WILDERNESS STEWARDSHIP CHALLENGE

AIR QUALITY VALUES MONITORING PLAN

OUACHITA NATIONAL FOREST ARKANSAS AND OKLAHOMA

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If future generations are to remember us with gratitude rather than contempt, we must leave them more than the miracles of technology. We must leave them a glimpse of the world as it was in the beginning, not just after we got through with it.

President Lyndon Johnson upon signing The Wilderness Act of 1964

INTRODUCTION

The Wilderness Act of 1964 established National Wilderness Areas (NWAs) as places "where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain." By definition, then, vehicles, industry and other pollution-causing activities are not allowed within NWA boundaries. However, as anyone who has observed smoke billowing from factories and wildfires can attest, air pollution has no boundaries, and emissions from outside sources can adversely impact the unspoiled nature found in our wildernesses.

The "Wilderness Stewardship Challenge" was instituted in 2004 to ensure that wildernesses are being properly managed to leave them unimpaired for present and future generations. Monitoring air quality values was identified as one of ten accountability elements in the Challenge. An air quality value (AQV) is simply a resource that can be affected by air pollution. An AQV is selected based upon relative sensitivity to pollution, value as an indicator of the natural conditions of the wilderness and importance to wilderness visitors.

This plan provides a thorough evaluation of currently available air quality monitoring and modeling data for the six wilderness areas managed by the Ouachita National Forest, as well as a characterization of resources that might be affected by air pollution. This evaluation is used to select an AQV and develop a monitoring plan that will allow the Forest to determine whether air quality in wilderness areas is getting better or worse, and whether it is affecting wilderness values. The plan also identifies the sensitive receptors and indicators that can be measured to evaluate the effect of air pollution on the AQV, and describes how inventory and monitoring will be conducted. Finally, the plan identifies where the inventory and monitoring data will be stored and how the results will be reported.

AIR POLLUTION EFFECTS TO WILDERNESS

Several types of air pollution will be evaluated for their effects on wilderness resources: sulfur and nitrogen deposition, mercury deposition, ozone, and fine particulates. Sulfur and nitrogen deposition can cause stream acidification and leaching of important soil nutrients. Nitrogen deposition can also cause eutrophication or nutrient enrichment that negatively impact water quality, aquatic biota, and may increase invasive species growth, particularly plants. Sulfur is produced primarily from the combustion of coal at electrical generating units. Nitrogen compounds are derived from both the combustion of fuel at very high temperatures (such as in power plants, industrial boilers and automobiles) as well as from various agricultural processes.

Mercury is another important environmental contaminant that reaches the forest through atmospheric deposition. The primary source of anthropogenic (man-made) mercury is the combustion of coal. Mercury is fairly stable and accumulates in the environment until conditions are right for conversion to its most toxic form, methyl mercury (MeHg). The MeHg is ingested by aquatic organisms and bioaccumulates as it makes its way through the food chain, finally affecting humans when fish are consumed. Unhealthy levels of MeHg have led to fish consumption advisories in almost every state. Methyl mercury has also been found in numerous species of wildlife.

Elevated ozone concentrations can reduce the health and vigor of sensitive vegetation and stunt plant growth. Ambient, or ground-level, ozone is a secondary pollutant, which is not emitted directly from a stack or tail-pipe. Rather, ozone is formed when nitrogen oxides (NOx) and volatile organic compounds (VOC) combine in the presence of heat and sunlight. Nitrogen oxides come primarily from burning fossil fuels at high temperatures; VOC are emitted from vehicles, industrial processes, and primarily from natural sources such as trees and shrubs. Research has shown that in the southern US there is an over-abundance of naturally-occurring VOC. Ozone formation here is therefore "NOx-limited", which means that the concentration of ambient ozone is primarily dependant on the amount of nitrogen oxide emitted into the air.

Finally, fine particulate pollution affects visibility. Fine particles can be emitted directly from factories and vehicle exhaust, but they can also form in the atmosphere as secondary pollutants. These fine particles absorb and reflect light which make it difficult to see the spectacular view most of us expect in our wilderness areas; this is referred to as regional haze. Regional haze usually covers large areas and many sources of pollution contribute to the degraded visibility conditions. Regional haze is made up of several types of pollutants but in most of the southern US the primary contributors are sulfate compounds. As discussed above, most of the sulfate in the atmosphere is attributable to the burning of coal in power plants.

The primary air quality issues of interest in the National Wilderness Areas are atmospheric deposition, ambient ozone levels, and regional haze. The major pollutants contributing to these concerns are sulfates and nitrogen compounds, both of which are emitted as a result of fuel combustion. Agricultural sources of nitrogen can be significant in some areas.

This report focuses on the air quality issues in the Black Fork Mountain, Dry Creek, Caney Creek, Flatside, Poteau Mountain and Upper Kiamichi River Wildernesses. However, a regional overview of the air quality issues is presented first to give the reader a broader sense of how area-specific air quality concerns fit into the larger picture. As noted above, air pollution knows no boundaries, and thus it is important and relevant to discuss regional trends before focusing in on site-specific issues.

REGIONAL AIR QUALITY

The Southern Region of the Forest Service includes 13 states: Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas and Virginia; and Puerto Rico. National Forests in the Region manage 77 wilderness areas. This section provides a regional perspective on emissions of air pollutants; as well as sulfur, nitrogen and mercury deposition; ozone concentrations and visibility conditions.

Air Pollutant Emissions
Emissions of sulfur dioxide and nitrogen compounds have a large impact on the air quality issues of most concern in the National Wilderness Areas: atmospheric deposition, ground-level ozone concentrations, and reduced visibility. Therefore, it is critical to examine the emissions of these two important pollutants, and whether any trends are evident.

As stricter air pollution standards have been enacted over the past 30 years, emissions from many sources have decreased, resulting in downward trends in national sulfur dioxide (SO_2) and nitrogen oxides (NOx) emissions (Figure 1). Data from 2007 show that EPA's Acid Rain Program has resulted in a 6.8 million ton reduction in sulfur dioxide emissions since 1990 (EPA 2009). The majority of these reductions have occurred in the eastern half of the United States, where most of the large coal-fired power plants are located (Figure 2).

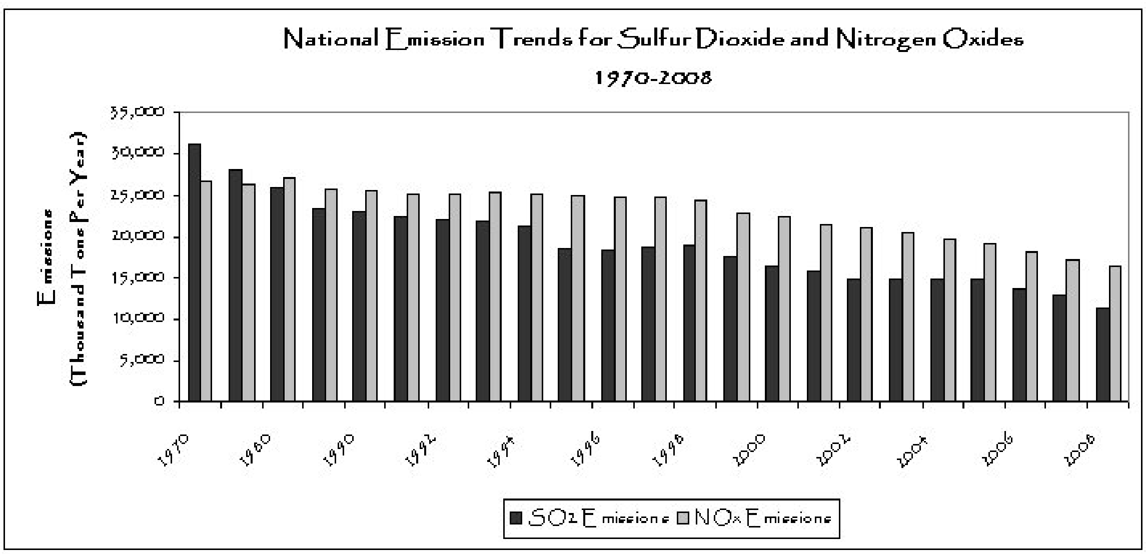


Figure 1. National emission trends for sulfur dioxide and nitrogen oxides from 1970 through 2008. From US EPA National Emissions Trends Data: http://www.epa.gov/ttnchie1/trends/

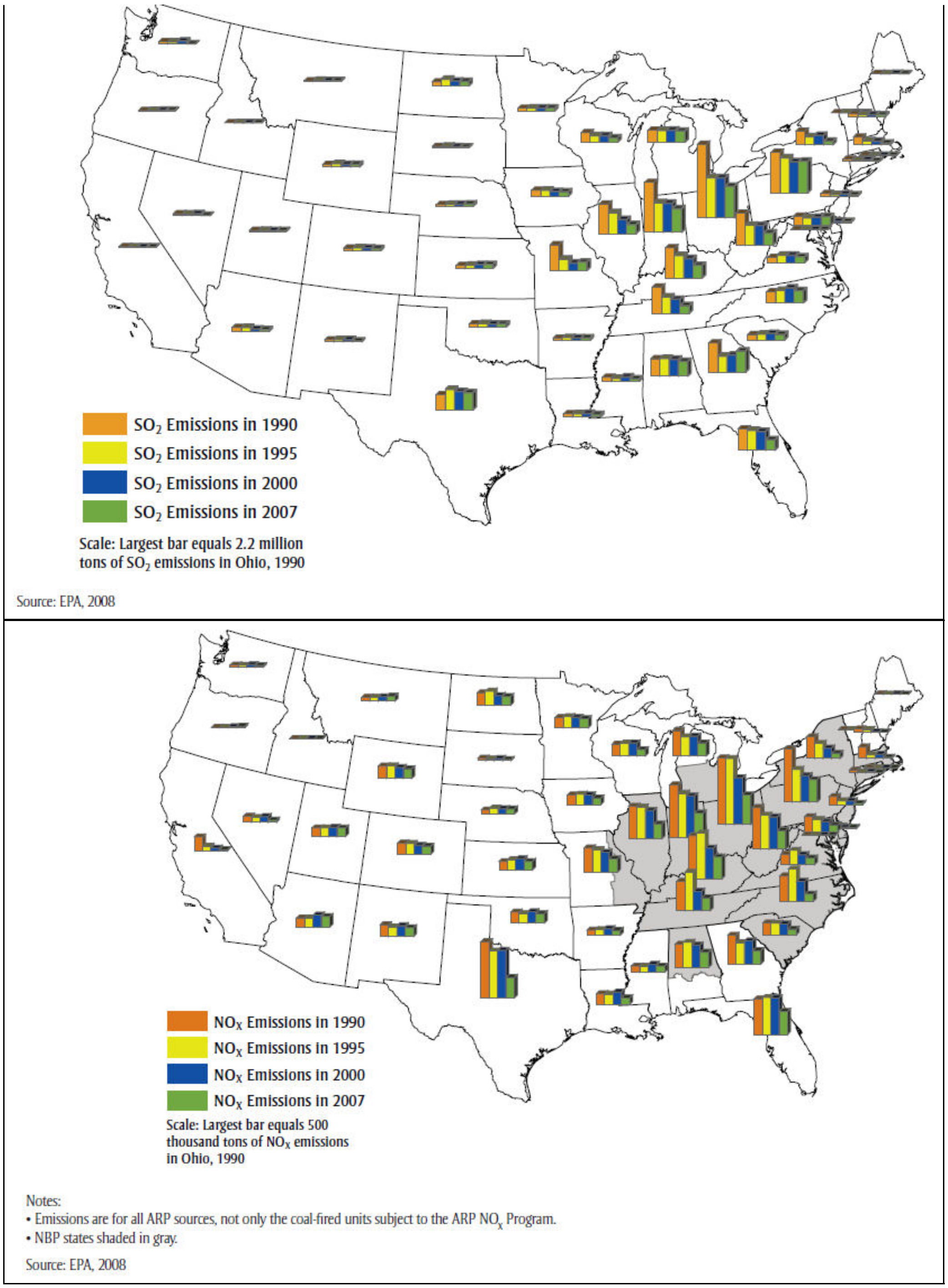


Figure 2. Sulfur dioxide and nitrogen emission reductions; 1990-2007. From the Acid Rain (ARP) and Related Programs-2007 Progress Report:
http://www.epa.gov/airmarkets/progress/docs/2007ARPReport.pdf
NBP refers to the Nitrogen Oxide Budget Trading Program, a market-based cap and trade program created to reduce emissions of nitrogen oxides from power plants and other large combustion sources in the Eastern US.

Nitrogen oxide emissions have not decreased as much as SO_2 emissions. This is because in addition to power plants, mobile sources contribute large amounts of NOx from the burning of fossil fuel in cars, trucks, off-road vehicles, etc. Although there are stricter rules in place that have reduced air pollution from individual vehicles, the number of vehicles on the road and the amount of miles being driven continues to increase and as a result, no decrease in vehicle emissions has been observed.

Emissions of SO_2 and NOx vary considerably depending on location. Although air pollution can be transported long distances from the original source and affect a large geographic area, the effects of emissions will be most significant close to the source. Localized pollution can increase regional haze and increase ground-level ozone concentrations as well as acidic deposition in nearby communities. Figure 3 shows total emissions of SO_2 and NOx at the county level, as well as the location of the wilderness areas within the southern states. Wilderness areas located near areas with significant air pollutant emissions are more likely to be impacted by pollution that areas located farther away.

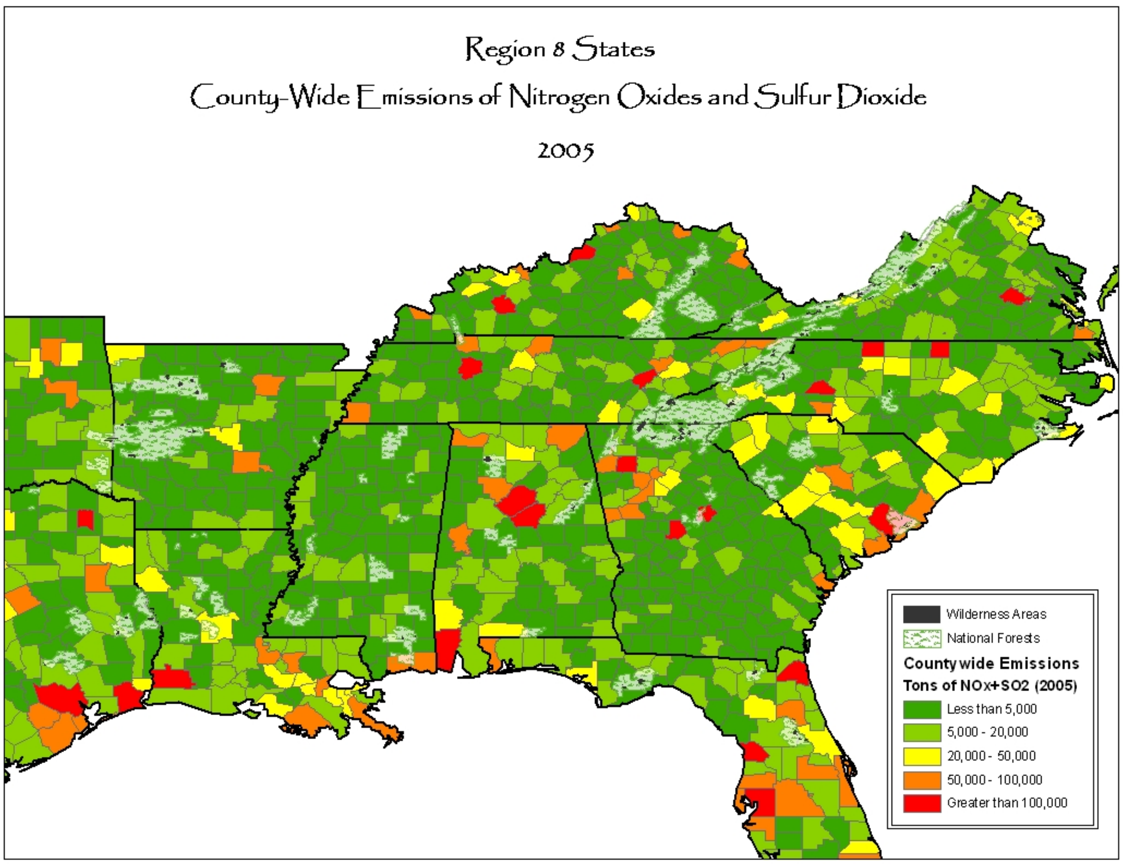


Figure 3. County level sulfur dioxide and nitrogen oxide emissions from the 2005 National Emissions Inventory. (http://www.epa.gov/ttnchie1/net/2005inventory.html)

Atmospheric Deposition of Sulfur and Nitrogen
Deposition of sulfur and nitrogen compounds can cause harmful effects to both aquatic and terrestrial ecosystems. Deposition can occur in three forms: dry, wet and cloud. Dry deposition is the direct fallout of fine particulates and gases from the atmosphere. Wet deposition occurs when acidic pollutants combine with water in the atmosphere, which is then deposited in the form of rain, snow or hail. Cloud deposition occurs when droplets of acid-containing water from clouds are deposited onto the earth's surface, typically at higher elevations.

Deposition monitoring does not occur on or near the majority of wilderness areas. However, wet deposition of sulfate and nitrate has been estimated across the southern United States using high resolution computer modeling (Grimm and Lynch 2004). The following input parameters are used:

- daily precipitation measurements from nearly 8,000 National Oceanic and Atmospheric Administration (NOAA) monitoring sites across the United States;
- weekly deposition measurements from 220 National Atmospheric Deposition Program/National Trends Network (NADP/NTN) monitoring sites across the U.S.;
- site-specific topographic variables including elevation, slope, and aspect.

The model predicts wet deposition of sulfate and total nitrogen. The sulfate predictions are then converted to sulfur. Data are available for 1993-2005, but only 2005 results are displayed graphically in Figure 4. (Data from all years is presented in the discussion of air quality for specific wildernesses.) The maps in Figure 4 show the spatial variation in deposition across the region with darker areas representing higher deposition amounts.

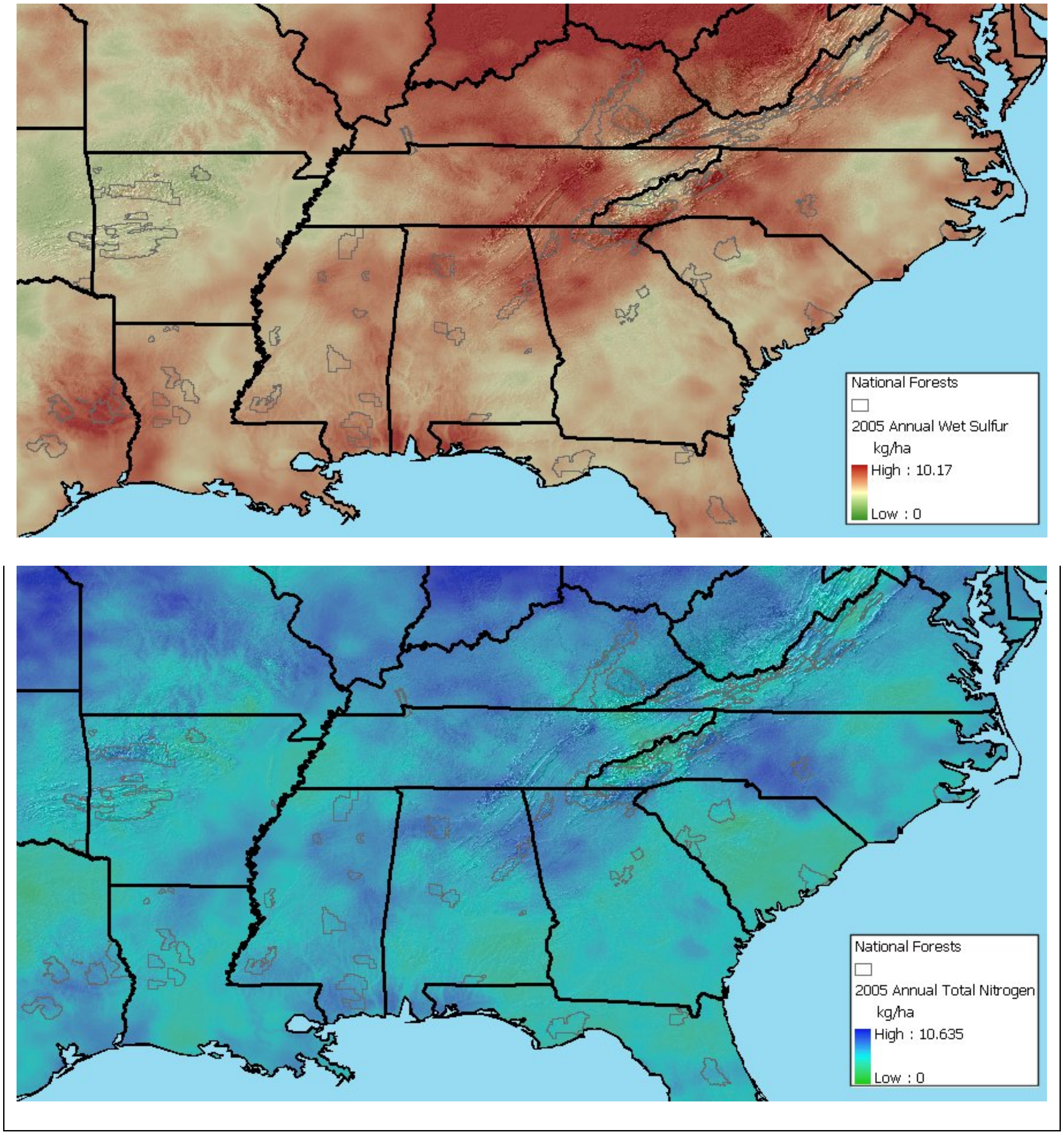


Figure 4. Annual wet sulfur deposition (top) and total nitrogen deposition (bottom) modeled for the year 2005. Deposition is presented in kilograms per hectare with a shaded relief map in the background.

Atmospheric Deposition of Mercury

A mercury (Hg) deposition monitoring network (MDN) has been established through the National Atmospheric Deposition Program. The network began in 1996 with 26 sites and has expanded to over 85 sites. Data from 2006-2008 are shown in Figure 5 to demonstrate both deposition patterns and the variability that can occur between years. Results from the

network demonstrate that the highest mercury deposition in the nation (>18 ug/m^2) is occurring in south Florida.

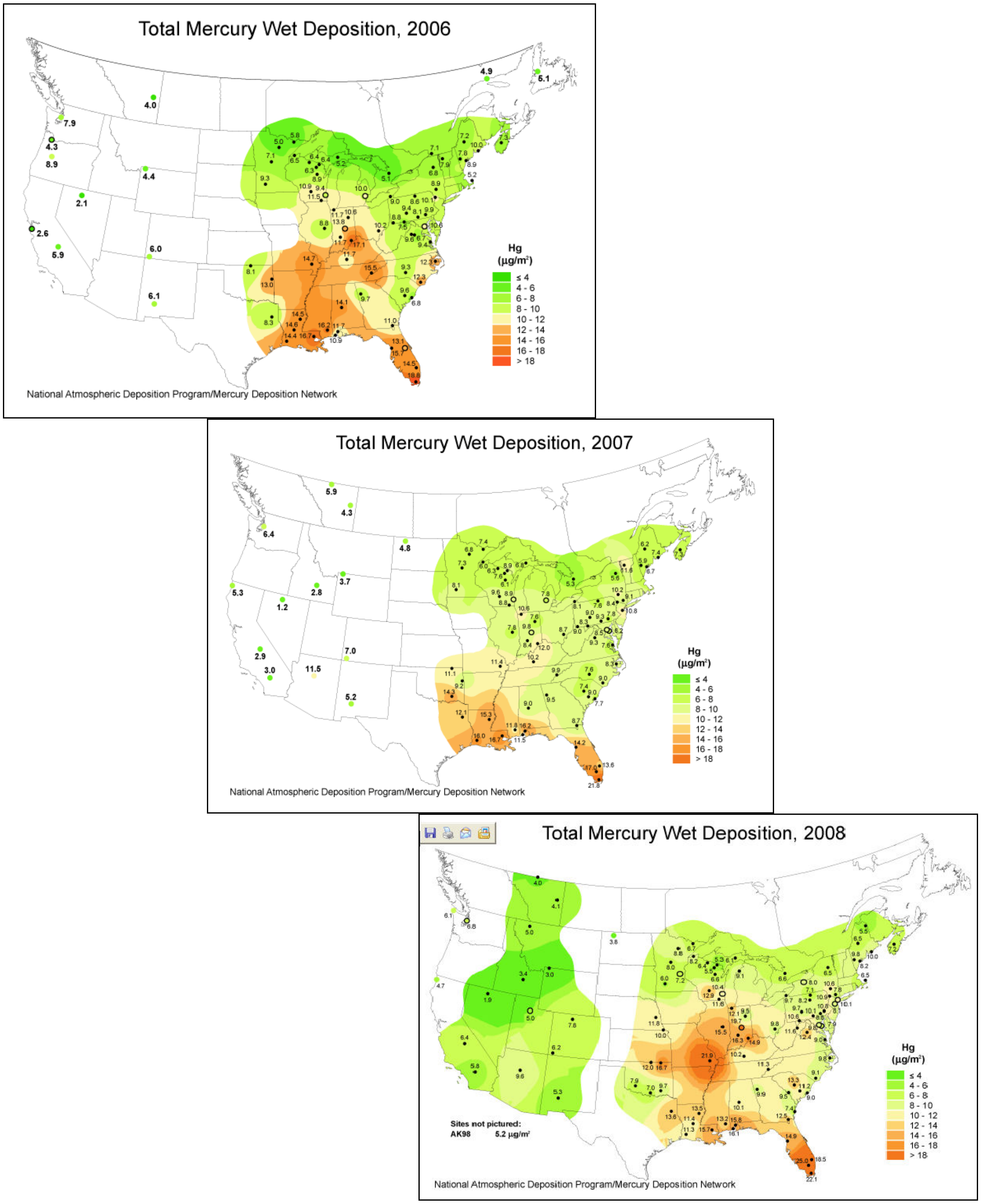


Figure 5. Annual wet deposition of mercury. From the NADP Mercury Deposition Network, http://nadp.sws.uiuc.edu/mdn/

Ambient Ozone Levels

Ozone is a colorless gas that can be both beneficial and harmful. When ozone is present high in the atmosphere, it provides a protective layer to filter harmful ultraviolet radiation. However, when the concentration at ground-level becomes too high, ozone will cause harm to humans as well as plant life. In order to protect human health as well as the environment, the United States Environmental Protection Agency (EPA) has established an ambient air quality standard for ground-level ozone; this ozone standard is currently set at 0.075 ppm[1]. Attainment of the standard is determined by calculating the 3-year average of the 4th highest 8-hour measured ozone concentration, and then comparing that value with the ozone standard. Areas that fail to meet the ozone standard are designated as "nonattainment", and generally have to enact stricter air quality rules in order to reduce emissions and reduce ozone concentrations (Figure 6). Concentrations above the standard are considered unhealthy for humans and detrimental to vegetation.

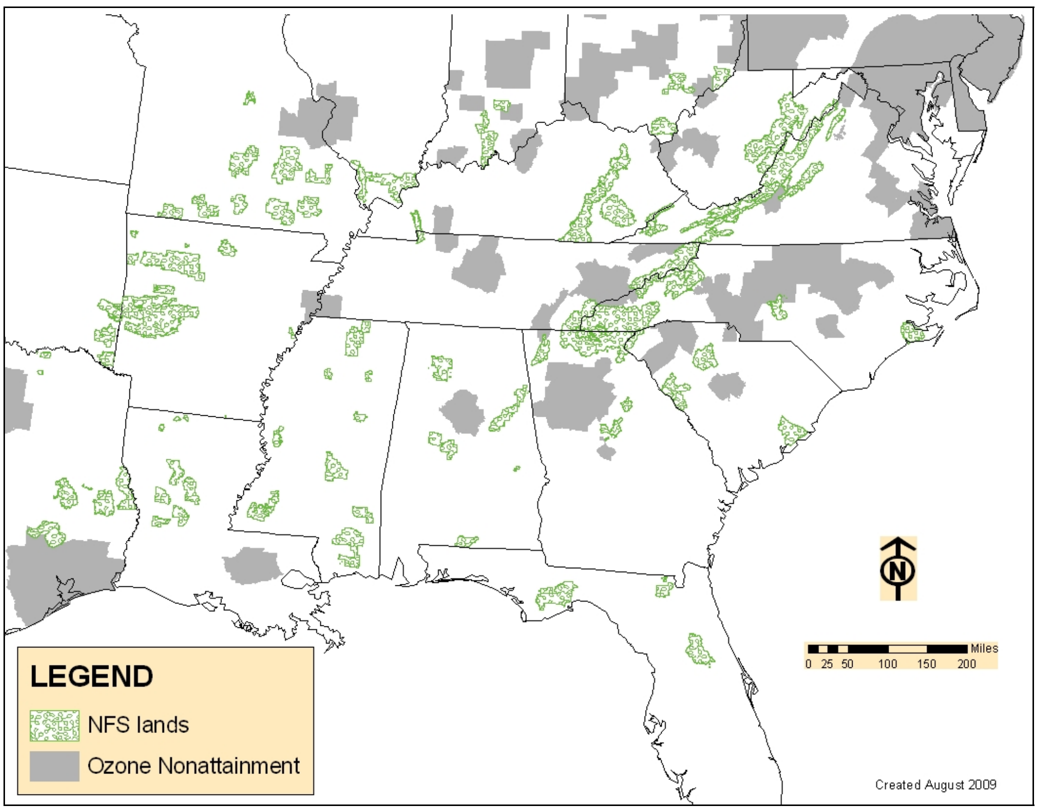


Figure 6. Ozone Nonattainment Areas (based on the 0.08 ppm standard) and National Forests.

1 EPA is required to periodically review the current scientific literature and adjust the ambient air quality standards accordingly. The current ozone standard of 0.075 ppm was finalized on March 12, 2008, and is more stringent than the previous standard of 0.08 ppm. Nonattainment designation is in progress.

Regional Haze/Visibility

Visibility across the nation is obscured to varying degrees by regional haze. The Southern Region has some of the poorest visibility (Figure 7); primarily due to sulfate particles in the atmosphere. States are currently finalizing emissions control plans (Regional Haze State Implementation Plans) to reduce visibility impairing pollutants and improve conditions at congressionally designated Class I areas (including 8 managed by the Southern Region of the Forest Service). Even though the focus is on Class I wilderness areas, benefits will be widespread and visibility improvements are anticipated for other wilderness areas in the Region.

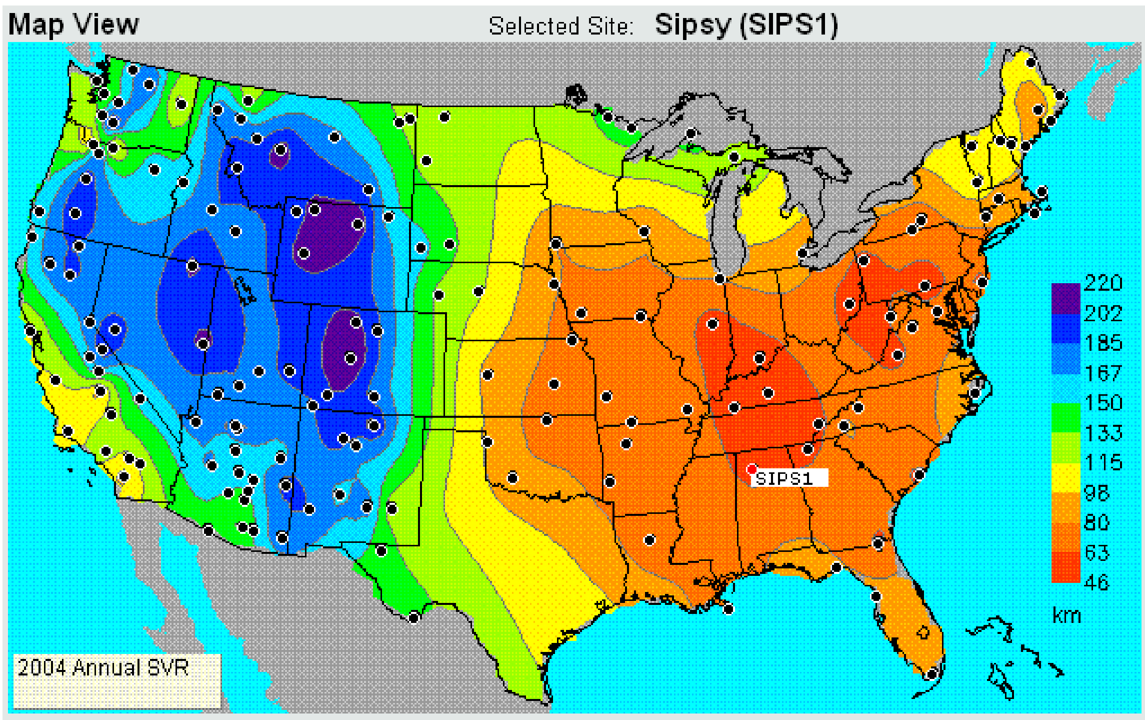


Figure 7. Annual average standard visual range in miles, as measured by the IMPROVE monitoring network. From VIEWS website: http://vista.cira.colostate.edu/views/Web/AnnualSummary/ContourMaps.aspx

OUACHITA NATIONAL FOREST

BLACK FORK MOUNTAIN, DRY CREEK, CANEY CREEK, FLATSIDE, POTEAU MOUNTAIN AND UPPER KIAMICHI RIVER WILDERNESSES

Air Pollutant Emissions

The wildernesses on the Ouachita National Forest are in an area of relatively low emissions compared to other wildernesses in the Region (Figure 5). The largest stationary sources of SO_2 and NOx emissions within 100 kilometers of these wildernesses are electrical generating units (power plants) and paper mills (Figure 8).

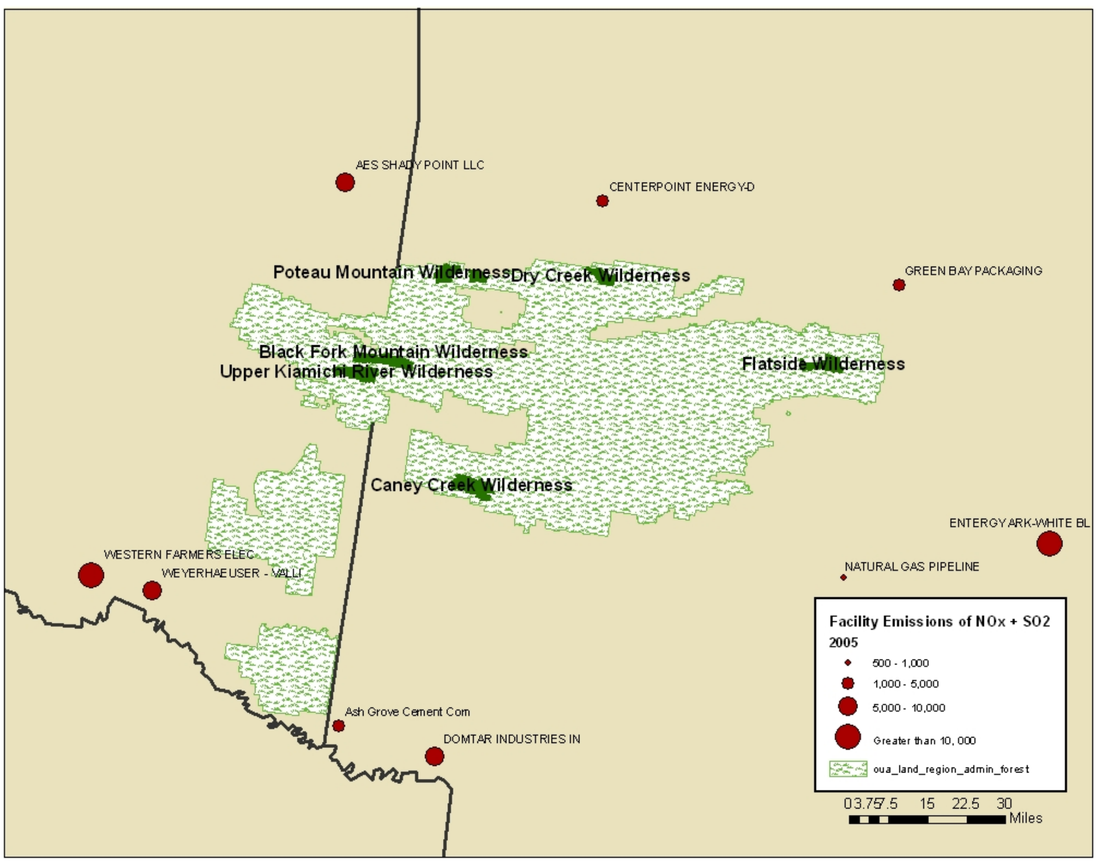


Figure 8. Point sources of sulfur dioxide and nitrogen oxide emissions within 100 kilometers (roughly 62 miles) of the Wildernesses. Data from the 2005 National Emissions Inventory (http://www.epa.gov/ttnchie1/net/2005inventory.html).

Atmospheric Deposition

As discussed earlier, estimates of wet sulfate and nitrate deposition for each wilderness were determined using computer modeling to extrapolate measured precipitation rates and deposition measurements across the United States based on site-specific topographic variables. Estimated average deposition rates for the years 1993 through 2005 are shown for each wilderness is Table 1. Although cloud deposition is considered to have a significant impact on deposition for areas with an average elevation above 800 meters, no wilderness areas within the Ouachita National Forest have elevations above this value and therefore cloud deposition was not considered. Estimated deposition rates for the years 1993-2005 are provided for each wilderness in Appendix A. Nitrogen deposition is considerably higher than sulfur, and sulfur deposition is the lowest in the Region. Only Florida and Mississippi wildernesses have sulfur deposition as low as is found on the Ouachita.

Table 1. Estimated sulfur and nitrogen deposition for the wildernesses on the Ouachita National Forest, 1993-2005.

Wilderness	**Estimated Average Annual Deposition (1993-2005) in kilograms/hectare**		**Elevation in meters**
	Sulfur	*Nitrogen*	
Black Fork Mountain	7	11	519
Caney Creek	7	10	447
Dry Creek	6	10	480
Flatside	6	8	324
Poteau Mountain	6	12	453
Upper Kiamichi River	7	11	518

Mercury Deposition

There are no mercury deposition monitors near the Ouachita National Forest. However deposition for this part of Arkansas in 2007 and 2008 has been estimated at 10-12 micrograms Hg per square meter (ug/m^2) (Figure 5).

Ozone

Ozone concentrations will vary based on geography, weather, and pollutant emissions; therefore it is important to evaluate site-specific ozone concentrations in order to determine if harmful effects to vegetation are likely to be occurring within the wilderness areas. For this analysis, ozone data from monitors located within 25 miles of a wilderness are considered representative. Most wilderness areas do not have nearby monitoring, but the state-operated ozone monitor in Polk County, AR (AIRS# 511300031) is located only 3 miles from Caney Creek Wilderness. This site began operation in 2004.

Figure 9 displays the trend in ozone concentrations compared to the 0.075 ppm ozone NAAQS at the Polk County monitor. Ozone levels have been increasing and currently are just below the NAAQS.

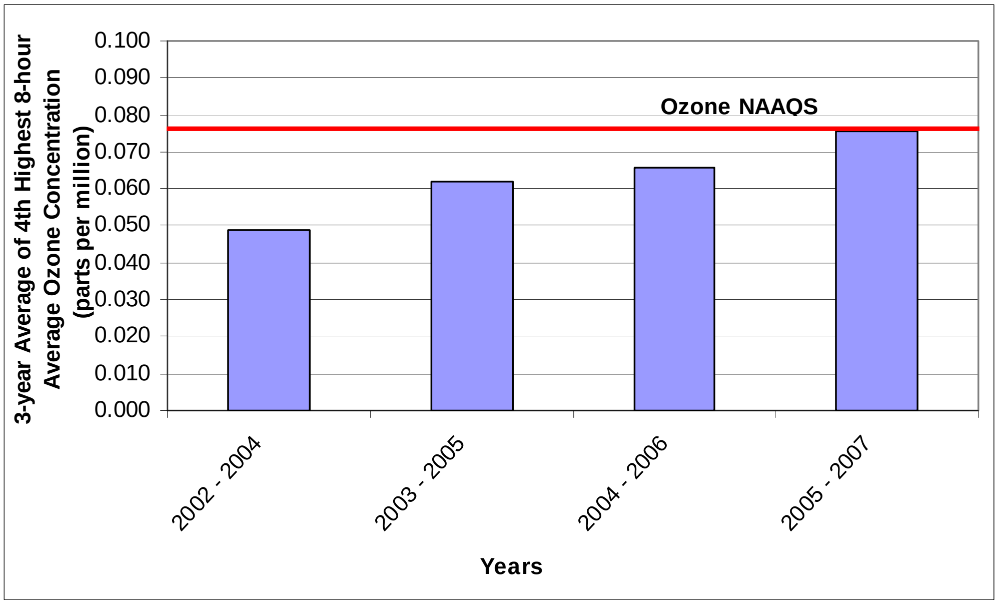


Figure 9. Ozone monitoring results near Caney Creek Wilderness (AIRS # 511300031); 2004-2007. http://www.epa.gov/air/data/index.html

Regional Haze/Visibility

Visibility is a mandatory air quality related value at most Class I wilderness areas; including Caney Creek Wilderness. Speciated fine particulate measurements have been taken since 2000 as part of the national monitoring network called IMPROVE (IMProving PROtected Visual Environments). The monitor at Caney Creek is considered to be representative of all wildernesses on the Ouachita National Forest. Data from 2006 shows that average visibility is 118 kilometers on the best days, and 31 kilometers on the worst. Figure 10 provides a timeline that shows both visibility and composition of pollutants affecting visibility for all monitored days in 2006 at Caney Creek. It is clear that the best visibility occurs in the winter, and that ammonium sulfate is the largest contributor to visibility impairment at that time of year.

Although visibility is an important value for all wildernesses, and it is affected by air pollution, it will not be recommended as the AQV to monitor in this plan because Forests are encouraged to select and monitor additional air quality values as part of the Wilderness Challenge.

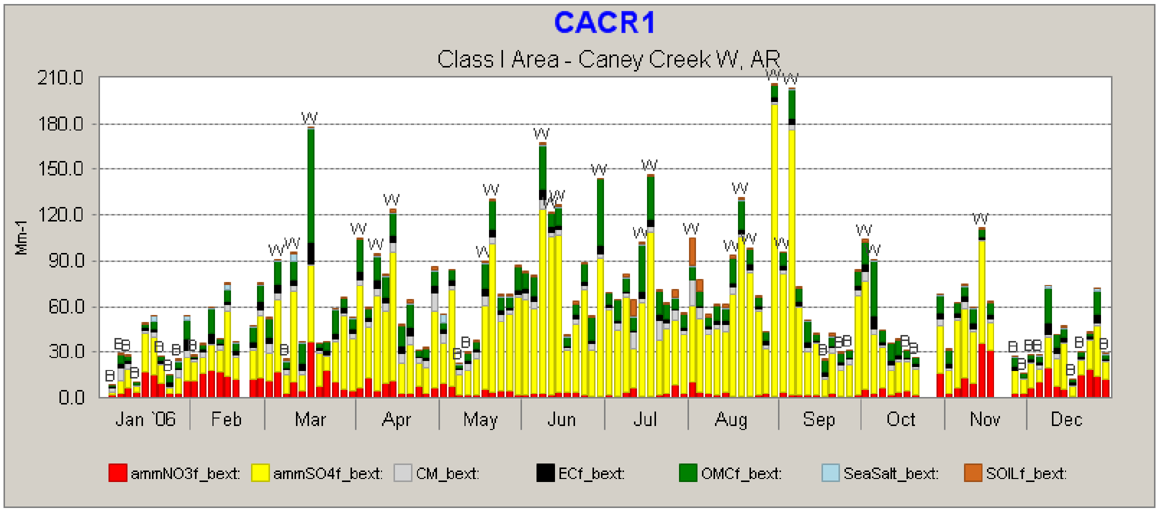


Figure 10. Contribution of various types of fine particulate to visibility impairment (described as the amount of light extinction in inverse megameters) from 2006 monitoring data at Caney Creek Wilderness. Higher numbers correspond to poorer visibility. B=best visibility and W=worst. *http://vista.cira.colostate.edu/views/*

CHARACTERIZATION OF WILDERNESS RESOURCES FOR RISK OF AIR POLLUTION EFFECTS

The next step in selecting an Air Quality Value is to review what is known about resource conditions in the wilderness. By combining resource sensitivity to various air pollutants and the amount of pollution those resources are exposed to, it becomes easy to identify the resource at highest risk for air pollution damage. For example, soil and stream characteristics will determine whether acid deposition is likely to have a deleterious effect or not. The risk of ozone affecting vegetation depends on the presence of ozone sensitive species and elevated ozone concentrations. This section will review the characteristics of the wilderness resources in terms of risk to air pollution effects.

There are six wilderness areas on the Ouachita National Forest. The Black Fork Mountain Wilderness Area was designated in 1984 and the Upper Kiamichi River Wilderness Area was designated in 1988. Caney Creek Wilderness was designated in 1975 and now has 14,460 acres. It is a Class I area, requiring the protection and improvement of visibility in the area. Black Fork Mountain Wilderness has a total of 13,139 acres with 8,350 acres in Arkansas and 4,789 acres in Oklahoma. The Upper Kiamichi River Wilderness has 9,754 acres in Oklahoma.

Black Fork, Upper Kiamichi and about half of Caney Creek Wilderness are part of the Fourche Mountain subsection of the Ouachita Mountains Meadow province. They have extensive folding and faulting of the terrain with steep east-west ridges. Erosion from many streams has carved deep slices out of the ridges. These areas have large rock flows or "glaciers" and sandstone bluffs. Distinct north-side and south-side vegetation communities prevail. The mesic (moist) north slopes and drainages are vegetated by hardwood and hardwood-pine forests. Xeric (drier) south slopes are vegetated by mid-successional, native short-leaf pine and pine-oak forest types. Black Fork and Upper Kiamichi Wilderness have a unique forest of dwarf oaks. Annual precipitation over both wilderness areas average 51 to 60 inches.

The remaining half of Caney Creek Wilderness is part of the Central Ouachita Mountains subsection which is characterized by mid-elevation mountains and hills aligned principally in an east-west orientation, interspersed within broad, narrow valley bottoms with elevations ranging from 600 to 1,700 feet above sea level. This part of the Ouachita Mountains is the richest in terms of plant community diversity. Natural communities include many seeps and springs, some of the most mesic (moist) forests found on the Ouachita National Forest (highlighted by stands of American beech and umbrella magnolia in coves, on north-facing slopes, and on stream terraces), and novaculite, shale, and sandstone glades and rock outcrops. Annual precipitation ranges between 60 and 72.

Dry Creek Wilderness (6,310 acres), Flatside Wilderness (9,507 acres) and Poteau Mountain Wilderness (11,299 acres) were designated in 1984 as Class II areas. They are part of the Fourche Mountains subsection of the Ouachita Mountains located in Arkansas.

Topography ranges from rolling hills to high elevation mountains (relative to the Ouachita Mountains as a whole) aligned in an east-west orientation interspersed with broad valleys. Geologic substrates are predominately Mississippian and Pennsylvanian shale and sandstone. The dominant vegetation is pine-oak forest and woodlands. There are several distinct plant communities within the Fourche Mountains subsection including sugar maple-oak-hickory forest, stunted white oak woodlands, and sandstone glades. Xeric (drier) south slopes are vegetated by mid-succession, native short-leaf pine and pine-oak forest types Annual precipitation ranges from 43 to 62 inches.

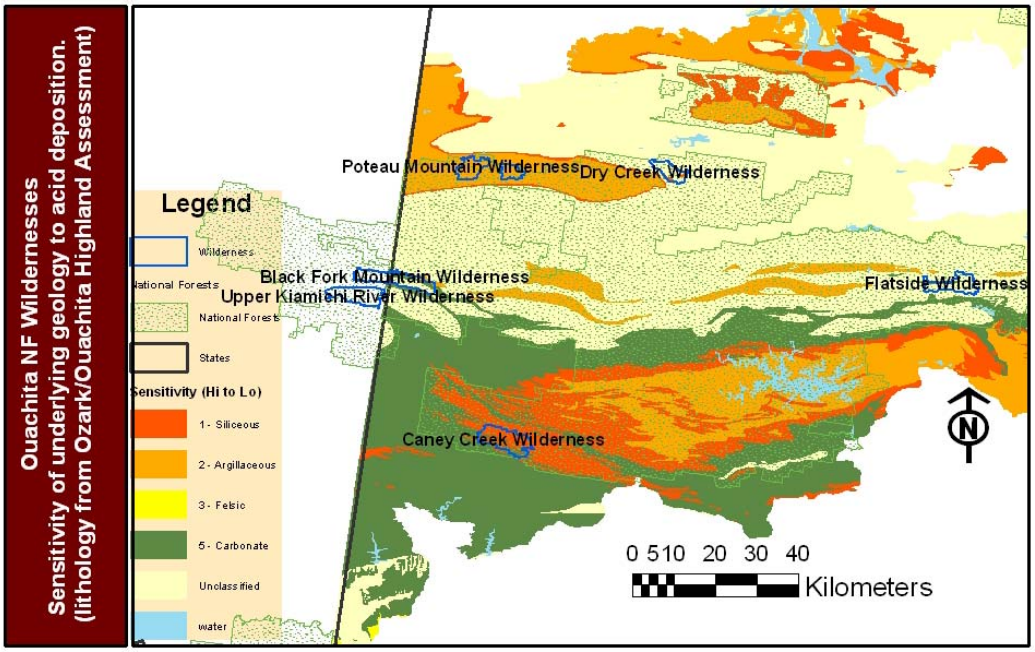
Potential for Acid Deposition Effects

Deposition of sulfates and nitrates (strong acid anions) will affect watershed soils and surface waters to different extents depending on the buffering capacity of the system. Acidification of soil or water is a reflection of an imbalance between the acid anions and base cations (calcium, magnesium, potassium and sodium ions). Soil acidification increases cation leaching, decreases soil pH and base saturation, and can negatively affect many biological processes. Stream water chemistry is the by-product of dynamic nutrient pathways and chemical processes occurring within the contributing watershed environment – atmospheric, terrestrial and biological. Surface water acidification is defined as a loss of acid neutralizing capacity (ANC) which occurs when the concentration of strong-acid anions increases relative to concentration of base cations. If surface water ANC is reduced to sufficiently low values, acidity may increase (as indicated by a depression in pH) to a level associated with adverse effects on aquatic life.

The amount of base-poor bedrock in a watershed plays a large role in determining surface water acidification and this has been used to help assess the risk of acidification of surface waters. A five-class lithology-based system has been developed by Sullivan et al. (2007) and classes are generally differentiated by composition and weathering properties of the primary rock type (Table 2). This classification scheme was applied to lithology from the Ozark-Ouachita Highlands Assessment (USDA 1999) to assess risk of acidification across the Forest (map follows). The risk assessment shows that Caney Creek Wilderness has the highest sensitivity to acidification. Poteau Mountain and Dry Creek Wildernesses have moderately high sensitivity. Lithology for Black Fork Mountain, Flatside and Upper Kiamichi River Wildernesses could not be classified because the lithology is alluvium.

Table 2. Lithology-based acid sensitivity rating.

Acid Sensitivity	Geologic Map Unit	Rock Types
Most sensitive	Siliceous	Sandstone, quartzite
↓	Argillaceous	Shale, siltstone
	Felsic	Granite, gneiss
	Mafic	Basalt, anorthosite
Least sensitive	Carbonate	Limestone, dolomite



Lithology alone cannot predict the water chemistry of a stream, but it can be used to identify areas more likely to contain acidic streams. Other variables that influence acid sensitivity are elevation, percent forested watershed and watershed area. The smaller watersheds at higher elevations (usually headwater areas) are more likely to be sensitive to acidification and/or contain acidic streams (Sullivan et al. 2007).

While a risk assessment based on lithology provides information on where acidification may occur, soil and water chemistry measurements are needed to confirm conditions on the ground. Water chemistry, particularly ANC, can been used to characterize the level of acidification and associated biological effects; from no impacts to complete loss of populations. The following classification (Table 3) is becoming increasingly accepted and will be used to describe water chemistry conditions in the wildernesses (Bulger et al. 1998, Stoddard et al. 2003, Lynch personal communication).

Table 3. Stream acidification classification based on associated biological response.

Classification	ANC in ueq/l (microequivalents/liter)	Biological Response
Chronically Acidic	< 0	Complete loss of fish populations is expected.
Episodically Acidic	0-20	During episodes of acidification, sensitive species such as brook trout may experience lethal effects.
Sensitive to Acidification	20-50	Fish species richness greatly reduced. Sub-lethal effects to brook trout. Acid sensitive species or life stages subject to episodic mortality.
Minimally Affected by Acidification	50-100	Fish species richness may begin to decline. Brook trout response variable, sub lethal effects possible.
Not Affected by Acidification	>100	Fish species richness unaffected. Reproducing brook trout expected where habitat is suitable.

Thirty years ago, the congressionally mandated National Atmospheric Precipitation and Assessment Program began measuring the effects of acid deposition to surface waters in those areas of the country considered sensitive to acidification. The Ozark-Ouachita Highlands region was included in National Stream Survey (NSS) of 1986 and considerable data was collected from the area, but few sample sites were located within the wilderness boundaries. Additional sampling was conducted by the Forest (1986-1989) which included stream reaches within or just outside of all Ouachita wilderness areas, except Black Fork and Upper Kiamichi River Wildernesses[2]. Results of the National Stream Survey and sampling conducted by the Forest show that most stream reaches in the Ouachita Mountains are not affected by acidification (ANC>50). However, a small population of streams in the Ouachita Mountains, about 7%, falls into the episodically acidic or sensitive to acidification categories (ANC 0-50). These are usually the upper reaches or headwater streams.

The Ozark-Ouachita Highlands Assessment (USDA 1999) also identified the headwater sections of the Ouachita Mountains as areas with very little limestone and suggested that these areas are at more risk of acidification than streams in the Ozark Plateau. However, none of the streams sampled from within wilderness boundaries fall into this category. Recent water chemistry data resides with the Forest Hydrologist who has communicated that none of the streams in the wildernesses are showing signs of acidification.

Potential for Mercury Effects

The negative effects of mercury on ecosystems have traditionally been observed first in aquatic biota, and monitoring efforts focused on collection and analysis of fish tissue for methyl mercury (MeHg). Inorganic mercury deposited from the atmosphere must be transformed into MeHg prior to bioaccumulating in fish. Research shows that both trophic dynamics (community composition and feeding relationships) and geochemical controls over the rate of methylation of mercury are important drivers of bioaccumulation (Chasar et al. 2009). Wetlands have been shown to be important sinks of mercury and sources of MeHg (Guentzel 2009), and the density of wetlands in a watershed is the most important basin-scale factor controlling MeHg production (Krabbenhoft et al. 1999).

A recently published study on mercury contamination of aquatic ecosystems showed higher mercury concentrations in fish sampled from sites closer to evergreen forests and woody

[2] This data is available on the the Air Resource Management Surface Water website : (http://www.fs.fed.us/ARMdata/).

wetlands, a finding which underscores the sensitivity of these land-cover types to mercury bioaccumulation (Scudder et al. 2009).   Currently, there is no risk assessment of the Ouachita wildernesses for mercury contamination.

Potential for Ozone Effects to Vegetation

Prolonged exposure of sensitive plants to chronic and acute ozone exposures in a predisposing environment (usually adequate soil moisture and open stomata that allow ozone to enter the plant) can result is visible foliar symptoms which are used to detect and monitor ozone stress in the forest. Leaves that are affected by ozone will have red, purple or black stippling on the leaf surface. Needles will show a chlorotic (yellow) mottle or tip burn. Ozone exposure can also lead to growth loss and biomass reduction in plants.

The Forest Pest Management unit of State and Private Forestry (now Forest Health Protection) conducted a five year assessment (1991-1995) of ozone caused symptoms in Caney Creek and Upper Buffalo Wildernesses in Arkansas and Little Lake Creek Wilderness in Texas (Kertz et al. 1991, 1993, 1994, 1995). Ozone sensitive species, including sassafras, wild grape and blackberry were inspected at 5 plots near Caney Creek Wilderness. Blackberry most commonly exhibited symptoms. Over the five years of the study, incidence of ozone symptoms declined from 14% in 1991 to less than 1% in 1995. Caney Creek sustained the lowest incidence of ozone damage of the three areas surveyed.

Ozone biomonitoring, the systematic examination of vegetation for symptoms of ozone injury, is one of the health based indicators currently used in the Forest Inventory and Analysis (FIA) Detection Monitoring Program. FIA biomonitoring provides information on visible symptoms of ozone rather than ozone concentrations in the air. The most recent interpretation of the ozone injury data presents a national ozone risk map (Smith et al. 2008). According to the report, western Arkansas and the Ouachita wilderness areas are at low risk for ozone impacts to forest ecosystems. However, ozone monitoring representative of Caney Creek shows that concentrations have been increasing and are approaching the NAAQS (which establishes a threshold for detrimental effects to vegetation) indicating that ozone exposures may pose a threat to vegetation.

Conclusions

The risk assessment for acidification points to Caney Creek and Flatside Wildernesses as the areas most at risk on the Forest. When lithology and water chemistry are combined, Caney Creek and Little Cedar Creek are rated as "minimally affected by acidification"; meaning that fish species richness may begin to decline. Stream chemistry from Dry Creek and Poteau Mountain Wildernesses indicate that these areas are not affected by acidification. Risk of acidification in Upper Kiamichi River and Black Fork Wildernesses is unknown because the lithology is unclassified and there is no stream chemistry available to use in the assessment.

Caney Creek is the only Wilderness on the Forest that is at risk from ozone.

AIR QUALITY VALUE (AQV) RECOMMENDATION

An air quality value (AQV) is simply a resource that can be affected by air pollution and is selected based upon relative sensitivity to pollution, importance as an indicator of the natural conditions of the wilderness, and importance to wilderness visitors. The most common ecological AQVs on national forests are surface water (and the associated aquatic fauna), soil and flora. For wildernesses that contain headwater streams, water is usually the first air quality value to be measured because stream water condition is a great integrator of impacts to both the water and soil of a watershed. In addition, unpolluted water is an expression of naturalness in a wilderness and an expectation of wilderness visitors. Although most information points to the streams on in the Ouachita Wildernesses being at low risk of acidification, there may be headwater streams that are sensitive but have not been inventoried. **Water is the recommended AQV to be inventoried and monitored for wildernesses on the Ouachita National Forest.**

Caney Creek Wilderness is a Class I area and the air quality related values (AQRVs) visibility, water and flora were identified in 1990. Visibility is a federally mandated AQRV and is already monitored through the national IMPROVE network. Water chemistry and ozone injury have been monitored at Caney Creek in the past. For more information, go to the Air Program website at http://www.fs.fed.us/air/technical/class_1/wilds.php?recordID=73. **Considering that past water data indicated the area is minimally affected by acidification and the lack of current data, it is recommended that water measurements be re-established at Caney Creek Wilderness.** Water monitoring recommendations are included in this plan. Follow up work for ozone at Caney Creek is recommended in Appendix B.

Initial assessment of the water AQV should involve collection and analysis of water samples so that an understanding of the chemical buffering of the system may emerge along with some estimation of the nutrient status of the system. This recommendation is in line with the guidance produced for the Forest Service by Sullivan and Herlihy (Sullivan and Herlihy 2007).

Water chemistry is the recommended *sensitive receptor* used to assess the effects of acid deposition on the water AQV, and the *indicators* are specific water chemistry parameters such as ANC, ph, and sulfate and nitrate concentrations; due to the relative ease and precision of collecting and measuring water chemistry compared to quantitative sampling of aquatic organisms, soils or vegetation.

INVENTORY AND MONITORING RECOMMENDATIONS

- Caney Creek Wilderness has already conducted an initial inventory and established baseline conditions. Any additional measurements would be part of long-term trend monitoring.

- Although some of the other wildernesses have water chemistry data, it is usually from only one stream location and one date. These areas should consider participating in the synoptic inventory to include more sample locations and establish consistent data.

Inventory: The purpose of the initial inventory is to determine whether any of the streams in the wilderness have been adversely affected by air pollution, and to identify streams that are more sensitive than others.

Study Design: Participate in a synoptic inventory of stream water condition to determine the extent to which air pollution is currently affecting water resources in each of the Wildernesses. A synoptic inventory strives to collect samples from many sites across similar geographic areas at times expected to exhibit fairly stable water chemistry. For streams in the southeastern United States this is usually spring base flow. All wildernesses selected for sampling should be included in the initial inventory.

Two samples, one is a replicate, are collected from each stream selected for sampling. It is desirable to standardize conditions at each site at the time of sample collection to generally consistent weather and runoff conditions. For that reason, periods of high temporal variability such as heavy rain are typically avoided to the extent possible during a synoptic survey. Appropriate Specialists should be involved in designing the details of the study; hydrologist, fisheries biologist, geologist, soil scientist, wilderness manager and air specialist.

Where to Sample: It is not necessary to collect water samples from each wilderness on the Ouachita National Forest. The close proximity, similarity of lithology and/or and deposition allows four groupings as shown in Table 4. Samples taken from one of the wildernesses could be considered representative of all in the group. It is recommended that samples be collected from Caney Creek, Upper Kiamichi River, Dry Creek and Flatside Wildernesses.

Once the wildernesses are selected for the inventory, stream water samples should be collected from 3-5 headwater streams within each wilderness boundary following the Standard Operating Procedures outlined in the "National Water Chemistry Field Sampling Protocols for Air Pollution Sensitive Waters" (Sullivan et al. *In Draft*). Previous water chemistry monitoring efforts should be considered and sites re-sampled as appropriate. The Forest Geologist should be involved in sample site selection so that locations can be selected with consideration of finer resolution geology (and acid sensitivity) information than is provided in this Plan.

Table 4. Water chemistry monitoring recommendations for the Ouachita National Forest.

Grouping for Monitoring	Wilderness	Sulfur Dep	Nitrogen Dep	Elevation	Lithology Rating for Sensitivity to Acidification
BOLD=representative wilderness		Kilogram/hectare		meters	
1	**Caney Creek**	7	10	447	High
2	**Upper Kiamichi River**	7	11	518	Unclassified
	Black Fork	7	11	519	
3	**Flatside**	6	8	324	Unclassified
4	**Dry Creek**	6	10	480	Moderately High
	Poteau Mountain	6	12	453	

When to Sample: Sampling should take place during springtime base flow as this is considered a good representation of annual average flow-weighted stream water quality in the southeastern US. All samples within an individual wilderness should be collected on the same day if possible, especially if storms are forecasted. It is important to collect samples under the same flow regime.

What to Sample: Stream water should be sampled for analysis of the following parameters: pH, alkalinity, acid neutralizing capacity (ANC), conductivity, anions (F, Cl, NO3, PO4, SO4) and cations (Li, Na, NH4, K, Mg, Ca). In addition to collecting water samples, it is desirable to have stream flow information. If there is an appropriate stream gauge in the vicinity of the wilderness, it could be used to record estimated flow. Otherwise a flow meter should be taken to the field and stream water flow measured. This is covered in the "Standard Operating Procedures for Stream Water Sampling" in the national protocol.

Sample Analysis and Data Storage: Send samples immediately after collection to the Water Lab in Fort Collins, CO. This lab is set up to do the appropriate measurements for waters potentially affected by acid deposition. The results of the analysis will be entered directly into the NRIS Water Module.

Reporting Results: Again, consult the Forest Geologist as they can provide valuable assistance in interpreting the water chemistry results relative to underlying geology at the sample site. The report should recommend a subset of sample sites for continued measurement to establish baseline condition. The results of the inventory can be reported in the annual monitoring and evaluation report.

Baseline Condition: Continue spring season measurements on the recommended subset of sample sites from the initial inventory for an additional two years. Baseline condition for water chemistry is established after 3 spring season samples have been collected, analyzed and results reported.

Caney Creek Wilderness established baseline conditions in the late 1980s after sampling for 3-4 years.

Long-term Monitoring: The need for long-term monitoring will depend on the results of the initial inventory and baseline conditions. If baseline condition concerns warrant that long-term monitoring is appropriate, the monitoring plan should be designed by the appropriate specialists on the Forest using the National Protocols for guidance. Air Specialists are available to assist in designing the monitoring plan.

COUNTING WILDERNESS CHALLENGE ACCOMPLISHMENTS

Activity	Description	Score (upon completion of activity)
1. Develop an AQV Plan	Reviews air quality and resource conditions; recommends AQV, sensitive receptor and indicator to measure; and provides guidance on initial inventory procedures.	2 – When AQV plan has been finalized.
2. Inventory Sensitive Receptor	Initial measurement and reporting of synoptic survey results. Select sites for continued monitoring to establish baseline if warranted.	4 – When initial inventory has been completed and results reported.
3. Establish Baseline Condition for Sensitive Receptor	No effects of air pollution evident; further resource measurement may not be necessary. **OR**	6 – If initial inventory indicates no further measurement is warranted.
	Possible effects of air pollution occurring; continue measurements until 3 years of spring season samples have been taken and establish baseline condition. Evaluate results of the baseline period of monitoring to determine whether long-term monitoring of the sensitive receptor is warranted.	6 – When baseline monitoring has been completed and results reported.
4. Monitor Sensitive Receptor for Trends from Baseline	Conduct modeling to predict trend in resource condition based on deposition projections under current air regulations. (Develop and implement a monitoring strategy with measurement interval appropriate to modeling results.) **OR**	10 – When modeling analysis has been completed.
	Develop and implement a long-term (> 5 to 10 years) monitoring strategy and report results.	10 – When trend report has been completed.

MONITORING FOR THE WILDERNESS STEWARDSHIP CHALLENGE VS WILDERNESS CHARACTERIZATION

The purpose of this section is to address how AQV (air quality value) monitoring is different from, but related to interpretation of air quality measurements to address the "natural" quality of wilderness character. The Wilderness Stewardship Challenge specifically identified monitoring of air quality values (resources affected by air pollution) as one of its elements. The recommendation contained in this AQV monitoring plan is based on air quality and natural resource information pertinent to specific wildernesses. The same air quality information used to develop the AQV plan (visibility information from the IMPROVE network, ozone, and sulfur and nitrogen deposition) is also used to monitor trends in wilderness character (Landres et al. 2008). These air quality measures will be used in concert with measures of plant and animal communities, other physical features, and biophysical processes to characterize the "natural" quality of the wilderness (Landres et al. 2009). Together, these two programs will provide air quality and air pollution effects information for wildernesses across the Region.

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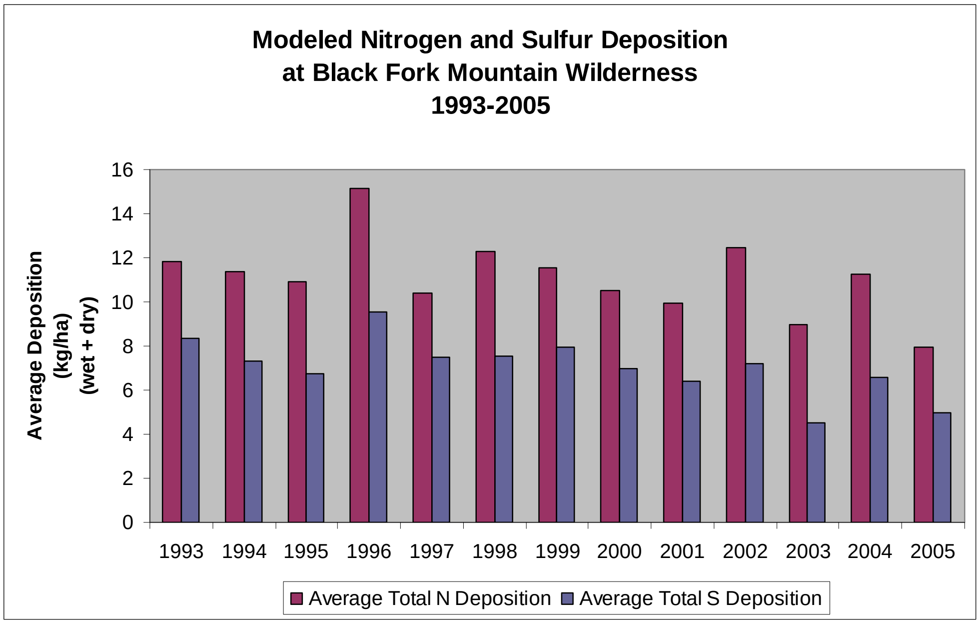
APPENDIX A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(kg/ha)
(wet + dry)
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4
2
0
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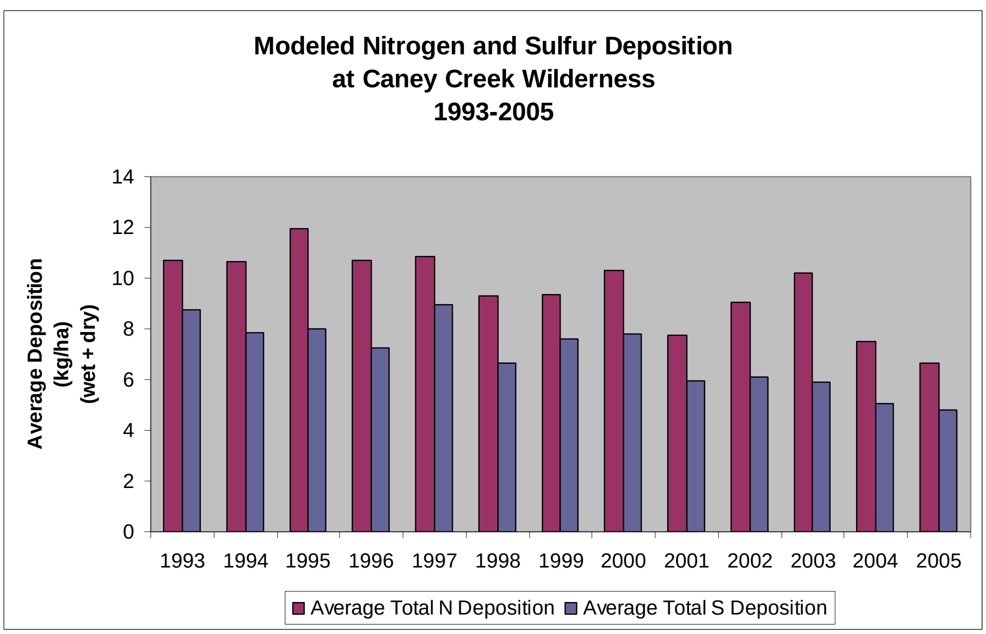
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at Caney Creek Wilderness
1993-2005
Average Deposition
(kg/ha)
(wet + dry)
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12
10
8
6
4
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1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005
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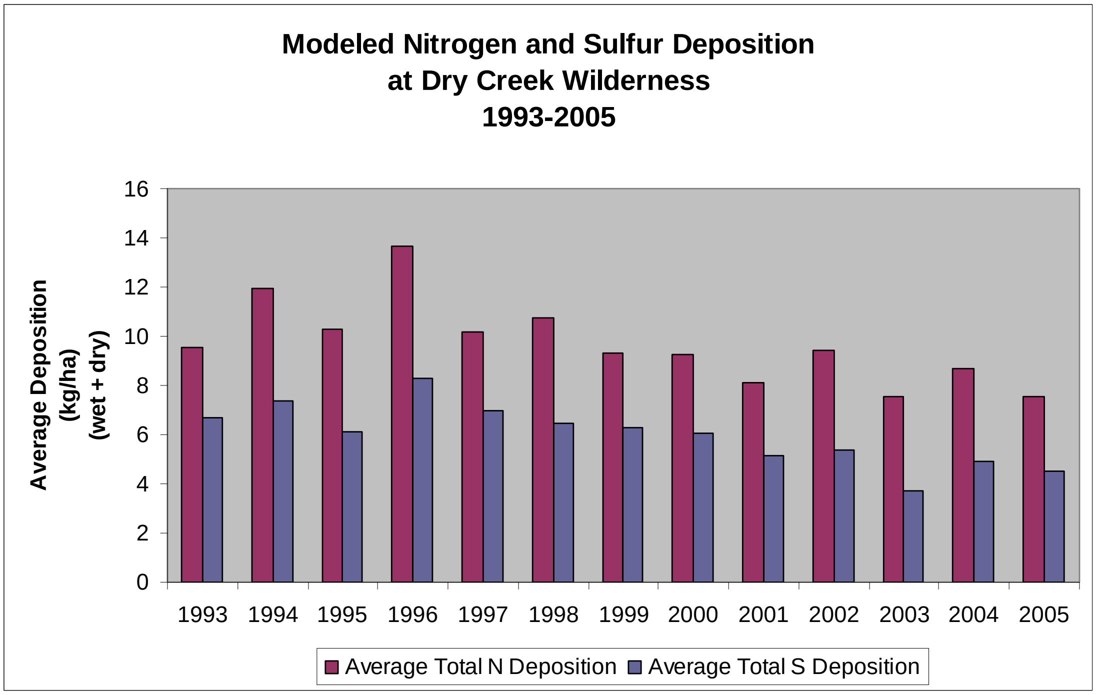
Average Total S Deposition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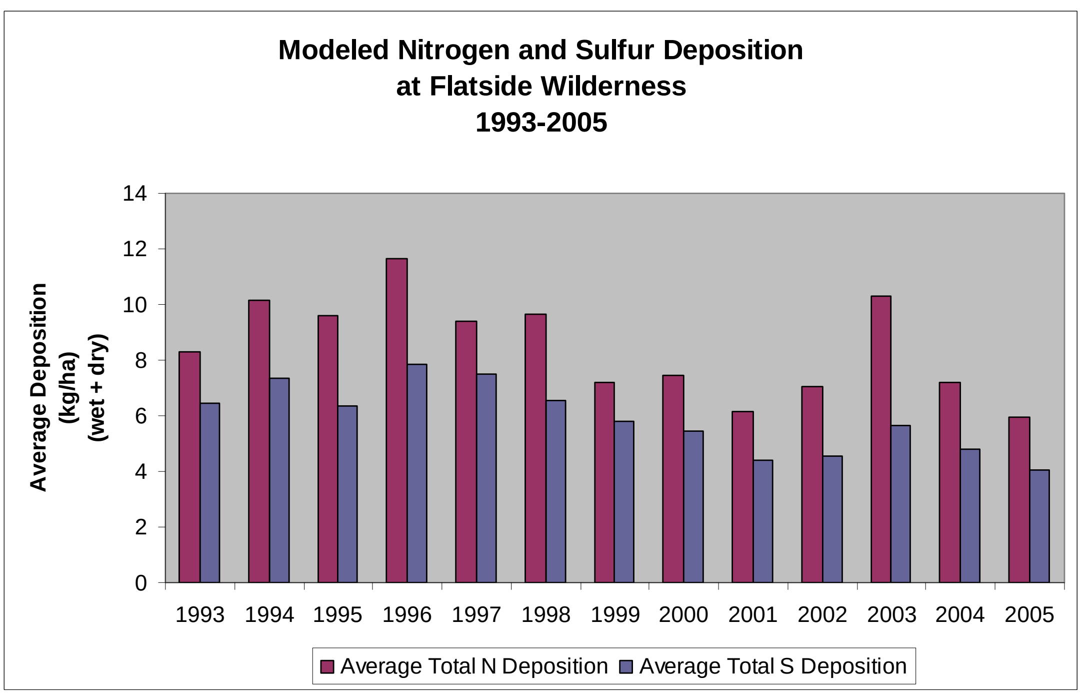
Average Deposition
(kg/ha)
(wet + dry)
16
14
12
10
8
6
4
2
0
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Average Total N Deposition
Average Total S Deposition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1993-2005
Average Deposition
(kg/ha)
(wet + dry)
14
12
10
8
6
4
2
0
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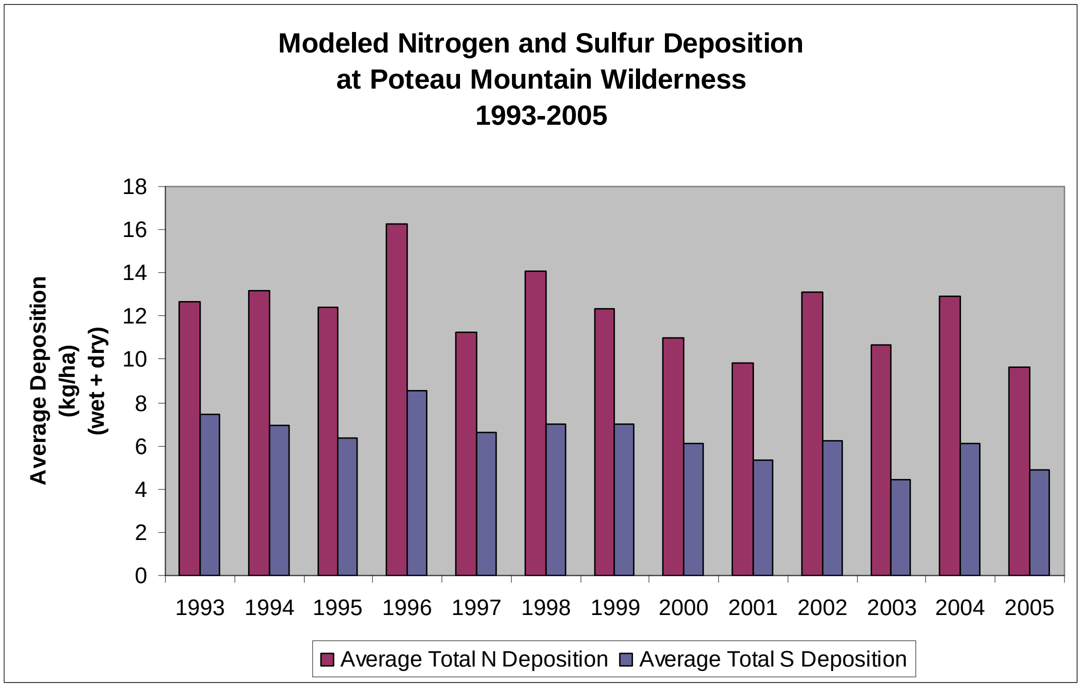
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Average Total N Deposition
Average Total S Deposition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(kg/ha)
(wet + dry)
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2
4
6
8
10
12
14
16
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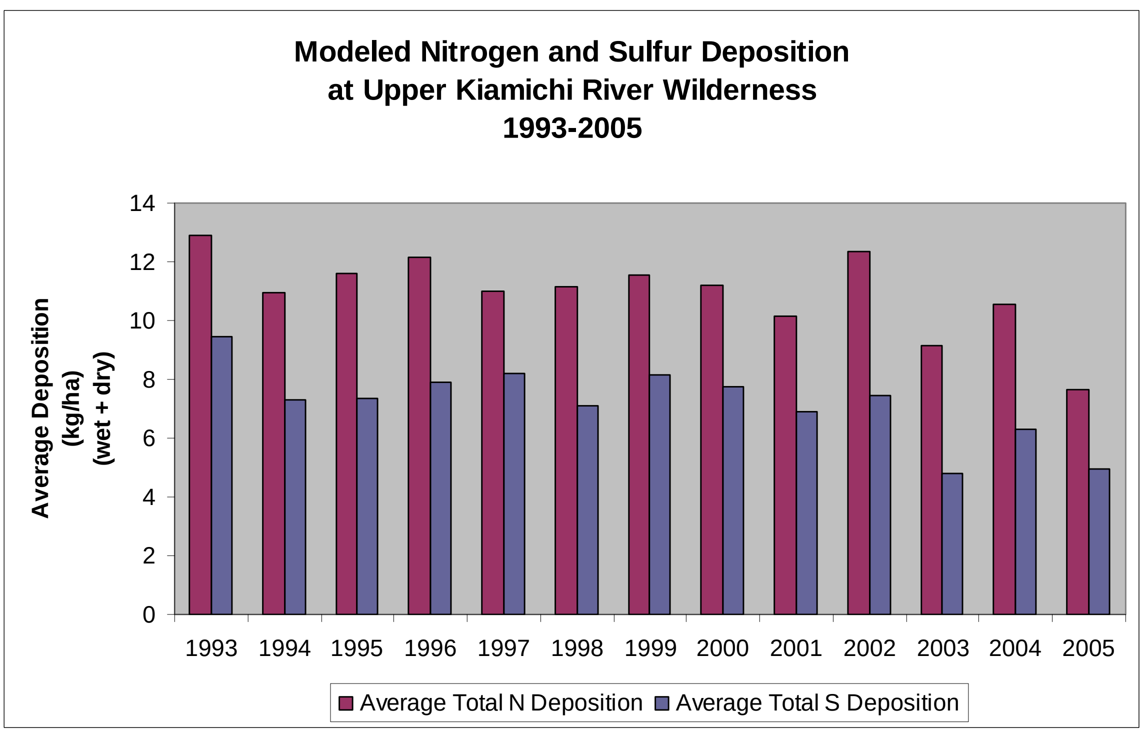
1998
1999
2000
2001
2002
2003
2004
2005
Average Total N Deposition
Average Total S Deposition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(wet + dry)
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4
6
8
10
12
14
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
Average Total N Deposition
Average Total S Deposition

APPENDIX B
OZONE INVENTORY AND MONITORING RECOMMENDATIONS

Ambient ozone measurements began at Polk County, AR in 2004. Biomonitoring of plants for symptoms of ozone exposure occurred 1991-1995. The following information is provided to show that the Forest has actually completed all stages, except long-term trend monitoring, for Caney Creek Wilderness.

Inventory: The purpose of the initial inventory is to better understand ozone exposures in the Wilderness. **This has been accomplished for Caney Creek.**
Study Design: Use ozone data from state-operated Federal Reference Monitors and/or spatially interpolated ozone metrics W126 and N100 to describe ozone exposures in the Wildernesses. Air Specialists can conduct this analysis.

Establish Baseline: Determine whether symptoms of ozone are occurring in the wildernesses. One year of biomonitoring will establish a baseline.
Study Design: Conduct an ozone biomonitoring survey to determine the amount and severity of ozone injury symptoms on vegetation in the Wildernesses. **This has been accomplished for Caney Creek.**

- Follow the protocol for ozone biomonitoring used on the Forest Inventory and Analysis (FIA) Detection Monitoring plots, also known as Phase 3 (P3) forest health plots (see References Cited for FIA Field Methods for Phase 3 Plot Measurements).
- Locate biomonitoring sites in areas with sensitive species in the appropriate setting as outlined in the FIA Field Methods manual. Strive to establish five plots in each Wilderness.
- Conduct the survey in August when ozone symptom expression should be at its peak in Arkansas.
- Consult with Forest Inventory and Analysis to see if biomonitoring results can be stored with other FIA data. Request the Forest Inventory and Analysis staff to conduct an analysis to compare the results from the wildernesses with other survey results in the same ecological region.
- The results of the inventory can be reported in the annual monitoring and evaluation report.

Long-term Trend Monitoring: The need for long-term monitoring depends on the results of the initial inventory and baseline conditions. If ozone symptoms are severe, a representative monitor should be identified or established near the wilderness. This could be accomplished through cooperative monitoring with the state, EPA or a research unit.

An ozone monitor has been established close to Caney Creek Wilderness, and five years of data have been collected. As long as this monitor does not exceed the NAAQS it is not necessary to initiate any additional ozone monitoring activities. If the monitor shows

an exceedence of the NAAQS, then it would be appropriate to conduct an assessment of modeled ozone information to further understand ozone exposures at Caney Creek Wilderness and conduct biomonitoring to see whether ozone symptoms are occurring on sensitive plants.

COUNTING WILDERNESS CHALLENGE ACCOMPLISHMENTS

Activity	Description	Score (upon completion of activity)
1. Develop an AQV Plan	Reviews air quality and resource conditions; recommends AQV, sensitive receptor and indicator to measure; and provides guidance on initial inventory procedures.	2 – When AQV plan has been finalized.
2. Inventory	Inventory additional ozone exposure information and potential effects to plants.	4 – When inventory has been completed.
3. Establish Baseline Condition for Sensitive Receptor	Conduct biomonitoring survey to establish baseline condition. Evaluate results of survey to determine need for long-term monitoring.	6 – When baseline monitoring has been completed and results reported.
4. Monitor Trends	Develop and implement long-term ambient ozone monitoring strategy, and where appropriate biomonitoring.	10 – When trend report has been completed.