AIR QUALITY ASSESSMENT FOR THE ANALYSIS OF THE MANAGEMENT SITUATION
DANIEL BOONE NATIONAL FOREST PLAN REVISION

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Treatment of Air Quality in the Existing Plan and AMS

The existing Forest plan, completed in 1985, had minimal discussion of air quality. The Plan simply stated that air quality was excellent; most likely based on the fact that the National Ambient Air Quality Standards established by the Clean Air Act were being met. This treatment of air quality is typical of Forest Plans developed in the 1980s, but consequently identifies no Desired Future Condition for air quality.

Changes in Air Resource Management Since 1985

Many changes have occurred since 1985 which have influenced air resource management on the Forest. Most significant was the release of extensive research findings from the National Acid Precipitation Assessment Program and subsequent amendment of the Clean Air Act in 1990. Both of these events received a great deal of media coverage which in turn has increased public concern that air pollution could be adversely affecting natural resources. Some people believe air pollution could be causing stress on forest ecosystems or limiting the production of goods and services on the National Forests. To address these concerns the Forest has increased emphasis on air quality and it's effects on forest resources. An air pollution effects inventory and monitoring program was initiated in 1992 to establish current conditions on the Forest. In addition, the Forest is an active participant in regional partnerships recently formed to address air pollution issues.

Another major change since the mid-1980's has been increased recognition of the necessity of fire in maintaining the health and productivity of many forested ecosystems. As the Forest Service moves to duplicate natural processes through the use of prescribed fire there will be increases in smoke. How will these emissions affect air quality?

This document will address: 1) the most important air pollutants which could be impacting forest resources, 2) results of air pollution effects monitoring, and 3) changes that are needed in the Forest Plan to better integrate air resource issues into ecosystem management.

Status of Air Quality in Relation to State and Federal Laws

The Clean Air Act (CAA) Amendments of 1977 established three classes of air quality across the United States. Class I is the most restrictive and allows the least increase in pollution from new or modified stationary sources (for example, a manufacturing plan, a pulp mill, an electrical utility, etc.). The Forest does not manage any Class I lands. Mammoth Cave National Park is the closest Class I area and is located roughly 100 miles west of the Forest. The Forest has a Class II designation, which is less restrictive than Class I. Class III designation allows the most pollution, however no areas of the country have been designated as Class III.

The CAA also designates six criteria pollutants with established thresholds to protect human health and welfare. The thresholds are referred to as the National Ambient Air Quality Standards (NAAQS). The State of Kentucky has been granted authority by EPA to carry out implementation of the CAA, which includes monitoring the air to determine if NAAQS have been violated. When air monitoring equipment measures values above NAAQS, the area (usually on a county basis) is designated as non-attainment. Most regions of Kentucky currently comply with the national air quality standards for these air pollutants, however there are areas where ozone and sulfur dioxide pollution are unacceptable. Ozone levels near Louisville and in northern Kentucky (Boone, Campbell and Kenton counties) exceed the NAAQS, making these non-attainment areas. Sulfur dioxide exceeds the standard in the southern end of Boyd County, and again this is a non-attainment area. National ambient air quality standards are being met in the rest of the state, which includes national forest lands. This is good news; the bad news is that natural resources can be impacted by air pollution concentrations below the national ambient air quality standards.

What are the important pollutants?

The words "air pollution" can invoke different images. Some people may imagine smog hanging over a city, smoke coming from a stack at a factory, or a dark cloud following a vehicle. These sources of pollution and many others have an influence on air quality at the Daniel Boone National Forest. Modern society is dependent on the combustion of fossil fuels for transportation, electricity, manufacturing, and heating of homes and businesses. The combustion of fossil fuels generates energy, but also toxic gases and particulates. The emissions of air pollution from human activity, along with gases and particulates from biogenic (natural) sources, have the potential to impact the Forest. It is unlikely that any air pollution impacts on the forest can be traced back to a single source. Instead, any pollution impacts occurring on the Forest are the result of emissions originating across a broad regional area from sources near and far. Pollutants emitted into the air with the greatest potential to impact forest resources include: sulfur dioxide, nitrogen oxides, volatile organic compounds, and particulate matter. These primary pollutants undergo chemical transformation into secondary pollutants which result in acidic deposition impacts to terrestrial and aquatic ecosystems, ozone damage to forest trees, and visibility degradation. The following sections address each of these primary pollutants and the importance of secondary pollutant effects on forest resources.

Global climate change, resulting from emissions of carbon dioxode and other greenhouse gases, has received widespread media attention but will not be discussed at length in this report. There is concern that a warming trend in climate could possibly change forest species composition. However, there is great uncertainty associated with the magnitude of future climate change and this uncertainty makes it very difficult to estimate forest changes over the next 50 years.

Sulfur Dioxide, Nitrogen Oxides and Acidic Deposition

Acidic compounds are deposited on forests through rain and cloudwater, or directly from the atmosphere (this is called dry deposition). The sum of these three is what we refer to as acidic deposition. The primary acidifying substances are sulfates and nitrates. Sulfates are formed when sulfur dioxide reacts with other substances in the air. Likewise, nitrates result from the chemical transformation of nitrogen oxides. Both sulfate and nitrate are referred to as secondary pollutants.

There is concern about acidic deposition, because high amounts of acidic deposition over a long period of time can eventually have adverse effects on soil productivity, forest health, and stream water quality. As soils become acidified several things happen. Calcium and magnesium, essential nutrients for plant growth, are leached from the soil. Aluminum is also mobilized as soil acidification occurs, which may further inhibit nutrient uptake. Acidic deposition can also affect stream water chemistry, and again this is a soil-mediated process. Streams flowing through watersheds with little buffering capacity (dependent on geology and soils of the area) are susceptible to acidification. As the water chemistry of the stream changes, aquatic insects and fish can be adversely affected. Aquatic organisms are particularly susceptible to water chemistry changes during the late winter and early spring, when reproduction is taking place.

Three streams on the Forest were selected for baseline inventory and monitoring; Rockbridge in Clifty Wilderness, and Little Hurricane and Helton in Beaver Creek Wilderness. These streams were chosen because they were considered "pristine" (relatively unaffected by acid mine drainage or other human influences), and therefore any air pollution effects would be easier to detect. Monthly water sampling began in 1993, although all streams had some amount of earlier data. Analysis of the stream water chemistry indicates that pH for all three streams stays near 7.0, dipping occasionally to 6.5 (Figure 1). Acid neutralizing capacity is well over 200 ueq/liter (alkalinity of 10 mg/liter) in the springtime in all streams, and climbs to 600 to 900 ueq/liter (30-45 mg/liter alkalinity) in the summer (Figure 2). These measurements indicate that the streams are well buffered against incoming acid deposition. Aquatic insects were collected from the same locations as the water samples in the spring and summer of 1993, 1994 and 1995. Results of this inventory indicate that aquatic insects are not being adversely affected by acid deposition at this time; aquatic insect diversity is good and species sensitive to acidic conditions are still present in the streams (Mangum 1995).

These findings were expected since Rockbridge flows over the Renfro and Nada members of the Borden Formation and the lower tongue of the Breathitt Formation. The Renfro and Nada members contain shale, siltstone and limestone, offering excellent buffering capacity. The Breathitt Formation contains at least minor limestone deposits and marine shales which offer some buffering capacity, however this formation has less of an influence on Rockbridge than the Renfro and Nada. Little Hurricane and Helton are influenced by the Pennington Formation which is shale, dolomite, limestone and sandstone; all offer good buffering opportunities for the water resources. Based on the geology and the results of stream monitoring, it appears that the aquatic ecosystems on the Forest are not likely to be affected by acid deposition in the near future. Other situations, such as acid mine drainage and sedimentation, pose a greater threat to aquatic resources in spite of high sulfate deposition on the Forest.

The effects of acid deposition on terrestrial resources is under investigation. Generally, soils on the Forest are able to buffer acid inputs from the atmosphere due to a high sulfate absorption capacity and favorable cation exchange capacity. However soils that are forming on more exposed, higher elevation sites in quartzose sandstone and shale, have a relatively low buffering capacity due to low cation exchange capacity and base saturation. Two sites on these more sensitive soil types were chosen to monitor soil water chemistry.

Soil water chemistry monitoring is being conducted to establish baseline condition, but there is not enough data to make any definitive statements at this time.

Where does the sulfate and nitrate come from? Coal-fired electrical utilities are the largest emitters of sulfur dioxide in Kentucky and nearby states and sulfur dioxide sources (emissions exceed 25,000 tons per year) ring the Forest (Figure 3). These sources, as well as others at further distances, are contributing the precursors of sulfates that have the potential to affect forest resources. The largest contributors of nitrogen oxides are electrical power plants, and vehicles traveling the extensive road network. These two sources have roughly equal annual emissions. Nitrogen oxides are important because they are a major precursor to ozone, and they combine with water to form acidic compounds.

How much sulfate and nitrate is deposited on the Forest? There are no acid deposition monitors located on the Forest, therefore indirect techniques have been used to help understand deposition on the Forest. A statistical model, the Pollution Exposure Index model (CH2M Hill 1995), was used to estimate the impact of sulfur dioxide emissions on the Forest. Data from point sources located within 100 kilometers of the Forest and emitting more than 100 tons per year in 1993 were used for this analysis. The output shows relative exposure to sulfur dioxide across the Forest with the higher numbers representing greater sulfur dioxide exposure. The Morehead District, on the northern tip of the Forest, shows about twice the exposure as Berea and Districts to the south (Figure 4).

Another way to estimate exposure to acid deposition across the Forest is to look at deposition data from existing National Atmospheric Deposition Program (NADP) monitoring sites located off-Forest and extrapolating deposition on-Forest. The most recent NADP data, from 1994, shows that sulfate deposition was around 20 kilograms per hectare per year (kg/ha/yr) in eastern Kentucky (Figure 5). This map also shows that the Forest lies between two of the highest areas of sulfate deposition in the nation; southeastern Ohio and eastern Tennessee. Figure 6 indicates nitrate deposition levels of 10-15 kg/ha/yr in 1994.

The NADP information was further refined using a longer-term estimate of wet deposition based on precipitation and topography-weighted interpolation of wet deposition between NADP monitoring sites (Lynch 1995). The process uses NADP chemical data (1983-1990) from locations in the eastern United States, along with Unites States Geological Survey (USGS) digital elevation data sets and National Oceanic and Atmospheric Administration (NOAA) rainfall measurements to model deposition chemistry spatially through the eastern United States (SAMAB 1996). This analysis considered the influence of regional topography on deposition and estimated an average background sulfate loading of 25-30 kilograms per hectare per year across the Forest (Figure 7).

Nitrate deposition was estimated at 10-15 kilograms per hectare per year (Figure 8). Although the sulfate estimate in particular is higher using this analytical technique, both sulfate and nitrate are most likely still underestimated because they represent only wet deposition. Dry deposition and cloudwater are more difficult to measure, but research has shown that they can contribute significantly to the total chemical load falling on forested-watersheds.

No matter how it is measured, the Forest receives high levels of acidic deposition due to it's position downwind of high sulfur dioxide and nitrogen oxide emissions in Ohio and Tennessee.

What is the expected trend for acid deposition on the Forest? Some indication of trends can be found in "The State of Kentucky's Environment: 1994 Status Report" published by the Kentucky Environmental Quality Commission in February of 1995. Ambient sulfur dioxide concentrations declined between 1980 and 1990, even though coal consumption increased (Figure 9). This can be attributed to better pollution control at coal-fired power plants. Between 1990 and 1993 sulfur dioxide emissions in eastern Kentucky appear to have remained steady. Concentrations are expected to decrease in the near future as SO2 emissions are reduced as a result of Title IV of the 1990 CAA Amendment which stipulates a 50% reduction in sulfur dioxide emissions by the year 2010. The expectation is that this will have positive benefits on air quality across the nation, but especially in those areas near concentrations of fossil fuel burning power plants. While many Kentucky power plants have shown great decreases in sulfur dioxide emissions between 1980 and 1993, the two that are located closest to the Forest (East Kentucky Power Cooperative plant in Clark County and the Cooper Plant in Pulaski County) show increases (Figure 10). When more recent data becomes available it may show decreases since 1993, but not necessarily. This is due to the fact that the market-based emissions reduction strategy in the CAA Amendments of 1990 calls for companies, not individual facilities, to meet sulfur dioxide reduction targets. This gives the company flexibility in determining where the reductions will be met, but also allows for increases at some facilities. Unless future reductions are made at plants closest to the Forest, it is likely that sulfate deposition on the Forest could remain the same or increase.

Nitrogen dioxide (NO2) concentrations in Kentucky showed a fairly steady decrease between 1980 and 1991, most of which is attributed to emission controls on vehicles (Figure 11). Although NO2 levels remain well below the

NAAQS, concentrations have increased slightly since 1991. Due to limited nitrogen oxides reduction strategies in the CAA Amendments of 1990, these pollutants are expected to increase in the future as vehicle miles driven increase.

Nitrogen Oxides, Volatile Organic Compounds, and Ozone

Nitrogen oxides contribute to acid deposition, but they are also an important component in the formation of ground-level ozone. Ozone, a chemical composed of three oxygen atoms linked together, is highly beneficial in the upper atmosphere. At ground level, however, sensitive plants can suffer tissue damage when exposed to sufficient doses of ozone. Ground-level ozone is not emitted directly from a source but is formed when nitrogen oxides and volatile organic compounds undergo a chemical reaction during hot and sunny weather. Interestingly, one main source of volatile organic compounds is trees. Current scientific evidence indicates that nitrogen oxides are the limiting factor in the formation of ground-level ozone, especially in rural areas; and almost half of the pollution contributing to ground-level ozone formation comes from vehicles.

Ground-level ozone affects plants by entering the leaf through openings called stomates. Once inside the leaf, ozone can kill cells that produce food for plant growth. The results of cell death can be seen on the upper leaf surface and are referred to as symptoms of injury. The Forest conducted a survey of ozone injury for three years, 1993-1995, and found low to moderate ozone injury on all Districts, except the Redbird (Brantley 1995). The Redbird District found no injury for the first two years and only slight injury the third year, due either to low ozone concentrations or drought.

What does it mean if plants show injury; are they also suffering growth loss or are trees weakened and predisposed to damage by other agents such as insects and disease? These questions are still under investigation but research has shown that growth loss due to ozone exposure can occur in forest species. Both the magnitude and duration of ozone exposure, as well moisture availability affect whether growth loss will occur. Since ozone enters a plant through the stomates, and stomates close during times of moisture stress, ozone is able to affect plants only when there is adequate moisture available and stomates are open.

This leads to the question "what ozone exposures are known to cause growth losses and how close are current ozone exposures and environmental conditions to those that cause growth reductions for species on the Forest?" It is a combination of consistently high ozone concentration combined with frequency of peak concentrations, that causes damage to a plant. The potential for ozone damage on the Forest has been estimated utilizing data and a technique developed for the Southern Appalachian Assessment (SAA). The analysis combines information on ozone exposure and soil moisture availability to estimate potential for ozone damage. Details of this analysis can be found in the SAA Atmospheric Technical Report (SAMAB 1996).

Potential for ozone damage was estimated for 1988, a year with record high ozone exposures; and for 1993, a more average year for ozone exposures. Comparison of results from the two analyses allows us to see the differences in predicted impacts of varying ozone exposures. The results of the 1988 analysis predicted growth loss for the most sensitive species, like black cherry (Prunus serotina), as well as moderately sensitive species, like tulip poplar (Liriodendron tulipifera), on all Districts except the Redbird (Figure 12). The Redbird did not reveive as high an ozone exposure as the rest of the Forest, therefore only the most sensitive species were likely to have been affected. These predictions assume that adequate moisture is available for plant growth.

In 1993 ozone exposures were considerably less. Results of the analysis showed that only the most sensitive species on the Morehead and Stanton Districts would have suffered growth loss under this ozone exposure scenario; again assuming adequate available moisture (Figure 12). It is important to remember that under drought conditions, regardless of ozone exposure, minimal damage is expected on any species. This is due to the fact that stomates remain closed during drought conditions and ozone uptake is very limited.

Ozone has been referred to as potentially the most significant pollutant affecting forests in North America (Barnard and others 1991). Based on the information presented, it appears that ozone could be affecting growth in some forest species. What do we expect for the future?

The State of Kentucky has made great strides in reducing ozone, and bringing areas into attainment. Figure 13 shows how average ozone levels have fluctuated over the past 25 years (Kentucky Division of Air Quality 1994). There are still two areas in the eastern part of Kentucky that do not meet the air quality standard for ozone: Louisville (Jefferson Co. and portions of Oldham and Bullitt Counties) and Northern Kentucky (Boone, Campbell and Kenton Counties). Areas closer to the Forest, Lexington and Ashland-Huntington, have had ozone problems in the past but these areas have recently been redesignated as attainment for ozone based on several years of data indicating that the standard is now being met.

Will this downward trend in ozone continue? Efforts are underway by the Commonwealth to bring the remaining areas into attainment. It is expected that ozone levels will remain stable or decrease slightly by the year 2010, but exposures could increase on the Forest if the regional population expands rapidly. An increasing population is likely to result in more nitrogen oxide emissions from vehicles. Also, electrical facilities may need to generate more power which could result in increased nitrogen oxide emissions. Both of these situations would likely increase ozone which could pose a threat to the more ozone-sensitive species on the Forest.

Particulate Matter and Visibility Impairment

Prescribed fire is the one activity on the Forest with the potential to significantly affect air quality. Smoke generated during burning contains small particles that affect the human respiratory system, and scatter light causing visibility reductions. Because prescribed fire activities produce particulate matter we need to be aware of the regulations governing open burning in the State of Kentucky. Open burning (specifically prescribed fire) in Kentucky is regulated by two agencies; the Division of Forestry, and the Division for Air Quality. The air regulations generally discourage open burning, however prescribed fire for silvicultural, range and wildlife management purposes is allowed. The Division of Forestry has additional regulations focused on preventing wildland fires. These generally prohibit daytime burning during the months of highest fire danger.

Given the current particulate matter standards, monitored PM10 levels have been below the NAAQS since measurements began in 1987 (Figure 14). Likewise there are no PM10 non-attainment areas in Kentucky. However, EPA is currently reviewing the particulate matter standard and is considering development of a new standard which emphasizes particles 2.5 microns or smaller (PM2.5) in size. Each of the previous changes in NAAQS has placed an emphasis on smaller particles (total suspended particles to a PM10 standard) and has also reduced the maximum allowable concentrations. The reason for considering a PM2.5 standard is that current medical research has shown that fine particles have the greatest impact on human health. Also, fine particles are primarily responsible for regional haze and the associated visibility reduction present throughout the Eastern United States (National Research Council 1993).

Fine particles, PM2.5, are known to be more efficient at scattering light than larger sized particles. Results from the southeastern United States show that sulfates (which are very efficient at scattering light) comprise the majority of the fine particle mass in the atmosphere, especially on days when regional haze is the worst (SAMAB 1996). The light scattering appears as a uniform haze that veils scenic views. Sources of air pollution outside the Forest cause regional haze. But Forest Service activities, primarily prescribed fire, have the potential to cause short term reductions in visibility . About 80 percent of the particulates generated from prescribed fires are one micron or less in diameter (USDA Forest Service 1976). Therefore, there is a potential for emissions from prescribed fire to impact human health and reduce visibility if smoke at ground level has high particulate matter concentrations. Visibility conditions become especially significant if the smoke crosses highways.

In addition to the visibility issue related to prescribed fire, it is also possible that the PM10 NAAQS can be violated within one mile of a prescribed fire. Studies conducted downwind of prescribed fires in Florida (Florida Department of Environmental Protection 1993) and Texas (Hunt and others 1994) have demonstrated that monitored maximum 24-hour concentrations exceeded the NAAQS. Since the Daniel Boone National Forest covers more complex terrain smoke dispersion will be different, but the possibility remains for exceeding the NAAQS at some distance from the fire for a short duration (24 hours or less). Currently the Forest uses smoke management guidelines designed to minimize impacts to smoke sensitive targets, such as visibility reduction on highways. The same guidelines also help reduce the impact of smoke on air quality, through rapid dispersion of smoke. The Forest has recently expanded the prescribed fire program for management of red cockaded woodpecker habitat. The Plan Revision may consider additional changes to the prescribed fire program; if so the short and long-term impacts to air quality should be considered.

Changes Needed in the Forest Plan

The Forest Plan Revision needs to recognize air quality as an important basic resource that touches and affects the entire ecosystem. Air quality may meet National Ambient Air Quality Standards, yet still affect natural resources. The eastern United States is overwhelmingly affected by regional air pollution. Many sources emit a variety of pollutants into the atmosphere, which are transformed and transported on wind currents over long distances, ultimately being deposited far from the source. Wilderness areas are not immune from air pollution, and the Plan Revision needs to recognize that air quality may be affecting the Wilderness resources adversely.

The Plan needs to explain how the Forest will address air pollution impacts to forest resources when the pollution is mainly generated off-Forest. First, the Forest needs to monitor the impacts of air pollution to forest resources, and this should be integrated into other inventory and monitoring activities on the Forest. Second, the Forest needs to make sure that the effects are understood by the air regulatory community, so that this information can be used in the development of regulations.

Prescribed fire is the main forest activity that affects air quality. Particulate matter standards are currently under revision by the Environmental Protection Agency, and are expected to change. Depending on the results, prescribed fire programs could be affected. Therefore, prescribed fire programs considered in the Plan Revision should be evaluated for impacts on air quality and visibility.

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