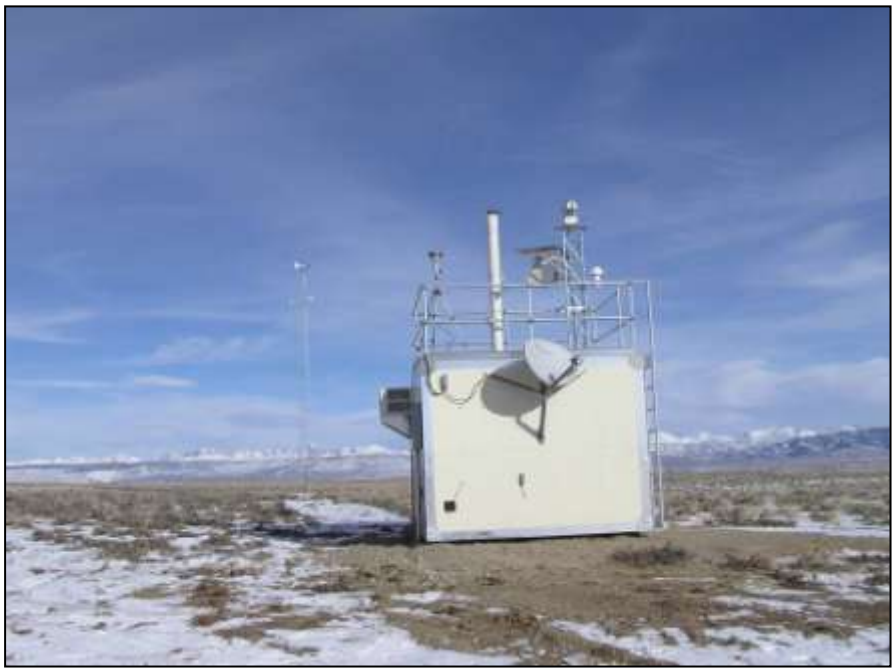
2005 Air Quality Monitoring Report
Presented to the Pinedale Anticline Working Group
May 12, 2006



Prepared by the Air Quality Task Group

Executive Summary

This document is the 2005 Air Quality Monitoring Report (2005 Report) produced by the Air Quality Task Group (AQTG) of the Pinedale Anticline Working Group (PAWG). The 2005 Report is intended to initiate fulfillment of the goals and objectives of the Adaptive Environmental Management Process contained in the July 2000 Bureau of Land Management Record of Decision for the Pinedale Anticline Oil and Gas Exploration and Development Project (ROD/EIS).

Although we are charged with examining activities within the administrative boundary of the Pinedale Anticline Project Area (PAPA), the nature of the air resource extends beyond those administrative boundaries. From a technical standpoint, to appropriately address air quality, the AQTG needs to examine areas adjacent to and near the PAPA. Additionally, the ROD/EIS specifies that the AQTG focus on nitrogen oxides (NO_x) however, it is also relevant to expand our scope to encompass criteria pollutants (NO_2, SO_2, PM_{10}, etc.), Volatile Organic Compounds (VOCs), and Hazardous Air Pollutants (HAPs).

Although the focus of the AQTG is related to emissions directly from the PAPA, but we must acknowledge the likelihood that air pollutants measured in these areas can also originate from regional sources in southwest Wyoming, other western states and even other countries. Additionally, weather and climate are two of the pronounced variables that must be considered when attempting to identify air quality trends from existing data.

The following pages summarize the main discussions, results, concerns, and other relevant aspects that are reviewed in detail in the main body of this document. It is highly recommended that interested readers continue to the full section(s) associated with the topic(s) of interest in this summary to review associated data and detailed discussion.

<u>Air Quality Monitoring</u>

In the PAPA and throughout southwest Wyoming there are several air quality monitoring stations collecting data. In 2005, three ambient air quality monitoring sites were established, the Boulder Monitoring station, the Daniel South Monitoring Station and the Pinedale particulate monitor. Air quality models for southwest Wyoming which have been developed and utilized since 1997, when the Southwest Wyoming Technical Air Forum (SWWYTAF) modeled sources in southwestern Wyoming, eastern Idaho, northeastern Utah and northwestern Colorado. SWWYTAF evaluated air quality on a cumulative basis for the entire southwestern region of Wyoming. Additionally, in 2005 the Wyoming Department of Environmental Quality – Air Quality Division (WDEQ-AQD) modeled sources in and near Sublette County to determine NO_2 increment consumption. The PAPA is also monitored by the tracking of activities that can affect air quality. In 2005 activity such as drill rigs counts, wildfires, prescribed burning and institution of mitigation measures were tracked and presented in this report.

<u>Lake Monitoring Results</u>

The United States Forest Service on the Bridger-Teton National Forest (USFS) performs long-term lake sampling on lakes in the Bridger and Fitzpatrick Wilderness Areas. Results are presented in this report in great detail. Increasing nitrates at all sampled inlets of lakes indicate that regional sources are probably contributing to local deposition. The decrease of acid

neutralizing capacity (ANC) at Hobbs Lake outlet is of concern, because it is showing that acidification is starting to occur. From the USFS standpoint, Black Joe Lake is a major concern, as the ANC and nitrates are increasing at the inlets, outlet and hypolimnion, and sulfate is increasing at the outlet. This indicates that fertilization (nitrification) of the lake is occurring meaning that the lake is not able to use all of the nitrogen entering the lake system. This is a first step to eutrophication of the lake, and changes within the lake biota may be starting to occur.

Due to these findings, USFS thinks it is worthwhile to investigate biological data (macroinvertibrates and zooplankton) at Black Joe Lake to determine if a shift to more nitrophyllic species is occurring. This should also include some paleosediment sampling to look at historical diatom community structure changes over time. Currently this investigation is unfunded and will be moved forward as an AQTG recommendation and request for funding.

NADP

Based on the atmospheric concerns in the Pinedale area, only data associated with the deposition of nitrogen and sulfur-based compounds (NH_4, NO_3 and SO_4) are evaluated in this report. Although NADP stations provide both wet and total deposition, only the total deposition data are presented since these are more relevant to the atmospheric needs of this report. Therefore, NADP data (presented as mass deposited per area [kg/hectare]) are not directly comparable to the lake chemistry data, which measure concentrations per volume of water.

Nitrogen: Although it appears that on a seasonal scale, summer nitrogen deposition values are generally the highest and winter values the lowest, there is a good deal of variation among most of the seasonal data. Positive and negative trends appear to follow about the same timeline across all three sites, which normally might suggest that regional sources and events are playing a far more important role than local sources. However, based on the changes in source activity among the various years and the extensive area affected by the source activity, no obvious conclusions can be seen, and it is beyond the scope of this report to analyze the specific sources of air pollution.

Sulfur: Annual SO_4 concentrations have shown a decrease at all three NADP sites over time. As with the nitrogen compounds, there are _ups and downs' along the trend line. Atmospheric sulfur concentrations have been affected by numerous regional and local factors. On a national scale, the 1990 Clean Air Act Revision acid rain provisions have greatly reduced SO_2 emissions from power plants. More recently, low sulfur diesel has been implemented for on-road and non-road diesel engines. Both actions, as expected, appear to contribute to a reduction of sulfur at the local and regional level. However, an analysis of the full suite of SO_4 data, meteorological conditions and source activity data would be needed to fully evaluate the causes of the apparent decrease in sulfur deposition but such an evaluation is well beyond the scope of this report.

Visibility

There are three instruments commonly used to assess visibility conditions. These include optical instruments (nephelometers and transmissometers) and aerosol samplers (see associated sections in report for detailed information). The least technical way to describe visibility in terms of human recognition is by referring to —visual range" in miles or kilometers. Therefore, where possible, visibility data are translated into visual range to make the information presented more understandable for less technical audiences.

Results of aerosol sampling:

In general, there are several seasonal trends that are observed in the long term IMPROVE aerosol data from the Bridger monitor:

- The highest visual ranges (best visibility) generally occur during the winter months.
- Fall visibility (October-December) appears to be slightly less than winter values but better than spring and summer.
- Visual ranges in the spring and summer months are most often lower than fall and winter ranges, and are very similar with several years of slightly better visibility occurring in the spring and a few in the reverse pattern.

Long term observations of the seasonal and annual data (from 1989-2004; 2005 aerosol data are not yet available due to laboratory methods) show some observable increases and decreases in visual range over time. Some of the more notable decreases in visual range appear to be tied to large-scale regional events (likely wildfires due to season and impacts); this likelihood is supported by similar patterns observed from regional IMPROVE sites located outside of the area (e.g. Yellowstone National Park). In terms of evaluating impacts to visibility from local development, modeling suggests that the existing Bridger IMPROVE station is not, by itself, located to effectively capture potential impacts (the Bridger site was chosen close to 20 years ago to evaluate visibility in the Bridger-Fitzpatrick Wilderness Areas only). This concern has been discussed by the AQTG. See the recommendations section for additional information,

Optical and Scene Monitoring

Visibility monitoring also includes nephelometers, a transmissometer and cameras throughout the air quality network. Each instrument is intended to measure a specific attribute associated with visibility. Presented alone, the data from each monitor will not accurately represent long term visibility trends (see full section for details). However, reviewed together, these data provide useful information and extend the area monitored for visibility impacts. Events noticed by all visibility-related monitoring are discussed in section 3.3.4. These include regional wildfires, local prescribed burns, and increased particulate levels preceding frontal passages.

New mitigation in 2005

As part of As required in the November 2005 ASU FONSI, November 2005, ASU operators (Anschutz-Shell-Ultra) were required to test emission levels of NOx reduction- demonstration technology for drilling rig engines. In December 2005, Shell and Ultra installed SCR (selective catalyst reduction) technology on four drilling rigs and Ultra for Anschutz installed bi-fuel technology on two drilling rigs.

A condensate and water gathering system was constructed by Questar on the Mesa and began operation late in 2005. By gathering water and condensate from all Questar operated wells and pads into a centralized system almost all tanks which were used to hold water and condensate have been taken out of service. The net effect of these changes is to reduce emissions of PM, VOCs, HAPs, and NOx. Details are included in section 4.3.

In July 2005, WDEQ-AQD regulations started to require the use of Best Management Practices, including the use of "green completion" technology (which captures in the system most of the fluids that were historically flared), to reduce by at least 90% visible and other emissions from completions. Limited exceptions apply when necessary for safety or lack of infrastructure reasons.

Monitoring Needs

The task group has developed a list of overall monitoring and other needs it has discussed could be of importance in strengthening the existing monitoring network. Some needs are funded for upcoming years; remaining needs deemed necessary are carried over into recommendations and/or for additional discussion by the AQTG in 2006. The following briefly summarizes identified needs:

* Establishment of ambient air monitoring stations at South Pass, Uintas and Wyoming Range .
* Increased VOC/HAP monitoring
* Establishment of SO_2 monitoring at the South Pass and Unitas monitoring site.
* Installation of an IMPROVE Protocol monitor and/or scene monitor and nephelometer near Muddy Ridge
* Placement of a WARMS monitor at the Gypsum Creek NADP site.
* Continuation of existing USFS monitoring of the NADP wet deposition monitoring, long-term lake monitoring and bulk deposition monitoring
* Continuation of Bridger transmissometer
* Survey to determine the extent of O_3 impacts to vegetation in the Bridger Wilderness
* Analysis of macroinvertibrates in long term lakes and paleosediment analysis in Black Joe Lake
* Installation of a scene camera at Fortification Mountain

Recommendations

This report provides a list of recommendations the AQTG has determined, through consensus, are necessary for the enhancement of existing and proposed monitoring (which are currently not funded or in progress). They are:

* Adding a WARMS monitor near Gypsum Creek NADP site.
* Revisit the objectives and strategy of the NO_x Tracking Report.
* Analysis of macroinvertibrates and zooplankton and paleosediment in long term lakes.

Table of Contents

Executive Summary ii
1 Introduction 4
1.1 Background 5
1.2 Weather and Climate 6
1.3 New monitoring 7
1.4 Use and interpretation of data 8
2 Activity Tracking 8
3 Data Analysis 10
3.1 Regulated Pollutant Monitoring 10
3.2 Atmospheric Deposition/Concentration Monitoring 20
3.2.1 Long-term Lakes 20
3.2.2 National Atmospheric Deposition Program (NADP) 25
3.2.3 Clean Air Status and Trends Network (CASTNet) 32
3.2.4 Wyoming Air Resources Monitoring system (WARMS) 35
3.2.5 Bulk Deposition Monitoring 38
3.3 Visibility 47
3.3.1 Aerosol Monitoring 47
3.3.2 Scene Monitoring 50
3.3.3 Optical Monitoring 54
3.3.3.1 IMPROVE Transmissometer 54
3.3.3.2 Nephelometer 56
3.3.4 Visibility Events 59
3.3.4.1 Fire Events 59
3.3.4.2 PM_{10} Events Associated with Frontal Passages 65
3.3.4.3 Flaring Event 71
4 Summary 73
4.1 Characterize current conditions 73
4.2 Status of Existing Mitigation 73
4.3 New Mitigation Measures Implemented in 2005 74
5 Monitoring Needs and Objectives 75
6 Recommendations 77
6.1 Recommended Long Term Monitoring Projects 77
6.2 Recommended Long-term Mitigation Strategy 78
7 Future of AQTG 79
8 References 80
Appendix A: Regulated Pollutant Monitoring
Appendix B: Atmospheric Deposition/Concentration Monitoring
Appendix C: Visibility Monitoring
Appendix D: Acronyms and Definitions

List of Figures

Figure 3-1 Location and geographical orientation of the three (3) monitoring locations. 11
Figure 3-2 Diurnal Patterns Showing Average Concentrations of O_3 and NO_2 at the Boulder Monitoring Station; and O_3, NO_2, and NO at the Jonah Monitoring Station for February 2005. 15
Figure 3-3 Timeline of Selected Parameters from the Boulder Monitoring Station 17

Figure 3-4 Wind Roses from the Boulder Monitoring Station from February and March 2005.. 18
Figure 3-5 Image Taken from the Boulder Camera March 5, 2005 (0830)..... 19
Figure 3-6 Image Taken from the Boulder Camera March 6, 2005 (0830)..... 19
Figure 3-7 Seasonal deposition values for NH_4, NO_3 and SO_4 at the Gypsum Creek Site (WY 98). Values are in kg/Hectare (kg/Ha). NOTE: 1 Hectare = 10,000 square meters..... 27
Figure 3-8 Seasonal deposition values for NH_4, NO_3 and SO_4 at the South Pass Site (WY 97). Values are in kg/Ha. NOTE: 1 Hectare = 10,000 square meters. 28
Figure 3-9 Seasonal deposition values for NH_4, NO_3 and SO_4 at the Pinedale Site (WY 06). Values are in kg/Ha. NOTE: 1 Hectare = 10,000 square meters. 29
Figure 3-10 Annual deposition values for NH_4, NO_3 and SO_4 at the Gypsum Creek, South Pass and Pinedale Site, respectively. Values are in kg/Ha. NOTE: 1 Hectare = 10,000 square meters. 30
Figure 3-11 Mean annual concentrations of nitrogen compounds, Pinedale, WY 32
Figure 3-12 Mean annual concentrations of sulfur compounds near Pinedale, WY 33
Figure 3-13 Mean annual dry deposition near Pinedale, WY..... 34
Figure 3-14 Weekly concentrations of particulate nitrate near Pinedale, WY 35
Figure 3-15 Weekly concentrations of ammonium near Pinedale, WY 36
Figure 3-16 Weekly concentrations of sulfur dioxide near Pinedale..... 37
Figure 3-17 Weekly concentrations of sulfate near Pinedale, WY..... 38
Figure 3-18 Annual Precipitation..... 39
Figure 3-19 Nitrate Deposition 40
Figure 3-20 Sulfate Deposition..... 41
Figure 3-21 Annual nitrate concentrations 42
Figure 3-22 Annual sulfate concentrations 43
Figure 3-23 2004 Monthly Nitrate Concentrations..... 45
Figure 3-24 2004 Monthly Sulfate Concentrations 46
Figure 3-25 Seasonal average visual range as calculated from IMPROVE data collected at the BRID monitoring site. *Note that the visual range axis begins at 60 miles, not zero, so that more detail can be seen.*..... 48
Figure 3-26 Annual standard visual range for annual average visibility and visual ranges for the 20% best days, the 20% mid-days, and 20% worst days as calculated from IMPROVE data collected at the BRID monitoring site. *Note that the graph's visual range axis begins at 60 miles so that more details can be seen.*..... 49
Figure 3-27 Photographs Illustrating the Visual Conditions at Boulder, Wyoming..... 51
Figure 3-28 Photographs Illustrating the Visual Conditions at Daniel, Wyoming..... 52
Figure 3-29 Photographs Illustrating the Visual Conditions at Jonah, Wyoming. 53
Figure 3-30 Transmissometer data by season..... 55
Figure 3-31 Seasonal average visual range based on transmissometer data. Winter represents the first quarter (i.e. January – March), spring the second quarter, etc. *Note that the visual range axis begins at 70 miles in order to better see details.*..... 55
Figure 3-32 Annual average visual range based on transmissometer data 56
Figure 3-33 HMS Analyzed Smoke from Fires on June 25, 2005, for Regions Around Wyoming..... 60
Figure 3-34 Selected Monitored Parameters for Regional Sites, Including Light Extinction (b_{ext}) at the Bridger Wilderness Site; and Aerosol Scattering (b_{sp}), Particulate (PM_{10}) and Gaseous (NO_2 and O_3) Measurements at the Boulder Monitoring Station, During Fires Observed in June, 2005. 61
Figure 3-35 Images Taken from the Boulder Camera during Periods of High Scattering 62

Figure 3-36 HMS Analyzed Smoke from a Prescribed Fire Near the Bridger Wilderness Area on September 20, 2005. Red dots indicate HMS detected hotspots and gray masses indicate analyzed smoke. 63
Figure 3-37 Combined Images Taken from the Boulder Camera (September 20, 2005 (1630)) Showing the Expansion of the Smoke Plume Later in the Day. 64
Figure 3-38 Surface Map Showing the Passage of an Occluded Front Over Southwest Wyoming on 9/10/2005 (0500). Wyoming is highlighted in yellow. 65
Figure 3-39 Timeline Indicating Aerosol Scattering (b_{sp}) at the Boulder Station; and PM_{10} Measured at the Daniel, Boulder, and Jonah Stations, During the Passage of a Front on September 10, 2005. 66
Figure 3-40 Images Taken from the Boulder Camera Before and After the Passage of an Occluded Front on September 10, 2005. 67
Figure 3-41 Images Taken from the Jonah Camera Before and After the Passage of an Occluded Front on September 10, 2005. 68
Figure 3-42 Timeline Indicating Aerosol Scattering (b_{sp}) at the Boulder Monitoring Station, and PM_{10} Measured at the Daniel, Boulder, and Jonah Stations for the Passage of a Front on October 3, 2005. 69
Figure 3-43 Images from the Boulder Digital Archive Before and After the Passage of a Cold Front on October 3, 2005. 70
Figure 3-44 Photo taken by a Local Resident on December 6, 2005 (1351 MST). 71
Figure 3-45 Timeline Indicating Aerosol Scattering (b_{sp}), PM_{10} and NO_2 Measured at the Boulder Station During a Flaring Event that Occurred Somewhere NW of the Site. 72

List of Tables

Table 3-1 Site Specifications for Gaseous Monitoring Sites January 1, 2005 – December 31, 2005 12
Table 3-2 Standards Summary Report Nitrogen Dioxide (NO_2) 12
Table 3-3 Standards Summary Report Particulate Matter ≤10µg/m3 (PM_{10}) 13
Table 3-4 Standards Summary Report Ozone (O_3) 14
Table 3-5 Five highest 24 hour PM2.5 concentrations for 2005 20
Table 3-6 Statistically Significant Trend in Long Term Lakes 21
Table 3-7 2004 Monthly Weighted Precipitation for Hobbs and Black Joe Bulk Deposition Collectors 44
Table 3-8 Visibility Measurements in the Central Rocky Mountain Region in 2005 58
Table 5-1: Table of monitoring needs and current status 75

1 Introduction

This document is the 2005 Air Quality Monitoring Report (2005 Report) produced by the Air Quality Task Group (AQTG) of the Pinedale Anticline Working Group (PAWG). The 2005 Report is intended to initiate fulfillment of the goals and objectives of the Adaptive Environmental Management Process (Appendix C) contained in the July 2000 Bureau of Land Management Record of Decision for the Pinedale Anticline Oil and Gas Exploration and Development Project (ROD/EIS). Those objectives are specifically listed as:
Nitrogen oxide emissions

1. Complete an annual monitoring report of actual, on-the-ground calculated potential NO_x emissions (i.e., the level of NO_x emission permitted, actually constructed/installed facilities based upon the permitted level of emissions per well location, compressor facility, etc.) for the Jonah II and Pinedale Anticline project areas.
2. Continue to cooperate in the implementation of existing visibility and atmospheric deposition impact monitoring programs. Evaluate need for additional monitoring.

The ROD/EIS that authorized creation of the PAWG and its Task Groups to facilitate adaptive environmental management applies only to the Pinedale Anticline Project Area (PAPA) and not to areas outside that project area. It is critical to convey that while we are charged with examining activities within the administrative boundary of the PAPA, the nature of the airshed resource extends beyond those administrative boundaries. From a technical standpoint, to appropriately address ―local" air quality, the AQTG needs to examine areas adjacent to and near the PAPA. Additionally, the ROD/EIS specifies that the AQTG focus on nitrogen oxides (NO_x) however, it is also relevant to expand our scope to encompass criteria pollutants (NO_2, SO_2, PM_{10}, etc.), Volatile Organic Compounds (VOCs), and Hazardous Air Pollutants (HAPs).

The AQTG also works for the PAWG and provides them with summary reports (such as this one) to help them to achieve the goals of the Adaptive Management process to:

- Determine the effectiveness of mitigation measures contained in the ROD.
- Provide a rapid response to unnecessary/undue environmental change.
- Validate predictive models used in the EIS and revise the models/projections as necessary based on field observations and monitoring.
- Complete an annual monitoring report of actual on-the-ground calculated potential NO_x emissions.
- Continue to cooperate in the implementation of existing visibility and deposition impact monitoring programs.
- Evaluate the need for additional monitoring.

This report contains information on existing air quality and air quality related value (AQRV) monitoring that is within and adjacent to the PAPA, existing NO_x emission tacking for the PAPA and Jonah field, existing emissions sources, modeling exercises and mitigation measures in and near the PAPA, and recommendations on future monitoring within and adjacent to the PAPA. This document will be presented annually to the PAWG leadership who will use the information contained therein to advise the Bureau of Land Management (BLM) on the status of the air resource in the PAPA. This document is meant to tier to our 2005 Air Quality Monitoring Plan

(hereafter referred to as the Monitoring Plan), which was submitted to the PAWG in March of 2005 and therefore this report will reference the Monitoring Plan for more detailed information where appropriate. This 2005 Report is due to the PAWG on May 10, 2006 and is considered the first annual update to the PAWG. This report should be viewed as an ongoing work in progress that will be modified annually. The AQTG's current recommendations can be found in Section 6.0.

While the focus of the AQTG is related to emissions directly from the PAPA, we need to acknowledge that many of the emissions measured in these areas can come from regional sources in SW Wyoming, other western states and even other countries. The Western Regional Air Partnership (WRAP) is currently working towards developing a source attribution assessment to evaluate the percentage of permitted emissions from these other sources that may impact each Class I Area in the western US. AQTG will consider the information from the assessment (once it is available) and may recommend further evaluation of the significance of local emissions versus regional emissions related to potential cumulative impacts to adjacent Class I Areas.

The following list represents the AQTG members and additional participants that helped assemble this report and develop recommendations on monitoring and mitigation.

Members:

- Terry Svalberg – AQTG co-chair; Air Quality Specialist for USFS Bridger –Teton NF
- Perry Walker – AQTG co-chair; Citizen participant
- William Belveal – Citizen participant
- Jonathan Ratner – Western Watersheds
- Jim Sewell – Staff Environmental Engineer for Shell Exploration and Production Company
- Mike Golas – General Manager, Environment and Health and Safety for Questar Exploration & Production Company
- Kate Forsting – Energy Labs
- Cara Keslar – Monitoring Project Advisor for Wyoming DEQ-Air Quality Division Monitoring Program

Additional Participants:

- Ted Porwoll – Hydrologic Technician for USFS Bridger –Teton NF
- Jennifer Quashnick – Environmental Representative for Questar Exploration & Production Company
- Joe Delwiche – NEPA Analyst for Region 8 EPA
- Susan Caplan – Meteorologist for Wyoming BLM
- Caleb Hiner—Geologist for BLM Pinedale Field Office

Background

The Pinedale Anticline Project Area (PAPA) (see Map 1 in the Monitoring Plan) covers approximately 197,345 acres of Federal, State, and private land, of which 80% is public land managed by the BLM. The PAPA extends from west of the town of Pinedale Wyoming approximately 25 miles to the south-southeast of the town of Pinedale and is generally bounded on the east by U.S. Highway 191.

The Pinedale Anticline ROD/EIS approved exploration and development of the PAPA for conventional oil and natural gas production. Drilling of wells and production and transportation of oil and gas necessitates equipment that emits air pollutants. These activities raise the question of whether air emissions from these projects will significantly affect the local or distant air resource and whether those effects can be measured, monitored and mitigated. Additionally, the proximity of the Jonah Field prompted BLM to specify in the ROD/EIS that the AQTG examine NO_x emissions from both fields collectively. The emissions in question are ―criteria pollutants" (e.g. nitrogen dioxide, particulate matter, sulfur dioxide), volatile organic compounds (VOCs) and hazardous air pollutants (HAPs). The long term, air resource impacts in question are local visibility and local health impacts as well as air quality related values (e.g. visibility, acid deposition, foliar damage from ozone, and changes in surface water chemistry) in the Bridger and Fitzpatrick Wilderness ―Class I" areas. The BLM and the FS have identified levels of impact that they consider ―significant" when reviewing effects in potentially impacted areas. These criteria can be found in Appendix B of the Monitoring Plan.

A great deal of air quality research and monitoring has been performed in the PAPA and in surrounding areas. The area's monitoring network includes several stations located in and adjacent to the PAPA, and boasts a variety of monitoring instruments to evaluate a diverse range of air quality aspects. Further, research concepts have incorporated the use of air quality *models* for southwest Wyoming, which have been developed and utilized in the area since 1997, when the Southwest Wyoming Technical Air Forum (SWWYTAF) modeled pollution sources in southwestern Wyoming, eastern Idaho, northeastern Utah and northwestern Colorado. The SWWYTAF used the CALPUFF modeling package to evaluate the degree of degradation to air quality, visibility, and other AQRVs in the Bridger and Fitzpatrick Wilderness Areas from anthropogenic (i.e. human) and biogenic (i.e. natural source, such as trees) sources. The model and inventory were not maintained due to technical advances, however, the 1995 MM5 data developed for the project is still used extensively for regulatory and NEPA modeling purposes. These models have evaluated air quality on a cumulative basis for the entire southwestern region of Wyoming.

Air emission mitigation measures within the PAPA are extensive and include those mandated by BLM in RODs/DRs, the Wyoming Department of Environmental Quality and the Environmental Protection Agency as well as numerous voluntary measures implemented by oil and gas producers in the PAPA. Details are discussed in Section 4.

Weather and Climate

Weather and climate are two of the pronounced variables when reviewing air quality conditions, therefore must be included attempting to identify air quality trends from existing data. For the purpose of this document, discussion of weather averages, extremes and climate trends will be limited to the Pinedale area.

Climate is defined as the average condition of the weather, at a particular location, over a long period of time which may be years, decades, or even centuries. Weather is defined as the state of the atmosphere with respect to temperature, precipitation, wind, and cloudiness, among other things, at a given time and place. While climate changes can confound interpretation of air quality data, weather changes are even more difficult to account for given their short duration and often extreme variability.

Weather affects all aspects of air quality to certain degrees. The dynamic nature of weather necessitates that it be considered in terms of events and short term fluxes as opposed to solely long term trends. The weather's effects are more pronounced in data collected and reviewed in short intervals. While short term variability is relatively high for weather data the sheer number of samples tends to average out spikes in the data when averaged or viewed over the longer term.

Visibility is affected by the weather in several ways. Precipitation has the most obvious effect, but high relative humidity can also significantly affect visual range when light is scattered or absorbed by visibility impairing pollutants (e.g. sulfate, nitrate) that are hygroscopic in nature. Wind can affect visibility by picking up and suspending fine particulate or transporting pollutants from other regions. Stratification and stagnation of air masses due to similarities or differences in temperature and density may also affect visibility.

Atmospheric deposition is affected by short term wind patterns and precipitation events. Wind can change the direction from which pollutants are transported and can disperse pollutants where they may otherwise be more concentrated. Precipitation events effectively scrub pollutants from the atmosphere and deposit them on the surface. Lower precipitation amounts generally result in a higher concentration of pollutants while higher precipitation amounts will result in more dilute samples. During periods of higher precipitation more pollutants may be deposited, but that deposition is more dilute and may have a different effect on terrestrial and aquatic systems.

The effects of weather on regulated pollutant monitoring are similar to those associated with deposition. Wind or the lack of can transport, disperse, or concentrate pollutants. Precipitation can clean pollutants out of the atmosphere and lower their concentrations in the air. Seasonal variations in parameters such as temperature or solar radiation can also have an affect on pollutants emitted (or controlled) by oil and gas operations. Appendix A contains more detailed information on meteorological data collected at the ambient air quality monitoring stations (windroses, etc.). Seasonal affects on monitored pollutants (e.g. NO_2, O_3) and AQRVs (e.g. visibility, deposition) can also be found in Appendix A.

New monitoring

Since the Monitoring Plan was submitted in March 2005, two new monitoring stations have been established near the Pinedale Anticline Project Area. WDEQ-AQD established a monitoring station in July 2005 approximately five miles south of Daniel (called ―Daniel South"). This station has NO_x, ozone, continuous PM_{10}, meteorological parameters and a camera. The WDEQ-AQD also established a $PM_{2.5}$ monitor in the town of Pinedale in July 2005. These monitors are discussed in more detail in Section 3.1 of this report. Both of these monitors were planned by WDEQ-AQD as separate actions, not suggested by the AQTG. The only monitoring that took place as a result of AQTG recommendations to the PAWG was BLM's fulfillment of the NO_x Tracking Report agreement. Currently, BLM is in the process of finishing this report.

Use and interpretation of data

There are several ways in which ambient air quality is reported, each meeting specific technical needs. Many federal and state air quality standards are based on the *annual average* concentration of a pollutant. Annual averages are necessary for evaluating historical and current air quality trends, long-term health impacts associated with air quality values (e.g. human health, water quality, etc.), and to assess the air quality conditions in a given area (whether to answer specific questions or assess an area without historical data). Some Federal and State standards are based on studies that have shown negative impacts when pollution levels exceed a specified annual concentration, therefore standards are set at a level where, as long as the standard is met, impacts are within a range determined acceptable by federal and state governments.

Another way to express air quality concentrations is by season, month, day, hour, etc. Some federal and state standards based on protecting human health include a 24-hour average standard (and in some cases, even shorter time frames) where negative impacts have been seen with pollution levels that exceed a certain value for even just one day or less. Another reason for looking at data within these shorter time frames is to evaluate source impacts, and by extension, mitigation strategies. This is because it is often difficult to evaluate specific sources, weather impacts, etc., when only looking at conditions averaged over an entire year. For example, weather conditions can play a very significant role in air quality conditions, including ambient pollution levels. This may result in higher pollution levels in the summer versus winter regardless of mitigation applied consistently throughout the year. However, if data are not analyzed by season in addition to annual values, then the effects of weather and, where applicable, seasonal mitigation measures, may not be easy to see and therefore one can not be very certain of which sources are creating which impact (and whether mitigation measures are truly doing what was expected). For example, annual averages may not answer a question such as: is the reduction in annual NOx due to mitigation control —Ã last winter, ”B” from last summer, and/or weather impacts? If the answer is unknown, and decisions are made based on assumptions, then air quality levels could irreversibly deteriorate if those assumptions were wrong. Again, this is not meant to suggest that annual averages are not useful; rather, this discussion is meant to explain that data evaluated both annually and in shorter time frames are most useful in combination.

2 Activity Tracking

This section displays notable activities such as drill rig numbers, events and observations that were made in the Pinedale Anticline area during 2005 by month. Some of these events have been correlated to events monitored by the ambient air monitors and cameras located at those sites. Tracking this information gives us a way to evaluate sources present on days when monitor data indicates particulates or NO_x are elevated. Please note that this list does not contain all activities occurring in and around the PAPA; it is an attempt to characterize notable activities specifically related to air quality.

January

- Rig Count: 17
- Boulder AQ Monitoring Station installation underway
- Jonah AQ Monitoring Station operational

February

- Rig Count: 20
- Boulder AQ Monitoring Station operational
- Elevated ozone events measured at Boulder and Jonah AQ Monitoring Stations
- Inversions noted in valley

March

- Rig Count: 20
- Agricultural burning begins in Utah and Idaho
- Operators switch to low sulfur diesel

April

- Rig Count: 20

May

- Rig Count: 23
- End of winter drilling restriction on Federal lands north of Hwy 351
- Questar begins bussing rig crews
- Construction season begins

June

- Rig Count: 30
- Sublette County began treating gravel roadways (Paradise Road) in area
- Operators began treating roadways on the Mesa
- Forest fire smoke in area from fires in Utah / Nevada
- Operator upset flare

July

- Rig Count: 31
- Daniel South AQ Monitoring Station operational
- Reduced flare completions required by WDEQ
- Pinedale $PM_{2.5}$ monitor operational

August

- Rig Count: 33

September

- Rig Count: 31
- Forest Service - Soda Lake controlled burn

October

- Rig Count: 30

November

- Rig Count: 25
- Winter drilling restrictions begin on Federal lands north of Hwy 351
- ASU approved to drill on Mesa during winter, six rigs allowed
- Questar approved to drill year round on Mesa, seven rigs allowed
- Questar condensate and water gathering systems begins operation
- Construction season ends

December

- Rig Count: 23
- Operator flare upset event
- Inversions noted in valley
- ASU operators install NOx reduction technologies on six rigs

Note: Rig count is from Rig Data, 2006 and is an approximation for PAPA. Discrepancies were noted when reviewed.

3 Data Analysis

Regulated Pollutant Monitoring

This section of the report discusses regulated pollutant monitoring and meteorological data being collected in the Pinedale Anticline area. Additional information related to these data is located in Appendix A.

Three stations are performing air quality monitoring in the Upper Green River Basin. The Jonah Monitoring Station is located on the southeastern edge of the Jonah gas development area, the Boulder Monitoring Station is located southwest of the town of Boulder and the Daniel South Monitoring Station is located south of the town of Daniel. This section describes the air quality, and meteorological monitoring at these monitoring stations from January 1, 2005 – December 31, 2005.

<u>Boulder Monitoring Station</u>
ARS collects and validates nephelometer (particle scattering), ambient temperature, and relative humidity data at the Boulder station. The ambient temperature and relative humidity values are used to validate the nephelometer data. ARS also operates a high resolution digital camera that collects digital images at 15-minute intervals. Intermountain Laboratories (IML) collects nitrogen dioxide, ozone, PM_{10}, ambient temperature, relative humidity, wind speed, wind direction, precipitation, barometric pressure, and solar radiation data. They validated all parameters, and provided a final data set to ARS for inclusion in this report.

<u>Daniel South Monitoring Station</u>
IML collects nitrogen dioxide, ozone, PM_{10}, ambient temperature, relative humidity, wind speed, wind direction, precipitation, barometric pressure, and solar radiation at the Daniel station. IML validated all parameters and provided a final data set to ARS for inclusion in this report. ARS operates a high resolution digital camera that collects digital images at 15-minute intervals.

Because the Daniel South Monitoring Station has been operating for less than a year (since July of 2005) comparisons to NAAQS and WAAQS are not appropriate, however it is still important to examine data that has been collected to this point. Daniel South data is not presented in Tables 3.2-3.4; summary data for July 2005- December 2005 can be found in Appendix A.

Jonah Monitoring Station

Meteorological Solutions, Inc. (MSI) collects oxides of nitrogen, ozone, PM_{10}, ambient temperature, wind speed, wind direction, precipitation, barometric pressure, and solar radiation at the Jonah infill station. Relative humidity was not collected at this station during 2005. MSI validated and provided final data to ARS for inclusion in this report. ARS operates a high resolution digital camera at this station that collects digital images at 15-minute intervals.

The scope of the monitoring program(s) include the collection and reporting of air quality, meteorological, and visibility data from three (3) monitoring stations in the Pinedale Anticline Region and Jonah infill area. All instrumentation operated on Mountain Standard Time (MST).

Figure 3-1 Location and geographical orientation of the three (3) monitoring locations.

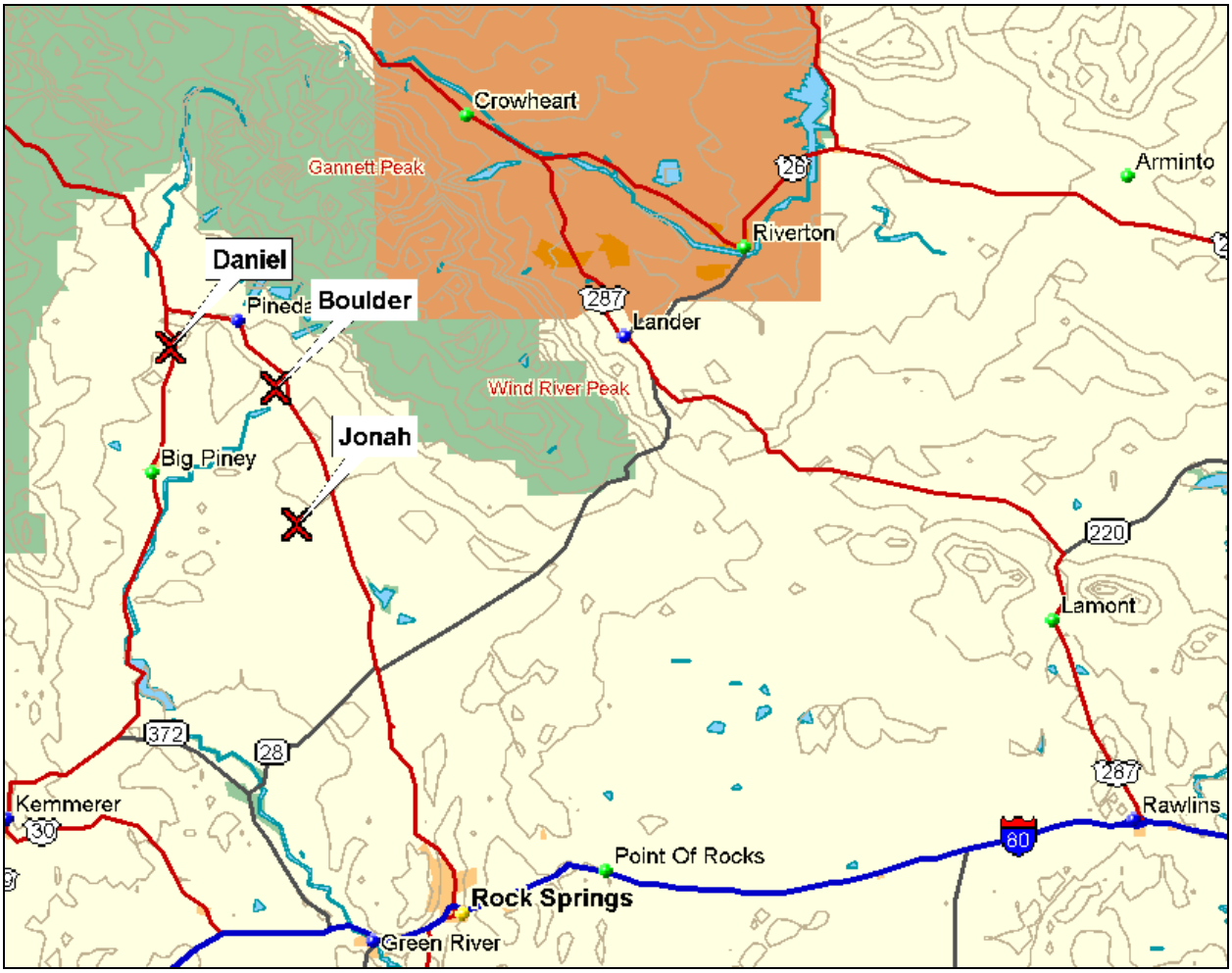


Table 3-1 Site Specifications for Gaseous Monitoring Sites January 1, 2005 – December 31, 2005

Site Name	Latitude (°N)	Longitude (°W)	Elevation (feet)
Boulder	42° 43‘	109° 45‘	7,109
Daniel	42° 48‘	110° 03‘	7,356
Jonah	42° 25‘	109° 41‘	6,649

The following tables present values from the Boulder and Jonah Monitoring Stations that can be compared to the NAAQS/ WAAQS. It is important to note that compliance with the NAAQS/WAAQS cannot be determined until three consecutive years of data have been collected.

Table 3-2 Standards Summary Report Nitrogen Dioxide (NO_2)

WAAQS (Annual Arithmetic Mean)*: 54 ppb/0.05 ppm (100 µg/m^3) **1/1/2005 – 12/31/2005**			
Site	**Valid Days (% valid)**	**Measured Value**	**Date(s)**
Boulder	311 (85%)	Annual Arithmetic Mean: 2 ppb	02/01-12/31/05
Jonah	333 (91%)	Annual Arithmetic Mean: 9 ppb	01/01-12/31/05

* To calculate a valid annual arithmetic mean, the year must have at least 75% valid days, or at least 75% valid days for the scheduled sampling days in each calendar quarter.

Table 3-3 Standards Summary Report Particulate Matter ≤10µg/m3 (PM_{10})

WAAQS (Annual Arithmetic Mean)*: 50 µg/m^3 WAAQS (24-hour average)**: 150 µg/m^3 **1/1/2005 – 12/31/2005**			
Site	**Valid Days per Quarter** (% valid)**	**Measured Value**	**Date(s)**
Boulder	Q1: 53 (58%) Q2: 91 (100%) Q3: 84 (91%) Q4: 89 (97%)	Annual Arithmetic Mean: 10.4 µg/m^3	4/1/05-12/31/05
		24-hour Max: 39.5 µg/m^3	9/10/05
Jonah	Q1: 90 (100%) Q2: 88 (97%) Q3: 89 (97%) Q4: 73 (79%)	Annual Arithmetic Mean: 10.3 µg/m^3	1/1/05-12/31/05
		24-hour Max: 61.3 µg/m^3	8/30/05

* To calculate a valid annual mean, each quarter must have 75% valid days.
** To attain this standard, the average cannot exceed the standard more than once per year.

Table 3-4 Standards Summary Report Ozone (O_3)

WAAQS (Rolling 8-hour)*: 0.08 ppm (84 ppb or 157 µg/m^3) WAAQS (1-hour): 0.12 ppm (124 ppb or 215 µg/m^3) 1/1/2005-12/31/2005					
Site	**Period**	**Averaging Time**	**Valid Days (percent valid)**	**Measured Value**	**Date(s)**
Boulder	Annual (2005)	Rolling 8-hour	313 (86%)	Highest Daily Max.: 89 ppb	2/20
				4th Highest Daily Max.: 81 ppb	2/3
		1-hour	313 (86%)	Highest Daily Max.: 110 ppb	2/20
	Ozone Season (5/1-9/30)	Rolling 8-hour	140 (92%)	Highest Daily Max.: 72 ppb	6/27
				4th Highest Daily Max.: 68 ppb	7/12
		1-hour	142 (93%)	Highest Daily Max.: 81 ppb	7/23
Jonah	Annual (2005)	Rolling 8-hour	334 (92%)	Highest Daily Max.: 98 ppb	2/3
				4th Highest Daily Max.: 76 ppb	2/4
		1-hour	334 (92%)	Highest Daily Max.: 119 ppb	2/3, 2/26
	Ozone Season (5/1-9/30)	Rolling 8-hour	145 (95%)	Highest Daily Max.: 73	6/27
				4th Highest Daily Max.: 67	7/22
		1-hour	142 (93%)	Highest Daily Max.: 80	6/27, 7/16

* To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area during the designated ozone season (May 1 through September 30) must not exceed the standard. A year of ozone data is only considered if valid daily maximums are available for at least 75 percent of the ozone season.

Please note that on June 15, 2005 the Federal 1-hour ozone ambient air quality standards was revoked to coincide with the 1-year anniversary of the 8-hour ozone nonattainment designations. WDEQ-AQD followed suit and revoked the 1-hour State standard in January of 2006.

The Boulder and Jonah monitoring stations each recorded their highest ozone readings in February of 2005. The Boulder station recorded an 8-hour average of 89 ppb on February 20,

2005. The Jonah site recorded daily maximum 8-hour averages of 98 ppb on February 3, 2005, and 89 ppb on February 26, 2005.

Ozone exhibits a diurnal cycle at both the Boulder and Jonah stations, with the lowest concentrations in the early morning hours and maximum concentrations in the late afternoon. This pattern results from daytime photochemical production from NO_X ($NO + NO_2$) and VOC precursors or downward transport of O_3 rich air from above, and ozone loss by dry deposition and reaction with NO at night (Seinfeld and Pandis, 1998). The basic formation and depletion equations for O_3 are presented below:

$$NO_2 + \text{sunlight} \rightarrow NO + O$$

$$O + O_2 \rightarrow O_3$$

$$NO + O_3 \rightarrow NO_2 + O_2$$

Figure 3-2 presents the diurnal cycles of measured O_3 and NO_2 at the Boulder station, and for O_3, NO, and NO_2 at the Jonah station in February 2005. A NO_X pattern is very pronounced at the Jonah station, where the concentrations of NO and NO_2 rise and reach a maximum average in the early morning, with concentrations falling as O_3 is formed.

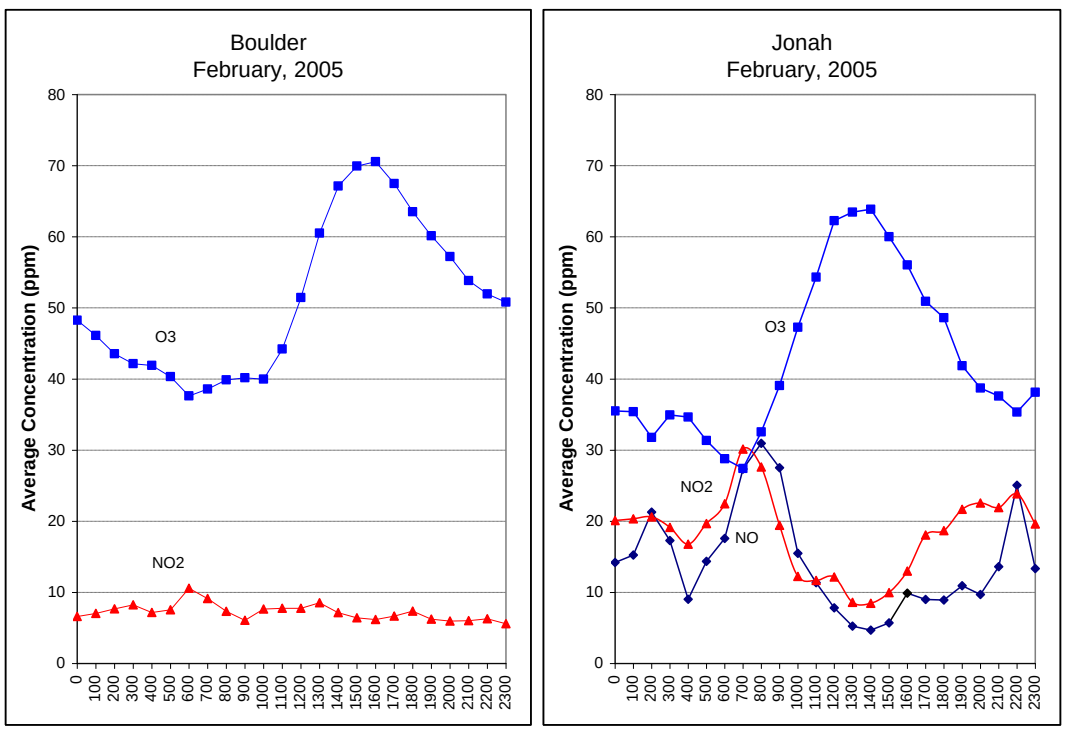


Figure 3-2 Diurnal Patterns Showing Average Concentrations of O_3 and NO_2 at the Boulder Monitoring Station; and O_3, NO_2, and NO at the Jonah Monitoring Station for February 2005.

Throughout most of February and early March 2005, when the highest values of O_3 were observed at the Boulder and Jonah stations, winds were calm and the air was cold. Regional characteristics including the mountain ranges around the Pinedale Anticline Region can prevent local air mixing, allowing colder, heavier air to settle into the valley. This settling of cold air creates a temperature inversion, which can confine pollution close to the surface.

On March 6, the weather pattern appears to change abruptly from the low wind speeds that were observed throughout most of February, to a strong northwesterly wind pattern. Figure 3-3 presents a timeline of selected parameters from the Boulder monitoring station, illustrating a stark reduction in NO_2 and O_3, and a coinciding increase in wind speed. Figure 3-4 presents February and March wind roses showing wind speeds in February were generally less than 4 m/s, from various directions, and wind speeds in March increased to as high as 16 m/s coming from the northwest (NW) and north-northwest (NNW).

Figure 3-5 presents a digital image looking to the southwest taken from the Boulder camera on March 5, 2005 (0830) showing an inversion trapping air in the valley. The image presented in Figure 3-6 shows the same southwesterly view the next morning (March 6, 2005, 0830) after the predominant winds in the area have changed speed and direction.

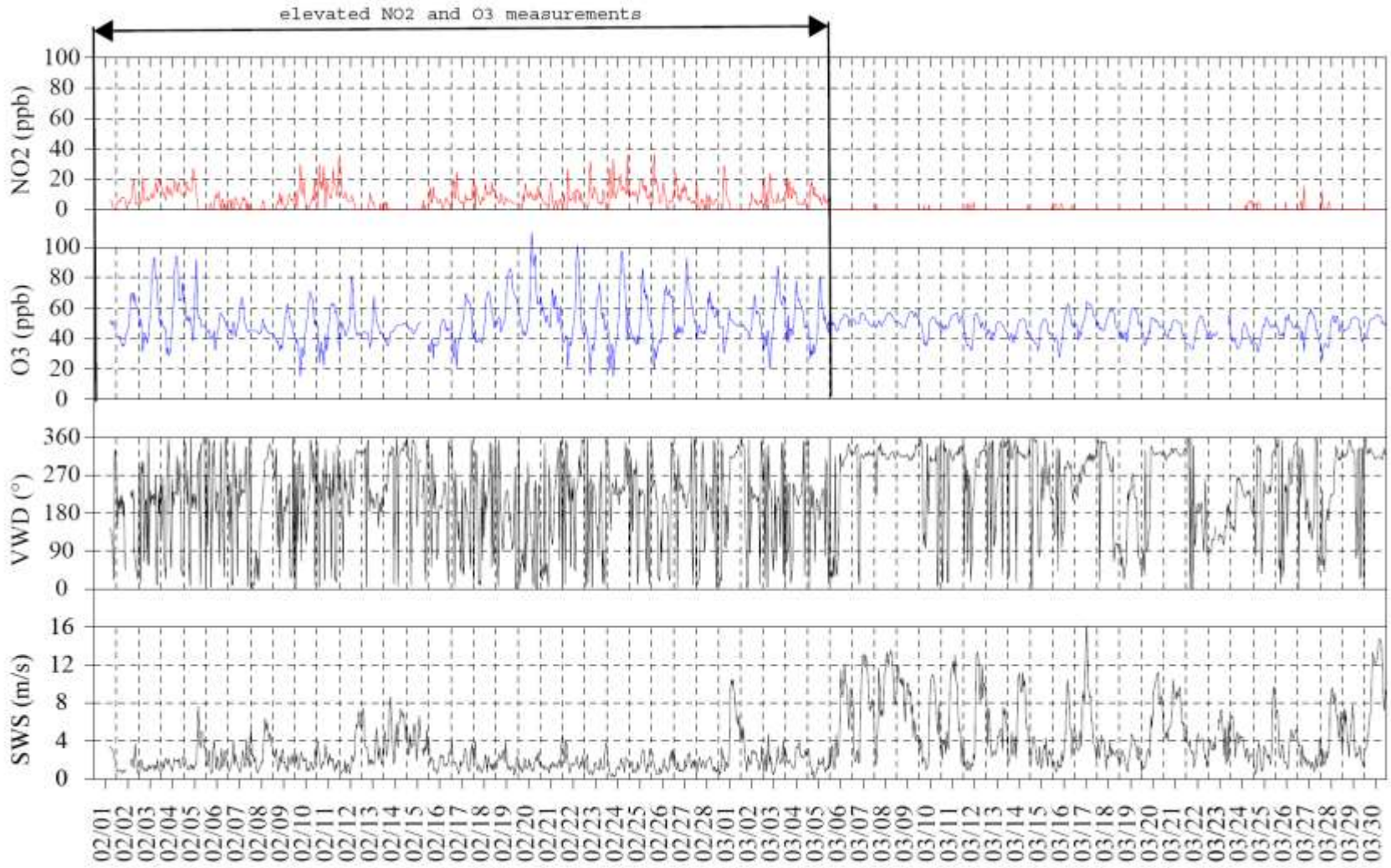


Figure 3-3 Timeline of Selected Parameters from the Boulder Monitoring Station

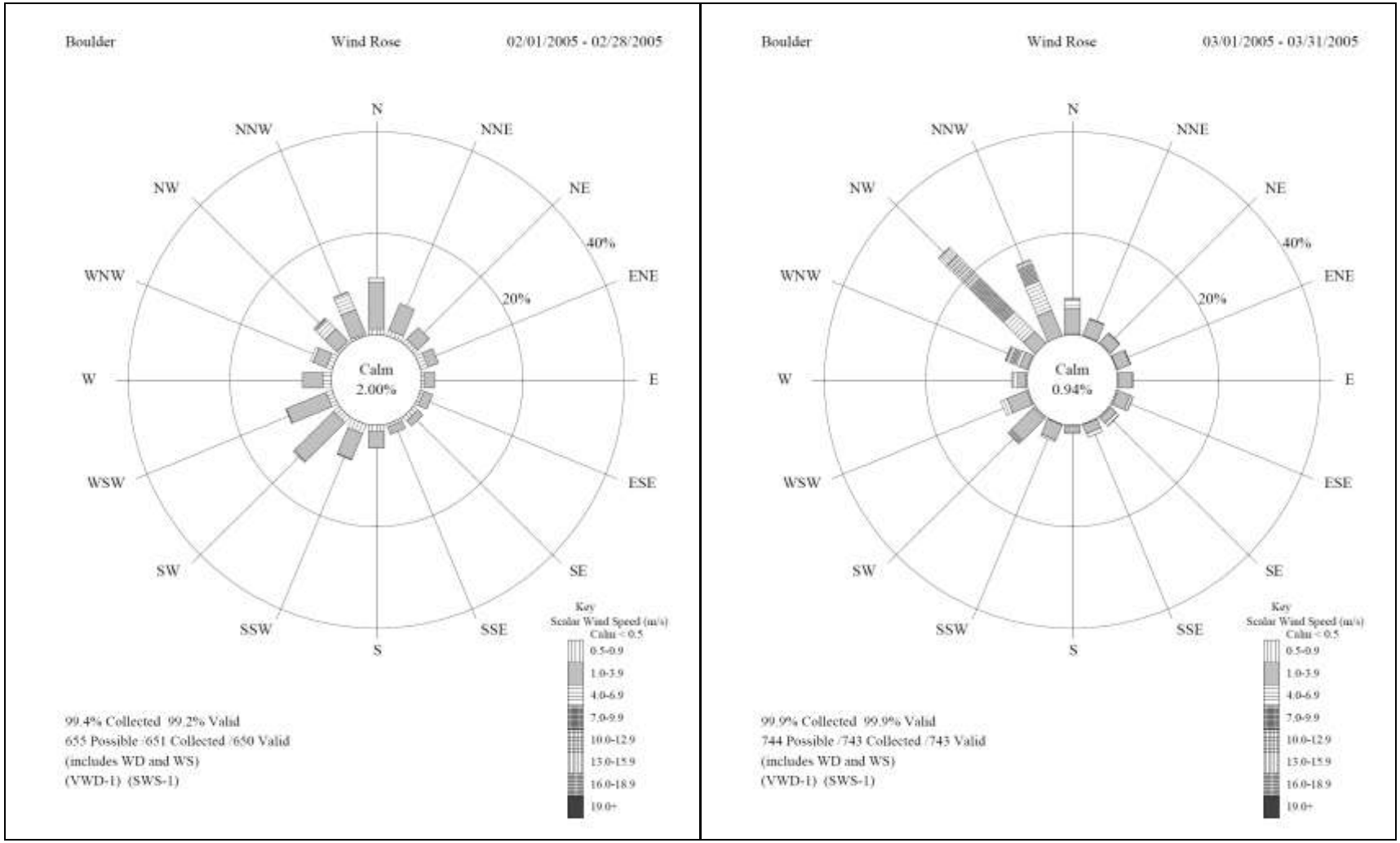


Figure 3-4 Wind Roses from the Boulder Monitoring Station from February and March 2005

Figure 3-5 Image Taken from the Boulder Camera March 5, 2005 (0830)

Figure 3-6 Image Taken from the Boulder Camera March 6, 2005 (0830)

PM 2.5

The Pinedale $PM_{2.5}$ monitor began operation in July of 2005. The Pinedale $PM_{2.5}$ monitor operates on the 1-in-3 day sampling schedule; during the third and fourth quarter of 2005, the monitor had 92% and 81% valid samples, respectively. Because there has not been a full year of data collected, a comparison cannot be made to the NAAQS Annual or 24-hour $PM_{2.5}$ standard. However, for informational purposes the following table lists the five highest 24-hour $PM_{2.5}$ concentrations collected in 2005 and the dates of their collection. For reference, the current 24-hour standard for $PM_{2.5}$ is 65 $\mu g/m^3$.

Table 3-5 Five highest 24 hour PM2.5 concentrations for 2005

Date	$PM_{2.5}$ Concentration ($\mu g/m^3$)
12/03/05	24.3
12/21/05	13.2
12/30/05	12.8
12/12/05	12.7
11/30/05	9.1

Atmospheric Deposition/Concentration Monitoring

This portion of the report discusses ongoing deposition and concentration monitoring occurring in the Pinedale Anticline area. This section addresses long-term lake monitoring, NADP monitoring, CASTNet monitoring, WARMS monitoring and bulk deposition monitoring. Additional and more detailed information for these monitoring results are presented in Appendix B.

Long-term Lakes

Currently there are six long-term lakes that are being monitored in the Wind River Mountains to determine if changes from atmospheric deposition are occurring. These lakes are Hobbs, Black Joe, Deep and Upper Frozen Lakes on the Bridger-Teton NF, and Ross and Lower Saddlebag Lakes on the Shoshone NF. Recent funding has been allocated to do a detailed statistical analysis of the long-term lake chemistry for the lakes on the Bridger-Teton NF. The analyzed data for the Bridger-Teton NF will be the focus of this discussion, while data from the Shoshone NF long-term lakes will be analyzed in the future.

Protocols for long-term lake sampling entail sampling the inlet and outlets 3 times a year (June-early July, August and October), as well as additional sampling in the center of the lake during the August sampling trip. This additional sampling includes sampling the epilimnion (sampled just below the surface in the center of the lake) and hypolimnion (sampled below the thermolcline in the middle of the lake, often 30 to 60 feet below the surface). In addition, on the August sampling trip, samples of macroinvertibrates are collected at the inlet and outlets and zooplankton samples are collected at the center of the lake. The single exception to the sampling protocol is Upper Frozen Lake which is only sampled once a year during the August sampling period because of limited and hazardous access.

Laboratory analysis has been completed by the United States Geological Survey (USGS) laboratory in Denver Colorado from 1984 to 1991, and the Rocky Mountain Research Station (RMRS) laboratory in Fort Collins, Colorado from 1991 to present.

Trends in nitrate, sulfate, and acid neutralizing capacity (ANC) for the long term data sets were analyzed using the WQStatPlus statistical package. For lakes in which samples are collected at the epilimnion, hypolimnion, inlets and outlets, each sampling location is analyzed separately. For non-seasonal data, the Mann-Kendall test was run to determine if there were significant temporal trends. Where data were seasonal, as indicated by the Kruskal Wallis statistic, both the Mann-Kendall and the Seasonal Kendall tests were run to determine if both tests provided essentially the same results. They matched in all cases of this analysis. A minimum of eight data points are necessary to perform the non-parametric test. Upper Frozen Lake had exactly eight data points, but the first two were collected early in its season, while the remaining six samples were collected later in the year. This could give the appearance of a false trend, so the data are plotted on a time-series plot, but no trend analysis is presented.

A simple summary of the statistical analysis that has been completed for 1984-2005 is shown in Table 3-6. An upward arrow indicates there is a minimum of an 80% confidence that the trend is upward (in this case, an 80% confidence level is indicative of a significant trend with a statistically sound level of certainty). A downward arrow indicates that there is a minimum of an 80% confidence level that the trend is decreasing and a dashed line indicates there is no significant trend. One anomaly is for Hobbs Lake Hypolimnion that is marked with a triple asterisks (***). This indicates there is a significant (95% confidence) that no change is occurring. Please note that in this table, the direction the arrow is pointing is not meant to signify ―good or bad," but rather to show that there is a significant trend and illustrate the direction of the trend (increasing or decreasing). Highlighted cells in the table indicate trends that are of concern. A more detailed discussion of the trend analysis for the period of record is included for each lake below and detailed information and graphs including seasonality are presented in Appendix B.

Table 3-6 Statistically Significant Trend in Long Term Lakes

	ANC Trend	NO3 Trend	SO4 Trend
Black Joe Lake Epilimnion	---	---	---
Black Joe Lake Hypolimnion	↑	↑	---
Black Joe Lake Inlet	↑	↑	---
Black Joe Lake Outlet	↑	↑	↑
Deep Lake Epilimnion	---	---	↓
Deep Lake Hypolimnion	---	---	↓
Deep Lake Inlet	---	↑	---
Deep Lake Outlet	---	---	↓
Hobbs Lake Epilimnion	---	---	↓
Hobbs Lake Hypolimnion	---	***	↓
Hobbs Lake Inlet	---	↑	↓
Hobbs Lake Outlet	↓	---	---

Note: Shaded cells indicate there is a concern with the trend that is occurring.

Black Joe Lake

The data analysis shows a significant seasonality to the chemistry (ANC, NO3 and SO4) at the inlet to the lake. This pattern is not significant for either the outlet, hypolimnion or epilimnion samples.

ANC is increasing at the 90 and 95% confidence levels at the inlet, outlet and hypolimnion samples. The rate of increase in ANC is ranging from 0.54 μeq/l/yr to 0.68 μeq/l/yr

Nitrate concentrations are also increasing at the 90 to 95% confidence levels for the inlet, outlet and hypolimnion samples. The rates of increase for these sites range from 0.002 mg/l/yr to 0.03 mg/l/yr.

Sulfate concentrations at Black Joe Lake are increasing slightly (80% confidence level) at the outlet only at a rate of 0.011mg/l/yr.

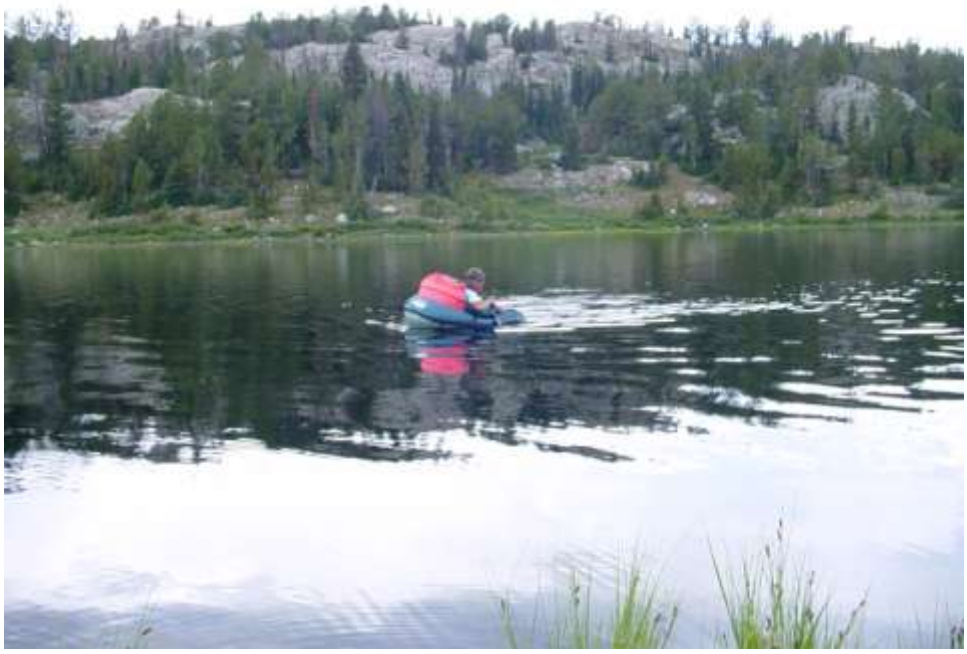
Deep Lake

The data analysis shows a significant seasonality to the chemistry (ANC, NO_3 and SO_4) at the inlet to Deep Lake. This pattern is not significant for either the hypolimnion or epilimnion samples, though there is seasonality for NO3 at the outlet.

ANC at this lake has no significant trends.

Nitrate concentrations are also increasing at the 95% confidence levels for the inlets. The rate of increase for this is about 0.021 mg/l/yr.

Sulfate concentrations are decreasing slightly (80 to 95% confidence level) at the outlet, epilimnion and hypolimnion at a rate of 0.008mg/l/yr to 0.018 mg/yr.



Hobbs Lake

The data analysis shows a significant seasonality to the chemistry (ANC, NO_3 and SO_4) at the inlet to Hobbs Lake. This pattern is not significant for either the outlet, hypolimnion or epilimnion samples.

ANC is decreasing at the 80% confidence levels at the inlet and the outlet. The rate of decrease in ANC is about 0.34 μeq/l/y.

Nitrate concentrations at Hobbs Lake are also increasing slightly at the 95% confidence levels for the outlet and epilimnion samples. Concentrations fluctuate from 0.0 mg/l/yr to 0.002 mg/l/yr.

Sulfate concentrations at Hobbs Lake are decreasing slightly (80% to 95 %confidence level) at the inlet, epilimnion and hypolimnion at a rate of 0.006 mg/l/yr to 0.008 mg/l/yr.

Upper Frozen Lake

There were too few samples at Upper Frozen Lake to complete the statistical analysis. The data shows that from 1997 to 2005 ANC ranged from 2.0 to 21.4 μeq/l. During that same time period nitrate ranged from.0166 to 0.596 mg/l, and SO4 ranged from 0.386 to 0.572 mg/l, both generally increasing over time.

Discussion

Increasing nitrates at all sampled inlets of lakes indicate that regional sources are probably contributing to local deposition. The decrease of ANC at Hobbs Lake outlet is of concern, because it is showing that acidification is starting to occur. From the USFS standpoint, Black Joe Lake is also a major concern because the ANC and nitrates are increasing at the inlets, outlet and hypolimnion, and sulfate is increasing at the outlet. This indicates that fertilization (nitrification) of the lake is occurring meaning that the lake is not able to use all of the nitrogen entering the lake system. This is a first step to eutrophication of the lake, and changes within the lake biota may be starting to occur.

Due to these findings, USFS thinks it is worthwhile to investigate biological data (macroinvertibrates and zooplankton) at Black Joe Lake to determine if a shift to more nitrophyllic species is occurring. This should also include some paleosediment sampling to look at historical diatom community structure changes over time. Currently this investigation is unfunded and is included in the recommendations.

National Atmospheric Deposition Program (NADP)

There are three NADP sites in operation that are included in the air monitoring network for the Pinedale area. Of these three, the Bridger-Teton and Shoshone Forests operate two sites (Gypsum Creek and South Pass). The Pinedale site is operated by the BLM. Individual site parameters are discussed in the Monitoring Plan. Additional network information, monitoring data, summaries and quality assurance information can be found at http://nadp.sws.uiuc.edu.

NADP Data

Based on the atmospheric concerns in the Pinedale area, only data associated with the deposition of nitrogen and sulfur-based compounds (NH_4, NO_3 and SO_4) are evaluated in this report. For quality assurance purposes, the NADP program includes criteria developed to assess the validity of a sample. Unfortunately, the annual trend summaries generated by the NADP website contain numerous data points which do not meet all of the program's criteria. This is primarily due to issues the NADP network has had with their collectors' efficiencies. The collectors are not efficient when collecting snow blown by high winds. This creates a discrepancy between the sample collected and the amount of precipitation recorded by the rain gauge, which is responsible for a majority of the samples being designated as ―not meeting all criteria.". This is an issue that NADP has at several northern, high altitude sites (see the NADP website for more details). However, only the total deposition data are included in this report, and therefore it is expected that this discrepancy is not likely to affect total deposition values as much as the precipitation-weighed values (also provided by NADP on the website). Additionally, because these are the only historical and current deposition data available for the area, this report will present figures based on all data regardless of whether all NADP criteria were met. However, data used to support any regulatory changes or needs must undergo extensive technical scrutiny which is beyond the scope of this report. The following graphs were created with the data listed in the individual annual and seasonal data summaries (from the NADP website) for all years associated with each monitoring site.

The seasonal and annual averages for the NADP data are presented below. As the website states, there is a five to six month lag time between data collection and data availability on the web, therefore data from the latter half of 2005 are not yet available. Winter and spring 2005 values are shown in the following seasonal graphs, where applicable.

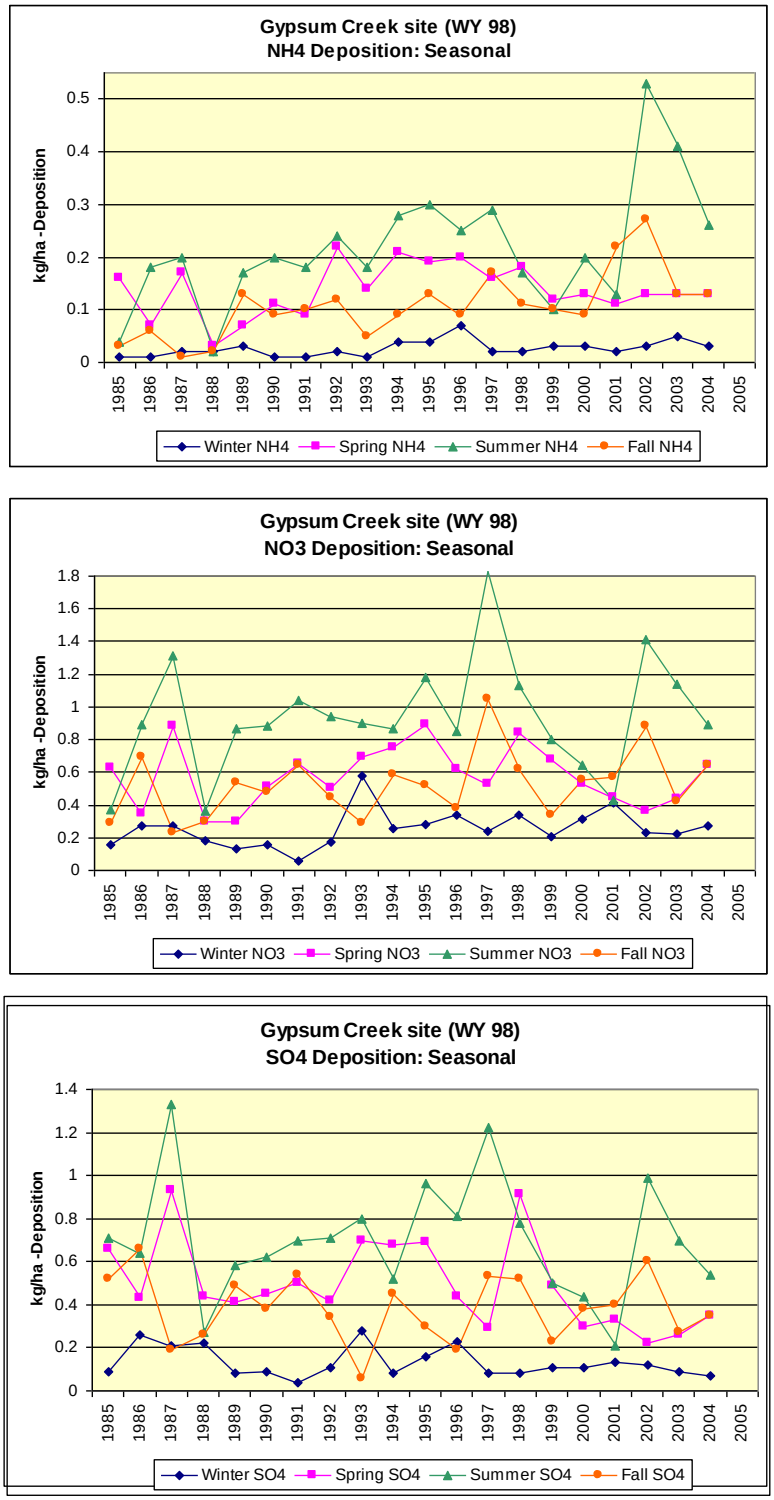
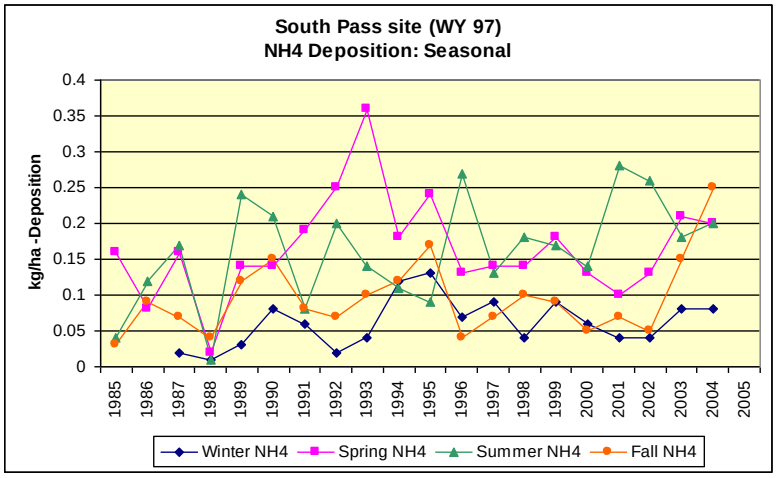
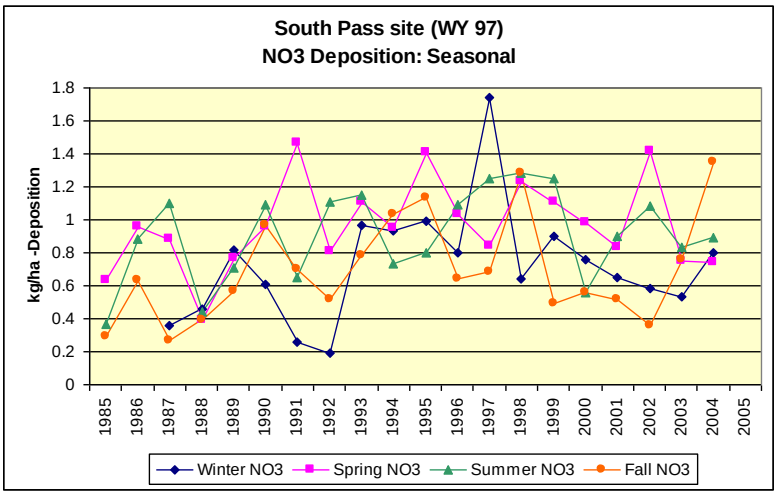


Figure 3-7 Seasonal deposition values for NH_4, NO_3 and SO_4 at the Gypsum Creek Site (WY 98). Values are in kg/Hectare (kg/Ha). NOTE: 1 Hectare = 10,000 square meters.





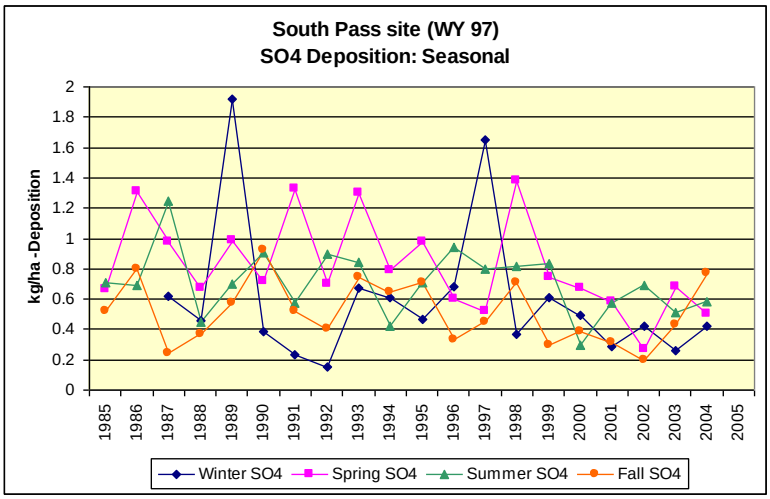


Figure 3-8 Seasonal deposition values for NH_4, NO_3 and SO_4 at the South Pass Site (WY 97). Values are in kg/Ha. NOTE: 1 Hectare = 10,000 square meters.

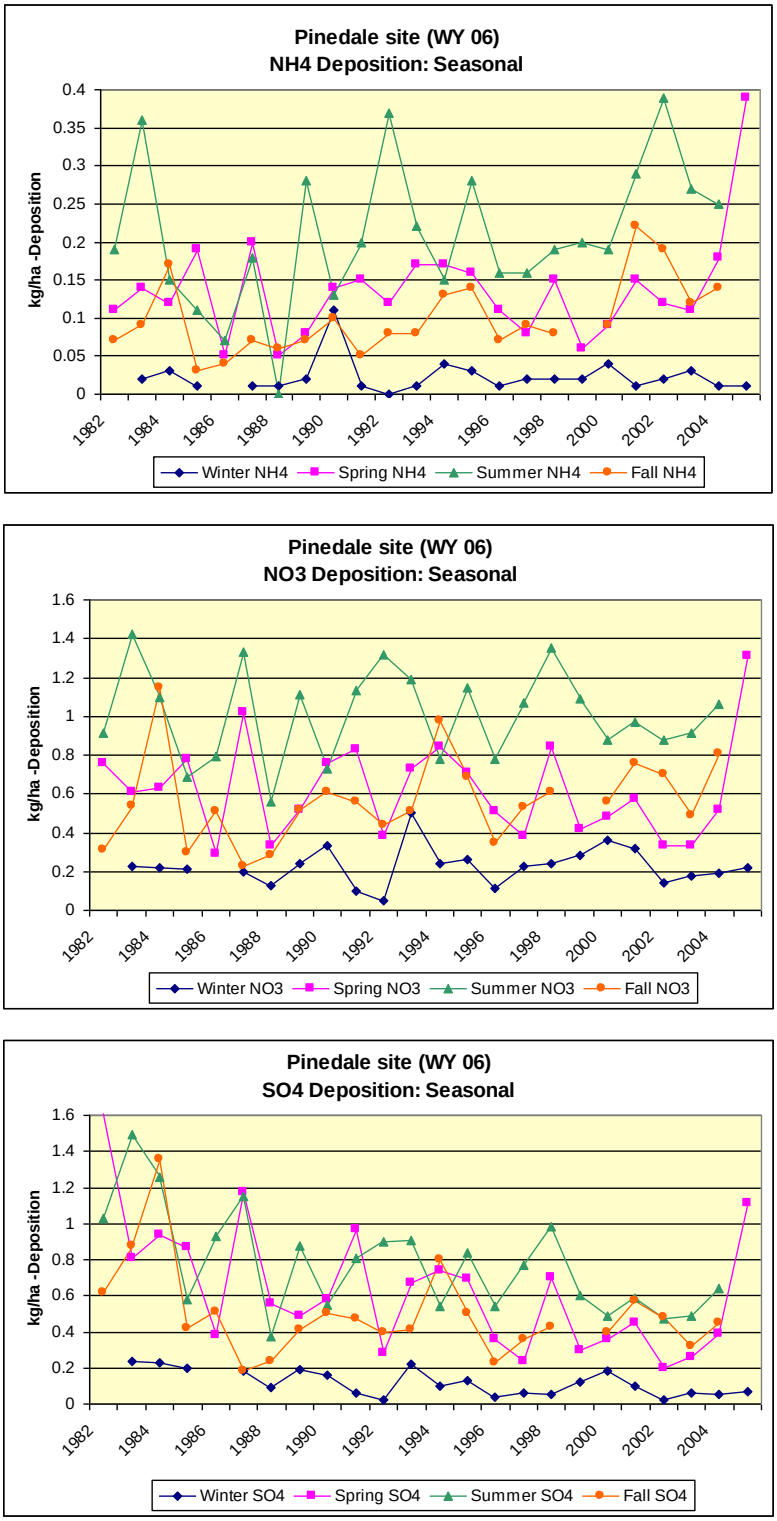


Figure 3-9 Seasonal deposition values for NH_4, NO_3 and SO_4 at the Pinedale Site (WY 06). Values are in kg/Ha. NOTE: 1 Hectare = 10,000 square meters.

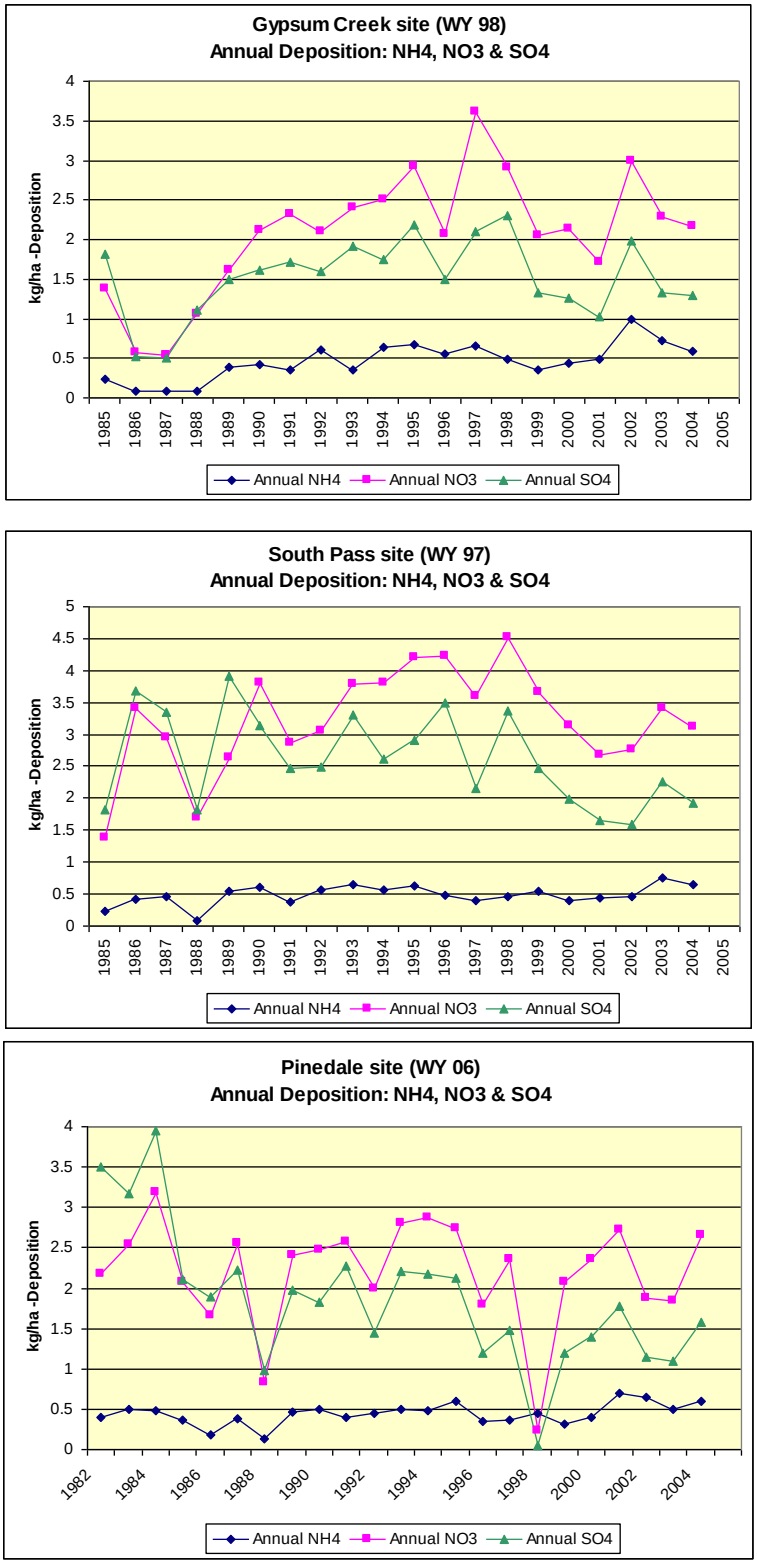


Figure 3-10 Annual deposition values for NH_4, NO_3 and SO_4 at the Gypsum Creek, South Pass and Pinedale Site, respectively. Values are in kg/Ha. NOTE: 1 Hectare = 10,000 square meters.

Discussion

Although it appears that on a seasonal scale, summer nitrogen deposition values are generally the highest and winter values the lowest, there is a good deal of variation among most of the seasonal data. For annual average data, the nitrogen-based compounds show an almost steady line between all years, with increases and decreases occurring throughout, but generally forming an almost horizontal trend line across the entire period. Positive and negative trends (points above and below the _horizontal line‘) appear to follow about the same timeline across all three sites, which normally might suggest that regional sources and events (e.g. weather, large-scale pollution events such as wildfires, etc.) are playing a far more important role than local sources (since irregular or acute local impacts tend to get _lost‘ when data are averaged over a full year). However, based on the changes in source activity among the various years (including level of activity and other changes, such as the addition of pollution controls to industrial operations, improved technology that reduces motor vehicle and stationary source emissions, etc.) and the extensive area affected by the source activity (which could have annual or seasonal impacts that mimic regional source impacts at the area‘s monitors), no obvious conclusions can be seen, and it is beyond the scope of this report to analyze the sources of air pollution.

Annual SO_4 concentrations have shown a decrease at all three sites over time. As with the nitrogen compounds, there are _ups and downs‘ along the trend line, however the variability appears to be far less than with nitrogen. Atmospheric sulfur concentrations have been affected by numerous regional and local factors. On a national scale, the 1990 Clean Air Act Revision acid rain provisions have greatly reduced SO_2 emissions from power plants. More recently, low sulfur diesel has been implemented for on-road and non-road diesel engines. Both actions, as expected, appear to contribute to a reduction of sulfur at the local and regional level. Based on national trends and ―upwind” controls, it is not surprising that sulfate concentrations in the area appear to have declined. As with the nitrogen compounds, an analysis of the full suite of SO_4 data, meteorological conditions and source activity data is needed to evaluate the causes of the apparent decrease in sulfur deposition. However, this evaluation is also well beyond the scope of this report.

Clean Air Status and Trends Network (CASTNet)

CASTNet provides atmospheric data on the dry deposition component of total acid deposition, ground-level ozone and other forms of atmospheric pollution. In Wyoming, there are three CASTNet sites, one in Yellowstone National Park, one at Centennial and one at Pinedale. The Pinedale site is co-located with the Pinedale NADP site, approximately 4 miles northeast of the Town of Pinedale between Fremont and Half Moon Lakes. For additional information, see the Monitoring Plan and visit the CASTNet website at http://www.epa.gov/castnet/.

The following figures illustrate the annual total deposition of sulfur and nitrogen (calculated on website through evaluation of SO_2 and SO_4 data and NO_3 and NH_4 data, resp.).

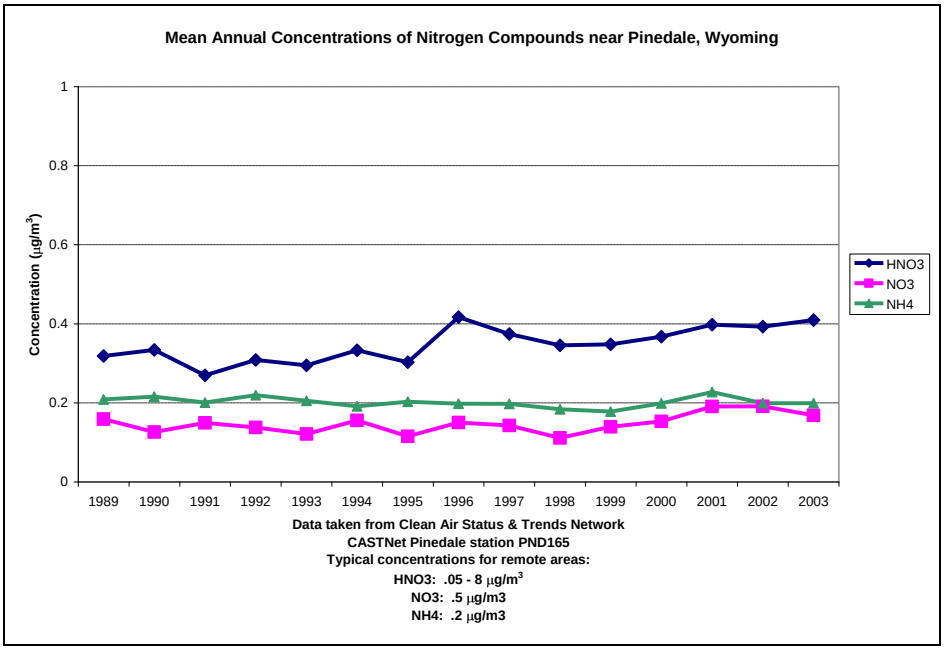


Figure 3-11 Mean annual concentrations of nitrogen compounds, Pinedale, WY

The deposition of nitrogen compounds at the Pinedale CASTNet site does not indicate a significant change between 1989 and 2003. There appears to be a very slight increase in HNO_3 during the time period plotted, however the annual values have experienced very mild increases and decreases over time.

The deposition of nitrogen compounds at the Pinedale CASTNet site does not indicate a significant change between 1989 and 2003. There appears to be a very slight increase in HNO_3 during the time period plotted, however the annual values have experienced very mild increases and decreases over time.

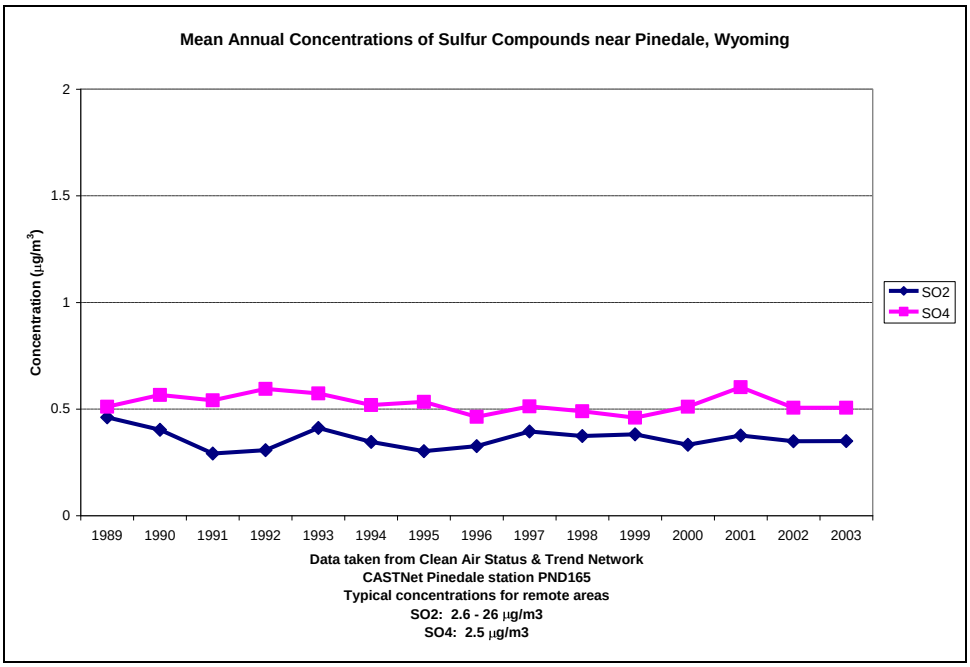


Figure 3-12 Mean annual concentrations of sulfur compounds near Pinedale, WY

The deposition of sulfur compounds at the Pinedale CASTNet site does not indicate a significant change between 1989 and 2003. Although the annual values have experienced extremely mild increases and decreases over time the general trend has been relatively horizontal, indicating little to no change.

The mean annual dry deposition values for the five nitrogen- and sulfur-containing compounds are shown below in Figure 3-13. As is fairly consistent with the annual deposition values in the preceding two figures, there have been no apparent significant increasing or decreasing trends or spikes during the time period plotted. There have been a few notable ―jumps" up and down in the HNO3 data, however these may appear more dramatic due to the concentrations being at higher values that show up more on this particular graph. Therefore, these data do not appear to raise any concerns when reviewed exclusively. However, the CASTNet data are considered ―sister" data to the NADP data, and are generally co-located at stations because the data are complimentary. Therefore, it may be useful to consider these two data sets together if performing a more in depth analysis.

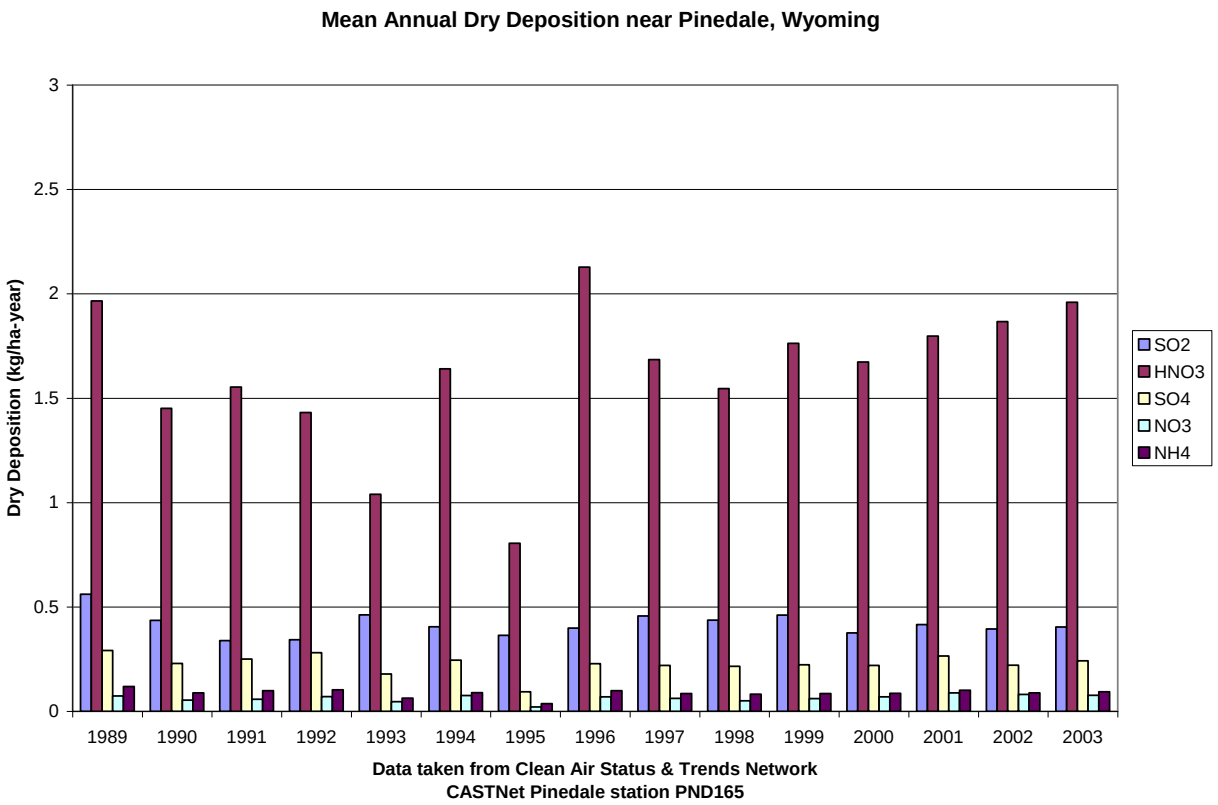


Figure 3-13 Mean annual dry deposition near Pinedale, WY

Wyoming Air Resources Monitoring system (WARMS)

The BLM Wyoming established the Wyoming Air Resources Monitoring System in 1999 to measure concentrations of nitrogen and sulfur compounds, although the WARMS network did not operate during 2002 due to funding constraints. The WARMS network includes one station near Pinedale as well as six stations (near Buffalo, Sheridan and Newcastle) in northeast Wyoming. WARMS stations are portable and powered by solar panels or battery, so they can be installed in remote areas without line power.

Weekly concentrations of particulate nitrate (NO_3^-) near Pinedale are consistent with concentrations typical for remote areas. Concentrations of ammonium (NH_4) are slightly higher than typical for remote areas, but are well below concentrations typical for urban areas. Concentrations of sulfur dioxide (SO_2) and sulfate (SO_4) are both well below remote concentrations. WARMS concentrations of NO_3, NH_4, SO_2 and SO_4 have not increased over the monitoring period from 2000 through 2005.

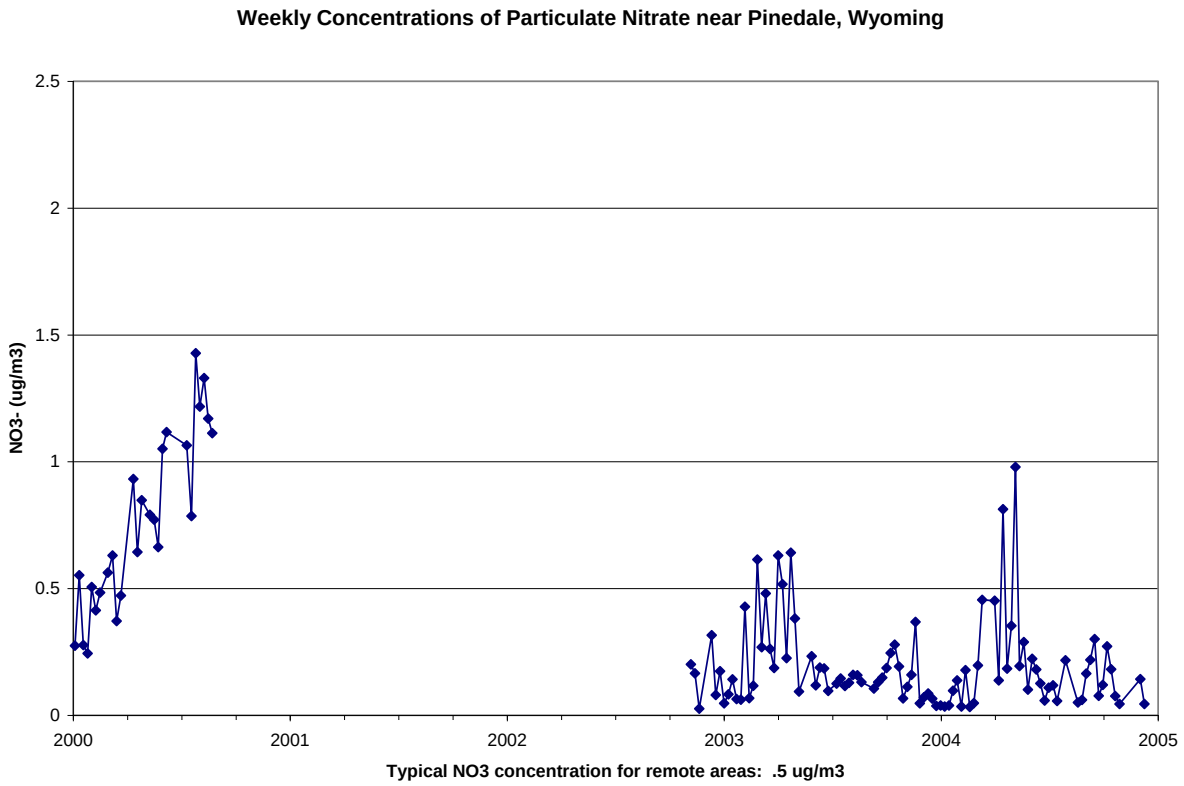


Figure 3-14 Weekly concentrations of particulate nitrate near Pinedale, WY

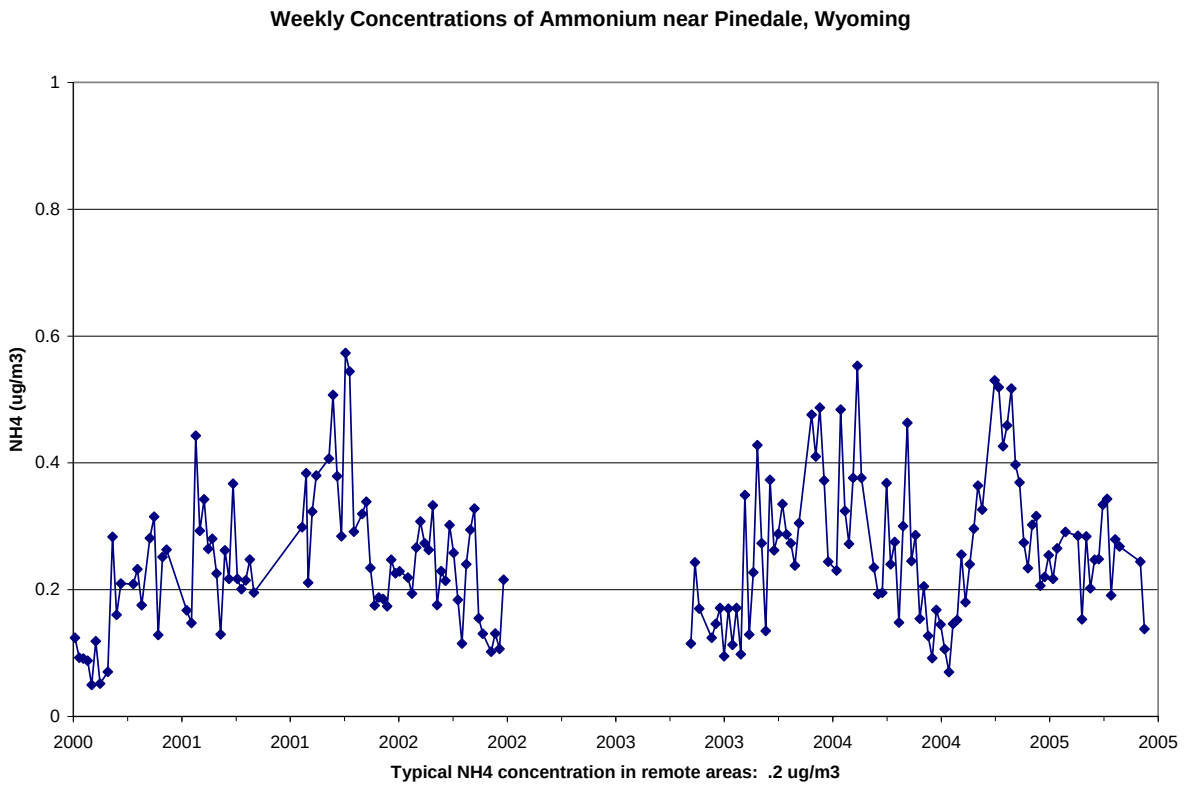


Figure 3-15 Weekly concentrations of ammonium near Pinedale, WY

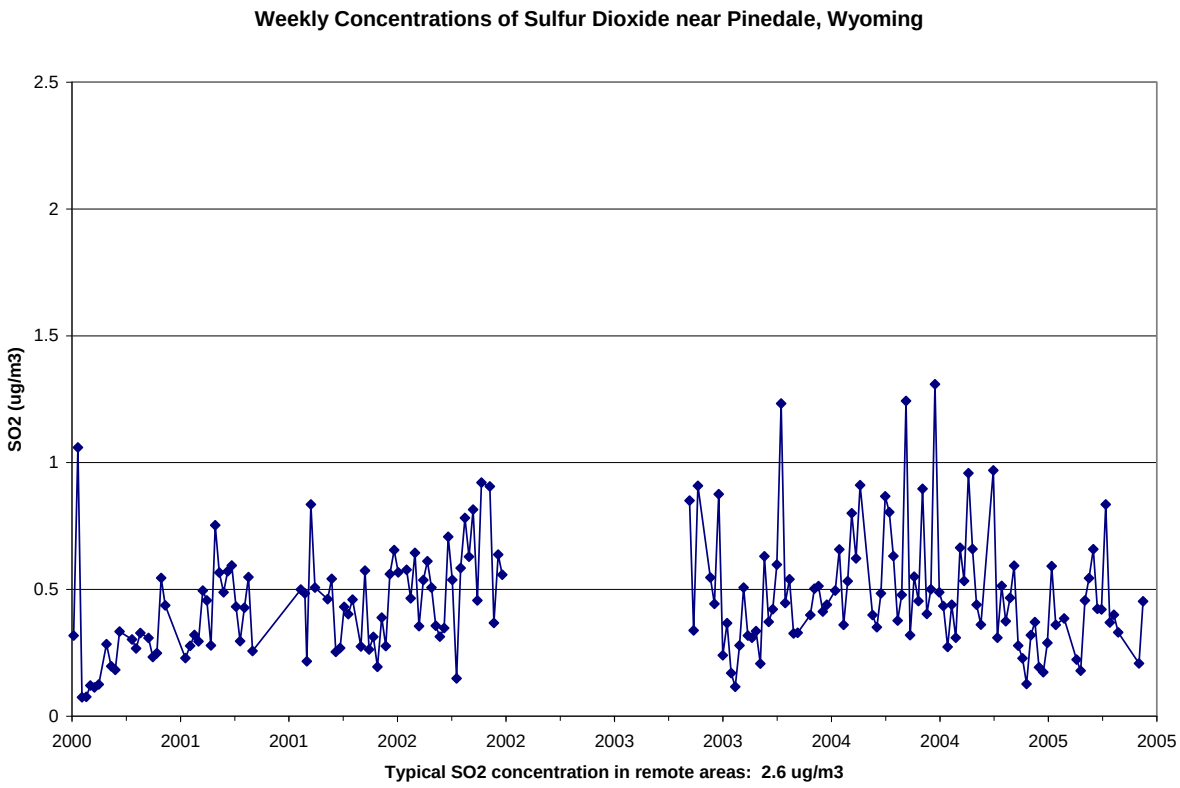


Figure 3-16 Weekly concentrations of sulfur dioxide near Pinedale

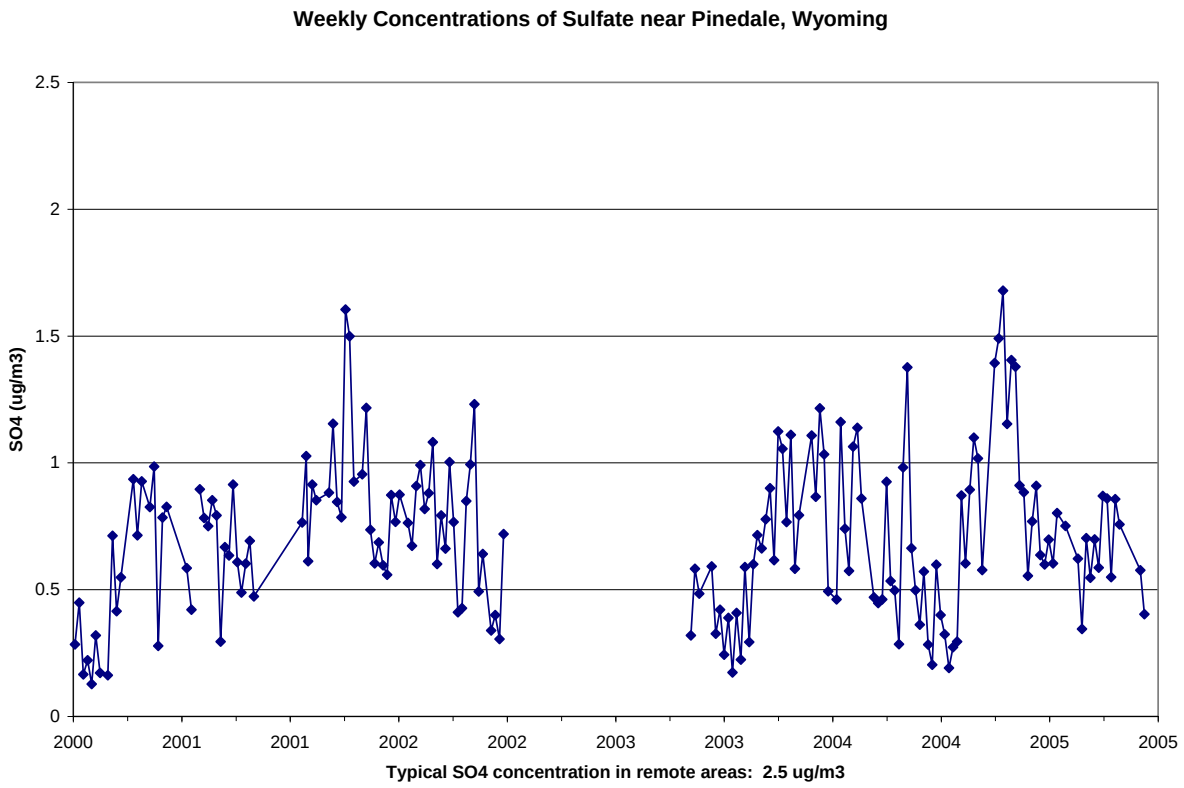


Figure 3-17 Weekly concentrations of sulfate near Pinedale, WY

Bulk Deposition Monitoring

Bulk deposition monitoring occurs at 2 sites located in the Bridger Wilderness area. These sites are co-located with Forest Service long-term lake monitoring sites at Hobbs and Black Joe Lakes. The Hobbs lake site is located in the center part of the Wind River Range, while the Black Joe site is located on the southern end of the range. The purpose of this monitoring is to collect total deposition (wet and dry) in open containers to determine actual high elevation deposition rates, and as a mechanism to help determine cause and effect relationships if changes in lake chemistry are observed. Annual precipitation can also be determined from these data. In the summertime, deposition is collected in a modified Hubbard Brook bulk sampler, and samples (mostly rain) are collected bi-weekly. In the winter, samples (mostly snow) are collected using an open cylinder lined with plastic bags. Winter samples are collected every 4 weeks. Please note that a bulk deposition sample includes both wet and dry deposition components.

This section of the document includes graphs illustrating the historical and recent data from these sites, and a short discussion of any observable trends. The data used to develop these graphs is available in Appendix B and complete datasets are available from the Pinedale Ranger District. Statistical analyses have not been completed on these data. Due to schedule for report completion 2005 data is not processed. Only data through 2004 is displayed.

Figure 3-18 Annual Precipitation

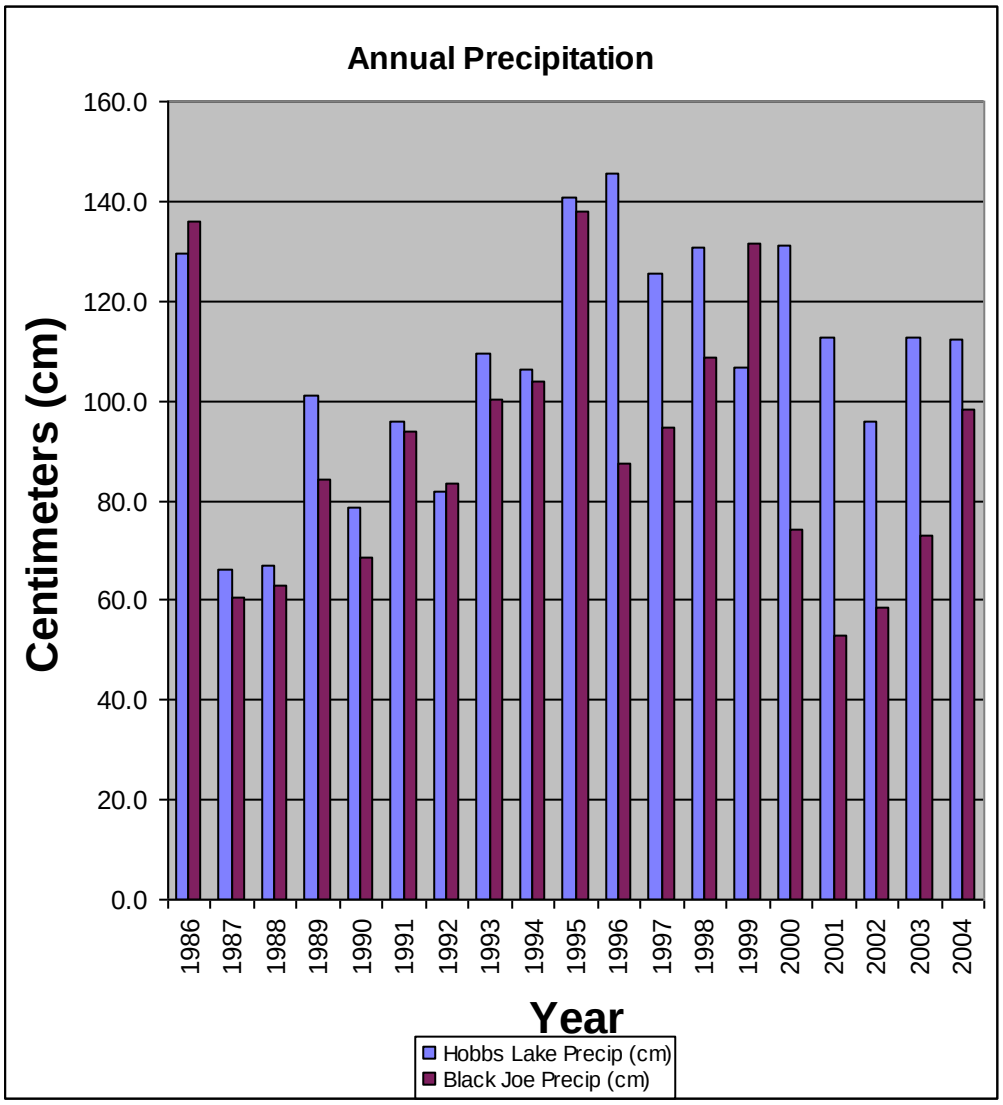


Figure 3-18 shows the annual precipitation at the 2 sampled sites since 1986. The average precipitation for Hobbs Lake is approximately 108 centimeters/year (cm/yr), and for Black Joe lake is approximately 90 cm/yr. This graph shows how Black Joe Lake is normally drier than Hobbs Lake, and the drought cycle that began several years ago was stronger at the Black Joe lake site. Understanding the precipitation is a key to understanding what the bulk deposition data represent, especially given the impacts precipitation has on the annual deposition data which are very noticeable in values illustrated in this section.

Figure 3-19 Nitrate Deposition

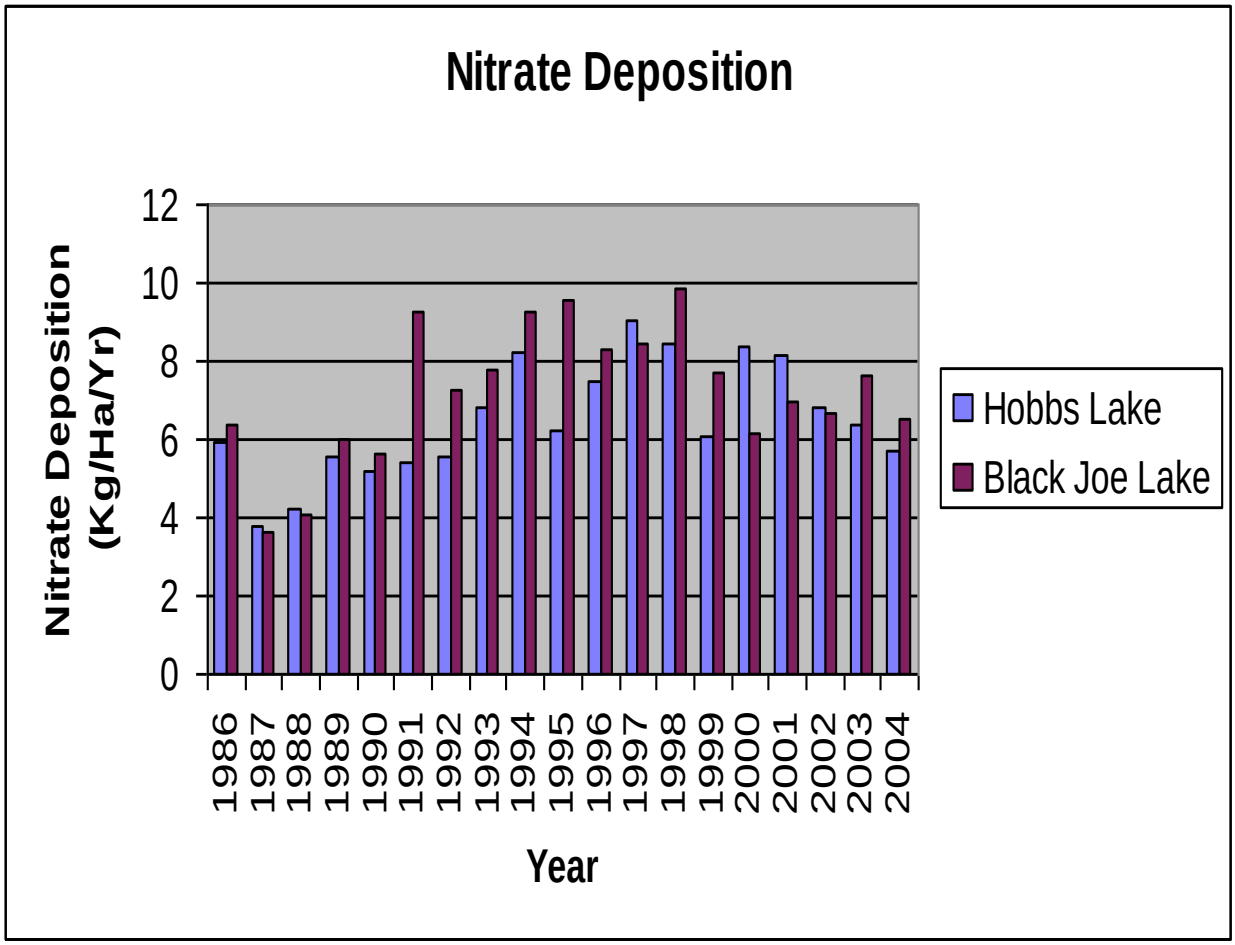


Figure 3-19 shows that the highest levels of nitrate deposition at Black Joe Lake occurred in 1995 and 1998, with 1991 and 1994 also showing relatively high deposition values. Nitrate deposition has generally decreased since that time. It appears that since 1988, in general, rates of nitrate deposition are higher at the Black Joe site than at the Hobbs site.

Figure 3-20 Sulfate Deposition

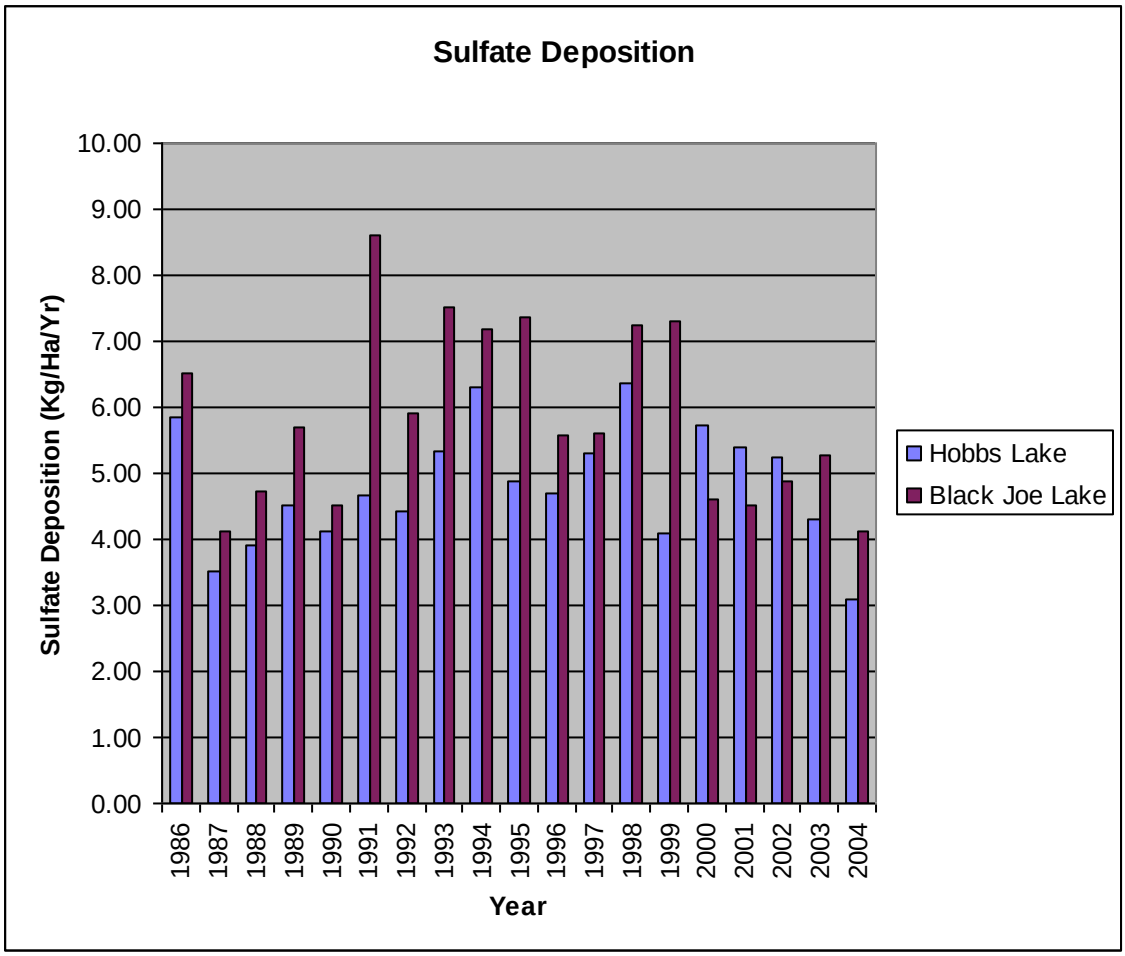
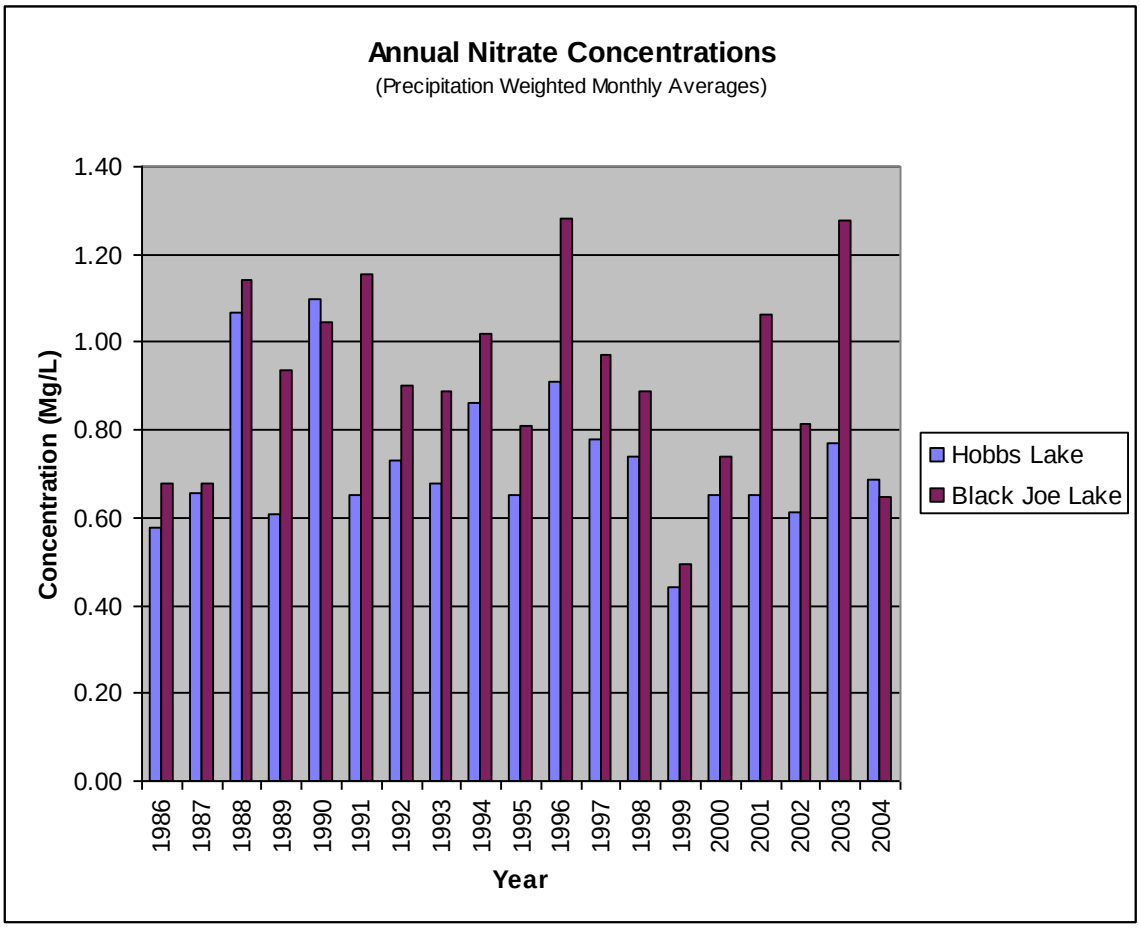


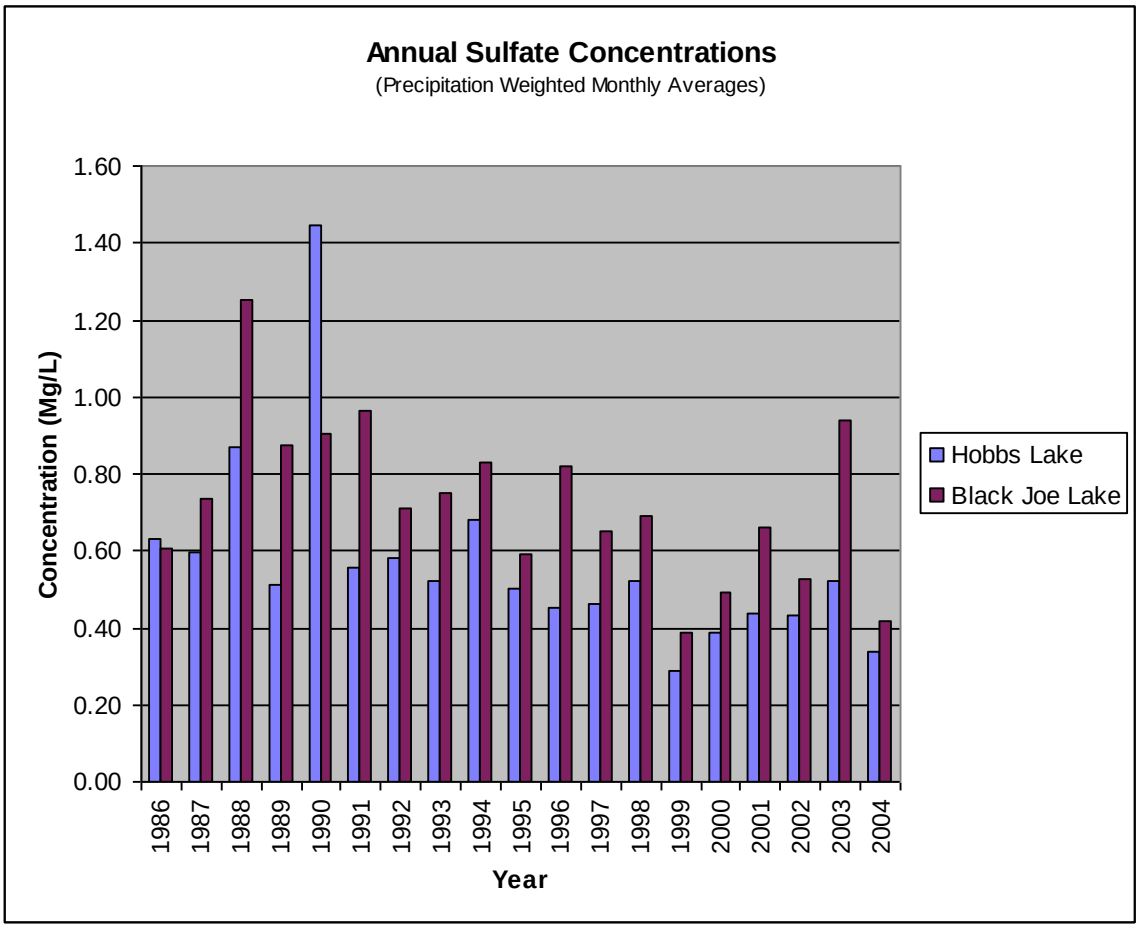
Figure 3-20 shows the highest levels of sulfate deposition at Black Joe Lake occurred between 1991 and 1999, with levels remaining fairly steady since 2000. At the Hobbs Lake site, there has been a fairly steady decrease in sulfate deposition since 1998. This general decrease in sulfate deposition is consistent with findings at other monitoring sites such as the NADP.

Figure 3-21 Annual nitrate concentrations



The annual nitrate concentrations displayed in Figure 3-21 show the concentration of dissolved nitrates in the rain and snow samples analyzed. The highest nitrate concentrations at the Hobbs Lake site occurred in 1988 (which correlate with large local fire events the Yellowstone and Fayette fires) and 1990. The high values observed in 1990 correlate with large fire events in California and Arizona. At the Black Joe site, in all years since 1987 (except 2004), nitrate concentrations were generally higher than the Hobbs Lake site. The lowest concentrations at this site were observed in 1999. The high values seen in 1996, 2001 and 2003 are likely caused by a combination of factors, including drought conditions (precipitation at Black Joe Lake during these years does appear to be below _average‘ in Figure 3-18), impacts from wildfires, and the way precipitation can affect the level of deposition (for example, the combination of less precipitation and the same concentration of nitrates can lead to a higher nitrate concentration per volume in the snow and rain samples).

Figure 3-22 Annual sulfate concentrations



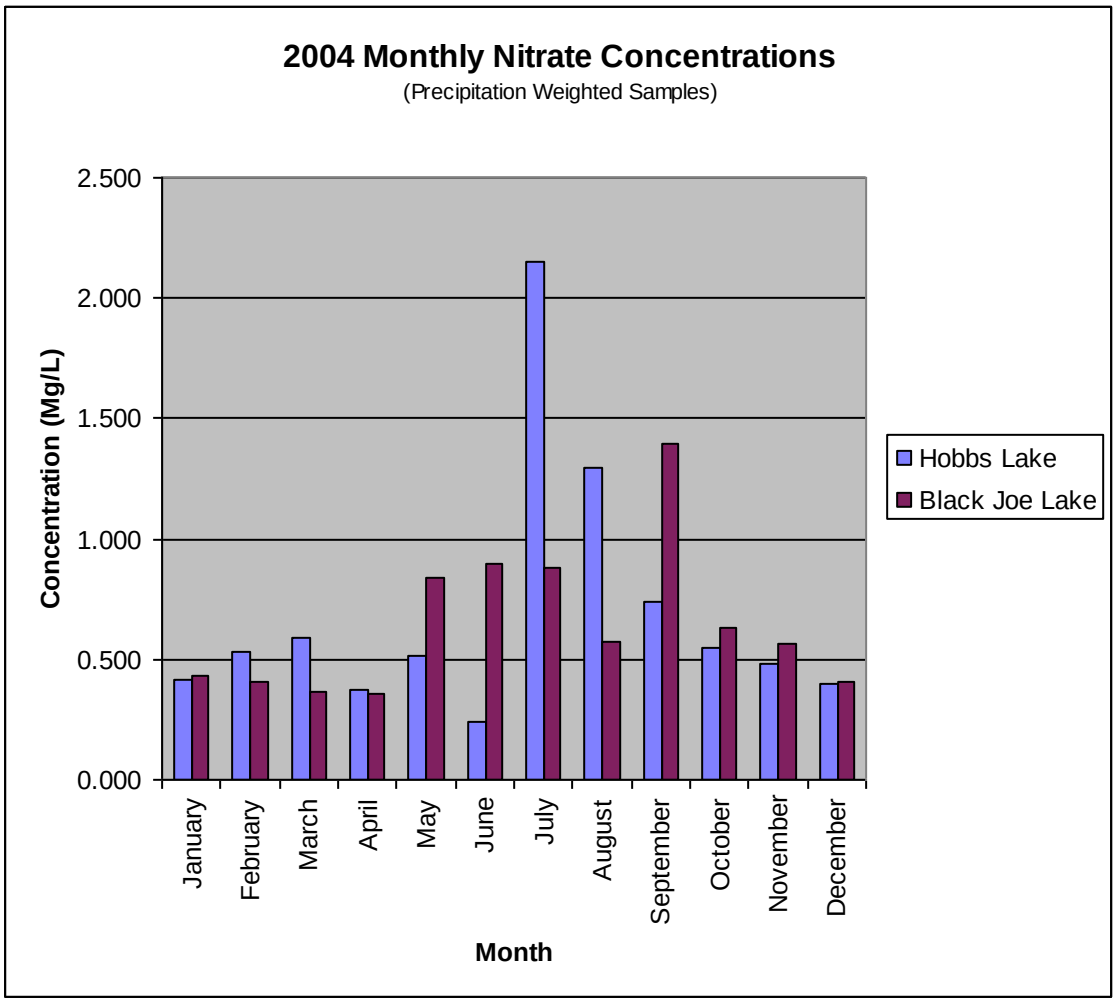
Annual sulfate concentrations are shown in Figure 3-22. This figure shows that the highest sulfate deposition values at both the Hobbs and Black Joe sites occurred in 1990 and before with a decrease in trend since that year. The figure also shows that with the exception of 1990, concentrations of sulfates are generally higher at the Black Joe site versus the Hobbs site. This may be related to the lower levels of precipitation observed most years at the Black Joe site in addition to occasional drought conditions as seen in Figure 3-18 because with less precipitation but the same levels of sulfates, this will lead to a higher concentration in the snow and rain samples.

The following table presents the 2004 monthly weighted precipitation data. Please note that these values are not actual monthly precipitation, because the samples were not collected on the first of the month. Rather, these values are extrapolated from the samples collected on the predetermined sampling schedule and attributed to their respective month.

Table 3-7 2004 Monthly Weighted Precipitation for Hobbs and Black Joe Bulk Deposition Collectors

	Hobbs BD Site (Precipitation in cm)	**Black Joe BD Site (Precipitation in cm**
January	10.01	5.36
February	8.28	5.56
March	6.21	7.73
April	4.56	5.52
May	7.6	6.84
June	8.91	8.24
July	5.29	3.2
August	7.66	8.72
September	7.81	7.79
October	17.59	10.6
November	7.12	8.03
December	6.21	5.45
Annual Total	97.5	83.04

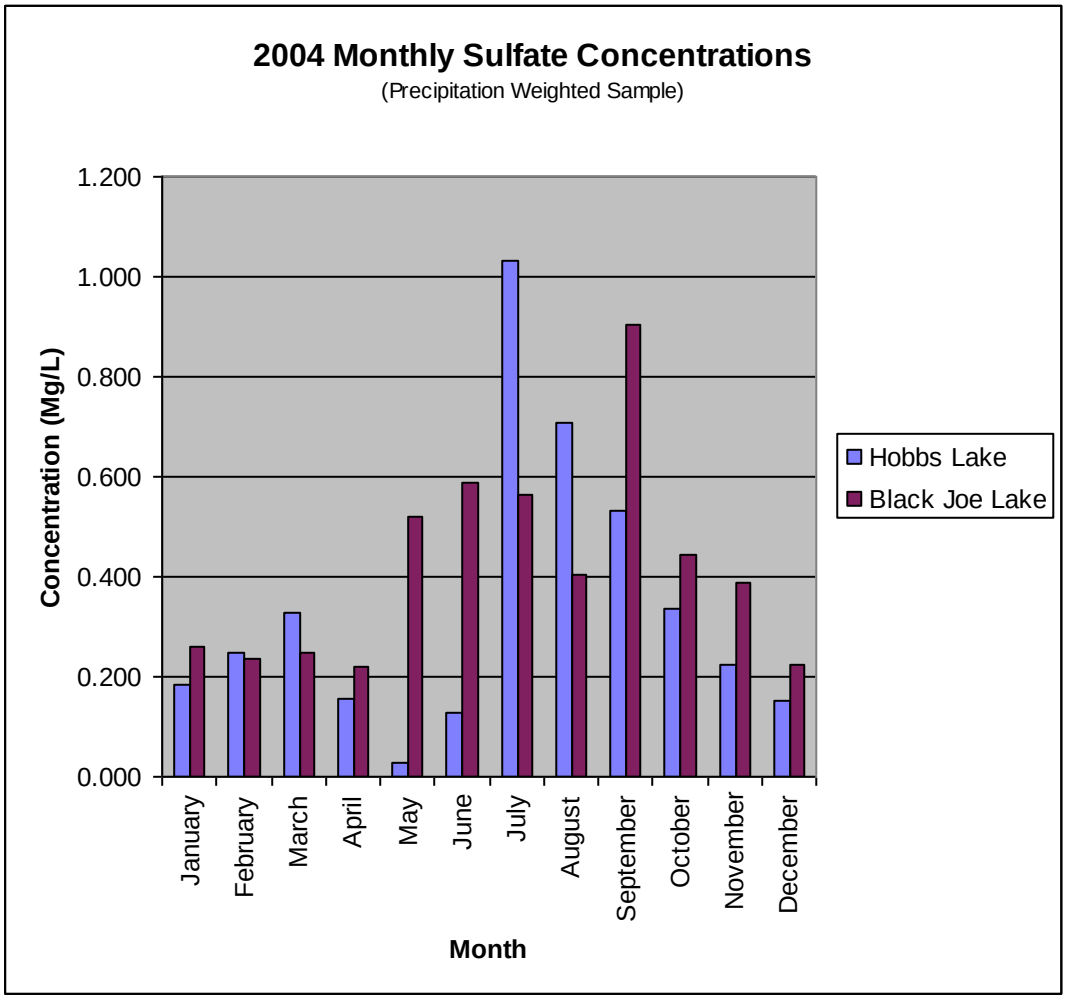
Figure 3-23 2004 Monthly Nitrate Concentrations



In Figure 3-23, the monthly nitrate concentrations are shown for 2004. This graph shows that in 2004 there was a seasonal increase in the concentrations of nitrate in the precipitation that is collected during the summer months. There may be several reasons for this difference, including increased pollution sources (traffic, wildfires, industrial activities, etc.) and lower rates of precipitation. With more year round activity in upcoming years in the Pinedale Anticline area, it will be worthwhile to see if this seasonal distribution changes.

Spikes of nitrate occurring during the summer months (as seen in Figure 3-23) are of concern for the protection of aquatic ecosystems. These spikes indicate there is a relatively large input of nitrogen to the high elevation lakes and streams, which tends to acidify and enrich the lakes when they are most active and productive. Such enrichment may cause changes in the lake function including the creation of eutrophic conditions, where oxygen may become limited and cause changes in the biotic community structure of these lakes. This in turn can impact communities ―up the food chain" as the lakes' food supply for other animals is modified.

Figure 3-24 2004 Monthly Sulfate Concentrations



In Figure 3-24, the monthly sulfate concentrations are shown for 2004. This graph shows that in 2004 there was a seasonal increase in the concentration of sulfate in the precipitation that is collected during the summer months. There may be several reasons for this difference, including increased pollution sources (traffic, wildfires, industrial activities, etc.) and lower rates of precipitation. With more year round activity expected in coming years in the Pinedale Anticline area, it will be worthwhile to see if this seasonal distribution changes. Spikes of sulfate occurring during the summer months are of concern to aquatic ecosystems because they indicate that there is a relatively large input of sulfur to the high elevation lakes and streams that can acidify and enrich the lakes when they are most active and productive. Acidification may contribute to changes in the biotic community structure and function of the lakes.

The following summarizes general observations seen in the bulk deposition data:

- Since monitoring began in 1986, there has been a lot of variation in the annual precipitation at both the Hobbs and Black Joe sites measured, with annual precipitation at Black Joe Lake generally being less than Hobbs Lake.

- Since 1988 there has been a general trend of increasing nitrate and sulfate deposition at both sites through the late 1990's, followed by an apparent decrease in the latter years through 2004.
- The concentrations of nitrates in precipitation do not show any obvious trends during the monitored years, but rather vary from year to year while staying within an general _range' at each site over time.
- The concentration of sulfates has been steadily decreasing since 1991, which is generally consistent with nationwide trends.

Visibility

This section of the document addresses aerosol, scene, and optical monitoring being conducted in the Pinedale Anticline area. More detailed information on the methods and results of this monitoring are presented in Appendix C.

Aerosol Monitoring

There is one IMPROVE site near Pinedale serviced by the USFS Pinedale Ranger District personnel. The Bridger aerosol sampling site (BRID) is located at the White Pine Ski Area approximately 12 miles NE of Pinedale.

Readers may note that the IMPROVE aerosol data are based on extinction values (Mm^{-1} or inverse megameters); however most of the environmental discussions regarding Pinedale air quality have been based on deciview levels. While there is no one definition of visibility that meets all the criteria of ―seeing" landscape features, a number of visibility indices have evolved. However, the least technical way to describe visibility is by referring to ―visual range" in miles or kilometers. Visual range is defined as ―the distance at which a large black object just disappears from view" (IMPROVE website) [whereas aerosol extinction is a more complex measure that addresses other aspects, such as the ability to see an object's features rather than just the object].Therefore, the IMPROVE aerosol data were translated into visual range to make the following figures more understandable for less technical audiences. The aerosol extinction data for the BRID site and additional information regarding the various ways visibility can be described are included in the Appendix C. Information and data associated with the IMPROVE network are available in the Monitoring Plan and at http://vista.cira.colostate.edu/views.

The BRID IMPROVE site began operation in 1988. Because evaluating the _annual averages' for visibility impairment requires a full year's worth of data, the annual trends developed from the IMPROVE website begin with 1989. Seasonal trends included 1988 data where applicable, however to be consistent all illustrations in this report begin in 1989. Figure 3-25 below illustrates the long-term visual ranges by season.

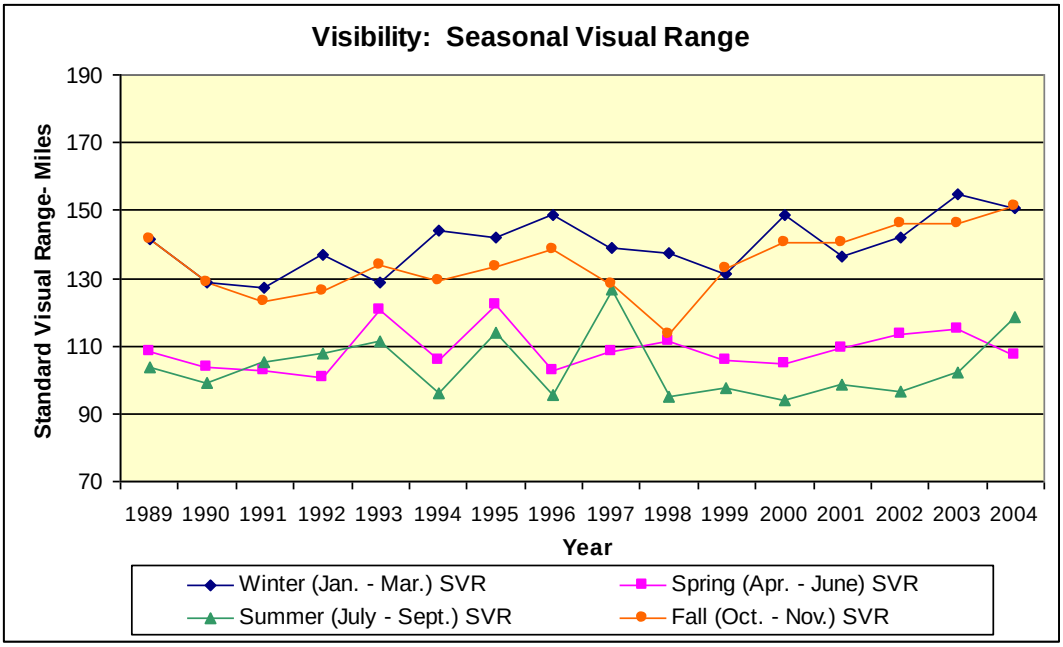


Figure 3-25 Seasonal average visual range as calculated from IMPROVE data collected at the BRID monitoring site. ***Note that the visual range axis begins at 60 miles, not zero, so that more detail can be seen.***

In general, there are several seasonal trends in the above figure:

- The highest visual ranges (best visibility) generally occur during the winter months.
- Fall visibility (October-December) appears to be slightly less than winter values but better than spring and summer.
- Visual ranges in the spring and summer months are most often lower than fall and winter ranges, and are very similar with several years of slightly better visibility occurring in the spring and a few in the reverse pattern.

The annual average visual ranges for all years available at the BRID site are shown below.

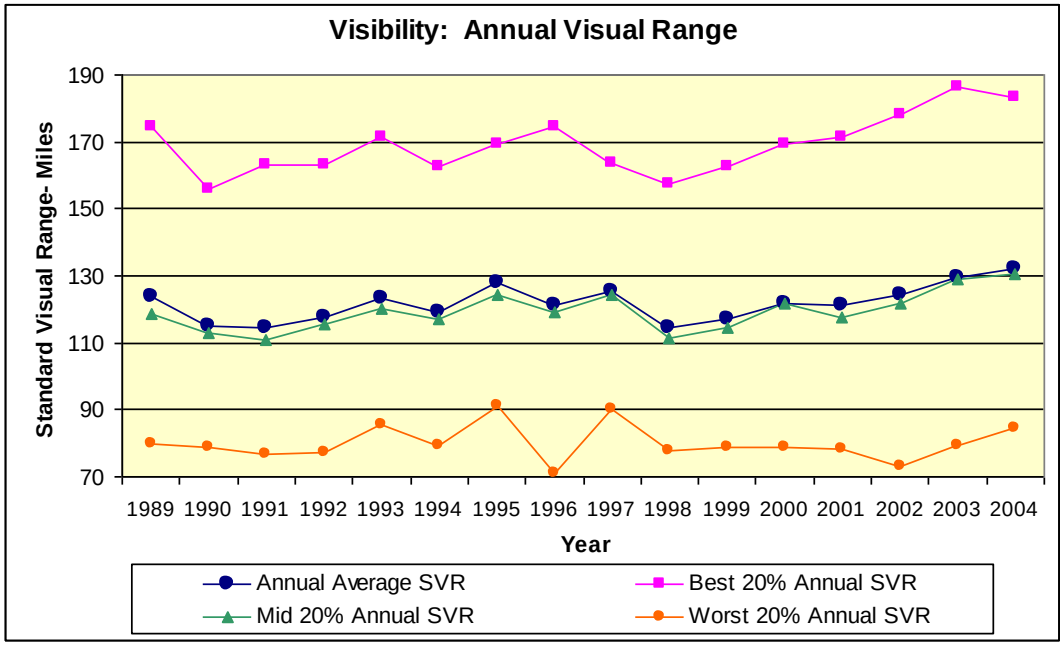


Figure 3-26 Annual standard visual range for annual average visibility and visual ranges for the 20% best days, the 20% mid-days, and 20% worst days as calculated from IMPROVE data collected at the BRID monitoring site. ***Note that the graph's visual range axis begins at 60 miles so that more details can be seen.***

A general look at the annual and seasonal data together provides the following observations:

- Seasonal impacts can have a significant impact on annual averages, even when just one or two seasons are ‗setting' the trend seen in the annual data;
    - This is strong evidence of why seasonal *and* annual data should be presented;
- Conversely, seasonal impacts can be ―smoothed out" when averaged into annual data and therefore not seen;
- In the mid 1990s (e.g. 1996, 1998), it appears that there were ‗above-average' levels of visibility-reducing pollutants during the warmer months; this may suggest large regional events, such as wildfires in the absence of large, ―spring and summer only" sources in the area
    - A glance at visibility data from other IMPROVE sites around the area (i.e. Yellowstone, Lone Pine) shows a similar drop in visual range around 1996 and 1998, further supporting the likelihood that these impacts were due to regional events such as wildfires (annual trend graphs and summaries can be accessed on the IMPROVE website for all IMPROVE monitoring sites)

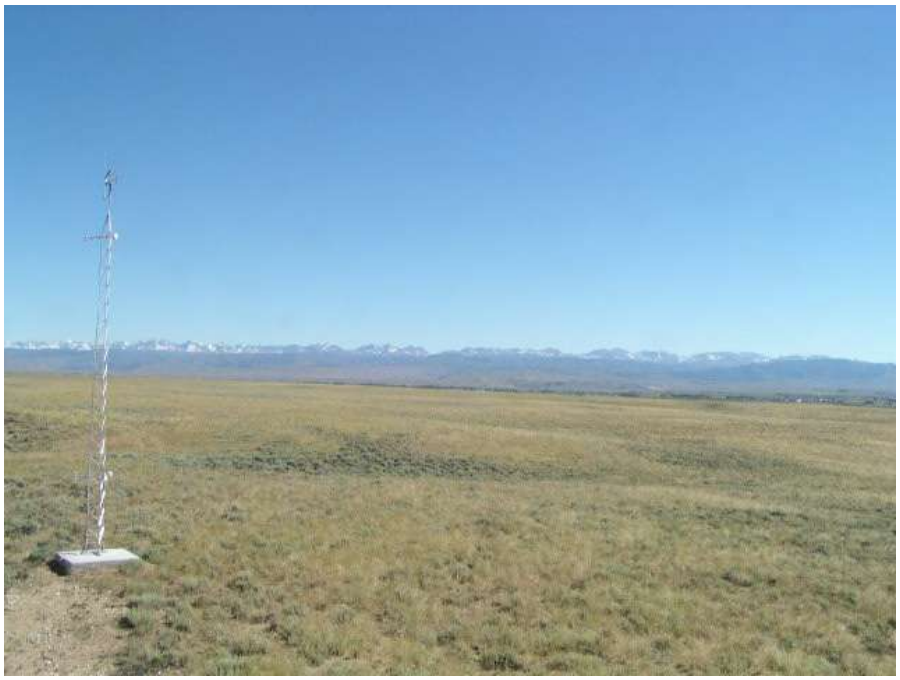
As of May 2006, the 2005 IMPROVE aerosol data were not yet available, therefore 2005 data will not be reported. Additionally, the BRID site is just one monitoring site among the many historically and recently installed around the PAPA, although it is the only IMPROVE site in the area. The most useful and extensive air quality information will come from a complete review of data from all air quality sites, including cross-comparisons among the different site measurements, topography and weather, etc.

Scene Monitoring

High resolution digital cameras systems are located at the Daniel South, Boulder and Jonah monitoring stations and operate as part of the Wyoming Visibility Monitoring Network. Figures 3-28 through 3-30 present a range of conditions observed during the January 1, 2005, through December 31, 2005 period. Where available, the associated hourly monitored values of ozone, nitrogen dioxide, PM_{10} mass, and relative humidity for each station are presented for reference (particle scattering and estimated visual range are also included for the Boulder station). It is important to remember that each of these measurements is made at a single location, and the visual image represents an extended sight path. The visual quality of the scene is affected differently by each major PM_{10} species, and by relative humidity. Therefore, none of the measured air quality parameters alone will completely determine the visual quality of the digital image. Visual range is available for the Boulder station because the station has a nephelometer; visual range is not available for the Jonah and Daniel South stations.

Figure 3-27 Photographs Illustrating the Visual Conditions at Boulder, Wyoming.

Boulder, Wyoming
Clear Conditions
07/11/05 0900 hr
Ozone = 55.74 ppb
NO_2 = 0.00 ppb
PM_{10} = 0.1 µg/m^3
RH = 29.6%
b_{sp} = 3 Mm^{-1}
Estimated
Visual Range = 300 km
(187 miles)



Boulder, Wyoming
Hazy Conditions
06/25/05 1100 hr
Ozone = 62.1 ppb
NO_2 = 0.0 ppb
PM_{10} = 35.7 µg/m^3
RH = 22.9%
b_{sp} = 84 Mm^{-1}
Estimated
Visual Range = 42 km
(26 miles)

Figure 3-28 Photographs Illustrating the Visual Conditions at Daniel, Wyoming.

Daniel, Wyoming
Clear Conditions
09/19/05 1200 hr
Ozone = 51.3 ppb
NO_2 = 0.0 ppb
PM_{10} = 4.8 µg/m^3
RH = 21.0%

Daniel, Wyoming
Hazy Conditions
09/15/05 1200 hr
Ozone = 48.1 ppb
NO_2 = 0.0 ppb
PM_{10} = 12.2 µg/m^3
RH = 27.7%

Figure 3-29 Photographs Illustrating the Visual Conditions at Jonah, Wyoming.

Jonah, Wyoming
Clear Conditions
10/14/05 1200 hr
Ozone = 48 ppb
NO = 0 ppb
NO_2 = 0 ppb
NO_X = 0 ppb
PM_{10} = 0 $\mu g/m^3$
RH = N/A

Jonah, Wyoming
Hazy Conditions
08/15/05 0900 hr
Ozone = 32 ppb
NO = 10 ppb
NO_2 = 9 ppb
NO_X = 19 ppb
PM_{10} = 5 $\mu g/m^3$
RH = N/A

Optical Monitoring

Two types of optical monitoring occur in the area, transmissometer (as part of the IMPROVE network) and nephelometer monitoring. These two monitoring sites and methods are discussed separately below. The data from optical monitoring should be used in conjunction with other visibility data, such as IMPROVE aerosol data, to further validate and analyze total extinction and visibility trends (see appendix C).

IMPROVE Transmissometer

The Bridger Wilderness Area IMPROVE monitoring site (BRID) includes aerosol samplers and a transmissometer for measuring optical properties. The transmissometer was installed in September 1988 and remains in operation. Transmissometer data are used in conjunction with aerosol data (and nephelometer measurements when available) to analyze different aspects associated with visibility. Specifically, transmissometers measure the irradiance of a light at some distance from the source. Anything that modulates the measured irradiance will affect the estimated extinction coefficient (and therefore estimated visual range). Besides aerosols and absorbing gases along the path, this can include (but is not limited to): snow, rain, fog, clouds, airborne insect swarms, birds, fogged or dirty optical surfaces, misalignment of the detector or light source, optical blooming or turbulence, non-uniform light beam, or varying irradiance (in absence of gases or aerosols) [Molenar, 2002]. Therefore, these data come with a ―warning:" although transmissometer data are presented in this report, visibility experts caution against the use of historical transmissometer data alone for long term trend analysis (see Appendix C for additional information). Therefore, the data presented here are for informational purposes only, and <u>should not be used exclusively in any analyses of long-term trends</u>.

The following graphs represent the transmissometer data from 1989-2005. Please note that seasonal data was only available through 2004, while the annual averages were available through 2005.Seasonal and annual averages for standard visual range (as estimated from the transmissometer data) are presented below. Data were provided in two sets: one set is based on all data points whether 50% validity was met or not, while the other set only includes data from >50% valid sets. Both data sets are illustrated where appropriate. As with other monitoring protocols, there are certain criteria developed that, when all met, indicate data to be ―valid" on some level; factors that prohibit data from meeting all criteria vary by program. Data for the transmissometer were assigned a percent validity based on review by ARS staff

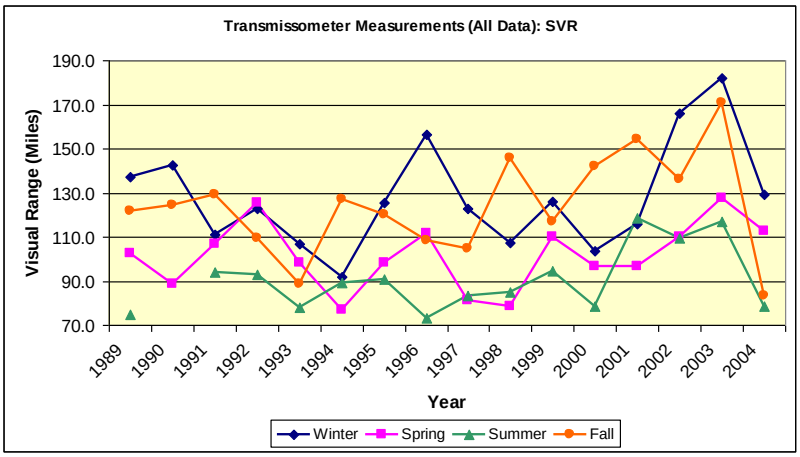


Figure 3-30 Transmissometer data by season

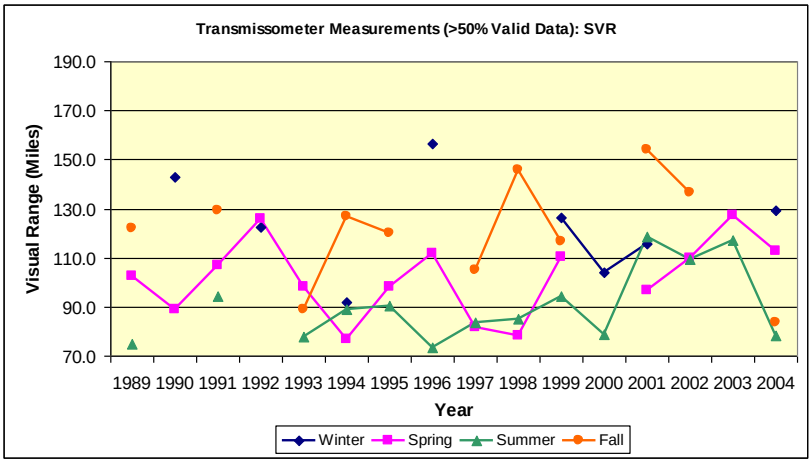


Figure 3-31 Seasonal average visual range based on transmissometer data. Winter represents the first quarter (i.e. January – March), spring the second quarter, etc. ***Note that the visual range axis begins at 70 miles in order to better see details.***

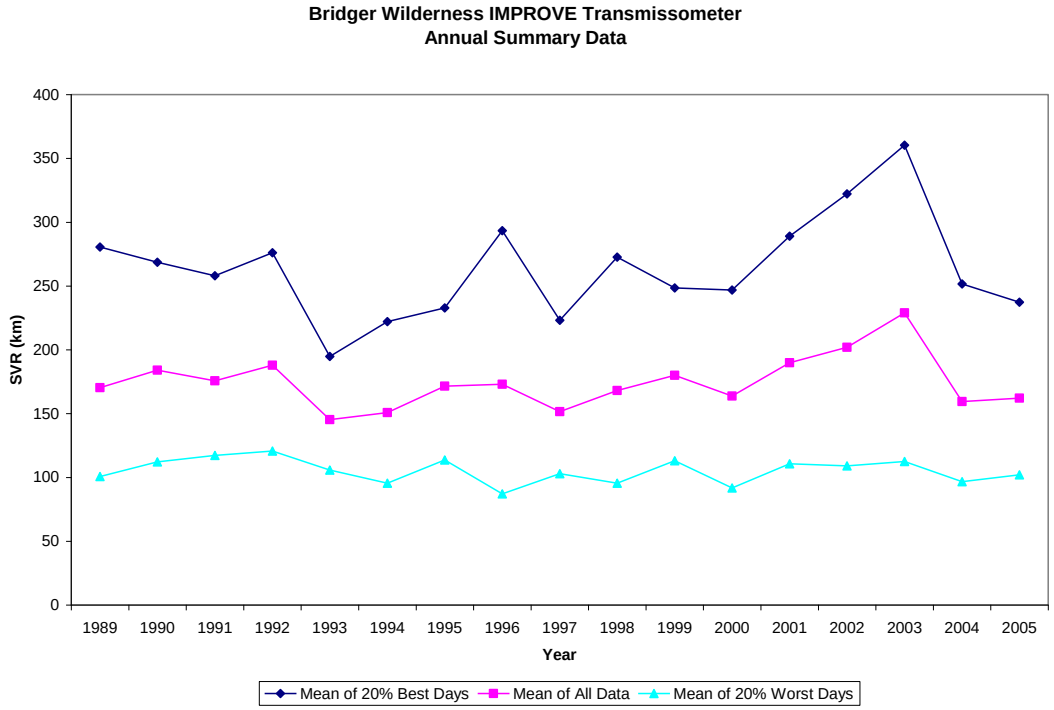


Figure 3-32 Annual average visual range based on transmissometer data

The seasonal transmissometer data plotted alone indicate that in general, visibility is higher in the winter and fall months than spring and summer. This finding is similar to those based on observations of the long-term seasonal visual ranges calculated from the IMPROVE aerosol data. The transmissometer data alone appear to indicate that visibility was best in 2002-2003 for the data period (1989-2005), with similar-sized increases and decreases in the remaining years,. However, these findings do not follow those observed in the aerosol data. (which better represent the more complex aspects of visibility and are generally less affected by interferences than transmissometer data) [see Appendix C for the graphical comparison]. This difference may be representative of the _warning‘ provided regarding the uncertainty associated with the sole use of transmissometer data. There is no comparison to nephelometer data since the BRID site does not include a nephelometer. Additional discussion and comparisons between aerosol and transmissometer data are found in Appendix C.

Nephelometer

An ambient nephelometer draws air into a chamber and measures the scattering component (b_{scat}) of light extinction (b_{ext}). The total light scattered out of a path is measured directly, and is the same as the reduction of light along a path due to scattering. ARS collects and validates nephelometer data at the Boulder monitoring station. Air temperature and relative humidity measurements are also collected simultaneously with nephelometer measurements to provide information required to assess weather interferences and humidity related visibility affects (weather filtered b_{scat}). A detailed description of Quality Assurance is in Appendix C. This section presents a description of the nephelometer system and data validation methods for nephelometer data.

Nephelometer measurements can be greatly influenced during periods of:

- Fog
- Heavy rain
- High relative humidity (> 90%)
- Blowing snow
- Other extreme meteorological conditions

Under these conditions nephelometer readings will no longer correspond to the optical properties of particulates in the atmosphere. Periods of meteorological interference identified during validation are labeled "Weather Affected."

The measurement uncertainty of the Optec NGN-2 ambient nephelometer is calculated from the distribution of calibration slopes determined during manual span/zero calibrations (normally performed every week to two weeks). The reported uncertainty is the 95% confidence limit of a two-tailed t-distribution. The overall uncertainty for the Boulder nephelometer from 01/20/2005 through 12/31/2005 was 11% , which is relatively good in less scientific terms.

Table 3-8 shows a regional comparison of the Boulder nephelometer and other IMPROVE or IMPROVE Protocol nephelometers and transmissometers in the Central Rocky Mountain Region for the year 2005. Visual range was calculated using the mean of the 20% cleanest days, 20% dirtiest days, and mean of all data collected during the period. Visual range calculated from nephelometer data does not take into consideration any visibility degradation due to light absorption (b_{abs}) which is mostly attributable to black carbon (typical sources include diesel combustion sources, prescribed burning, wildfire and residential fuel combustion[i.e. wood stoves, fireplaces]). For this reason, nephelometer-based visual range estimates may be overestimated when impacts by these sources. Visual range calculations from the transmissometer data includes both light scattering and light absorption, and is a more accurate representation of visual range (when interferences are minimal or non-existent; see previous discussion).

EPA Class I and Class II designations are included in Table 3-8 for the area that the monitoring station represents. Mandatory Class I areas include all international parks, national wilderness areas, national memorial parks exceeding 5,000 acres in size and national parks exceeding 6,000 acres in size designated before August 7, 1977. The Class I designation provides the greatest degree of protection against air quality degradation, and a Class II designation includes protected areas that do not meet Class I specifications.

Table 3-8 Visibility Measurements in the Central Rocky Mountain Region in 2005

Nephelometer Summary
Visibility Metric (Filtered Data)
Particle Scattering (b_{sp})

Site (EPA Designation)	Mean of 20% Cleanest Days		Mean of all Filtered Data		Mean of 20% Dirtiest Days	
	b_{scat}	*Estimated* Visual Range*	b_{scat}	*Estimated* Visual Range*	b_{scat}	*Estimated* Visual Range*
Boulder Monitoring Station (Class II Area)	3.6 Mm^{-1}	288 km 179 mi	13.3 Mm^{-1}	168 km 104 mi	28.5 Mm^{-1}	102 km 63 mi
Cloud Peak Wilderness Area (Class II Area)	0.5 Mm^{-1}	373 km 232 mi	7.3 Mm^{-1}	226 km 141 mi	19.8 Mm^{-1}	131 km 81 mi
Thunder Basin National Grasslands (Class II Area)	2.9 Mm^{-1}	303 km 188 mi	15.7 Mm^{-1}	152 km 95 mi	38.4 Mm^{-1}	81 km 50 mi
Mt. Zirkel Wilderness, CO (Class I Area)	2.5 Mm^{-1}	313 km 195 mi	11.3 Mm^{-1}	184 km 114 mi	26.0 Mm^{-1}	109 km 68 mi

Transmissometer Summary
Visibility Metric (Filtered Data)
Total Extinction (b_{ext}*)

Site (EPA Designation)	Mean of 20% Cleanest Days		Mean of all Filtered Data		Mean of 20% Dirtiest Days	
	b_{ext}	Standard Visual Range**	b_{ext}	Standard Visual Range**	b_{ext}	Standard Visual Range**
Bridger Wilderness (Class I Area)	16.8 Mm^{-1}	237 km 147 mi	26.5 Mm^{-1}	162 km 101 mi	39.4 Mm^{-1}	102 km 63 mi
Cloud Peak Wilderness Area (Class II Area)	12.7 Mm^{-1}	312 km 194 mi	23.7 Mm^{-1}	198 km 123 mi	42.1 Mm^{-1}	103 km 64 km
Thunder Basin National Grasslands (Class II Area)	19.6 Mm^{-1}	203 km 126 mi	33.8 Mm^{-1}	135 km 84 mi	59.2 Mm^{-1}	73 km 45 mi

*Estimated visual range from nephelometer measurements includes only particle and gas scattering (b_{scat}), and does not include particle absorption (b_{abs}).

**Standard visual range is calculated from total aerosol extinction (b_{ext}), which includes both particle scattering (b_{scat}) and particle absorption (b_{abs}).

Visibility Events

Events impacting the PAPA and surrounding areas presented in this section were visually characterized by intense haze episodes observed in digital images taken by the automated camera system, low visibility measurements recorded by the Boulder nephelometer, and particulate and gaseous data available from the Daniel South and Jonah stations. In some cases smoke analysis derived from satellite images and weather surface maps are presented. These analyses present data and a narrative of observed conditions, but do not represent rigorous scientific investigations of source attribution and possible environmental impacts.

The following events were chosen in an effort to more fully understand visibility impairment in and around the PAPA in 2005:

- In late spring 2005, smoke from large wildfires in Arizona, Nevada, and Utah caused significant regional visibility impacts and elevated particulate.
- In July and September 2005, small prescribed fires were burning just north of the Boulder station causing localized visibility and particulate impacts.
- 2005 was marked by several instances of regionally high particulate concentrations preceding frontal passages.

Fire Events

Large Fires

Numerous large fires developed in late June 2005 across the Southwest and Great Basin regions, with activity concentrated in Arizona, Nevada, and Utah. Figure 3-33 presents a map of analyzed smoke from satellite images on June 25, 2005, from the Arizona and Nevada fires using the NOAA National Environmental Satellite Data and Information Service (NESDIS) Hazard Mapping System (HMS). The HMS is an interactive system allowing satellite analysts to manually integrate data from various automated fire detection algorithms with imagery from geostationary and polar-orbiting satellites, resulting in a display of the locations of fires and major smoke plumes in the continental United States, Mexico, and Canada. HMS data were acquired from their Geographic Information System (GIS) Web page[1]. The figure shows smoke from the fires advecting over Utah and covering most of Wyoming.

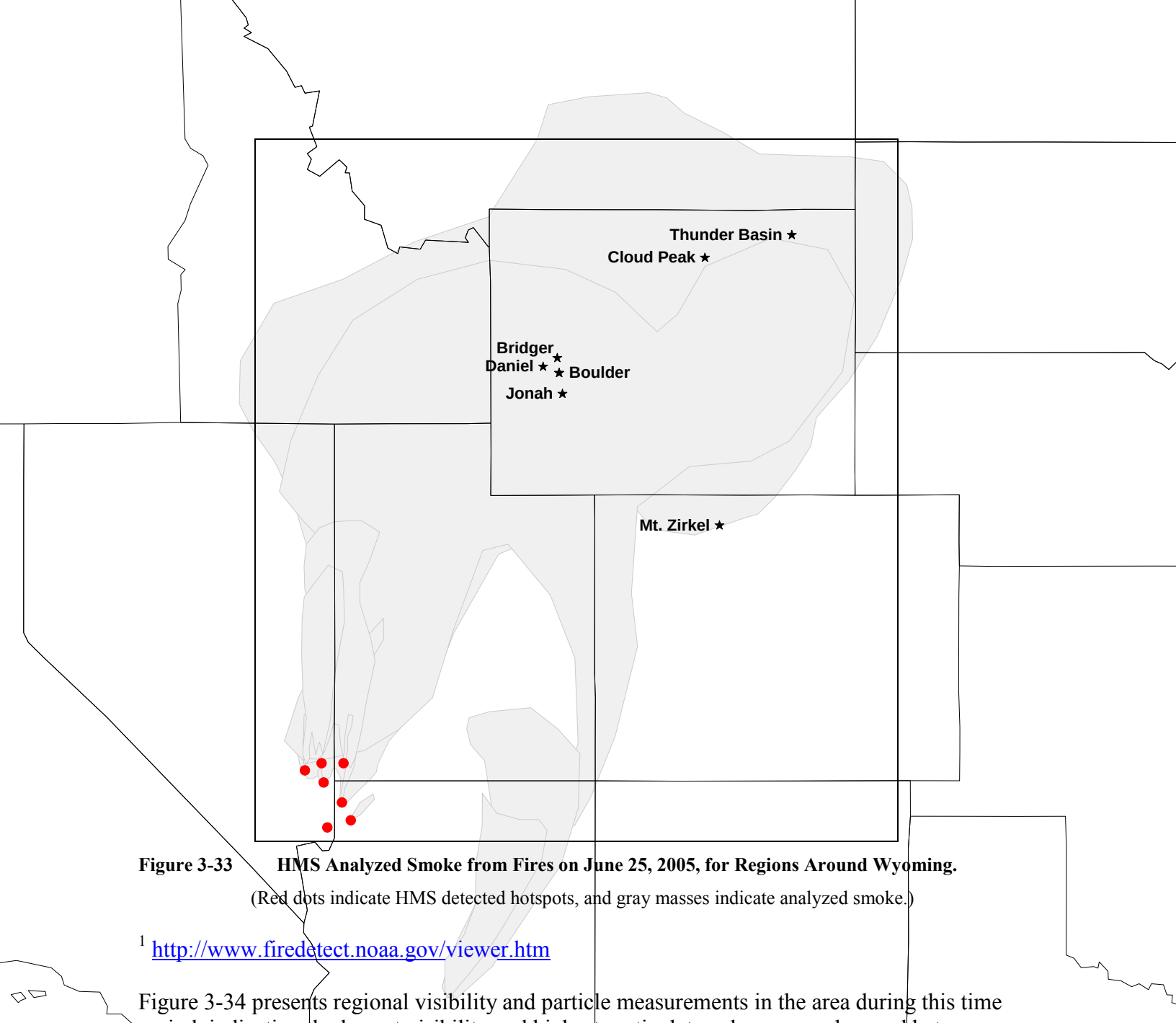


Figure 3-33 HMS Analyzed Smoke from Fires on June 25, 2005, for Regions Around Wyoming.

(Red dots indicate HMS detected hotspots, and gray masses indicate analyzed smoke.)

[1] http://www.firedetect.noaa.gov/viewer.htm

Figure 3-34 presents regional visibility and particle measurements in the area during this time period, indicating the lowest visibility and highest particulate values were observed between June 24, 2005, and June 28, 2005. The figure includes atmospheric extinction measured by the IMPROVE transmissometer at the Bridger Wilderness Area, north of the Boulder station, and aerosol scattering, PM_{10}, NO_2, and O_3 measured at the Boulder station. Unfiltered b_{ext} and b_{sp} data are presented here because filtered data uses standard defined criteria in an initial systematic effort to identify possible weather interferences, but these criteria can filter visibility data related to events like fire and are not applied in this plot. Figure 3-35 presents images taken during these high b_{sp} readings.

Some of the highest PM_{10} readings in 2005 were also recorded at the Boulder station during this time period, reaching a 1-hour average concentration of 77 $\mu g/m^3$ on June 25, 2005. NO_2 and O_3 were slightly elevated at the Boulder station during the fires, reaching a 1-hour NO_2 average value of 24 ppb, a 1-hour O_3 measurement of 76 ppb, and an 8-hour O_3 average of 73 ppb on

July 27, 2005. Regionally, measured atmospheric extinction was also elevated at the Wyoming Department of Environmental Quality (WDEQ) visibility stations in northeast Wyoming (Cloud Peak Wilderness Area and Thunder Basin National Grasslands) and at the IMPROVE Mt. Zirkel visibility monitoring site in Colorado.

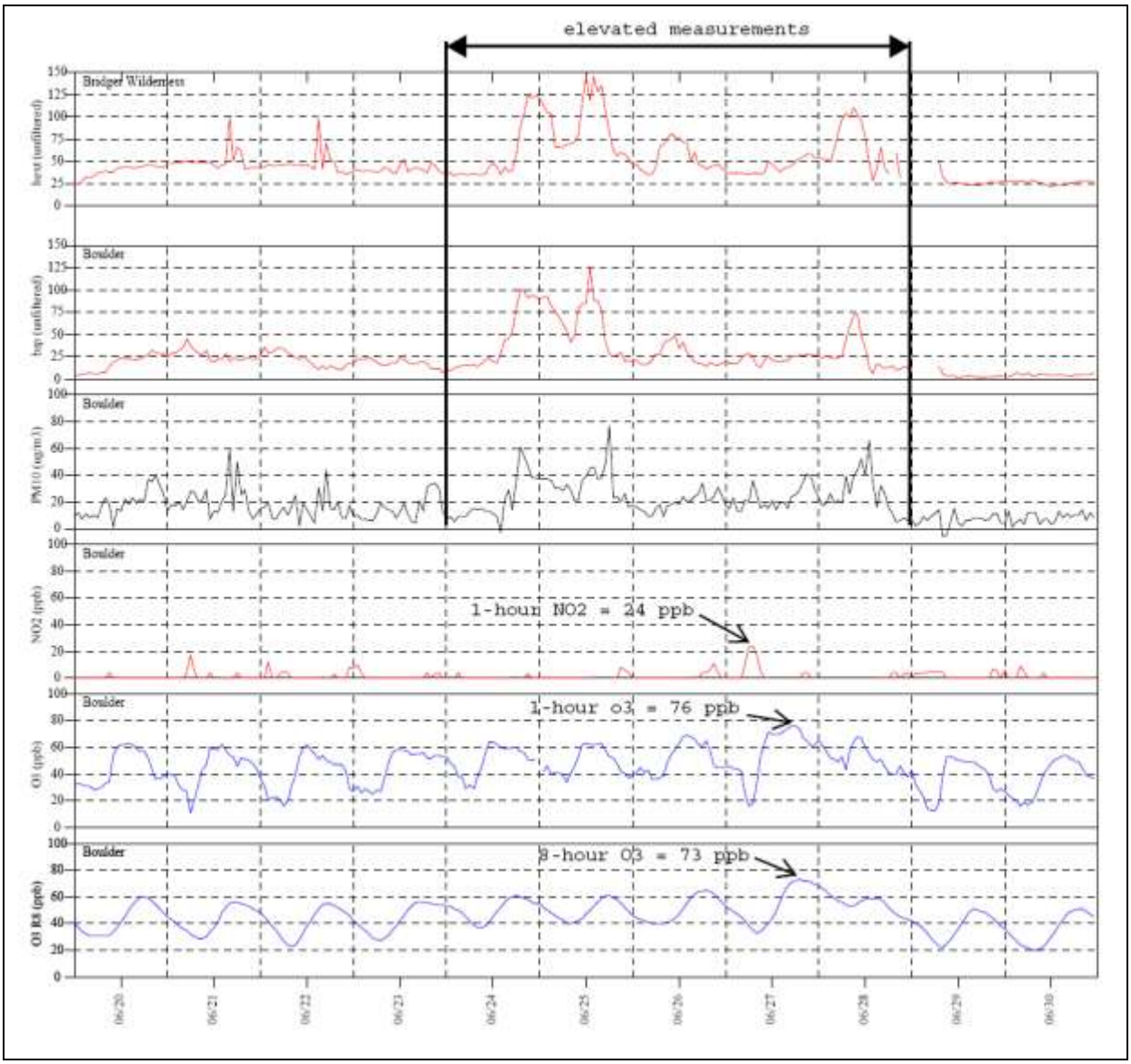


Figure 3-34 Selected Monitored Parameters for Regional Sites, Including Light Extinction (b_{ext}) at the Bridger Wilderness Site; and Aerosol Scattering (b_{sp}), Particulate (PM_{10}) and Gaseous (NO_2 and O_3) Measurements at the Boulder Monitoring Station, During Fires Observed in June, 2005.

View 1 (North)
June 25, 2005 (1100)
b_{sp}= 84 Mm^{-1}
Est. Visual Range 41.6 km (25.8 mi)
RH = 22.9%

View 5 (South-southwest)
June 25, 2005 (1300)
b_{sp}= 126 Mm^{-1}
Est. Visual Range 28.8 km (17.9 mi)
RH = 17.9%

Figure 3-35 Images Taken from the Boulder Camera during Periods of High Scattering

Small Local Fires

A prescribed burn on Fremont Ridge near Soda and Fremont Lakes, north of the Boulder station, was conducted on September 20, 2005. Figure 3-36 presents HMS analyzed smoke on this day. Figure 3-37 shows the smoke plume as it spans across two of the camera's views, later in the afternoon. During this fire, the Boulder station measured elevated NO_2 concentrations reaching a high of 28 ppb in the early morning of September 20, 2005.

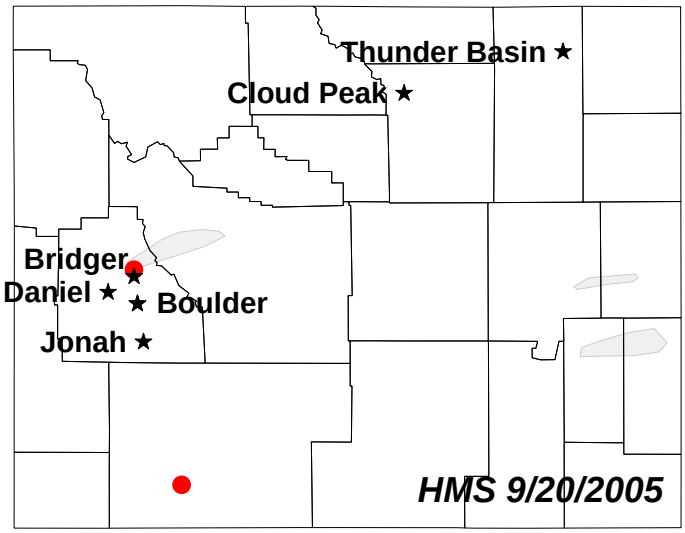


Figure 3-36 HMS Analyzed Smoke from a Prescribed Fire Near the Bridger Wilderness Area on September 20, 2005. Red dots indicate HMS detected hotspots and gray masses indicate analyzed smoke.

Figure 3-37 Combined Images Taken from the Boulder Camera (September 20, 2005 (1630)) Showing the Expansion of the Smoke Plume Later in the Day.

PM_{10} Events Associated with Frontal Passages

There were several instances of elevated PM_{10} concentrations associated with frontal passages. For example, a regional buildup of PM_{10} appears to be transported along the edge of an occluded front on September 10, 2005, with concentrations dropping after the front passage. Figure 3-38 presents a surface data plot indicating the location of the front in the early morning on September 10, 2005. Figure 3-39 presents a timeline indicating Boulder aerosol scattering measurements and particulate concentration spikes that were seen regionally at the Boulder, Daniel, and Jonah monitoring stations.

The Boulder station recorded a 1-hour concentration of 124 $\mu g/m^3$ at 1300. The Daniel station reached its highest PM_{10} value of 2005 with a 1-hour concentration of 178 $\mu g/m^3$ at 1200, and the Jonah station had two concentration spikes during the day, with a second spike of 95 $\mu g/m^3$ at 1300 that appeared to be associated with the passage of the front. Digital camera images are presented in Figure 3-40 for the Boulder station and in Figure 3-41 for the Jonah station, presenting visual conditions before and after the passage of the front on September 10, 2005. Images from the Daniel camera are not available for this time period.

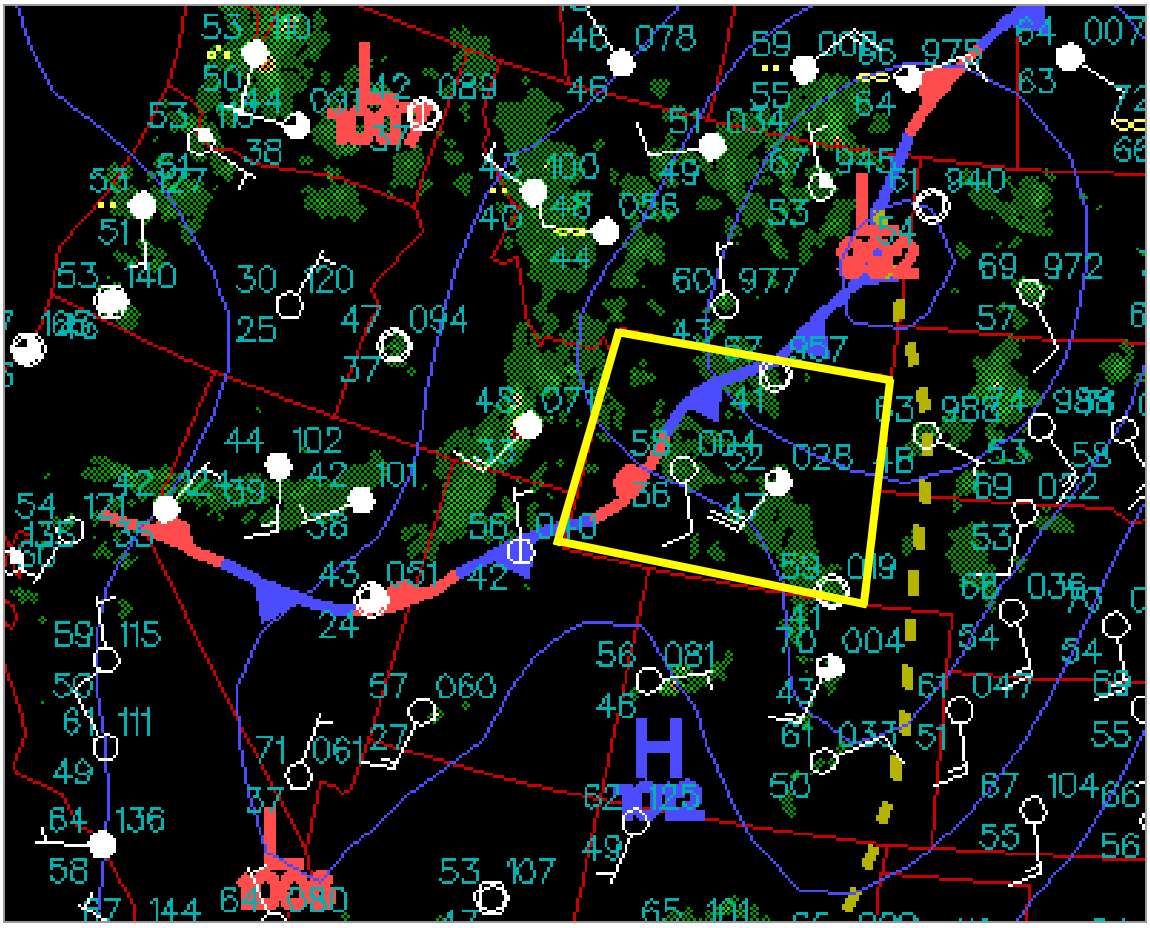


Figure 3-38 Surface Map Showing the Passage of an Occluded Front Over Southwest Wyoming on 9/10/2005 (0500). Wyoming is highlighted in yellow.

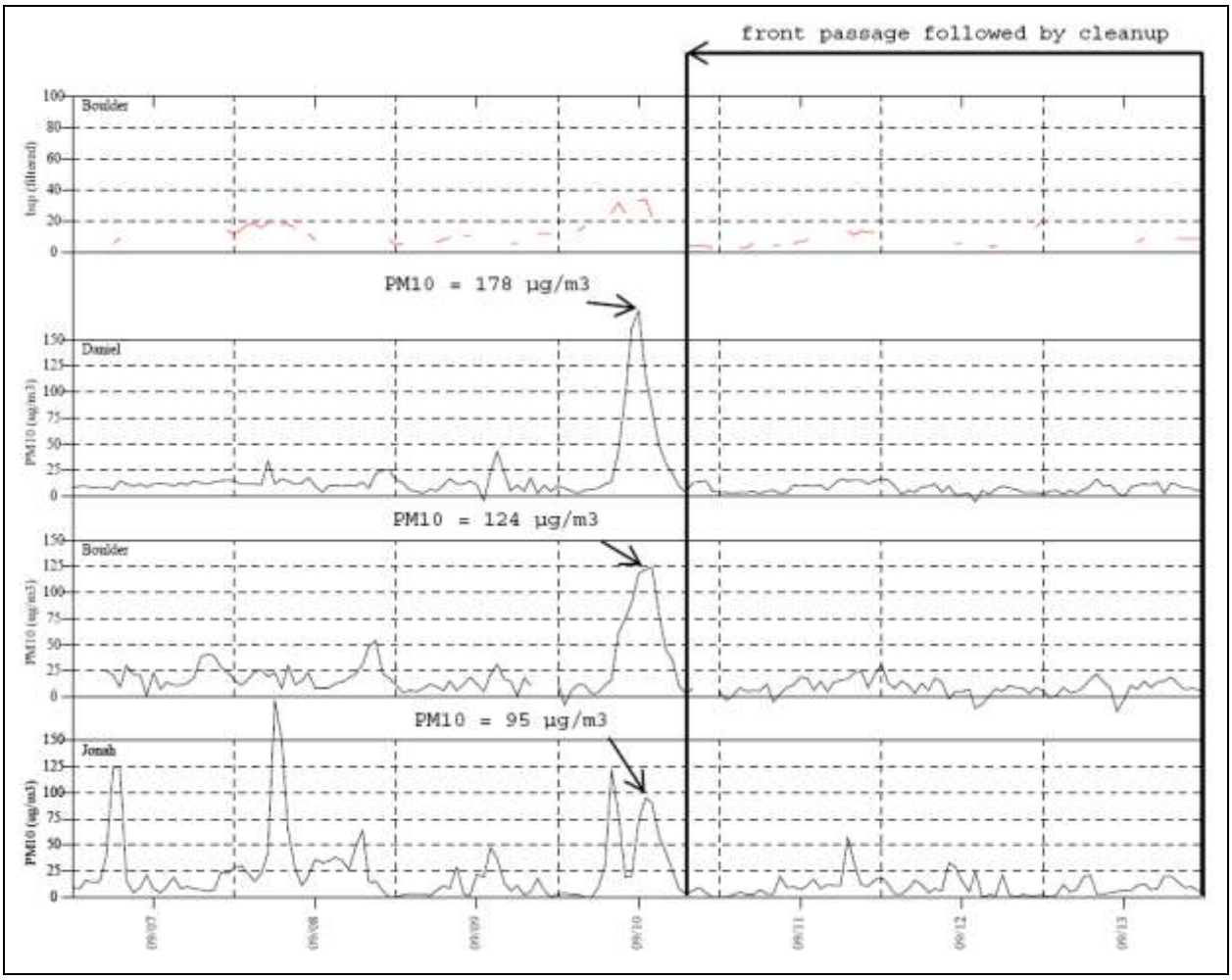


Figure 3-39 Timeline Indicating Aerosol Scattering (b_{sp}) at the Boulder Station; and PM_{10} Measured at the Daniel, Boulder, and Jonah Stations, During the Passage of a Front on September 10, 2005.

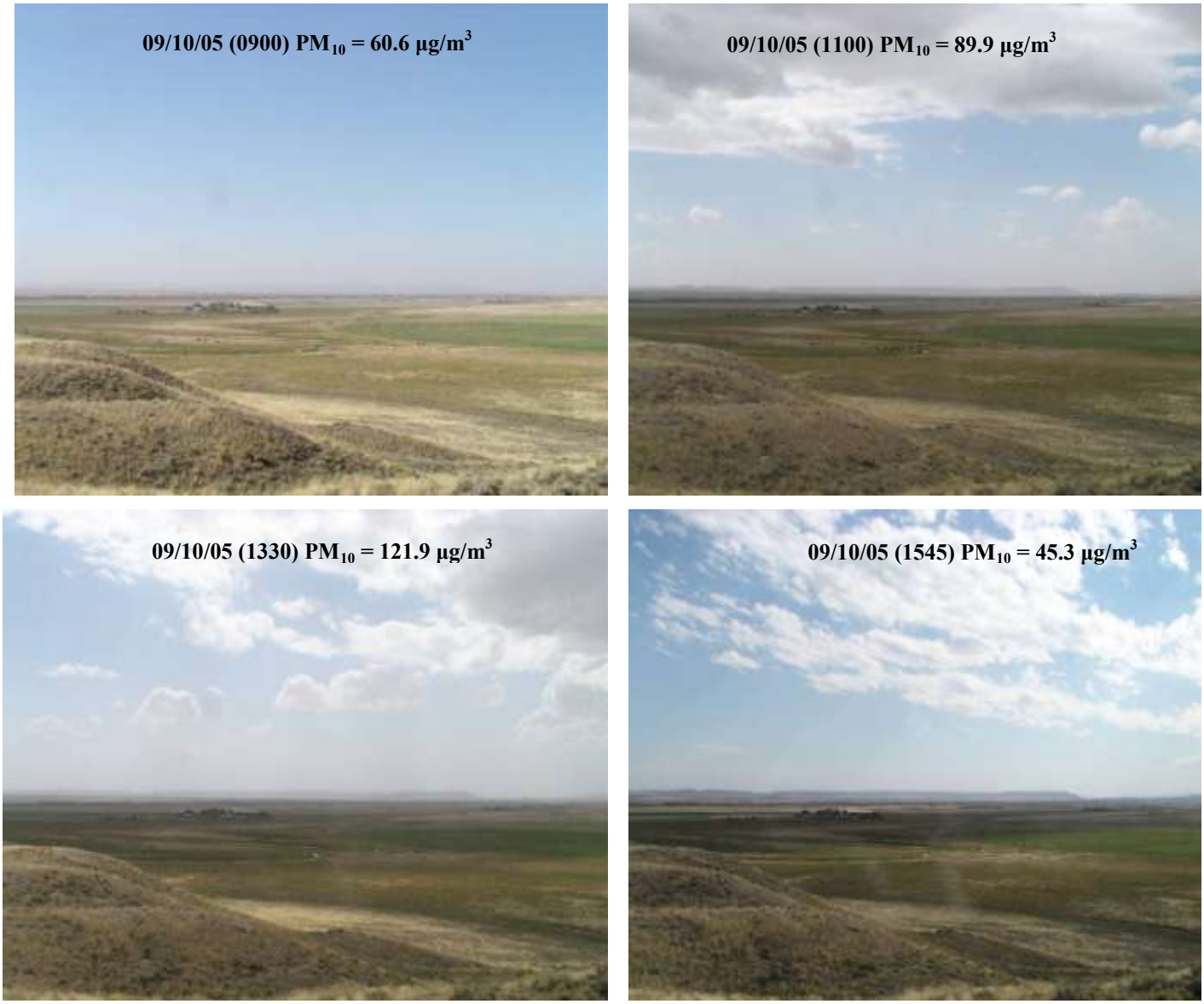


Figure 3-40 Images Taken from the Boulder Camera Before and After the Passage of an Occluded Front on September 10, 2005.

September 10, 2005 (0800)
PM_{10} = 122 µg/m^3

September 10, 2005 (1100)
PM_{10} = 20 µg/m^3

Figure 3-41 Images Taken from the Jonah Camera Before and After the Passage of an Occluded Front on September 10, 2005.

Another example of PM_{10} buildup prior to a frontal passage was detected on October 2, 2005. Figure 3-42 presents a timeline indicating Boulder aerosol scattering measurements and particulate concentrations showing high 1-hour values of 52.7 µg/m^3 at 0900 at the Boulder station, 38.2 µg/m^3 at 0800 MST at the Daniel station, and 42 µg/m^3 at 1000 at the Jonah monitoring station. Daily maximums on October 3, 2005, following the front passage were 23.6 µg/m^3, 5 µg/m^3 and 5 µg/m^3 for the Boulder, Daniel, and Jonah stations respectively. Digital images are presented in Figure 3-43 showing the haze and pollutant concentrations at the Boulder station preceding the front, and the conditions and pollutant concentrations after the front. Images from the Jonah archive are not available for the period.

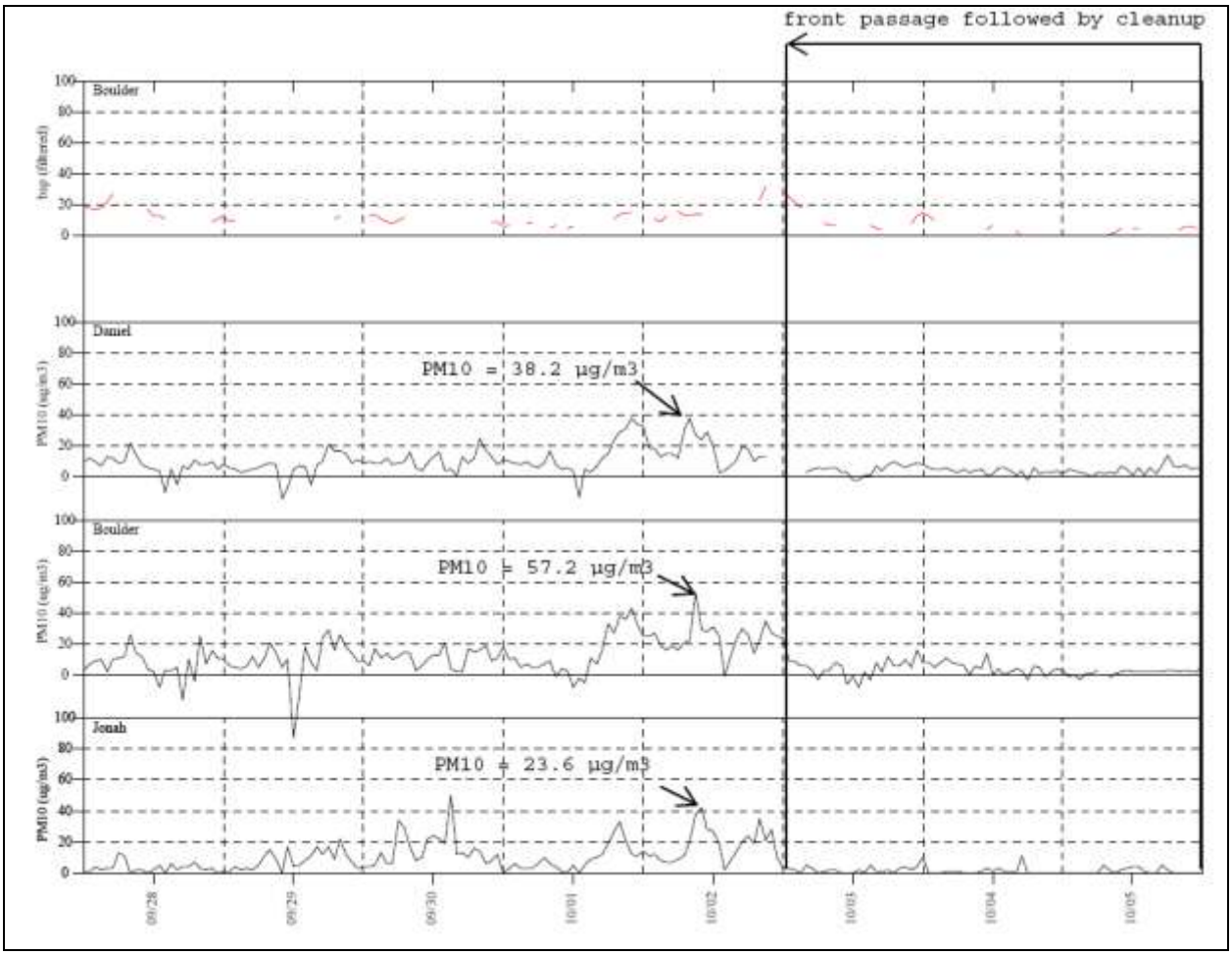
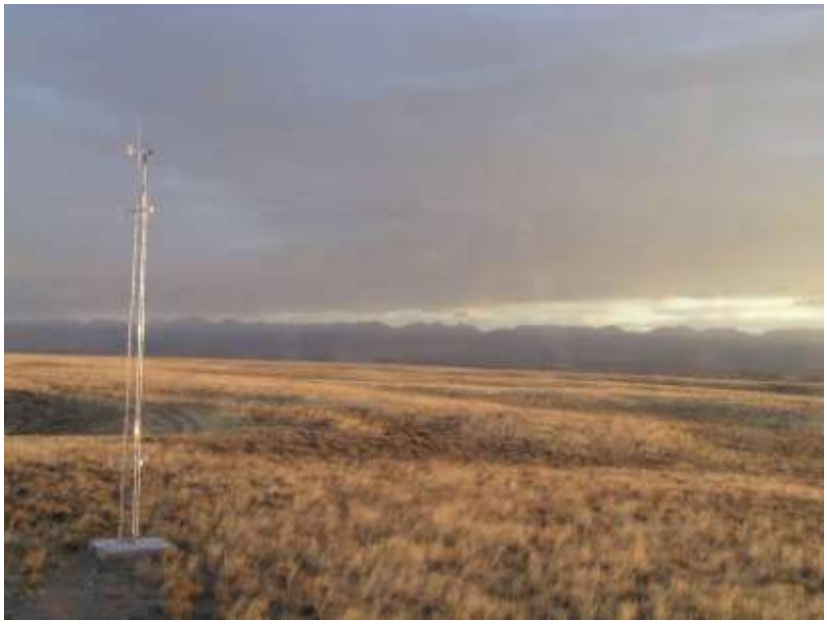


Figure 3-42 Timeline Indicating Aerosol Scattering (b_{sp}) at the Boulder Monitoring Station, and PM_{10} Measured at the Daniel, Boulder, and Jonah Stations for the Passage of a Front on October 3, 2005.

October 2, 2005 (0630)
PM_{10} = 16.3 μg/m^3



October 3, 2005 (0900)
PM_{10} = 9.0 μg/m^3

Figure 3-43 Images from the Boulder Digital Archive Before and After the Passage of a Cold Front on October 3, 2005.

Flaring Event

Figure 3-4 is a photo that was taken from a point about two miles south of Pinedale looking southwest by a local resident showing a black plume somewhere northwest of the Boulder monitoring site on December 6, 2005 at 1351 MST. Figure 3-45 presents a timeline indicating unfiltered aerosol scattering, PM_{10} and NO_2 measured at the Boulder station during the time period that may have been impacted by the smoke plume. Unfiltered b_{sp} data are presented here to avoid rapidly changing and/or high readings influenced by the fire being filtered as weather related. Aerosol scattering values appear elevated between 1800 MST on December 6, 2005 and 1300 MST on December 9, reaching a high value of 141 Mm^{-1} on December 7 at 2200 MST. On December 9, 2005, PM_{10} concentrations reach 24 $\mu g/m^3$ and high NO_2 is measured at 40 ppb. Data was not available for the Jonah station between December 1, 2005 and December 13, 2005.

Figure 3-44 Photo taken by a Local Resident on December 6, 2005 (1351 MST).

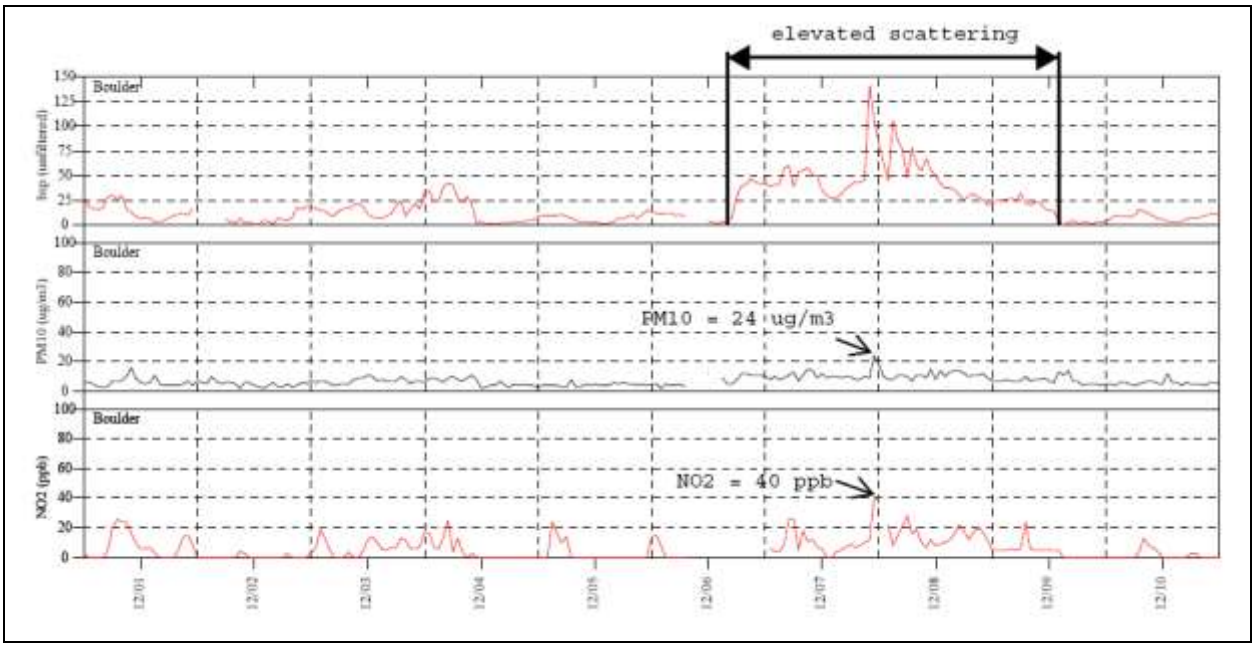


Figure 3-45 Timeline Indicating Aerosol Scattering (b_{sp}), PM_{10} and NO_2 Measured at the Boulder Station During a Flaring Event that Occurred Somewhere NW of the Site.

4 Summary

Characterize current conditions

This is the first annual monitoring report produced by the AQTG. The 2005 Report covers results of monitoring data collected through 2005 (where available) and reviews observable long term trends from monitoring stations that were originally discussed in AQTG's Monitoring Plan, submitted to PAWG in March of 2005 (with the exception of the two new sites, Daniel South and Pinedale).

Currently, the PAPA area is not exceeding NAAQS/WAAQS levels. There were however, days in February 2005 that had unusually elevated concentrations of O_3. These elevated concentrations can be cause for concern because of the possibility for negative health affects to impact unusually sensitive people (e.g. children, elderly, asthmatics, etc.).

In 2005 the USFS performed a statistical analysis of their long term lake data. The USFS has concerns about the acid neutralizing capacity (ANC) of the subject lakes changing significantly. The USFS also has concerns about the increasing trends in nitrate concentrations. The changes monitored at Black Joe Lake are of particular concern to the USFS because they indicate that fertilization (nitrification) of the lake is occurring meaning that the lake is not able to use all of the nitrogen entering the lake system. This is a first step to eutrophication of the lake, and changes within the lake biota may be starting to occur. Although 2005 data were not yet available for the bulk deposition sampling, long term data through 2004 are still presented in this report. The data show that 2004 results were not substantially different than the preceding few years and that deposition tends to increase in the summers months. The NADP data also show similar results in that there is a seasonality associated with wet deposition and the 2004 results fell within levels of normally expected variation over the last few years.

The 2005 Report also summarized visibility by presenting several different types of data. Although 2005 data were not yet available for the IMPROVE aerosol samples, historical data through 2004 are presented. Regional haze visibility impairment, as measured by the Bridger monitor, did not show any substantial changes from the preceding years. As with deposition, visibility data show a strong seasonal influence. Nephelometer and transmissometer data for 2005 show data that are consistent with results expected in their respective Class I and Class II locations. This report also shows examples of regional and local visibility impacts as evidenced through scene monitoring and supported by other ambient monitoring located in and near the PAPA. Examples of impairment from large wildfires, prescribed burns, flaring activities and elevated particulate levels associated with frontal passages are discussed. Additionally, examples of clear and hazy days are also shown from each scene monitor

Status of Existing Mitigation

Section 5.0 of the Monitoring Plan listed numerous required and voluntary mitigation measures which were being implemented in the PAPA at that time. Those measures are still in place or have been expanded either by voluntary efforts or by new regulations. Operators are required to comply with WDEQ-AQD Jonah & Pinedale Anticline Gas Field Permitting Requirements (July 2004) requiring air emission controls be installed sooner at individual well locations and upon start up at pad well locations. Also, the emission thresholds requiring control have been lowered

as has the emission threshold where removal of certain control devices is allowed. Most operators install emission control devices upon startup of the first well at a pad facility rather than waiting until startup of additional wells, even though this may not be required under the WDEQ-AQD's permitting process.

New Mitigation Measures Implemented in 2005

As required in the Anschutz, Shell, Ultra (ASU) FONSI, November 2005, ASU operators were required to install and test emission levels of NOx reduction demonstration technology for drilling rig engines. In December 2005, Shell and Ultra installed SCR (selective catalyst reduction) technology on four drilling rigs and Ultra for Anschutz installed bi-fuel technology on two drilling rigs. SCR technology on the Shell diesel electric (Tier 1) engines achieved 80% reduction of NOx emissions with no ammonia slip. The overall application of the technology of these specific engines worked well related to emission reductions but some operational issues were noted and will continue to be addressed as Shell becomes more familiar with the technology. The other SCR application was on two diesel mechanical drilling rigs which uncovered several shortcomings for the technology. Several of the engines did not have high enough exhaust temperature to facilitate the necessary urea to ammonia conversion in the exhaust stream in order to facilitate the NOx reduction. Other engines had a high exhaust temperature and risked damaging the catalyst bed. Ultra has completed the emission testing.

Bi-fuel technology was also installed and tested on several drilling rigs. Reported results indicated fuel cost savings by supplementing diesel with natural gas and mixed test results related to the emission reductions.

Questar constructed a condensate and water gathering system and began operation late in 2005 to serve Questar's wells. By gathering water and condensate from all Questar operated wells and pads into a centralized system almost all tanks which were used to hold water and condensate have been taken out of service (they will be physically removed from the Mesa in the summer 2006 when the BLM allows construction activities to proceed). Additionally, operations which have been consolidated to multi-well pads have diminished the number of gas dehydrators in place on the Mesa. The net effect of these changes is to greatly reduce the following emissions from Questar's operations:

- Particulate
  - Road dust from truck traffic
  - From diesel truck tailpipe emissions
- VOCs
  - From condensate tank operations
  - From gas dehydrator operations
- HAPs
  - From gas dehydrator operations
- NO_X
  - From diesel truck emissions

In July 2005, WDEQ-AQD issued completion flaring permits for each company operating in the Pinedale Anticline and Jonah Project Areas. The permits require the use of Best Management Practices, including the use of ―green completion" technology, to reduce by at least 90% visible and other emissions associated with the fluids typically flared or vented during well completion operations. The permits require the use of ―green completion" technology except for those times when safety concerns or lack of infrastructure prohibit its use. Reporting requirements of the permits allow DEQ personnel to observe planned completions and recordkeeping/monitoring requirements provide information for tracking the effectiveness of the permits on reducing emissions.

5 Monitoring Needs and Objectives

Over the last year the AQTG has spent time evaluating current monitoring in addition to identifying needs for additional monitoring needed to evaluate the impacts of ongoing natural gas development in the Pinedale Anticline area. This work has included presentations from Scott Copeland, a USFS Visibility Analyst and a joint meeting with WY DEQ, EPA, BLM, Shell and USFS to discuss overall air quality monitoring in southwest Wyoming and assess the effectiveness of current monitoring programs through ongoing AQTG meetings. Most of the monitoring proposed is outside of the immediate PAPA area; however the AQTG believes that the proposed monitors would assist in fully understanding the existing air quality conditions in southwest Wyoming (since regional conditions have a direct impact on local conditions) and in addition, will provide benefits beyond the Pinedale Anticline project. Table 5.1 (below) briefly summarizes the needs that were identified and their current status.

Table 5-1: Table of monitoring needs and current status

Monitoring Need	Current Status
Ambient air monitor at South Pass that will include limited aerosol monitoring.	WDEQ-AQD has issued a contract for this site and is in the process of determining the exact location. Start-up is expected in late summer 2006
Ambient air monitor for Uintas and Wyoming Range.	WDEQ-AQD has begun the bidding process to hire a contractor for the Unitas site. Start-up is expected in Fall 2006. The Wyoming Range site will be bid in 2007.
VOC Monitoring	WDEQ-AQD is evaluating VOC monitoring methods.
SO_2 Monitor	WDEQ-AQD will place SO_2 monitors at the South Pass Site and the Uinta site in 2006. WDEQ-AQD will continue to evaluate the need for SO_2 monitors at the

	Boulder, Jonah and Daniel South monitors.
O_3 Monitors	Since there is only one year of data from the ambient air monitors, it was agreed that it would be best if we would hold off on adding additional O3 monitors until more data are available..
IMPROVE Protocol Aerosol Monitoring and/or scene and nephelometer monitoring near Muddy Ridge.	Under further discussion by AQTG in 2006.
Continuation of IMPROVE Bridger Transmissometer	State/Industry MOU funded project
Installation of a scene camera at Fortification Mountain	Agreement pending with Shell.
Place WARMS station at Gypsum Creek NADP site.	Unfunded. Recommended in Section 6.
Long-term lake chemistry in Northern Wind River Mountains.	The USFS committed to add an additional very sensitive lake, Lazy boy Lake located on the northern portion of the Range to the monitoring network using existing staff and resources.
Analysis of macroinvertibrates and zooplankton data in long term lakes.	Unfunded, recommended in Section 6.
Paleosediment analysis (diatoms) in Black Joe Lake	Unfunded, recommended in Section 6.
Survey O_3 impacts to vegetation in the Bridger Wilderness	USFS commitment.
Continue existing USFS monitoring of the NADP wet deposition monitoring, long-term lake monitoring and bulk deposition monitoring.	State, industry (Exxon-Mobil and others) and USFS will contribute funding for the next 5 years. Agreements pending.
Review of current monitoring network	Under further discussion by AQTG in 2006.

Funding for most of the monitoring needs identified above are a result of an agreement between WDEQ-AQD and industry operators (Exxon-Mobil, EnCana, Shell, Ultra, BP, Questar and EOG) from the Jonah/Pinedale fields to fund monitoring over the next 5 years. Other funding includes USFS commitments, and contributions from Shell for the installation and operation of a scene camera at Fortification Mountain and Exxon-Mobil for agreeing to fund the operation of the Gypsum Creek NADP site as well as the Hobbs Lake Bulk Deposition monitoring. The unfunded needs identified will be discussed in greater detail in Section 6 of this report.

6 Recommendations

Several of the monitoring needs identified in Section 5 of this document are being moved forward as recommendations. These needs were discussed and agreed upon by the AQTG through consensus and are described in detail in the following sections as are discussions on long-term monitoring and mitigation strategies.

Recommended Long Term Monitoring Projects

The AQTG has evaluated existing and proposed air quality monitoring in the PAPA area to determine if local air quality and emissions from drilling activities are adequately characterized. WDEQ-AQD and industry participants have formed an agreement to purchase and operate new ambient air quality monitors across southwest Wyoming as detailed in Section 5 of this report. Additionally, these parties have agreed to help finance NADP monitoring and bulk deposition monitoring performed by the USFS through 2010. The AQTG believes continuation of existing monitoring and the addition of proposed monitoring listed in Section 5 of this report, will provide valuable information to characterize ambient air quality, existing emission levels from PAPA oil and gas development and potential impacts to sensitive receptors. The long term monitoring project will also help the WDEQ-AQD and BLM and industry, and evaluate whether modifications (changes/additions/removals) are warranted. The following are the AQTG's monitoring recommendations based on review of the information presented in this report::

1. <u>Adding a WARMS monitor near Gypsum Creek NADP site</u>: Currently, the Gypsum Creek site only houses a NADP wet deposition monitor. Adding a WARMS monitor at the site will provide valuable information on dry deposition and other air quality parameters that are not currently monitored in the northern part of the Green River Valley. The BLM has a spare WARMS monitor that could be deployed at the Gypsum Creek site. Another option is to move an existing WARMS monitor (presently there is a WARMS monitor co-located with the Pinedale CASTNet monitor). Since the methodologies and parameters collected at the two monitors are similar, it would provide more value to move the WARMS monitor to the Gypsum Creek location. The AQTG recommends that the PAWG ask the BLM to fund and deploy a WARMS monitor to the Gypsum Creek NADP site. Deploying the spare monitor will cost approximately $10,000 to deploy and $27,000 annually to operate. Moving the existing monitor from the Pinedale site to the Gypsum Creek site would cost approximately the same amount.

2. Revisit the objectives and strategy of the NO_x Tracking Report:
   The PAPA ROD requires the BLM to track NO_x sources within the project area. The ―Amended Letter of Agreement for Tracking Nitrogen Oxide Emissions" has been in place since 2000. Since 2000 there have been substantial changes in tracking oil and gas emissions in the PAPA. Emissions from non-regulated (by WDEQ-AQD) operations equipment are now quantified in great detail by operators. The WDEQ-AQD is also gathering annual emissions data from operators for use in the NO_2 increment consumption analyses. The AQTG recognizes that the NO_x tracking report has specific objectives that differ from the previously mentioned emission inventories. The AQTG

also recognizes that the NO_x tracking report contains information on sources located outside the PAPA and source categories outside of the traditional oil and gas sector and that the tracking report allows BLM to quantify, in one location, sources operating on BLM lands. The AQTG questions the efficiency and the practicality of having several emissions inventories for the PAPA that use differing (and outdated) emission estimation methodologies. Therefore, the AQTG recommends to the PAWG that the PAWG urges BLM to revisit the objectives and strategy of the NO_x tracking report with the WDEQ-AQD.

3. Analysis of macroinvertibrates and paleosediment in long term lakes
   Increasing nitrates at all sampled inlets of lakes indicate that regional sources are probably contributing to local deposition. The decrease of ANC at Hobbs Lake outlet is of concern, because it is showing that acidification is starting to occur. From the USFS standpoint, Black Joe Lake is a major concern, as the ANC and nitrates are increasing at the inlets, outlet and hypolimnion, and sulfate is increasing at the outlet. This indicates that fertilization (nitrification) of the lake is occurring meaning that the lake is not able to use all of the nitrogen entering the lake system. This is a first step to eutrophication of the lake, and changes within the lake biota may be starting to occur.

   Due to these findings, USFS has advised the AQTG that it is important to investigate biological data (macroinvertibrates and zooplankton) at Black Joe Lake to determine if a shift to more nitrophyllic species is occurring. Studies should also include paleosediment sampling to look at historical diatom community structure changes over time. The AQTG recommends to the PAWG that funding is requested from BLM for the USFS to perform sampling and analysis on the biological data and paleosediment. Analysis of the biological data will cost approximately $5,000 and the sampling and analysis of the paleosediment will costs approximately $12,000. Please note that these monitoring activities will be one-time costs rather than an annual funding commitment. Additionally, the macroinvertibrate samples have already been collected, therefore costs are based solely on identification and analysis of assemblages.

Recommended Long-term Mitigation Strategy

The 2000 ROD used monitoring and tracking of emissions as a means to determine when mitigation measures should be implemented. WDEQ-AQD and oil and gas operators have been very proactive in trying to reduce emissions in the PAPA in a variety of ways. Operators explored ―green completion" techniques and found them to not only be practical, but also cost effective. WDEQ-AQD has issued completion flaring permits that require the use of best management practices including ―green completion" technology. The permits also require notification of planned completion flaring events and emissions reports. WDEQ-AQD also amended the oil and gas permitting guidance for the PAPA and the Jonah fields to require controls on dehydrators and storage tanks when more than one well is drilled on a single pad. This has reduced emissions of VOCs from these sources. Questar has installed pipelines for water and condensate reducing truck traffic and storage tank emissions from the anticline. Operators have also committed to reduce drill rig engine emissions by a variety of techniques.

Questar will replace some of their older drill rig engines with tier 2 engines by the end of 2006. Anschutz, Shell and Ultra are testing dual fuel drill rigs and selective catalytic reduction to assess the application of these technologies to further reduce NO_x emissions from rig engines.

The mitigation being applied by the WDEQ-AQD and industry commitments are reducing emissions of NO_x, VOCs and particulate in the PAPA. The AQTG believes that the detailed annual tracking of NO_x emissions (as required by the PAPA ROD) is critical to understanding and determining whether existing emission-reducing mitigation strategies are reducing air impacts as expected and/or when modified or additional mitigation is necessary. Annual tracking will show increases or decreases in NOx emissions that occur when regulatory and/or voluntary mitigation measures are implemented. The AQTG is concerned that the approach defined in the 2000 Letter of Agreement may be outdated in terms of emission inventory strategies. Once BLM finishes the 2005 NO_x tracking report, the AQTG thinks a reevaluation of the Agreement is warranted to assure the production of a tracking report that supports existing needs..

The current approach of mitigation advances through required and voluntary measures is succeeding in reducing pollutant emissions from oil and gas operations. Industry, WDEQ-AQD, BLM and the USFS should continue with this proactive approach to protect the air quality resource in the PAPA area. This approach should include the continuation of the PAWG and the AQTG as a forum for the above mentioned groups and the public to identify needs share information and concerns regarding air quality in the PAPA area.

7 Future of AQTG

The AQTG has been working for approximately 1.5 years and has accomplished several important tasks including 1) a summary of air quality monitoring activities in the area, 2) recommendations to PAWG for additional monitoring and/or funding, and 3) is in the process of completing one of the AQTG major milestones, compilation of the first annual Air Quality Monitoring Report.

What does the AQTG believe their function should be over the next several years?

Future AQTG Activities:

- Continued review of ongoing monitoring data from existing and proposed monitoring stations in the area.
- Ongoing dialog between task group members, representing varied points of view and experiences, to discuss the data and what they mean
- Discussion of ongoing air quality mitigation and effectiveness based on air quality monitoring results over a period of time.
- Provide PAWG with recommendations related to air quality monitoring.
- Compilation of an Annual Air Quality Monitoring Report.

- Maintaining a forum to educate task group members by bringing in subject matter experts to present pertinent air quality topics (i.e.: Scott Copeland, FS contractor)

- Serving as a means of communication between industry, regulators, public, environmental non-governmental organizations (e.g. non-profit groups), and others regarding activities occurring in the field related to regulation, gas development and mitigation efforts.

8 References

Air Resource Specialists, Inc., 2004, Standard Operating Procedure 4300, Collection of Optical Monitoring Data (IMPROVE Protocol), Version 1.0, December.

Air Resource Specialists, Inc., 2004, Technical Instruction 4300-4002, Nephelometer Data Collection via Telephone Modem (IMPROVE Protocol), Version 2.0, April.

Air Resource Specialists, Inc., 2004, Technical Instruction 4300-4006, Nephelometer Data Collection via Campbell Scientific Data Storage Module (IMPROVE Protocol), Version 2.0, April.

Air Resource Specialists, Inc., 2005, Technical Instruction 4400-5010, Nephelometer Data Reduction and Validation (IMPROVE Protocol), Version 1.1, November.

Pinedale Anticline Working Group - Air Quality Task Group, 2005 Air Quality Monitoring Plan, March 2005.

Seinfield and Pandis, 1998, Atmospheric Chemistry and Physics, from Air Pollution to Climate Change, John Wiley & Sons, Inc., New York, NY.

505