National Park Service
U.S. Department of the Interior

Natural Resource Program Center

Air Quality Monitoring in the Northern Colorado Plateau Network

Annual Report 2009

Natural Resource Technical Report NPS/NCPN/NRTR—2010/374

ON THE COVER

Lava Point Overlook, Zion National Park. NPS photo.

Air Quality Monitoring in the Northern Colorado Plateau Network

Annual Report 2009

Natural Resource Technical Report NPS/NCPN/NRTR—2010/374

Prepared by

Dustin W. Perkins
Northern Colorado Plateau Network
National Park Service
P.O. Box 848
Moab, UT 84532

Editing and Design

Alice Wondrak Biel
Northern Colorado Plateau Network
National Park Service
P.O. Box 848
Moab, UT 84532

September 2010

U.S. Department of the Interior
National Park Service
Natural Resource Program Center
Fort Collins, Colorado

The National Park Service, Natural Resource Program Center publishes a range of reports that address natural resource topics of interest and applicability to a broad audience in the National Park Service and others in natural resource management, including scientists, conservation and environmental constituencies, and the public.

The Natural Resource Technical Report Series is used to disseminate results of scientific studies in the physical, biological, and social sciences for both the advancement of science and the achievement of the National Park Service mission. The series provides contributors with a forum for displaying comprehensive data that are often deleted from journals because of page limitations.

All manuscripts in the series receive the appropriate level of peer review to ensure that the information is scientifically credible, technically accurate, appropriately written for the intended audience, and designed and published in a professional manner. This report received informal peer review by subject-matter experts who were not directly involved in the collection, analysis, or reporting of the data.

This report is available from the Northern Colorado Plateau Network website, http://www.nature.nps.gov/im/units/NCPN, as well as at the Natural Resource Publications Management web site, http://www.nature.nps.gov/publications/NRPM.

Please cite this publication as:

Perkins, D. W. 2010. Air quality monitoring in the Northern Colorado Plateau Network: annual report 2009. Natural Resource Technical Report NPS/NCPN/NRTR—2010/374. National Park Service, Fort Collins, Colorado.

NPS 960/105741, September 2010

Contents

Figures

Tables

Executive Summary

The National Park Service Organic Act and the Clean Air Act protect air resources in national parks, and in 2005, the National Park Service's Northern Colorado Plateau Network (NCPN) selected ozone, wet and dry deposition, and visibility as vital signs for long-term natural resources monitoring. Information relative to these three vital signs supports evaluation of compliance with legislative requirements of the Clean Air Act's Regional Haze Guidelines and facilitates interpretation of plot-based vegetation and water-quality measurements. In 2010, the National Park Service's Air Resources Division published a nationwide report on air quality in national park units. This report expands on that information to provide a more comprehensive look at air quality in NCPN parks. Highlights from this report appear below.

- Some type of air quality monitoring occurs in six network park units: Bryce Canyon National Park (BRCA), Canyonlands National Park (CANY), Capitol Reef National Park (CARE), Colorado National Monument (COLM), Dinosaur National Monument (DINO), and Zion National Park (ZION).

- An additional six park units have air quality monitoring stations close enough to the park to be reasonably considered representative of the park's air quality: Arches National Park (ARCH), Black Canyon of the Gunnison National Park (BLCA), Cedar Breaks National Monument (CEBR), Curecanti National Recreation Area (CURE), Natural Bridges National Monument (NABR), and Timpanogos Cave National Monument (TICA).

- All reporting NCPN parks met the 2009 Government Performance and Results Act (GPRA) goals for air quality for which trend could be determined. There was not enough data to determine whether goals for ozone were being met at COLM, DINO, or ZION. All reporting parks showed stable or improving trends in visibility (9 parks), ozone concentrations (2 of 2 parks; 3 could not be determined due to limited data), and atmospheric deposition (2 parks).

- Nitrogen deposition was estimated to be in good condition at CANY and moderate condition at BRCA, with no trend at either park. Ammonium deposition showed no significant trend at CANY over the past 10 years, but showed an increasing trend over the entire 20-year data set.

- Sulfur deposition was estimated to be in good condition at BRCA and CANY. Sulfates in deposition declined at BRCA and were stable at CANY.

- Ozone levels were estimated to be in moderate condition at CANY, COLM, and DINO, and of significant concern at ZION and TICA. Ozone showed a decreasing trend at TICA and no trend at CANY; trend could not be determined for COLM, DINO, and ZION.

- Visibility was estimated to be in moderate condition at ARCH, BLCA, BRCA, CANY, CARE, CEBR, CURE, NABR, and ZION, with no degrading trends. Visibility has improved significantly on the clearest days over the past 10 years at all NCPN parks where trends can be analyzed (ARCH, BLCA, BRCA, CANY, CARE, CEBR, CURE, NABR, and ZION).

Acronyms

AQRV	air quality-related value
ARCH	Arches National Park
BLCA	Black Canyon of the Gunnison National Park
BRCA	Bryce Canyon National Park
CANY	Canyonlands National Park
CARE	Capitol Reef National Park
CASTNet	Clean Air Status and Trends Network
CEBR	Cedar Breaks National Monument
COLM	Colorado National Monument
CURE	Curecanti National Recreation Area
DINO	Dinosaur National Monument
DV	deciviews
EPA	Environmental Protection Agency
GPRA	Government Performance and Results Act
IMPROVE	Interagency Monitoring of Protected Visual Environments
N	nitrogen
NAAQS	National Ambient Air Quality Standards
NABR	Natural Bridges National Monument
NADP	National Atmospheric Deposition Program
NCPN	Northern Colorado Plateau Network
NH_3	ammonia
NH_4	ammonium
NO_2	nitrogen dioxide
NO_3	nitrate
NOx	nitrogen oxides
NP	national park
NPS	National Park Service
NTN	National Trends Network
NPS-ARD	National Park Service Air Resources Division
OMC	organic mass by carbon
$PM_{2.5}$	mass of particulates up to 2.5 μm in diameter (fine particles)
PM_{10}	mass of particulates up to 10 μm in diameter (coarse particles)
POMS	portable ozone monitoring system
ppb	parts per billion
S	sulfur
SO_2	sulfur dioxide
SO_4	sulfate
TICA	Timpanogos Cave National Monument
VOCs	volatile organic compounds
ZION	Zion National Park

Acknowledgements

We are grateful to the Sonoran Desert Network for developing the air quality monitoring protocol that we adapted and implemented to create this report. Thanks also to Ellen Porter and Debbie Miller, of the National Park Service Air Resources Division, and Mark Miller, of the Southeast Utah Group, for their thoughtful review of this report.

1 Introduction

1.1 Background

The National Park Service (NPS) is charged with maintaining national park units and their resources unimpaired for the enjoyment of future generations. Park resources affected by air quality include scenery and vistas, vegetation, water, and wildlife. Both the NPS Organic Act and the Clean Air Act protect air resources in national parks. Six Northern Colorado Plateau Network (NCPN) park units are designated as Class I areas: Arches National Park (ARCH), Black Canyon of the Gunnison National Park (BLCA), Bryce Canyon National Park (BRCA), Canyonlands National Park (CANY), Capitol Reef National Park (CARE), and Zion National Park (ZION). These parks receive the highest protection under the Clean Air Act.

The NCPN has identified three aspects of air quality as high-priority vital signs for long-term natural resources monitoring: atmospheric deposition, ozone, and visibility. Over the past three decades, the NPS has developed several internal and cooperative programs for monitoring these measures of air quality. The NCPN relies on the results of that cooperative monitoring for its reporting (NPS-ARD 2002). NCPN air quality reports include data from parks with any type of monitoring—currently BRCA, CANY, CARE, Colorado National Monument (COLM), Dinosaur National Monument (DINO), and ZION. Table 1-1 lists air quality monitoring currently occurring in the NCPN.

Table 1-1. Summary of ambient air quality monitoring in and nearby to NCPN parks.

Park code	Wet deposition	Dry deposition	Ozone	Visibility
Parks with monitoring stations within their boundaries				
BRCA	UT99 (NADP/NTN)	-	-	Bryce Canyon NP (BRCA1-IMPROVE)
CANY	UT09 (NADP/NTN)	CANY 407 (CASTNet)	CANY-IS (CASTNet)	Canyonlands NP (CANY1-IMPROVE)
CARE	-	-	-	Capitol Reef NP (CAPI1-IMPROVE)
COLM	-	-	COLM-MY (POMS)*	-
DINO	-	-	DINO-WE (POMS)*	-
ZION	-	-	ZION-DP (NPS-GPMP)	Zion NP (ZICA1-IMPROVE)
Parks with monitoring stations close enough to be reasonably considered representative of the park				
ARCH	-	-	-	Canyonlands NP (CANY1-IMPROVE)
BLCA	-	-	-	Weminuche Wilderness (WEMI1-IMPROVE)
CEBR	-	-	-	Bryce Canyon NP (BRCA1-IMPROVE)
CURE	-	-	-	Weminuche Wilderness (WEMI1-IMPROVE)
NABR	-	-	-	Canyonlands NP (CANY1-IMPROVE)
TICA	-	-	EPA Site # 490495008442011	-

"Nearby" is defined as 10 miles from a park's boundary for ozone or deposition monitors, and 60 miles (100 km) for visibility monitors.

*[2]Portable ozone monitoring stations (POMS) sites are generally used for short-term monitoring (≤ 5 years) Source: http://www.nature.nps.gov/air/studies/portO3.cfm

In addition, the National Park Service Air Resources Division (NPS-ARD) has determined that deposition and ozone monitors within 16.1 km (10 miles) of a park boundary, as well as particulate (visibility) monitors within 100 km (60 miles), may be reasonably considered representative of a park's air quality (NPS-ARD in press). Under these guidelines, the NCPN also reports on status for ARCH, BLCA, Cedar Breaks National Monument (CEBR), Curecanti National Recreation Area (CURE), Natural Bridges National Monument (NABR), and Timpanogos Cave National Monument (TICA) (Table 1-1).

1.1.1 Atmospheric deposition

Wet deposition occurs when air-pollutant emissions, such as sulfur dioxide (SO_2), nitrogen oxides (NOx), and ammonia (NH_3) from power plants, automobiles, agriculture, and other sources are transported and transformed in the atmosphere and deposited to ecosystems as sulfate [SO_4], nitrate [NO_3], and ammonium [NH_4] compounds via rain or snow. Dry deposition of particles and gases occurs through complex processes, such as settling, impaction, and adsorption.

Atmospheric deposition can have a variety of effects on ecosystems, including acidification, fertilization or eutrophication, and accumulation of toxins. In freshwater lakes, streams, and watersheds, acid deposition from nitrogen (N) and sulfur (S) compounds can cause changes in water chemistry that affect algae, fish, submerged vegetation, and amphibian and aquatic-invertebrate communities.

Throughout the Southwest, there is concern that soils and vegetation may be affected by increasing loads of nitrogen from atmospheric deposition. Deposition can cause changes in soil that affect soil microorganisms, plants, and trees. Because certain plants are better able to utilize nitrogen than others, N deposition can result in shifts in plant-species composition and potentially facilitate invasive exotic plant invasion (Schwinning et al. 2005). In some parts of the country, N deposition has altered soil nutrient cycling, and native plants that have evolved under nitrogen-poor conditions have been replaced by invasive species better able to utilize nitrogen (NPS-ARD 2006a). Excess N deposition can cause unwanted fertilization effects, leading to changes in plant-community structure and diversity. Nitrogen additions also can result in higher plant biomass and, consequently, higher fire frequency and severity (Rao et al. 2010).

The NPS monitors the chemistry of precipitation in national park units as a partner in the National Atmospheric Deposition Program (NADP) National Trends Network (NTN) (NADP 2002). Rainwater samples are collected weekly using standard methods and are sent to a central laboratory for analysis. Measured constituents include hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations (including calcium, magnesium, potassium, and sodium). In the NCPN, BRCA has participated in this program since 1985, and CANY since 1997. Nitrogen dioxide (NO_2) and SO_2 are also contaminants for which "non-attainment" areas are designated when regulatory thresholds for human-health effects are exceeded, although impacts to ecological systems could occur below these thresholds. No NCPN park units are currently in non-attainment areas for NO_2 or SO_2 (EPA 2009).

Dry-deposition chemistry is monitored in CANY in conjunction with the Clean Air Status and Trends Network (CASTNet) (MACTEC 2003). Over a weeklong period, fine particles and gases suspended in the air are collected on filters that are sent to a central laboratory for analysis. Meteorological, vegetation, and land-use data from the sites are used to calculate deposition velocities, which are combined with the concentration measurements to estimate dry deposition in kilograms per hectare per year (kg/ha/yr) of ammonium, nitrate, nitric acid, sulfate, and sulfur dioxide.

1.1.2 Ozone

Ozone is a gaseous constituent of the atmosphere usually formed by reactions of NOx and volatile organic compounds (VOCs) in the presence of sunlight. Ground-level ozone is the major constituent in smog. Ozone in certain concentrations is toxic to humans, and some plant species are particularly sensitive to ozone damage (Porter 2003). The Environmental Protection Agency (EPA) has set national standards for ozone to protect human health (primary standard) and the environment (secondary standard). Both standards are identical and set at 0.075 parts per million; ppm). Areas not meeting the standards are designated as non-attainment areas, and states are required to develop plans to bring such areas into attainment. No NCPN park units are currently in non-attainment areas for ozone (EPA 2009). In January 2010, the EPA proposed to strengthen the primary ozone standard to a level from 0.060 to 0.070 ppm. Based on data from 2006 to 2008, if the standard were set at 0.070 ppm or lower, counties where CANY, ZION, and TICA are located may be considered for a non-attainment designation. However, any designations will likely be based on data from 2008 to 2010.

Ozone has been monitored using continuous samplers at CANY and ZION since 1992 and 2004, respectively. This method employs a gas analyzer that measures ultraviolet absorbance to produce hourly ozone concentration measurements. Continuous monitoring is done as part of the NPS Gaseous Pollutant Monitoring Program, in partnership with the EPA's CASTNet program (MACTEC 2003). At COLM and DINO, ozone data have been collected by portable ozone monitoring system (POMS) units, which are small, low-power ozone analyzers, since 2006 and 2005, respectively. Two POMS versions are available: one with and one without filter-pack sampling for dry deposition. POMS are generally used for survey and temporary monitoring projects. TICA has an ozone monitoring station located within 16.1 km of the park.

The NPS-ARD completed an ozone risk assessment for NCPN parks in 2004, based on the concept that foliar ozone injury to plants is the result of the interaction of the plant, ambient ozone, and the environment. The risk for foliar injury is high if three factors are present: plant species that are genetically predisposed to ozone injury; concentrations of ambient ozone that exceed a threshold required for injury; and environmental conditions that foster gas exchange and ozone uptake by the plant. The assessment concluded that the risk of foliar injury to plants is low in all NCPN parks (NPS 2004). Several parks have ozone levels that exceed thresholds for foliar injury to plants, but these ozone levels tend to occur during drought conditions, which reduce the potential for injury. However, recent information suggests that well-watered plants in riparian areas may be at increased risk. NCPN parks have not been recently surveyed for ozone injury. In 1999, ARD staff surveyed plants at BRCA, CEBR, and ZION, where they examined plants in areas with high soil moisture and found ozone injury on at least one sensitive plant species at each park (E. Porter, NPS-ARD, pers. comm.).

1.1.3 Particulate matter and visibility

Visibility-obscuring particulate matter consists of dust, soot, and other fine solid materials that become suspended in the air. Major sources of particulates are burning of fossil fuels, fires, wood smoke, and wind-blown soil. Regulatory standards for particulates and visibility include (1) designation of non-attainment areas and (2) visibility improvement goals for Class I areas under the Clean Air Act. Timpanogos Cave National Monument, located in Utah County, Utah, is in a moderate non-attainment area for PM_{10} (mass of particulates up to 10 µm in diameter) and is adjacent to a non-attainment area for $PM_{2.5}$ (EPA 2010). (TICA is not one of the six NCPN units designated as Class I areas.)

Visibility monitoring currently occurs in BRCA (since 2000), CANY (since 2000), CARE (since 2000), and ZION (since 2003) as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE) program (Crocker 1996; IMPROVE 1998). Stations are located nearby to two additional Class I NCPN parks, ARCH and BLCA. The CANY station is located 35 km south of ARCH, and the Weminuche Wilderness site, in the San Juan National Forest, is located 96 km southwest of BLCA. Three non-Class I parks have sites nearby: NABR (CANY site), ZION (BRCA site), and CURE (Weminuche Wilderness site).

1.2 Monitoring objectives

The NPS monitors air quality parameters in NCPN park units in cooperation with national air quality monitoring programs. Air quality data are summarized and analyzed for conditions and trends by both the NPS-ARD and those national programs. Therefore, it is not the NCPN's objective to replicate these analyses. Instead, the network aims to compile the data summaries performed by these groups and provide them in a concise report to be analyzed in conjunction with other NCPN vital signs. In addition, the NCPN seeks to understand how ozone, nitrogen deposition, sulfur deposition, and visibility-reducing pollutants vary with associated vital signs (e.g., integrated upland systems, integrated riparian systems, climate, land condition in and around parks).

NCPN air quality monitoring objectives are to:

1. Determine the seasonal and annual status and trends in concentrations of N- and S-containing ions from wet deposition at BRCA and CANY;
2. Determine the seasonal and annual status and trends in dry-deposition chemistry at CANY;

3. Determine the seasonal and annual status and trends in ozone concentrations at CANY, COLM, DINO, and ZION, and make status estimates for TICA, which has a station in the vicinity of the park; and

4. Determine the seasonal and annual status and trends in concentrations of visibility-reducing pollutants at BRCA, CANY, CARE, and ZION from stations in the park and make status estimates for ARCH, BLCA, CEBR, CURE, and NABR based on stations from the vicinity.

2 Methods

2.1 Atmospheric deposition

Atmospheric deposition is monitored in the NCPN by the NADP and CASTNet. Because of differences between wet and dry deposition, NADP and CASTNet monitoring and analysis methods are different. The NADP collects and analyzes rainfall samples for cations and anions, reporting concentrations of those constituents in milligrams per liter of rainfall. Rainfall amount is factored in to estimate deposition rates in kilograms per hectare per year (kg/ha/yr). The NADP reports individual site data and produces isopleth maps of wet deposition concentrations and deposition.

The NADP maps of interpolated wet deposition values are useful for examining spatial differences in the loadings of pollutants to ecosystems. NADP concentration data (as opposed to deposition data) are typically used to track temporal trends in the components of deposition. Deposition data are less useful for tracking temporal trends because they are affected by annual variations in rainfall amounts, are used to estimate condition (see Section 2.5.1).

CASTNet uses filters to collect atmospheric particles and gases suspended in the air, analyzes the filters, and reports concentrations in micrograms per cubic meter of air. CASTNet interpolates ambient concentrations and produces isopleth maps for the U.S. An inferential model is then applied to ambient concentrations to estimate deposition in kg/ha/yr. Because the inferential model is very site-specific (e.g., dependent on vegetation types), CASTNet does not recommend extrapolating the dry-deposition data between areas, and does not produce isopleth maps of deposition as NADP does. CASTNet has recently started reporting both dry and wet (from NADP) deposition data, providing total deposition estimates for areas with CASTNet samplers.

2.2 Ozone

Ozone is known to be harmful to human health, and research shows that not only are certain plant species even more sensitive than humans to ozone, but also that effects on plants can occur at levels well below the National Ambient Air Quality Standards (NAAQS) for ozone. Scientists use various exposure indices to quantify ozone exposure to plants—indices considered biologically relevant because they take into account both peak ozone concentrations and cumulative exposure to ozone. These indices include the SUM06 (the running, 90-day maximum sum of the 0800–2000 hourly concentrations of ozone equal to or greater than 0.06 ppm) and the W126 (the annual index of the sum of weighted hourly concentrations, 8AM–8PM, during the three-month period with the maximum index value). In general, both SUM06 and W126 need to be satisfied in order for there to be a moderate-to-high risk for ozone injury, and soil moisture needs to be sufficient enough that plant stomates are likely to be open, allowing ozone to enter the leaves. Continuous ozone analyzers and POMS are used to monitor ozone in NCPN parks.

2.3 Visibility

IMPROVE monitoring protocols include three types of visibility monitoring: particle (or aerosol), scene, and optical. Particle samplers, located at all IMPROVE sampling sites, are used to calculate the mass and chemical composition of fine particle matter ($PM_{2.5}$) and the mass of coarse particulate matter (PM_{10}) in the atmosphere. Fine particles of two size classes are collected on filters and sent for laboratory analysis of chemistry and mass. Samples are collected for a 24-hour period every third day.

2.4 Statistical Analyses

To calculate the servicewide percentages necessary for comparison with air-quality goals, the NPS-ARD (2009) performed 10-year trend analyses for:

1) annual precipitation weighted means of sulfate, nitrate, and ammonium ion concentrations; and volume-weighted concentrations of ammonium, nitrogen, and sulfur in wet deposition as reported by NADP, multiplied by a normalized precipitation amount to give a total deposition in kg/ha;

2) three-year average of the annual fourth highest eight-hour ozone concentration; and

3) particle measurements (visibility) used to calculate the annual reconstructed atmospheric extinction in deciviews for 20% clearest and 20% haziest days.

The FY2009 analysis used data collected from 1999 to 2008, and required that each monitoring site have at least six years of data in this 10-year period. The trend time period is a sliding, 10-year window, chosen (rather than a variable length trend from a single, fixed, baseline year) because individual parks began monitoring in different years; thus, there is no single, fixed, baseline year that can be applied to all parks. We used a significance level of 0.05.

Trends were computed using the Thiel test, a nonparametric technique that does not require any assumptions about data distribution. In this method, all possible ordered pairs of points are compared and the differences are computed. Each positive difference is recorded as a +1, each negative difference is recorded as a -1, and the sum of the +1 and +1 values is computed. This sum is then used to determine the probability that the observed differences could have occurred by chance as a result of random fluctuations in the time series. The EPA has also used this method to determine trends in air quality data (see http://www.epa.gov/visibility/report/APPd.pdf). Trended statistics were computed for (1) the three-year average of annual fourth-highest eight-hour ozone concentration, as defined by EPA; (2) annual volume-weighted concentrations of N and S in wet deposition as reported by NADP, multiplied by a normalized precipitation amount to give a total deposition in kg/ha; and (3) annual deciviews (dv) for the 20% clearest and 20% haziest days, as defined by the Tracking Progress Guidance Document for EPA's regional haze rule.

The NADP Technical Committee defines completeness based on four criteria:

- Criterion 1: the percentage of the summary period for which there are valid samples.
- Criterion 2: the percentage of the summary period for which precipitation amounts are available, either from the rain gage or the sample volume.
- Criterion 3: the percentage of the total measured precipitation associated with valid samples.
- Criterion 4: the collection efficiency as defined by the sum of the sample bucket depths (in centimeters) in the summary period divided by the sum of the rain gage amounts (in centimeters) for all valid samples, where both values are available.

To qualify as complete, the values for criteria 1, 3, and 4 must be ≥75%. The values for criterion 2 must be ≥90% (http://nadp.sws.uiuc.edu). For the trend analyses, only values that met criteria 1, 2 and 3 ≥75% of the time were used; others were set to missing. No smoothing was applied.

2.5 Condition Assessments

The NPS-ARD has developed condition assessments for the major air quality parameters based on interpolated five-year averages (2004–2008) (NPS-ARD in press). The following three assessment methods sections are derived from the division's 2009 Annual Performance & Progress Report (NPS-ARD in press).

2.5.1 Atmospheric deposition condition

Park scores for current condition of atmospheric deposition were based on a five-year average of wet deposition, because dry deposition data were not available for most areas. Wet deposition was calculated by multiplying N or S concentrations in precipitation by a normalized precipitation amount. Deposition data were obtained from the NADP. Several factors were considered when rating deposition condition, including natural background deposition estimates and the effects of deposition on ecosystems. Estimates of natural background deposition for total deposition are approximately 0.25 kilograms per hectare per year for N and S (kg/ha/yr) in the American West. For wet deposition only, this is roughly equivalent to 0.13 kg/ha/yr in the West. Certain sensitive ecosystems respond to levels of deposition on the order of 3 kg/ha/yr total deposition, or about 1.5 kg/ha/yr wet deposition. There is currently no evidence to indicate that less than 1 kg/ha/yr of wet deposition causes ecosystem harm. Therefore, parks with wet deposition of less than 1 kg/ha/yr were considered to be in good condition for deposition. Parks with 1–3 kg/ha/yr were considered to be in moderate condition, and parks with more than 3 kg/ha/yr were considered to have a significant concern for deposition (Table 2-1).

Table 2-1. Deposition condition as determined by kg/ha/yr.

Deposition condition	Wet deposition (kg/ha/yr)
Good	<1
Moderate	1–3
Significant Concern	>3

Scores for parks with ecosystems potentially sensitive to N or S were adjusted up one category (e.g., a park with N deposition of 1–3 kg/ha/yr that contained N-sensitive ecosystems would be assigned the deposition condition "significant concern").

2.5.2 Ozone condition

The NAAQS for ozone was 85 ppb until March 2008, based on the three-year average of the fourth-highest daily maximum eight-hour average ozone concentration. In March 2008, the standard value was lowered to 75 parts per billion (ppb) to be more protective of human health (Ray 2009). To attain this standard, the three-year average of the fourth-highest daily maximum eight-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 75 ppb. In January 2010, the EPA proposed to strengthen the primary ozone standard, intended to protect human health, still further, to a value in the range of 60–70 ppb.

To derive an estimate of current ozone condition at parks, the five-year average of the annual fourth-highest eight-hour ozone concentration was determined for each park from the interpolated values described above. Good condition for ozone was assigned to parks with average five-year ozone concentrations of less than 61 ppb (concentrations less than 80% of the standard). Moderate condition for ozone was assigned to parks with average five-year ozone concentrations of 61–75 ppb (concentrations greater than 80% of the standard). If the resulting five-year average was greater than or equal to 76 ppb, then a condition of "significant concern" was assigned to that park (Table 2-2).

In addition to the standard, vegetation sensitivity was considered when assigning park condition. Data show that some plant species are more sensitive to ozone than humans, and the ozone standard is not protective of some vegetation. In accordance with the 2004 risk assessment, which rated parks as either at low, moderate, or high risk for ozone injury to vegetation, parks that were evaluated at high risk were moved into the next condition category (e.g., a park with an average ozone concentration of 72 ppb, but judged to be at high risk for vegetation injury, would move from the category "moderate" for ozone to "significant concern") for this report. No NCPN parks were rated as high-risk.

Table 2-2. Ozone condition as determined by ppb.

Ozone condition	Ozone concentration
Good	≤60 ppb
Moderate	61–75 ppb
Significant Concern	≥76 ppb

While condition assessments are not made for W126 and SUM06, thresholds for ozone effects to vegetation have been identified for these indicators (Table 2-3).

Table 2-3. Thresholds for ozone effects to vegetation.

Growth reduction	W126	SUM06
Tree seedlings: Natural forest stands	7–13 ppm-hrs	10–15 ppm-hrs
Tree seedlings: Plantations	9–14 ppm-hrs	12–16 ppm-hrs
Visible foliar injury: Plants in natural systems	6–9 ppm-hrs	8–12 ppm-hrs

2.5.3 Visibility condition

Individual park scores for visibility were based on the deviation of the current Group 50 visibility conditions from estimated Group 50 natural visibility conditions, where Group 50 is defined as the mean of the visibility observations falling within the range from the 40–60th percentiles. Current visibility was estimated from the interpolation of the five-year averages of the Group 50 visibility. Visibility in this calculation is expressed in terms of a haze index in deciviews (dv). As the haze index increases, visibility worsens. The visibility condition is expressed as:

Visibility Condition = current Group 50 visibility – estimated Group 50 visibility under natural conditions

Good condition was assigned to parks with a visibility condition estimate of less than two dv above estimated natural conditions. Parks with visibility condition estimates ranging from two to eight dv above natural conditions were considered to be in moderate condition, and parks with visibility condition estimates more than eight dv above natural conditions were considered to have a significant concern (Table 2-4). The dv ranges of these categories, while somewhat subjective, were chosen to reflect the variation in visibility conditions across the monitoring network.

Table 2-4. Visibility condition as determined by number of dv above estimated natural conditions.

Visibility condition	dv above estimated natural conditions
Good	<2
Moderate	2–8
Significant Concern	>8

2.6 GPRA Goals

Data from visibility monitoring, gaseous air pollutant monitoring (primarily ozone), and precipitation monitoring are used to assess air-quality trends. Six total measures are used to calculate the goal percentages: two are used to measure progress toward the visibility goal, one is used for the ozone goal, and three measures are used for the atmospheric-deposition goal. Not all parks monitor all six indicators. A park is considered to have improving or stable air quality if none of the measures used for that goal show a statistically significant degrading trend (NPS-ARD in press).

Performance assessments for these goals are based on a 10-year trend of three performance indicators: atmospheric deposition, ozone, and visibility. Trends in annual precipitation weighted means of sulfate, nitrate, and ammonium ion concentration are used as indicators of atmospheric deposition, because they can be directly linked to ecological effects (e.g., acidification of surface waters, nutrient enrichment that disrupts natural systems). The NPS calculates ozone by determining the 10-year trend in the annual fourth-highest eight-hour ozone concentration. For visibility, the NPS examines the 10-year trend in annual reconstructed atmospheric extinction in deciviews for both clear and hazy days. Extinction depends on the mass and chemical composition of the particles and is a quantitative measure of how the passage of light through the atmosphere is affected by air pollutants.

3 Results

3.1 Regional Trends

The NPS-ARD's FY2009 Government Performance and Results Act (GPRA) report (NPS-ARD in press) addressed air quality trends in parks nationwide where long-term monitoring occurred from 1999 to 2008. Of all 10 NCPN parks for which there were sufficient data to test for trends, none had significantly degrading trends in air quality; therefore, all 10 parks met their 2009 GPRA goals for air quality. This was an improvement from the previous year, when CANY did not meet its 2008 GRPA goal for atmospheric deposition due to increasing amounts of ammonium.

3.1.1 Visibility

Visibility improved on the 20% clearest days in all NCPN parks where measurements were taken (ARCH, BLCA, BRCA, CANY, CARE, CEBR, CURE, NABR, and ZION). Similar improvement was found at parks close to the NCPN, including Great Basin, Great Sand Dunes, and Mesa Verde national parks. Trends for parks further south on the Colorado Plateau (Glen Canyon National Recreation Area, Grand Canyon National Park, and Walnut Canyon National Monument) remained stable. Visibility trends have been stable on the 20% haziest days for all NCPN parks and surrounding parks for the past 10 years.

3.1.2 Nitrate, sulfate, and ammonium concentrations in precipitation

Sulfates decreased significantly (improving air quality), and nitrates and ammonium were stable at BRCA. All three ions were stable at CANY. Similarly, nitrates and sulfates decreased and ammonium was stable at Mesa Verde NP and Bandelier NM. At Grand Canyon NP, none of the three ions showed a significant trend, but nitrates and sulfates were very close to showing a declining trend.

3.1.3 Ozone

Ozone decreased significantly at TICA (improving air quality). In contrast, ozone was stable at CANY, Grand Canyon NP, Mesa Verde NP, and Great Basin NP.

3.1.4 Spatial patterns

Spatial patterns of sulfate, nitrate, and ammonium in precipitation in 2008 appear in Figures 3-1 (concentration) and 3-2 (deposition) (figures begin on page 17). Sulfate concentrations and deposition remain low throughout the NCPN and the western United States, reflecting regional differences in SO_2 emissions (whose primary source is coal-burning power plants). Nitrate concentrations and depositions were also generally lower in the West, reflecting lower emissions of nitrogen oxides from vehicles, power plants, and other combustion sources. However, northern Utah has elevated ammonium concentrations, including the areas of Golden Spike National Historic Site, TICA, CANY, CARE, ARCH, and, to a lesser extent, Fossil Butte National Monument, in Wyoming. Ammonium forms from ammonia emissions emanating from agriculture, feedlots, and fires. Both nitrate and ammonium contribute to total N deposition. Figure 3.3 shows spatial patterns in visibility on the clearest days and haziest days. The NCPN has some of the better visibility in the country. Spatial patterns for ozone concentrations are not available.

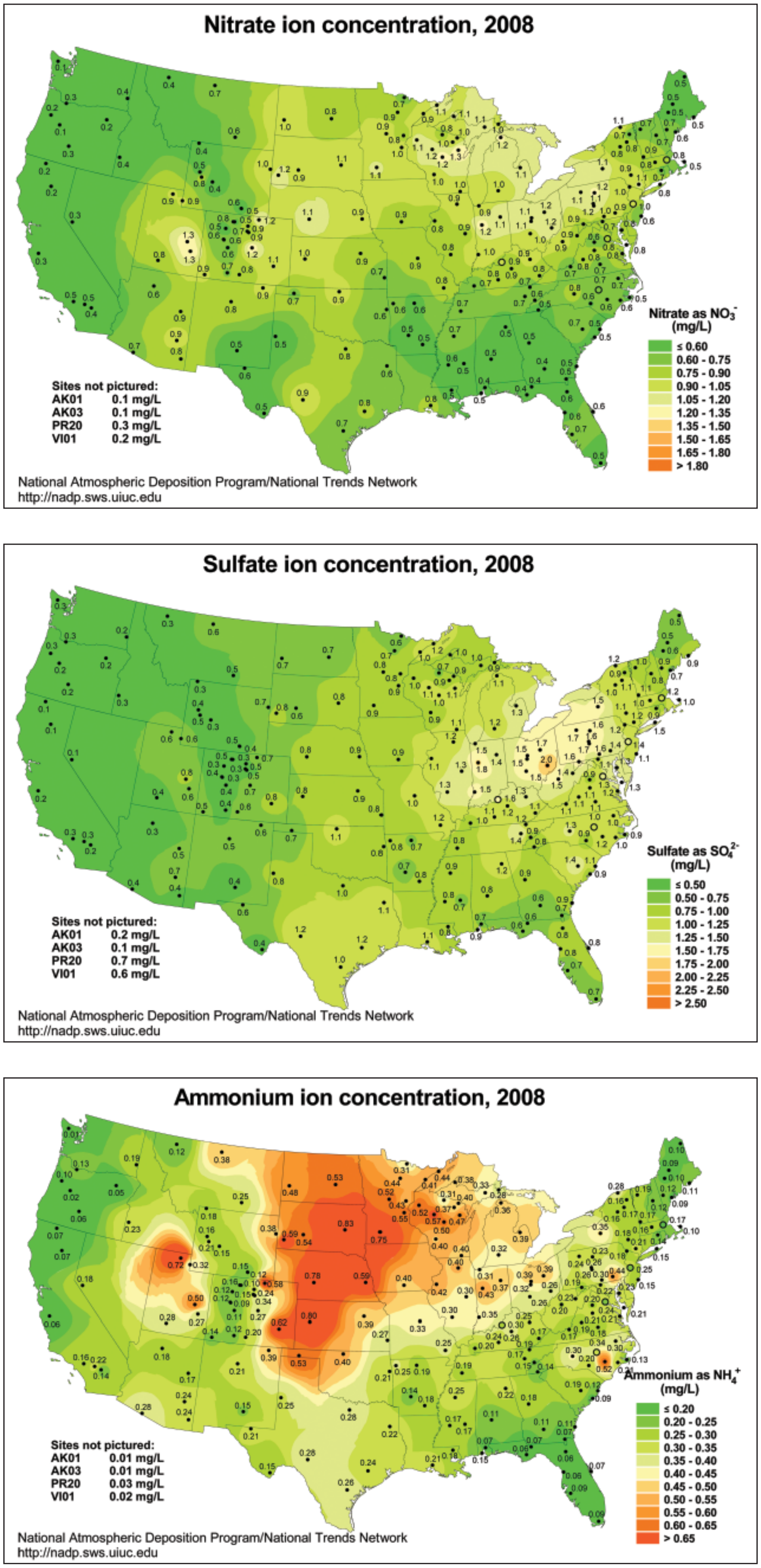


Figure 3-1. Spatial distribution of nitrate, sulfate, and ammonium concentrations, 2008 (http://nadp. sws.uiuc.edu/).

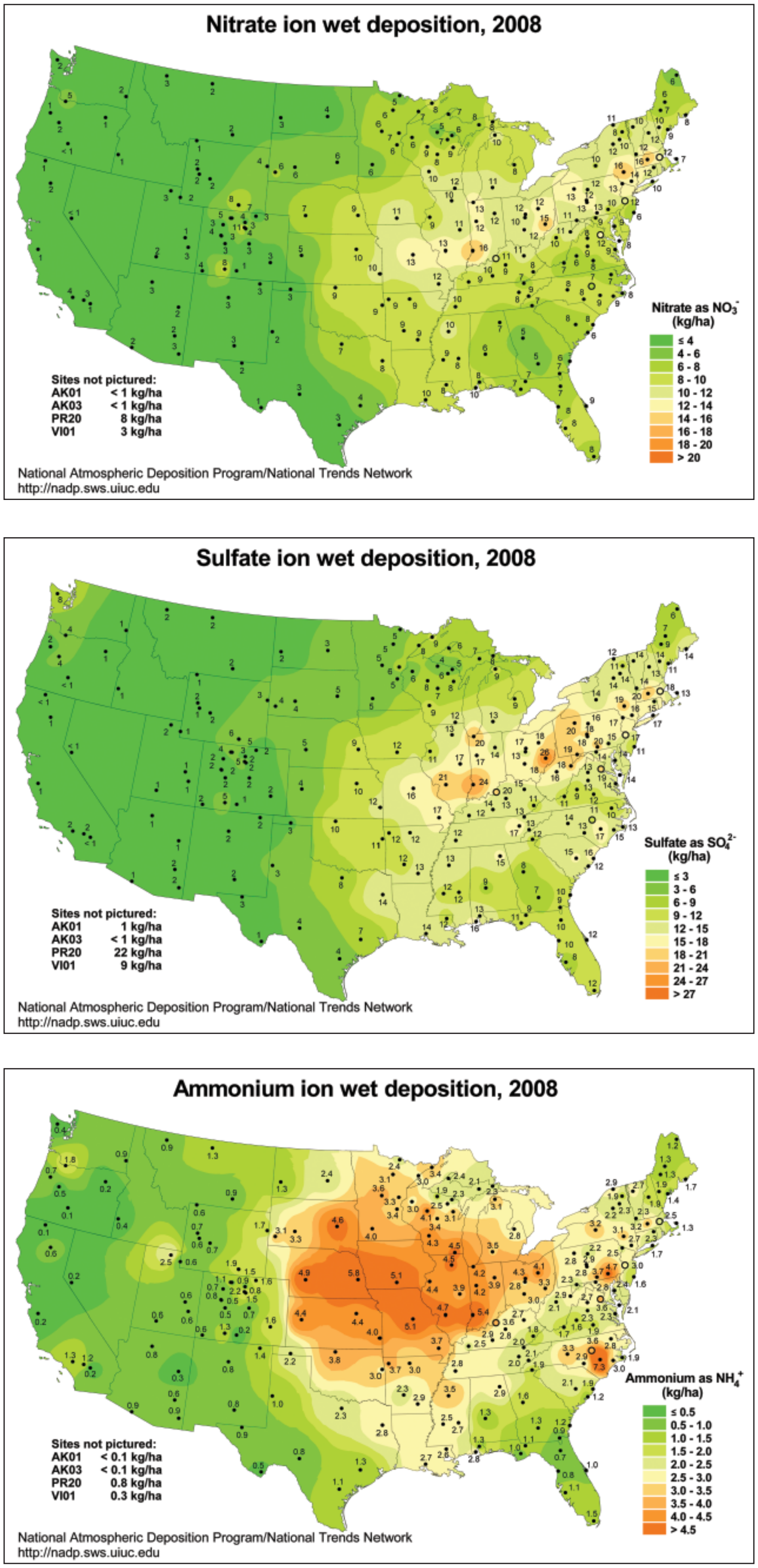
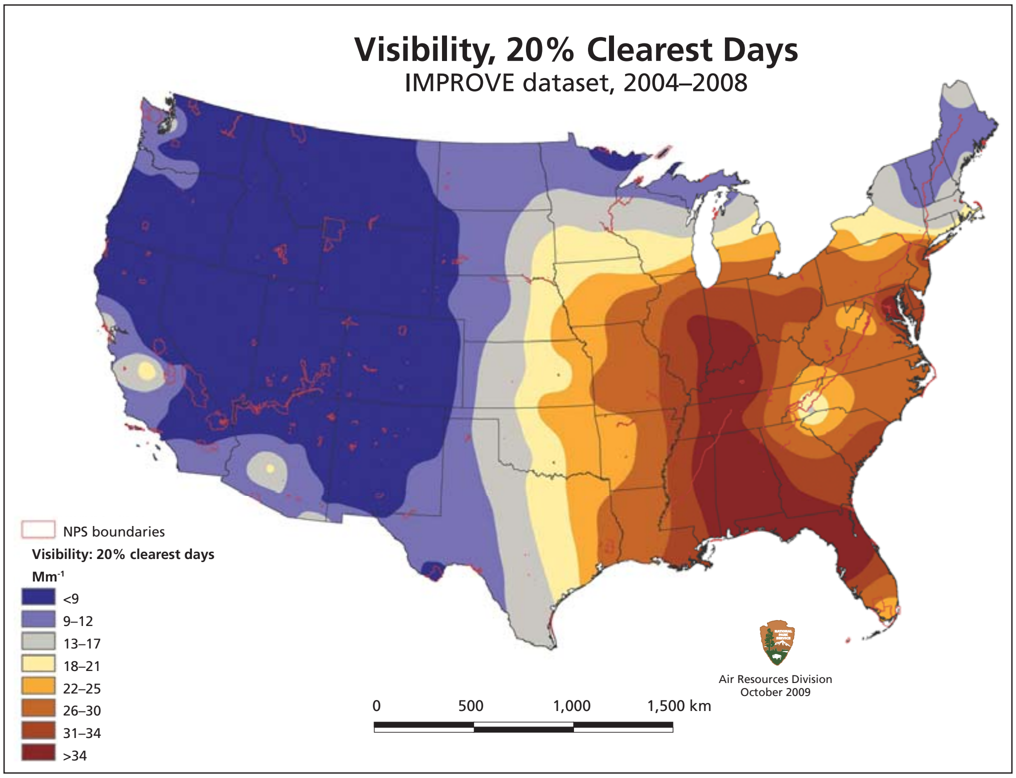


Figure 3-2. Spatial distribution of nitrogen and sulfate depositions, 2008 (http://nadp.sws.uiuc.edu/).



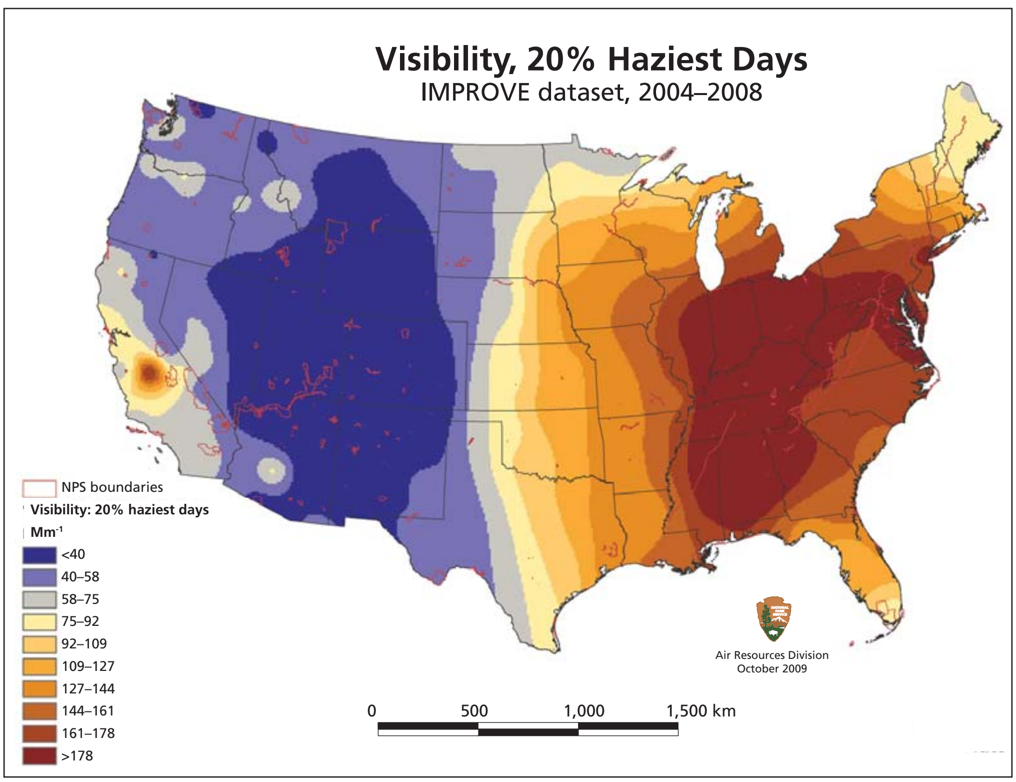


Figure 3-3. Spatial distribution of light extinction on the 20% best (clearest) days (above) and the 20% worst (haziest) days (below) in the U.S., 2004–2008. Locations of NPS units are outlined in red.

3.2 Black Canyon of the Gunnison National Park and Curecanti National Recreation Area

3.2.1 Class I park overview

Black Canyon of the Gunnison NP was designated a Class I air quality area in 1977, receiving the highest protection under the Clean Air Act. Both local and distant air pollutant sources affect air quality in BLCA and adjacent CURE. Power plants in Mesa and Montrose counties, Colorado, are the largest nearby point sources of SO_2 and NOx. Other large power plants in the Four Corners area, as well as urban areas throughout the Southwest, contribute to pollution in the park (NPS-ARD 2006a). Visibility is a very sensitive air quality-related value (AQRV), and in many parks on the Colorado Plateau, is often impaired by light-scattering pollutants (haze). Other AQRVs may also be sensitive and at risk from air pollution.

Surface waters in BLCA are generally well-buffered because of adequate amounts of cations, such as calcium and magnesium, and, therefore, not likely to be acidified by atmospheric deposition.

Most soils are also likely to be well-buffered from acidification. However, there may be areas in the park where rock is resistant to weathering, where cation concentrations are low, and soils and water (e.g., in potholes) may be sensitive to inputs of acidic deposition (NPS-ARD 2006a).

3.2.2 Visibility

In 2008, based on data from the Weminuche Wilderness site in the San Juan National Forest, the average light extinction for the 20% clearest days was 3.95 inverse megameters (Mm^{-1}) and, for the 20% haziest days, 22.89 Mm^{-1} for BLCA and CURE. Light-extinction trends for the 20% clearest days decreased significantly (increasing air quality) based on three-year running averages from 1999 to 2008 (slope = –0.14, $p < 0.01$), but no trend has been shown for the 20% haziest days (slope = –0.06, $p = 0.38$) (Figure 3-4).

Visibility impairment largely results from small particles in the atmosphere. Figure 3-5 shows the contributions made by different classes of particles toward haze. On the 20% best days (the bottom 20% of the distribution by deciview, or haze index), ammonium sulfate made the largest contribution toward visibility impairment. Ammonium sulfate is derived primarily from sulfur dioxide emitted from coal-fired power plants. On the 20% worst days (the top 20% of the distribution by deciview), fine organic carbon made the largest contribution toward haze, likely a result of fire, which is often the source of organic particles in the West. Some seasonal patterns in haze composition were evident at BLCA/CURE in 2008 (Figure 3-6), with highest haze occurring in the late spring.

Average visibility was estimated to be 3.4 dv at BLCA and 3.3 at CURE, based on interpolated averages from 2004 to 2008, and estimated to be in moderate condition (see Table 2-3). The park is often impaired by light-scattering pollutants (haze) (NPS-ARD 2006a). BLCA and CURE are currently meeting their 2009 GPRA goal for visibility because they have had improving visibility on clear days, and visibility on the haziest days has shown no degrading trends.

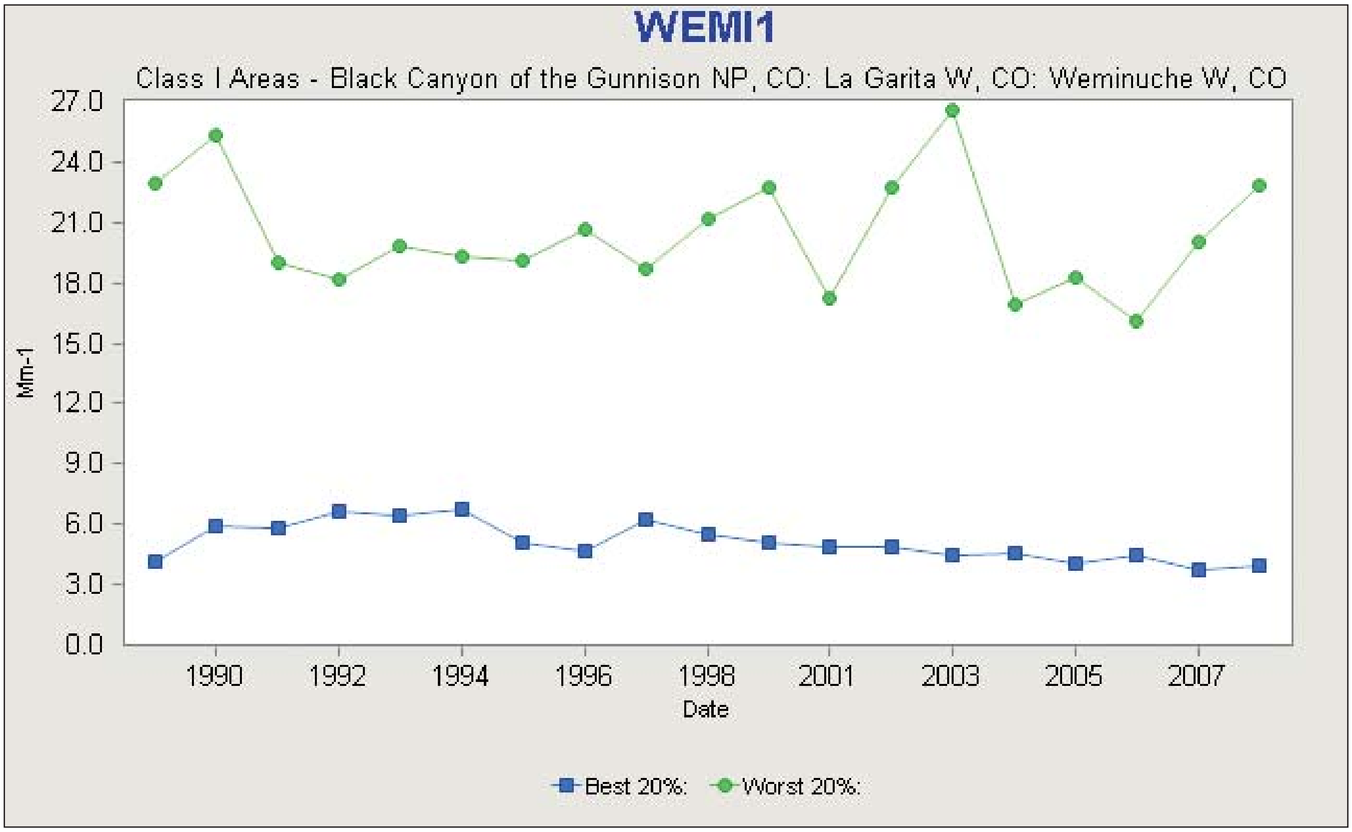


Figure 3-4. Trends in aerosol light extinction on the 20% best (clearest) days and 20% worst (haziest) days at the Weminuche Wilderness Area, San Juan National Forest, used to represent conditions at Black Canyon of the Gunnison National Park and Curecanti National Recreation Area (VIEWS 2010).

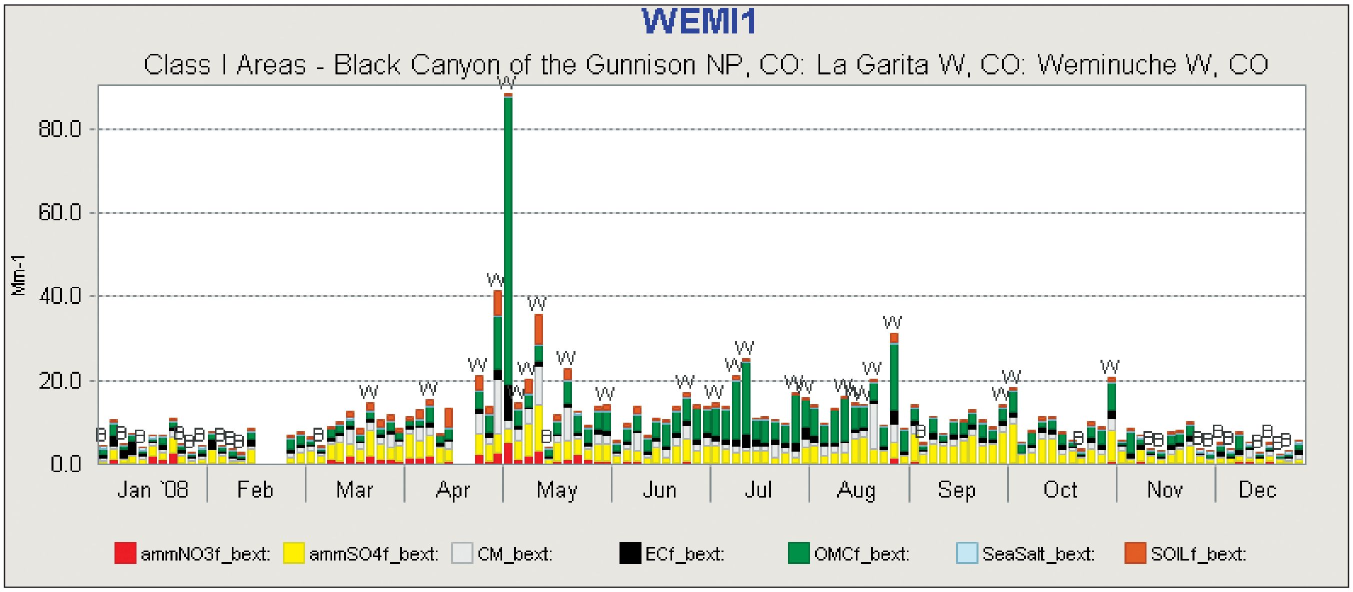


Figure 3-5. Composition of fine particles at the Weminuche Wilderness Area, San Juan National Forest, in 2008, used to represent conditions at Black Canyon of the Gunnison National Park and Curecanti National Recreation Area (VIEWS 2010). Legends refer to B extinction rates related to the following: ammno3f_bext = ammonium nitrate; ammso4f_bext = ammonium sulfate; cm_bext = coarse mass (particles 2.5–10 microns in size); ecf_bext = particles <2/5 microns in size (soot, black carbon); omncf = fine organic mass from carbon; sea salt_bext = sea salt; and soilf_bext = fine soil.

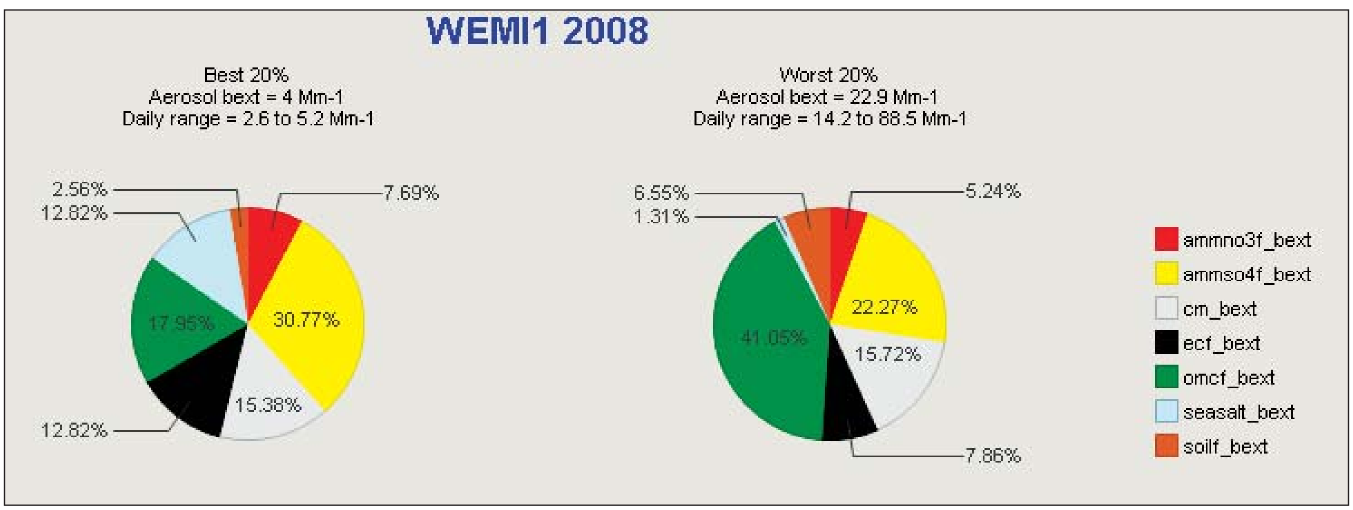


Figure 3-6. Seasonal patterns in haze composition at the Weminuche Wilderness Area, San Juan National Forest, in 2008, used to represent conditions at Black Canyon of the Gunnison National Park and Curecanti National Recreation Area (VIEWS 2010). Legends refer to B extinction rates related to the following: ammno3f_bext = ammonium nitrate; ammso4f_bext = ammonium sulfate; cm_bext = coarse mass (particles 2.5–10 microns in size); ecf_bext = particles <2/5 microns

3.3 Bryce Canyon National Park and Cedar Breaks National Monument

The EPA has determined that particulate (visibility) monitors within 100 km (60 miles) may be reasonably used to characterize a park's visibility conditions; therefore, visibility conditions at CEBR can be estimated from the IMPROVE visibility monitor in BRCA. Because ozone and atmospheric deposition are likely to vary more over distance than visibility, the NPS-ARD only uses monitors within 16 km (10 miles) of a park to characterize ozone and deposition conditions, so those parameters cannot be extrapolated from BRCA to CEBR.

3.3.1 Class I park overview

Bryce Canyon National Park was designated a Class I air quality area in 1977, receiving the highest protection under the Clean Air Act. Both local and distant air pollutant sources affect air quality in Bryce Canyon NP. Nearby large point sources include power plants, refineries, and lime kilns in Coconino County, Arizona, and Clark County, Nevada. Pollutants also travel greater distances to the park from both mobile and point sources throughout the Southwest (NPS-ARD 2006b).

Surface waters in BRCA are expected to be generally well-buffered because of adequate amounts of cations, such as calcium and magnesium, and, therefore, not likely to be acidified by atmospheric deposition. However, there may be areas in the park where rock is resistant to weathering, where cation concentrations are low, and soils and water (e.g., in potholes) may be sensitive to inputs of acidic deposition. Soils and vegetation in the park may also be sensitive to nutrient enrichment from nitrogen deposition (NPS-ARD 2006b).

3.3.2 Atmospheric deposition (BRCA only)

Wet deposition at BRCA has been monitored for the past 20 years (1989–2008). Concentrations of nitrate in BRCA have been variable over the past 20 years (slope = –0.13, p = 0.14), but have declined (non-significantly) over the past 10 years (1999–2008) (slope = –0.64, p = 0.05) (Figure 3-7). Sulfates have significantly declined over the past 10 years (slope = –0.51, p = 0.03), and over the 20-year sampling period (slope = –0.42, p = <0.01) (Figure 3-8). Ammonium has increased over the past 20 years (slope = 0.33, p = 0.04), but for the past 10 years, the increase has not been significant (slope = 0.51, p = 0.14) (Figure 3-9). From 1999 to 2008, BRCA had significant declining trends (improving air quality) for sulfates, and no significant trends for nitrates and ammonium concentrations; therefore, the park is currently meeting its 2009 GPRA goal for deposition.

In 2008, nitrate, sulfate, and ammonium deposition were 1.60, 0.80, and 0.59 kg/ha/year, respectively. Five-year averages based on interpolated data from 2004 to 2008 were 1.2 and 0.5 kg/ha/yr for nitrogen and sulfur wet deposition, respectively. Estimates for nitrogen and sulfur at BRCA were higher than natural background deposition levels (0.13 kg/ha for wet deposition) for the overall West. Based on the interpolated five-year averages, BRCA has sulfur levels in good condition, while nitrogen levels are in moderate condition (see Table 2-1). There has been an increase in ammonium in central and northern Utah over the past 10 years, and the levels of nitrates and sulfates at BRCA bear watching as a result.

3.3.3 Visibility

In 2008, the average light extinction for the 20% clearest days was 3.35 Mm^{-1} and, for the 20% haziest days, 22.26 Mm^{-1} for BRCA and CEBR. Light-extinction trends for the 20% clearest days decreased significantly (increasing air quality) based on three-year running averages from 1999 to 2008 (slope = –0.16, p < 0.01) and for the entire data set at BRCA from 1990 to 2008 (slope = –0.10, p = <0.01), but light extinction showed no trend for the 20% haziest days for the past 10 years (slope = 0.00, p = 0.50) or for the past 20 years (slope = 0.03, p = 0.11) (Figure 3-10).

Visibility impairment largely results from small particles in the atmosphere. Figure 3-11 shows the contributions made by different classes of particles toward haze. On days with best visibility (the bottom 20% of the distribution by deciview, or haze index), most haze was caused by ammonium sulfate, followed by fine organic carbon mass and ammonium nitrate. On the worst days (the top 20% of the distribution by deciview), most haze was caused by fine organic carbon mass, followed by ammonium sulfate and coarse mass (2.5–10 microns in size). Ammonium sulfate is derived primarily from sulfur dioxide emitted from coal-fired power plants. Most fine organic carbon mass comes from forest fires, which usually occur in the summer. As such, some seasonal patterns in haze composition were evident at BRCA in 2008 (Figure 3-12), with highest haze occurring in the summer and spring months. Average visibility was estimated to be 3.9 deciviews at BRCA and CEBR based on interpolated values.

A camera is used at the BRCA IMPROVE monitoring site as an additional visibility monitoring tool. The acquired photographs provide images representing the range of visibility conditions at each site. Photography began in 1984 at BRCA but was suspended in 1996, then resumed at Yovimpa Point in 2009. These pictures can be downloaded, as available, from http://vista.cira.colostate.edu/improve/Data/IMPROVE/Data_IMPRPhot.htm, and will be integrated into next year's report, when the 2009 IMPROVE light extinction and composition data are analyzed.

At present, visibility has been identified as the most sensitive AQRV in BRCA; other AQRVs may also be sensitive, but have not been sufficiently studied. Although visibility in the park is still superior to that in many parts of the country, it is estimated to be in moderate condition at BRCA and CEBR (see Table 2-3), as both parks are often impaired by light-scattering pollutants (haze) (NPS-ARD 2006b). Visibility on the clearest days has improved, and visibility on the haziest days has had no degrading trends. Therefore, BRCA and CEBR are currently meeting their 2009 GPRA goal for visibility.

Figure 3-7. Trend lines (composed of a three-year, centered, weighted, moving average value) for concentrations of nitrate in wet deposition at Bryce Canyon National Park, 1985–2009 (NADP 2010).

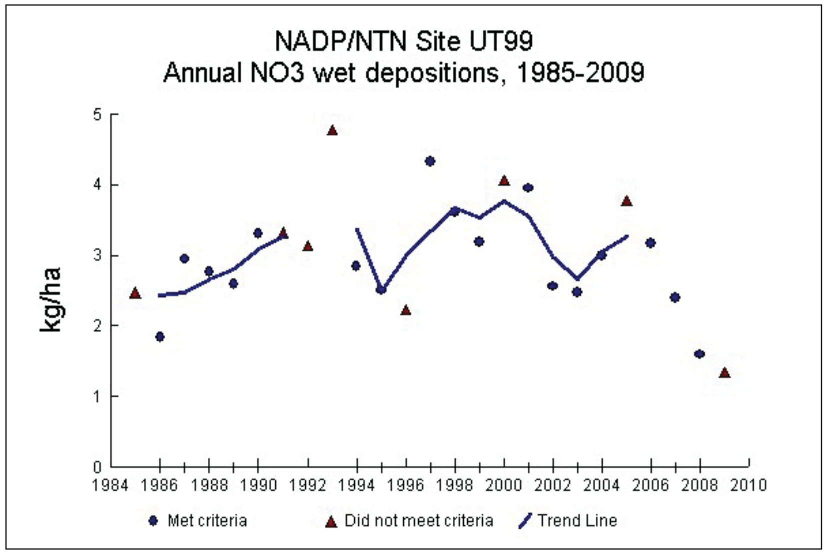


Figure 3-8. Trend lines (composed of a three-year, centered, weighted, moving average value) for concentrations of sulfate in wet deposition at Bryce Canyon National Park, 1985–2009 (NADP 2010).

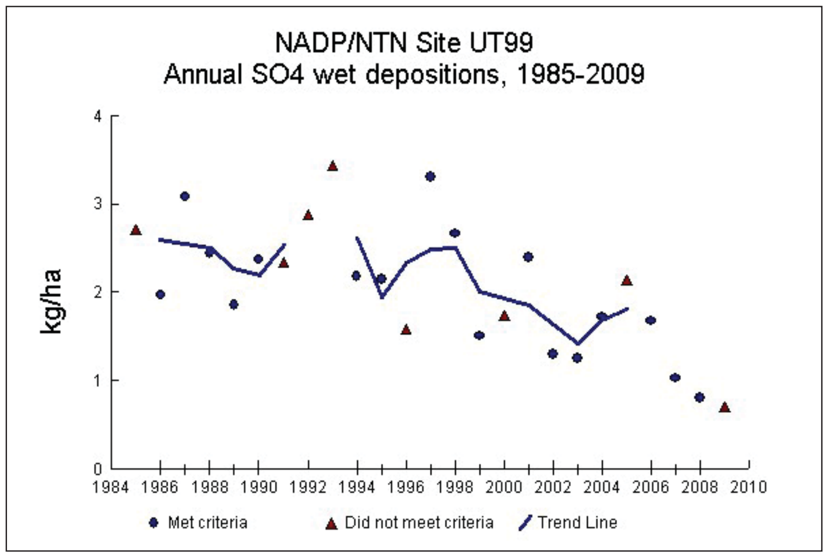
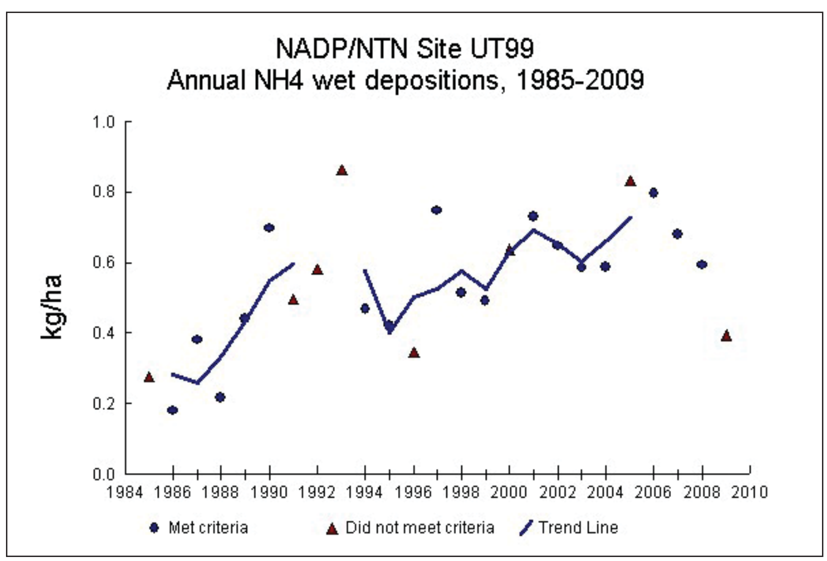


Figure 3-9. Trend lines (composed of a three-year, centered, weighted, moving average value) for concentrations of ammonium in wet deposition at Bryce Canyon National Park, 1985–2009 (NADP 2010).



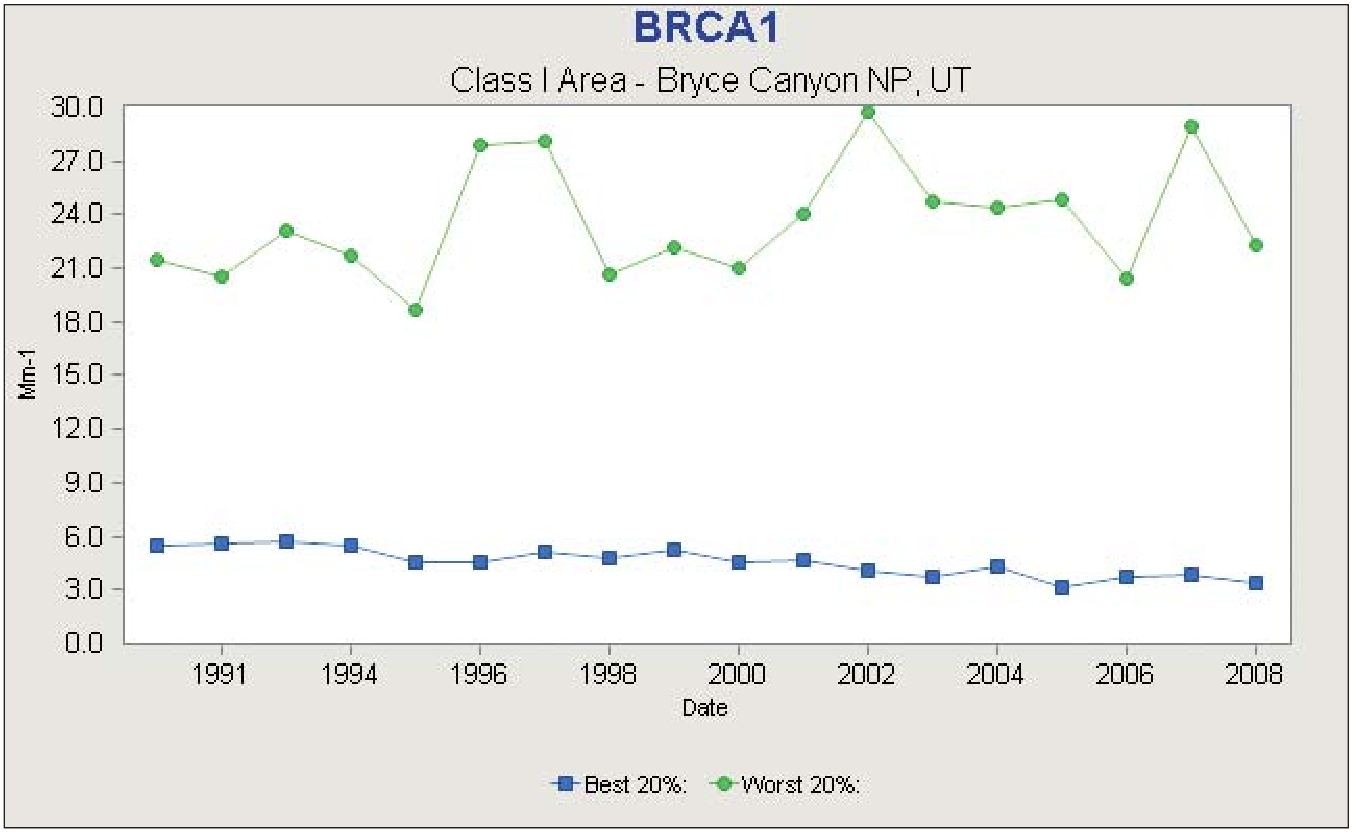


Figure 3-10. Trends in aerosol light extinction on the 20% best (clearest) days and 20% worst (haziest) days at Bryce Canyon National Park, 1990–2008 (VIEWS 2010).

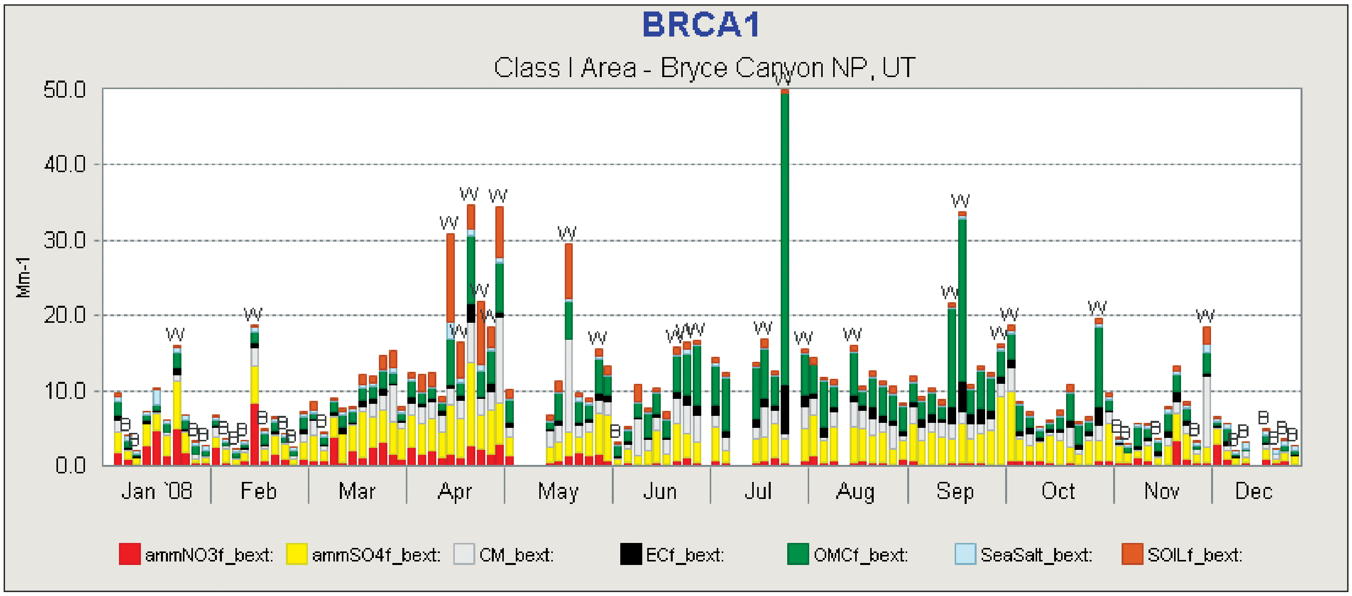


Figure 3-11. Composition of fine particles in Bryce Canyon National Park, 2008 (VIEWS 2010). Legends refer to B extinction rates related to the following: ammno3f_bext = ammonium nitrate; ammso4f_bext = ammonium sulfate; cm_bext = coarse mass (particles 2.5–10 microns in size); ecf_bext = particles <2/5 microns in size (soot, black carbon); omncf = fine organic mass from carbon; sea salt_bext = sea salt; and soilf_bext = fine soil.

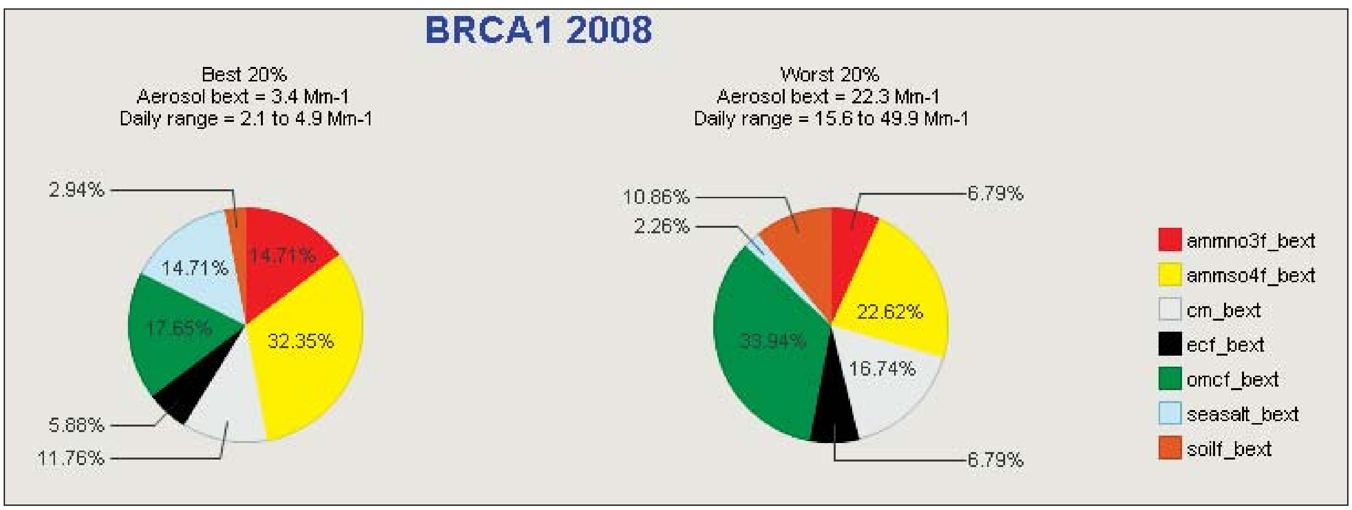


Figure 3-12. Seasonal patterns in haze composition at Bryce Canyon National Park, 2008 (VIEWS 2010). Legends refer to B extinction rates related to the following: ammno3f_bext = ammonium nitrate; ammso4f_bext = ammonium sulfate; cm_bext = coarse mass (particles 2.5–10 microns in size); ecf_bext = particles <2/5 microns in size (soot, black carbon); omncf = fine organic mass from carbon; sea salt_bext = sea salt; and soilf_bext = fine soil.

3.4 Canyonlands National Park, Arches National Park, and Natural Bridges National Monument

The EPA has determined that particulate (visibility) monitors within 100 km (60 miles) may be reasonably used to characterize a park's visibility conditions; therefore, visibility conditions at ARCH and NABR can be estimated from the IMPROVE visibility monitor in CANY. Because ozone and atmospheric deposition are likely to vary more over distance than visibility, the NPS-ARD only uses monitors within 16 km (10 miles) of a park to characterize ozone and deposition conditions, so those parameters cannot be extrapolated from CANY to ARCH and NABR.

3.4.1 Class I parks overview

Arches and Canyonlands national parks were designated Class I air quality areas in 1977, receiving the highest protection under the Clean Air Act. Both local and distant air-pollutant sources affect air quality in ARCH and CANY. Power plants in Emery, Uintah, and Carbon counties, Utah, and Mesa County, Colorado, are the largest nearby point sources of both SO_2 and NOx. Pollutants also travel greater distances to the parks from both mobile and point sources throughout the Southwest (NPS-ARD 2006c).

Surface waters in ARCH and CANY are generally well-buffered because of adequate amounts of cations, such as calcium and magnesium; therefore, they are not likely to be acidified by atmospheric deposition. Most soils are also likely to be well-buffered from acidification. However, there may be areas in the park where rock is resistant to weathering, where cation concentrations are low, and soils and water (e.g., in potholes) may be sensitive to inputs of acidic deposition. There is concern that soils and vegetation in the park may be sensitive to nutrient enrichment from nitrogen deposition. Studies are underway in CANY to investigate nitrogen effects on soil dynamics, susceptibility to exotic plant invasion, and biological soil crusts (NPS-ARD 2006c).

3.4.2 Atmospheric deposition (CANY only)

3.4.2.1 Wet deposition

Wet deposition has been monitored at CANY for the past 20 years (1989–2008). Concentrations of nitrate and sulfate showed no trends in CANY from 1999 to 2008 (nitrate: slope = –0.28, p = 0.38; sulfate: slope = –0.07, p = 0.38) (Figures 3-13, 3-14) or for the entire 20-year data set (nitrate: slope = 0.05, p = 0.43; sulfate: slope = –0.05, p = 0.36). However, ammonium has had an increasing but non-significant trend over the last ten years (slope = 0.58, p = 0.09) (Figure 3-15) and an increasing significant trend over the entire 20 years (slope = 0.64, p = 0.02). There has been a noted increase in ammonium in central and northern Utah. In 2008, nitrate, sulfate, and ammonium concentrations were 2.64, 1.29, and 0.56 kg/ha/year, respectively. Five-year averages based on interpolated data from 2004 to 2008 were 0.9 and 0.4 for nitrogen and sulfur, respectively, and were rated as being in good condition. CANY was one of only five (out of 89) NPS units nationwide rated as being in good condition (NPS-ARD in press). Estimates for both nitrogen and sulfur in CANY were higher than natural background deposition levels (0.13 kg/ha for wet deposition) for the West. It is disturbing that ammonium has seen increasing (although not significant) trends over the past 10 years. CANY is currently meeting its 2009 GPRA goal for wet deposition because there were no significant degrading trends for nitrates, ammonium, or sulfates.

3.4.2.2 Dry deposition

CASTNet reports trends in dry and total deposition for Canyonlands National Park. Figure 3-16 summarizes wet and dry (total) nitrogen and sulfur deposition from 1995 to 2008 in CANY. The amounts of N and S in 2008 were the second- and third-lowest, respectively, for the 14-year record for these stations.

Figure 3-17 depicts the composition of nitrogen and sulfur deposition at CANY during 2006–2008. Figure 3-18 depicts overall contributions of wet and dry deposition from 1995 to 2008. Although these estimates suggest that wet deposition exceeded dry deposition, the CASTNet method may underestimate dry deposition. Nitrate and ammonium contributed almost equally in total nitrogen deposition at the site.

3.4.3 Ozone (CANY only)

Ozone summary data from continuous samplers at CANY are provided in Table 3-1. CANY had no days that exceeded the eight-hour average of 75 ppb in 2008 (Ray 2009). The fourth-highest eight-hour ozone concentration for CANY was 71 ppb in 2008. The five-year average (2004–2008) of the fourth-highest daily eight-hour ozone concentration based on interpolated values was 70.1 ppb. Since data collection began in 1993, CANY has only had one year in which the fourth-highest average exceeded 75 ppb (2000; 76 ppb), and no three-year averages have exceeded the 75-ppb threshold. In January 2010, the EPA proposed to lower the primary standard from 75 ppb to a level within the range of 60–70 ppb (Federal Register 2010). Canyonlands NP would exceed a standard of 60–70 ppb.

The fourth-highest eight-hour average showed no significant trends for the past 10 years (slope = –0.25, p = 0.19) (NPS-ARD in press) or for the entire sampling period (slope = 0.32, p = 0.18) (Figure 3-19). However, while they are currently not used as GPRA goals (i.e., no 10-year periods were tested for trends), the SUM06 for annual maximum three-month period (Figure 3-20) and cumulative sum W126 for annual maximum three-month period (Figure 3-21) both had increasing (degrading air quality) trends from 1993 to 2008. None of these measurements showed a strong linear trend. The SUM06 and W126 indices exceeded the thresholds at which damage can occur to trees and plants (Table 2-3).

Ozone levels based on interpolated values at CANY (70.1 ppb) are rated as being in moderate condition (61–75 ppb; see Table 2-2). Because the NPS-ARD's ozone risk assessment for CANY concluded that vegetation in the park was considered at low risk from ozone injury (NPS 2004), there is no reason to adjust the moderate rating for CANY. CANY is currently meeting its 2009 GPRA goal for ozone due to the lack of significant trends in the fourth highest eight-hour average.

3.4.4 Visibility

In 2008, the average light extinction for the 20% clearest days at CANY was 4.64 Mm^{-1} and, for the 20% haziest days, 23.04 Mm^{-1}. Light-extinction trends for 20% clearest days decreased significantly (improved in air quality) based on three-year averages from 1999 to 2008 (slope = –0.20, p <0.01), but showed no trend for the 20% haziest days (slope = –0.07, p = 0.36) (Figure 3.22). However, when the three-year averages are tested for the entire data set at CANY from 1990 to 2008, light-extinction trends decreased significantly for both the 20% clearest days (slope = –0.16, p = <0.01) and the 20% haziest days (slope = –0.10, p = <0.01).

Visibility impairment largely results from small particles in the atmosphere. Figure 3-23 shows the contributions made by different classes of particles toward haze. On days with best visibility (the bottom 20% of the distribution by deciview, or haze index), most haze was caused by ammonium sulfate, followed by fine organic mass and ammonium nitrate. On the worst days (the top 20% of the distribution by deciview), coarse mass (2.5–10 microns in size) contributed most to haze, but ammonium sulfate and fine organic mass were also significant contributors. Ammonium sulfate is derived primarily from sulfur dioxide emitted from coal-fired power plants. Some seasonal patterns were evident in haze composition at CANY in 2008. The highest haze composition levels occurred in the spring, with increases in coarse mass and fine soil, likely from spring dust storms. Based on interpolated values, average visibil-

Table 3-1. Ozone concentrations (parts per billion-ppb) and exposure indices summaries for Canyonlands National Park, 2008.

Site code	Number of days with 8-hr average O_3 values at >75 ppb[a]	1st-highest 8-hr concentrations	2nd-highest 1-hr concentrations	4th-highest 8-hr concentrations	SUM06 (ppm-hr)[b]	W126 (ppm-hr)[c]
CANY-IS	0	75	73	71	22	16

(Ray 2008)

[a]The National Ambient Air Quality Standard for ozone was 85 ppb until March 2008, based on the three-year average of the fourth-highest daily maximum 8-hour average ozone concentration. In March 2008, the primary standard was lowered to 75 ppb.

[b]SUM06 exposure index represents the 0800-2000 hourly ozone concentrations ≥ 0.06 ppm. The value reported here represents a three-month maximum value during the ozone season. Units are ppm-hr.

[c]W126 exposure index represents the sum of all hourly ozone concentrations where each concentration is weighted by a function that gives greater emphasis to the higher hourly concentrations while still including the lower ones. Units are ppm-hr. For more information on the W126 exposure index go to http://www.nature.nps.gov/air/maps/airatlas/docs/air_quality_glossary.pdf.

ity was estimated to be 3.8 deciviews for CANY, 3.7 deciviews for ARCH, and 3.9 deciviews for NABR, and is rated as being in moderate condition for these three parks.

At present, visibility has been identified as the most sensitive AQRV in ARCH and CANY; other AQRVs may also be sensitive, but have not been sufficiently studied. Although visibility in southeast Utah is still superior to that in many parts of the country on clear days, visibility is rated as moderate at ARCH, CANY, and NABR (see Table 2-3), and is often impaired by light-scattering pollutants (haze) (NPS-ARD 2006c). Visibility on the clearest days has improved at CANY, and has shown no trends on the haziest days. Therefore, ARCH, CANY, and NABR are currently meeting their 2009 GPRA goal for visibility.

Figure 3-13. Trend lines (composed of a three-year, centered, weighted, moving average value) for concentrations of nitrate in wet deposition at Canyonlands National Park, 1997–2009 (NADP 2010).

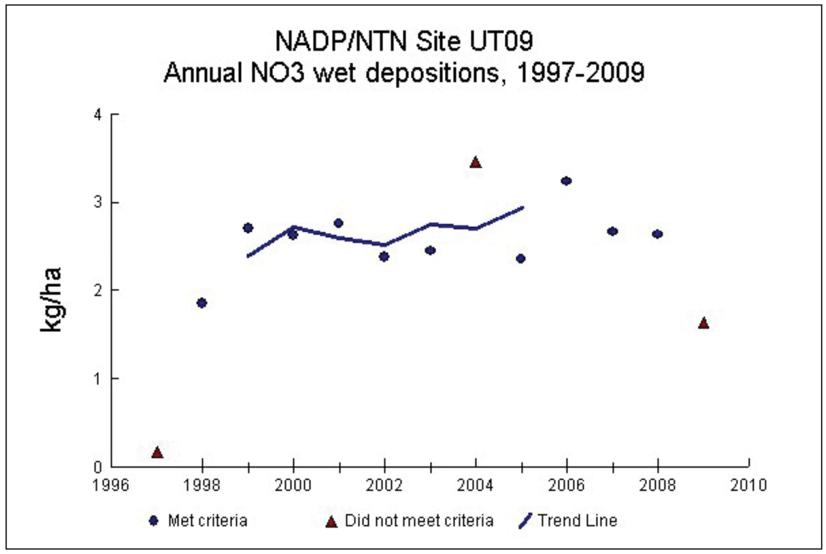


Figure 3-14. Trend lines (composed of a three-year, centered, weighted, moving average value) for concentrations of sulfate in wet deposition at Canyonlands National Park, 1997–2009 (NADP 2010).

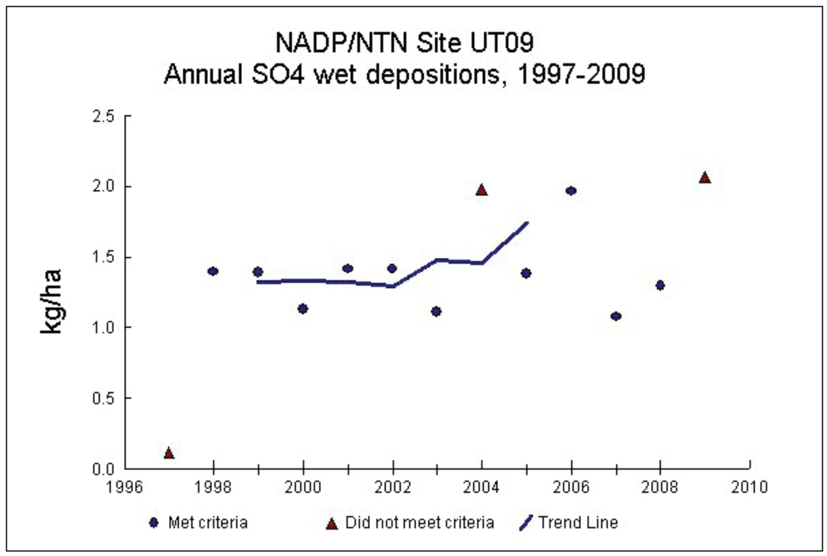
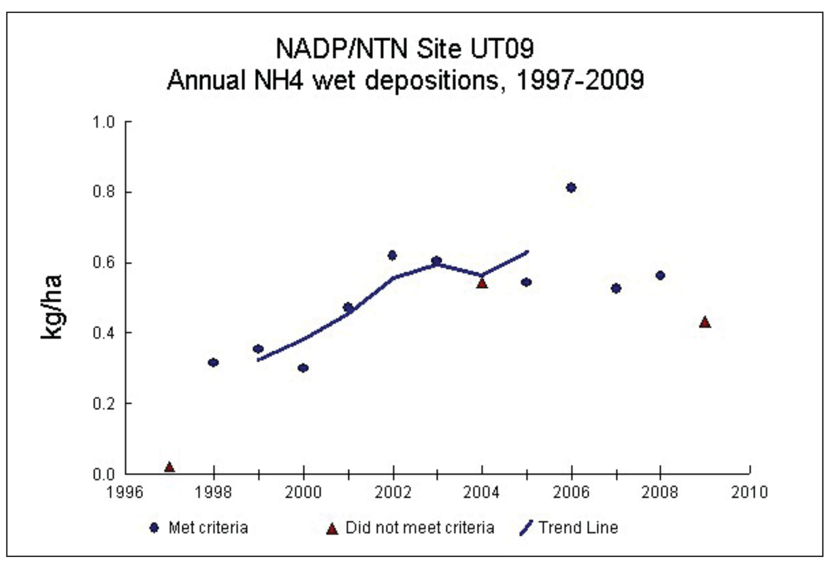
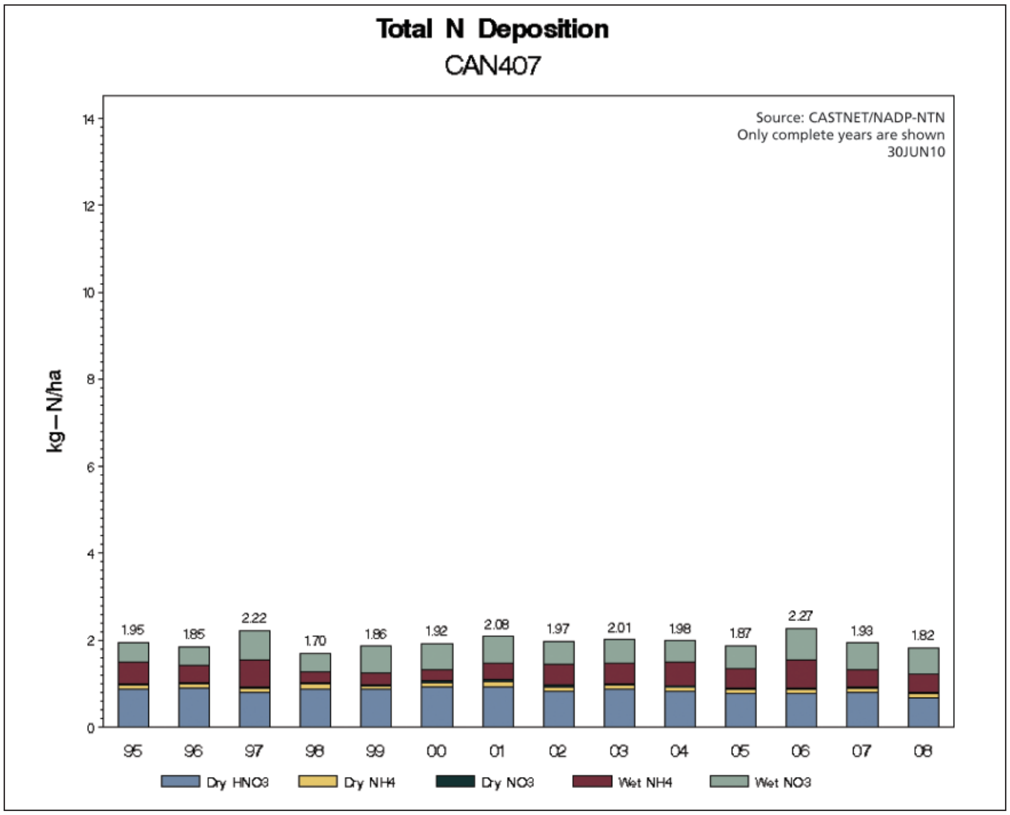


Figure 3-15. Trend lines (composed of a three-year, centered, weighted, moving average value) for concentrations of ammonium in wet deposition at Canyonlands National Park, 1997–2009 (NADP 2010).





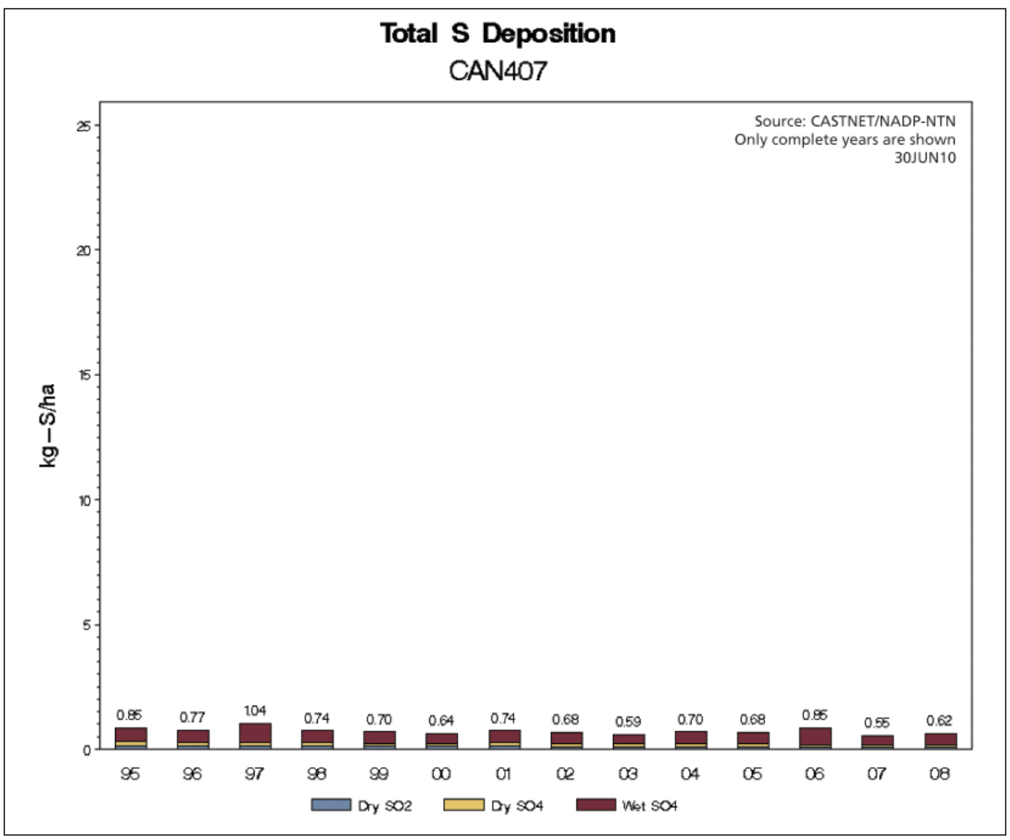
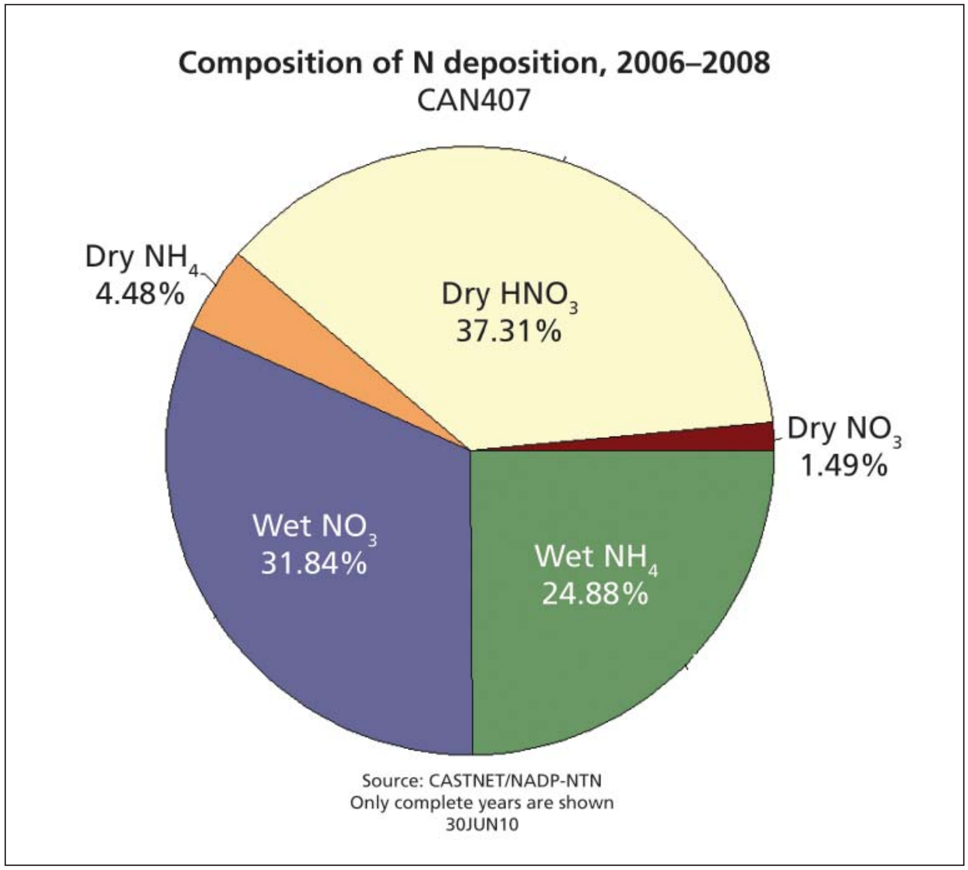
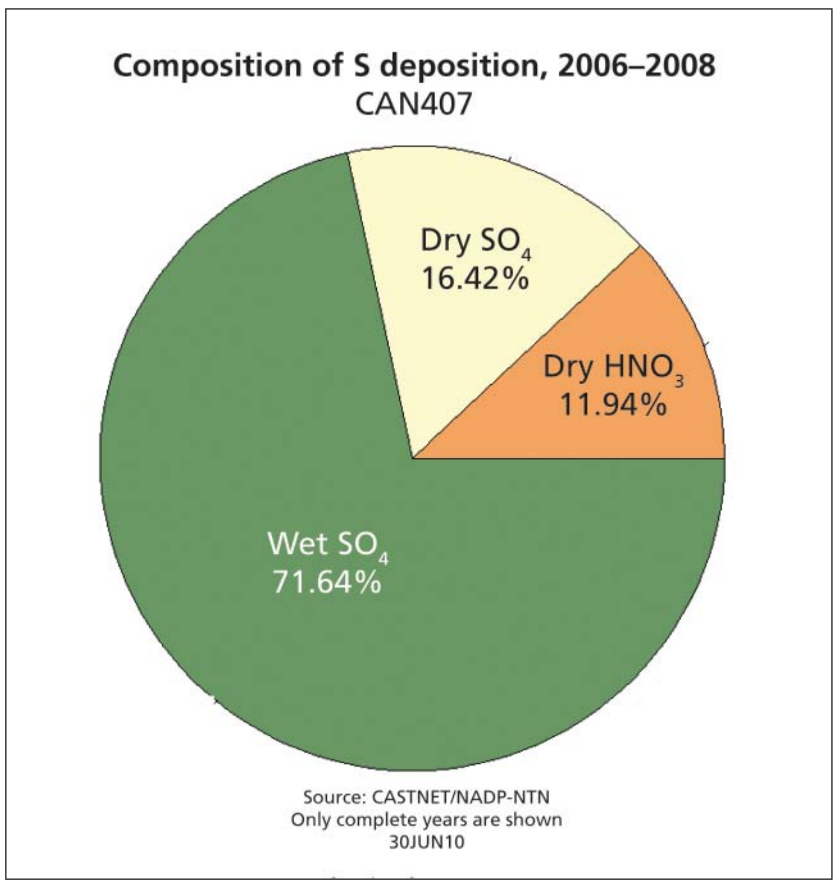
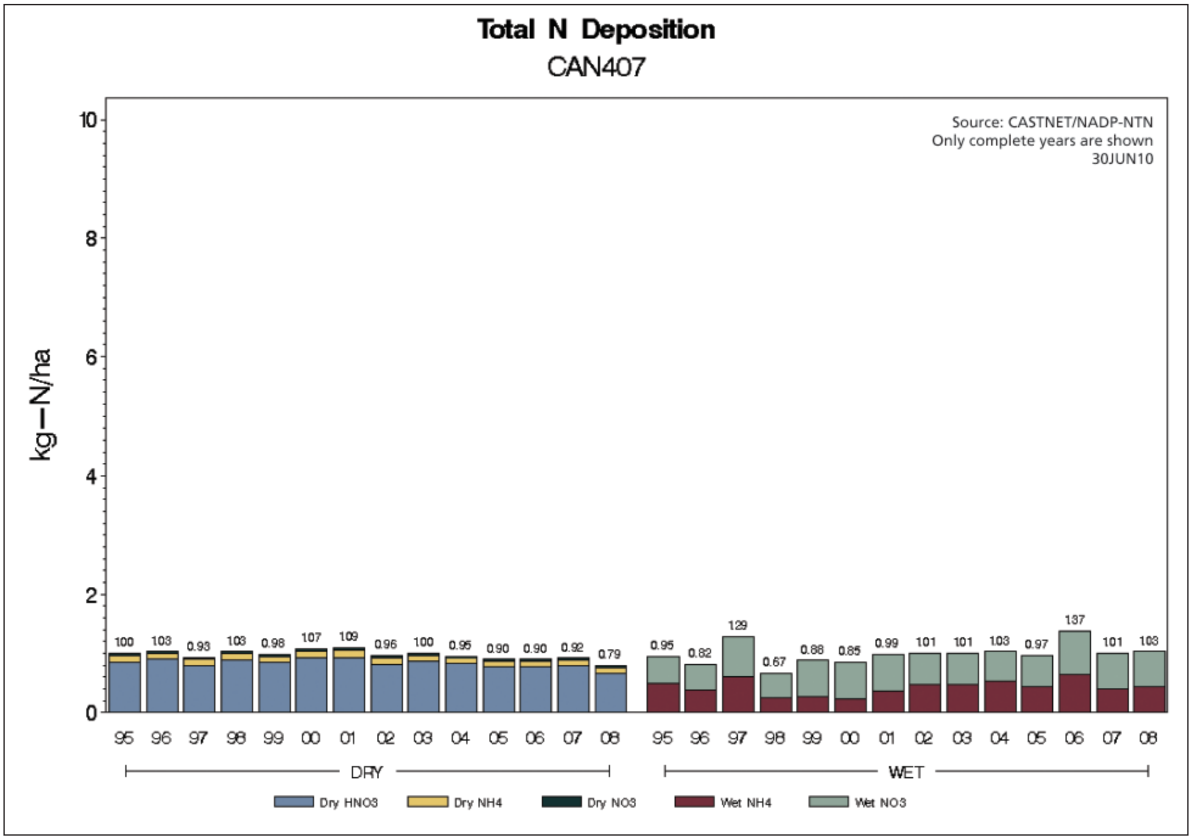


Figure 3-16. Trends in total nitrogen and sulfur deposition at Canyonlands National Park, 1995–2008 (CASTNET 2010).

Figure 3-17. Contributions of wet and dry chemical species in total deposition at Canyonlands National Park, 2006–2008 (CASTNET 2010).







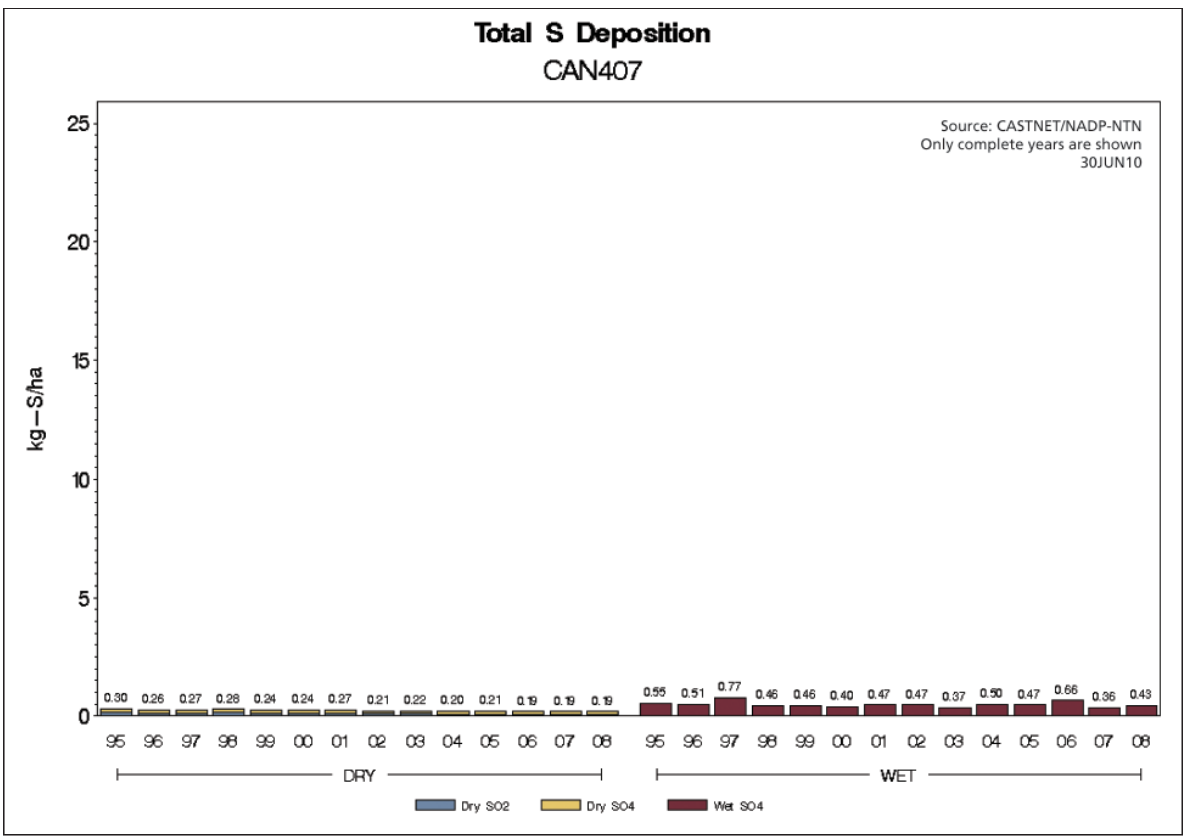


Figure 3-18. Wet and dry deposition of nitrogen and sulfur at Canyonlands National Park, 1995–2008 (CASTNET 2010).

Figure 3-19. Fifteen-year trend, annual fourth-highest daily maximum eight-hour ozone concentration, Canyonlands National Park.

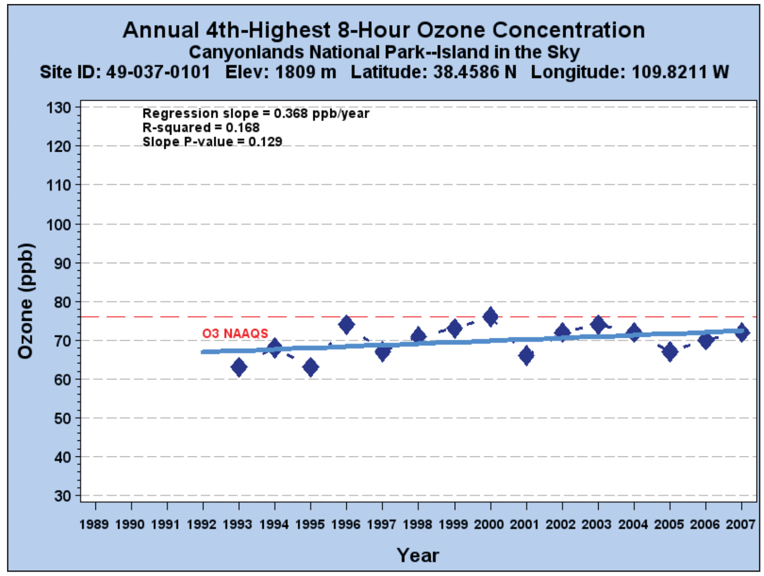


Figure 3-20. Fifteen-year trend, SUM06 for annual maximum three-month period, daytime hours, Canyonlands National Park.

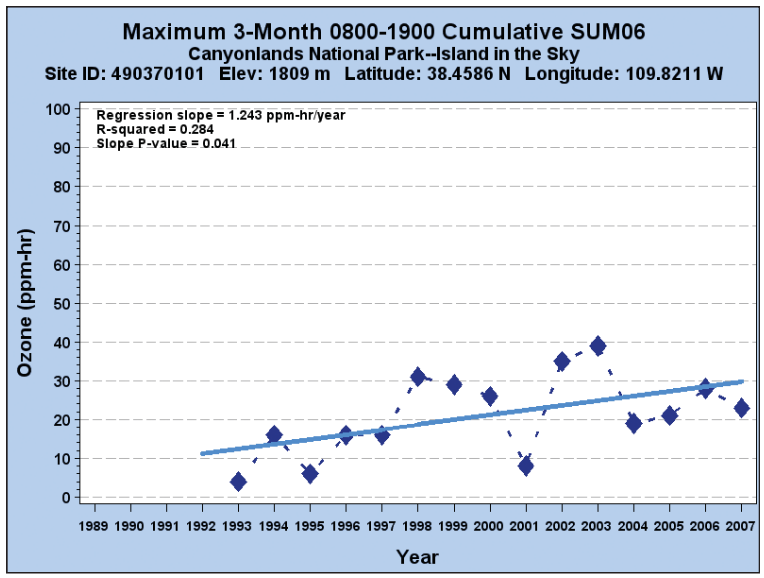
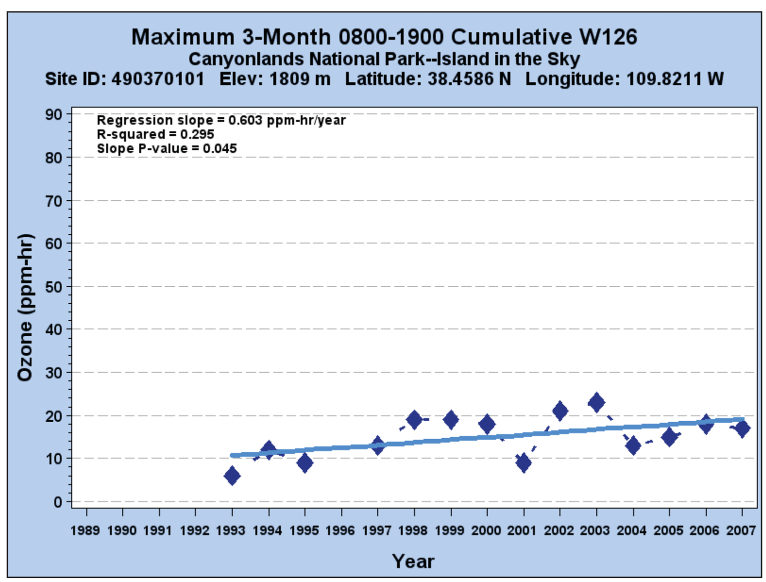


Figure 3-21. Fifteen-year trend, cumulative sum W126 for annual maximum three-month period, daytime hours, Canyonlands National Park.



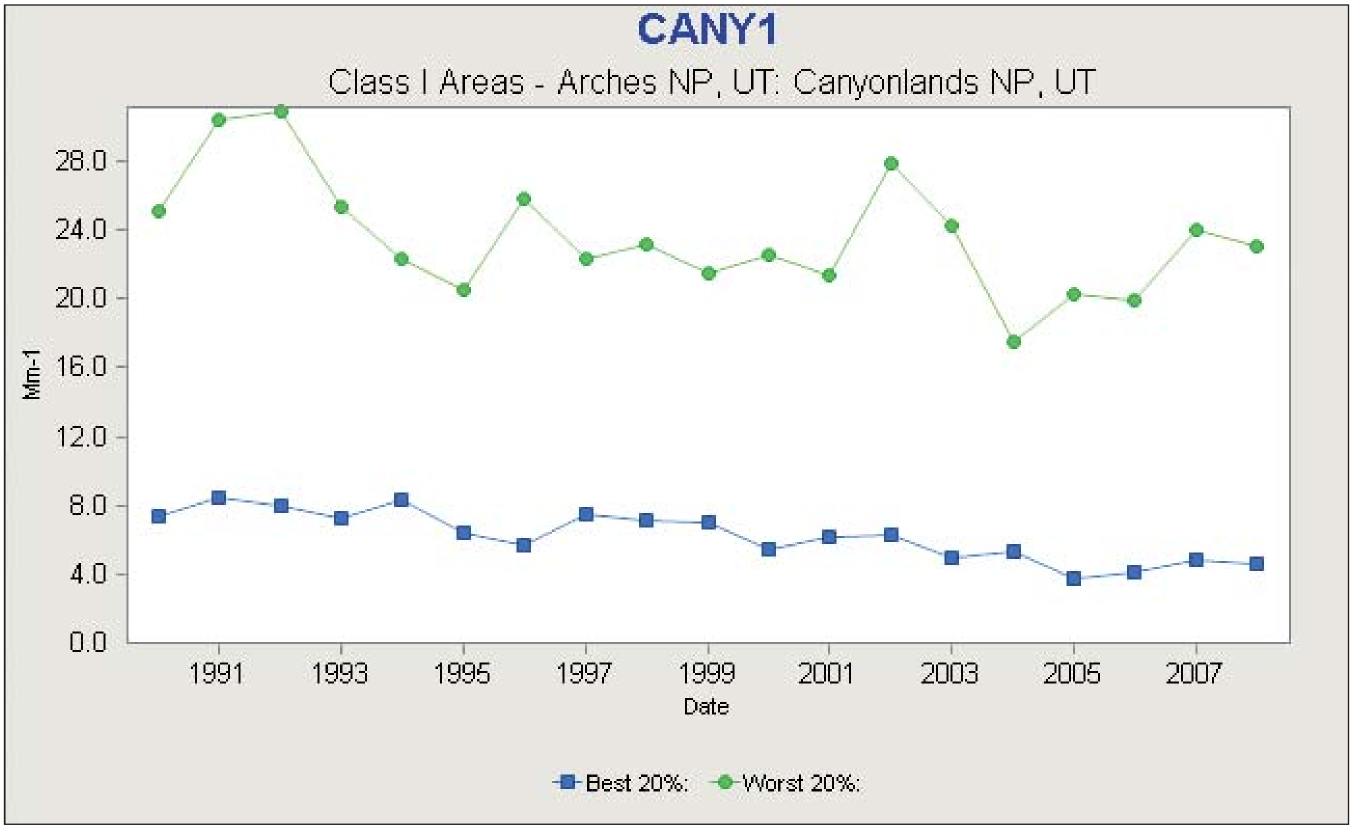


Figure 3-22. Trends in aerosol light extinction on the 20% best (clearest) days and 20% worst (haziest) days at Canyonlands National Park, 1990–2008 (VIEWS 2010).

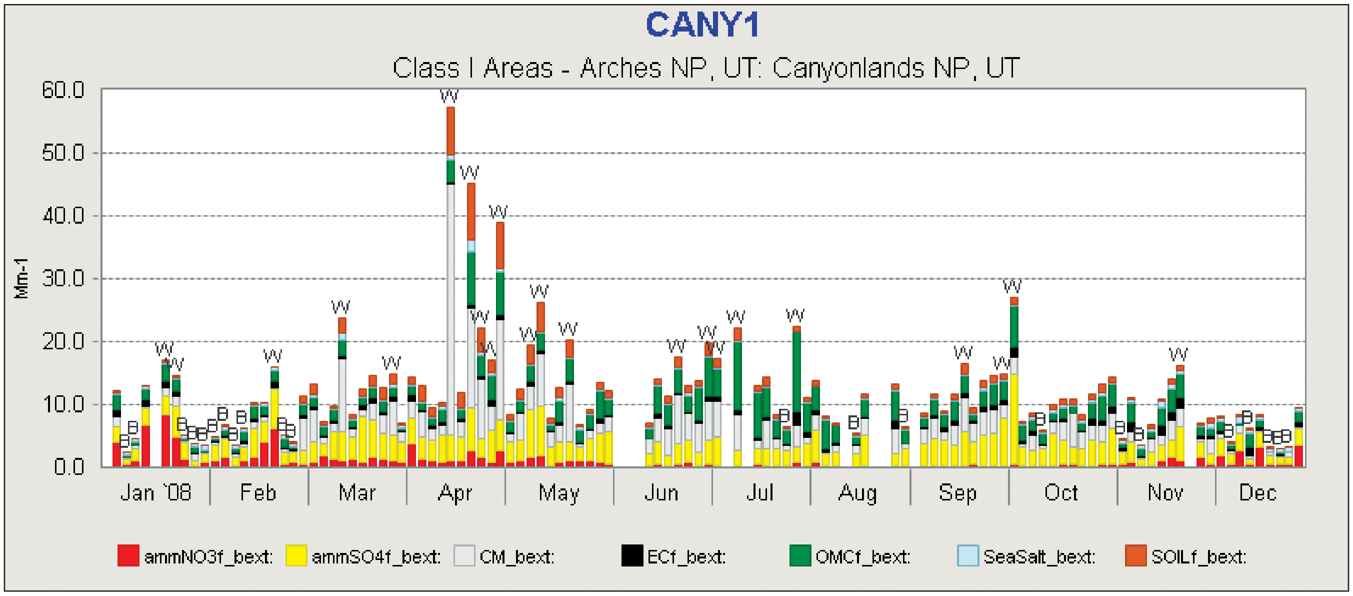


Figure 3-23. Composition of fine particles in Canyonlands National Park, 2008 (VIEWS 2010). Legends refer to B extinction rates related to the following: ammno3f_bext = ammonium nitrate; ammso4f_bext = ammonium sulfate; cm_bext = coarse mass (particles 2.5–10 microns in size); ecf_bext = particles <2/5 microns in size (soot, black carbon); omncf = fine organic mass from carbon; sea salt_bext = sea salt; and soilf_bext = fine soil.

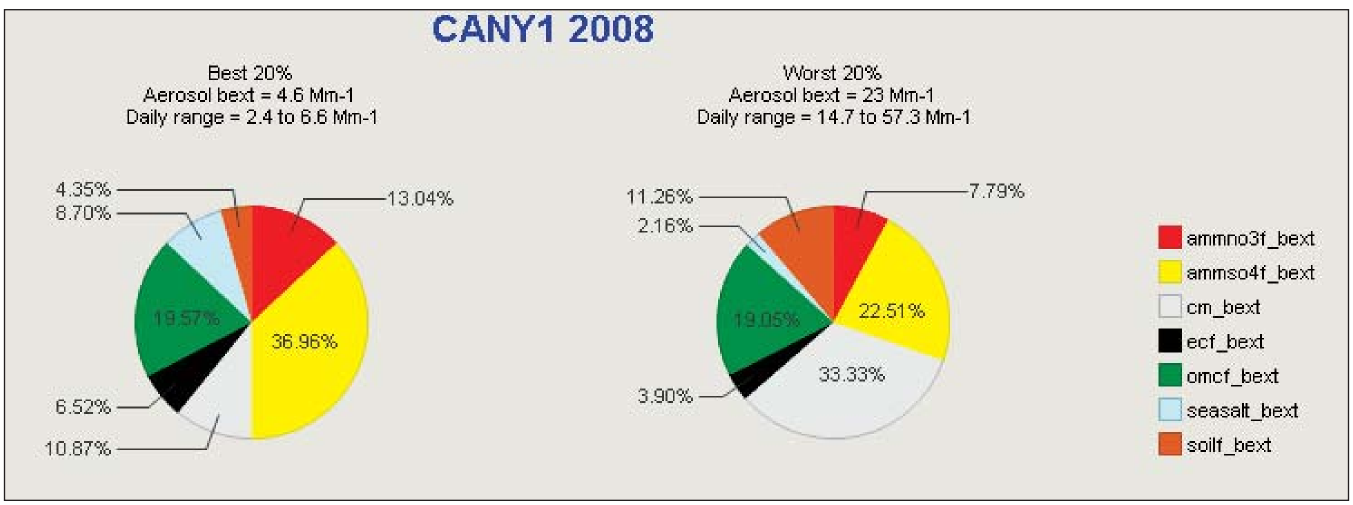


Figure 3-24. Seasonal patterns in haze composition at Canyonlands National Park, 2008 (VIEWS 2010). Legends refer to B extinction rates related to the following: ammno3f_bext = ammonium nitrate; ammso4f_bext = ammonium sulfate; cm_bext = coarse mass (particles 2.5–10 microns in size); ecf_bext = particles <2/5 microns in size (soot, black carbon); omncf = fine organic mass from carbon; sea salt_bext = sea salt; and soilf_bext = fine soil.

3.5 Capitol Reef National Park

3.5.1 Class I park overview

Capitol Reef National Park was designated a Class I air quality area in 1977, receiving the highest protection under the Clean Air Act. Both local and distant air pollutant sources affect air quality in CARE. Nearby large point sources include power plants, refineries, and lime kilns in Coconino County, Arizona, and Clark County, Nevada. Pollutants also travel greater distances to the park from both mobile and point sources throughout the Southwest (NPS-ARD 2006d).

The AQRVs of CARE are those resources that are potentially sensitive to air pollution, including vegetation, wildlife, water quality, soils, and visibility. At present, visibility has been identified as the most sensitive AQRV in the park; other AQRVs may also be sensitive, but have not been sufficiently studied. Although visibility in the park is still superior to that in many parts of the country, it is only rated as being in moderate condition, and visibility in the park is often impaired by light-scattering pollutants (haze) (NPS-ARD 2006d).

While there are no deposition monitoring sites in CARE, surface waters are well-buffered because of adequate amounts of cations, such as calcium and magnesium, and, therefore, not likely to be acidified by atmospheric deposition. Most soils are also likely to be well-buffered from acidification. Soils and vegetation in the park may be sensitive to nutrient enrichment from nitrogen deposition (NPS-ARD 2006d).

3.5.2 Visibility

For CARE, the average light extinction for the 20% clearest days was 4.31 Mm^{-1} and, for the 20% haziest days, 23.48 Mm^{-1} in 2008. Light extinction trends from the CARE site cannot be determined due to the limited amount of data (Figure 3-25). However, the site at BRCA is close enough to examine trends. Based on the BRCA site, light-extinction trends for 20% clearest days decreased significantly based on three-year averages from 1999 to 2008 (slope = –0.16, $p < 0.01$), but showed no trend for the 20% haziest days (slope = 0.00, $p = 0.50$).

Visibility impairment largely results from small particles in the atmosphere. Figure 3-26 shows the contributions made by different classes of particles toward haze. On the 20% clearest days (the bottom 20% of the distribution by deciview, or haze index), ammonium sulfate was the largest contributor to visibility impairment, followed by fine organic carbon mass and ammonium nitrate. Ammonium sulfate is derived primarily from sulfur dioxide emitted from coal-fired power plants. On the 20% haziest days (the top 20% of the distribution by deciview), fine organic carbon mass particles were the largest contributors to haze. This was likely a result of fire, which is often the source of organic particles in the West.

Some seasonal patterns were evident in haze composition at CARE in 2008 (Figure 3-27). The highest haze composition levels occurred in the spring and summer, with additions of fine soil from spring dust storms and fine organic carbon mass—likely from fires. Average visibility for CARE was estimated to be 3.8 deciviews based on interpolated values. This level is deemed in moderate condition (see Table 2-3). Based on the data from the BRCA site, visibility on the clearest days has improved and has shown no trends on the haziest days. Therefore, CARE is currently meeting its 2009 GPRA goal for visibility.

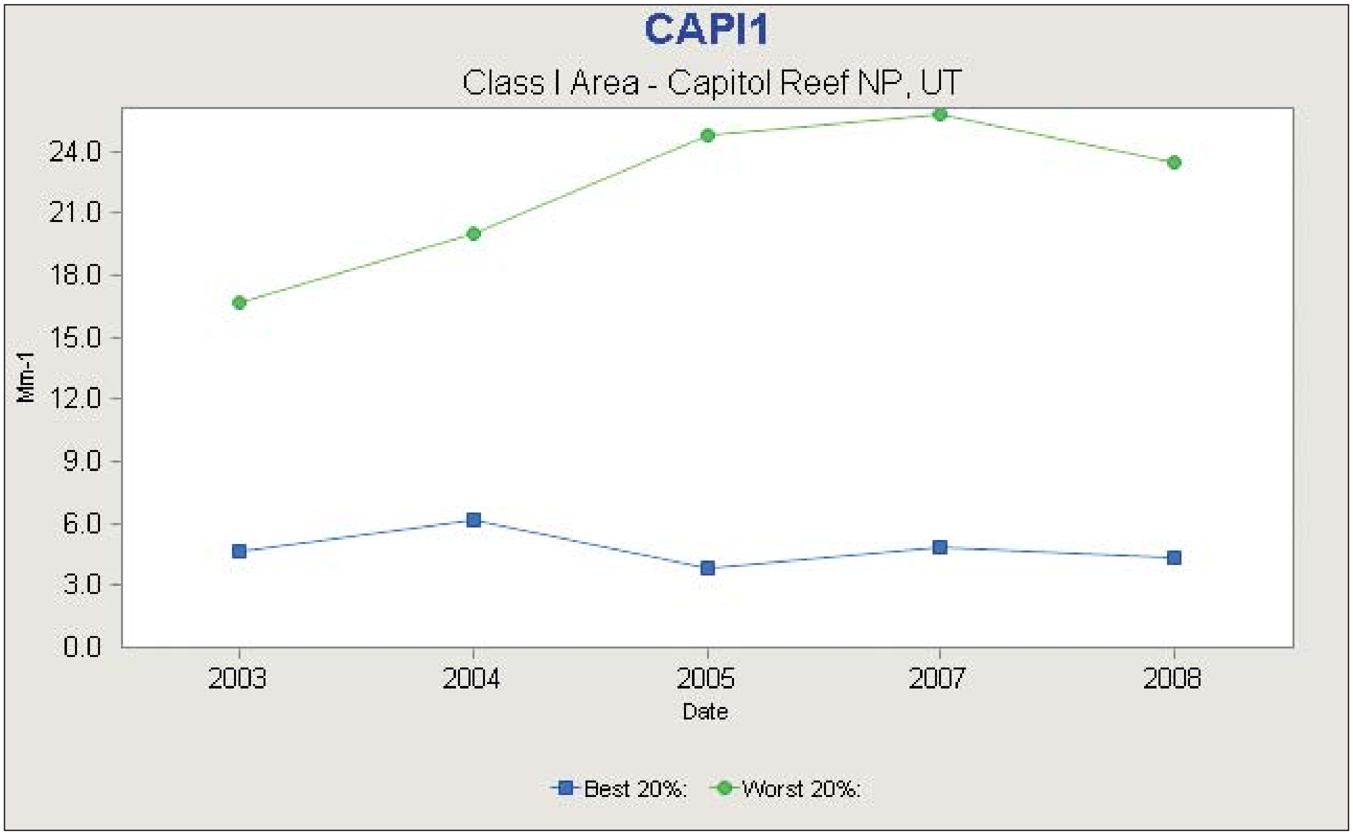


Figure 3-25. Trends in aerosol light extinction in the 20% clearest days and the 20% haziest days at Capitol Reef National Park, 2003–2008 (VIEWS 2010).

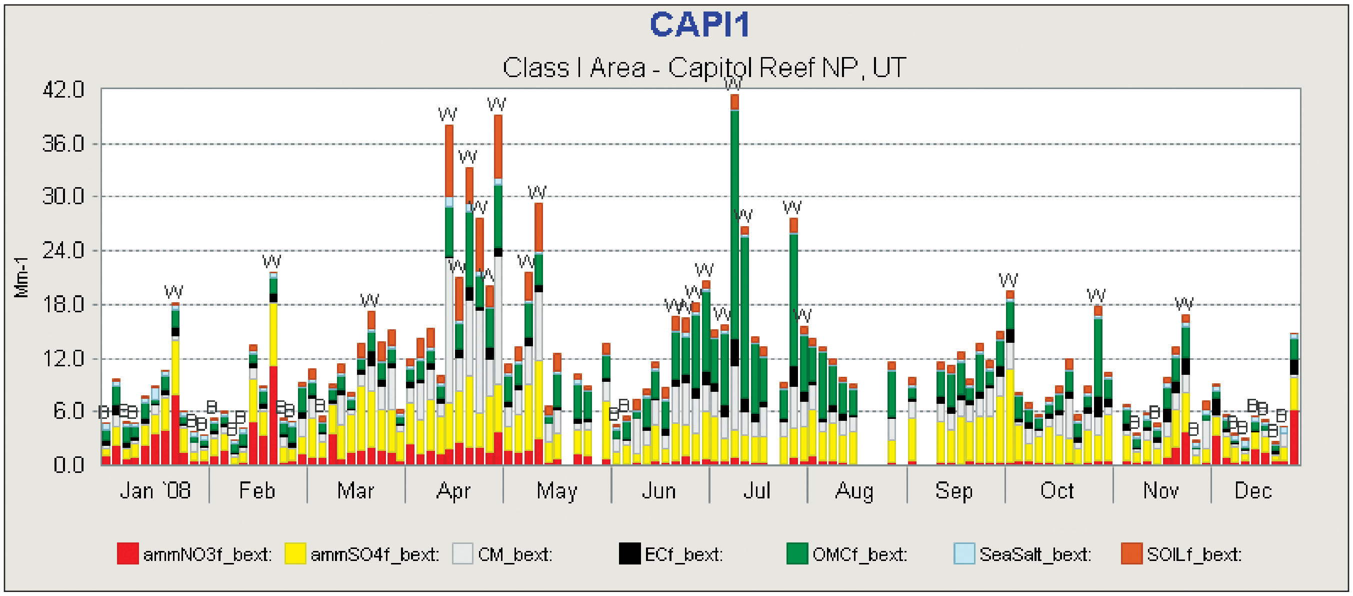


Figure 3-26. Composition of fine particles at Capitol Reef National Park, 2008 (VIEWS 2010). Legends refer to B extinction rates related to the following: ammno3f_bext = ammonium nitrate; ammso4f_bext = ammonium sulfate; cm_bext = coarse mass (particles 2.5–10 microns in size); ecf_bext = particles <2/5 microns in size (soot, black carbon); omncf = fine organic mass from carbon; sea salt_bext = sea salt; and soilf_bext = fine soil.

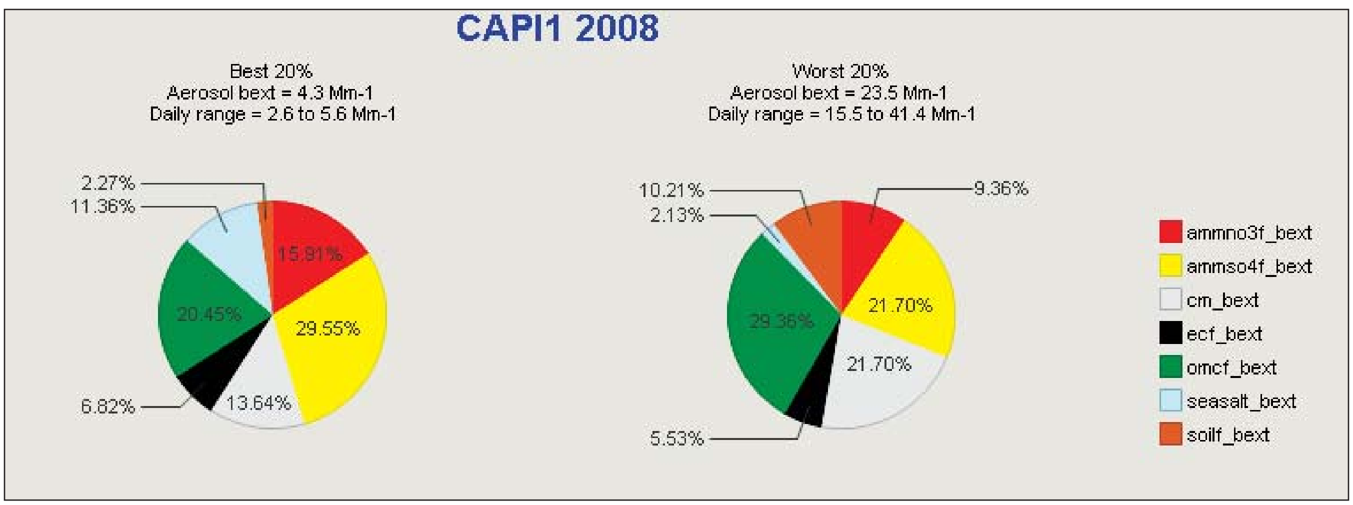


Figure 3-27. Seasonal patterns in haze composition at Capitol Reef National Park, 2008 (VIEWS 2010). Legends refer to B extinction rates related to the following: ammno3f_bext = ammonium nitrate; ammso4f_bext = ammonium sulfate; cm_bext = coarse mass (particles 2.5–10 microns in size); ecf_bext = particles <2/5 microns in size (soot, black carbon); omncf = fine organic mass from carbon; sea salt_bext = sea salt; and soilf_bext = fine soil.

3.6 Colorado National Monument

3.6.1 Ozone

Ozone has been monitored in Colorado National Monument using POMS units since 2006; summary data are provided in Table 3-2. COLM had no days that exceeded the eight-hour average of 75 ppb in 2008 (Ray 2009). The fourth-highest eight-hour concentration for 2008 was 67, with a three-year average of 69.0. The interpolated value of ozone based on a five-year average is 67.4. Both of these values are below the primary standard threshold of 75 ppb for a three-year average of the fourth-highest eight-hour concentration. Ozone levels at COLM are rated as being in moderate condition (61–75 ppb; see Table 2-2). In January 2010, the EPA proposed to lower the primary standard from 75 ppb to a level within the range of 60–70 ppb (Federal Register 2010). If this new standard is implemented, COLM may have exceedances, based on current measurements.

The SUM06 index exceeded the thresholds at which damage can occur to trees and plants (Table 2-3) in 2006 and 2008. In 2007, the SUM06 index fell within the range at which damage can occur to plants.

The W126 index exceeded the thresholds at which damage can occur to plants and trees (Table 2-3) in 2006. In 2007, the W126 index fell within the range at which damage can occur to plants and trees. In 2008, the W126 index exceeded the thresholds at which damage can occur to plants and natural-forest seedlings, and fell within the range for possible damage to plantation seedlings.

Because the NPS-ARD's ozone risk assessment for COLM concluded that vegetation in the park was considered at low risk from ozone injury (NPS 2004), there is no reason to adjust the moderate rating for COLM. Because no trends should be estimated until at least 10 years of data have been collected, it cannot be determined whether COLM is meeting its 2009 GPRA goal for ozone.

Table 3-2. Ozone concentrations (parts per billion-ppb) and exposure indices summaries for Colorado National Monument, 2006–2008.

Site code	Year	Number of days with 8-hr average O_3 values at >85 (75) ppb[a]	1st-highest 8-hr concentrations	2nd-highest 1-hr concentrations	4th-highest 8-hr concentrations	SUM06 (ppm-hr)[b]	W126 (ppm-hr)[c]
COLM-MY	2008	0	71	69	67	19	14
COLM-MY	2007	0	67	67	67	9	9
COLM-MY	2006	0	78	76	73	48	44

(Ray 2009)

[a]The National Ambient Air Quality Standard for ozone was 85 ppb until March 2008, based on the three-year average of the fourth-highest daily maximum 8-hour average ozone concentration. In March 2008, the standard was lowered to 75 ppb.

[b]SUM06 exposure index represents the 0800–2000 hourly ozone concentrations ≥ 0.06 ppm. The value reported here represents a three-month maximum value during the ozone season. Units are ppm-hr.

[c]W126 exposure index represents the sum of all hourly ozone concentrations where each concentration is weighted by a function that gives greater emphasis to the higher hourly concentrations while still including the lower ones. Units are ppm-hr. For more information on the W126 exposure index go to http://www.nature.nps.gov/air/maps/airatlas/docs/air_quality_glossary.pdf.

3.7 Dinosaur National Monument

3.7.1 Ozone

Ozone has been monitored in Dinosaur National Monument using POMS units since 2005; summary data are provided in Table 3-3. DINO had no days that exceeded the eight-hour average of 75 ppb in 2008 (Ray 2009). The fourth-highest eight-hour concentration for 2008 was 66, with a four-year average of 66.0. Based on interpolated values, the five-year average was 65.8. Both of these values are below the ozone standard threshold of 75 ppb for a three-year average of the fourth-highest eight-hour concentration. Ozone levels at DINO are rated as being in moderate condition (61–75 ppb; see Table 2-2). In January 2010, the EPA proposed to lower the primary standard from 75 ppb to a level within the range of 60–70 ppb (Federal Register 2010). If this new standard is implemented, DINO could have exceedances, based on current measurements.

The SUM06 exceeded the thresholds at which damage can occur to trees and plants (Table 2-3) in 2006 and was within the range at which damage can occur to trees and plants in 2005. In 2008, the SUM06 exceeded the thresholds at which damage can occur to plants and was within the range at which damage can occur to trees. Because the NPS-ARD's ozone risk assessment for DINO concluded that vegetation in the park was considered at low risk from ozone injury (NPS 2004), there is no reason to adjust the moderate rating for DINO. Because no trends should be estimated until at least 10 years of data have been collected, it cannot be determined whether DINO is meeting its 2008 GPRA goal for ozone.

Table 3-3. Ozone concentrations (parts per billion-ppb) and exposure indices summaries for Dinosaur National Monument, 2005–2008.

Site code	Year	Number of days with 8-hr average O_3 values at >85 (75) ppb[a]	1st-highest 8-hr concentrations	2nd-highest 1-hr concentrations	4th-highest 8-hr concentrations	SUM06 (ppm-hr)[b]	W126 (ppm-hr)[c]
DINO-WE	2008	0	69	67	66	15	10
DINO-WE	2007	0	68	64	63	7	12
DINO-WE	2006	0	69	69	68	19	28
DINO-WE	2005	0	73	72	67	12	18

(Ray 2009)

[a]The National Ambient Air Quality Standard for ozone was 85 ppb until March 2008, based on the three-year average of the fourth-highest daily maximum 8-hour average ozone concentration. In March 2008, the standard was lowered to 75 ppb.

[b]SUM06 exposure index represents the 0800-2000 hourly ozone concentrations ≥ 0.06 ppm. The value reported here represents a three-month maximum value during the ozone season. Units are ppm-hr.

[c]W126 exposure index represents the sum of all hourly ozone concentrations where each concentration is weighted by a function that gives greater emphasis to the higher hourly concentrations while still including the lower ones. Units are ppm-hr. For more information on the W126 exposure index go to http://www.nature.nps.gov/air/maps/airatlas/docs/air_quality_glossary.pdf.

3.8 Timpanogos Cave National Monument

3.8.1 Ozone

Ozone has been monitored near TICA (EPA site #490495008) since 1998; summary data are provided in Table 3-4. The fourth-highest eight hour concentration for 2008 was 71. Ozone levels based on interpolated values are currently at 77.0 at TICA, and are rated as being in a condition of significant concern (>75 ppb; see Table 2-2). However, based on the actual data from the EPA site, the current five-year average is 74.8, just below the ozone standard threshold of 75 ppb. The NPS-ARD uses interpolated values to make consistent condition assessments at all park units nationwide; however, an air-quality violation would only be based on actual data—never on interpolated data.

Based on data from 1999 to 2008, the fourth-highest eight-hour average showed a significant decline (improving air quality) (slope = –1.00, p = 0.04). Therefore, TICA is currently meeting its 2009 GPRA goal for ozone. Because the NPS-ARD's ozone risk assessment for TICA concluded that vegetation in the park was considered at low risk from ozone injury (NPS 2004), there is no reason to adjust the significant concern rating for TICA. In January 2010, the EPA proposed to lower the primary standard from 75 ppb to a level within the range of 60–70 ppb (Federal Register 2010). Timpanogos Cave National Monument would exceed a standard of 60–70 ppb.

Conditions favoring the uptake of ozone can occur under any levels of exposure and soil moisture. If ozone levels continue to be a concern at TICA, a program to assess the presence of ozone injury there could employ spreading dogbane (*Apocynum androsaemifolium*) (NPS 2004).

Table 3-4. Ozone concentrations (parts per billion-ppb) and exposure indices summaries for Timpanogos Cave National Monument, 1998–2008.

Site code	Year	Number of days with 8-hr average O_3 values at >85 (75) ppb[a]	1st-highest 8-hr concentrations	2nd-highest 1-hr concentrations	4th-highest 8-hr concentrations
490495008442011	2008	2	88	85	71
490495008442011	2007	6	85	81	78
490495008442011	2006	5	81	78	77
490495008442011	2005	7	95	88	80
490495008442011	2004	0	72	68	68
490495008442011	2003	9	103	81	79
490495008442011	2002	11	85	83	82
490495008442011	2001	5	77	77	76
490495008442011	2000	4	78	77	86
490495008442011	1999	8	85	84	83
490495008442011	1998	21	95	93	90

(EPA 2010)

SUM06 and W126 data were not available for this site.

[a]The National Ambient Air Quality Standard for Ozone was 85 ppb until March 2008, based on the three-year average of the fourth-highest daily maximum 8-hour average ozone concentration. In March 2008, the standard was lowered to 75 ppb.

3.9 Zion National Park

3.9.1 Class I park overview

Zion National Park was designated a Class I air quality area in 1977, receiving the highest protection under the Clean Air Act. Both local and distant air pollutant sources affect air quality in Zion NP. Nearby large point sources include power plants, refineries, and lime kilns in Coconino County, Arizona, and Clark County, Nevada. Pollutants also travel greater distances to the park from both mobile and point sources throughout the Southwest (NPS-ARD 2006e).

The AQRVs of Zion NP are those resources that are potentially sensitive to air pollution, including vegetation, wildlife, water quality, soils, visibility, and night skies. At present, visibility has been identified as the most sensitive AQRV in the park; other AQRVs may also be sensitive, but have not been sufficiently studied. Although visibility in the park is still superior to that in many parts of the country, it is only rated as being in moderate condition, and is often impaired by light-scattering pollutants (haze).

Surface waters in Zion NP are expected to be generally well-buffered because of adequate amounts of cations, such as calcium and magnesium, and, therefore, not likely to be acidified by atmospheric deposition. Most soils are also likely to be well-buffered from acidification. However, there may be areas in the park where rock is resistant to weathering, where cation concentrations are low, and soils and water (e.g., in small ponds and potholes) may be sensitive to inputs of acidic deposition. Soils and vegetation in the park may also be sensitive to nutrient enrichment from nitrogen deposition (NPS-ARD 2006e).

3.9.2 Ozone

Ozone has been monitored in ZION since 2004; summary data are provided in Table 3-5. ZION had one day that exceeded the eight-hour average of 75 ppb in 2008 (Ray 2009). The fourth-highest eight-hour concentrations for 2008, 2007, 2006, 2005, and 2004 were 72, 71, 75, 91, and 74, respectively. The current five-year average of 76.6 is above the ozone standard threshold of 75 ppb. The interpolated value for condition assessment is 75.1. Under both of these values, ozone condition at ZION is rated as being of significant concern (>75 ppb; see Table 2-2).

The SUM06 indices exceeded the thresholds at which damage can occur to trees and plants (Table 2-3) from 2004 to 2008. Because the NPS-ARD's

Table 3-5. Ozone concentrations (parts per billion-ppb) and exposure indices summaries for Zion National Park, 2008.

Site code	Year	Number of days with 8-hr average O_3 values at >85 (75) ppb[a]	1st-highest 8-hr concentrations	2nd-highest 1-hr concentrations	4th-highest 8-hr concentrations	SUM06 (ppm-hr)[b]	W126 (ppm-hr)[c]
ZION-DW`	2008	0	76	74	72	28	18
ZION-DW	2007	0	77	77	71	35	25
ZION-DW	2006	2	138	137	75	50	52
ZION-DW	2005	4	109	100	91	43	50
ZION-DW	2004	0	80	78	74	41	48

(Ray 2009)

[a]The National Ambient Air Quality Standard for ozone was 85 ppb until March 2008, based on the three-year average of the fourth-highest daily maximum 8-hour average ozone concentration. In March 2008, the standard was lowered to 75 ppb.

[b]SUM06 exposure index represents the 0800-2000 hourly ozone concentrations ≥ 0.06 ppm. The value reported here represents a three-month maximum value during the ozone season. Units are ppm-hr.

[c]W126 exposure index represents the sum of all hourly ozone concentrations where each concentration is weighted by a function that gives greater emphasis to the higher hourly concentrations while still including the lower ones. Units are ppm-hr. For more information on the W126 exposure index go to http://www.nature.nps.gov/air/maps/airatlas/docs/air_quality_glossary.pdf.

ozone risk assessment for ZION concluded that vegetation in the park was considered at low risk from ozone injury (NPS 2004), there is no reason to adjust the significant concern rating for ZION. Because no trends should be estimated until at least 10 years of data have been collected, it cannot be determined if ZION is meeting its 2009 GPRA goal. However, there is reason for concern, because the NAAQS standard was exceeded in two of the five years of data. In January 2010, the EPA proposed to lower the primary standard from 75 ppb to a level within the range of 60–70 ppb (Federal Register 2010). Zion National Park would exceed a standard of 60–70 ppb.

3.9.3 Visibility

For ZION, the average light extinction for the 20% clearest days was 5.47 Mm^{-1} and, for the 20% haziest days, 29.43 Mm^{-1} in 2008. Light extinction trends from the ZION site cannot be determined due to the limited amount of data (Figure 3-28). However, the site at BRCA is close enough to examine trends. Based on the BRCA site, light-extinction trends for 20% clearest days decreased significantly based on three-year averages from 1999 to 2008 (slope = –0.16, $p < 0.01$), but showed no trend for the 20% haziest days (slope = 0.00, $p = 0.50$).

Visibility impairment largely results from small particles in the atmosphere. Figure 3-29 shows the contributions made by different classes of particles toward haze. On days with best visibility (the bottom 20% of the distribution by deciview, or haze index), most haze was caused by ammonium sulfate and fine organic carbon mass, followed by coarse mass (particles 2.5–10 microns in size). On the worst days (the top 20% of the distribution by deciview), fine organic carbon mass contributed most to haze, but coarse mass and ammonium sulfate were also significant contributors.

Ammonium sulfate is derived primarily from sulfur dioxide emitted from coal-fired power plants. Most fine organic carbon mass comes from forest fires, which usually occur in the summer. As such, some seasonal patterns were evident in haze composition at ZION in 2008, notably a large spike in October (Figure 3-30). The largest cluster of high levels of haze composition occurred in the spring and in October. Average visibility for ZION is estimated to be 4.1 deciviews. This level is deemed in moderate condition (see Table 2-3). Due to the increasing quality of visibility on clear days and lack of significant trends on the haziest days, ZION is meeting its 2009 GPRA goal for visibility.

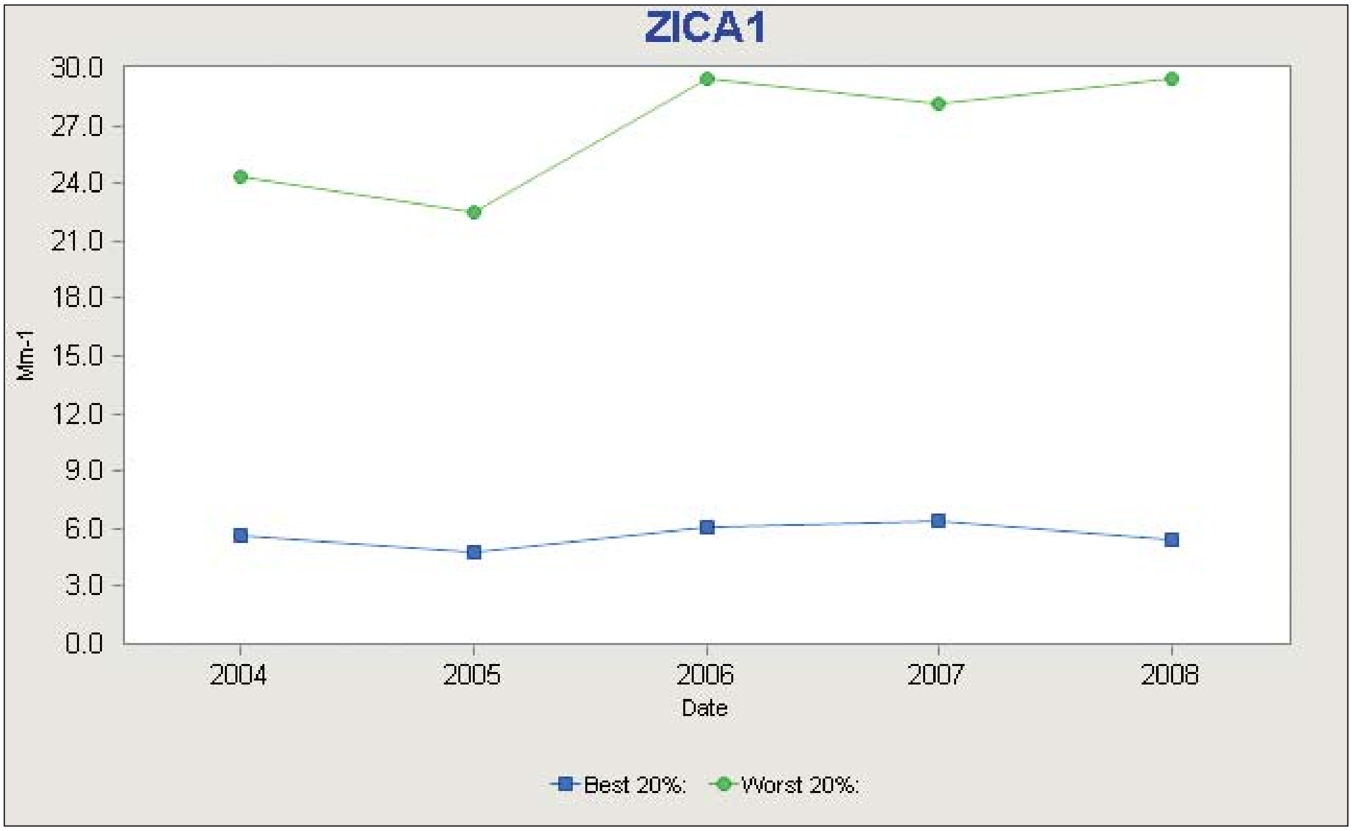


Figure 3-28. Trends in aerosol light extinction on the 20% best (clearest) days and 20% worst (haziest) days, Zion National Park, 2004–2008 (VIEWS 2010).

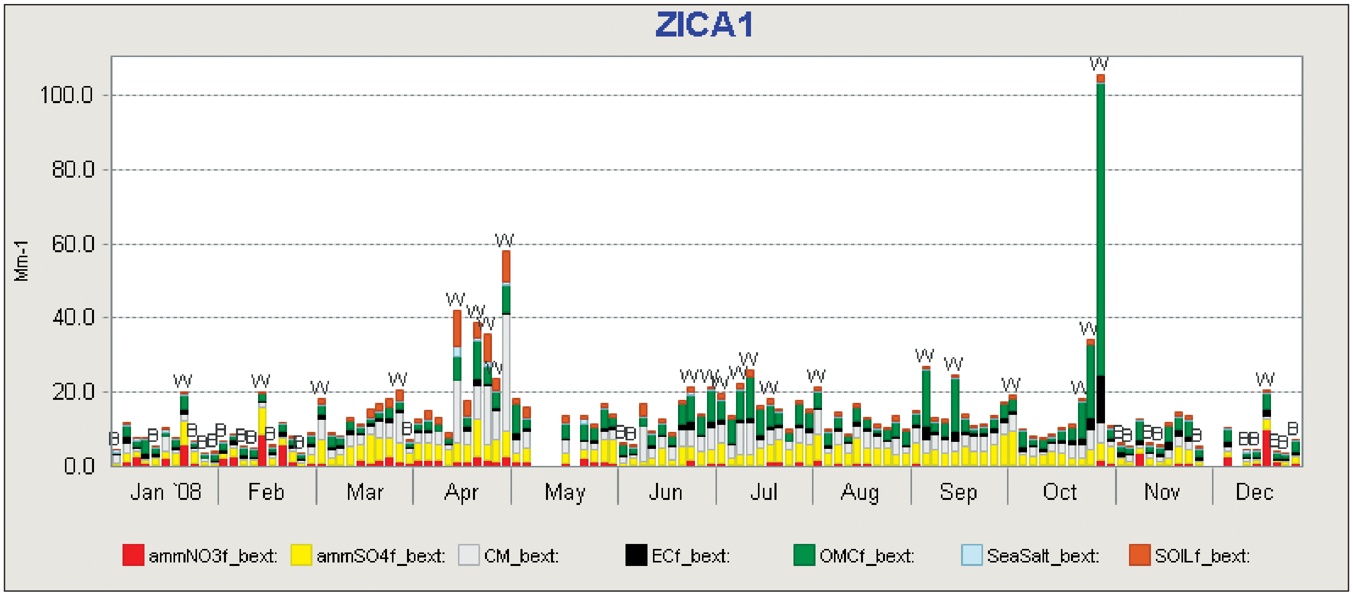


Figure 3-29. Composition of fine particles at Zion National Park, 2008 (VIEWS 2010). Legends refer to B extinction rates related to the following: ammno3f_bext = ammonium nitrate; ammso4f_bext = ammonium sulfate; cm_bext = coarse mass (particles 2.5–10 microns in size); ecf_bext = particles <2/5 microns in size (soot, black carbon); omncf = fi ne organic mass from carbon; sea salt_bext = sea salt; and soilf_bext = fine soil.

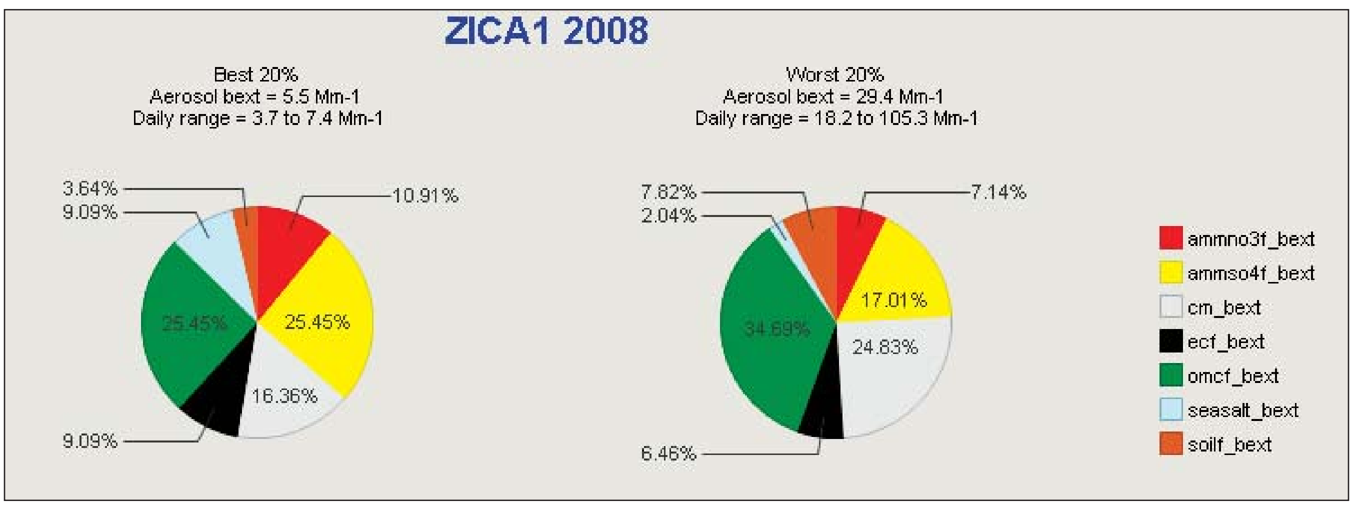


Figure 3-30. Seasonal patterns in haze composition at Zion National Park, 2008 (VIEWS 2010). Legends refer to B extinction rates related to the following: ammno3f_bext = ammonium nitrate; ammso4f_bext = ammonium sulfate; cm_bext = coarse mass (particles 2.5–10 microns in size); ecf_bext = particles <2/5 microns in size (soot, black carbon); omncf = fine organic mass from carbon; sea salt_bext = sea salt; and soilf_bext = fine soil.

4 Discussion

Nationwide, the NPS is exceeding air quality performance goals for 2009, with 97% of reporting parks showing stable or improving trends in visibility, 100% showing stable or improving trends in ozone concentrations, and 93% showing stable or improving trends in atmospheric deposition (NPS-ARD in press). NCPN parks generally follow this trend, with parks meeting 15 of the 15 GPRA goals (100%). Currently, 100% of reporting NCPN parks show stable or improving trends in visibility (9 parks), ozone concentrations (2 of 2 parks; 3 could not be determined due to limited data), and atmospheric deposition (2 parks).

Sites in the West, including the Colorado Plateau, are generally reporting increasing (improving) visibility on clear days. The NPS-ARD expects air quality in parks to improve as regulations aimed at reducing tailpipe emissions from motor vehicles and pollution from electric-generating facilities take full effect over the next few years. One such regulation, EPA's Regional Haze Rule (RHR), requires states to demonstrate progress in improving visibility in Class I areas to meet the goal of natural conditions by 2064. By 2018, states are expected to show significant progress.

Although visibility is improving, progress in western states is modest and, to date, largely due to reduced tailpipe emissions rather than industry or power plant reductions. Many states are not expected to meet the 2018 interim goal. However, recent legislation in Colorado requires coal-fired power plants in the state to reduce nitrogen oxides emissions by up to 80% by 2017, benefiting areas downwind of those sources, primarily to the east. Other western states are also considering significant reductions. Wildfires will continue to present a challenge to meeting visibility goals. Years of drought have increased the frequency and severity of fires in the West; climate change is expected to exacerbate this situation.

Ozone concentrations in some western parks outside the NCPN have been increasing, and ozone could become a concern in NCPN parks. Increasing concentrations are possibly due to increasing regional emissions of nitrogen oxides, changes in the distribution of emissions, increased biomass burning, or increased global background ozone (Jaffe and Ray 2007). No NCPN parks are currently designated as in non-attainment for the ozone standards, but if the primary ozone standard is strengthened (as was proposed in early 2010), CANY, ZION, and TICA could be in non-attainment areas.

In addition to human health concerns, ozone can harm plants. Little is known about the effects of ozone on plants in the Southwest, but brief surveys in 1999 found ozone injury to plants at BRCA, CEBR, and ZION. No subsequent surveys have been conducted. Research suggests that plants close their stomates to reduce water loss in dry, hot conditions that can coincide with high ozone concentrations. Stomatal closure also limits ozone uptake and subsequent injury. However, in riparian areas, where plants are well watered, ozone uptake may be significant and injury may occur.

Although atmospheric deposition of sulfur and nitrogen compounds is relatively low in NCPN parks (e.g., about 2 kg/ha/yr in CANY), research in other arid areas suggests that plant communities can be affected at low levels of nitrogen deposition. In Joshua Tree NP, researchers found that nitrogen deposition of about 3 kg/ha/yr increased the risk of fire in creosote bush scrub and pinyon-juniper communities because nitrogen increased growth of annual grasses, making a continuous fuel layer available (Rao et al. 2010). Nitrogen has also caused changes in plant species composition, sometimes with increases in invasives, in arid areas (Brooks 2003). Vehicles, power plants, and oil and gas production emit nitrogen oxides that result in nitrogen deposition. Agriculture, feedlots, and fires emit ammonia that also contributes to nitrogen deposition.

The NPS is collaborating with states and industry to encourage the adoption of twenty-first century technology, negotiate tighter pollution controls (including mercury), and secure emission-offset agreements. For example, the states of Colorado and New Mexico initiated a collaborative effort involving Arizona and Utah, interested tribes in the area, the U.S. Environmental Protection Agency, and federal land management agencies (NPS, Bureau of Land Management, and U.S. Forest Service) to explore air quality issues associated with present and future air pollutant emissions in the Four Corners region. These parties entered into a Memorandum of Understanding that defines an Interagency Policy Oversight Group, which, in turn, facilitated the Four Corners Air Quality Task Force. The Task Force was open to all interested parties to discuss and formulate options to address regional air quality issues. The Four

Corners Air Quality Task Force Final Report, issued in November 2007, includes hundreds of options for reducing air pollution. Local regulators of air quality continue to use the report to develop air quality management strategies for the Four Corners region (NPS-ARD in press).

5 Literature Cited

Brooks, M. L. 2003. Effects of increased soil nitrogen on the dominance of alien annual plants in the Mojave Desert. Journal of Applied Ecology 40:344–353.

CASTNet. 2010. http://www.epa.gov/castnet/. Last accessed July 26, 2010.

Crocker Nuclear Laboratory (CNL). 1996. IMPROVE standard operating procedures: SOP 251, sample handling. Davis, Calif.

Environmental Protection Agency (EPA). 2009. EPA greenbook: Currently designated nonattainment areas for all criteria pollutants. http://www.epa.gov/oar/oaqps/greenbk/. Last accessed July 29, 2010.

——. 2010. National Ambient Air Quality Standards for ozone. Federal Register 75(11) 2988–3037. http://www.epa.gov/glo/fr/20100119.pdf.

Interagency Monitoring of Protected Visual Environments (IMPROVE). 1998. IMPROVE preserves monitoring images with permanent photographic archive CD-ROMs. IMPROVE newsletter 7(3).

MACTEC Engineering & Consulting, Inc. 2003. Clean Air Status and Trends Network (CASTNet) quality assurance project plan (QAPP), Revision 2.0. MACTEC Engineering and Consulting, Inc., Gainesville, Fla. October, 317 pp.

National Atmospheric Deposition Program (NADP). 2002. Quality assurance plan, version 1.3, NADP CAL QA plan 2002–01, August. Central Analytical Laboratory, Illinois State Water Survey, Champaign, Ill.

National Atmospheric Deposition Program (NADP). 2010. http://nadp.sws.uiuc.edu/. Last accessed July 23, 2010.

National Park Service–Air Resources Division (NPS-ARD). In press. 2008 Annual performance & progress report: Air quality in national parks.

——. 2006a. Black Canyon of the Gunnison National Park air quality information. http://www.nature.nps.gov/air/permits/aris/blca/. Last accessed September 8, 2010.

——. 2006b. Bryce Canyon National Park air quality information. http://www.nature.nps.gov/air/permits/aris/brca/. Last accessed September 8, 2010.

——. 2006c. Canyonlands National Park air quality information. http://www.nature.nps.gov/air/permits/aris/cany/. Last accessed September 8, 2010.

——. 2006d. Capitol Reef National Park air quality information. http://www.nature.nps.gov/air/permits/aris/care/. Last accessed September 8, 2010.

——. 2006e. Zion National Park air quality information. http://www.nature.nps.gov/air/permits/aris/zion/. Last accessed September 8, 2010.

——. 2002. Air quality in the national parks, 2nd edition. National Park Service Air Resources Division, U.S. Department of the Interior, Lakewood, Colo.

——. Unpublished data. File name: NPS_2003_2007_AQ_Estimates.pdf.

National Park Service (NPS). 2004. Assessing the risk of foliar injury from ozone on vegetation in parks of the Northern Colorado Plateau Network. October.

Porter, E. 2003. Ozone-sensitive plant species on National Park Service and U.S. Fish and Wildlife Service lands: Results of a June 24–25, 2003, workshop. U.S. Department of the Interior, Baltimore, Md. Natural Resource Report NPS/NRARD/NRR-2003/01.

Rao, L. E., E. B. Allen, and T. Meixner. 2010. Risk-based determination of critical nitrogen deposition loads for fire spread in southern California deserts. Ecological Applications 20(5):1320–1335.

Ray, J. D. 2009. Annual data summary 2008: Gaseous pollutant monitoring program. NPS/NRPC/ARD/NRDS—2009/011. National Park Service, Denver, Colo.

Ray, J. D. 1998. Ambient ozone measurements in the national parks using passive samplers, 1995–1996. Ver. 2.75 9-9-98. National Park Service Air Resources Division, Denver, Co.

Schwinning, S., B. I. Starr, N. J. Wojcik, M. E. Miller, J. E. Ehleringer, and R. L. Sanford, Jr. 2005. Effects of nitrogen deposition on an arid grassland in the Colorado Plateau cold desert. Rangeland Ecology and Management 58:565–575.

VIEWS. 2010. http://vista.cira.colostate.edu/views/. Last accessed July 26, 2010.

NPS 960/105741, September 2010

National Park Service
U.S. Department of the Interior

Natural Resource Program Center
1201 Oak Ridge Drive, Suite 150
Fort Collins, Colorado 80525

www.nature.nps.gov

EXPERIENCE YOUR AMERICA™