Air Quality and Smoke Management

The Superior National Forest (SNF) monitors the effects of air pollution on Forest resources. Sources of air pollution are found both outside and inside Forest boundaries. Notable sources within the SNF include wildfires and certain project management activities, particularly prescribed burning. Air pollution over the SNF is a regional scale phenomena caused by many sources from many states. In comparison, air pollution from SNF management activities represents a very small source to the Forest's annual air pollutant concentrations. Large prescribed burning projects are however an exception as they affect air quality for a short period of time.

Air quality related values are any resource that air quality can affect. The monitoring question listed below relates to specific air quality items from the BWCAW management plan.

- Effectiveness of state and federal laws related to air and water pollution
- Acid deposition impacts to lakes
- Mercury concentration to fish
- Mercury concentration in water and zooplankton
- Passive monitoring for ozone, sulfur dioxide and fluoride
- Mercury concentration in select animals, including loons and eagles
- Plant plots with known sensitivity to ozone, sulphur dioxide and fluoride to measure air pollutant-caused damage

These items were thought to have been the most sensitive at the time the plan was written (1993) and most are still relevant today.

Air toxics are a class of air pollutants that can affect ecosystems and are an emerging concern. There are 188 air toxics listed by the Environmental Protection Agency (EPA) (Air Toxics). These pollutants do not have standards set by EPA but rather health benchmarks that are used as guidelines and not enforceable standards (MPCA, 2005).

Air quality impacts measured on the SNF are dominated by sources outside the SNF. In the Minnesota Pollution Control Agency's (MPCA) Regional Haze plan, all air emission sources in Minnesota are estimated to be responsible for only 28 percent of the fine particulate pollution that causes visibility impairment in the BWCAW. Northeast Minnesota is responsible for half of that amount (MPCA Regional Haze Plan). For mercury pollution, the MPCA estimates that the State is responsible for 10 percent of the deposition that contributes to elevated concentrations of mercury levels in fish (MN Mercury Estimates).

The Forest Plan directs the SNF to maintain high air quality standards. Both air (and precipitation) quality and the resources air can affect (water quality) are routinely monitored by SNF resource managers.

Regional Air Quality

Monitoring Question

The Forest Plan includes the following monitoring questions related to Air Quality:

- To what extent is Forest management contributing or responding to air quality effects on ecosystems, human health or human enjoyment?
- Are air quality related values of the BWCAW being maintained?

For the purposes of this report, air quality monitoring is divided into two monitoring questions.

1. Is poor air quality leading to impairment of other resources such as water and biota? This question is addressed by long-term monitoring of water quality in lakes and mercury concentration levels in biota (such as fish). Results are addressed in the Water Resources section of this monitoring report.

2. What is the quality of the air and precipitation? This question is sub-divided into two parts: regional scale and project scale monitoring. It should be noted that there is no commonly accepted demarcation between the two, but the division helps in the presentation of the information for this report.

For this subsection the pertinent monitoring question is:

- What is the quality of the air on the SNF at the regional scale?

Forest Plan direction provides the following direction for Air Quality:

- D-AQ-1. Air on the Forest is of high quality so that: 1) ecosystems are not impaired by pollutants originating in the air, 2) the health of visitors, residents, and employees are not impaired, 3) poor visibility does not impair scenic quality, and 4) other air quality related values are not adversely affected.
- D-AQ-3. Air emissions from National Forest management actions do not degrade natural resources or uses of the Forest.

An understanding of air quality at the regional scale is important because it determines the baseline from which any project-level impacts are measured. The SNF also has a responsibility under the Clean Air Act and other legal authorities to measure and understand the impacts of the current air quality on the resources of the Forest. Impacts must then be communicated to the appropriate regulators (EPA, MPCA) so action can be taken to alleviate any adverse impacts.

This question will be addressed by looking at the data collected at the Forest's air monitoring station termed "Fernberg", which is located 20 miles east of Ely (Figure 1.1). The location of this site was chosen because it is representative of air quality conditions across the BWCAW and is located away from sources of air pollution. In addition, Forest activities that are large enough to affect regional air quality can be measured at this site. The impact of smaller project-scale SNF activities can also be measured at this site if these activities are located close enough.

The monitoring question above will be subdivided into two sub-questions. For each air quality parameter measured, does it:

- Exceed any established standard?
- Exhibit any clear time trends?

The monitoring drivers are very numerous and are listed in the Forest Plan on pages 4-10 and 4-16. As mentioned above, an emerging issue is a concern over a class of air pollutants termed "air toxics". To date the only air toxic that has been monitored is mercury. A new monitoring effort established in 2010 in cooperation with the MPCA will monitor the background level of nearly 70 air toxics at Fernberg.

These monitoring drivers are appropriate because they address the monitoring questions and desired future conditions in the Forest Plan. The unit of measure is the concentration of a number of air contaminants in air and precipitation. The concentration of contaminants is an effective and appropriate unit of measure because it allows comparison to state and national standards for each contaminant.

Figure 1.1. The Fernberg regional scale air quality monitoring site.

Monitoring Method(s)

Each monitoring program (data set) is part of a larger national network having national standards and protocols. From Table 1.1, the visibility/IMPROVE sampler collected 100 percent of the data possible for 2009. This is exceptional and follows another good year in 2008 when 95 percent was achieved. Another noteworthy event from the past year was the problems with one of the meteorological sensors, which had significant downtime for much of the last three months of 2009 (i.e., wind speed and direction). This was caused by ice falling from the tower and knocking the sensor off.

Table 1.1. Air monitoring data from the monitoring station at Fernberg on the Superior National Forest.

Data Set (AQ Indicators)	Monitoring Period (year to present)	Network Data Collection Standard (%)	Data Collection Achieved (%) (year)
Ozone, smog	1976	75/90 - EPA/MPCA	83 (2009)
Acid rain -precipitation chemistry (9 chemicals)	1980	75	85 (2008)*
Visibility - fine particulate chemistry (IMPROVE - 50 chemicals)	1991	75	100 (2009)
Mercury in precipitation	1995	75	94 (2008)
Meteorology	2000	90	75 (2009)
Continuous fine particulate	2005	75/90 - EPA/MPCA	99 (2009)
HazeCam, digital camera to document visibility	2005	75	88 (2009)
Ammonia, gaseous - passive	2007	75	100 (2008)
Air Toxics (70 chemicals)	2010	ND	ND

* The acid rain monitor did not meet uptime standard for 2008 due to poor performance for one quarter; this caused that quarter to fail which, for this program, invalidates it for the whole year
ND=No data yet available

Results

An analysis of trends over time was used to judge progress in implementing the Forest Plan. In addition to trends, this report will also assess the current level of air pollutants in comparison to EPA standards, where they exist.

Summarizing information for approximately 130 chemicals located in air and water precipitation is difficult. The chemicals selected for this report are a concern for both human and environmental health. Moreover, the chemicals selected for the report are those that have been studied for a longer duration than others.

Implications

This report will focus on the following 3 pollutants: precipitation acidity, fine particulate and ozone.

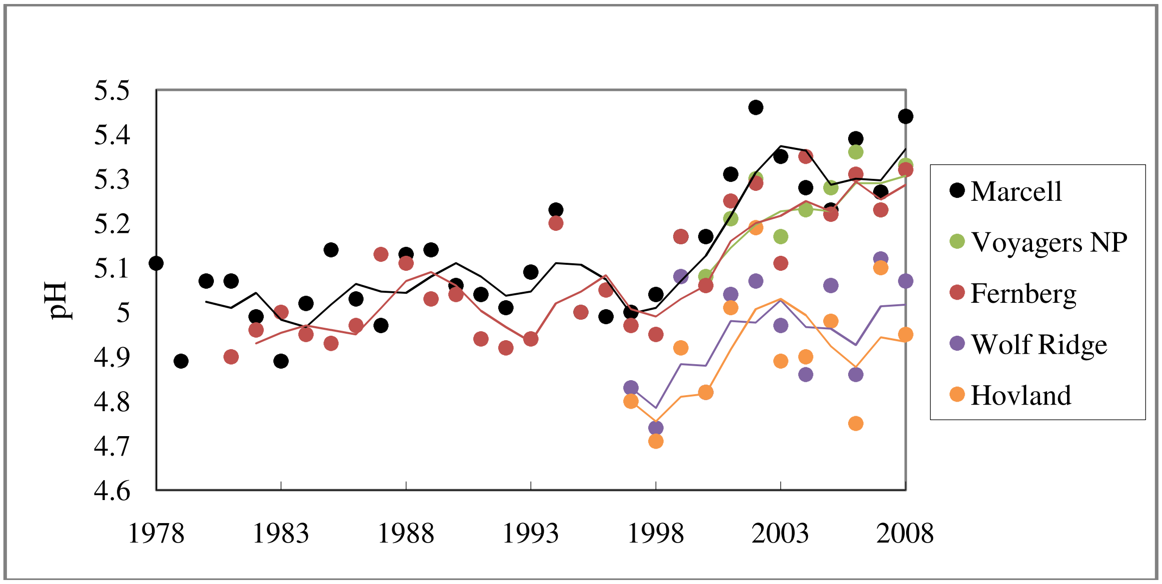
<u>Trends and Standards</u>

Trends in air quality often take many years to become evident. For most pollutants monitored at the Fernberg site, no major changes have been seen over the past five years.

Precipitation Acidity

Figure 1.2 shows that precipitation acidity has been fairly flat since 2003, although the previous seven years (since about 1998) showed a great improvement or lessening of acidity. There is no EPA standard for precipitation acidity.

Figure 1.2. Precipitation acidity in northern Minnesota. A lower pH value indicates an increase in acidity.



The likelihood that acidic precipitation will negatively affect the ecosystem depends on the chemical capacity of the soils to neutralize the precipitation and the sensitivity of the local waterbodies based on their hydrological setting (Webster 1995). The existence of natural organic acids from wetlands is also thought to play a role in mitigating acid precipitation (EPA 2009). The Forest measures the chemistry of sensitive lakes to determine if any are being negatively affected by acid precipitation or other pollutants from the air. A natural precipitation pH is thought to be about 5.6. Figure 1.2 shows that the three inland sites (Marcell, Voyagers National Park and Fernberg) are approaching this value; while the two sites on the shore of Lake Superior are more acidic (Wolf Ridge and Hovland). This may be evidence suggesting there are different air masses affecting the North Shore of Minnesota versus inland areas.

Sulfur is the dominant chemical in precipitation that causes acidity. Atmospheric deposition of sulfur is also monitored at the sites in Figure 1.2. Monson (2009) analyzed this data and found that sulfate significantly declined between 1982 and 1995, but then leveled off from 1996 to 2006. Average sulfate deposition declined 45 percent from 1982-1984 to 2004-2006. Linear regressions on sulfate deposition at three stations (two of which are Fernberg and Marcell) before 1995, have nearly identical decreasing regression slopes indicating that regional scale emissions are driving changes in sulfur deposition versus local sources. After 1995, the slopes are not significantly different from zero, which indicates that in recent years atmospheric deposition of sulfate has stopped declining. The trends in sulfate deposition strongly track national power plant sulfur emission trends. This again shows the influence of widely dispersed sources in precipitation quality on the Forest.

It is also important to note that another important source of sulfur to aquatic systems besides the atmosphere is wetlands. Global warming can cause an increase in sulfur loading from peatlands to surface waters (Monson 2009).

Particulate Matter

Particulate matter is classified according to its size. The smallest size, known as fine particulate matter, is the most dangerous because it can get deep in the lungs and cause both lung and heart problems. Fine particulates also scatter light and cause haze.

Clearly displaying long-term trends for particulate matter is difficult because over the years monitoring was done for different fractions of particulate matter based on what the EPA health standard was at the time. Fine particulate matter (also known as $PM_{2.5}$) monitoring has only been completed since the EPA $PM_{2.5}$ standard was promulgated in 1997. Before that, EPA was concerned with a broader size range of particulate matter (coarse) known as PM_{10}. Monitoring for PM_{10} has been ongoing since EPA's standard for PM_{10} was first promulgated in 1987. Before this time, monitoring was done for an even larger fraction of particulate matter known as total suspended particulate (TSP). All the sites in Figure 1-3, 1-4, and 1-5 are currently below the annual fine ($PM_{2.5}$) particulate standard for human health impacts of 15 micrograms per cubic meter (ug/m^3). EPA is currently considering lowering the $PM_{2.5}$ annual standard to as low as 11 ug/m^3 which could put some sites in southern Minnesota over the standard.

Figure 1.3. Trends for fine particulate matter in Minnesota (MPCA 2009a). Particles are regional pollutants with similar concentrations over large parts of Minnesota.

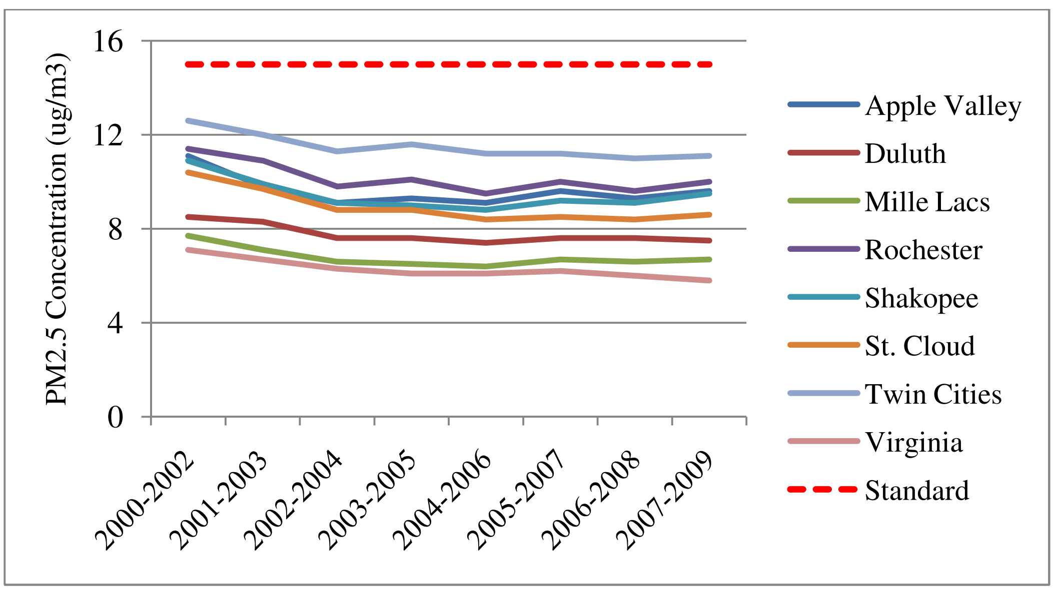


Figure 1.4 displays the fine particulate matter as measured in Virginia, MN since 1968. The trend in TSP shows a decrease until the mid 1980s and then another slight decrease in the early 1990s and a plateau since then. The smaller fractions of particulate matter (PM $_{2.5}$) do not have as long a record but show a slight decrease. Since larger particulate matter settles out faster and therefore does not travel as far, the TSP values should be more affected by local emission sources; while the smaller fractions, especially $PM_{2.5,}$ should be affected more by regional emission sources.

Additional fine particulate data gathered by monitors located in or near national parks and wildernesses is included in Figure 1.5. The BWCAW data is from the Fernberg site.

Figure 1.4. Fine particulate matter in Virginia, Minnesota.

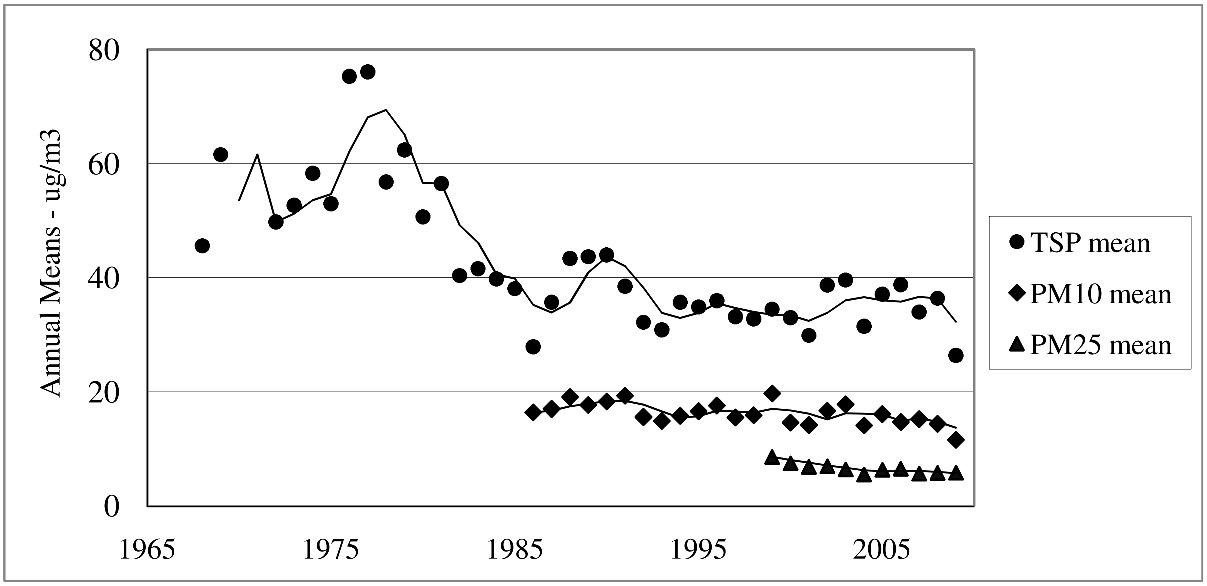
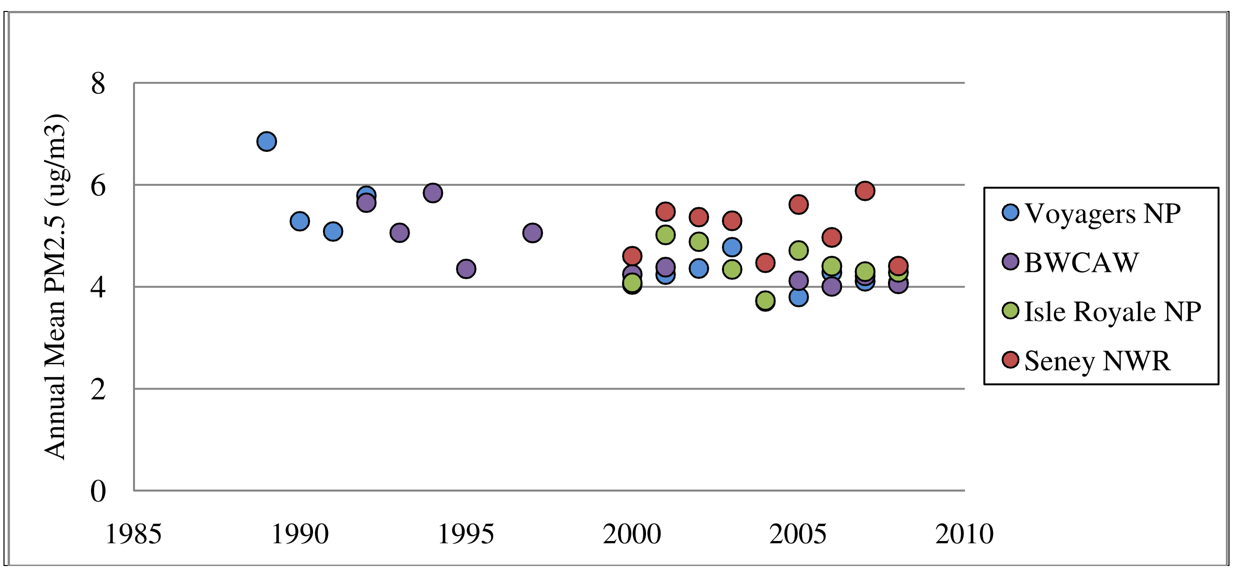


Figure 1.5. Fine particulate matter in natural areas of the Great Lakes.



Ozone

Monitoring for ozone has been done since the late 1970s. Ozone (also known as smog) is formed by nitrogen oxide and organic carbon emissions that are heated during the day and chemically react to form ozone. Since it needs heat and sunlight, effects from ozone occur during the summer in Minnesota. Ozone causes breathing problems and damages vegetation. Figure 1.6 shows reductions in ozone from the mid 1970s to the mid 1980s. Since that time minimal change has occurred. This is not surprising since national trends in nitrogen oxide emissions have been generally flat in recent times and the majority of organic carbon emissions in rural areas originate naturally from vegetation.

The EPA is proposing new standards for ozone for both the health of humans and vegetation. In Figure 1.6, the orange line shows the current level of the human health standard while the blue line shows the lowest possible level that could be used for the new standard. If the standard were set at 0.06 parts per million (ppm), the ozone levels from the last two years monitored at Fernberg would meet the standard.

Figure 1.7 shows the range EPA is considering for the new vegetation health standard. It appears that the Fernberg monitor will meet this standard, meaning that ozone should not be adversely affecting vegetation on the Forest.

Figure 1.6. Ozone (smog) measured at the Forest's air monitoring site and EPA human health standards.

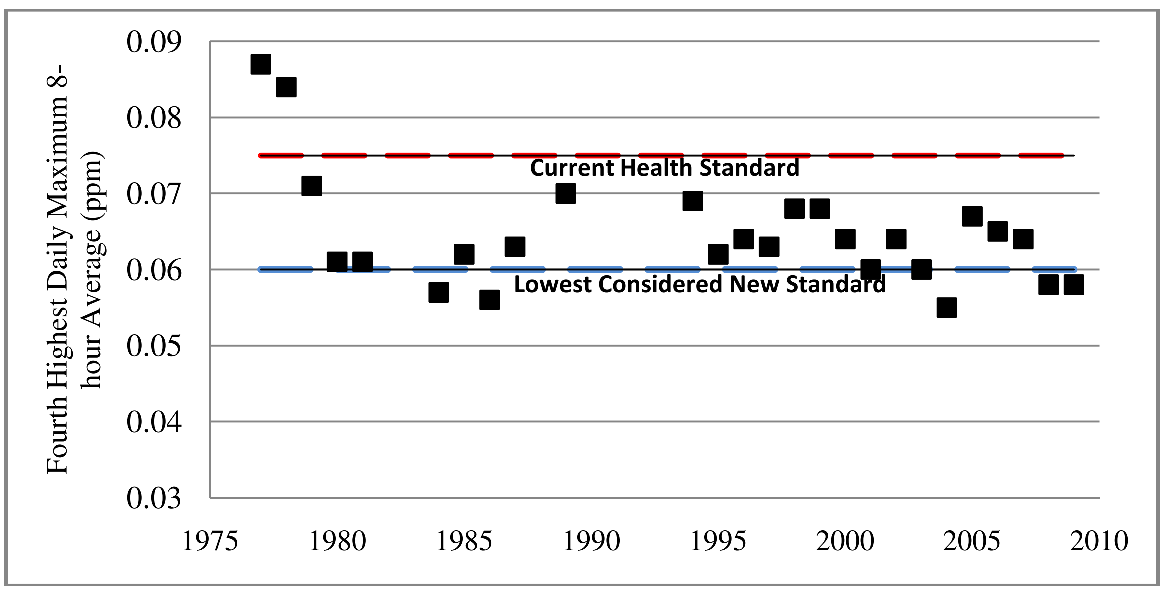
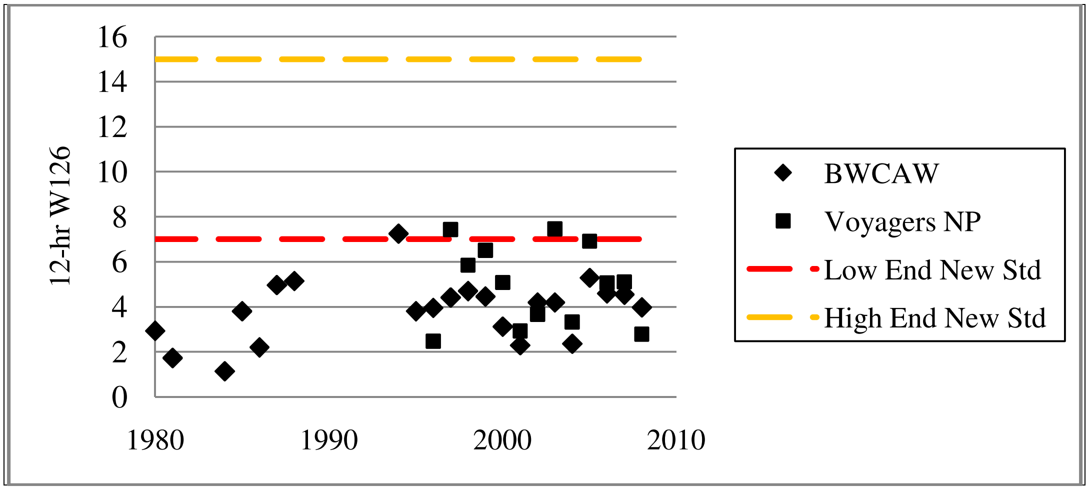


Figure 1.7. Northeast Minnesota ozone (smog) measured at the Forest's air monitoring site and vegetation health standards.



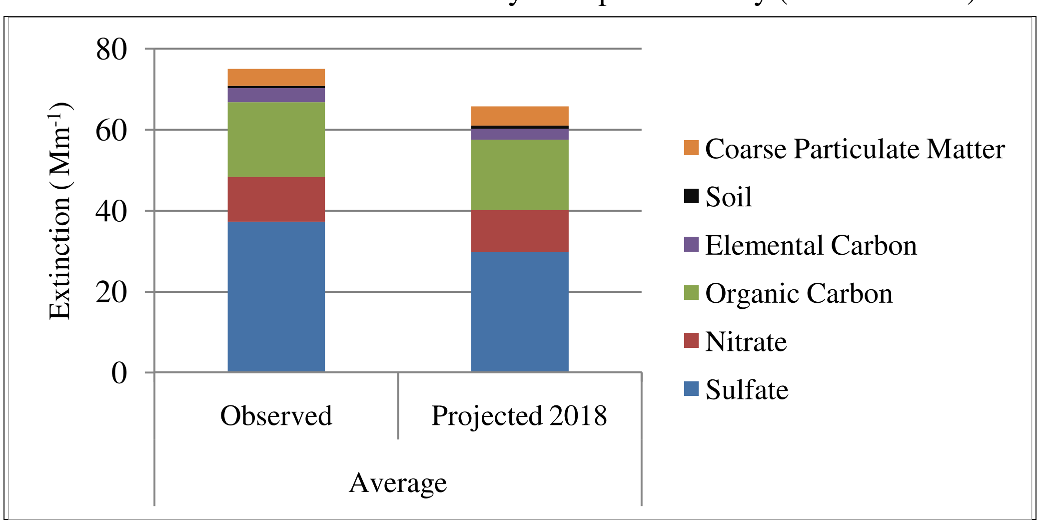
Since ozone formation is intimately tied to temperature, and climate change causes temperatures to increase, more ozone could be formed raising the values in the figures above. This could lead to more severe human health impacts and cause vegetation impacts to appear.

Sources of air and precipitation pollution

To determine the sources of air and precipitation pollution on the Forest, two pieces of information are needed: what is the chemical composition of pollution affecting the Forest, and where did it come from?

First, the chemical composition of the air pollution affecting the Forest will be examined. Once the dominant chemicals are known, the sources of emissions of those chemicals can often be determined. Sulfate is the largest portion of fine particulate matter causing regional haze at Fernberg and is shown as blue (SO_4) in Figure 1.8.

Figure 1.8. Observed (2002) and predicted (2018) types of fine particulate matter in The BWCAW based on their ability to impair visibility (MPCA 2009b)



Sulfate in the atmosphere can form particles causing haze or acid rain. As mentioned above, sulfate is a dominant chemical responsible for acidifying the precipitation measured at Fernberg. Power generation from coal is the dominant source of sulfur dioxide emissions which forms sulfate in the atmosphere. Regional and national scale emission control programs (i.e., Acid Rain Rule, which is a cap and trade program to control emissions of sulfur dioxide from power plants) that affect industrial sources located away from the BWCAW can have a positive effect on air quality and other associated ecosystem characteristics (i.e., water quality and mercury levels in fish).

For its Regional Haze Plan, the MPCA did an analysis of fine particulate pollution in the BWCAW (MPCA 2009b). MPCA estimated that the major contributing sources in 2018 will be from EGUs (power plants). Power plants are expected to remain a large contributor in 2018, as they were in 2002, partially due to major projected reductions in non-road and on-road emissions (car and trucks) due to national pollution control regulations on these sources.

The second piece of information needed to determine the primary sources of air pollution to the Forest is the location of air pollution sources. This is usually done using air quality models. When looking at the location of the sources affecting fine particulate matter, and therefore also light extinction or haze in the BWCAW, the MPCA concluded that sources within Minnesota make it the largest contributing State in the Great Lakes region, accounting for about 28 percent of the fine particulate haze (Table 1.2).

Table 1.2. State contributions to light extinction in natural areas in the Great Lakes.

	BWCAW (%)	VNP (%)	Isle Royale (%)
Minnesota	28	31	13
Wisconsin	10	6	16
Illinois	6	3	8
Iowa	8	7	8
Missouri	6	4	5
North Dakota	6	13	4

In its 2009 Air Quality Report (MPCA 2009a), MPCA hired Desert Research Institute (DRI) to investigate the sources of fine particles in Minnesota. DRI compared the results of several modeling approaches to estimate fine particle sources using monitoring data; directly measuring emission profiles from likely sources and meteorological data. The study found differences in fine particle concentrations and sources between urban and rural locations and between northern and southern Minnesota.

On average, urban concentrations of fine particles are 30 to 60 percent higher than rural concentrations. Rural concentrations in northern Minnesota are about 50 percent less than concentrations found in rural southern Minnesota. Sulfate and nitrate make up at least three-quarters of the average rural fine particle concentrations. Smaller amounts of rural fine particles were from biomass combustion, soil dust and mobile sources. A major difference between northern and southern fine particles is significantly less nitrate and slightly less sulfate in the north compared to the south. The main source of sulfate is power plants while the main source of nitrate is fuel burning (cars, trucks and industrial boilers).

In summary, background air quality on the Forest can be seen to be affected by broad categories of air emission sources, with about 75 percent from states and regions outside Minnesota. Northern Minnesota is currently meeting EPA standards for those air pollutants that have them, although currently proposed revisions to some of these standards challenge that conclusion for the future. These observations describe the baseline air quality conditions on the Forest. The impacts from project management activities are added to these baseline conditions.

Regional Air Quality Summary

Overall, air quality monitored at the Fernberg site for the most recent year of complete available data (2008 or 2009 depending on the network) showed no major changes from that seen over the past five years. Based on current understanding and the data from the Fernberg site, air pollution from sources outside the Forest are not degrading forest ecosystems, human health or enjoyment of forest resources except for the following areas: visibility and mercury deposition. The MPCA's regional haze plan and its supporting documents (MPCA 2009b) describe the important sources of visibility impairment to the BWCAW (i.e., power plants, cars and trucks), none of which are related to SNF management activities.

Figure 1.9. Uniform rate of progress for visibility in the BWCAW (MPCA 2009b)

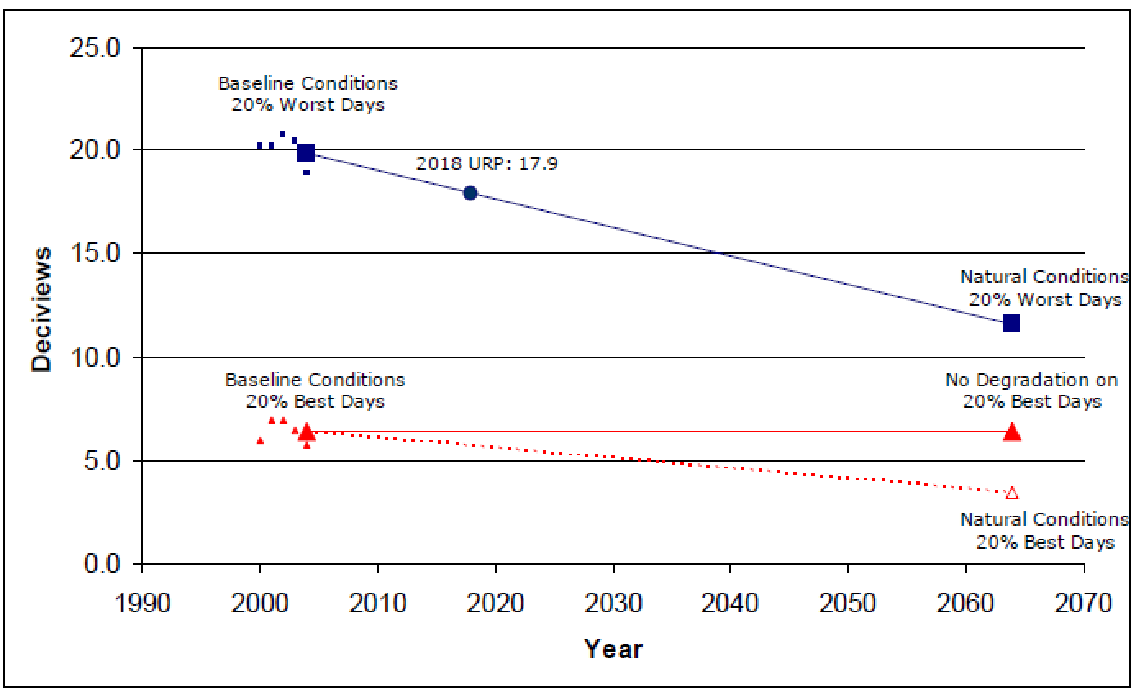


Figure 1.9 shows the current visibility conditions at Fernberg along with a "glide path" for improvement toward the goal of natural visibility in 2064. This goal (expressed in "deciviews"; the smaller the number, the less fine particulate matter and the farther you can

see) was taken from the MPCA's regional haze plan (MPCA 2009b) which is not yet final. Over the next 10 years the visibility monitoring at Fernberg will be critical since it will be used to determine whether the MPCA's plan is achieving its goal.

Recent concern has been expressed by some interest groups regarding the category of air pollutants called air toxics. As a part of a State-wide effort, the MPCA located an air toxics monitor at Fernberg. It started operation in January of 2010 and is planned to run for one year. After the data is collected and analyzed it should provide a good understanding of the background air toxics on the Forest.

In general, air deposition is the main source of mercury to watersheds on the SNF, but a more thorough discussion is in the Water Resources section of this report.

Air Quality at the Project Scale

Monitoring Question

What is the quality of the air on the SNF at the project scale?

Project scale monitoring attempts to measure the impacts that SNF management is having on air quality directly. The Forest management activity that generates the most air pollution on the SNF is prescribed burning and is therefore the focus of project scale monitoring. The MPCA calculates air emissions from sources in Minnesota. For recreation activities and logging in Cook, Lake and St. Louis counties, the total annual emissions of the common pollutants (nitrogen oxides, sulfur dioxide and particulate matter less than 10 microns) is about 480 tons (Wu 2009). A large prescribed burn may release 50 to 200 tons of particulate matter less than 10 microns. It would also release nitrogen oxides and a very small amount of sulfur dioxide. As a further point of comparison, nearby industrial sources emit significantly more air pollution. For example, the US Steel Minntac facility located near Virginia emitted 17,949 tons of these three air pollutants in 2008.

It should be noted that sometimes project scale monitoring can become regional scale monitoring. For example, pre-burn monitoring on a prescribed burn would be project scale monitoring that is measuring background or regional scale impacts up until the point where the prescribed burn begins.

The monitoring question above was addressed by comparing the monitoring data collected to established standards. Trends are not relevant for project monitoring because monitoring tends to be of short duration and at different locations across the Forest.

The monitoring drivers are listed in the Forest Plan on pages 4-10 and 4-16. One emerging issue of concern is over a class of air pollutants termed "air toxics". These are further discussed on pages 1.2 and 1.12 of this report.

Forest Plan direction for air quality on the SNF is not to degrade forest uses or natural resources through its management. As discussed above, the management activity with the most potential to degrade air quality is prescribed burning; therefore monitoring focuses on this activity.

The pollutant measured is the concentration of particulate matter, which is the main pollutant of concern from fires. This unit of measure allows rough comparisons to national standards.

Monitoring Method(s)

The monitoring discussed here focuses on particulate monitoring, although photographic (including satellite) and visual estimates are also useful. The SNF follows protocols developed by the Forest Service Missoula Technology and Development Center. For the largest burns, particulate monitors are generally located upwind and at sensitive receptors downwind that are most likely to be impacted by smoke. Data from existing permanent monitors in the vicinity (Fernberg) may also be used.

Results

Monitoring is usually only done for large, landscape scale burns since these are most likely to impact air quality. The only large landscape scale burning in 2009 was completed in the fall east of Ely, Minnesota. Smoke monitoring of these burns showed no adverse smoke impacts (Wickman 2009).

Implications

Our 2009 monitoring, as well as that completed in the past, shows that the Forest's smoke management experience along with adherence to the State's smoke management plan is preventing adverse impacts to the public.

Recommendations

1. The Forest should continue to use all appropriate smoke management tools (such as particulate monitoring when necessary) while implementing prescribed burns in the future. Many tools that mitigate smoke impacts can be used in the planning stage (such as screening techniques and/or modeling). The tools will continue to evolve as technology advances and it is important that fire staff and the air quality specialist monitor these changes. Participation with the Minnesota Incident Command System (MNICS) prescribed fire working team, following the State smoke management plan and effective public outreach are all key components of the Forest's effective smoke management program.

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