. March.

USEPA, 1991. *Nonroad Engine and Vehicle Emission Study Report*. EPA-21A-2001 and EPA460/3-91-02. November.

USEPA, 1995a. *Compilation of Air Pollution Emission Factors AP-42, Fifth Edition, Volume I: Stationary Point and Area Sources.*

USEPA, 1995b. *Highway Vehicle Particulate Emission Modeling Software "PART5".* Office of Transportation and Air Quality.

USEPA, 2000a. *Factor Information REtrieval (FIRE) Data System.* Office of Air Quality Planning and Standards.

USEPA, 2000b. *TANKS 4.09a.* Office of Air Quality Planning and Standards.

USEPA, 2002. *User's Guide to MOBILE6.1 and MOBILE6.2 Mobile Source Emission Factor Model*. EPA420-R-02-010. Office of Air and Radiation. March.

U.S. Federal Aviation Administration. 1997. *Emissions and Dispersion Modeling System*. Version 3.23. Office of Environment and Energy. February.

U.S. Forest Service. 1997. *First Order Fire Effects Model (FOFEM) 4.0 User's Guide*. January.