Chapter 10. Great Sand Dunes National Monument

Introduction

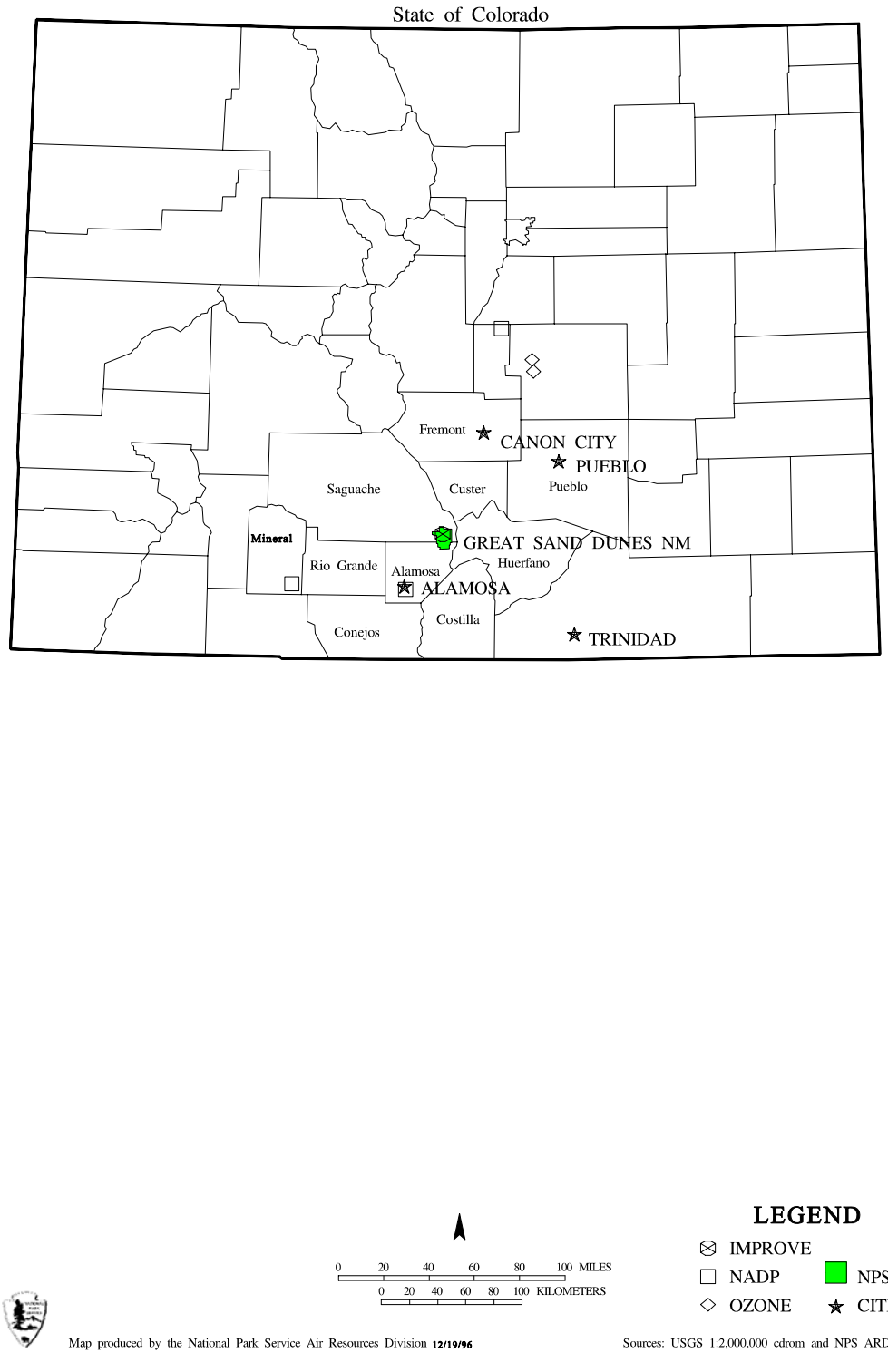
Great Sand Dunes National Monument was established in 1932 to protect the impressive sand dunes that are the highest in the U.S. The original proclamation cited additional values of scenic, scientific and educational interest. The landscape includes the abrupt threshold of the spectacular Sangre de Cristo range, canyon-mouth and desert-plain oases, and an unusual mixture of prairie and mountain environments.

The Monument includes about 15,650 ha of which all but 905 ha are federally owned. In 1976, 13,540 ha of the Monument was designated as Wilderness. The Great Sand Dunes lie in the San Luis Valley at the southwestern foot of the Sangre de Cristo mountain range in south central Colorado (Figure 10-1). This area is not geographically considered to be part of the Colorado Plateau. The Monument is bordered on its eastern flank by the Rio Grande National Forest and to the west by the San Luis Valley. The elevation of Great Sand Dunes visitor center is 2,493 m and dunes rise 200 m or more above the valley floor.

Geology and Soils

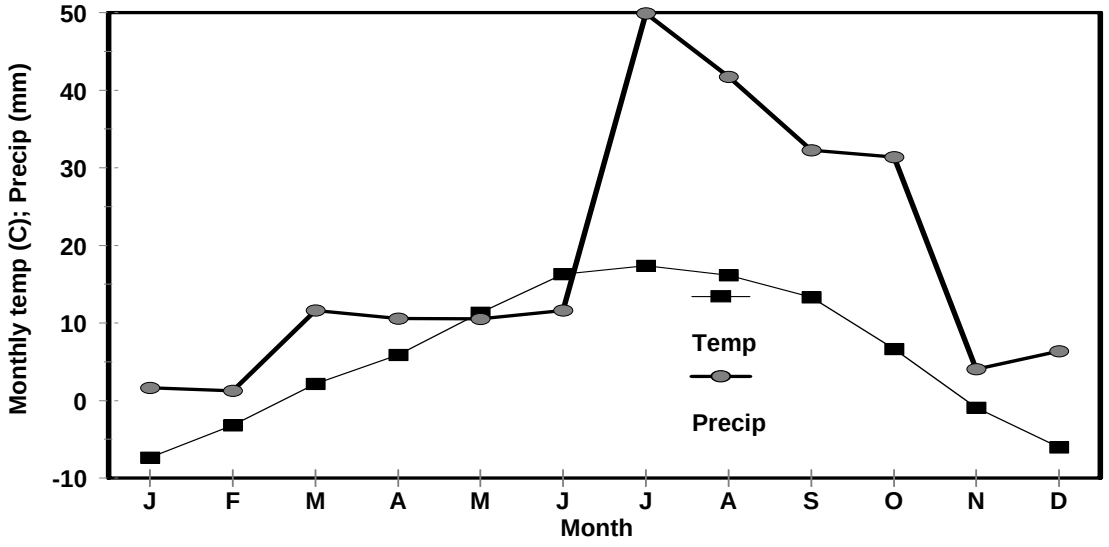
The sand of the dunes derives from the San Luis basin, where low precipitation since that last glacial period has prevented substantial vegetative cover for 10,000 yr. Strong southwesterly winds pick up the sand, and then deposit it as the wind is funneled between the peaks of the Sangre de Cristo Range. Medano, Music and Mosca passes to the east provide the backstop for the transported sand. The sedimentary sands in the San Luis Valley derive from volcanic parent materials in the surrounding mountains. Most of the deposited sediment resulted from uplift and erosion of the Sangre de Cristo mountains about 10 million years ago (Chronic 1984). The soils of the Monument are primarily sands, with dunes covering more than 65% of Great Sand Dunes National Monument.

Figure 10-1. Location of Great Sand Dunes National Monument.



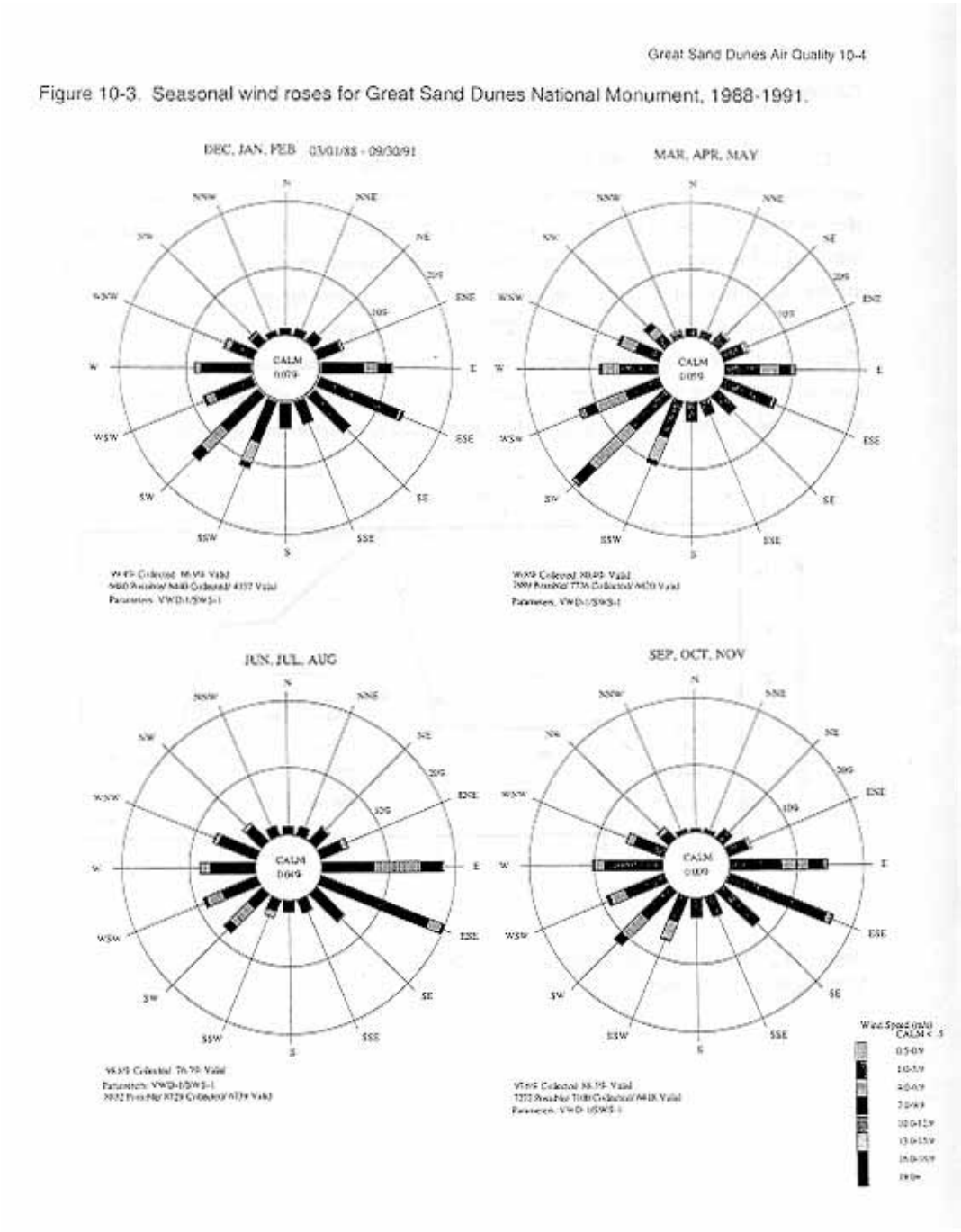
Climate

Great Sand Dunes National Monument has a climate typical of high mountain parks and valleys with cold winters and cool summers because of cold air drainage from surrounding mountains (Figure 10-2). Summers average about 17 ^{o}C, compared with -6 ^{o}C in winters. The Monument's proximity to the San Juan mountains to the west results in decreased orographic precipitation as storms from the west unload moisture before moving over this range. This rain shadow effect results in annual precipitation of about 230 mm. The winds at the Monument vary seasonally (Figure 10-3). Winter and spring winds come primarily from the southwest and the east, whereas



summer winds come primarily from the east, and autumn winds from all directions except north. The easterly wind in summer is mostly downslope and limited to a narrow area along the mountain front.

Figure 10-3. Seasonal wind roses for Great Sand Dunes National Monument, 1988-1991.



Vegetation

Vegetation in the dunes includes scurf pea (*Psoralea lanceolata*), Indian rice grass (*Achnatherun hymenoides*), blowout grass (*Redfieldia flexuosa*), and prairie sunflower (*Helianthus petiolaris*). The Monument as a whole supports such trees as ponderosa pine (*Pinus ponderosa*), pinyon pine (*Pinus edulis*), limber pine (*Pinus flexilis*), white fir (*Abies concolor*), alder (*Alnus tenuifolia)*, aspen (*Populus tremuloides*), serviceberry (*Amelanchier alnifolia*), mountain maple *(Acer glabrum*), and many shrubs, grasses and forbs. *Cleome multicaulus* is the only NPS plant species of special concern (F. Bunch, personal communication). Complete lists for plants and lichens are contained in NPFlora and NPLichen.

Air Quality

Air quality monitoring for Great Sand Dunes National Monument consists of data from 1988-1991 for ozone concentration, NADP monitoring in Alamosa, Colorado (30 km away) from 1980 to the present, SO_2 measurements from 1988-1992, and IMPROVE monitoring for visibility from 1988 to the present (particle sampling at Morris Gulch, camera near the landing strip).

Emissions

Table 10-1 provides summaries for emissions of carbon monoxide (CO), ammonia (NH_3), nitrogen oxides (NO_x), volatile organic compounds (VOC), particulate matter (PM), and sulfur oxides (SO_x) for 10 counties surrounding Great Sand Dunes National Monument. Emissions of SO_x from Pueblo County are the highest (particularly from the Comanche Plant of Public Service Company), but Great Sand Dunes probably receives very little of this material because the sources are across the Sangre de Cristo range and the prevailing wind direction (from the west) is away from the Monument. No information is available to relate these emissions to local air quality at Great Sand Dunes, or to apportion air quality impairment to local and regional sources.

Table 10-1. Emissions (tons/day) for counties surrounding Great Sand Dunes National Monument (Radian 1994).

County	CO	NH_3	NO_x	VOC	PM	SO_x

Alamosa, CO	18.58	0.77	2.13	5.99	9.1	0.20
Conejos, CO	21.22	1.71	2.44	10.65	11.5	0.24
Costilla, CO	8.95	0.70	0.96	8.74	4.9	0.10
Custer, CO	5.08	0.51	0.50	7.65	2.5	0.06
Fremont, CO	40.65	0.93	11.62	21.35	18.7	15.50
Huerfano, CO	10.86	1.21	1.07	14.26	4.9	0.17
Mineral, CO	2.75	0.31	0.25	6.42	1.4	0.03
Pueblo, CO	155.21	2.07	52.87	12.30	45.2	35.22
Rio Grande, CO	22.53	1.00	2.47	7.95	11.1	0.24
Saguache, CO	10.52	1.94	1.23	26.26	6.1	0.12

Air Pollution Concentrations

The concentrations of ozone in 1988 to 1992 averaged about 40 ppb, with peak 1-hr concentrations of 65 to 85 ppb (Table 10-2). These concentrations fall within a range that may produce visible effects or growth effects on very sensitive species (see Chapter 2), but no reports of injury or growth effects have been noted. The concentrations of SO_2 were far below any threshold of suggested sensitivity for any plants.

Table 10-2. Concentrations (ppb) of ozone and SO_2 for Great Sand Dunes National Monument. For ozone, upper value is mean daily concentration (ppb); middle number is the maximum 3-month Sum60 exposure (ppb-hr in excess of 60 ppb for 12 hr/day); and bottom number is the maximum 1-hr concentration observed each year. SO_2 24-hr averages by IMPROVE filter samplers (ppb) (1 $\mu g/m^3$ approximately equals 0.38 ppb). Ozone data from the NPS Air Resources Division's Quick Look Annual Summary Statistics Reports (provided by D. Joseph, NPS-ARD).

Year	Ozone	SO_2
1988		
Mean	40	0.1
Sum60	1174	
Max	76	0.3
1989		

Mean	41	0.1
Sum60	752	
Max	63	0.3
1990		
Mean	42	0.1
Sum60	4867	
Max	70	1.1
1991		
Mean	41	0.1
Sum60	7167	
Max	77	0.2
1992		
Mean		0.0
Sum60		
Max		0.0

Visibility

Great Sand Dunes National Monument is part of the IMPROVE Monitoring Network. The aerosol sampler began operation in May 1988 and the camera operated from July 1987 to April 1995. The data from this IMPROVE site have been summarized to characterize the full range of visibility conditions for the period May 1988 through February 1994, based on seasons of spring (March, April, May), summer (June, July, August), autumn (September, October, November), and winter (December, January, February). No transmissometer data are available, but visual ranges have been estimated based on aerosol sampling.

Aerosol Data

Aerosol sampler data are used to reconstruct the atmospheric extinction coefficient from experimentally determined extinction efficiencies of certain species (Table 10-3). The best visibility occurs during the winter. The reconstructed extinction in Table 10-4 is presented as seasonal and annual 50th and 90th percentile standard visual range for Great Sand Dunes. The 50th percentile means that visual range is this high or lower 50% of the time. This is an average 50th percentile for

each season. The 90th percentile means that the visual range is this high or lower 90% of the time. This is an average 90th percentile for each season.

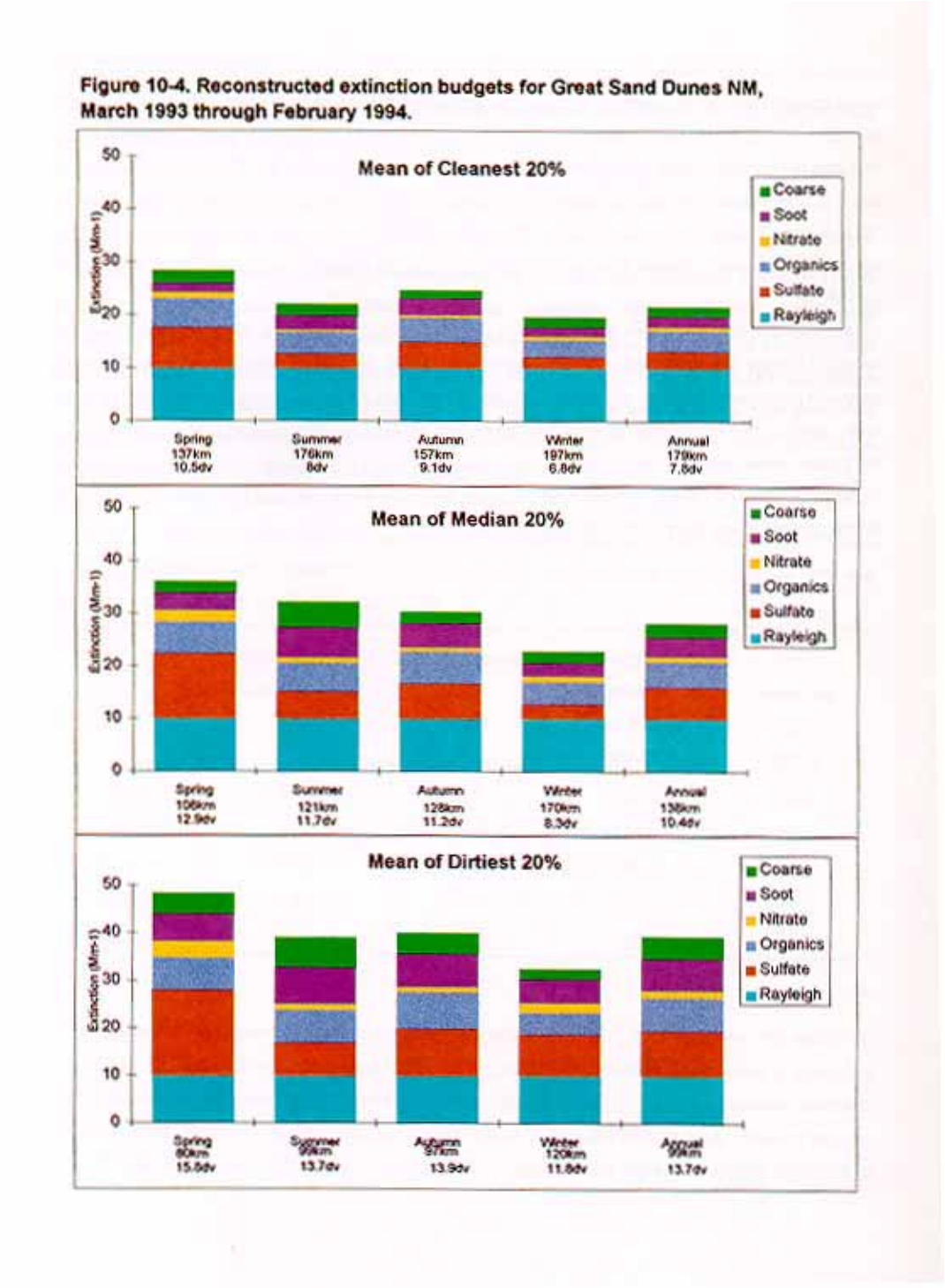
Table 10-3. Reconstructed visual range and light extinction coefficients for Great Sand Dunes National Monument, based on IMPROVE aerosol sampler, seasonal and annual average 50th and 90th percentiles, March 1988 - February 1994.

Season/Annual	50th Percentile Visual Range (km)	50th Percentile b_{ext} (Mm^{-1})	90th Percentile Visual Range (km)	90th Percentile b_{ext} (Mm^{-1})
Winter	148	26.4	190	20.5
Spring	102	38.3	144	27.1
Summer	120	32.6	161	24.3
Autumn	135	29.0	177	22.1
Annual	125	31.2	175	22.4

Reconstructed extinction budgets generated from aerosol sampler data apportion the extinction at Great Sand Dunes to specific aerosol species (Figure 10-4). Visibility impairment is attributed to atmospheric gases (Rayleigh scattering), sulfate, nitrate, organics, soot, and coarse particles. The extinction budgets are listed by season and by mean of cleanest 20% of days, mean of median 20% of days, and mean of dirtiest 20% of days. The "dirtiest" and "cleanest" signify highest fine mass concentrations and lowest fine mass concentrations respectively, with "median" representing the 20% of days with fine mass concentrations in the middle of the distribution. Each budget includes the corresponding extinction coefficient, SVR, and haziness in dv. The sky blue segment at the bottom of each stacked bar represents Rayleigh scattering which is assumed to be a constant 10 Mm^{-1} at all sites during all seasons. Rayleigh scattering is the natural scattering of light by atmospheric gases. Higher fractions of extinction due to Rayleigh scattering indicate cleaner conditions.

Atmospheric light extinction at Great Sand Dunes National Monument, like many rural western areas, is largely due to sulfate, organic, and soot aerosols. In pre-industrial times, visibility would vary with patterns in weather, winds (and the effects of winds on coarse particles), and smoke from fires. We have no information on how the distribution of visibility conditions at present differs from the profile under “natural” conditions, but the cleanest 20% of the days probably approach natural conditions (GCVTC 1996). Smoke from frequent fires may have reduced pre-settlement visibility below current levels during the summer months.

Figure 10-4. Reconstructed extinction budgets for Great Sand Dunes National Monument, March 1993 through February 1994.



Photographs

Three photos are provided to represent the range of visibility conditions for the Great Sand Dunes camera data (Figure 10-5). The photos were chosen to provide a feel for the range of visibility conditions possible and to help relate the SVR/extinction/haziness numbers to what the observer sees.

Figure 10-5. Photographs representing visibility conditions at Great Sand Dunes National Monument.

Great Sand Dunes Air Quality 10-12

Figure 10-5. Photographs representing visibility conditions at Great Sand Dunes National Monument.

Great Sand Dunes
National Monument
on a "clear" day.

Representative Conditions:
Visual Range: 170 - 210 km
b_{ext}: 23 - 19 Mm^{-1}
Haziness: 8 - 6 dv

Great Sand Dunes
National Monument
on a "average" day.

Representative Conditions:
Visual Range: 110 - 140 km
b_{ext}: 36 - 28 Mm^{-1}
Haziness: 13 - 10 dv

Great Sand Dunes
National Monument
on a "dirty" day.

Representative Conditions:
Visual Range: 65 - 80km
b_{ext}: 60 - 49 Mm^{-1}
Haziness: 18 - 16 dv

Atmospheric Deposition

The rates of atmospheric deposition for Alamosa, Colorado (about 30 km southwest of the Monument) are low (Table 10-4). Precipitation pH averages about 5.5, which is higher than most other NADP sites on the Colorado Plateau, probably reflecting the high alkalinity of the soils in the San Luis Valley. Deposition of N averages only 0.5 kg N ha^{-1} yr^{-1}, which is similar to the rate of S deposition. No trend is apparent for the concentration or deposition of N or S. There is no evidence that such low levels of deposition pose any threat to plants (see Chapter 2).

Table 10-4. Atmospheric deposition for Alamosa, Colorado, near Great Sand Dunes National Monument (NADP). Note the values for N and S compounds include the whole molecule and not just the N or S atoms.

	Concentrations (mg/L)			Deposition (kg ha^{-1} yr^{-1})				Conductivity (μS/mm)	Precipitation (mm/yr)
year	NH_4	NO_3	SO_4	NH_4	NO_3	SO_4	pH		
1980	0.38	0.93	1.33	0.41	1.00	1.44	5.68	0.88	108
1981	0.41	1.03	1.81	0.93	2.34	4.11	5.24	1.34	227
1982	0.43	0.89	1.51	0.54	1.11	1.89	5.59	0.99	125
1983	0.51	1.15	1.39	0.94	2.13	2.57	5.58	1.00	185
1984	0.21	0.79	1.11	0.38	1.43	2.00	5.51	0.86	180
1985	0.19	0.55	0.75	0.48	1.38	1.88	5.29	0.66	251
1986	0.21	0.66	1.09	0.42	1.33	2.19	5.28	0.88	201
1987	0.22	0.71	0.75	0.37	1.20	1.27	5.42	0.67	169
1988	0.12	0.66	0.99	0.17	.91	1.37	5.49	0.79	138
1989	0.47	1.21	1.19	0.52	1.34	1.32	5.59	0.98	111
1990	0.27	0.68	0.86	0.78	1.96	2.48	5.50	0.68	288
1991	0.19	0.77	1.10	0.36	1.46	2.08	5.35	0.97	189
1992	0.28	0.59	0.52	0.64	1.35	1.19	5.70	0.54	229
1993	0.26	0.69	0.61	0.65	1.72	1.52	5.56	0.59	249

1994	0.24	0.74	0.73	0.44	1.34	1.32	5.25	0.69	181

Sensitivity of Plants

No air pollution injury has been reported for vegetation in or near Great Sand Dunes National Monument. Only a few of the Monument's species have been tested under controlled conditions for sensitivity to pollutants, and none of these tests included genotypes representative of the plants in the Monument. Based on the ozone concentrations required to affect very sensitive plants (such as aspen), we expect that current ozone exposures could be high enough to affect some species. Current levels of ozone are probably too low to affect the conifers, and levels of SO_2 are far below any demonstrated threshold of sensitivity for any plants. In the absence of empirical evidence of any effects, no substantial problem is likely.

Water Quality and Aquatic Organisms

Water resources in the Great Sand Dunes National Monument include Medano, Mosca, Cold and Sand Creeks. Because of the sandy nature of the Monument, these streams sink into the sand and disappear within the Monument's boundaries. Medano Creek is sampled by the U.S. Geological Survey (USGS) as part of the National Water Quality Assessment Program (NAWQA). Water samples collected from September 1992 through January 1995 showed a range in pH from 7.0-8.7, with a range in alkalinity values of 22-47 mg/L (as CaCO3, = 440 to 940 μeq/L ANC). Water chemistry has been monitored for Medano Creek as part of the USGS NAWQA Program; pH values between 1992 and 1995 were 7.0 to 8.3, with ANC from 440 μeq/L to 980 μeq/L. These values indicate a relatively well-buffered stream, with sufficient ANC to prevent chemical change due to acidic deposition.

Amphibians

The species list for Great Sand Dunes includes: Great Plains toad *(Bufo cognatus*), the plains spadefoot toad (*Scaphiopus bombifrons*), and tiger salamander *(Ambystoma tigrinum*). Although there are few data on amphibian species abundance in Great Sand Dunes, the northern leopard frog (*Rana pipiens*) is declining the San Luis Valley of Colorado, a region immediately adjacent to the Monument (Navo, personal communication). Given the chemistry of surface waters in the

Monument, it is unlikely that acidification is affecting the resident amphibian populations.

Recommendations for Future Monitoring and Research

General recommendations for NPS Class I areas of the Colorado Plateau are presented in Chapter 14, and many of these apply to Great Sand Dunes National Monument. Monitoring of air quality at Great Sand Dunes National Monument involves an IMPROVE site and NADP sampling in nearby Alamosa. No ozone monitoring occurs at Great Sand Dunes; we anticipate no critical AQRV issues about ozone, but long-term monitoring at this Class I site may be useful given the lack of ozone monitoring in any nearby locations.

Currently monitored stream reaches in the Monument are not at risk to chronic acidification due to deposition. However, upper stream reaches that drain lands managed by the USFS might have lower ANCs than those monitored at lower elevations. Snowmelt runoff could have an influence on stream water quality in the spring. More needs to be known about the contributing areas for Monument streams and patterns of flow before a monitoring scheme could be developed for water quality. Since the USGS researchers have collected data in the Monument as part of the NAWQA program, we recommend that Monument staff review the existing data with these researchers to determine the likelihood that more dilute waters might be found upstream of the current stations. These headwater reaches might provide information on snowmelt runoff nitrate in stream water, indicating the need for annual sampling during this sensitive period.

Park Summary

Visibility is currently the only AQRV known to be impacted by pollution, as with the other National Park Service Class I areas of the Colorado Plateau. Current levels of pollution in southern Colorado are lower than across most of the Colorado Plateau. However, any increase in aerosols would reduce visibility further.

Little information has been collected on air pollution effects on the Park's biota. No sign of air pollution impacts on plant or animal species has been reported; ozone concentrations are high enough that some impact is possible for sensitive plants, but SO_2 concentrations are too low to affect plants.

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