Forever Wild

PROTECTING THE ADIRONDACKS FROM ACID DEPOSITION

ENVIRONMENTAL DEFENSE FUND
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In 1894, the New York State Constitution was amended to mandate that the state-owned Forest Preserve in the Adirondack Park "shall be forever kept as wild forest lands." Air pollution threatens the state's long-standing commitment, forged in law, to protect the Adirondacks as "forever wild."

> *The lands of the state, now owned or hereafter acquired, constituting the forest preserve as now fixed by law, shall be forever kept as wild forest lands. They shall not be leased, sold or exchanged, or be taken by any corporation, public or private, nor shall the timber thereon be sold, removed or destroyed.*

ENVIRONMENTAL DEFENSE FUND

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Contents

Executive summary

Adirondack Park in northern New York is a unique six-million-acre region of protected land. It hosts a distinctive array of plants, fish and wildlife, and contains the headwaters of many of the state's major rivers. Unfortunately, this natural treasure also receives the brunt of much of the nation's acid rain pollution. Acid rain has seriously damaged ecosystems throughout the Adirondacks. State and federal laws have done much to reduce acid deposition—but not enough. As of 2000, 21% of monitored lakes in the region still showed chronic acidification.

The effort to restore the Adirondacks ecosystem suffered a significant setback in July when a federal court of appeals overturned the United States Environmental Protection Agency's Clean Air Interstate Rule, a program to help reduce power plant pollution across the East responsible for harming human health and damaging the Adirondacks. The airborne contaminants released from power plant smokestacks in distant states can drift hundreds of miles downwind and deposit in the Adirondacks and other areas. There are a number of efforts underway to respond to the court's decision and get the nation back on track in addressing power plant pollution. As policy makers craft responses to address the CAIR judicial decision, EPA's own modeling analyses indicate that it will be necessary to secure emissions reductions beyond those provided for under CAIR to protect the Adirondacks.

These recent developments only underscore that science has an essential role in guiding public policies to protect the lakes and forests of the Adirondacks. An important way to help safeguard the health of the Adirondacks is to establish *critical load* levels for acid deposition in the region. A critical load represents the level of pollution an ecosystem can tolerate without adverse impacts. It represents a clear benchmark for policymakers. If pollution deposition levels exceed the critical load, the ecosystem is compromised. If deposition is reduced below the critical load level, the ecosystem can be restored.

Critical load levels have been established in Europe for more than a decade, and have more recently been adopted in the western United States to protect sensitive ecosystems. Southeastern Canada also has adopted critical loads for protected ecosystems.

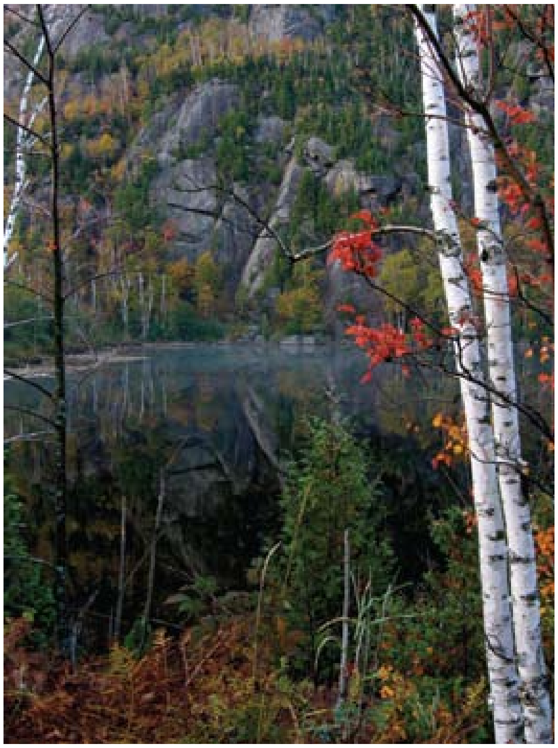
Establishing critical loads for a region requires consideration of a number of complex factors. Fortunately, some of the most comprehensive acid deposition research in the nation has been conducted in the Adirondacks. This rich body of research can be used to support critical load calculations. The state of New York is well positioned with the data, models and expertise needed.

Environmental Defense Fund urges the state of New York to adopt critical loads as the target limits for sulfur and nitrogen deposition in the Adirondacks. Adopting critical loads will provide the targets needed for policymakers and the public to define, enforce and assess progress toward full and permanent recovery of Adirondack lake and forest ecosystems.

CHAPTER 1

Significance of the Adirondack region

The six-million-acre Adirondack Park in northern New York is a unique quilt of public and private lands protected under state law. More than 2.6 million acres within the park are owned and managed by the state. About one-sixth of the park is wilderness, with 17 distinct wilderness areas encompassing a total area of about one million acres. Nearly nine million people visit the Adirondack Park each year (Banzhaf et al. 2004).



The Adirondack Park was originally conceived as an area where additions to the New York State Forest Preserve would be concentrated. The Forest Preserve is critical for protecting the headwaters of many of New York's major rivers and as a haven for distinctive plants, fish and wildlife. New York's Constitution states that the public lands in the Adirondack Park, which was established by the New York legislature in 1892, must never be developed and "...shall be forever kept as wild forest lands." The New York State Department of Environmental Conservation (NYSDEC) is charged with fulfilling this constitutional mandate.

Despite the protections New York has extended to the Adirondack Park, the region is heavily impacted by air pollution. With shallow soils and bedrock that have low capacity for buffering acids, the area is highly sensitive to acid deposition, which originates from sulfur dioxide (SO_2) and nitrogen oxides (NO_x) emissions produced by power plants and other pollution sources located in the eastern United States and Canada. Moreover, high elevation areas in the Adirondacks have received some of the greatest amounts of acid deposition in the nation for more than 50 years. Because of acid deposition, roughly half of the 3,000 lakes within the park are degraded, many of them to the point that they are devoid of fish (Baker et al. 1990; 1993). Forests in the region are also harmed by acid deposition, which causes reductions in growth and increased susceptibility to drought and disease (NAPAP 1998; DeHayes et al. 1999; Schaberg et al. 2001).

In 2004, New York residents were surveyed to assess their willingness to pay for improvements in the ecological health of the Adirondacks. The survey asked how much residents would be willing to pay in increased taxes for a ten-year-long program to reduce acidification of waters in 600 to 900 Adirondack lakes so the lakes could support fish. The research showed New York residents were willing to pay from $50 to $160 per year per household for this benefit, depending on the discount rate and amount of lake recovery assumed. Considering the number of households in the state, the total economic value of the ecosystem recovery program to New York residents was estimated at $340 million to $1.1 billion per year (Banzhaf et al. 2004).

The State of New York has been a national leader in research and policy to address acid deposition, passing the Acid Deposition Control Act in 1984 to help protect the Adirondack and Catskill regions of the state. Concern about the Adirondack region also helped motivate passage of the acid rain provisions of the 1990 amendments to the federal Clean Air Act. In 2004, New York passed the Acid Deposition Reduction Program to further reduce pollution impacting the state's natural areas. The existing regulatory programs have led to emissions reductions and in turn reduced acid deposition in the Adirondack region. But to restore the ecological health of the Adirondacks, additional reductions in the power plant pollution upwind of the Adirondacks and other sources of contamination will be necessary. By establishing critical loads, New York can put in place a durable science-based benchmark for evaluating progress.

CHAPTER 2

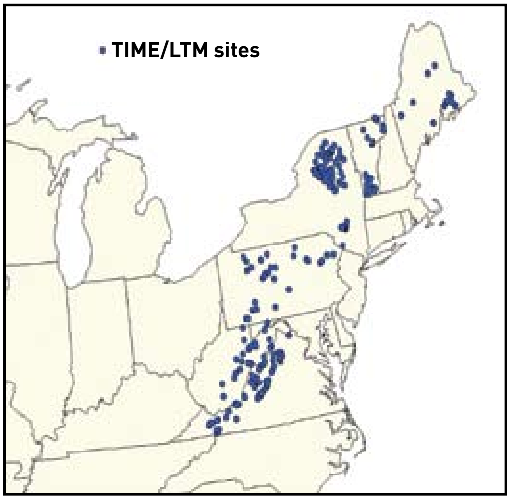
Current status and projections of acid deposition impacts in the Adirondacks

Extensive research has been conducted on the acid deposition loading and ecosystem health in the Adirondacks over the past decades. This body of knowledge indicates that existing pollution control programs are helping to reduce acid deposition in the Adirondacks and leading to improvements in water quality (Jenkins et al. 2005). Ongoing research and modeling indicate, however, that ecosystem health in the Adirondacks is still not secure and substantial additional progress is necessary.

The research record of acid deposition measurements in the Adirondacks extends back more than three decades, with continuous long-term monitoring extending back for 25 years (Driscoll et al. 2007). The New York State Department of Environmental Conservation undertook the first chemical surveys of Adirondack lakes in the early 1970s. Systematic monitoring began with the Adirondacks Long Term Monitoring Program (ALTM) in 1982; the ALTM program was expanded to cover 52 lakes in 1992 and continues with monthly sampling to this day. In 1997, the ALTM program was supplemented with annual summer sampling of close to 40 additional Adirondack lakes through EPA's Temporally Integrated Monitoring of Ecosystems (TIME) project. The TIME network uses statistical sampling methods; therefore, the 73 lakes sampled each year in this network in New York and New England represent approximately 2,500 lakes in the region that have low acid neutralizing capacity (ANC).[1] (Asbury et al. 1989) A map of the combined network is presented in Figure 1.

FIGURE 1

Surface water monitoring sites in the TIME/LTM network



Source: U.S. EPA 2005a]

Research conducted in the 1970s and 1980s concluded that acid deposition in the Adirondack region led to release of toxic forms of aluminum from soils to

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[1] The acid neutralizing capacity (ANC) of a lake or stream describes its resistance to acidification by addition of a strong acid, i.e., a substance that increases the concentration of hydrogen ion (H^+) when it is dissolved in water. Correspondingly, ANC describes how much base the water contains, with a base being a substance that neutralizes acids by increasing the concentration of hydroxide ion (OH^-) in water. The neutralization effect occurs when hydroxide ions combine with hydrogen ions to produce water. A lake or stream with a base flow or summer ANC < 0 is defined as chronically acidic—it is acidic throughout the year. Lakes with a summer ANC between 0 and 50 are considered susceptible to seasonal or episodic acidification and at risk for harm to aquatic organisms (Driscoll et al., 2001).

surface waters, reduced the pH[2] and acid neutralizing capacity of surface waters, and killed fish in affected lakes and streams (Jenkins et al., 2005). The 1984–1987 Adirondack Lakes Survey, undertaken by the New York State Department of Environmental Conservation and the Empire State Electric Energy Research Corporation, surveyed nearly 1,500 Adirondack lakes and found that 27% of the lakes were chronically acidic, with acid neutralizing capacity < 0 μequiv L^{-1} (Driscoll et al. 2003). In another study of note for policymakers, the Adirondack Lakes Survey established a clear relationship between increased lake acidity and reduced fish diversity (Baker et al. 1993).

Spurred in part by concerns for the ecosystem health of the Adirondacks, the 1970 and 1990 Clean Air Act Amendments have helped reduce emissions of sulfur dioxide and nitrogen oxides, two key sources of acid deposition in the Adirondacks. Over the period from 1970 to 2005, emissions of sulfur dioxide decreased by about 50% nationwide (U.S. EPA, Air Emissions Summary through 2005, available at www.epa.gov/air/airtrends/2006/emissions_summary_2005.html) (See also Likens et al. 2001). Nitrogen oxides emissions declined by about 30% over the same period, although most of this reduction in NO_x emissions has occurred since 1990 (U.S. EPA, Air Emissions Summary through 2005).

Research has now demonstrated corresponding reductions in acid deposition in the Adirondacks. Sulfate (SO_4^{2-}) concentrations in precipitation in the Adirondacks have decreased by about 50% since 1980 (Jenkins et al. 2005). Reductions in concentrations of nitrate in precipitation have also occurred, although only in recent years. Burns et al. (2006) found statistically significant decreases in precipitation nitrate concentrations over the period from 1984–2001 at three Adirondack wet deposition monitoring sites. Driscoll et al. (2007) found that precipitation pH at the Huntington Forest site in the Adirondacks correspondingly increased from about 4.2 during the period from 1979–1981 to about 4.6 during the period from 2001–2004. Similarly, precipitation pH at Whiteface Mountain increased from 4.1 during the period from 1984–1987 to about 4.6 during 2001–2004.

Scientists expect a time lag between reductions in acid deposition and improvements in ecosystem health. Over time, watersheds impacted by acid deposition can store acids, which are typically later released, further acidifying soils and surface waters and delaying ecosystem recovery. Sensitive soils also become depleted in base cations (calcium, Ca^{2+}; magnesium, Mg^{2+}; sodium, Na^{2+}; and potassium, K^{+}), which are essential forest nutrients and help buffer acid inputs. (Likens et al. 1996 and 1998) Consequently, even if emissions continue to decline, ecosystem recovery can

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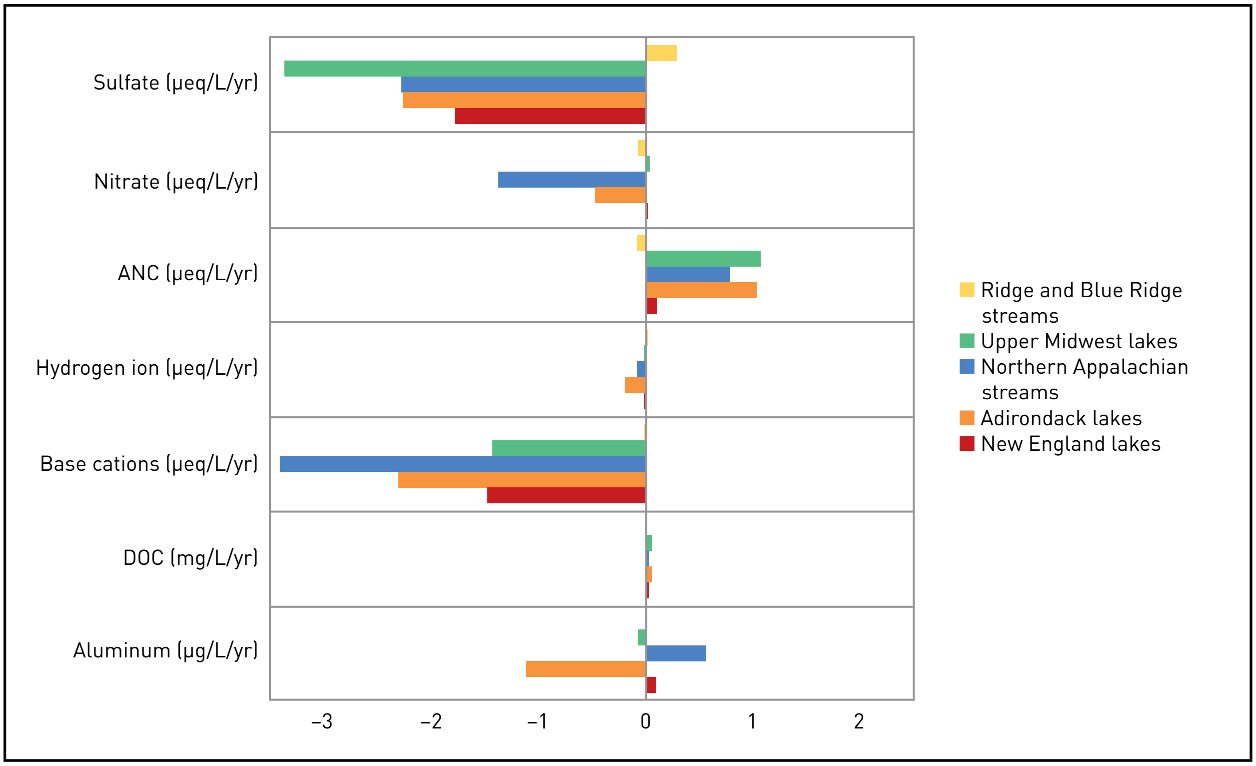
[2] The pH of a lake or stream or of precipitation measures the quantity of free hydrogen ions (H^{+}) the water contains, using a logarithmic scale. The scale is defined such that hydrogen ion concentration or acidity increases as pH value declines. ANC (defined above) and pH are both commonly used measures of lake or stream acidification, with pH characterizing the current state of the water body and ANC indicating how well the water body would resist the effect of adding more acid. The water found in most (though not all) lakes and streams is naturally somewhat acidic, with pH below the "neutral" value of 7. At pH = 6, lakes in the Adirondacks generally have diverse aquatic life, with all major groups of aquatic plants and animals represented (Jenkins et al., 2005). Diversity declines as pH declines (i.e., acidity increases) below about 6. Lakes and streams in the Adirondacks with pH below 5 lack major groups of aquatic plants or animals.

take decades (Sullivan et al. 2006). After sulfate and nitrate concentrations in precipitation decline, scientists expect a time lag before seeing reductions in sulfate and nitrate concentrations in surface waters, and further delay before acid neutralizing capacity and pH increase.

In recent years, researchers have identified some signs that Adirondack ecosystems are responding to decreasing acid deposition. Sulfur and nitrogen concentrations in the upper soil layers of red spruce stands in the Adirondacks and New England show that levels decline as wet deposition decreases (Driscoll et al. 2001). Research on the water quality of Adirondack lakes has identified significant declines in sulfate and nitrate concentrations. As shown in Figure 2, sulfate concentrations in surface water have declined in most Adirondack lakes since the early 1980s. The figure also shows that reductions in sulfate in the Adirondacks fall between those seen to the west in higher deposition areas and those seen in lower deposition areas to the east. Driscoll et al. (2007) found that sulfate concentrations in 16 Adirondack lakes monitored since 1982 declined significantly ($p < 0.1$) over the period from 1982–2004; sulfate concentrations in 47 of 48 lakes monitored since 1992 declined significantly in the ensuing twelve years. Burns et al. (2006) found small but statistically significant declines in nitrate concentrations over the period from 1992–2001 at 6 of 12 Adirondack lakes included in their study. Driscoll et al. (2007) similarly found a significant decrease in nitrate concentrations in 10 of 16 lakes monitored since 1982, and in 27 of 48 lakes monitored since 1992. These authors point out that the reason

FIGURE 2

Regional trends in lake and stream acidity, 1990–2000



Source: Stoddard et al. 2003

for the decline in nitrate concentrations during the 1990s is not clear, as NOx emissions did not decline significantly during that period. They suggest the decrease in nitrate concentrations may be related to climatic or hydrologic change or shifts in tree species.

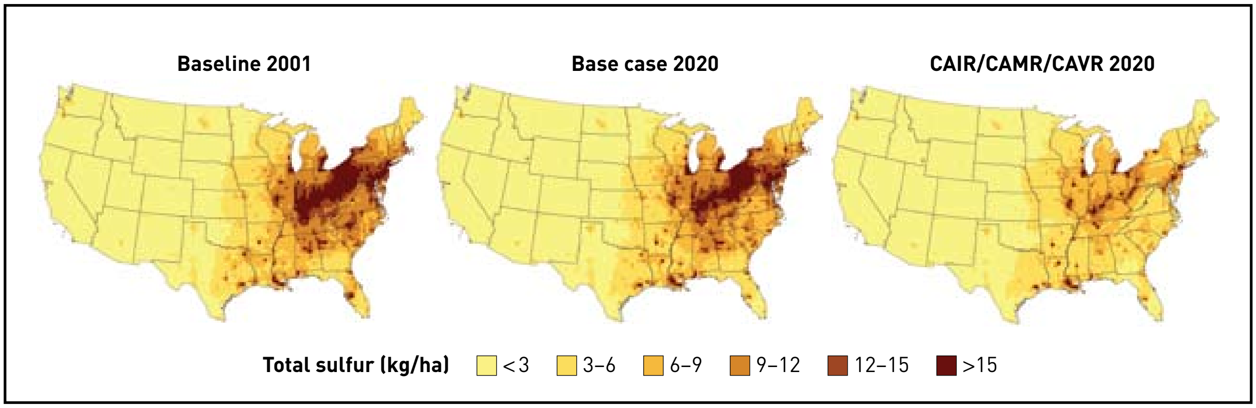
Along with the decline in lake water concentrations of sulfate and nitrate, research has identified some improvements in acid neutralizing capacity and concentrations of toxic inorganic aluminum in surface waters. Driscoll et al. (2007) found significant increases in acid neutralizing capacity in 11 of the 16 lakes monitored since 1982 and in 37 of 48 lakes monitored since 1992. This is an encouraging result, as earlier trend analyses had detected little response of ANC to emissions reductions. Increasing ANC is an important sign of chemical recovery in surface waters. Recent evidence of reduced concentrations of toxic inorganic aluminum in surface waters is another important indicator that ecosystem health is improving. Acid deposition is linked to fish deaths in part through its impact in mobilizing aluminum from soil in a toxic form. Driscoll et al. (2003) found decreased concentrations of toxic inorganic aluminum in 28 of 48 lakes considered in their study.

Recovery of Adirondack ecosystems is far from complete, however. As of 2000, the majority of monitored lakes still had ANC < 50 μequiv L^{-1}, the threshold for concern for aquatic biota, with 10 of the 48 monitored lakes (21%) having ANC < 0 μequiv L^{-1}, which indicates chronic acidification. Many more lakes and streams in the Adirondacks are thought to remain episodically acidified (NAPAP 2005). These lakes and streams may still not support sensitive fish species. High concentrations of inorganic aluminum also remain common: Driscoll et al. (2003) found that in 2000, 16 of the 48 lakes still had average inorganic aluminum concentrations > 2 μmol L^{-1}, a level considered toxic to juvenile fish.

Moreover, evidence indicates that even with further pollution controls and time for ecosystem recovery, the health of the Adirondacks is still not assured. Further reductions in sulfur and nitrogen oxides were expected as a result of EPA's 2005 Clean Air Interstate Rule. Figures 3 and 4 show the declines in sulfur and nitrogen deposition in the eastern United States that were predicted due to the Clean Air

FIGURE 3

Estimated annual sulfur deposition in 2001 and in 2020, with and without recent federal air pollution control programs including several recently overturned on judicial review

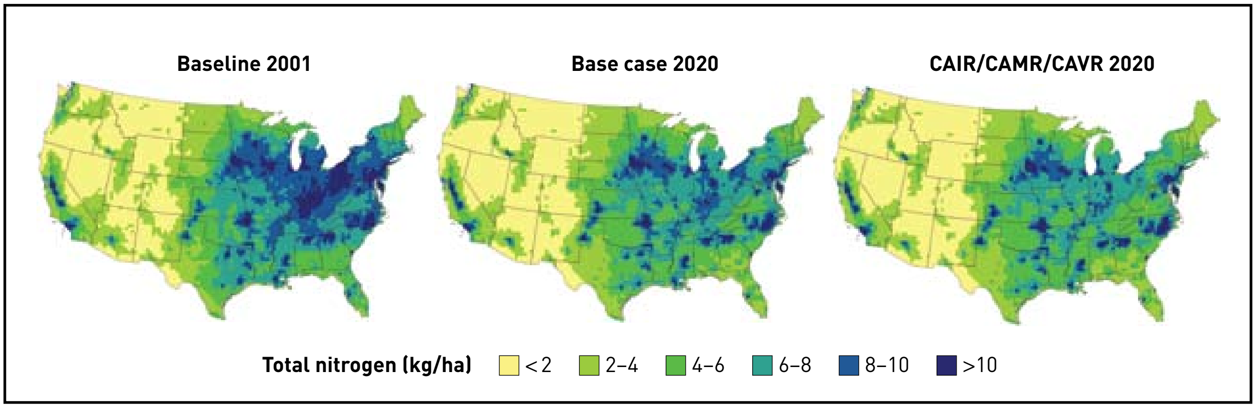


CAIR = Clean Air Interstate Rule; CAMR = Clean Air Mercury Rule; CAVR = Clean Air Visibility Rule

Source: U.S. EPA 2005c

FIGURE 4

Estimated annual nitrogen deposition ($NO_3^- + NH_4^+$) in 2001 and in 2020, with and without recent federal air pollution control programs including several recently overturned on judicial review



CAIR = Clean Air Interstate Rule; CAMR = Clean Air Mercury Rule; CAVR = Clean Air Visibility Rule Source: U.S. EPA 2005c

Interstate Rule. EPA projected that in 2030, after CAIR was fully implemented, most Adirondack lakes would still be episodically acidified, although no lakes would remain chronically acidified (U.S. EPA 2005b). In July, a federal court of appeals overturned CAIR. The “Baseline 2001” and “Base case 2020” scenarios depicted in the first two maps of Figures 3 and 4 reflect estimated sulfur and nitrogen deposition based on current pollution measures, without CAIR, and thus corresponded to the current situation. These cases show how critical it is to restore the reductions that would have been required under CAIR. Moreover, as policy makers craft responses to address the CAIR judicial decision, the CAIR/CAMR/CAVR scenarios indicate that it will be necessary to secure emissions reductions *beyond* those provided for under CAIR to protect the Adirondacks.

While existing pollution control methods have resulted in important reductions in acid deposition at Adirondack State Park, the health of Adirondack ecosystems is still at risk. Research demonstrates that Adirondack lakes still have harmfully low acid neutralizing capacity and high concentrations of toxic inorganic aluminum, putting fish populations and ecosystem health at risk. Additional pollution reductions will be necessary to ensure a complete ecosystem recovery for the Adirondacks.

CHAPTER 3

Definition and rationale for adopting critical loads

Environmental Defense Fund respectfully urges the State of New York to adopt critical loads for sulfur and nitrogen deposition effects for the Adirondack region in order to assess the adequacy of existing pollution control programs and evaluate the need for further reductions. Environmental Defense Fund recommends critical loads be developed for sulfur and nitrogen deposition based on pH and ANC as chemical indicators of surface water quality, mobilization of toxic inorganic aluminum and nutrient cation depletion in forest ecosystems. Although surface waters in the Adirondacks are beginning to exhibit chemical recovery in response to emissions reductions, current assessments suggest that additional emissions reductions are necessary to ensure full recovery of the area's ecosystems.

Critical loads represent the level of pollutant deposition that an ecosystem can tolerate without adverse impacts. As such, they represent a vital benchmark for tracking progress and designing remedial actions. If deposition levels exceed the critical load, harmful effects may occur. With deposition reduced below the critical load, the health of the ecosystem should be maintained. Critical loads are generally expressed as loading rates in kilograms of S and N per hectare per year (Porter et al. 2005). Critical loads should be set based on scientific understanding of ecosystem responses, without regard to the levels of emissions reductions or cost of meeting them. In this respect they are analogous to ambient air quality standards that are based purely on human health and environmental effects, without regard to cost. With critical loads in place, policymakers can more reliably establish targets and timetables for emissions reductions that are needed for ecosystem protection. A recent report from the National Research Council of the National Academy of Sciences strongly recommended use of critical loads to help improve effectiveness of air quality management and associated regulations and emission reduction strategies (NRC 2004).

Critical loads are being used successfully in Europe and have recently been established in the western United States to set emission management goals for protecting sensitive ecosystems. Available data and proposed new assessment efforts provide a sound basis for development of quantitative critical loads for the Adirondacks.

The common definition of critical loads was originally developed by the United Nations Economic Commission for Europe in 1988:

A critical load is a quantitative estimate of the exposure to one or more pollutants below which significant harmful effects on specific sensitive elements of the environment do not occur according to present knowledge (UN ECE, 1988).

Establishing critical loads for a region requires consideration of many factors. Critical loads differ with each pollutant or pollutant mix being considered (e.g., sulfate versus nitrate or a combination of the two), the nature and location of the ecosystem (e.g., aquatic versus terrestrial ecosystems, altitude, climate factors, soil chemistry), and the indicators being used to define damage (e.g., surface water or soil acidification, nitrogen saturation and biotic community changes resulting in loss of aquatic species, forest dieback and other problems).

Critical loads have been formally used to help establish emission reduction targets in Europe for more than a decade (http://www.unece.org/env/wge/mapping.htm). In Europe, critical loads are used to inform air pollution policy and are directly linked to air quality regulations and emissions reductions agreements. The value of critical loads is increasingly being recognized in North America. Critical loads have been established for protected ecosystems in southeastern Canada (http://www.ec.gc.ca/pdb/can_us/2004CanUs/section3_e.html#35), New England and more recently in the western United States. The Conference of New England Governors and Eastern Canadian Premiers has undertaken a collaborative project to map critical loads for forests in the region based on nutrient cation depletion effects (NEG EGP 2001; Miller 2006).

In 2006, the National Park Service, U.S. EPA and the State of Colorado formally adopted a critical load for reactive nitrogen deposition as a management goal for Rocky Mountain National Park. This critical load is 1.5 kg N/ha/yr (as wet deposition), based on empirical analysis of the threshold for change in aquatic species in high elevation lakes (Baron 2006). The critical load is intended to help protect areas showing changes in both type and abundance of aquatic species, chronically elevated levels of nitrate in surface waters, elevated levels of nitrogen in spruce tree chemistry, accumulation of nitrogen in forest soils, and nitrogen-induced shifts in alpine tundra plant communities from wildflowers toward more sedges and grasses (Bowman et al. 2006).

Recent articles, workshops and planning activities have been devoted to exploring further development and expanded use of critical loads in the United States (e.g., Porter et al. 2005; U.S. EPA, 2006). Fortunately, some of the most comprehensive acid deposition research in the nation has been conducted in the Adirondacks and can be used to support critical load calculations. The Adirondack region is a key area for prompt development of critical loads because it has a rich scientific basis for establishing critical load values, and because ecosystem recovery in the region must be carefully monitored to track the adequacy of emission management strategies.

CHAPTER 4

Resources for establishing critical loads for the Adirondacks

Establishing critical loads entails:

- Identifying resources of concern, along with appropriate indicators of the health of those resources. For example, ANC is a widely used indicator for the health of freshwater lakes and streams (Porter et al2005).
- Using data and models to relate ecosystem health indicators such as ANC to rates of pollutant loading.
- Identifying critical loads that correspond to the threshold between safe and harmful deposition levels.
- Providing for ongoing deposition monitoring and environmental modeling to track progress toward achieving and maintaining target critical loads.
- Developing outreach tools and approaches to communicate the basis for critical loads and progress toward meeting them.

The State of New York is well positioned with data, models and expertise needed to set critical loads for the Adirondack region, and should undertake a formal process to establish and adopt them. Once critical loads have been adopted as resource management goals, the state should assess anticipated progress toward meeting them, secure additional emissions reductions to achieve them and deploy the critical loads as a strong science foundation for communicating with policymakers and the public about the benefits of pollution reduction measures that have already been undertaken and the need for additional measures.

Driscoll (2006) summarized the databases and analytical tools available for developing critical loads for the Adirondack region. They include extensive survey and long-term monitoring data from the following programs:

- Adirondack Lakes Survey (chemistry, fish; sponsored by the Empire State Electric Energy Research Corp. [ESEERCO], NYSDEC and EPA)
- Adirondack Long-Term Monitoring (LTM) Program (chemistry; sponsored by the New York State Energy Research and Development Authority [NYSERDA], NYSDEC and EPA)
- The Temporally Integrated Monitoring of Ecosystems (TIME) program (chemistry; sponsored by EPA, NYSERDA and NYSDEC)
- The Direct Delayed Response Project (watershed response, chemistry, soils, foliage; sponsored by EPA)
- The Environmental Monitoring, Evaluation and Protection (EMEP) Soil Chemistry Survey (soils, water chemistry; Sullivan et al., 2006; sponsored by NYSERDA and NYSDEC)
- The Adirondack Effects Assessment Program (chemistry, aquatic biota; sponsored by EPA)

The area also has extensively evaluated models available for application to critical loads determination and assessments:

- PnET-BGC, is a dynamic, integrated forest-soil-water model designed to simulate the response of soil and surface waters in northern forest ecosystems to various disturbances, including acid deposition (e.g., Chen and Driscoll 2004). Efforts are already underway to use PnET-BGC to develop critical loads for the Adirondack region (Ecological Analysis and Communications 2006).
- MAGIC, the Model of Acidification of Groundwater in Catchments, is a dynamic model that links watershed properties with surface water chemistry (e.g., Cosby et al., 1985). EPA applied this model to the Adirondack region to project the impacts of the Clean Air Interstate Rule (U.S. EPA 2005) before it was overturned.

Many other ongoing and planned studies in the Adirondacks can support the development of critical loads for the region. The New York State Energy Research and Development Authority (NYSERDA) administers the Environmental Monitoring, Evaluation and Protection (EMEP) research program using funds from a system benefits charge collected by the state's investor-owned utilities (see http://www.nyserda.org/programs/Environment/EMEP/), and is already supporting research that will inform critical loads development (Environmental Research and Monitoring Needs in New York State, August 2007, www.nyserda.org/environment/emep/emepplan2007.pdf)).

Conclusion

Significant recovery of Adirondacks ecosystems damaged by sulfur and nitrogen deposition has been spurred—but also limited by—pollution control programs currently in place. Adirondack lakes still have harmfully low acid neutralizing capacity (ANC), and high concentrations of toxic inorganic aluminum, putting fish populations and ecosystem health at risk. Current measures will not insure complete ecosystem recovery. EPA's own analysis of the pollution reductions under the Clean Air Interstate Rule indicated that additional progress would be necessary to protect the Adirondacks. The recent decision by a federal court of appeals overturning CAIR only underscores the importance of a durable scientific framework for guiding and evaluating progress in protecting the health of Adirondacks lakes and forests.

Environmental Defense Fund urges the State of New York to adopt critical loads as the target limits for sulfur and nitrogen deposition in the Adirondack region, to assess the adequacy of existing pollution control programs, and to evaluate the need for further reductions, so that ecosystem recovery already underway can be complete and permanent.

Specifically, Environmental Defense Fund recommends critical loads be developed for sulfur and nitrogen deposition based on pH and ANC as chemical indicators of surface water quality, mobilization of toxic inorganic aluminum and nutrient cation depletion in forest ecosystems.

This goal of establishing and enforcing further emissions reductions based on critical loads is a natural extension—a necessary, next-stage refinement—of policies and programs already in place. These vital changes can be accomplished. If nothing is done, the Adirondack ecosystems will not recover in the foreseeable future.

A New York and national treasure, the Adirondack region is among the areas in the country most heavily impacted by acid deposition. Over the past three decades, researchers working in the Adirondacks, with vital support from the state of New York, have developed an extensive body of scientific understanding that has stimulated and guided efforts to reduce this devastating form of pollution. Environmental Defense Fund urges the state of New York to provide essential leadership once again, by adopting critical loads for the Adirondack region to help track and promote the region's recovery from the assault of acid deposition. Stewards of the Adirondacks must take this vital, historic step to insure that the region's lakes and forests remain, indeed, *forever wild*.

References

Asbury, C. E., F. A. Vertucci, M. D. Mattson and G. E. Likens. 1989. Acidification of Adirondack lakes. *Environ. Sci. Technol.* 23(3):362–365.

Baker, J.P., Gherini, S.A., Christensen, S.W., Munson, R.K., Driscoll, C.T., Newton, R.M., Gallagher, J., Reckhow, K.H., Schofield, C.L. (1990) Adirondack Lakes Survey: An Interpretive Analysis of Fish Communities and Water Chemistry, 1984–87. Adirondack Lakes Survey Corporation, Ray Brook, NY.

Baker, J.P., Warren-Hicks, W.J., Gallagher, J., and Christensen, S.W. (1993) Fish population losses from Adirondack lakes: The role of surface water acidity and acidification, Water Resources Research, 29:861-874.

Banzhaf, S., Burtraw, D., Evans, D., Krupnick, A. (2004) Valuation of Natural Resource Improvements in the Adirondacks, Resources for the Future, September (available at www.rff.org/Documents/RFF-RPT-Adirondacks.pdf).

Baron, J. (2006) Hindcasting nitrogen deposition to determine an ecological critical load, Ecological Applications, 16:433–439.

Bowman, W.D., Gartner, J.R., Holland, K., Wiedermann, M. (2006) Nitrogen critical loads for alpine vegetation and terrestrial ecosystem response: Are we there yet? Ecological Applications, 16:1183–1193.

Burns, D.A., McHale, M.R., Driscoll, C.T., Roy, K.M. (2006) Response of surface water chemistry to reduced levels of acid precipitation: comparison of trends in two regions of New York, USA, Hydrological Processes, 20:1611–1627.

Chen, L., Driscoll, C.T. (2004) Modeling the response of soil and surface waters in the Adirondack and Catskill regions of New York to changes in atmospheric deposition and historical land disturbance, Atmospheric Environment, 38:4099-4109.

Cosby, B.J., Wright, R.F., Hornberger, G.M., Galloway, J.N. (1985) Modeling the effects of acid deposition: Assessment of a lumped parameter model of soil water and streamwater chemistry, Water Resources Research, 21:51–63.

DeHayes, D.H., Schaberg, P.G., Hawley, G.T., Strimbeck, G.R. (1999) Acid rain impacts calcium nutrition and forest health: alteration of membrane-associated calcium leads to membrane destabilization and foliar injury in red spruce, Bioscience, 49:789–800.

Driscoll, C.T., Lawrence, G.B., Bulger, A.J., Butler, T.J., Cronan, C.S., Eagar, C., Lambert, K.F., Likens, G.E., Stoddard, J.L., Weathers, K.C. (2001) Acidic deposition in the northeastern United States: Sources and inputs, ecosystem effects, and management strategies, Bioscience, 51:180-198.

Driscoll, C.T. (2006) Effects of acidic deposition and calculating critical loads of acidic deposition in the Adirondack region of New York, presentation at the Multi-Agency Critical Loads Workshop: Sulfur and Nitrogen Deposition Effects on Freshwater and Terrestrial Ecosystems, May 23-25, 2006, Charlottesville, VA (available at nadp.sws.uiuc.edu/cladws/presentations.asp, last accessed November 23, 2007).

Driscoll, C.T., Driscoll, K.M., Roy, K.M., Mitchell, M.J. (2003) Chemical response of lakes in the Adirondack Region of New York to declines in acidic deposition, Environ. Sci. Technol. 37:2036–2042.

Driscoll, C.T., Driscoll, K.M., Roy, K.M., Dukett, J. (2007) Changes in the chemistry of lakes in the Adirondack region of New York following declines in acidic deposition, Applied Geochemistry 22:1181-1188.

Jenkins, J., Roy, K., Driscoll, C., Buerkett, C. (2005) Acid Rain and the Adirondacks: a Research Summary, Adirondack Lakes Survey Corporation (available at www.adirondacklakessurvey.org).

Likens, G. E., C. T. Driscoll and D. C. Buso. 1996. Long-term effects of acid rain: response and recovery of a forest ecosystem. *Science* 272:244–246.

Likens, G. E., C. T. Driscoll, D. C. Buso, T. G. Siccama, C. E. Johnson, G. M. Lovett, T. J. Fahey, W. A. Reiners, D. F. Ryan, C. W. Martin and S. W. Bailey. 1998. The biogeochemistry of calcium at Hubbard Brook. *Biogeochemistry* 41(2):89–173.

Likens, G. E., T. J. Butler and D. C. Buso. 2001. Long- and short-term changes in sulfate deposition: Effects of The 1990 Clean Air Act Amendments. *Biogeochemistry* 52(1):1–11.

Miller, E. (2006) Assessment of Forest Sensitivity to Nitrogen and Sulfur Deposition in Maine, Conference of New England Governors and Eastern Canadian Premiers Forest Mapping Group, prepared for Maine Department of Environmental Protection (available at www.maine.gov/dep/air/acidrain/ME-Forest-Mapping-Report-2007-01-26.pdf, last accessed November 23, 2007).

NAPAP (1998) NAPAP biennial report to Congress: An integrated assessment, U.S. National Acid Precipitation Assessment Program (available at http://www.p2pays.org/ref/11/10588/).

NEG ECP (2001) New England Governors and Eastern Canadian Premiers Forest Mapping Group, Protocol for Assessment and Mapping of Forest Sensitivity to Atmospheric S and N Deposition.

NRC (2004) Air Quality Management in the United States, Committee on Air Quality Management in the United States, 68, National Research Council, Washington, DC.

Porter, E., Blett, T., Potter, D.U., Huber, C. (2005) Protecting resources on federal lands: Implications of critical loads for atmospheric deposition of nitrogen and sulfur, Bioscience, 55:603–612.

Schaberg, P.G., DeHayes, D.H., Hawley, G.J. (2001) Anthropogenic calcium depletion: a unique threat to forest ecosystem health? Ecosystem Health, 7:214-228.

Stoddard, J.L., Kohl, J.S., Deviney, F.A., DeWalle, D.R., Driscoll, C.T., Herlihy, A. T., Kellogg, J.H., Murdoch, P.S., Webb, J.R., and Webster, K.E. (2003) Response of Surface Water Chemistry to the Clean Air Act Amendments of 1990, U.S. Environmental Protection Agency, Report No. 620/R-03-001 (executive summary available at www.epa.gov/ord/htm/CAAA-Executive Summary-1-29-03.pdf).

Sullivan, T.J., Fernandez, I.J., Herlihy, A.T., Driscoll, C.T., McDonnell, T.C., Nowicki, N.A., Snyder, K.U., Sutherland, J.W. (2006) Acid-base characteristics of soils in the Adirondack Mountains, Soil Science Society of America Journal, 70:141-52.

UN ECE (1988) Protocol to the 1979 Convention on Long-Range Transboundary Air Pollution Concerning the Control of Emissions of Nitrogen Oxides on Their Transboundary Fluxes, United Nations Economic Commission for Europe.

U.S. EPA (2005a) Protecting Ecosystems from S and N Emissions—EPA's Perspective, Office of Air and Radiation, U.S. Environmental Protection Agency, presentation by R. Haeuber and V. Sandiford, given at the Riverside, CA Critical Loads Workshop, February 16, 2005.

U.S. EPA (2005b) Regulatory Impact Analysis for the Final Clean Air Interstate Rule, EPA-452/R-005-002, U.S. Environmental Protection Agency, Office of Air and Radiation, March.

U.S. EPA (2005c) Protecting Ecosystems: An EPA Perspective on What Critical Loads Can Offer, Office of Air and Radiation, U.S. Environmental Protection Agency, presentation by R. Haeuber given at the WESTAR "Understanding the CL Approach" Workshop, November 16, 2005.

U.S. EPA (2006) Multi-Agency Critical Loads Workshop, May 23–25, 2006, Charlottesville, VA, Final workshop report prepared by Ecologic Analysis and Communications (available at nadp.sws.uiuc.edu/cladws/presentations.asp, last accessed November 23, 2007).

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