TESTIMONY SUMMARIES AND INDEX TO MATERIALS FOR THE WYOMING ACID RAIN COORDINATING COMMITTEE: May 1985-April 1987

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Section 1

INTRODUCTION

As a result of growing public concern and uncertainty about potential effects from acid deposition on the resources of Wyoming, Governor Ed Herschler appointed an Acid Rain Coordinating Committee to provide cohesion and direction for the State's research, regulation, and policy-forming efforts on issues related to acid depositions. Appointed to the Committee in May, 1985, were Mr. David B. Park, from the Wyoming Environmental Quality Council; Mr. Robert Wallick, from the Wyoming Industrial Siting Council; Ms. Bonnie Pendleton, from the Wyoming Air Quality Advisory Board; Dr. Jim Barlow, a member of the Wyoming House of Representatives; and Dr. Ron Surdam, from the University of Wyoming. Mr. Randy Wood, Director of the Wyoming Department of Environmental Quality, served as Executive Secretary for the Committee.

Testimony from twenty-two expert witnesses and discussions at nine public meetings provided an understanding and perspective for both the Committee and the public at large on acid deposition issues they relate to Wyoming. To help direct State involvement in acid deposition research, the Committee, using results from these meetings, was to evaluate existing research projects in the State and identify research needs, goals, and priorities for the State. In particular, Federal research efforts in the state were to be evaluated to promote coordination with State efforts and to encourage additional Federal involvement where appropriate. Then, the Committee was to prepare a report containing their recommendations on appropriate actions, priorities, policies, and positions for Wyoming. Finally, a reference document was to be produced supporting all of the Committee's recommendations on the acid deposition issues. The Committee's report was issued in April, 1987.

Currently, scientists are uncertain how patterns for atmospheric depositions are changing in space and time, and the extent of their actual or potential effects in Wyoming, in the rest of North America, and in Europe. Intense concerns about the potential effects due to acid depositions have led to extensive ongoing scientific research and widespread public speculation. In the end, scientists can only offer guidance on the likely consequences of altering regulatory standards for atmospheric emissions. But, by their nature, alterations to regulations are political decisions, often motivated by an informed public. This document, the Committee's report, and the supporting materials provide a basis to better understand issues related to atmospheric depositions and their potential effects in Wyoming.

The following sections summarizes testimony heard by the Committee and indexes materials compiled by the Committee in support of their April 1987 report. Testimony provided by the experts to the Committee is highlighted in Section 2; and an appendix at the end of this section presents an overview of current scientific knowledge on acid depositions and its actual or potential effects. Section 3 summarizes discussions occurring at each of the nine public meetings, and then Section 4 presents more detailed summaries from the testimonies and comments provided by the twenty-two expert witnesses. Section 5 contains the bibliography of material compiled by the Committee. Finally, a general index to these materials is provided in Section 6. This index catalogs the Committee materials by scientific subject, providing a reference index appropriate for identifying all materials on a given topic that were compiled by the Committee.

Section 2

OVERVIEW OF REPORT

This section first reiterates the recommendations, policies and positions developed and presented by the Acid Rain Coordinating Committee in their April 1987 report. This is followed by general statements, drawn from testimony given to the Committee during the nine public meetings, that relate to (1) current or potential atmospheric deposition impacts in Wyoming; (2) current monitoring and research activities in Wyoming; (3) considerations for monitoring atmospheric depositions in Wyoming; and (4) relationships between emission sources and resource receptors. Accompanying each statement presented is the name(s) of the expert(s) that provided the testimony on which the statement is based.

Readers desiring greater information on the statements presented in this section should consult Section 4, the expanded summaries of the presentations by each expert, and Section 5, the index of supporting materials. In addition, documents providing excellent overviews of many of the Committee meetings, which include recommendations for future research and monitoring efforts in the State, have been provided by Drs. Chris Bernabo, Douglas Fox, and George Hidy. These documents were the focus of a round table discussion by the Committee on July 23, 1986. For easy reference, these documents are reproduced in their entirety with that summary of meeting in Section 3. Finally, appended at the end of this section is a general overview of acid depositions and its potential consequences in Wyoming. This article was prepared by one of the authors of this document, and was based, in part, on testimony and materials compiled by the Committee. It was published in the December 1987 issue of Wyoming Wildlife.

THE COORDINATING COMMITTEE'S RECOMMENDATIONS, POLICIES, AND POSITIONS

SPECIFIC RECOMMENDATIONS

1. The existing monitoring program in Wyoming, which is in its initial stages, consists mainly of measuring atmospheric deposition. This program, operated by various industry, State, and Federal agencies, should be continued but coordinated and expanded. Additional monitoring sites should be established at locations to create an optimum network. These stations should monitor all critical elements of atmospheric deposition.

2. Monitoring should be designed to characterize the situation in Wyoming as well as the situation upwind of Wyoming.

3. Research and monitoring programs should be established for data development in cloud, lake, and stream chemistry, as well as biological activity. These research programs should be designed to meet Wyoming's needs, and should be carefully coordinated and integrated with ongoing industry, Federal, and State programs. This coordination is essential to maximize efficiency, to reduce duplication, and to minimize cost.

4. Once a credible data base is established through the monitoring program, modeling techniques should be developed and utilized to predict rates of deposition and to study source-reception relationships. Based on periodic reviews of the state of the science relating to conditions in Wyoming the State should establish thresholds of unacceptable atmospheric deposition.

GENERAL RECOMMENDATIONS

1. An atmospheric deposition coordinator having an appropriate technical background should be appointed by the Governor and function under the direction of the Governor with the authority to initiate State programs, to coordinate industry, State, and Federal efforts, and to monitor all research related to atmospheric deposition. Program funding would be at the discretion of the Governor in accordance with the budgetary process. To utilize the existing technology base, research facilities, and scientific expertise, the

Committee recommends that the coordinator be located at the University of Wyoming.

2. A small committee, chaired by the Governor, and consisting of distinguished, nationally recognized atmospheric, aquatic, and terrestrial scientists should be appointed to advise the coordinator.

POLICIES AND POSITIONS

1. The State must promote the most efficient development and use of all its resources.

2. All states should actively implement appropriate provisions, such as application of best available control technology in order to protect available clean air resources, so as to accommodate future economic development.

3. Those who use and develop the resources are responsible for minimizing adverse impacts. The costs associated with addressing this responsibility must be internalized.

4. It is of paramount importance that the Federal Clean Air Act should be amended to require states to comply with measures and standards which have been adopted by another state to protect its resources from adverse impacts due to atmospheric deposition.

5. The State must monitor all State, federal, and industry resources dedicated to the atmospheric deposition issue to assure that these are coordinated and integrated into the most efficient process.

6. The data and information necessary to make informed resource management decisions must be gathered, used and made available to others.

7. Consistent with the existing provisions of the Federal Clean Air Act, the State must be the decision maker on the question of development affecting the State's resources.

8. The prevention of adverse impacts due to atmospheric deposition will be more efficient and less costly than remedying adverse impacts after they have taken place. Thus, the State must make its decisions carefully and analytically.

9. National legislation requiring emission reduction to address acidic deposition in other parts of the country should (a) require such reduction in the most cost effective manner, (b) recognize the efforts and results already achieved by Wyoming to implement best available control technology, (c) be based on the premise that the polluter should pay for the cleanup, and (d) not discriminate against the natural resources that Wyoming could offer to the solution.

PRESENT OR POTENTIAL ATMOSPHERIC DEPOSITIONS AND IMPACTS IN WYOMING

- To date, Wyoming has insufficient data to establish any indication that impacts due to acid depositions are occurring in Wyoming (Bernabo, Galbraith, Hidy, Sanders, Svoboda).

- The U.S. EPA's National Lakes Survey did not find any lakes in Wyoming that had unnaturally high acidity levels, but episodic increases in acidity may nevertheless occur in some lakes (Brakke, Svoboda).

- Analysis of metals and diatoms in sediment cores collected from lakes in Rocky Mountain National Park, near southeastern Wyoming, revealed no indication of impacts due to acid deposition (Baron).

- There is no clear evidence that forest resources in the West or elsewhere in North America are being impacted by acid depositions. Acid depositions may be a secondary cause of damage, however, adding to forest stresses produced by other factors, including other air pollutants, disease, and natural stresses (Bruck, Fox, Hoffnagle, Reich).

- There are no known effects of acid deposition on agricultural crops. Only with unrealistic simulated precipitation at pH levels below 3.0 are there observed effects, such as physical damage or reduced yield, (Bruck).

- Due to relatively low concentrations of calcium and other base cations, very thin soils, poor vegetation growth, relatively high precipitation volumes, and high spring runoff of snowmelt waters, surface waters in many high elevation areas of the Rocky Mountains (e.g., the Wind River Mountain Range) appear to be highly susceptible to potential impacts due to acidification. In fact, these resources may be much more sensitive than are lakes and streams found, for example, in the Adirondack Mountains of New York (Bergman, Brakke, Galbraith, Gibson, Grant, Yuhnke).

- While there is potential for acid depositions to affect natural resources in Wyoming, the amount of acid deposition to the State will have to be several times greater for actual effects to occur (Bruck).

- Data from Scandinavia indicate that a deposition rate of 20 kg/ha sulfate is the critical level producing effects on acid sensitive natural resources. Maximum deposition levels in the eastern United States are approximately 30 kg/ha of sulfate as compared to approximately 4-5 kg/ha in the West (Gibson).

- Concentrations of acidic materials in rain and snow in the Wind River Mountains are only about one-fourth to one-third the concentrations found in the Adirondack Mountains of New York (Galbraith).

- Data from the NADP site near Pinedale indicate that rainwater pH tends to average 4.6. to 4.7 (Galbraith). Natural precipitation tends to have pH minimums in the range pH 4.8-5.2, and precipitation in Wyoming averages pH 5.2 (Gibson).

- Collections of rime ice on Elk Mountain had a pH of about 4.3, and tended to concentrate hydrogen, sulfate, nitrate, and chloride ions over levels observed in precipitation and snow (Vali).

- Data from Colorado indicate a slight but statistically significant trend of increasing acidity in precipitation (1) over the past eight years, and (2) with higher elevation. Precipitation in mountain regions average approximately pH 5, and in plains regions it is about pH 6 (Grant).

- It appears that Wyoming can tolerate continuing industrial development, governed by current regulations, without significant risk of impact due to atmospheric depositions (Hidy).

CURRENT MONITORING AND RESEARCH ACTIVITIES IN THE STATE

- There are currently eight National Acid Deposition Program monitoring sites in Wyoming: four in or near the Wind River Range, two in the Snowy Range, one in Yellowstone National Park, and one near Newcastle (Gibson).

- The U.S. Forest Service, with additional support from the U.S. Geological Survey and the U.S. EPA, is monitoring the chemistry of atmospheric depositions and surface waters in the Bridger and Fitzpatrick Wilderness Areas of the Wind River Mountain Range. These studies include collection and analyses of snow cores, lake sediment cores, bottom insects, zooplankton, adult mayflies, and lichens (Galbraith).

- Depositions of NO_x in the Wind River, Pinedale, and Hobbs Lakes areas are being investigated by personnel from the Idaho National Engineering Laboratory in attempts to develop a quantitative model for transport and deposition of nitric acid and its precursors. They are also investigating airborne microscopic particles, which may be useful in future tracer studies (Bruns).

- Wyoming Game and Fish Department personnel are monitoring populations of golden, rainbow, and cutthroat trout populations in a limited number of lakes sensitive to potential acidification in the Wind River Mountains and a few other high-elevation areas. A program also is underway to classify the sensitivity to potential acidification of some 1,800 lakes located in the State at or above 7,500 feet elevation (Wiley).

- An investigation of potential changes in the chemistries for surface waters, especially related to smowmelt, is being conducted in the Snowy Range Mountains by personnel from the Wyoming Water Research Center and the U.S. Forest Service (Sanders).

- Studies of atmospheric physics and chemical concentrations in air, snow, and rime ice, have been underway for over eight years on Elk Mountain of the Medicine Bow Range (Vali).

- The U.S. EPA sampled lake chemistries from some 900 lakes in the West, including 126 lakes in Wyoming. These data will be used to select lakes for establishing long-term monitoring sites (Brakke, Svoboda).

- Toxicological, physiological, and histological responses by brook trout, rainbow trout, smallmouth bass, and white suckers to chemical changes associated with surface water acidification are being investigated in the five-year long "Lake Acidification and Fisheries" project at the University of Wyoming. Data resulting from this project are being combined with data from previous projects to develop models to project the presence/absence of fish populations in lakes based on their water chemistries and the biological characteristics of fish (Bergman).

- The Western Atmospheric Deposition Task Force was established by Region VIII of the U.S. EPA to facilitate communication between all interested parties and to establish a comprehensive, integrated monitoring and research program. It includes representatives from Environmental Defense Fund, the Western Regional Council, Rocky Mountain Oil and Gas Association, U.S. Park Service, U.S. Forest Service, U.S. Geological

Survey, U.S. EPA, and state agencies. Randy Wood from the Department of Environmental Quality represents Wyoming (Bernabo, Svoboda).

CONSIDERATIONS FOR MONITORING ATMOSPHERIC DEPOSITIONS IN WYOMING

- Wyoming is in a position to gather unique "natural baseline" data on atmospheric chemistry, on aquatic and terrestrial biota, on soils and subsoils, and their interrelationships. These data can help in evaluating present deposition and ecological conditions, from which the nature and magnitude of exposure to acid deposition occurring in sensitive areas of Wyoming can be established (Baron, Bergman, Bernabo, Bruck, Hidy, Sanders, Vali, Wiley).

- Most federally supported research and monitoring efforts related to atmospheric depositions are centered in the eastern United States (Gibson).

- A suitable deposition monitoring program for Wyoming must include consideration of and close coordination with other western regional studies, both private and government supported. State funding by Wyoming should focus on important questions not addressed by funding from other sources (Baron, Bergman, Bernabo, Fox, Hidy, Gibson, Schoettle).

- A Wyoming acid deposition monitoring and research program should have a coordinator that would act under the direction of the Governor, who could be associated with the University of Wyoming and the Department of Environmental Quality (Bergman, Fox, Galbraith, Sanders, Wiley).

- Rather than supporting basic research activities, the State should primarily establish a widely distributed, carefully designed, and well coordinated program to monitor emissions, atmospheric depositions, and the chemistry and biology of potentially sensitive surface waters (Bergman).

- There are three components to atmospheric deposition: (1) wet deposition, e.g., snow and rain; (2) dry deposition, e.g., particles and gases; and (3) "occult" precipitation, e.g., fog droplets and rime ice (Gibson, Hidy, Reiners).

- A program for monitoring atmospheric depositions to potentially sensitive aquatic and forest resources should extend for five to seven years, at a minimum. It should include analysis of wet, dry, and occult deposits of acidity, sulfate, nitrate, ammonium, ozone, hydrocarbons, and basic cations. It should concentrate on depositions at high elevations (Baron, Bernabo, Brakke, Hidy, Reiners, Schoettle, Yuhnke).

- While both dry deposition and "occult" deposition can be a significant source of potential impact of some terrestrial plants, these sources are very difficult to quantitatively measure (Gibson, Hidy, Reiners, Turk).

- Dry deposition often can be a greater contributor than wet deposition (Grant, Hidy), but dry deposition appears to have relatively minor contributions at high elevations (Turk).

- Concentrations of pollutants in direct occult depositions can be much greater than is found in other forms of wet deposition (Bruck, Vali).

- Two important research needs in Wyoming include (1) accurate measurement of dry and occult depositions, and (2) determination of how concentrations of deposited materials change with elevation (Bernabo, Hidy, Reiners, Turk, Vali).

- Total bulk deposition collectors, snowpack accumulations, or whole watershed monitoring may be used as alternatives or to supplement monitoring of individual atmospheric deposition components (Brakke, Turk).

- Chemical characteristics of precipitation can differ considerably over relatively small changes in distance or elevation (Gibson).

- o Any monitoring program should include assessing potentials of insect and disease damage in the vegetation of the high elevation spruce/fir ecosystem (Bruck).

- o Measurements and research are expensive: wet deposition monitoring stations costs at least $5,000 to set up plus $5,000 per year to operate, while dry deposition stations cost $10,000 to $70,000 to set up plus at least $10,000 per year to operate (Gibson, Hidy).

- o In the West precipitation monitoring is most useful for measuring actual changes in amounts and types of pollutants deposited in sensitive areas from point sources, such as smelters (Turk).

- o Losses of fish populations from lakes in Scandinavia and the Adirondack Mountains of New York due to acid deposition have been documented. The high mountain lakes in the West, which are most susceptible to potential acidification, tend to have very low productivities and small fish populations. A monitoring program should be established to document any future loses of fish from sensitive lakes and streams in Wyoming. It is particularly important to monitor surface water chemistries during periods of snowmelt (Bergman, Bernabo, Wiley).

RELATIONSHIPS BETWEEN EMISSION SOURCES AND RESOURCE RECEPTORS

- o Although industry is expanding near sensitive areas of Wyoming, there is little or no information to determine the significance of these sources, relative to contributions from natural or regional sources of atmospheric acids. Studies are needed to clarify contributions by long-range transport versus local Wyoming sources (Hidy).

- o To be of regulatory significance, it is necessary to identify the resources in Wyoming that are actually susceptible to potential damage by acid depositions (Bernabo, Hidy).

- Since atmospheric pollutants have both in-state and regional sources and since Wyoming can only regulate in-state sources, regional cooperation will be necessary to control atmospheric depositions in the State (Hidy).

- Perhaps 25-50% of all atmospheric depositions in Wyoming originate from in-state sources (Hoffnagle); half to two-thirds of the SO_2 in Wyoming's atmosphere originate from in-state sources (Yuhnke).

- Because few hard data exist on the responses of ecosystems in the West to atmospheric depositions, atmospheric transport models are currently used to establish acceptable emission levels in granting permits for new sources. An unacceptable emission level is one that will result in any increase in depositions to Class 1 air quality areas, e.g., national wilderness areas. Such permit levels can be overly restrictive (Fox, Hidy, Svoboda).

- Currently, in establishing air quality emission limits, Wyoming regulators use a regulatory-predictive model, COMPLEX I, to estimate potential concentrations, usually, for a 50-km radius around the proposed emission sites. This radius was increased to 100-200 km for sources potentially affecting the Wind River Range. This approach, however, tends to be conservative, that is, it tends to overestimate potential impacts from the emission sources (Dailey, Hoffnagle).

- The relationships between sources and receptors of atmospheric depositions are poorly understood, partly because of variable wind patterns (Gibson).

- Most present air quality models used by regulators are limited by using only point values for wind, when, in fact, winds vary vertically, horizontally, and over time (Fox, Hoffnagle).

- There are both responsible and irresponsible uses of air quality modeling. The strengths and weaknesses of the various models must be recognized and accounted for during their application (Fox, Hidy).

- o Research underway by the Idaho National Engineering Laboratory may help in developing more accurate models for atmospheric pollutant transport (Bruns).

- o The U.S. EPA is developing the "Rocky Mountain Acid Deposition Model," which is hoped to improve the available regulatory models (Svoboda).

- o Needs of twelve western states for modeling source-receptor relationships and performance of available models are being reviewed by Task Force B of the Western States Acid Deposition Group (Dailey).

In addition to the above points, one final, critical point was presented by Dr. Larry Svoboda. Much inaccurate information about acid depositions and their environmental effects reaches the public through over- and under-reactions, and irresponsible reporting. Thus, along with needs to broaden our scientific knowledge and understanding about this problem, an equally important need is to accurately inform the public about the known relationships and realistic consequences of acid depositions.

Appendix to Section 2

ACID RAIN: A CHANGE IN THE WIND?

(Prepared by M. Marcus for the December 1987 issue of Wyoming Wildlife)

"Fish in thousands of lakes and streams and the forests in the northeastern United States, eastern Canada, Scandinavia, and central Europe are being destroyed by acid rain. Such impacts are found even in the Rocky Mountains." News reports have contained many similar claims over the past several years. Yet, we also hear that many individuals, even our President, doubt these claims. What is the truth?

While we are uncertain about the extent of actual damage caused, we do know that acid rain has caused and will probably continue to cause some environmental damage. Also, we know that most legislative measures suggested in the U.S. Congress for controlling emissions potentially contributing to acid rain will be very costly.

In this article I briefly examine what acid rain is, where it comes from, how and where it produces effects, relating this knowledge to Wyoming where possible. I introduce why there are uncertainties surrounding this problem. Also, I review work underway in Wyoming that is helping to understand how acid rain produces effects.

First, "acid rain" is really a popularized phrase for larger phenomenon better called "acid deposition." Besides acidic rainfall, there also can be deposition of acids in other forms, including snow, sleet, dew, fog, dry particles (dusts), and adsorption of gases onto surfaces. Approximately half of the acids deposited from the atmosphere onto terrestrial plants and into lakes and streams can be as dry materials. And in high mountain areas there is concern about damage to trees due to acidic ice accumulating on surfaces of conifer needles. In a larger sense, this phenomenon also can be described as "atmospheric deposition" when problems associated other atmospheric pollutants, including metals and ozone, are present.

The acid deposition problem is a technically complex issue. Investigations into acid depositions are teaching us a great deal about how our environment works. But to understand these problems requires an understanding of several scientific concepts.

First, "acidity" refers to the concentration of hydrogen ions in a solution: the higher the hydrogen ion concentration, the higher the acidity. (A hydrogen ion is a hydrogen atom that has lost its electron, giving it a positive charge.) The scale used to measure acidity in a solution is called "pH." This scale ranges from zero for highly acidic solutions to 14 for highly basic solutions. Since pH is a negative logarithmic scale, its use can be somewhat confusing; a one unit decrease in pH, say from 7 to 6, equals a 10-fold increase the concentration of hydrogen ions.

Levels of pH at 7.0 are considered "neutral," while pH levels less than 7.0 are acidic, and greater than 7.0 are basic. Lemon juice with a pH of 2, orange juice at pH 4, and milk at pH 6 are acidic solutions, while sea water at pH 8 and milk of magnesia at pH 10 are basic. Most lakes and streams have pH levels between six and eight.

Distilled water containing no dissolved gases has a pH of 7.0, and here begins the first problem in understanding acid deposition. As atmospheric carbon dioxide dissolves into precipitation, it forms carbonic acid, which can naturally depress the pH of water to approximately pH 5.6. Recent studies also reveal that chemicals released to the atmosphere during natural decomposition, for example, can additionally increase acidity levels in precipitation. For example, pH levels as low as 4.9 have been recorded in unpolluted rainfall. Thus, unpolluted rain water tends to be naturally acidic, with pH levels generally ranging between 5.0 and 7.0. Many earlier concerns about acid depositions were directed at all rainfall having pH levels below 7.0, but concerns now focus on polluted rainfall with pH levels below 5.0.

Where problems associated with acid rain are being reported, including Scandinavia and the Adirondack Mountains of New York, rainfall acidity levels tend to range from pH 4.0 to 4.5. In Wyoming, a single rainfall during late July 1982 in Rock Springs had a pH level of 3.89 and one during August 1983 in Pinedale had a pH of 3.99. During 1984-85, combined wet and dry depositions collected in the Wind River Range ranged in pH from 4.4 to 7.3, with most values ranging from pH 5.0 to 6.5. Snow collected during April 1986 from the Snowy Range west of Laramie had an average pH of 5.6. Recent data from the Wind River Range suggest that some depositions to this area may show a trend of decreasing acidity.

Levels of pH less than 5.0 are primarily associated with the presence of strong acids, including sulfuric acid and nitric acid, which can form when oxides of sulfur (SOx) and of nitrogen (NOx) are emitted to the atmosphere. SOx is emitted primarily during coal combustion and metals smelting. NOx is primarily formed during burning gasoline, natural gas, and oil.

Most sources associated with acid depositions do not actually emit acids, but emit compounds that later are converted to acids in the atmosphere. Work is underway to better understand how these emitted sulfur and nitrogen compounds react chemically to form acids in the atmosphere. Some results indicate these reactions are limited by the presence of other chemicals. Not all of the emitted sulfur and nitrogen compounds are necessarily converted to acids. Therefore, when emissions of SOx and NOx are reduced, the actual atmospheric formation and deposition of acids may not be reduced by a similar magnitude.

The National Research Council reports that in the eastern half of the U.S. and southeastern Canada concentrations of sulfate and nitrate in precipitation are at least five times greater than in remote regions of the world. These levels were reached in northeastern North America sometime before the 1950s.

Presently, average national emission rates are declining due to improved control of air pollution. On a regional basis, however, emission rates show various trends. Since about 1970 emissions of chemicals related to acid depositions have increased in the southwestern United State, while a lower rate of increase has also occurred in the Midwest. In the Northeast the trend has been one of moderately decreasing emissions. Emission rates are lowest and appear to be somewhat stable west of the Mississippi River.

The National Acid Precipitation Assessment Program (NAPAP) coordinates most of the federally supported study of acid deposition in this country. In their 1986 annual report, NAPAP concluded that emissions of sulfur and nitrogen compounds are expected to continue to decrease nationally due to retirement of many older power plants, conversion of other power plants to new cleaner power sources (e.g., natural gas), use of new cleaner power production technologies, coal cleaning, and implementation of more restrictive emission standards for all new emission sources.

Of particular concern in western Wyoming is the fate of emissions from natural gas "sweetening" plants near La Barge, up wind of the Wind River Mountains. Natural gas in this area is "sour," containing high concentration of hydrogen sulfide. Some hydrogen sulfide is released to the atmosphere during sweetening. It should be added, however, that these sweetening plants are required by the Wyoming Department of Environmental Quality (DEQ) to install the best available technology to control their emissions to the atmosphere. Therefore, over 99% of the potential air pollutants are removed prior to emission during typical plant operations.

A great number of very substantial national impacts to fisheries, lakes, streams, forests, and even agricultural crops have been attributed to acid depositions. What is the actual extent of the documented impacts? The 1986 NAPAP annual report suggests that at current levels, acid deposition appears to have no significant effect on the national yield of agricultural crops, and, in fact, may have a modest net benefit to croplands by adding nitrogen and sulfur to the soil. (The report further noted, however, that ozone is estimated to reduce the value of crop production by about one billion dollars annually.)

For forest seedlings at lower elevations, present levels of acid deposition were suggested by the report to have no apparent effect on leaves, but it is as yet unclear whether some effects can be transferred through soils.

Further, reductions in forest growth, particularly in mountainous areas of the eastern United States, may be mostly related to atmospheric concentrations of ozone and hydrogen peroxide, rather than to acid depositions.

A NAPAP observation concurs with one also found in the National Research Council report, referred to above, that the only confirmed loss of natural resources due to acid deposition in the United States is the lost of fish populations from approximately 200 lakes in the Adirondack Mountains of New York. High levels of acidity in depositions to these lakes and their watersheds have elevated weathering rates for aluminum from minerals in these watersheds, and have led to toxic concentrations of acids and dissolved aluminum.

Effects on lakes, streams, and their fisheries, in fact, have drawn the most attention to the acid deposition problem. The extent of these potential effects by acid depositions depend largely on how well lakes and their surrounding watersheds can buffer or neutralize incoming acids.

"Alkalinity" is a chemical measurement used to determine how well water can neutralize acids. It measures the total concentration for three basic ions: carbonates, bicarbonates, and hydroxides. In lakes and streams the alkalinity levels depend primarily on the types of mineral deposits, the amount of soil development, and the character of vegetation in the watershed.

Alkalinity levels in most lakes tend to range between 45 and 200 parts per million (ppm). Whereas, lakes and streams considered to be potentially acid sensitive have alkalinities below 10 ppm. In general, surface water alkalinities decrease with increasing elevation as outcroppings of weathering resistent bedrocks become more prevalent, soils become thinner, and growths of terrestrial vegetation become more sparse.

In the West, most low-alkalinity, acid-sensitive lakes are in high mountain drainages dominated by metamorphic and igneous rocks, such as granite and quartzite, which are relatively resistent to weathering. Lakes in areas having sedimentary rocks, including limestone, or having agricultural development have high alkalinities and low acid sensitivities. Even small deposits of limestone in a watershed can cause lakes to be acid insensitive. Significant alkalinity also can be generated within lakes themselves during decomposition of organic materials and during the chemical breakdown of sulfur compounds by bacteria.

The U.S. EPA Western Lake Survey reported numerous acid-sensitive lakes in mountainous regions of the West, with those having the greatest sensitivities tending to be concentrated in designated wilderness areas. A survey by Wyoming Game and Fish Department personnel indicated that 70 per cent of the lakes above 9,000 feet elevation in the Wind River Range have alkalinities below 10 ppm. And U.S. Forest Service records suggest that the average alkalinity for lakes in the Bridger and Fitzpatrick Wilderness Areas in the Wind River Range is below 5 ppm.

While the Wind River Range is the largest area in the central Rocky Mountains with sensitive lakes, other Wyoming areas contain potentially acid sensitive lakes. These include the Yellowstone area, Absaroka Range, Bighorn Mountains, and Snowy Range. Because of bedrocks that are highly resistent to weathering, poor soil development, and slight vegetative growth in their surrounding watersheds, these Wyoming lakes may have greater potential susceptibility to acid deposition than those lakes that have been acidified in the Northeast. This means that rates of acid depositions lower than rates that have occurred in the Northeast could acidify some Western lakes.

There is a general consensus, however, that lakes and streams in Wyoming and the West are not currently becoming more acid. The U.S. EPA Western Lake Survey sampled over 700 lakes, which represented the some 10,000 lakes in the Rocky Mountains, Sierra Nevada, and Cascade Range during the fall of 1986. Over 99 percent of the sampled lakes had pH levels above 6.0. Studies supported by the U.S. Forest Service indicate that the pH levels in sensitive Wind River Range lakes has not changed over the past 100-200 years. Some readers may recall earlier reports that suggested lakes in the mountains of Colorado showed signs of recent acidification. These reports, however, have since been determined to contain errors and invalid scientific assumptions, indicating that these earlier conclusions were incorrect.

Does all of this suggest that we should not worry about effects of acid deposition in Wyoming? No. We do have highly sensitive lakes, which may be even more acid sensitive than lakes acidified in the Northeast. And we know that other forms of atmospheric pollution have entered lakes in the Wind River Range. (Analysis of sediment cores from these lakes show evidence that starting about 1925 to 1940 concentrations of lead, zinc, and copper, such as are associated with smelter emissions, began to increase.) With the recent shut down of metal smelters in Utah and Arizona, the threat to these lakes has decreased. But current monitoring indicates that acid deposition continues in Wyoming.

What should we do? In April 1987 the Acid Rain Coordinating Committee, which was appointed by Governor Ed Herschler, issued a report after collecting testimony and supporting materials from over twenty national experts on acid deposition. The Committee recommended that the State support and conduct monitoring of our air, water, and biological resources to determine how Wyoming's environment is being altered by acid deposition and other air pollutants. In addition, they suggested that the national and international research efforts underway be reviewed to determine how their results may apply to Wyoming. They further recommended that all appropriate industrial, Federal, and State monitoring and research efforts within the State be "carefully coordinated and integrated."

Several important studies are currently underway in Wyoming. First, the National Acid Deposition Program (NADP) has sites for monitoring atmospheric depositions near Lander, Pinedale, the upper Green River Valley, South Pass, Newcastle, Tower Falls in Yellowstone National Park, and West Glacier Lake in the Snowy Range. (Some data from these sites were used in this article.) Of particular interest are six sites operated by the U.S. Forest Service to monitor depositions in the Bridger and Fitzpatrick Wildernesses. These include the Green River Valley and South Pass NADP sites outside, and four collectors for wet and dry precipitation inside the wildernesses. These six sites are funded by both Exxon and Chevron Corporations, as required in permits issued by the Wyoming DEQ for their gas sweetening plants in southwestern Wyoming.

Other studies within the Wind River wildernesses supported by the Forest Service include monitoring for possible pollution-induced changes in growth patterns for lichens. Attempting to reconstruct historical water chemistry changes, cores from lake sediments and old water quality data are being analyzed. And Forest Service personnel maintain a monitoring program to detect ongoing changes in lake and stream water chemistries, which is supported partly by the U.S. Geological Survey (USGS).

Intensive research and monitoring efforts are underway also at West Glacier Lake and its watershed in the Snowy Range. This site has been selected by the Forest Service for long-term monitoring of air quality. These efforts are supported by the Forest Service, the USGS, the Wyoming Water Research Center (WRC), and the electrical utilities through Living Lakes, Inc., of Washington, D.C.

The West Glacier Lake/Watershed studies have emphasized seasonal changes in the chemistry for rain and snow, and for water flowing into, out of, and within the lake. Additional studies are focusing on chemical relationships in watershed soils and plants. Studies on snowmelt chemistries have shown that depositions to the West Glacier Lake watershed appear to be as unpolluted as found anywhere in the continental United States.

The Wyoming Game and Fish Department is identifying thirty to forty acid-sensitive lakes throughout Wyoming to sample annually for possible changes in water chemistry and fish populations. Observations for lakes in northern Europe and around the Sudbury smelter in Ontario suggest that acid stress in lakes can cause losses of an entire year's production of young, sensitive fish. Thus, annual fish samplings can be directed at identifying missing age groups. If such gaps are found, more intensive studies can be performed to identify possible causes.

We are just beginning to understand the causes of mortality and losses of fish from acidifying lakes. Often the most sensitive period for fish is during the first weeks after hatching in the spring and early summer. (Also during this period pulses of acidic waters can enter lakes and streams with potentially acidic snowmelt and spring storms.) Overall, fish mortalities appear to be more a result of dissolved aluminum leaching from watersheds than to the acidity of the water. The actual causes of fish mortality in acidic waters appear to be the losses of essential ions from fish.

A critical study on the effects of acid depositions on fish is centered at the University of Wyoming's (UW) Red Buttes Environmental Biology Laboratory. This five-year study, the largest ever to focus solely on effects to fisheries, is supported by the Electric Power Research Institute and involves scientists from UW, Oak Ridge National Laboratory in Oak Ridge, Tennessee, McMaster University in Hamilton, Ontario, Western Aquatics, Inc. in Laramie, and an international team of advisors. These scientists are studying how acidification affects four fish species (brook trout, rainbow trout, smallmouth bass, and white suckers). Using laboratory data from these studies, plus other data collected in the field, a model is being constructed to predict the probable responses by lake fisheries to acid deposition.

Additional studies are also underway at the U.S. Fish and Wildlife Service laboratories in Jackson. These studies, funded by the U.S. Forest Service, are attempting to determine the potential effects of acidity on Western trout species, including golden trout, and West Slope, Yellowstone, and greenback cutthroat trout. Preliminary results suggest that these Western species may be more sensitive than those included in the UW studies.

Some acidified lakes and streams exist and will likely continue to exist, even with control of SOx and NOx emissions. One approach for reversing this acidity is to apply limestone to the acidified lakes and streams. This approach is similar to taking antacid tables for upset stomachs. Based on studies supported by Living Lakes in the eastern U.S., costs for liming lakes currently range from $200 to $250 per acre when the limestone is dispersed by helicopter to $40 per acre when dispersed by boat. The duration that the resulting acid neutralization is effective largely depends on the rates at which water flush through lakes. While liming treats the symptoms of surface water acidification without curing the cause, for many lakes the treatment can be long lasting.

Under state law, the Wyoming Game and Fish Commission is "the principal proponent for the maintenance and perpetuation of wildlife in Wyoming." As such, the Commission adopted a position in 1986 to advocate control of acid deposition at its source to prevent loss of any sensitive Wyoming resources. This position maintains that emission control is preferable to resource mitigation (liming) in maintaining Wyoming lakes and fisheries. In particular, it "Advocates that mitigation through liming of acidified waters is not an acceptable program (short or long term) to maintain affected fisheries."

Currently, most present and all new industrial sources of emissions within Wyoming are required by DEQ to install and maintain state-of-the-art control technologies. Historically, emissions from smelters in Utah and Arizona posed potential threats to Wyoming's acid-sensitive resources, but these smelters were closed in recent years. If these or other new smelters again open, strict emission controls will be required under federal law. Remaining sources that can potentially affect Wyoming's acid-sensitive resources include a new copper smelter in northern Mexico (on which emission control technologies are also being installed), a few older power plants existing in states upwind of Wyoming, and automobile emissions.

With respect to emission controls, some 26 bills to legislate control of acid forming emissions have been introduced into the U. S. Congress. None have passed. Most have emphasized control of sulfur oxides from coal-fired electrical power plants. While this focus was initially on plants in the Midwest, it now generally extends to older plants throughout the country.

Most proposed regulations require installation of "scrubbers" to remove sulfur from stack gases prior to emission. Earlier legislative proposals largely ignored sulfur emissions from smelters and nitrogen emissions from any source.

However, some, not all, of the more recent legislative efforts recognize these as potentially important sources of impacts and include proposed restrictions on emissions from metal smelting and petroleum combustion, including automobile emissions.

While scrubbers are required on all new power plants in the U.S., they are lacking on most older units. Installing one scrubber on an existing power plant costs about $100 million. Under some proposed legislation, all older power plants will be required to install scrubbers on each generation unit.

Besides scrubbers, alternative approaches exist to reduce pollutant emissions. These include use of more efficient coal combustion techniques, washing coal prior to combustion, and burning coals that contain lower sulfur concentrations. Wyoming coal, for example, contains only a fraction of the sulfur that is contained in most eastern coal.

The total cost of control under the various proposed legislative measures ranges from $35 to 95 billion. This range depends primarily on the extent that scrubbers are required. The overall costs of control will be toward the lower end of this range if (1) older power plants are allowed to be phased out without installing scrubbers, as new plants are brought on line; (2) the use of low sulfur coals is allowed, and (3) regional differences in regulatory requirements are permitted,

In conclusion, scientists are reasonably certain that acid deposition has damaged natural resources. But the only natural resources that can be confirmed as damaged in the U.S. are some 200 lakes in the Adirondack Mountains of New York. While forests and crops also have been damaged by air pollutants, there is reasonable doubt that such damage can result from current levels of acid depositions. In fact, acid rain can benefit crops in many agricultural areas. While acid depositions continue to fall over much of North America, current regulations are reducing the rates at which potentially acid forming chemicals are being emitted nationally. This is particularly true in the Northeast. West of the Mississippi River emission rates are relatively stable. Finally, Wyoming has many lakes that are very sensitive to acid depositions, and all current and new sources of emissions in our State are already under the most stringent limitations.

Many of us feel that our natural resources are a priceless heritage. The total costs associated with the various measures pending in the U.S. Congress to control emissions of potentially acid-forming compounds run in the many ten of billions of dollars. Currently, tens of millions of dollars are being spent annually in attempts to understand what and how effects to natural resources result from acid depositions. One estimate, contained in a draft report from NAPAP, suggests that to rehabilitate the damaged lakes in the Northeast could cost $500,000 annually.
The question is, "Should more restrictive emission controls be required now or should they wait, as monitoring and research continue to better define the actual potentials for resource damage?" This is a question that scientists cannot answer. It can only be answered by the public, us, through our elected officials.

Section 3

SUMMARIES OF MEETINGS BY THE WYOMING ACID RAIN COORDINATION COMMITTEE

Summary of the Acid Rain Coordinating Committee Meeting--July 22, 1985

Herschler Building
Cheyenne, Wyoming

Members of the committee present were:

Dr. Jim Barlow
Mr. David B. Park
Ms. Bonnie Pendleton
Dr. Ron Surdam
Mr. Bob Wallick
Mr. Randy Wood

The following experts gave testimony at this meeting:

Dr. Douglas Fox
Rocky Mountain Forest and Range Experiment Station
Fort Collins, Colorado

Dr. Alan Galbraith
Bridger Teton National Forest
Jackson, Wyoming

Dr. George Hidy
Desert Research Institute
Reno, Nevada

Dr. Larry Svoboda
Region VIII
U.S. Environmental Protection Agency
Denver, Colorado

Mr. Robert Yuhnke
Environmental Defense Fund
Boulder, Colorado

Others present included Darrell Bushman, Nancy Freudenthal, Larry Wolfe, Debra Beck, Al Riebau, Marilyn Kite, Brent Kunz, and Mary Adamy.

This was the first meeting of the Governor's Acid Rain Coordinating meeting. The first part of the meeting was organizational, with selection of Dave Park as Chairman of the Committee, Ron Surdam as Vice Chairman, and Jim Barlow as Secretary. Randy Wood, the Executive Secretary of the Committee, clarified the general purpose and direction of the Committee. Governor Herschler had suggested that the Committee take an overview, assessing the degree of the acid deposition problem in Wyoming, identifying current research efforts in the State and suggesting ways to coordinate this research, possibly resulting in regulatory or legislative changes in goals. The Committee's final report should include recommendations to the Governor on priorities for funding and research, and recommended positions and policies for Wyoming.

Randy Wood outlined a suggested general schedule and agenda for the Committee. He proposed a series of eight meetings over the course of one and one-half to two years, each dealing with a specific aspect of the acid deposition problem.

- Meeting 1: General orientation and overview of acidic deposition.
- Meeting 2: Acid deposition: measurement, characterization, wet deposition, dry deposition, cloud water, rime ice, spatial and temporal variation of deposition, and variation with altitude.
- Meeting 3: Identification of deposition sources, source-receptor relationships, and projection of future source impacts.
- Meeting 4: Impacts to vegetation.
- Meeting 5: Terrestrial and aquatic systems and linkages.
- Meeting 6: Prioritization of research and monitoring efforts in the State.
- Meeting 7: Policy issues and positions for the State.
- Meeting 8: Public review of the final report.

The Committee members discussed general details for holding and organizing the meetings, inviting experts to make presentations, and disseminating meeting results to the public and to news agencies.

Dr. Larry Svoboda, the first expert to make a presentation, said EPA Region VIII's emphasis in the western United States is on preventing damage to ecosystems. To date, there is no evidence to indicate damage has occurred, but that may be due to a lack of data. The EPA is promoting and developing research and monitoring programs that will help achieve the four basic needs: 1) support for the PSD (Prevention of Significant Deterioration) program and other regulatory programs to facilitate better decision-making on both the local and national level; 2) a national assessment of the acid deposition problem; and 3) basic research needs. 4) Responsible distribution of information to the public.

The EPA Region VIII office has established the Western Atmospheric Deposition Task Force. The primary objective of this group is to facilitate a dialogue between all interested parties so that a comprehensive and integrated approach to research and monitoring can be developed. The EPA is also involved in The National Lake Survey, initiated in September of 1985. Under this program, the EPA and USFS have sampled over 1,000 lakes in the western United States. Primary objectives were to identify, during a single point in time, the sensitivity of lakes from a broad region, compare the lakes, and then select lakes for future, more intensive studies. EPA Region VIII also is involved with regional watershed studies, supports the State Acid Rain Project, and has been planning an emission inventory for the western United States to better define how individual sources may be impacting sensitive areas.

During the next testimony, Dr. George Hidy stated that only relatively recently have areas in the western United States, particularly at high altitudes, been recognized as having biogeochemistries similar to those found in areas sensitive to acid deposition in eastern North America and in Europe. In Wyoming, because of the low population densities, small communities, and geographic and topographic conditions, the primary concern about acid deposition is potential effects in wilderness areas and national parks. Dr. Hidy cited that the first effect of potential concern to the State is acidification of surface waters and impacts on aquatic biota. The second potential concern is forest deterioration.

There are a number of factors that compound the problems faced by researchers trying to accurately assess the effects by acidic deposition. Two forms of deposition besides precipitation contribute significantly to environmental acidity, especially in the West, dry deposition and occult deposition. Because there is no consensus on methods for measuring deposition rates and chemical parameters for these forms, he said researchers are essentially able to reliably assess only one third of the deposition occurring in the West. Also, acid is only one of many chemical constituents in atmospheric deposition

that can produce environmental effects. Hence, sorting out the effects of the different chemicals and determining individual mechanisms of atmospheric deposition are more complex than initially thought.
Researchers cannot, according to Dr. Hidy, currently identify any environmental damage or change in the intermountain West due to acid depositions. Present deposition levels to this area may effect only small perturbations in nutrient budgets for ecosystems, unlike in the East where deposition effects major ecosystem changes. He said it appeared as though Wyoming could tolerate continuing industrial development governed by current regulations. He questioned whether Wyoming needed further regulations specific for acid depositions. He felt that existing air quality laws in Wyoming are sufficient for controlling the problem for the near future.

Dr. Doug Fox spoke next. Because of the different atmospheric variables that may be present in depositions, including sulfur, nitrogen, ozone, and oxidants, it is difficult to ascribe effects to causes. Another major difficulty is determining whether sources of atmospheric depositions are from distant or local sources. Only extensive, long-term research will yield definitive answers.

Dr. Fox said that in the Rocky Mountain area, concentrations of sulfur and nitrogen per unit of precipitation are about three- to four-times greater than background levels. However, sulfur concentrations in precipitation to the eastern United States are three- to four-times higher than those found in the Rocky Mountains, while nitrogen concentrations are two-times greater.

There are a number of resources at risk in the Rocky Mountain west, including alpine lakes and terrestrial ecosystems with naturally low buffering capacities. We need more information about what the natural processes are and whether systems are approaching some kind of a saturation point, before we can be very confident about assessing this environmental problem or potential for problem.

Mr. Robert Yuhnke was concerned that pollutants from growing industry in the West will be added to the atmosphere before their effects can be accurately determined. Even though deposition rates in the West are significantly lower than in the East, western lakes may be at the threshold of experiencing damage from acidic deposition. In the West, the emphasis should be to prevent overloads of acid into sensitive lakes, such as has occurred in the eastern United States and in Scandinavia. A water body's alkalinity is a good indicator of its sensitivity to potential acid depositions. For the East, the EPA has defined a sensitive lake as one with an alkalinity measurement less than 200 ueq/l. In the Jim Bridger Wilderness in Wyoming, a number of lakes have been discovered to have alkalinities as low as 20 ueq/l. This indicates that these lakes have very little buffering capacity; that 10 times less acid than received by Adirondack lakes could produce damage.

Data from 38 of the NADP stations in the West indicated that acid deposition "hot spots" occur at higher elevations and that deposition at these higher altitudes can be significantly more acidic. In addition, Mr. Yuhnke said that such high altitude lakes are often subject to spring snowmelt events during which pHs can decline as much as two pH units.

Mr. Yuhnke said we need to question how far we can go in adding new pollution to the environment. He suggested that using best available control technology on all sources to reduce emissions is the most appropriate solution, and, using this strategy, a safe pollution level can be maintained in the West.

Next, Dr. Galbraith discussed the monitoring program initiated by the U.S. Forest Service in the Bridger Wilderness Area in the Wind River Mountains two and a half years ago. This program was developed to ascertain what effects, if any, energy developments in the area might have on the Bridger Wilderness Area. Data from the first year showed an average precipitation pH of 4.8-4.9 with individual snowstorms having pHs anywhere from below 4.0 to 6.5. The average alkalinity of the lakes was 60-90 ueq/l, with one as high as about 165 ueq/l and one as low as 10 ueq/l. Dr. Galbraith pointed out that these are all below the alkalinity level of 200 ueq/l that the U.S. Environmental Protection Agency (EPA) uses to define a lake potentially sensitive to acid deposition.

In addition they are monitoring a number of other parameters. Sediment cores are being collected from three of the monitoring lakes to reconstruct the chemical history of the lakes through analysis of heavy metals and diatom content. Bedrock and soil chemistries are being analyzed and samples of lichens have been collected as possible bioindicators.

Dr. Galbraith stressed that there is a substantial cause for concern regarding acidity in the wilderness areas. He suggested that spring depressions of pH due to snowmelt are a sign that we should become increasingly concerned about high mountain areas, especially the Bridger Teton Wilderness Area, where lakes may be near the threshold level for acidification to occur.

Summary of the Acid Rain Coordinating Committee Meeting--September 11, 1985

Civic Center
Laramie, Wyoming

Members of the committee present were:
- Mr. David B. Park
- Ms. Bonnie Pendleton
- Dr. Ron Surdam
- Mr. Robert Wallick
- Mr. Randy Wood

The following experts gave testimony at this meeting:

Dr. James Gibson
Colorado State University
Fort Collins, Colorado

Dr. Michael Grant
University of Colorado
Boulder, Colorado

Dr. George Hidy
Desert Research Institute
Reno, Nevada

G.F. Hoffnagle
TRC Environmental Consultants Incorporated
East Hartford, Connecticut

Dr. William Reiners
University of Wyoming
Laramie, Wyoming

Dr. John Turk
U.S. Geological Survey
Denver, Colorado

Dr. Gabor Vali
University of Wyoming
Laramie, Wyoming

Others present included Jeannette NewVille, Orville Paschke, Dean Forsgren, Bill Thomson, Ted Phillips, Dick Goddard, Nancy Freudenthal, Debra Beck, Al Riebau, Becky Mathiesen, Terri Lorenzon, Harold Bergman, Bill Garland, Bob Brocksen, Wendy Frueauf, Bill Doyle, and Mary Adamy.

The subject matter of this meeting was how acid deposition affects vegetation with emphasis on the potential for adverse effects in Wyoming. Dr. Hidy first spoke about the three types of acidic deposition, wet, dry, and occult deposition. He was primarily concerned with dry deposition and occult deposition, which is deposition or interception of fog droplets on surfaces. In freezing conditions this can form rime ice. He emphasized that all three types of deposition must be monitored and he called attention to several important monitoring techniques. Dr. Hidy finished by discussing deposition data from the western United States and concluded that dry and occult deposition need to be better monitored and the relationship between elevation and acidic deposition needs to be determined.

As the coordinator of the National Atmospheric Deposition Program (NADP) Dr. Gibson spoke primarily on NADP sampling techniques and data collected at NADP sample sites. He explained that only wet deposition is measured at NADP sites because dry and occult deposition are very difficult and expensive to measure. However, he stated that dry and occult deposition may be very important and should be appraised. Finally he discussed the NADP data, which indicate that most of the western United States has relatively clean air. However, regions close to urban areas or smelters show elevated nitrate and/or sulfate concentrations.

Dr. Grant reported on data his group has collected throughout Colorado. Based on these data, although they contain considerably variability, he concluded that there is a measured trend of decreasing pH for precipitation to the mountains directly west of the Denver urban area. His data also indicate greater masses of atmospheric pollutants are deposited at higher elevations, due largely to greater volumes of precipitation. Based on estimated total sulfate depositions for the entire state of Colorado, he concluded that there are few or no significant emission sources outside the state that influence air masses in the state.

Dr. Turk reviewed three approaches for monitoring atmospheric deposition and data his group has collected on depositions in the West. He emphasized that rather than measuring depositions directly, it can be more practical and cost efficient to monitor receptor accumulations. He suggested that high elevation lakes and watersheds can be used as very effective and sensitive monitoring surrogates. Lastly he discussed how alkaline materials in the atmosphere appear to have greater influences on precipitation pH than do sulfates. He also noted that masses of pollutants deposited tend to be greater at higher than lower elevation elevations due to greater volumes of precipitation received.

Dr. Vali reviewed his group's research on monitoring cloud chemistry at the high elevation observatory on Elk Mountain. They have found concentrations of sulfur the cloud droplets that are too great to be solely from local sources. In addition, they found that concentrations of hydrogen ions, sulfates, and nitrates occurring in cloud droplet deposition (occult deposition) can be much greater than occurring in either snow and rain. He concluded that monitoring programs in Wyoming must include measures of occult deposition because of these high concentrations and because large volumes of depositions appear to occur in this form.

Dr. Reiners primarily discussed dry and cloud droplet deposition. In New England he found that cloud droplet deposition accounted for close to half the water and hydrogen ion input to forest watersheds. He feels that similar levels may be found for forest watersheds in Wyoming. Therefore, cloud droplet deposition should be included in future monitoring programs in the State. He believes that research on dry and cloud droplet deposition and how they interact with vegetative types should be a monitoring and research priority for Wyoming.

Mr. Hoffnagle discussed trends in NADP data from the Rocky Mountains. He found sulfur levels in depositions to be slightly greater in the south than the north, but fairly uniform overall. Since concentrations in deposition tend to be uniform throughout the region, it is Mr. Hoffnagle's opinion that this suggests that concentrations are not dependent on local sources or on long range transport from any particular direction. He feels that rime ice, which is a form of cloud droplet deposition, is not important because the high elevation areas that are most sensitive to acidification have little vegetation.

In the discussion following the testimonies Dr. Vali suggested that concentration is a intermediate measure and is not as important as total deposition masses, which are a function of both precipitation concentrations and volumes. Mr. Hoffnagle agreed with Dr. Vali, but felt that concentration values can provide important information. For example, based on concentrations, the Environmental Protection Agency has found that emissions from Arizona smelters are not included in sulfur depositions to northwest Colorado, contradicting previous work.

Committee members were confused because they had heard testimony that rime ice was both very important and not important. Dr. Vali reiterated that at most of the elevations in Wyoming a large portion of the input water mass comes from rime ice. But, Dr. Turk said that there is no evidence that rime ice influences the chemistry of alpine lakes, suggesting that it is not important at these high elevations. The meeting concluded with the importance of rime ice undecided.

Summary of the Acid Rain Coordinating Committee Meeting--November 6,1985

Casper City Council Chambers
Casper, Wyoming

Members of the committee present were:

Dr. Jim Barlow
Mr. David B. Park
Ms. Bonnie Pendleton
Dr. Ron Surdam
Mr. Bob Wallick
Mr. Randy Wood

The following experts gave testimony at this meeting:

Dr. Dale Bruns
Idaho National Engineering Laboratory
Idaho Falls, Idaho

Mr. Bernard Dailey
Wyoming Department of Environmental Quality
Cheyenne, Wyoming

Dr. Doug Fox
Rocky Mountain Forest and Range Experimental Station
U.S. Forest Service
Ft. Collins, Colorado

Gale Hoffnagle
TRC Associates, Inc.
East Hartford, Connecticut

Dr. Larry Svoboda
Region VIII
U.S. Environmental Protection Agency
Denver, Colorado

Other individual present included Al Galbraith, Bob Missen, Dean Forsgren, Bill Thomson, Darrell Bushman, Terri Lorenzon, Paul Krza, K.C. Bishop, John Wagner, Dave Hogan, Mike Barrash, and Mary Adamy.

Beginning the days testimony, Mr. Bernard Dailey outlined methods through which Wyoming considers potential acid deposition when permitting new emission sources. By way of example, he discussed the permitting process used for the Exxon Phase I and Phase II facilities and the Chevron fertilizer plant near Rock Springs. He noted that, in general, Wyoming ambient and PSD air quality standards consider only a 50-km radius around a site, using a regulatory-type predictive model, COMPLEX I, to predict SO_2 and NO_x emissions. But in the case of these sources affecting the Wind River Range, the model was extended to 100-200 km radii to account for the distance from the source to these potentially sensitive receptors. He emphasized that the approach being used was "conservative" in that it tends to overestimates actual probable impacts. There is a need for models with better predictive capabilities over ranges greater than the 50 km radius for which the COMPLEX I model is designed. Finally, it was noted that Mr. Dailey currently chairs Task Force B of the Western States Acid Deposition Group, which is attempting to define model needs and appropriate models for better defining source-receptor relationships for 12 western states.

After Mr. Dailey's presentation, Committee members reiterated that since the West is quite arid, dry deposition is probably much greater than wet deposition, rather than roughly equal as it is in the eastern states. This means then that the current approach does overestimate actual depositions. Furthermore, the current model assumes that all SO_2 and NO_x in the atmosphere deposits at the source. This is also not true in reality, and adds to the overestimation of actual deposition.

Question was raised as to why other acid sensitive areas near southwest Wyoming, such as Utah's Uinta Mountains were not considered in the analysis. Randy Wood said that because of prevailing winds in the area, the Wind River Range was the only area likely to be impacted.

Conversation next centered on the fact that the current modeling approach does not account for any alkaline input from the soils of the Green River Basin, and the neutralizing effect they might have on any atmospheric acid sources. This is yet another source of possible overestimation of acidic deposition in the modeling process. There are pros and cons to this overestimation. Although it may further protect the environment, it may needlessly limit industry in the area by overestimating its impact. The Committee suggested that research into the nature of alkaline inputs to the atmosphere and how they may affect the acidity of depositions is badly needed to improve the accuracy of the modeling process. Until better models are available, however, decisions must still be made and the current approach may very well be the best available.

Some Committee members expressed interest that industry be forced to bear some of the economic burden for research into improving the predictive modeling efforts. The state does not have sufficient funds to pursue the needed research problems itself.

In beginning his testimony, Mr. Gale Hoffnagle first reiterated that protecting the Wind River Range on the basis of "worst case" scenarios also insures that there will not be unforeseen impacts in other areas from the source in question. He then turned to the modeling of atmospheric transport and noted difficulties in predicting meteorological conditions within the altitudes at which industrial plumes travel, because such estimates are frequently based on wind movement vectors derived from ground stations. He admitted that modeling is currently weak, and model development and validation tends to be very costly. Much more data are also needed for development of good models. But he said that modeling can provide some useful information.

Based on model estimates he reported that approximately 34% of the air in western Wyoming enters the area from the Salt Lake City area, and air masses other areas of the Wyoming enter primary from Idaho, Utah, and Colorado. Also, model results indicated that relative contributions to western Wyoming vary little from season to season. Through his model analyses he suggested that smelters are not as pertinent sources of potential impacts to the Wyoming and Colorado area as has been conjectured. Also, while relative contributions by inter- and intrastate sources to deposition in southwestern Wyoming are unknown, he estimated that 25-50% of the deposition in Wyoming is from intrastate sources.

He felt that deposition studies and terrestrial and aquatic studies should be given priority to ascertain whether or not there is sufficient deposition occurring to cause damage and then, if warranted, modeling studies could be intensified. For depositions that are already occurring, monitoring is probably a first priority to determine if any problem exists, but that is of little immediate help in the permitting process. In his opinion, the present permitting approach used by Wyoming is overly conservative, in that it overestimates the actual depositions that will result from a new facility.

In discussing Mr. Hoffnagle's presentation, the Committee was in general agreement that it would be wiser for the State to support monitoring efforts that could produce data potentially useful for modelers than to support modeling efforts directly.

Dr. Svoboda began his testimony by reiterating that the National Lakes Survey did not find any lakes in Wyoming showing evidence of acidification, but that does not mean that episodic events and associated ecosystem impacts are not occurring. The survey was not designed to address that question. He also overviewed the National Acid Precipitation Assessment Program's (NAPAP) three approaches to the acid deposition problem: effects, source-receptor relationships, and control mitigation.

Dr. Svoboda then discussed the goals of and problems with atmospheric modeling efforts, noting that models should also help with policy decisions concerning mitigation procedures, linking impacts with specific sources, and cost analyses of various regulatory approaches. The EPA is involved in three modeling activities: 1) a regional acid deposition model (RADM) being developed at the National Center for Atmospheric Research in Boulder, CO; 2) a meso-scale spinoff model of RADM that eventually may be useful for regulatory problems primarily in the eastern U.S.; and 3) the Rocky Mountain Acid Deposition Model that is directed at selecting and/or developing a model appropriate for use in the West.

In beginning his testimony, Dr. Fox reviewed his extensive background in atmospheric modeling. He emphasized that there are both responsible and irresponsible uses of air quality modeling, and that the strengths and weaknesses of various models must be recognized and accounted for in their application. One must be very cautious about how a model is used. He discussed the results and problems of several recent modeling efforts.

Dr. Fox felt that the biggest problem in air quality modeling is defining wind patterns that transport emissions, which vary vertically, horizontally, and through time. He noted that present regulatory practices allow the use of only a point value for wind. He emphasized the need for cooperation with other states and with the EPA in developing and evaluating models, including the continued collection of data to feed into models as they are developed.

Other important research by the Forest Service discussed by Dr. Fox was research to better understand effects of acid deposition on alpine and sub-alpine ecosystems. This involves identifying sensitive area, then working with toxicology and response relationships to try to identify at what levels acid deposition and air pollution might be a problem. The area east of Lander was especially identified as a potential high risk source area for siting emissions sources, because it is generally upwind of the Wind River Range.

Dr. Fox next noted that adverse effects of acidification on aquatic ecosystems are quite well documented in his opinion, but the cause-effect relationships with respect to terrestrial effects are unclear. While there is evidence that air pollution kills forests in the vicinity of a source, there is no conclusive evidence of effects on a regional scale. Forest declines seen in some areas, which are occasionally attributed to acidic deposition, are very complicated and poorly understood. Dr. Fox said that the cause of these forest declines may include acid deposition, ozone damage, hydrogen peroxide, direct leaf injury, injury from beetles, increases in nitrogen, and/or an undetected organic contaminant. About 20% of the foresters even believe air pollution is not involved, but rather that the declines are a part of natural forest cycles. Forest Service research is currently attempting to identify the actual cause(s).

Dr. Bruns began with a brief review of his background and then discussed his group's investigations on atmospheric depositions in the Wind River, Pinedale, and Hobbs Lake areas. Their study emphasizes NO_x rather than SO_2 because relatively little is known about NO_x emissions; NO_x and SO_2 emissions are roughly equal in the West; NO_x emissions are expected to increase in the West as SO_2 emissions decrease; and controlling NO_x emissions are relatively more costly than for SO_2. Their primary goal is to develop a quantitative model of transport and deposition of nitric acid and nitric acid precursors. These studies are being coordinated with ecological studies of sensitive aquatic and terrestrial indicators for acidification effects, and are complimentary to studies by the Forest Service and NADP. They plan to gather data over an 8 to 10 year period.

Dr. Bruns emphasized that their research will provide needed data for developing better and more accurate models of transport phenomena. He also stressed the promise of microparticle analysis for future tracer studies which are badly needed to evaluate modeling efforts.

Ron Surdam asked if it was possible to just use stable sulfur isotopes that are individual to facilities to track emissions--a method that would be substantially less expensive. Dr. Bruns thought that the method might not have been tried or that analyses in the field at the low levels involved might be difficult. He also surmised that there might not be sufficient variation in characteristics to isolate particular emissions when a sample is mixed with more than one facility's emissions.

The day's meeting ended with a brief discussion on research Forest Service research in the Wind River Range and the problem of not being able to use helicopters to gain access to the wilderness areas. Al Galbraith commented that based on chemical comparisons completed, analytical results do not seem to be adversely affected by the delays incurred by packing out samples.

Summary of the Acid Rain Coordinating Committee Meeting--January 9, 1986

Herschler Building
Cheyenne, Wyoming

Members of the committee present were:

- Mr. David B. Park
- Dr. Jim Barlow
- Ms. Bonnie Pendleton
- Dr. Ron Surdam
- Mr. Randy Wood

The following experts gave testimony at this meeting:

Dr. Robert I. Bruck
North Carolina State University
Raleigh, North Carolina

Dr. Peter Reich
University of Wisconsin
Madison, Wisconsin

Dr. Anna Schoettle
Rocky Mountain Forest and Range Experiment Station
U.S. Forest Service
Fort Collins, Colorado

Others present included Alan Galbraith, Al Riebau, Donn Kesselheim, Larry Svoboda, Bill Thomson, Darrell Bushman, Dean Forsgren, Rich Boyd, Brent Kunz, Bob Missen, Terri Lorenzon, John Wagner, Dave Hogan, Mike Barrash, Chuck Collins, Bobbi Brown, Beverly Gorney, and Mary Adamy.

The subject matter of this meeting was how acid deposition affects vegetation with emphasis on the potential for adverse effects in Wyoming. Dr. Bruck first directed attention to the fact that no evidence exists directly linking forest declines in Europe and the eastern United States to atmospheric deposition. In addition, he stated that some effects attributed to acid precipitation in the eastern United States are actually natural phenomena, not related to acidic deposition. He recommended that the State of Wyoming gather baseline data on diseases and insect populations in Wyoming forests.

Dr. Reich then pointed out that no study has shown physiological effects on plants by the application of acidic water at pollutant concentrations found in the environment. However, field studies have shown that tree damage is occurring and that it is correlated with pollution levels. He stated that researchers have not gathered enough data over a long enough period of time to identify the exact cause. He recommended that the State increase monitoring efforts and keep informed of regional, national, and international research on the acid deposition problem.

Ms. Schoettle spoke of the U.S. Forest Service goal to identify potential effects of air pollution in wilderness areas. To accomplish this goal, they are designing a long term study at a high elevation site, one representative of wilderness areas in the Rocky Mountains. Within a few years they hope to have gathered the necessary data to define how wet and dry acidic depositions affect alpine and subalpine vegetation. She recommended that the State conduct additional monitoring of air quality at high elevations, and to coordinate monitoring and research efforts by the State with efforts sponsored by federal agencies.

Experts were asked questions about whether it was possible to use cores from tree rings or from mountain glacial deposits to help to establish historical patterns for atmospheric depositions. Dr. Bruck noted that a recently published technique provides a method to analyze chemicals, including metals, incorporated in the layers of tree rings. He added, however, that the validity of this method and how to appropriately interpret its results are still a subject of scientific debate, because such incorporated chemicals may migrate within the wood over time.

With respect to chemicals deposited on glaciers in the region, Dr. Bruck suggested the same problems were present. Seasonal thawing of temperate glaciers causes chemical profiles in the ice to become smeared, producing considerable interpretation problem. In agreeing with this statement, Al Riebau, who had worked on cores from St. Mary's Glacier near Denver and now works for BLM in Rock Springs, added that investigation of cores from glaciers could still provide some interesting information.

The discussion then shifted to the fact that one reason for extensive monitoring programs is to identify components of aquatic and terrestrial ecosystems that are most sensitive to potentially affects by atmospheric depositions. Dr. Schoettle and Dr. Bruck emphasized that scientists do not know what the most sensitive components of these systems are.

Discussions by Donn Kesselheim of the Wyoming Outdoor Council and Jim Barlow raised the question of whether it is worse to over protect resources by implementing unneeded regulations or to fail to implement needed regulations and lose the resource. Dr. Bruck noted that he had been involved in similar discussions during a recent Congressional hearing. At the time he stated that questions on defining appropriate regulations requires scientific knowledge that currently is not available. To get the necessary information requires expenditure of much research time and money. At this time Congress appears willing to direct only limited funding toward the problem of atmospheric depositions to answer questions pertaining to potentially important regulatory needs. Dr. Bruck then noted that the entire budget of the National Acid Deposition Assessment Program for the United States is equal to the cost of one intermediate-range missile.

Summary of the Acid Rain Coordinating Committee Meeting--March 5, 1986

Herschler Building
Cheyenne, Wyoming

Members of the committee present were:

Mr. David B. Park
Dr. Jim Barlow
Ms. Bonnie Pendleton
Mr. Bob Wallick
Mr. Randy Wood

The following experts gave testimony at this meeting:

Ms. Jill Baron
Colorado State University
Fort Collins, Colorado

Dr. Harold Bergman
University of Wyoming
Laramie, Wyoming

Dr. David Brakke
Western Washington University
Bellingham, Washington

Dr. Alan Galbraith
U.S. Forest Service
Jackson, Wyoming

Dr. Frank Sanders
University of Wyoming
Laramie, Wyoming

Dr. Robert Wiley
Wyoming Game and Fish Department
Laramie, Wyoming

Others present were E.A. Wells, Terri Lorenzon, Mike Barrash, Dean Forsgren, K.C. Bishop, Darrell Bushman, John Wagner, Dave Hogan, Jeannette NewVille, Al Riebau, Paul Krza, Debra Beck, Donn Kesselheim, Melinda Brazzale, Bill Thomson, Doug Fox, Bob Missen, Bobbi Brown, Chuck Collins, and Mary Adamy.

The subject matter of this meeting was how acid deposition affects terrestrial and aquatic systems with emphasis on the potential for adverse effects in Wyoming. Dr. Brakke first discussed characteristics of watersheds that could influence their sensitivity to potential acidification. He concluded that western watersheds are probably more sensitive than those in the east and could acidify fairly rapidly if deposition levels were to increase greatly. He recommended that the state initiate long-term monitoring of deposition, especially at high elevations, and analyze major biogeochemical processes in sensitive watersheds. He stated that data from the EPA lake survey would be very useful in setting up a monitoring program in Wyoming.

Ms. Baron addressed her 6 years of research on acid precipitation and aquatic systems in Rocky Mountain National Park. She has found that nitric acids behave very similarly to sulfuric acids in watershed processes. She also found that watersheds are most vulnerable to acidification during the spring snowmelt because the meltwater has no chance to react with the soil and be neutralized. She has not found any evidence of past or present acidification in lakes she has studied. Ms. Baron recommended that long term monitoring be performed in Wyoming to prevent rather than rectify the problems of acid precipitation.

Dr. Bergman discussed recent reports of declines by fish populations due to acid deposition, and how his groups research is determining the effects of acidic water on fish. He stated that fish populations have been lost due to lake acidification in Scandinavia, eastern Canada, and in the northeast U.S. He suggested that the primary mechanism through which fish populations are affected in sensitive lakes and streams is through the mortality of eggs and/or developing fry during spring snow melt. He stated that the effects of acidity in waters with low calcium levels, typical of high elevation lakes in Wyoming, are move severe than in waters with high calcium levels. Dr. Bergman recommended that the state monitor emissions, depositions, and the chemistry and biology of surface waters.

Dr. Sanders presented his views on the current situation of acid deposition and acidification in Wyoming. He said that in Wyoming there are nearly 500 lakes with trout populations that are considered susceptible to acidification. However, there is no evidence of acidification in any of these lakes. He recommended that Wyoming establish a small research and monitoring program to perform a baseline inventory and subsequent monitoring at selected sites.

Dr. Galbraith reviewed his research on watersheds in the Wind River Mountain Range. He stated that western watersheds are sensitive because they have insufficient vegetation, litter, and soil to buffer acidity. He emphasized that there is not enough information to state if Wind River lakes are being affected by acid deposition. He recommended that research be directed at geologic and watershed processes and that state government take a more active role coordinating the various research efforts within the state.

Dr. Wiley discussed how acid deposition is important to the Game and Fish Department and some of the research the department has done. Data from high elevation lakes in Wyoming show that many have fish populations and that most are susceptible to acidification. Currently the department is classifying over 1,800 lakes that are considered potentially susceptible to acidification. He stated that revenue generated by fishermen who fish these lakes is approximately 4 million dollars. If these lakes become acidified, the cost of mitigation would be much greater than the revenue that they generate. Thus, mitigation solutions, such as liming, are unacceptable to the Game and Fish Department. He recommended that the state develop inventories of resources at potential risk and select study sites for long-term collection and monitoring of baseline environmental data.

There were no comments or questions from the audience and the meeting adjourned.

Summary of the Acid Rain Coordinating Committee Round Table Discussion--July 23, 1986

Pinedale, Wyoming

Members of the Committee present were:
- Mr. David B. Park
- Mr. Jim Barlow
- Ms. Bonnie Pendleton
- Mr. Bob Wallick
- Mr. Randy Wood

The following experts gave testimony at this meeting:

Dr. Chris Bernabo
Science and Policy Associates Inc.
Washington, D.C.

Dr. Douglas Fox
Rocky Mountain Forest and Range Experiment Station
Fort Collins, Colorado

Dr. George Hidy
Desert Research Institute
Reno, Nevada

Others present were James Scroggins, Terri Lorenzon, Paul Krza, Dennis Haddow, K.C. Bishop, Bobbi Brown, Bob Schick, Bob Millis, Alan Galbraith, Chuck Collins, Chip Rawlins, Larry Svoboda, Robert Missen, Steve Pierett, Darrell Bushman, Gary Austin, Dean Forsgren, Colin Voigt, Al Rieban, Rich Fisher, Duane Howe, Donn Kesselheim, John Barlow, Katharine Collins, and Steve Laster.

Mr. Wood initiated the meeting, stating that Governor Herschler appointed this committee to make recommendations on the research and monitoring of acid deposition in the State of Wyoming. Up to that date the Committee had met five times. In the course of these meetings, many recognized experts in various fields had provided testimony. Transcripts of the statements made at the five previous meetings were reviewed by three scientists with expertise on acid deposition and its effects, Dr. Bernabo, Dr. Fox, and Dr. Hidy. Based on these reviews, each scientist prepared a series of recommendations to the State on important issues and priorities. The purpose of this meeting was to discuss these recommendations.

Each of the three experts provided a written statement of their recommendations to the Committee. Therefore, rather than summarizing the testimony that each presented based on their individually prepared statements, their written statements are reproduced here. After presentation of each statement, the discussions that followed each expert's presentation are summarized.

Issues and Priorities for the Governor's Acid Rain Coordinating Committee.
Prepared by Dr. Douglas G. Fox

Two general conclusions are apparent from any study of the literature on Western Acid Deposition. The first is that our data resources are inadequate to answer detailed questions about the air quality environment in rural locations in the western U.S., and the second is that the role acid deposition plays in natural western ecosystems is not understood in any quantitative fashion. From these assumptions I have developed a specific list of recommendations for your consideration:

1) Establish a State Program for Acid Deposition

In the following recommendations I shall suggest a number of activities which seem to be appropriate for Wyoming to establish and coordinate. I feel this can best be accomplished through a single state office with line authority to accomplish the tasks. Since the acid deposition program, at this point in time, is primarily a research activity, I suggest this function be established in the University; however, it should be closely tied to monitoring and regulatory functions of the Department of Environmental Quality. Among the responsibilities of this office will be a major coordination role between researchers, resource managers and regulators in the private sector, as well as State and Federal government. I estimate that this could be accomplished by a half-time position for someone in the University staff.

2) Monitor Deposition

There are three aspects to deposition monitoring: wet, dry and cloud interception. As a result of cooperation among various agencies and the private sector (because of permit requirements), a few wet deposition collectors are operating in the State. Because dry deposition measurement is a research activity at present, ambient air concentrations is recommended as an upperbound estimator of that parameter. No routine monitoring of rural air pollutant concentration is now being done. Measurement of cloud interceptions is done as a research study, but not in a routine fashion. Protocols for "filter-pack" instruments which are capable of measuring concentrations of SO_2, SO_4, NO_x, and NO_3, among other species, are currently being developed. Similarly, procedures for making cloud water measurements are also being standardized. I recommend Wyoming establish monitoring at a few locations around the State. Each site should include a wet only deposition sampler, a "filter-pack" for ambient air concentration, meteorological parameters and a passive cloud water collector. Since it is difficult to separate effects of ozone from acid deposition, each site should also include an ozone monitor. These sites are both expensive and elaborate. They must be carefully chosen and maintained so that quality controlled and assured data result that are compatible with national efforts. Because of this, monitoring should be conducted in association with existing research sites, say, one in the Wind River Mountains and one at the Snowy Range Observatory as a minimum. The State should also be responsible for maintaining a data archive on this information.

3) Establish a Wyoming Acid Deposition Model

In cooperation with surrounding states, Region VIII of the EPA, the BLM, Forest Service, and Park Service, a regional, permit oriented, air quality and acid deposition model should be selected, evaluated and adopted for permitting in Wyoming. A current contract effort funded by EPA and coordinated through the Western Acid Deposition Task Force, Atmospheric Modeling Group chaired by Al Riebau (BLM, Wyoming State Office) is reviewing the literature on available techniques. Once a model has been selected or developed, the Forest Service and BLM plan to implement the model as a component of the Topographic Air Pollution Analysis System (TAPAS) that provides friendly topography and graphics support to model users. The State may wish to use this system or install a similar system. Wyoming will also want to devise various tests of the "community" model to ensure that it will be acceptable for permit applications. This testing may involve a field program associated with existing pollution sources.

4) Establish a Grants Funding Program

A number of major research efforts are currently underway in Wyoming. These efforts are funded by a variety of sources and have specific objectives and purposes. Among the efforts, for example, are monitoring and research in the Bridger Wilderness supported by the Forest Service and the Department of Energy; fisheries research supported by the Electric Power Research Institute, Fish and Wildlife Service, and Rocky Mountain Station at Jackson, and University of Wyoming; atmospheric sciences research at Elk Mountain supported by National Science Foundation; and monitoring and research at the Snowy Range Observatory supported by Rocky Mountain Station, Environmental Protection Agency, and others. Wyoming funds could be used to establish a competitive grants program to provide support to study specific Wyoming questions and issues within the framework of these major research efforts. The program office, mentioned in #1 above, would identify such questions and issues and entertain proposals from researchers. Among the functions of the program office would be the annual development of a report on the status of acid deposition knowledge in Wyoming and a plan for research funding in the future.

5) <u>Survey Air-Quality-Related-Values of Class I Areas</u>

The Clean Air Act established Class I areas as locations where adverse impacts of anthropogenic air pollution are unacceptable. These Class I Areas are generally Federally managed but the State plays a major role in deciding if a projected impact is acceptable or not. In order to do this, it is necessary to have onsite data regarding the status of air quality related values in these areas. The Rocky Mountain Station is in the process of establishing a set of measures and associated protocols for these measures that will, in a parsimonious manner, characterize the current status of air quality related values. Since the responsibility to establish this current condition is not clearly assigned under the Act, it seems prudent to recommend the State take a leadership role, coordinated with federal land managers, in establishing such values for its Class I areas. I have enclosed the latest draft report of these protocols for your consideration.

<u>Discussion following Dr. Fox's prepared testimony</u>

Dr. Fox further emphasized that, currently, results from research on acid deposition in the western United States are uncertain and policy decisions are difficult to make based on these results. There is enough potential for a future problem, however, to warrant investigation of possible impacts. If any acid precipitation effects are observed in Wyoming, they likely will be very complex due to interacting ecological relationships and toxicological effects. In addition, sulfur, which is associated with acid deposition, may not be as important to the deterioration of forests as other air pollutants, such as ozone and nitrogen compounds. Studies underway in the Wind River and Snowy Range Mountains can address some of these questions.

Dennis Haddow from the Forest Service stated that the Forest Service would provide the State with information on the environmental impacts of acidic deposition. But, he noted that the Forest Service is not trying to dictate how the State should manage non-federal lands.

Dr. Fox remarked that data are only worth collecting if it can be assured that they are of acceptable quality, i.e., that they are meaningful, representing actual environmental conditions. To ensure high quality data and research, competitive grants funded by the State to study specific Wyoming questions should be peer reviewed. This could be accomplished by requiring results to be submitted in journal articles rather than in reports. Dr. Bernabo agreed, but emphasized that an annual report should be completed for each research project. This report should put the results into a context that can be understood by regulators and administrators.

Dr. Fox stated that the Forest Service is establishing a standard set of procedures and protocols for researching acid deposition that would help ensure the quality of data. He encouraged researchers in Wyoming to consider formally participating in this to gather useful data.

He concluded that there is no evidence that acid precipitation has impacted any ecosystem in Wyoming. But there is evidence that acidic deposition does occur in Wyoming and that there are resources in Wyoming with little acid buffering capability that are potentially sensitive to acidification.

Review of Summary Documents on Acid Rain.
Prepared by Dr. George M. Hidy.

1) Overview

The technical discussions of the Wyoming Governor's Coordinating Committee on Acid Rain took place in five sessions, dated July 22, 1985; Sept. 11, 1985; Nov. 6 1985; Jan. 9, 1986; and March 5, 1986. These meetings were organized along topic lines that were (a) general issues, (b) measurements and monitoring, (c) modeling, and (d) potential for terrestrial and aquatic effects. Experts were invited to present their views at these meetings, and discuss issues with the members of the Committee. The minutes of the meetings serve as a basis for identifying key issues and questions for Wyoming, and set a framework for action.

This review summarizes the central issues raised, and comments on monitoring, research and organization needs to address these issues.

2) Key Issues

Several key issues emerged from the Committee discussions. These are:

A. What natural (or other) resources are at risk from acid rain exposure in Wyoming?

B. What are the exposures of susceptible systems to acid deposition in Wyoming?

C. Is there any evidence for alterations in susceptible systems in Wyoming resulting from acid deposition?

D. Are there trends in acid deposition and measurable system-symptoms that suggest changes?

E. What are the relationships between sources of airborne acid forming material and receptor conditions in Wyoming?

F. What measurements and/or research are needed to characterize the environmental consequences (if any) of acid deposition in Wyoming?

G. How should these requirements be carried out and who should do them?

Resources at Risk. To be of regulatory significance, it is necessary to identify the resources that have potential for deterioration by acid deposition in Wyoming. Without such concern, the phenomenon is of interest academically, but has no relevance to environmental protection.

The resources at risk are identified in terms of certain low alkalinity lakes, soil and bed rock media and fir forests in acid soil conditions. The airborne chemicals deposited in certain areas such as the Bridger and Fitzpatrick Wildernesses have the potential for producing undesirable alternatives in terrestrial and aquatic ecosystems.

Exposures. The secondary issue is the nature and magnitude of exposure to acid deposition that occurs in sensitive areas of Wyoming. This is important to establish relative to some "natural baseline" to determine the severity of exposure in space and time.

Deposition occurs in three forms: wet--precipitation, dry--by absorption of gases and collection on airborne particles, and "occult"--by collection of fog or mist droplets or rime ice. Deposition processes vary with location and time; much of the wet deposition comes from snow. It is not known how deposition is partitioned between components. There may be differences in partitioning with altitude that are significant.

Effects on susceptible systems are suspected to differ depending on the deposition process so that the components need to be characterized. Finally, exposure levels may be low--below any known effect. Thus, the potential problem may be minimal in Wyoming.

Evidence of Alterations. To establish an environmental issue, evidence for alterations in ecosystems resulting from acid deposition is necessary in Wyoming. To date, such (scientifically credible) evidence has not been found, either in Wyoming or elsewhere in the West.

Trends. If exposures are significant over a "natural baseline," and alterations are observed or suspected, trends in exposure or in measures of alteration become important. If exposure is increasing, particularly beyond hypothesized threshold limits, concern for potential damage is increased.

To date, Wyoming has insufficient exposure and alteration index information to establish trends.

Source-Receptor Relationships (SRRs). Without regional cooperation, Wyoming can only regulate sources in-state. Sources of acid deposition are threefold: natural, in-state and regional. Although industry is expanding locally near sensitive areas of Wyoming, there is little or no information to determine the significance of these sources relative to the other two on acid deposition in the sensitive areas. Studies or measurement programs are needed to clarify the long range transport component vs. local sources in Wyoming. A "natural baseline" will require an arbitrary definition based on western regional data.

Measurements and Research. A rational policy to determine the environmental significance of acid deposition in Wyoming requires acquisition of data or information addressing the first five issues. Measurements and research are expensive so that Wyoming's initiatives should be closely coordinated with other programs to minimize redundancy.

Implementation. A variety of measurements and studies are currently underway. To ensure comparability of results and utility to Wyoming for regulatory decisions, responsibility, authority and communication routes need to be established.

3) Monitoring and Research Program

To determine a suitable acid deposition program for the State of Wyoming, account must be taken of western regional programs and privately sponsored studies as well as the federal government activities. With the exception of research in Colorado, there is little work available that is directly relevant to Wyoming conditions. However, the U.S. Forest Service, Wyoming Game and Fish Department, the National Atmospheric Deposition Program (NADP), and private industry are engaged in studies in southwestern Wyoming. Central to all of these studies and to addressing key issues is the reliability of measurements. Although coarse measurements of rain deposition can be made, there remain serious problems in determining snow deposition, as well as the dry and occult components. Lake water quality and fish surveys are easily done, but determinations of alterations in soil and terrestrial systems remain problematic. Further, in mountainous terrain, the sampling for spatially and temporally representative data is uncertain. Establishment of SRRs generally relies on modeling, which is virtually untested for deposition against actual field observations. Tracer release techniques are available to determine where emissions go with air flow and how much atmospheric mixing occurs. But essentially no experiments of a long range character (>100 km) have been attempted.

Faced with such measurement or technique research needs, Wyoming should consider a very basic program at this time while awaiting improvements in technology. With such a basic program, conventional (and comparable) baseline data can be obtained, but investments in potentially unreliable research level techniques would not be warranted. With this view, the following programs are proposed at highest priority.

1. Expand and maintain an NADP linked wet deposition network in the Wind River Range, including stations at different heights to establish spatial and temporal average conditions over a period of at least 5 years. (Snow sampling and analysis will be critical and may require special techniques.)

2. Establish and maintain at least 3 stations for 5 years to measure ambient gas (SO_2, NO_x, HNO_3, and O_3) and particulate concentrations at remote locations in the Wind River Range ($SO_4^=$, alkaline metals) (elevation coverage preferred) to provide baseline data for dry deposition estimates.

3. Establish and maintain for at least a year a ridge-top or mountain-top site to measure cloud chemistry in the Wind River Range, perhaps at the White Pines Ski Area (for accessibility).

4. Conduct a high altitude lake water alkalinity survey of selected high altitude lakes in the Wind River Range during spring snow melt, and during fall turnover. (This work should be coordinated with federal initiatives.)

   -- Select a small subset of lakes with different alkalinities and watershed characteristics and maintain alkalinity monitoring for several years.

   -- In conjunction with the water quality surveys and monitoring, include periodic fish and invertebrate surveys to characterize aquatic biota conditions.

5. Conduct a soil and bedrock survey in the Wind River Range around selected lakes, which completes unsurveyed areas of the soil conservation service maps.

6. Establish with the U.S. Forest Service controlled spruce-fir control tracts for monitoring forest and soil conditions over an extended period.

7. Conduct special projects in coordination with other sponsors to include in southwestern Wyoming:

   a) regional air quality modeling to estimate SRRs;

   b) tracer studies to determine SRRs based on air mass transport and mixing;

   c) aircraft surveys at altitudes that will yield data on gas and particle concentrations at different heights and cloud chemistry data;

d) ecosystem dynamics studies to characterize chemical linkages between atmospheric deposition, and alpine terrestrial-aquatic ecosystems in the Wind River region.

8) Establish, through the Governor's office, a State coordination office for Wyoming Acid Deposition Studies that will be led by a senior technical person with appropriate responsibility and authority to integrate industrial, state and federal activities.

4. Other Comments

Acid deposition occurs in Wyoming based on past measurements. However, the levels are low compared with eastern North America and parts of Europe. The levels are low despite substantial industrial development near (<60 mi.) sampling sites. Work to date has not shown any alterations of susceptible ecosystems resulting from acid deposition. New measurements are warranted over an extended period, but these must be interpreted to characterize current conditions, and serve as a basis for more sophisticated monitoring in the future.

Wyoming should not enter on its own into a significant, expensive research program, but should rely heavily on work of others to guide an evolving monitoring program to seek alterations in the environment from acid deposition.

Discussion following Dr. Hidy's prepared testimony

Dr. Hidy additionally noted that besides the Bridger-Fitzpatrick Wilderness areas, Yellowstone National Park, and the Grand Tetons, other regions in Wyoming, including the Big Horn Mountains, may be sensitive to acidification effects. The Black Hills contain relatively alkaline materials and should be fairly resistant to acidification.

He stated that any State-sponsored research should focus on evaluating features that are unique to Wyoming. This would help reduce possible duplication with research efforts supported by other states and federal agencies.

Dr. Hidy suggested that industry would be likely to support research activities that would aid site permitting processes. A state economic development commission could act as liaison between state government and industry groups. In addition, the State should better inform the public regarding the current knowledge of acidification effects in Wyoming, and he encouraged the media to present a complete discussion about the uncertainties surrounding the acid precipitation issue.

Western states should develop better methods of measuring snow accumulations and chemical compositions to provide more precise and accurate measurements. Improving these measurements would allow comparison of data among states. Stations for measuring ambient gas, SO_2, NO_x, and cloud chemistries should be established at current NADP sites, but it is also important to get data from high elevations. He thought that the best locations to measure cloud chemistry would be in the Wind River or Teton Mountains.

He suggested that chemical monitoring is more important than biological monitoring because measurement techniques are quantitative and their limitations are well known. Biological systems are extremely complex and not enough is known about them for effective use as monitoring tools. Dr. Fox added, however, that biological components are important and the Forest Service is trying to identify threshold points where sensitive biological components of an ecosystem might begin to show effects.

<u>Monitoring and Research Recommendations to the Wyoming Acid Rain Coordinating Committee.</u> Prepared by Dr. Chris Bernabo.

I have examined all the testimony and transcripts of your hearings and prepared a brief set of research recommendations. The following statements are selected high priorities and are not meant to be an exhaustive evaluation of the directions and types of studies that would be appropriate for Wyoming.

Many researchers and experts have made presentations and provided recommendations to the Acid Rain Coordinating Committee. I have not duplicated this information but rather attempted to provide some overall programmatic recommendations that should be considered in this initial developmental stage of Wyoming's program.

Because the existing evidence does not point to a current acidic deposition problem, these recommendations do not deal with investigations of the full range of studies that might be necessary if a serious acidic deposition problem emerged in the State. The direction of Wyoming's program should be appropriate to the situation and therefore focus on:

1) determining the current patterns of wet and dry deposition,

2) identifying the potentially sensitive resources,

3) defining baseline conditions, and

4) establishing long-term monitoring to detect any future changes where they are most likely to appear first.

Any program initiated by the State should build on existing and planned federal efforts by filling the gaps most critical to Wyoming's local needs. The monitoring and research program should be designed to the maximum extent possible using the existing protocols and procedures so that comparability of data and results is ensured. To optimize the value of the State's investment and avoid unnecessary duplication, the potential for working with other western states and appropriate private sector organizations also should be explored.

Based on these general considerations I suggest the following approaches for the Wyoming State program:

1) Explicitly Defining Program Goals

Before the State of Wyoming begins any monitoring and research efforts, the ultimate purpose of these efforts should be made clear. A distinction should be made between monitoring and research, as well as the end use of the results from each. For example, sites designed to monitor changes in air quality and deposition may be very different from monitoring sites set up to support research on the effects of deposition.

Research sites also may be designed quite differently depending upon the questions that are being asked--are you attempting to detect and quantify changes in the resources or to determine the processes by which changes are occurring, and are thresholds and limits critical information needs?

Recommendation: Any new monitoring and research efforts should be focused upon a well-developed and integrated set of policy questions, with associated assessment and scientific questions. These are the questions that will drive monitoring and research. The policy questions are those that decision makers need to answer in order to regulate and manage the State's resources. Assessment questions, developed from these policy questions, determine the directions of the monitoring and research program.

The scientific questions are specific hypotheses examined in the scientific investigations. The resulting data from these studies will provide the basis for an assessment of the resource and any changes, that in turn is used by the decision makers to develop appropriate policies. These different sets of questions are essential to the success of the program and the usefulness of the information. They should be developed and be firmly in place before the projects and studies are proposed.

2) Coordination with Other Programs

Several research and monitoring efforts currently exist which are applicable to the State of Wyoming. These include work under the National Acid Precipitation Assessment Program (NAPAP) such as deposition monitoring by NADP/NTN and the western lakes portion of the National Surface Water Survey. A USFS project developing protocols for western wilderness areas and other USFS research projects also are directly relevant to Wyoming.

The State should continue to actively participate in the development of the regional research plan now evolving under the Western Acid Deposition Task Force (WADTF) sponsored by U.S. EPA Region VIII. Representatives from Wyoming are already involved in these efforts, but a strong emphasis must be placed on productive interaction with other research and monitoring programs on both the national and state levels. This type of active coordination can help ensure these other efforts address some of Wyoming's concerns so the State's resources can be targeted on the remaining gaps.

Recommendation: A concerted effort should be made wherever possible to acquire, apply, and exploit available information and data for Wyoming and to directly involve Wyoming in the planned studies (e.g., sites, personnel, etc.). By building onto the existing work in and relative to Wyoming, the new efforts initiated by the State will be better integrated, more cost-effective, and more credible.

3) Baseline Measurements and Process Studies

Acid deposition currently is not a problem in Wyoming, but because the State contains some very sensitive resources, there is sufficient concern to begin collecting data. In all of the monitoring and research efforts, the initial focus should be on determining the current baseline conditions, or the background measurements for the resources at risk. Once this information has been developed, the likely sensitivity of different receptors (e.g., watersheds, water bodies, vegetation, aquatic biota) can be evaluated.

Appropriate sites should be chosen to continue long-term monitoring for changes in the system. In some cases, these sites may need to be only the most sensitive systems, those which will be the first to exhibit changes. Ideally, these monitoring sites should also be the sites of more intensive research studies on the processes and mechanisms of change.

Recommendation: Monitoring of deposition and air quality alone will not determine or prevent damage to sensitive systems. The ability to predict long-term change must be developed in addition to understanding baseline conditions. Representative watersheds of different geographic areas and sensitivities should be selected for sites of intensive process-level research, co-located with monitoring and meteorological measurement studies.

4) Deposition Monitoring

The coverage of current monitoring efforts as well as the type of monitoring itself should be increased. The deposition data base in Wyoming currently is inadequate to determine spatial and temporal variability, due to the short length of time that most of the stations have been in operation and the small number of NADP stations.

In addition, precipitation chemistry is not the only monitoring required. In some areas of Wyoming, the contribution from other forms of deposition are likely to be at least equal to that of wet deposition and often may be much greater. High-elevation systems are not being monitored routinely for precipitation chemistry and none of the systems are being monitored regularly for the additional contributions of snow, rime ice, and cloudwater, or of dry deposition in any form. Dry deposition monitoring is a high priority effort within the NAPAP but initially has an eastern focus despite the fact that a greater percent of deposition is dry in the West.

Recommendation: Begin intensive monitoring of deposition at one to three high-elevation sites, focusing on total deposition. In addition to wet deposition, this effort should include snowpack studies (total deposition over cold season), cloudwater and rime ice collection, filter pack sampling, and meteorological measurements.

As stated earlier, sites representative of background conditions are needed to determine baselines in addition to sites in areas most likely to be impacted. The pilot dry deposition network (NAPAP) and filter packs being developed for EPA will be providing essential information and equipment for such studies. The wet deposition monitoring sites in place should continue, and the trends in the data should be analyzed when a sufficient amount has been collected. All monitoring data should be collected under accepted protocols with appropriate Quality Assurance programs.

5) Sensitive Resource Protection

The greatest potential for change (and where changes are likely to occur first) due to atmospheric deposition appears to be in surface water chemistry. Wyoming contains many aquatic systems with alkalinities less than 200 ueq/l which are considered very susceptible to acidification.

Recommendation: Although no evidence exists that lakes in Wyoming are becoming acidified due to deposition, it is appropriate at this time to begin initiating long-term monitoring of specific lakes. The western lake survey by EPA would be an excellent starting point for this effort. The lakes sampled in that survey plus other lakes being studied by the U.S. Forest Service and others should provide a base for determining future long-term sites. The acidity during spring snowmelt in particular should be monitored closely as an "early warning" signal of potential future changes in surface water chemistry and effects on biota.

6) Conclusion

Wyoming is in the vanguard with only a handful of other states that have or are planning acid deposition research and monitoring programs. These efforts are laudable particularly because they are coming before major problems are detected. By planning a well focused set of activities now, the State can help ensure the development of environmentally and economically sound policies based on credible scientific information. This will enable Wyoming to avoid the problem of eventually relying on the unproven assumptions and best guesses that often accompany decision making during periods of actual or perceived crisis.

Discussion following Dr. Bernabo's prepared testimony

Dr. Bernabo further discussed what some states are doing about acid precipitation and natural resource monitoring. Wisconsin, Florida, Maryland, and Massachusetts have recently developed monitoring programs. He believes that there is currently no acute acid deposition problem in Wyoming, but that problems can become acute quickly. Because of this potential, surface waters in the State should be monitored closely.

Dr. Bernabo stated that it will be relatively easy to focus scientific research in Wyoming if the State's policies are explicit. The State should first consider what questions need to be answered then consider what research would be necessary to address those questions.

Dr. Hidy pointed out that the federal government should increase its research involvement in the western states because it owns nearly 85% of the land where resources susceptible to acidification are located. Dr. Fox also suggested that the potential for industrial growth is greater in the western United States and that, in general, emissions are increasing. Dr. Hidy disagreed and stated that his reviews indicate that emissions are decreasing due to decreasing smelter activity in the West.

Dr. Bernabo concluded by emphasizing that an administrative position should be established for organizing and coordinating research on acid deposition within the State. The person in this position should be a generalist who can synthesize and integrate research results from many diverse fields. He felt that the position should not be assigned an academic chair.

Additional Discussion

John Barlow of the Wyoming Outdoor Council spoke regarding his organization's concern about the very sensitive areas in Wyoming and the fact that rainfall in some areas is more acidic than normal. He stressed that it is important not to wait until there is demonstrable damage before doing something about acid precipitation because there may be little possibility of reversing any damage that may occur. (Editor's note: Recent evidence from Sudbury, Ontario suggests that with reduced atmospheric input of acids, lake pH will increase within a few years to permit development of diverse biological communities.) He disagreed with Dr. Hidy and stated that emissions, especially oxides of nitrogen, are expected to increase in the West.

Paul Krza of the Casper Star Tribune asked if emissions of SO_2 and NO_X in Wyoming were increasing or decreasing. Randy Wood answered that data from the emissions inventory of the State had not yet been summarized. In general though, Mr. Wood thought that if the economy of Wyoming were to improve, the emissions inventory would increase. Mr. Wood pointed out that electric power plants within the State are regulated to minimize emissions.

Dwight Howe from the Dubois Wildlife Association expressed his concern over the possible impacts of acid precipitation on the economy of western Wyoming, which depends on tourists and fishermen.

Summary of the Acid Rain Coordinating Committee Meeting--September 17, 1986

Rawlins, Wyoming

Members of the Committee present were:
- Mr. James Barlow
- Mr. Dave Park
- Ms. Bonnie Pendleton
- Dr. Ron Surdam
- Mr. Robert Wallick
- Mr. Randy Wood

Others present included Donn Kesselheim (the listing showing all individuals present at this meeting was missing).

Randy Wood began this meeting with a synopsis of the previous six meetings. The first five meetings were each limited to a specific topic related to acid deposition. At each meeting, a number of scientists having expertise on the specified topic were invited to testify. The last meeting was a round table discussion during which three nationally recognized experts, Dr. George Hidy, Dr. Chris Bernabo, and Dr. Doug Fox, presented recommendations and suggested priorities based on testimony from the previous five meetings. The purpose of the present meeting was to review those recommendations and outline priorities for the State on technical issues and monitoring.

Dave Park suggested that Committee members outline their impressions and suggestions based on the material presented at the previous six meetings.

Jim Barlow began by pointing out that during the round table discussion all three experts concluded 1) there is no evidence of environmental degradation in Wyoming due to acidic depositions, and 2) it was important to monitor air quality in the State. He emphasized that while air quality was a concern nationwide, that it was the Committee's responsibility to focus on Wyoming, and the experts' consensus was that there is no evidence of damage in the State from acid rain. He supported the need for air quality monitoring, monitoring emissions from in-state sources, and monitoring to determine how out-of-state sources affect Wyoming's air quality. He also felt Wyoming should have greater involvement in development of laws and regulations at the national level. The Natural Gas Policy Act of 1978 was an important example.

This Act restricted use of methane as a fuel and encouraged the use of coal. He recognized conflicting interests within the State, as Wyoming is a large producer of both coal and natural gas, but he felt the air quality of the nation should be the foremost consideration. He felt it important that Wyoming be more involved at the national level in such issues.

Bob Wallick thought it was important to coordinate various monitoring programs conducted in Wyoming. This could include a central program or organization, perhaps at the University of Wyoming, to collect, evaluate, and report results from monitoring programs throughout the State. Another responsibility that should be included in this program is to ensure continuity in monitoring programs. There should also be a means developed to distribute gathered information to appropriate federal organizations or agencies for nationwide coordination of research. Mr. Wallick felt the biggest problem currently facing the State with regard to acid deposition is identifying point sources of pollutants.

Ron Surdam also wished to emphasize the experts' conclusion that there is no evidence of damage in the State due to atmospheric deposition. He did not feel this meant that no problem existed, it merely stated the present situation. Before making conclusions about long-term problems, though, it is important to define current trends for atmospheric depositions in the State. He agreed that a statewide monitoring program was needed in the Wyoming. He also felt it was important to establish this system as soon as possible because of the possibility that clean air and atmospheric pollution may eventually be treated like a water right. To protect Wyoming's rights, it is essential that Wyoming be able to document the amount of pollution the State is actually contributing to the overall atmospheric budget. He also recommended that a professional position be established that will coordinate monitoring efforts within the State and integrate those efforts with similar efforts across the country.

Bonnie Pendleton thought that monitoring in the State needed to include more sites in more areas and be more comprehensive. She agreed with the need for coordination of research within the State. Such coordination could help assure that Wyoming would be in a good position to receive additional out-of-state funding support for research, and that useful data would be provided for State policy makers.

Dave Park agreed that while there is no evidence of damage, not enough data is available to establish any trend for depositions in the State. He said the State has an obligation to monitor its resources. He, too, felt a need to established a coordinator, perhaps within the University, for research and monitoring efforts in the State. This person should have the authority to direct efforts by various agencies and to prevent unnecessary duplication of these efforts. The coordinator would have the authority and ability to continue a program or initiate a program to fill information gaps. In addition, this position would have to have some political influence because of necessary involvement with federal programs. To assist the coordinator with helping to coordinate activities and providing some political force, he suggested forming a committee comprised of representatives from each of the various agencies conducting research in the State, from public interest groups, from State agencies such as the Environmental Quality Council, and from industry. In addition to the coordinator and the advisory committee, he also suggested a third body to review research resulting from this coordinated program. This would help ensure that research and monitoring data would be reliable and of good quality.

As a member of the Environmental Quality Council, Mr. Park said it was his experience that the Council has continually rejected the notion that there is a property right to pollute. If the State were in a situation where air became a property right, there would be no motivation for or emphasis on improvement. He did not feel treating air quality as a property right would be in the best public interest.

Jim Barlow thought it was important not to disregard natural sources of acidity, such as the sulfur springs in Yellowstone, and natural sources of buffers, such as the alkaline soils in many areas of the State. He brought up statements by each of the three scientists at the round table discussion in Pinedale. He noted Dr. Fox said that present data are inadequate to answer detailed questions about air quality in rural locations in the West, and that the impact by acid deposition in natural ecosystems is not quantitatively understood. Similarly, Dr. Bernabo also had stated that acid deposition is not currently a problem in Wyoming, but because the State contains some very sensitive resources there is sufficient concern to begin collecting data. And Dr. Hidy had said that to establish an environmental issue, evidence for alterations in the ecosystem resulting from acid deposition is necessary, and, to date, such evidence has not been found in the State. These statements indicate that while the experts all have a slightly different perspective, they all agreed that monitoring is very important.

Ron Surdam said that it was important that Wyoming not end up in the same situation with air rights as they are, for instance, in the case of water rights on the Colorado River. Here, the State has lost some of its water to another state that had used the water before Wyoming. Everyone on the Committee agreed that their the recommendations include the position that pollution from out-of-state sources should not limit development of Wyoming's resources by in-state industries and facilities.

To help the Committee focus its discussion, Randy Wood outlined six recommendations he thought all three experts agreed on.

1) A baseline of ecological factors needed to be established in the State. Monitoring for this should include one to three stations operated for at least five years. As a part of this program, the following parameters must be evaluated: SO_2, SO_4, NO_x, nitric acid, ozone, particulates, and meteorology.

2) Additional high elevation cloud chemistry work needs to be done, including estimates of cloud interception and rime ice accumulations.

3) The State needs to support long-term aquatic research efforts that would include entomology, snowmelt, and lake mixing research.

4) Further biological and forest research is needed, including analyses on soils and bedrock sensitivities, and the importance of rime ice.

5) Develop modeling tools to characterize existing sources.

6) Establish a mechanism, having both authority and resources, for coordinating research efforts within the State. This would include providing an annual report of activities and results.

Ron Surdam asked what the approximate cost of a monitoring program would be for Wyoming. Mr. Wood said that although an extensive program had been proposed, that many aspects of it were already included by other, on-going efforts, including those by the Forest Service. The State's responsibilities might include as little as helping where needed or as much as adding monitoring stations for dry deposition or cloud chemistry. He said that Dr. Fox had suggested a budget of about $200,000 to $300,000 for the program.

Jim Barlow suggested that two objectives be cited for monitoring. First, to see that there is no internal or external deterioration of air quality from internal or external sources; and second, to see that industrial activity is not discouraged or prohibited unnecessarily because of unnecessary requirements or regulations, either internal or external. He noted that from his experience in the legislature, the cost of paying a person such as the suggested coordinator and his support would likely amount to $100,000.

Bob Wallick remarked that an annual report summarizing results from research and monitoring in the State could cost $20,000 to $30,000. He said that the actual research is just half the project, the other half is publishing it in a form that is accessible.

One of the main recommendations the Committee wanted to make for monitoring was that it, at least in part, be directed at quantifying in-state versus out-of-state pollution sources. Dave Park remarked that a popular environmental magazine had estimated that half of the pollution found in Wyoming's air was generated within the State. Randy Wood thought this figure was high and cited figures from the mid-1980s that showed in-state emissions to significantly increase in the southwest part of the State, but monitored depositions at Pinedale showed no increase. This indicated, he suggested, that the percentage of Wyoming's in-state emissions is not high enough to produce a major influence in the State.

Dave Park asked if the source-receptor relationships could be better understood by modeling or by monitoring. Randy Wood responded that very good and extensive monitoring activities were necessary to improve modeling capabilities, so monitoring would be a first priority. The basic monitoring program outlined by the experts would probably be adequate to answer the question on the percentage of emissions coming from in-state versus out-of-state sources. Ron Surdam thought they should recommend this monitoring program, including, but not limited to, the point outlined by Randy Wood.

The Committee recommended that a coordinated statewide monitoring program must begin soon to determine trends, to prevent unnecessary regulation, and to quantify in-state pollution sources versus out-of-state sources. Existing monitoring programs should be used where possible, duplication should be avoided, and there should be continuity. To provide information that may useful for evaluating new technologies or theories, it is important to include as many variables in the monitoring program as possible. A coordinator for this monitoring program also should be established, who would be aided by, perhaps, an advisory committee and a review committee. Bonnie Pendleton felt that including a rationale statement in the report would be very important in underscoring the reasons for their recommendations.

It was stressed that Wyoming need not establish an independent research program. However, the State should be capable of promoting or funding research unique to Wyoming that may not be encompassed by other programs. It is also important that all work in the State establish standard protocols followed by researchers to ensure high quality, consistent data. Randy Wood said the Forest Service is developing such protocols for use by federal agencies that other Wyoming researchers could follow their lead.

With respect to modeling, Randy Wood said the experts from the round table discussion agreed that Wyoming should be active in the process, but not working to develop models on its own. Instead, the State should support models such as those being developed by the EPA.

At the end of the meeting, Donn Kesselheim said he thought it was very important that the report not say that there is no problem. He also thought there should be an emphasis on future emissions inventories.

Summary of the Acid Rain Coordinating Committee Meeting--December 5, 1986

Carbon County Library
Rawlins, Wyoming

Members of the Committee present were:

Mr. Dave Park
Ms. Bonnie Pendleton
Dr. Ron Surdam
Mr. Robert Wallick
Mr. Randy Wood

Others present included Frank Sanders, Donn Kesselheim, Terri Lorenzon, Jay Lyon, Carl Demshar, Dennis Haddow, Al Riebau, Wendy Frueauf, Dean Forsgren, Jeannette NewVille, Robert Missen, Bob Wiley, Jim Tiemann, Paul Krza, Bill Schilling, Duane Howe, Chuck Collins, Bob Schick, and Mary Adamy.

Randy Wood began the meeting with a review of the Western Lakes Survey, conducted by the EPA under NAPAP. The purpose of this survey was to characterize the chemistry of lakes in the different regions of the West. The survey was conducted in 1985 and the final report was not yet available at the time of the meeting, so review and discussion was limited to preliminary data from Wyoming. Randy Wood emphasized two conclusions he reached from the report. First, ion ratios and the relationship of base cations to acid neutralizing capability provide no convincing evidence to suggest that regional lake acidification has occurred in Wyoming. Second, the similarity of the total ionic concentration of the dilute western lakes to that of precipitation suggests that the watersheds will provide little buffering against acidic deposition.

Dr. Frank Sanders, of the Wyoming Water Research Center, presented an overview of the report. He emphasized that this was Phase I and that additional phases are expected. The objectives for Phase I were to determine present chemical conditions of acid sensitive surface waters and to determine the extent of present damage, if any, to aquatic resources as a result of current levels of atmospheric deposition. Throughout the West, regions of alkalinity were estimated and delineated into three categories, very sensitive (>100 ueq/l [microequivalents per liter]), sensitive (100-200 ueq/l) and less sensitive (>200 ueq/l). Within each of these alkalinity regions, samples were taken from 50 randomly-selected lakes. The samples were taken during the fall and each lake was sampled only once. Among the chemical parameters measured were pH, alkalinity, sulfate, calcium, extractable aluminum, and dissolved organic carbon. Dr. Sanders pointed out that there were a number of problems with the sampling program that would affect the representativeness of the samples. Among these were 1) many of the alkalinity regions were established using inadequate data, 2) use of alkalinity as a variable because alkalinity takes into consideration other watershed components beyond surface water chemistry; and 3) samples were taken only during the fall when lake waters are totally mixed.

Of the 720 lakes sampled in the West, only one lake was found to be acidic. However, Dr. Sanders thought that this lake is naturally organically acidic. Approximately 17% of the lakes had alkalinities below 50 ueq/l, which is considered very sensitive. Although there are a number of lakes in this very sensitive category, 99% of the lakes had a pH greater than 6.

He then summarized the findings for each subregion. California has the highest percentage of lakes with low alkalinity, while the Pacific Northwest has the second highest percentage. The southern Rocky Mountains have the lowest number of lakes in the sensitive category. In the central Rocky Mountains, about 7% of the lakes have alkalinities of less than 50 ueq/l, and 78% of the lakes are in the sensitive category (100-200 ueq/l). If this percentage were extrapolated to all the lakes in the central Rocky Mountains, Dr. Sanders said, it would mean that approximately 1,800 lakes in that region are in the sensitive category. These lakes tend to be very dilute systems and are not affected a great deal by bedrock weathering.

A relationship is evident between bedrock type and surface water alkalinity. Lower alkalinity, more sensitive systems are found primarily on granite bedrock, while non-sensitive systems are on dolomite bedrock. An inverse relationship was found between alkalinity and elevation, as elevation increases so did sensitivity as indicated by alkalinity. Thus, high elevation alpine areas are the most susceptible and most in need of protection.

According to these data, Dr. Sanders stated, no acidified lakes are present in Wyoming. However, sensitive systems of concern include the Wind River, Big Horn, Absaroka and Beartooth Mountains. In these areas, ionic concentrations in the dilute lakes are very similar to the ambient precipitation, suggesting that there is very little buffering capacity added by watershed processes. Dr. Sanders said, based on this data, that if the West were to get atmospheric deposition on the order of what the East receives, that lake acidification would be seen in the West. At present, deposition rates are very low so there is currently no cause for concern. But there is a large potential for seeing changes if deposition were to increase.

Dr. Sanders indicated some weak points in this study. First, some samples, and hence data, were eliminated because a storm caused ice to form on some Rocky Mountains lakes during the sampling period. Also, the alkalinity regions were defined using very sparse data. While the overall conclusion is that there is no documented damage, some resources in Wyoming are very sensitive to potential deposition impacts. Complicating this is the inadequate understanding of deposition thresholds that lead to change.

Ron Surdam emphasized that an alkalinity of 50 ueq/l does not provide very much buffering capacity. It would be useful to know how quickly that could change. How close are we to using up that little bit of buffering capacity?

While planning for ensuing phases for the National Surface Waters Survey is still underway, Larry Svoboda said the EPA will probably develop a plan for a long-term, intensive monitoring program on maybe 10 or 15 lakes in the western states. This program would be designed to incorporate a number of other specific research questions and include monitoring for episodic acidification.

Chuck Collins of the Wyoming Department of Environmental Quality (DEQ), Air Quality Division, presented information from the 1985 Emission Inventory that Jim Barlow of the Committee had requested. This information included the tonnage of sulfur dioxide and nitrogen oxides produced by industry in the State compared to what was legally allowed, the types of systems used to measure emissions, how emission numbers were derived, and how many people worked on the project for how long. Mr. Collins also provided the information in a packet of materials that he distributed to the Committee.

Although the emission inventory has been an ongoing task for the DEQ, it has only been in recent years, with the growing concern about acid deposition and in cooperating with the National Acid Precipitation Assessment Program (NAPAP) effort, that the inventory has detailed sulfur dioxide, nitrogen oxides, and volatile organic compounds (VOCs) emissions.

The facilities are inventoried by sending them a form asking what they emitted for that particular year. It is each company's responsibility to complete the form and return it. Inventory estimates are verified based on information from DEQ field offices. Mr. Collins said that if they are unable to continuously monitor emissions, then they have to make some assumptions. When emissions are not scrubbed, emission masses can be calculated based on the amount and kind of fuel used. The Dave Johnson Plant, for instance, is not scrubbed so it is very simple to estimate emissions from the plant based on the sulfur content of the coal. Although this method (EPA AP-42) is fairly accurate, it can over estimate emissions, as it does not allow for possible retention of sulfur in the ash. Mr. Collins said that he felt comfortable with the emissions shown for each plant.

For NO_x, Mr. Collins said that the accuracy of the data from sources with continuous emissions monitors should be the same as for SO_2. But for the unscrubbed units, they generally use the allowable emission rate for their computations. He said that there is no number for coal from which they can calculate the amount of NO_x being released, because NO_x is a function of combustion air as well as the coal itself.

Mr. Collins said that there is a certain amount of information that has to be accepted from industry because neither the state nor industry has the capability to install a continuous monitor on every source. He also said that because they inspect the facilities throughout the year, they have a feeling for what is going on, so they do feel fairly comfortable with the information supplied by industry. Randy Wood pointed out in the case of facilities with continuous monitors, the monitors are subject to a very rigorous quality control program that ensures accurate data.

In conjunction with the emissions inventory, the DEQ is developing a "source system" that will contain all of the sources and information pertaining to each source in a computer database. Among the information to be included in the system are emissions data, stack data, pollutants, seasonal variations in operations, compliance activities and permit information. The inventory program would be conducted and the data updated on a yearly basis. This system will also facilitate new permitting by estimating inventory emissions in the area to determine total impact. Mr. Collins said they hope to complete the system within two to three years.

Total emissions of SO_2 for the state in 1985 were 186,000 tons. Total emissions of NO_x and volatile organic carbon (VOC) were 121,000 and 14,300 tons, respectively. Mr. Collins also presented a breakdown of allowable and actual SO_2 and NO_x emissions by the top 10 of the 127 major sources for each in the State. The respective top ten facilities for both SO_2 and NO_x accounted for about 85 to 86% of the state's total emissions for each. The highest source of SO_2 in the State, accounting for 35% of the State's total emissions, is the Jim Bridger Power Plant which emitted 64,621 tons in 1985. This plant began operation before the State developed the SO_2 emissions regulations in 1974. A compliance schedule has been negotiated for this plant, and has been approved by the Advisory Board and the Environmental Quality Council. After all scrubbers are in place, allowable emissions from the Bridger plant will drop to approximately 26,000 tons. Other pre-1974 plants, such as the Dave Johnson and the Naughton power plants, are not required to install scrubbers on some or all of their smaller sized units because they are already within the allowable limits under the regulations.

Along with allowable and actual emissions, there is a third category of emissions reported under Section 19 of the Regulations "Abnormal conditions and equipment malfunction." These emissions are part of normal operations that do not require permits, and include flaring, plant turn arounds, emergency upsets, and emergency conditions such as equipment malfunctions, power failures, etc. These incidents must be reported within 24 hours and a corrective program must be submitted. This information is necessary in order to manage the clean air resource on a regional basis.

During 1983-84 there were several problems leading to excess emissions in southwestern Wyoming. First, the Chevron Carter Creek Plant had trouble with control equipment, causing release of approximately 29,000 tons of SO_2 in 1984. They were on a compliance schedule approved by the Air Quality Advisory Board to make modifications to the control equipment. Improvements were made in 1984 and 1985 to the point that Mr. Collins felt there would not be a need for any further improvement. The facility now runs at a very high efficiency for sulfur recovery. Although their permit did not allow any SO_2 emissions, except for approximately 460 lbs/yr of carbonyl sulfide, a reduced sulfur compound, they were still emitting some SO_2 under Section 19 of the regulations. However, even with these emissions, the plant only emitted 1,000 tons of SO_2 in 1985 and 1986 as compared to 29,000 tons in 1984. So the plant is operating within their permit restrictions, emitting only trace amounts of SO_2. The unit is allowed 460 lbs/hour of COS but is only emitting 16, so on the whole, Mr. Collins feels that they are operating very well and the amount of emissions under Section 19 are reasonable and to be expected when a plant is controlling such a large amount of sulfur at a usual 99.9% efficiency.

Also during 1983-84, the Amoco Whitney Canyon plant had problems with its coal bed adsorption unit for sulfur recovery. Their permitted emissions were about 13,000 tons per year. Through equipment improvements and tighter control on operator attention, they reduced their emission level from 19,000 tons in 1983-84 to 9,000 tons in 1986.

The Air Quality Division, with assistance from the Forest Service, has monitored wet acidic deposition since 1980. Mr. Collins presented some of the data from this program. Seven sites in the State are in the NADP program and include sites resulting from permits for the Chevron Fertilizer Plant in Rock Springs, Exxon's La Barge project and Amoco's site at Evanston. He also presented data from four more sites in the Wind River Mountains that are monitored using bulk samplers. These four sites extend into wilderness areas, and were chosen particularly to collect data from different elevations to determine effects of elevation on deposition. A conventional NADP wet deposition monitor is also located at one of these sites so that data between the two monitors can be compared and correlated for more reliable interpretation of data from all of the bulk samplers.

Mr. Collins compared data from the monitoring and emissions inventory programs. According to the 1982 emissions inventory, emissions from southwestern Wyoming sources totalled 108,000 tons, while sulfate depositions measured at the Pinedale Half Moon monitoring site were 3.5 kg/hectare/year. The following year, emissions jumped nearly 20% to 130,000 tons and sulfate measurements at the Pinedale station decreased 10%. He felt this indicated that the Wyoming sources were not the only influence at the site, and that out-of-state sources also must be influencing the area.

Mr. Collins also reviewed data from other Rocky Mountain states. He felt that deposition rates at the Wyoming sites did not differ significantly from that recorded from other Rocky Mountain area sites. He noted that concentrations of sulfur in precipitation to Oregon are not very high, but this state receives so much precipitation that their annual sulfate deposition level is quite high.

Mr. Collins concluded that in order to have a permitting program and allow growth in the state, an adequate data base must be maintained in order to make reasonable determinations of impact. The data base must include results from the monitoring programs and from the annual emission inventory.

Question was raised whether most of the emissions in the State were permitted or if there are many remaining fugitive or unallowable emissions. Mr. Collins said that in terms of SO_2 and NO_x emissions, there are a few facilities in the state that are not regulated, including some smaller gas sweetening and sulfur recovery plants that pre-date the permit. He also said that there probably are relatively more NO_x sources that are not permitted or regulated in the state, including older trona and soda ash refineries using natural gas fired calciners. Many of these may be regulated by now through the permit application process. In answer to another question, Mr. Collins said they have inventoried every known major emitting facility in the State, but have not gone through and compared the permitted or allowable emissions to the actual emissions.

Dave Park asked Mr. Collins if he could foresee problems with increased demand and competition for permitted clean air resources, possibly resulting in adjudications similar to the current water rights problem. Mr. Collins said that such problems already exist, most notably in Campbell County. He felt that as more development took place, competition would get more intense.

Ron Surdam asked what caused the air pollution visibility problem along I-80 near Little America. Mr. Collins replied that he was not sure but it could possibly be due to secondary particulate matter formed from gaseous sulfate and nitrate pollutants released by both Wyoming and Utah sources. Randy Wood noted that it could also be from soda ash plants in the area. The control equipment on those plants is generally less efficient at removing the finer particulate matter. Particles ranging in size from 1 to 2.5 microns are the most efficient at scattering light and most likely to create visibility problems. It could also be that there is so little mass involved, that these emissions are within a plant's allowable limits. They agreed that it was probably from a combination of both the industrial complexes in the area and also from in- and out-of-state SO_2 and NO_x emissions. Mr. Collins said the DEQ was planning to sample in that area to provide data necessary to develop a program through which visibility in the area could be improved.

In response to a question on how much effort was required to complete the 1985 Emissions Inventory, Mr. Collins responded that although they did not actually keep track of the project through cost accounting or time tracking, they estimated that approximately 600 man hours were expended. Eleven people were directly involved on a part-time basis. The EPA provided $15,000 in contractual assistance primarily for data entry and development of a data base format compatible with that submitted from the rest of the country.

The Committee then reviewed the draft of the Priorities sections of their final report. Dave Park said that in the report the Committee wished to emphasize 1) while there is currently no documented damage, there are, nonetheless, fragile, sensitive ecosystems that could potentially be impacted by acid deposition; and 2) if there is an acceptable level of impact that can be tolerated by resources in Wyoming's airshed, those impacts should be derived from in-state rather than out-of-state industries. To allow for future flexibility, the Committee also made the recommendations presented in the report more general, while not changing their substance. Bonnie Pendleton emphasized the desirability of requiring out-of-state industries affecting Wyoming's airshed to be subject to regulations equivalent to those Wyoming's industries are subject to.

A three-tiered system was suggested for coordinating research and monitoring efforts, consisting of a main coordinator, an advisory committee, and a liaison committee. The advisory committee would advise the coordinator whose job would be to coordinate and direct all of the different agencies in the state into a united research program. This would be accomplished through the liaison committee, composed of representatives from all appropriate State agencies. An important emphasis of this system was to avoid duplication of effort at any level.

The Committee then reviewed their recommendations for Wyoming's positions on national or interstate policies before Congress or EPA that could impact Wyoming's resources. Randy Wood read a list of recommendations he had developed through the course of the meetings.

1) The State must have necessary information to plan for development of its clean air resource in conjunction with all of its natural resources.

2) The State should make the final decisions on clean air resource allocation with input from the Federal Land Manager Program and the public.

3) The State should actively implement program provisions such as Best Available Control Technology to provide for clean air resource to accommodate future economic development.

4) The State, not the federal government, should make decisions on developments affecting the State's clean air resources.

5) The Clean Air Act should be amended to provide Wyoming with the ability to object to activities in other states which either adversely impact Wyoming or interfere with Wyoming's ability to develop its own resources.

6) The federal government should complete the research necessary to protect and manage resources on federal lands.

A main concern of the Committee was that the State be in a position of primacy with regard to its clean air resource. Ron Surdam emphasized that it was necessary to be ready, so that if an opportunity were to arise for the State to gain primacy, Wyoming would be in a position to protect its interests. The best way to be ready is to stay well informed and to have the necessary data.

Dave Park said that, although it seems obvious, perhaps it should be stated that it is the policy of the State to anticipate and prevent problems. The Committee also expressed that it is the responsibility of industry to develop resources in the most efficient manner, to minimize adverse impacts and to clean up after themselves.

Dennis Haddow, of the U.S. Forest Service, outlined some questions and considerations he thought important for development of atmospheric deposition programs related to the Prevention of Significant Deterioration (PSD) portion of the Clean Air Act.

1) States need to decide whether to develop regulatory mechanisms before or after an actual problem exists and then whether to develop standards based on deposition concentrations or effects or both.

2) To what extent is PSD relevant to states in preventing acid deposition impacts? Only Class I areas are currently mandated for protection under PSD.

3) Should states develop different deposition standards for wilderness versus non-wilderness areas? Not all of the wilderness areas in Wyoming are protected by law as Class I areas. Some, including the Cloud Peak, Gros Ventre, Popo Agie and Jedediah Smith Wilderness Areas are Class II wilderness areas. He explained that under the Wilderness Act, federal land managers (FLMs) have the responsibility to protect all wilderness areas equally.

4) Should states develop different effects-based standards for wilderness versus non-wilderness?

5) Should states develop effects-based standards that reflect the different sensitivities of wilderness or Class I areas? For example, should a state develop a single set of standards based on the most sensitive wilderness area or individual standards that look at the different sensitivities of the wilderness areas?

6) Should states adopt policies that give added protection from atmospheric deposition to Class II wilderness areas through best available control technology (BACT) decisions?

7) Should states consider other impacts of nitrate deposition, such as depletion of dissolved oxygen in surface waters?

8) Should states require new sources to provide pre-construction and/or post-construction monitoring related to atmospheric deposition?

9) If so, should states require monitoring only of deposition or deposition and deposition effects? Should industry be required to help pay for monitoring?

10) Should states in the West develop atmospheric deposition standards and programs that apply only to new sources or to both new and existing sources?

11) Should federal land managers (FLMs) develop atmospheric deposition and deposition effects monitoring plans/programs for wilderness areas?

12) Should FLMs present their "standards" and policies for review and comment by the states and public? If so, how?

13) What kind of state-FLM relationships need to be established in order to effectively develop atmospheric deposition standards?

14) What kind of quality-assurance, quality-control programs need to be developed for atmospheric deposition effects monitoring?

Further, Mr. Haddow suggested that the State should consider how to resolve existing problems. Should legal methods necessary to resolve existing problems be developed before problems are encountered or as they arise? He noted that it was often easier to develop ways to correct problems before they occur, especially environmental problems, since they frequently become emotional issues.

Mr. Haddow stressed that the Forest Service includes with evaluations of BACT, evaluations of potential environmental impacts, economic impacts, and energy costs before developing a program for protecting wilderness areas. To determine environmental impacts, he said, they have to determine what is being protected and the degree to which it is being protected. For wilderness areas the Forest Service considers the most sensitive resource, i.e., the most sensitive lake, not just lakes with average sensitivity.

Mr. Haddow also emphasized that a state makes the final decision in protecting wilderness areas that are not Class I areas. A permit could probably not be denied because of potential impacts to a Class II area, as could be done if impacts were to a Class I area. The state can, though, require stricter control technology on industry that would impact a Class II area.

Forest Service monitoring activities also depend on the kind of policies a state adopts. If a state decides they do not want to provide protection to Class II wilderness areas, say through BACT, the Forest Service would probably not have enough funds to monitor Class II areas in that state. Mr. Haddow concluded that he hoped Wyoming would stay involved with the STAR project and the Western Deposition Task Force.

Donn Kesselheim of the Wyoming Outdoor Council said that he would like to see more emphasis in the report on prevention as opposed to correction. He would like to see an emphasis on minimizing emissions that are inextricably liked to acid deposition. Ron Surdam pointed out that while this is emphasized in this draft of the report, it is very difficult to prevent something you do not know very much about, so there is more emphasis on research and monitoring in the report.

Al Riebau of BLM pointed out that there are quite a number of BLM wilderness study areas in Wyoming that are under consideration for Wilderness Area status. These should also be considered by the State during policy development.

It was resolved that the changes stipulated by the Committee would be incorporated into the draft document. Then the revised draft would be distributed for public comment.

Summary of the Acid Rain Coordinating Committee Meeting--January 29, 1987

Hathaway Auditorium
Cheyenne, Wyoming

Members of the Committee present were:
- Mr. Dave Park
- Ms. Bonnie Pendleton
- Dr. Ron Surdam
- Mr. Randy Wood

Others present included Donn Kesselheim, Mary Adamy, Mike Neumann, Bill Schilling, Chuck Collins, Dean Forsgren, Al Galbraith, and Bill Thomson.

Since the previous meeting on December 5, 1986, the Committee's draft report had been completed and distributed to all individuals wanting a copy within and outside the State, including Governor Herschler, Governor-elect Mike Sullivan, the State Legislators, all County Clerk offices, the media, and private citizens. The purpose of this meeting was to receive public comment and input on the report.

Donn Kesselheim, Executive Director of the Wyoming Outdoor Council, addressed the Committee first. Under Item 4 of the charges of responsibility originally assigned by Governor Herschler, the Committee was to organize the proceedings of the nine Committee meetings and its materials used into a reference document that supported the Committee's recommendations. Mr. Kesselheim felt that these materials, if compiled and organized appropriately, could be a valuable reference work. He suggested that if there was not staff time available within DEQ to accomplish this task, it might be possible to interest one or more University doctoral students in doing it as their doctoral project. The Committee agreed that, ideally, both a report synthesizing and refining the data and information pertaining to Wyoming and an organization system to facilitate further study of the resources would be desirable. They discussed the possibility of having University students do the work with funding from the DEQ or the Wyoming Water Research Center.

The main concern Mr. Kesselheim wanted to address, though, was Item 3 of the charges to the Committee, concerning development of recommendations on appropriate actions, priorities, policies and positions for the State. Mr.

Kesselheim noted that this section of the Committee's draft report was only one and one-half pages long. This, he felt, was not adequate to form a strong foundation on which to build a program of lasting importance in the State.

He further noted that the draft report points out that when damage occurs from acid deposition, it is likely to be irreversible and, also, will probably happen so quickly that a monitoring program would not be an adequate warning system. Mr. Kesselheim thinks that the basic goal of the State should be to prevent acid pollution damage in Wyoming and that a specific strategy needs to be designed to meet this goal.

Mr. Kesselheim cited portions of Robert Yuhnke's testimony and an EPA report in support of his position. From Mr. Yuhnke's testimony he recalled that 1) high country lakes in Wyoming are extremely acid sensitive; 2) acidity in rain and snow in the high country is elevated, and the amount of sulfur pollution entering lakes is near or exceeding the levels reported to acidify Scandinavian lakes; 3) buffering capacities in high country lakes are being consumed; 4) spring snowmelt events are acidifying lakes for short times; and (5) biologists have found trout and salamanders that have failed to reproduce in some lakes.

The EPA study attempted to predict pollution trends in the inter-mountain West from 1980 to 1995. In this study, the EPA predicts that SO_2 emissions will increase by 15%, even if U.S. copper smelters comply with emission limitations. NO_x emissions are predicted to increase by 40% if a moderately sized synfuels industry is developed in the oil shale and tar sand regions. In 20 years, SO_2 emissions could be expected to increase by 30% and NO_x emissions to double.

He suggested a possible strategy based on two objectives. The first objective would be to reduce emissions of acid-forming pollutants from existing sources, and provide a cushion for growth. The second objective would be to provide a tool for setting limits on emissions from new sources so that acid deposition does not reach levels at which damage would be expected to occur. Mr. Kesselheim then suggested two steps to implement the second objective. First, acid deposition standards be established for Wyoming lakes limiting deposition rates to levels that would ensure protection of water quality standards as defined by the federal Clean Water Act. Second, to better control water quality within national parks and Class I Wilderness areas, the Wyoming congressional delegation should be urged to seek amendment of the federal Clean Air Act that would enable federal land managers to require reduction of pollution levels based on potential damage to vegetation, acidification of lakes, and visibility.

Randy Wood suggested that the Committee had not been asked to develop a strategy to achieve a goal. Instead, the Committee was asked to provide recommendations on policies and positions. He said actual strategy is more the responsibility of the Legislature or the Environmental Quality Council or other various boards.

Mr. Kesselheim countered that this is a problem where a long range plan would be useful. He said there is a clear need for leadership in this area and he was not aware of any other group having the necessary knowledge and understanding of the subject that would be likely to do it.

The Committee agreed that the word "strategy" connoted a detailed schedule or list of things to be done in order to achieve a goal or recommendation. They felt this was not a part of their charge by the Governor, and that they had adequately fulfilled the charge as they perceived it.

An additional concern that Mr. Kesselheim had related to the phrase "clean air resource." In the draft report he felt it was being inadvertently classified with natural non-renewable resources such as oil, gas, trona, and other minerals--implicating that clean air will also be used up over time through the process of economic development. In part, because the final document may be used as an educational tool, he would like to see that clarified, not only for air, but also for water and soils. Randy Wood said that while the phrase in question was perhaps ambiguous, but it reflected the view of the Committee that clean air and water <u>are</u> non-renewable natural resources.

Mr. Kesselheim also felt that the report implied that progressively increasing amounts of damage to air may become progressively more acceptable over time, tolerated as people grew accustomed to it. He said that absolute purity is an unrealistic ideal, but the question remains of what is an acceptable amount of damage. He indicated the report has an economic bias. The Committee members explained that the air resource available for economic development is defined by an upper boundary by the ambient air standards, so not all of the clean air is available, as the draft report may imply. The Committee agree to define the term "available clean air resource" in a footnote.

Dave Park asked Mr. Kesselheim for clarification of a point in his letter concerning establishing acid deposition standards for Wyoming lakes. Mr. Kesselheim explained that he felt there was need for a "trigger," a point at which action should be taken. For instance, if acid deposition was reaching a point where some lakes would no longer be in compliance with the federal Clean Water Act, then that point could be considered an early warning signal for taking action to reduce emissions and maintain water standards. The Committee members felt it was not necessarily realistic to set some kind of a triggering standard and then expect to be able to identify a cause for each individual case and alleviate the problem.

Mike Neumann, on behalf of Rocky Mountain Energy, complimented the Committee on its work and the draft report. He said his company agrees with their findings, particularly with the need to implement a comprehensive baseline monitoring program so that future trends could be documented.

Bill Schilling, Executive Director of the Wyoming Heritage Society, outlined his questions concerning the draft report. He thought some clarification of "ecosystem" was needed in the Preamble of the draft report. Throughout the report, the main emphasis is on high elevation ecosystems, but he thought it should be pointed out that problems encountered with respect to acid deposition at lower elevations might be quite different.

In the first paragraph following the Preamble, Mr. Schilling felt that the relationship between natural resources and industry should be further emphasized since so much of the State's economy is dependent on industries that extract natural resources. He felt a statement commending these businesses for meeting or operating below State emission standards, which are more stringent than federal standards, would be appropriate. He cited a report completed by the DEQ analyzing the top ten point generators of gross SO_2 and NO_x. These ten facilities account for almost 87% of the State's total emissions. He thought it important to point out what the existing standards are versus actual emissions by these facilities. For SO_2 and NO_x, emissions from these ten facilities are about 25% and 50%, respectively, below those allowed under the existing standards. Mr. Schilling suggested that the report, by not pointing these things out, gave businesses the image of polluting and not meeting standards throughout the State. Ron Surdam did not see that the report gave that impression and felt that assessing emission levels and investigating who is doing what polluting in the State was not part of the Governor's assignment to the Committee. He thought this entered a socio-economic aspect. Dave Park did not think the Committee had any clear evidence one way or the other as to whether or not industry was complying in a commendable way. The Committee agreed on inserting a sentence saying that, in general, State industry was operating below current standards.

Mr. Schilling concurred with the statement in the draft report that scientific evidence to date does not show that there is a problem from acid deposition. However, he thought there should be a recommendation in the report for ongoing monitoring in order to establish damage threshold levels. Ron Surdam pointed out that the statement in the draft report says there is no documented damage to the environment. After also reviewing written comments submitted by Dr. Harold Bergman, the Committee agreed to insert a section recommending periodic review of scientific data, monitoring results, and other information necessary to develop unacceptable threshold levels.

Also, Mr. Schilling felt that in the Preamble the phrase "susceptible to damage which may be extensive and irreversible" was too strong. He agreed that the statement is correct, but as it is really only accurate for high elevation areas, he thought it should be softened. Ron Surdam emphasized that the reasoning behind setting standards for high elevation lakes was the strategy of protecting the weakest link in terms of the ecological chain. He also pointed out that they are considering all of atmospheric deposition, not just acid deposition. As such, lower elevation areas may, in fact, be very susceptible to other components of atmospheric deposition such as lead. Mr. Schilling thought it would clarify the point to insert that there are differences between high elevation and low elevation areas and that current concern focuses on high elevation areas because they are more susceptible to atmospheric deposition than the low lying areas.

The last point Mr. Schilling made was in reference to the Committee's recommendation that a statewide atmospheric deposition coordinator be appointed by the Governor. He felt that acid deposition was not a high priority in the State since it had not been determined to be a problem. Because of this and the current economic condition in the State, he thought this position could best be covered by DEQ without hiring an additional person, or, if necessary to hire someone, to do it by shuffling the DEQ budget. He thought that there were other, more pressing issues that would better deserve the State's time and money. Dave Park said it would be desirable to have someone outside of the potentially involved agencies so as to avoid possible territorial jealousies. The Committee had agreed, Park said, to leave the position loosely defined so the Governor or the Legislature could have more latitude to specify what was needed.

Dean Forsgrenthen then spoke on behalf of Chevron. He also complimented the Committee on its work and on the draft report. He had problems, though, with four words from the Preamble of the draft report, "uncontroverted," "significant," "extensive," and "irreversible." He felt that the subject is indeed very controversial and that "significant," in this context meant a majority of the State, which is not true. As for "irreversible," he thought it may be true that the damage is irreversible, but he didn't think there was scientific evidence to support it. The Committee decided to leave unmodified "uncontroverted," replace "significant" with "important" and to modify "uncontroverted" and "irreversible" by saying "may be extensive and irreversible." They also wished to thank Chevron again for assistance provided to the Committee.

Al Galbraith from the U.S. Forest Service said that he was in agreement with most of the specific positions and the general theme throughout the document. For Item 1 in Recommendations, he wanted to inform the Committee that the Forest Service plans to continue its monitoring program for at least two more years, after which the results will undergo an intensive review and then they will decide what future work is needed. In reference to Items 2 and 3, he said that a Forest Service research group, headed by Doug Fox, had begun an extensive program of evaluating and studying processes that are significant in alpine and sub-alpine areas identified as susceptible throughout the Rocky Mountain West. On the issue of establishing threshold levels, he believes that the single most important measurement is the alkalinity of surface waters, not pH.

In reference to coordinating effort, as described in the Policies and Positions section, he said the Forest Service was already working with the Air Quality Division on a visibility and monitoring site in the Pinedale vicinity. Also, the BLM, the Forest Service, and the Air Quality Division are in the process of negotiating an overall agreement that would help them 1) to better locate instruments to benefit all parties, and 2) to share information on the meteorology and climatology of the upper Green River airshed.

Ron Surdam said that they did not mean to imply that there was no coordination between individual agencies, but that they would like to see the State monitor coordination of all the involved research groups in Wyoming for maximum benefit and efficiency. The Committee decided to revise Item 1 to say that the State must monitor all state, federal and industry resources dedicated to the atmospheric deposition issue in order to assure that they are coordinated and integrated into the most efficient process. To Item 2, Dr. Galbraith suggested adding that information and data would be made accessible to others as it became available.

The Committee discussed including a recommendation that all emissions be kept at minimum levels through the use of Best Available Control Technology. Randy Wood cautioned that they would want to apply this only to new sources and not include existing industry in such a plan unless there was an established cause and effect relationship. They also decided to rearrange the order of the Position Statements to provide a clearer progression. To the Position Statement concerning the Federal Clean Air Act, the Committee agreed to add a sentence emphasizing that they want to insure that Wyoming's clean air resource is utilized to the greatest extent possible by in-state activities.

The final version of the report was to be sent to each Committee member to insure that all the necessary changes had been made and then was to be submitted to the Governor. The Committee decided not to meet again unless the Governor specifically requested another meeting.

Section 4

SUMMARIES OF EXPERT TESTIMONIES

Ms. Jill Baron

National Park Service
Colorado State University
Fort Collins, Colorado

Testimony given on March 5, 1986.

Material supplied to the Committee in support of her testimony:

- Proceedings from the workshop of the Western Atmospheric Deposition Task Force held in Colorado Springs, Colorado.
- A chapter on aquatic-terrestrial linkages from the above workshop.

Ms. Baron discussed her 6 years of research in Rocky Mountain National Park testing hypotheses on how acid precipitation interacts with soil, bedrock, sediment, ground water and vegetation and ultimately acidifies aquatic systems. She has found that nitrates, sulfates, and other strong acid anions pass freely through the soils in her study area. Anions, such as nitrate and sulfate, that enter aquatic systems after passing through the soil can carry (1) hydrogen ions, which can acidify or reduce the buffering capacity of the water; (2) aluminum, which can be toxic; or (3) other cations, which include nutrients required by vegetation. In her mountainous study area, soils are naturally acidic, have little buffering capacity, and aluminum is the dominant ion.

She stated that results from work done on eastern soils do not apply to western soils because eastern soils lack the large organic component found in most western soils. This component is very important because organic compounds in the soil can immobilize aluminum and create a lag in the time to acidification. Ms. Baron is now beginning to quantify the effect of vegetation type on organic matter and metal content for soils in her study area.

Generally, precipitation chemistries have been stable, with "clean" levels found for pH, sulfates, and nitrates. However, she has recorded acidic runoff events, dominated by sulfate and nitrate, entering the study lakes. In sediment cores collected from her study lakes, analysis of metals and diatoms revealed no evidence of acid precipitation.

She stated that the pH of precipitation following deposition may be increased by the weathering of bedrock, but the extent of pH increase depends upon the type of bedrock present. Limestone and dolomite deposits tend to reduce acidity levels because of the large proportion of basic anions (i.e., carbonates) they contain. Weathering of granite, a common rock in the West, may actually increase potential toxicity, as aluminum is the primary cation released. In addition to geology, land uses, such as mining, agriculture, and grazing, can affect how watersheds buffer and neutralize acid depositions.

Her research indicates that seasonality of precipitation in the western mountains may be a critical consideration. Snowfall makes up a large proportion of the yearly precipitation which melts over a relatively short period of time. This melt water has little time to interact with the soil or bedrock. She has found some spring pH values in surface waters to be depressed from a normal mean value of 6.4 to a mean value of 5.6, by melting snow, apparently due solely to the flush of naturally generated acids that accumulate in soils over the winter. Thus, aquatic systems can be especially vulnerable to acidification during this time of year.

Ms. Baron and her coworkers are using computer models, which incorporate the interactions discussed above, to predict how her study area will respond to acidification. They currently are using the MAGIC Model, developed at the University of Virginia. However, she presently lacks enough information to make confident predictions from the model. When the MAGIC model is adjusted for her study watershed, it also may be useful for other western watersheds, including those in Wyoming.

Ms. Baron emphasized that long term monitoring is essential in the West so that the presence of acid precipitation may be detected early and its associated problems can be prevented rather than be rectified later.

Recommendations made in letter to the Committee

In a letter subsequent to her testimony, Ms. Baron recommended that funding support by the State of Wyoming be applied towards research that is most beneficial to the State and least likely to be funded by other sources. For example, she suggested supporting a long-term program to monitor sensitive aquatic and forest resources; deposition that might affect one might not affect the other. With respect to aquatic systems, she advised monitoring the levels of pH, anions, cations, and alkalinity in several low alkalinity lakes. These lakes should be sampled several times throughout each year. Finally, she recommended that the state establish an acid rain coordinator to serve as liaison with federal agencies, university researchers, state government, and citizens.

Dr. Harold Bergman

Department of Zoology and Physiology
University of Wyoming
Laramie, Wyoming

Testimony given on March 5, 1986.

Material supplied to the Committee in support of his testimony:

- Summary report of the Western Atmospheric Deposition Task Force Research planning workshop.
- Project description of the Lake Acidification and Fisheries research project.
- A report from the Acid Deposition Symposium held in Boulder entitled, "A brief summary of surface-water acidification effects on fish."

Dr. Bergman discussed the loss or decline of fish populations and populations potentially at risk from acid deposition. He also reviewed his group's current research project entitled "Lake Acidification and Fisheries" (LAF). He stated that there are documented declines of fish populations in Scandinavia, eastern Canada, and the northeastern United States. Although documented fish kills are rare, the best documented and most severe cases have occurred in Scandinavia. Dr. Bergman concludes these areas have definitely lost fish populations, and that data must be gathered in Wyoming so that any potential future fish losses in the State can be documented. High mountain lakes that are most susceptible to potential effects due to acidification, have the smallest fish populations and very low productivities.

Dr. Bergman further stated that fish losses depend on both species sensitivity and the chemical factors of the aquatic habitat. Calcium concentrations are critical because higher levels of calcium protect the fish from the effects of acid stress. This is important in Wyoming because many systems found in the Rockies tend to have low calcium concentrations. He hypothesized that fish populations in the Wind River Mountains are as susceptible as those in Norway, and perhaps more susceptible than those in the Adirondack Mountains because of the presence of both low calcium levels and highly sensitive fish in surface waters of the Wind River Mountains.

His project at the University of Wyoming is assessing the sensitivity of brook trout, white suckers, smallmouth bass, and rainbow trout to chemical factors associated with acid deposition. Through this project, hypotheses are being tested on how fish die due to the toxic effects of acidification. Results indicate ionic imbalances that affect the early stages of life seem to be the most critical, while effects on egg production and development only occur at very sever conditions. Dr. Bergman suggested that the primary mechanism through which fish populations are affected in sensitive lakes and streams is through the mortality of eggs and/or developing fry during spring snow melt. In addition, his project is providing toxicological and physiological data that will ultimately help to develop models useful for predicting responses by fish populations to acidic water chemistries.

Dr. Bergman emphasized that monitoring aquatic resources is critical for Wyoming. He stated that many chemical components such as pH, alkalinity, calcium, aluminum, organic carbon, and fluoride, affect toxicity and must be monitored, especially during the critical snowmelt periods. He suggested that wet and dry deposition must also be monitored; a widely distributed monitoring program with less intensive data collection would be most effective. In Dr. Bergman's opinion, State funds should first be dedicated to establishing and maintaining monitoring programs, rather than supporting basic research.

Finally, he concluded that university, State, and federal agencies must cooperate and coordinate their efforts. Ideally this should be overseen by a non-academic person or a small committee with the backing of the Governor.

Recommendations made in letter to the Committee

Following his testimony, in a letter to the Committee, Dr. Bergman again recommended that the highest priority for Wyoming should be a carefully designed and well coordinated plan to monitor emissions, depositions, and the chemistry and biology of surface waters. This plan could be designed by holding a workshop and incorporating the resources of federal and state agencies. If research conducted by federal and other state agencies is periodically reviewed no new support research should be required. Dr. Bergman asserted that in order for the monitoring program to be successful it must have a strong coordinator who would act under the authority of the Governor.

Dr. David F. Brakke

Institute for Watershed Studies
Western Washington University
Bellingham, Washington

Testimony given on March 5, 1986.

Dr. Brakke discussed the most important components in determining sensitivities of western watersheds and of acidification and the results from studies he has been involved with in the north Cascade area of Washington state. He stated that there are many important watershed characteristics, such as geological, hydrological, biological, and land use components, which influence the input, processing, and output of materials.

Dr. Brakke emphasized that it is very important to know what the alkalinity values are in aquatic systems and how the alkalinity is generated. The Environmental Protection Agency lab at Corvallis, Oregon has produced a map of the nation showing areas considered most susceptible to acidification based on alkalinity values. These areas are primarily in the northeastern United States, some areas of the upper Midwest, and mountainous terrain in the West.

He said that in 1985 about 900 potentially sensitive western lakes were sampled once by the National Lake Survey to characterize the chemistry of these lakes. Based on this information, the U.S. EPA plans to implement a long term monitoring program by the summer of 1987. Dr. Brakke thought that the information gathered from 126 lakes surveyed in Wyoming could be very useful in setting up a long term monitoring program in the state.

Dr. Brakke has collected data in the north Cascades for the past four years. Based on these data he concluded that geology or bedrock geology of drainage basins is a good predictor of lake alkalinity. Areas composed of granites or similar metamorphic equivalents have very low alkalinities, whereas higher alkalinities are found over sedimentary or volcanic rock types. Older rocks tend to have higher alkalinities. While elevation has been used to predict alkalinity in some areas, Dr. Brakke found that it is not a very good predictor in the north Cascades.

He stated that compared to eastern lakes, western lakes have different hydrology, seasonal patterns, and, processes within the systems. In addition, pyrite veins found in western mountains can be a source of sulfate, which must be considered when selecting lakes for study and in evaluating the water chemistry for lakes.

Many sites in the West have very low alkalinities and could acidify fairly rapidly, he cautioned. Thus, it is prudent for a good monitoring program to be developed to determine any changes. It may require three to five years of data to detect a trend of change. Programs should be developed that will provide the data that will be required five or six years from now to determine how patterns may have changed. However, changes in pH probably will not occur in less than two years; for that to happen the volume of acids in depositions would have to increase to unrealistically high levels.

Dr. Brakke emphasized that temporal variability is very important and any long term monitoring must take this into consideration. Snowmelt has a large effect on the chemistry of surface waters by diluting alkalinities and by contributing nitrates and sometimes sulfates.

He advised that Wyoming should not depend entirely on the National Lake Survey for information, noting that the EPA often fails to maintain long-term commitments to monitoring, and monitoring programs must be long term. In addition, each state has uniquely sensitive systems, which national programs will probably not investigate.

Recommendations made in letter to the Committee

In a letter following his testimony, Dr. Brakke recommended that Wyoming undertake long-term monitoring of deposition (estimate loading rates of sulfur), especially at high elevations, and analyze major processes in watersheds regulating surface water chemistry in the Wind River and other mountain ranges. Also, he emphasized that information gathered by other agencies, including the U.S.Forest Service and Western Lake Survey, be evaluated and applied to help understand the conditions in Wyoming.

Dr. Robert I. Bruck

North Carolina State University
Raleigh, North Carolina

Testimony given on January 9, 1986.

Material supplied to the committee in support of his testimony:
- a copy of the written statement "Impacts of Acid Deposition on Vegetation.
- a report on a vegetation survey completed near Gothic, Colorado.

Dr. Bruck reviewed the effects of acid rain on agriculture, grasslands, and forest resources. The term acid rain, he said, refers to the precursors that lead to hydrogen ion deposition: the acidity and the wetfall. It does not include other gaseous pollutants such as ozone, hydrocarbons, fluorides, or gases such as sulfur dioxide or nitrogen oxides.

Dr. Bruck cited an EPA review summarizing nearly ten years of work concerning effects of acid precipitation on a large number of different agricultural crops. In experiments where vegetable and grass crops are exposed to simulated acid rain, conflicting data often result. But overall, there are no known effects on the crops due to acid precipitation. He said that at pHs above 4, rarely, if ever, affect agronomic crops with respect to physical damage to the plant or to the yield. Only with pHs below 3.0, which he pointed out is an unrealistic condition, are effects seen. Of all of the crops tested, only the common garden beet has showed a linear decrease in yield with pH decrease. In many of the experiments a quadratic effect was noted: at pH 5 there was a high yield, at pH 4 the yield decreased, at pH 3 it again increased, and at pH 2 it went greater still. One possible reason for this could be that as soils acidify, natural nutrients are released for use by the plants. Dr. Bruck also noted that these studies were performed at low elevations, where agricultural activities are concentrated.

For forest resources, Dr. Bruck said there is mounting evidence that acid rain may be a primary or secondary cause of forest deteriorations in central Europe and eastern United States. However, he cautioned, that unequivocal proof for this is lacking.

In central Europe, massive mortalities have occurred in low elevation forests, including the Black Forest. Ten species of trees, including seven hardwood species, have been affected simultaneously in central Europe. Dr. Bruck believes that no single cause is producing this phenomenon; rather, it probably has multiple causes. Many potential causes have already been ruled out, including insects, pathology, and soil acidification. Soils in these affected areas are extremely variable, from very acidic to very alkaline.

Such changes in forests are unprecedented in forestry literature, Dr. Bruck said. There is a great correlation to air pollutants, but there is currently little or no proof for any single or multiple agent as the cause of this.

In the United States, forest decline has been most evident in the Appalachian Mountains. Forests in the Black Mountain range have shown substantial deterioration since 1957. These forests include two tree species, red spruce and Fraser fir, that occupy the same subalpine habitat as Engleman spruce and subalpine fir do in the western mountains. Dr. Bruck estimated that 75 to 80% mortality occurred in the older trees. He said that younger trees show better survival, but as the older trees die the younger ones will lose some of the protection provided by the older trees. Once the younger trees become more exposed, it is difficult to predict what might happen. Also, with the loss of the older trees, ground temperatures could increase, further complicating potential effects.

The phenomenon of "dieback," common in central Europe, was not seen in the United States until early 1985. Dieback is the death of the tree from the top down. Many potential causes for both the mortality and the dieback, including insects, pathogens, fungi, and drought, have been ruled out. To demonstrate how rapidly some forests are being affected, Dr. Bruck cited that from 1984 to 1985 mortality in one white pine stand at 4,700 feet increased from 0 to 25%. Researchers have also noted that there is a very marked increase in mortality and damage with increase in elevation.

Further evidence can be found by inspecting bands of growth in cores taken from trees in the Appalachian Mountains. This research shows that between

1958 and 1963 growth rates for trees slowed, by as much as 90%. This was seen in approximately 83% of the trees inspected by Dr. Bruck's group.

One factor suspected of causing these forest decline is cloud deposition. Orographic cloud caps, where the mountains are sitting in the cloud, occur frequently both in the Appalachians and in other high elevation areas. The National Park Service found that the amount of water received from cloud deposition and rime ice is approximately equal to the total rain and snowfall in one area of the Appalachians. Equally important, concentrations of heavy metals and hydrogen ions are much greater in rime ice and cloud deposition than in rain and snow. The pH of cloud deposition water tended to be one-half unit lower than the pH of wetfall to the area. However, Dr. Bruck stressed that evidence supporting pollution as a cause of forest decline is only deductive. Currently, no evidence exists that ties forest decline directly to atmospheric pollution.

Dr. Bruck was one of the experts who assessed the forests near Gothic, Colorado, where it had been alleged that the trees were dying due to acid precipitation. This region is very similar to the mountainous regions in Wyoming. The trees were all found to show symptoms caused, not by acid rain, but by parasitic organisms. An analysis of the soils found them to be normal. He thinks that the tree deaths in the Gothic area are due natural causes, not due to acid precipitation.

Dr. Bruck commented that high elevation spruce/fir ecosystems and associated aquatic systems in Wyoming and the western United States are vulnerable due to the low buffering characteristics of the underlying soils and bedrocks. Precipitation pH measured in Wyoming ranges from 4.8 to 5.2, but the overall pH of depositions may be lower due to cloud droplet and rime ice deposition. He emphasized that no detrimental environmental effects to terrestrial ecosystems have been noted in this pH range. While there is a potential for an acid deposition problem in Wyoming, the amount of acid in depositions would have to be several orders of magnitude higher before effects similar to those found in Europe or the eastern United States might occur in Wyoming.

He said that Wyoming is in a unique position to gather baseline data on atmospheric chemistry, on aquatic and terrestrial biota, on soils and subsoils, and on their interrelationships. A first priority for Wyoming should be comprehensive ecosystem studies and intensive monitoring to assess the insect and disease status of the high altitude spruce/fir ecosystem. This would involve the cooperation of atmospheric chemists, foresters, soil scientists, and aquatic and terrestrial biologists.

Ron Surdam asked if Dr. Bruck had been in the Black Mountain area in 1959, if would he have anticipated the current problem. Dr. Bruck said that the approaching problem would not have been evident. One of the problems in the East was a lack of baseline data. The chance to gather this kind of data in the West before the onset of any potential problems is one of the characteristics that sets these two situations apart.

Dr. Surdam then asked if Dr. Bruck could think of any scenario that did not include air pollution, at least in part, to explain the massive forest mortalities described. Dr. Bruck said that researchers have examined every possible natural cause, but the only common factor is the large input of anthropogenic pollution. Hence, most are deductively convinced that it is a consequence of air pollution. The dilemma though, is that it is difficult to separate natural factors from manmade factors. Assuming the problem could be attributed to pollution, which of the hundreds of compounds that could potentially be responsible is the government going to regulate?

Dave Park asked if cloud deposition and rime ice might also affect economically important grassland areas in Wyoming. Dr. Bruck believes that potential effects from acid depositions are basically high altitude problems. He noted that rime ice is not the same as frost; they are formed differently and rime ice contain significantly higher concentrations of pollutants than does frost. No reduced growth or mortality has been seen in higher elevation grasses and sedges, but that is probably because they have not been studied to the same extent as forests.

Dr. Dale Bruns

Environmental Research
EG&G Idaho, Inc.
Idaho National Engineering Laboratory
Idaho Falls, Idaho

Testimony given on November 6, 1985.

Dr. Bruns began with a brief review of his background and affiliation with the Idaho National Engineering Laboratory (INEL). Dr. Bruns' group is investigating atmospheric deposition in the Wind River, Pinedale, and Hobbs Lake areas. This study emphasizes NO_x rather than SO_2 because: (1) in comparison to SO_2, very little is known about NO_x emissions; (2) NO_x emissions are roughly equal to SO_2 emissions in the West and are expected to increase in the future as SO_2 emissions decrease; and (3) control technologies for NO_x are much more costly and are not as well developed as those for SO_2. Their primary goal is to develop a quantitative model of transport and deposition of nitric acid and nitric acid precursors. These studies are being coordinated with ecological studies of plankton and of mycorrhiza on plant roots, both of which are thought to be sensitive indicators for acidification effects. They are also gathering data on ambient concentrations of NO_x, SO_2, and some trace metals. Wet deposition inputs for these components are being estimated in complimentary studies by the Forest Service and NADP. Another aspect of their research focuses on microparticle analysis, which is chemical and microscopic analysis of airborne particles, potentially useful to future tracer studies.

Dr. Bruns then reviewed INEL's reasons for selecting the Wind River Range for their studies. These included the large numbers of existing and potential for NO_x and SO_2 sources in the Green River Basin and the need for establishing a database for that area. They are in the process of gathering baseline NO_x and SO_2 data as well as some trace mineral data. Dr. Bruns said that there is currently no standard method for measuring NO_x. The sampling method they are using is an automatic sampler consisting of two filters: a teflon pre-filter and a backup filter. The teflon filter traps nitrates, which typically occur as particulates, and the backup filter traps nitric acid vapors that pass through the teflon filter. This filter system is operated for 8 hours, once a week; resulting samples are then shipped to the laboratory for analysis. Preliminary data from two sampling sites available at the time of Dr. Bruns' presentation showed ambient levels of 0.33 micrograms/m^3 for nitric acid and 0.4 for nitrates, whereas studies in Canada indicate that 0.25 micrograms/m^3 is the background level in areas with no anthropogenic contribution. Other samplers are being used to provide analyses of other air pollutants such as zinc and lead. They plan to gather such data over an 8 to 10 year period.

At INEL they have developed three complimentary techniques for elaborate chemical and microscopic analysis of tiny airborne particles. Using this technology, they can tell what elements make up the particle and in what patterns. From this information they hope to develop a chemical signature for particulate emissions from various sources. INEL believes this has great promise as a transport tracing technique and for answering important questions on chemical compositions of various emissions. This would also be much less expensive than studies that require the separate release of tracer material, such as radioisotope techniques.

Dr. Bruns also reviewed some of the other atmospheric modeling questions INEL is investigating, including vertical wind speed, changing wind speed, wind direction, properties of the aerosols involved, and particle size distribution.

Dr. Bruns emphasized that INEL's research will provide needed data for developing better and more accurate models of transport phenomena. He also stressed the promise of microparticle analysis for future tracer studies which are badly needed to evaluate modeling efforts.

Ron Surdam asked if it was possible to use stable sulfur isotopes that are individual to facilities to track emissions--a method that would be substantially less expensive. Dr. Bruns thought that the method might not have been tried and that analyses in the field at the low levels involved might be difficult. He also surmised that there might not be sufficient variation in characteristics to isolate particular emissions when a sample is mixed with more than one facility's emissions.

Mr. Bernard Dailey

Wyoming Department of Environmental Quality
Cheyenne, Wyoming

Testimony given on November 6, 1985.

Mr. Dailey outlined the methods by which the state considers potential acid deposition when permitting new sources. These processes were used for the Exxon Phase I and Phase II facilities and the Chevron fertilizer plant in Rock Springs. In the Exxon and Chevron permit applications, there were sections dealing with air quality-related values in the Wind River Range, including the potential for acid deposition.

First, acid deposition rates from both the proposed sites and existing sites were estimated. Then, this prediction was extended to predict potential change in lake pH, relating to these depositions. Since potential change in lake pH is the benchmark used by the Forest Service for unacceptable impact in wilderness areas, it was chosen as the goal of the state's modeling efforts.

In general, Wyoming ambient and PSD air quality standards consider only a 50-km radius around the site, using a regulatory-type predictive model, COMPLEX I. In the case of sources affecting the Wind River Range, the model was extended to 100-200 km radii to account for the distance from the source to the receptor. The COMPLEX I model was used to predict SO_2 and NO_x emissions, which were then combined with meteorological data to predict annual concentrations of these compounds for various receptor sites in the Wind River Range. From these SO_2 and NO_x concentrations, dry deposition was projected. In lieu of reliable information on wet deposition rates, the wet deposition rate was estimated to be equal to dry deposition rate; this is generally considered to be an overestimate of actual deposition rates. Total predicted deposition, therefore, was equal to two times the predicted dry deposition rate. Finally, potential change in lake pH was estimated from predicted deposition and measured lake alkalinity.

Mr. Dailey emphasized that the approach being used was "conservative" in that it overestimates the actual impacts. The approach does not account for any deposition between the source and receptor. It also assumes that all SO_2 and NO_x emissions are deposited as strong acids and are available to the lakes with no buffering by the soils. There is a need for models with better predictive capabilities over ranges greater than the 50 km radius for which the COMPLEX I model is designed.

The needs of western states for modeling potential acidic depositions are the concern of the Western States Acid Deposition Group, the Western STAR Group. Task Force B of the group is chaired by Mr. Dailey, and will survey the 12 western states as to their needs in better defining source-receptor relationships. One goal is to identify models that will perform best under the limitations of each application.

Dr. Doug Fox

Rocky Mountain Forest and Range Experimental Station
U.S. Forest Service
240 West Prospect
Ft. Collins, Colorado

Testimony given on July 22, 1985.

Dr. Fox emphasized that the scientific community prefers the term "atmospheric deposition" over "acid rain," because the major concern is the total impact by air pollution through the deposition processes. He also stressed that the problem is complicated. Because of the different atmospheric variables that may be present in depositions, including sulfur, nitrogen, ozone, and oxidants, it is difficult to ascribe effects to causes. Only extensive, long-term research will yield definitive answers.

Atmospheric sulfur in the West originates primarily from smelter and power plant emissions. Because these are closely regulated, Dr. Fox feels the sulfur emission inventory in the West is well known, with a few possible exceptions in areas such as the development of sour gas wells in the Overthrust area of Wyoming. The inventory for nitrogen emissions, along with other local air pollution problems, is expected to grow significantly with the increasing urbanization and growth in the West. A major difficulty is determining whether sources of atmospheric depositions are from distant or local sources. In the West, deposition patterns seem to be associated with major industries; often individual plumes can be identified. Because these plumes can be fairly narrow, monitoring may not always detect them.

In the Rocky Mountain area, concentrations of sulfur and nitrogen per unit of precipitation are about three- to four-times greater than background levels. However, sulfur concentrations in precipitation to the eastern United States are another three- to four-times higher than those found in the Rocky Mountains, while nitrogen concentrations are two-times greater.

There are a number of resources at risk in the Rocky Mountain west, including alpine lakes and terrestrial ecosystems with naturally low buffering capacities. Without studying an area over an extended time it is very difficult to tell whether an ecosystem is being impacted. There is some concern that ecosystems can be pushed to a threshold ability to resist impact from atmospheric depositions, after which they will degrade rapidly. Dr. Fox contends that we need more information about what the natural processes are and whether systems are approaching some kind of a saturation point, before we can be very confident about assessing this environmental problem or potential for problem.

Dr. Fox outlined how federal land managers must act under the Clean Air Act. The Clean Air Act was established by Congress to err on the side of environmental protection. Federal land managers must evaluate the potential impacts to ensure that no changes or effects are going to occur in protected ecosystems. Because this is done during the permitting process, evaluations are based primarily on modeling instead of actual measurements. Hence, Dr. Fox maintains, the permitting system is based on ignorance. The only assumption that can be made in this situation, as there is little hard data available from monitoring, is to define the unacceptable effects level as being any measurable change in deposition rate.

Dr. Fox felt that the kind of research needed to understand actual effects atmospheric deposition might have on ecosystems must be long-term, five to ten years, and fairly basic yet extensive in nature. To realize this goal requires coordination and cooperation within the scientific community. In the western United States, Fox felt a research program like this could be achieved through the U.S. EPA's Western Acid Deposition Task Force.

Testimony given on November 6, 1985

Dr. Fox presented his credentials as a speaker on air quality monitoring by reviewing his background. One responsibility he held was chairing a dispersion model panel that was established by the National Commission on Air Quality, as a part of the Clean Air Act to address the quality of models. He also has been involved since 1977 as a founding member of a national committee supported by the EPA to overview air quality modeling, to evaluate model accuracy, and also to evaluate the EPA's modeling program.

He emphasized that there are both responsible and irresponsible uses of air quality modeling, and that the strengths and weaknesses of various models must be recognized and accounted for in their application. His slide presentation started with data on the inaccuracies of the modeling process. In Doug Lattimer's report on the long-range transport "box" model (introduced by Gale Hoffnagle during his presentation earlier), he estimated that there were $\pm 100\%$ error margins introduced by "fugitive" dust and its potential alkaline inputs, and by inaccuracies in emissions inventories as well as in the meteorology and wind transport data. Because of inherent inaccuracies present in models, one must be very cautious about how a model is used. Dr. Fox pointed out that the more complicated and detailed processes are better represented in modeling, while the greatest uncertainty lies in the accuracy of simplifications models use to represent reality.

The next example was taken from a study funded by the Electric Power Research Institute and performed by TRC Environmental Consultants Incorporated on modeling the emissions and dispersion from a power plant in Indiana. This model did quite well at predicting the peak sulfur dioxide concentrations, but had little ability to predict when they would occur. Dr. Fox then showed an example from another study in Ohio, where the model used did well at predicting maximum values, but underestimated the average values considerably.

Dr. Fox felt that the biggest problem in air quality modeling is defining the wind field, that is, the atmospheric wind patterns that transport emissions. These wind fields are three dimensional, varying vertically, horizontally, and through time. At present, regulatory practices allow use of only point values for wind. Dr. Fox felt that models could be constructed to account for the three-dimensionality of actual wind fields. He gave an example of work done by the Forest Service and BLM that accounts for the effects of terrain and topography in air quality models. Current EPA models also are based on assumptions of "straight-line" transport, meaning that emissions are assumed to travel in a straight line from source to receptor. What is needed is a dispersion model that can calculate a concentration while taking into account wind flow patterns. Dr. Fox stated that the we currently have the ability to do this. For example, some states are currently using a type of modeling technology that takes "puffs" of pollution and moves them along on a model of the actual wind field. Another aspect of air quality modeling the EPA regulatory models do not consider is that of chemical decay and transformation. Appropriate technology exists to incorporate this feature into air quality models as well. He closed this discussion by emphasizing the need for cooperation with other states and with the EPA in developing and evaluating models, including the continued collection of data to feed into models as they are developed.

Other research by the Forest Service that Dr. Fox felt was probably even more important than modeling, is research to better understand effects of acid deposition on alpine and sub-alpine ecosystems. One study underway involves identifying a sensitive area, then working with toxicology and response relationships to try to identify at what levels acid deposition and air pollution might be a problem. As part of the identification of problem areas, he described modeling work done by the Forest Service and BLM in the Pinedale/Kemmerer area, which used an air quality model to predict what potential "source" areas would be likely to affect a known sensitive area. The area east of Lander especially was identified in this study as a potential high risk source area for siting emissions sources in that it is generally upwind of the Wind River Range. This result does not say that Lander is currently a problem, only that the potential exists, and actual measurements of the current air qualities might be in order.

Dr. Fox concluded with a discussion of the impacts of acid deposition on ecosystems. The adverse effects of acidification on aquatic ecosystems are quite well documented in his opinion, but the cause and effect relationships with respect to terrestrial effects are contested. While there is evidence that air pollution kills forests in the vicinity of a source, there is no conclusive evidence of effects on a regional scale. Forest declines seen in some areas, and occasionally attributed to acidic deposition, are very complicated and poorly understood. Dr. Fox said that there are at least seven hypotheses as to the cause of these forest declines, including ozone damage; direct leaf injury; injury from beetles; increases in nitrogen; and undetected organic contaminants. About 20% of foresters do not even believe air pollution is involved, but rather that the declines are a part of natural forest cycles. The Forest Service is currently involved in whole ecosystem studies to better understand what may be happening to terrestrial systems. These studies involve wet and dry deposition, including aerosols, and focus on both direct effects on leaves and indirect effects on nutrient cycling and water system effects.

Dr. Fox closed by again encouraging Wyoming to cooperate with the Forest Service and EPA in developing air quality models, and allowing models to be refined on applications within Wyoming.

(Note: Dr. Fox prepared a document on issues and priorities for the Coordinating Committee, which is included in the meeting summary for July 27, 1986.)

Dr. Alan Galbraith

Bridger Teton Nation Forest
U.S. Forest Service
Jackson, Wyoming

Testimony given on July 22, 1985.

Dr. Galbraith primarily discussed the monitoring program initiated by the U.S. Forest Service in the Bridger Wilderness Area in the Wind River Mountains two and a half years ago. Because of energy developments southwest of these mountains, and requirements of the Clean Air Act, this program was developed to ascertain what effects, if any, these energy developments might have on the Bridger Wilderness Area. One aim of the program is to establish baseline environmental conditions existing in sensitive parts of the wilderness area, especially in aquatic systems. The Wind River Mountain Range is potentially sensitive to acid deposition because the underlying rocks are very resistant to weathering. As a result, the lakes in the range have very low alkalinities, that is, abilities to buffer incoming acids.

In addition to potential contributions by local sources, Dr. Galbraith suggested that, because of airflow patterns from the southwest, the Los Angeles basin and Salt Lake City areas potentially contribute to air pollution and acid deposition in the Wind River Range.

As a part of the Forest Service monitoring program, researchers collected snow core samples to assess accumulations of chemicals in the snowpack. Data from the first year showed an average pH of 4.8-4.9 with individual snowstorms having pHs anywhere from below 4.0 to 6.5. Approximately 100 lakes have been surveyed, some just once, and some up to three times. The average alkalinity of the lakes was 60-90 ueq/l, with one as high as about 165 ueq/l and one as low as 10 ueq/l. Dr. Galbraith pointed out that these are all below the alkalinity level of 200 ueq/l that the U.S. Environmental Protection Agency (EPA) suggests to indicate sensitivity to potential acid deposition.

Stream bottom insects, zooplankton, and adult mayflies have been collected and identified as possible early indicators of acidification. Results from

Scandinavia suggest that a small shift in pH could result produce a substantial decline in total numbers of organisms even at the higher pHs that wouldn't necessarily kill fish.

Sediment cores have been collected from three of the monitoring lakes, hoping to reconstruct the chemical history of the lakes through analysis of heavy metals and diatom content. Bedrock and soil chemistries are also being analyzed. The geologic makeup of the area is granite and metamorphic rock, rock with very low potential for weathering rapidly enough to provide adequate buffering for excessive incoming acidity. Dr. Galbraith emphasized that soils are important as a primary defense against acidification through their capacities to absorb, retain, and neutralize acids or other pollutants. However, high alpine soils are naturally acidic, have very low buffering capacities and, therefore, are limited in their protective capabilities.

Samples of lichens have also been collected from the Bridger Wilderness area. Lichens are of particular interest because they do not obtain their nutrients from soils, but from the atmosphere. In the process, lead and other pollutants tend to accumulate in their tissue. What has been found in these analyses is that the lead content of the lichens increases with altitude, reaching levels three times higher than the lead content of lichens collected in Colorado at approximately the same elevation. Researchers have suggested that the increased lichen lead contents with increased altitude may result from increased snowfalls. Since lead is strictly a cultural pollutant, lead content in the lichens suggests the existence of polluted air in the Bridger Teton Wilderness area. The average annual precipitation pH in the area is estimated to be about 4.6 to 4.7, based on a NADP collection site near Pinedale.

Although all of the lakes and streams have low alkalinities, pHs are still in the 6.5 range and the waters still maintain positive alkalinities. Unfortunately, because of imprecise measuring and methods that are not easily compared to present day methods, comparison of current data with historical data is not possible, preventing researchers from assessing long-term changes in the environment.

Dr. Galbraith stressed that there is a substantial cause for concern about acidity in the wilderness areas. This is demonstrated by the example of snow meltwater in Colorado with low pH that depressed pHs in lakes receiving it. Such event were some of the first observations made by the Scandinavians before lakes were substantially affected due to acidification. Dr. Galbraith suggested that such spring depressions of pH due to snowmelt are a sign that we should become increasingly concerned about high mountain areas, especially the Bridger Teton Wilderness Area, where lakes may be near the threshold level for acidification to occur.

During the questions it was noted that pure rainwater would have a pH of 5.6. In Wyoming, much naturally occurring calcium and magnesium is contained in rainfall due to dusts from the desert basins. So the pH of natural rainfall in this area may actually be higher due to buffering effects from the calcium and magnesium. During one precipitation event a pH of 6.5 was measured, which Dr. Galbraith thought may have resulted from a storm originating in the Rock Springs area at a time when there was much atmospheric dust from the trona industry. For storms in the middle of the Pacific, pH values range from 5.4 to 5.6. 5.4 is also the value found in glacial corings in Greenland and Antarctica from 1,000 years ago.

Dave Park asked about the relationship between lake turn over and spring runoff. Lake waters stratify because of temperature differences through the vertical water column. Because water is most dense at 39^{o}F, when colder (32-38^{o}F) snowmelt waters enter lakes they tend to be less dense than lake waters, thus they tend to flow across the surface layers of the lake and exit the lake without mixing. Because fish can escape to deeper waters, they may not be exposed to acid shock, but plankton and organisms that live only in the surface layer would be exposed.

<u>Galbraith Testimony given on March 5, 1986.</u>

Dr. Galbraith discussed the Forest Service's research on a watershed in the Wind River Mountains and its sensitivity to potential acidification. He stated that sulfate and nitrate ions, especially sulfate ions, are the primary causes of acidification. While, he has found high sulfate concentrations in precipitation the Wind River Mountains, he has not found a pH reduction in surface waters. This may be because the surface water measurements were not taken at critical periods for potential pH depression, such as during snowmelt and rain storm events. He has found the highest concentrations of sulfates and nitrates in precipitation during the winter.

Dr. Galbraith explained that watershed processes can buffer the acidity related to deposited sulfate and nitrate ions. In other parts of the United States, vegetation, soils, and bedrock are important sources of buffering and neutralization. However, watersheds in the Wind River Range have little vegetation, litter, or soil, thus are poorly buffered. In addition, the bedrock geology of the Wind River Mountains has little ability to neutralize acidic water because the rocks are low in carbonate and are resistant to weathering.

He said that in some systems bacterial activity in lake sediments can reduce lake acidity, and this can be one of the more important buffering processes. Currently, it is unknown whether bacteria in lake sediments in Wind River lakes can contribute to reducing acidity. Buffering of acid by dry and wet materials in the atmosphere can also be important, but the importance of this source of buffering in the Wind River Range is unknown. He emphasized that currently there is not enough information to determine whether acidification or reduction in buffering capacities has occurred in the Wind River lakes.

Dr. Galbraith suggested that the Wind River Mountains are very similar to acidified areas in Scandinavia. In fact, lakes in the Wind River Range may even be more sensitive to acidification. Due to the poor soil and vegetation development, the Wind River Mountains are probably more sensitive to potential acidification than the Adirondack Mountains. Therefore, acidification could occur with deposition concentrations lower than those found in the Adirondack Mountains. Presently, the Wind River Mountain Range receives one-fourth to one-third the amount of acid materials in depositions that the Adirondack area receives.

He explained that the rate at which lakes acidify can vary. If acid deposition were to increase, lakes located at the highest elevations, surrounded by little or no vegetation, could acidify rapidly, whereas others at lower elevations might acidify in two or three years. A change in stream insects, zooplankton, or surface water alkalinity could warn of increasing acidification. Dr. Galbraith further noted that acid deposition affects terrestrial and aquatic systems differently; an area with sensitive vegetation may not have sensitive lakes and vice versa. Thus, an impact observed in one system does not necessarily indicate an eminent change in the other.

He recommended that Wyoming support research directed at determining rates of geochemical weathering. Data gathered on watershed processes in other granitic mountains, such as those in Colorado, Montana, or Washington, could be reasonably applied to Wyoming watersheds. In conclusion, he recommended that the State government take a more active role coordinating the various research efforts within the State.

Dr. James Gibson

Coordinator, National Atmospheric Deposition Program
Natural Resources Ecology Laboratory
Colorado State University
Fort Collins, Colorado

Testimony given on September 11, 1985.

Material supplied to committee to support his testimony:
- map of NADP sites.

As coordinator for the National Atmospheric Deposition Program (NADP), Dr. Gibson discussed NADP, their sampling methodology, and some of their collected data. NADP's major function is operation of the federal monitoring network, the National Acid Precipitation Assessment Program (NAPAP), which was initiated in 1982. The program was designed to monitor acid depositions and their effects on vegetation and surface waters. The program network had many participants, including the U.S. Geological Survey, the U.S. Forest Service, the U.S. Park Service, and the Bureau of Land Management.

Although acidic deposition includes a number of components, he explained that only wet deposition is measured at the NADP sites because of the difficulty and expense involved in measuring dry and gaseous components.

When designing wetfall monitoring programs, such as used by NAPAP, important considerations include sampling frequency, choice of sample sites, and quality control. Sampling frequency depends on the objectives of the project. To investigate atmospheric chemistry, source-receptor relationships or individual storm events, samples need to be collected at least daily, which is very costly and labor intensive. When assessing long-term trends and major environmental effects, rainstorm or snowstorm events are generally not of individual importance, so weekly sample collections are usually adequate. Some objectives underlying NAPAP's selection of sampling sites were to identify and characterize regional patterns of deposition and to obtain data that could be extrapolated to other areas. To meet these objectives, sampling sites were located in open rural areas that would not be affected by nearby pollution sources or by larger urban pollution sources.

Bulk collectors are used for weekly sample collections that include both dry and wet depositions. Dr. Gibson stressed that quality control is very important in analyses of precipitation samples. At NADP sampling sites, pH and conductivity are measured both in the field and in the lab for quality control purposes; sample handling is minimized to prevent contamination. All samples collected from NAPAP sites are sent to a single laboratory, the Illinois State Water Survey laboratory, for analysis.

The cost of a standard NADP site starts at about $5,000 and increases if power or basic structures are not available. Basic operation of the site for a year, including weekly sampling and analytical costs, also runs about $5,000.

A number of parameters are measured in each sample, including acidity, sulfates, nitrates, hydrogen ion, ammonia, and calcium. Sulfate and nitrate concentrations are emphasized because they are the major factors contributing to pollution in atmospheric deposition and environmental acidification. For example, hydrogen ions associated with sulfates are primarily credited with acidification of surface waters, while nitrates are hypothesized to be a primary cause of forest declines.

Data from the program show that the highest deposition rates for sulfates and nitrates occur in the East, where emissions are highest. Nitrate concentrations also tend to be high in the West. Calcium concentrations are generally higher in the West than in the East. Ammonia concentrations also tend to increase from the East to the West, possibly due to agricultural influences. One year's data from two sites in the Rocky Mountain National Park, 7 miles apart and 3-4,000 feet apart in elevation, show that deposition concentrations were similar between them, but that precipitation volumes were two-times greater at the higher elevation.

Currently, there are eight NADP sites in Wyoming: one in Yellowstone National Park, four in or near the Wind River Range, two in the Snowy Range of the Medicine Bow Mountains, and one near Newcastle. The pH of natural rainfall in Wyoming is about 5.2. Alkaline dusts appear to heavily influence the pH of rainfall in the State.

For comparison purposes, deposition concentrations measured in the southern hemisphere are assumed to be natural and unaffected by pollution sources. Initially the pH of natural rainfall was thought to be around 5.6, but in the southern hemisphere its range was from 4.8 to 5.2. This suggests that the pH of natural precipitations may be in this range, rather than pH 5.6 as previously thought.

Dr. Gibson presented data from another study showing that sulfate concentrations in the east are about 16 times as high as those found in the southern hemisphere, indicating the presence of anthropogenic sources. However, as one moves towards the West, sulfate concentrations drop off rapidly, possibly due in part to relatively clean air masses from the Pacific Ocean, plus higher levels of calcium and alkaline materials from dust. For example, acid deposition levels in Yellowstone and Glacier National Parks are equal to those found in the southern hemisphere. However, southwest U.S. areas show higher levels of sulfur and acidity, which are probably due to smelter emissions. In the west, nitrate levels tend to be elevated near urban areas such as Denver.

In Scandinavia soils are thin and lakes have low alkalinities, similar to conditions in the West. Data from Scandinavia show that a deposition rate of 20 kg/hectare of sulfate is the critical level at which lakes begin to acidify. In comparison, Dr. Gibson said that the eastern United States receives approximately 30 kg/hectare of sulfate deposition, while the West receives about 4-5 kg/hectare. While it has been surmised that this lower deposition rate in the West results from reduced smelter activity, Dr. Gibson noted that nitrates, which are not contributed by smelters, show a similar pattern.

Dr. Gibson said that no reliable methods currently exist for measuring dry deposition. One technique currently used is the surrogate surface method. However, it is not very accurate, as different surfaces have different collection efficiencies. An appropriate surrogate surface has not been devised that matches conditions in the environment. Another method is to calculate dry deposition from the deposition flux and the ambient air concentrations. The National Oceanic and Atmospheric Administration is developing a system to continuously measure ambient air concentrations of nitrogen and sulfur compounds, but not ozone. Even if site conditions were ideal, the estimated error margin for most components using this method are ±30%, deposition velocity measurements could vary by ±50%, and small particulate and aerosol measurements could vary by a factor of 2. So this method, too, will only provide an indication of dry deposition patterns. It costs approximately $10,000 per site annually.

NAPAP is setting up a 30 station network in the east to measure dry depositions. This equipment will cost approximately $70,000 per site, and each station will operate seven days a week; operational costs could run well over $10,000 per year. The program has been criticized because unimproved methods will be used and there is no guarantee, despite the cost of the project, that resulting data will be any better than gathered by other techniques presently used.

During the question and answer period, Dr. Gibson said that there is still much contention regarding source-receptor relationships. Wind patterns are not necessarily as consistent as commonly suggested, plus critical storm events come from all directions.

Regarding NAPAP's focus on monitoring in the eastern United States, Dr. Gibson said that western sites were excluded from the planned $70,000/site dry deposition monitoring network because emphasis has shifted from research on long-term effects at a national level to generating data for modelers. Randy Wood pointed out that of NAPAP's total budget of $88 million, $87 million was dedicated to the East, leaving $1 million for the West with much of this going only to California.

In response to a question from Randy Wood, Dr. Gibson stated that measuring "occult" or cloud droplet deposition is also very difficult and the numbers produced by current collecting devices are very hard to interpret. However, research has shown that 80% of the moisture received by some vegetation comes directly from cloud water, which can contain chemicals at 10-times rainwater concentrations. As a first step, he suggested that an expert on mountain meteorology should determine the actual volumes of "occult" deposition intercepted by natural surfaces, such as vegetation or rocks.

Dr. Michael C. Grant

University of Colorado
Boulder, Colorado

Testimony given on September 11, 1985.

Material supplied to the Committee in support of his testimony:
- reprint on the 40 site, one year study.

Dr. Grant initiated a watershed study in 1975, originally designed to investigate how nutrients are conserved and released in watersheds. The study site is located at 9600 feet on the eastern slope of the Rocky Mountains, about 50 miles northwest of Denver. Samples are collected weekly at a single site, using bulk collectors for accumulating both wet and dry depositions. For each year during the first three years, an increasing percentage of samples had pH values less than 4.5. Because of this increase, the study was altered to emphasize acidic depositions. In the fourth year of the study, a second site was added. After four years of monitoring at both sites, results between the sites were so consistent that collections at second site was stopped.

The first eight years of data from the study show that there is a great amount of variation in precipitation chemistry from week to week. Based on these data, Dr. Grant concludes that there is a statistically significant, but very slight trend of decreasing pH over time. He emphasized that although this trend is small it may be very important.

Dr. Grant reviewed data from a study funded by the Colorado Legislature through the Colorado Commission of Higher Education. This study was a one year study to establish bulk collectors and collect data once a week from a 40-site network. This allowed examination of spatial questions such as the difference between mountains and plains, or between urban and non-urban areas.

They found that the greatest volume of precipitation occurs in the southern part of the state in the San Juan mountains, while lowest precipitation volumes occur on the western slope, eastern plains, and highest mountains. Ion concentrations showed that some of the high levels of acidic deposition observed can be attributed to corresponding high precipitation volumes. Dr. Grant said they do see a trend of increasing acidity due to both greater acid concentrations and deposition volumes at higher altitudes. Part of this is due to an increase in amount of acidic components, but some is due to a reduction in basic neutralizing compounds. They also found that at any given elevation, the pH values in Colorado lakes tend to be quite variable.

Data from this study also showed that depositions in mountain regions tend to have pHs of about five and the plains regions tend to be in the high fives and low sixes. Nitrogen concentrations were significantly higher in the high country due to upslope winds from urban areas. Sulfate patterns over the state do not show an urban effect.

Dr. Grant concluded that many characteristics common to higher elevations make these areas most susceptible to acidification. These characteristics include thin soils, low base saturation capacities, greater levels of precipitation, and spring pulses of melt water from accumulated snow pack.

Randy Wood asked if they had examined point-source relationships, including temporal variations in emissions and meteorological conditions. Dr. Grant said that meteorologists told them that the time span of a week between collections was too long to track individual storms or emission patterns. They did calculate, however, that total amounts of sulfate deposited in the state were nearly equal to the calculated discharge within the state.

Dr. George Hidy

Desert Research Institute
Reno, Nevada

Testimony given on September 11, 1985.

Dr. George Hidy provided a historical background of acid deposition. The phenomenon of acid deposition was first recognized in England in 1860, at a time when England was heavily industrialized and sulfur emissions were probably much greater than emissions today. In late 1960s and the early 1970s the environmental consequences of acid deposition became increasingly recognized and studied. The initial focus of research was mostly in Scandinavia, where aquatic ecosystems have been clearly damaged by acidity. Canada and the United States joined in studying this problem in the late 1970s and early 1980s. Recently, Dr. Hidy said, areas in the western United States, particularly at high altitudes, also have been recognized as having biogeochemistries similar to sensitive areas in eastern North America and in Europe. In Wyoming, areas that are ecologically and geochemically sensitive to acid deposition exist in the Wind River Range, the Grand Tetons, and Yellowstone National Park.

With our increasing knowledge about acid deposition, the problem has emerged as much more complex than originally anticipated. Relationships between deposition chemistry and biological systems or material damage have proven very complicated and difficult to understand. To discern changes in the environment due to acidic deposition, it is necessary to study the same ecosystem or environmental process for many years. Good data from these kinds of ongoing studies do not yet exist. This compounds the problems faced by current researchers in trying to accurately assess the effects by acidic deposition.

In addition, acid is only one of many chemical constituents in atmospheric deposition that can produce environmental effects. Others include sulfur and nitrogen oxides, calcium, magnesium, potassium, and sodium. Consequently, sorting out the effects by the different chemicals and determining individual mechanisms of atmospheric deposition are also more complex than initially thought.

Two forms of deposition besides precipitation contribute significantly to environmental acidity, especially in the West. They are dry deposition and occult deposition. Dry deposition occurs both as gases and as particulate matter in the atmosphere. Gaseous sulfur and nitrogen oxides can adsorb onto vegetation and soils, becoming acidic with the addition of moisture. Similarly, particulate matter can be intercepted by vegetation or fall out to the ground, also potentially generating acidity. Occult deposition occurs as the condensation of clouds and fog and the chemicals they contain. This may be especially important at high altitudes. Only acidic precipitation (rain or snow) can be measured easily and characterized chemically. There is no consensus on methods for measuring deposition rates and chemical parameters in dry or occult deposition. So researchers are able to reliably assess only one of these kinds of the deposition occurring in the West.

Dr. Hidy outlined three sources of acid deposition of concern in Wyoming. The first is background levels that occur naturally. In Wyoming, these probably contribute very little to the overall acidity. The others include in-state and distant out-of-state industrial sources, especially smelters, power plants, and large urban regions. Within Wyoming, the actual ambient concentrations of sulfur and nitrogen oxides are very low, often an order of magnitude less than the lowest concentrations in remote areas of the eastern United States. Conditions in the West are actually very pristine with respect to acid deposition. Researchers cannot, according to Dr. Hidy, currently identify any environmental damage or change in the intermountain West due to acid depositions. Present deposition levels to this area may effect only small perturbations in nutrient budgets for ecosystems, unlike in the East where deposition effects major ecosystem changes. The uniformity of regional deposition rates and patterns is another characteristic peculiar to the West. Even when downwind sources are expected to influence an area, gradients are surprisingly small. However, little is known about actual source contributions to problem areas. Most predictions are made based on modeling and there has been much contention about the reliability of models.

In Wyoming, because of the low population density, small communities, geography, and topography, the primary concern about acid deposition is potential effects in wilderness areas and national parks. Dr. Hidy cited that the first, most widely publicized effect of potential concern in the State is acidification of surface waters and impacts on aquatic biota. The second potential concern is forest deterioration. Because very little is known about how and why forests are changing, and how much of this change is attributable to environmental pollution, it is difficult to make predictions about potential forest effects. It appears as though Wyoming could tolerate continuing industrial development governed by current regulations.

Dr. Hidy questioned whether Wyoming needed further regulations specific for acid depositions. He suggested that two opposing forces exist within the State. One is typified by the U.S. Forest Services's position that any change or impact due to acid deposition poses a threat to wilderness areas and no change can be tolerated. The other is typified by the State's position, through the Air Quality Division and Environmental Quality Council, that a determination of actual change or damage is necessary before the State can constrain permitted emissions.

Dr. Hidy suggested that the Committee keep in mind the three elements that generally go into a standard-setting process at the national level. None of these, he feels, are adequately satisfied for additionally regulating potential acid depositions in Wyoming. First, clear evidence of widespread effects must be established. Second, knowledge of source-receptor relationships must be present. And third, some criterion for a threshold of damage and an adequate measuring technique to measure progress must be available. Dr. Hidy felt that existing air quality laws in Wyoming are sufficient for controlling the problem for the near future.

Dr. Hidy agreed that continued monitoring and interpretation of results are very important. But along with this kind of a program are a number of things that need intensified research effort including the following:

1) measuring cloud chemistry and precipitation chemistry with altitude;

2) measuring dry deposition or at least measuring ambient concentrations of acid forming materials;

3) surface water monitoring, including definitions of important monitoring parameters (e.g., the watershed, bedrock and biota); and

4) defining source-receptor relationships.

Dr. Hidy also strongly emphasized the need to critically evaluate research findings before accepting them.

During the question and answer session, he was asked if effects due to acid deposition have been documented in the Los Angeles basin. Dr. Hidy said there are pollutant effects on the forests in the San Gabriel Mountains surrounding Los Angeles, but that these appear to be primarily ozone-produced effects. The only actual effects from acid deposition that have been even modestly documented, Dr. Hidy said, are crop and materials damage due to sulfur dioxide fumigation by an upwind chemical plant. Material damage is, he contended, strictly an urban problem that cannot be compared to wilderness effects.

He was also asked if air quality improvements had been made in Europe. According to Dr. Hidy, improvements have been slow. In 1972 Sweden called an international conference in an attempt to convince European nations to reduce sulfur dioxide emissions. However, because of economic factors, only about half agreed to any reductions. A similar conference was held in 1982, which was more successful. Since then, the Europeans have been trying to implement a scheduled program to reduce sulfur dioxide and hydrogen oxide emissions through the mid-1990's. Their principle method for reducing emissions has been by employing scrubbers. Another more recent incentive to control pollutants is forest damage observed in Germany over the last few years. These effects appear primarily due to atmospheric NO_x. In efforts to control at least part of this problem, the German government now offers discounts to citizens buying new cars having emission controls. While improvements are occurring, Dr. Hidy said there is still a long way to go.

Hidy Testimony given on September 11, 1985.

Material supplied to Committee in support of his testimony:
- Reprint describing analysis of historical data
- Reprint containing a discussion on source-receptor relationships

Dr. Hidy began by explaining that there are three components to atmospheric deposition: 1) wet deposition, e.g., snow or rain; 2) dry deposition, e.g., particles and gases absorbed onto surfaces; and 3) "occult" deposition, which includes the interception or deposition of fog and cloud moisture on surfaces. While wet deposition is the component customarily measured, Dr. Hidy believes that all three components need to be monitored to make correct management decisions. A total deposition study by Lewis and Grant has shown that dry deposition is significantly larger than the wet deposition in Colorado. Currently, established methods exist for measuring wet deposition, but there are no standard methods for measuring dry or occult depositions. He also emphasized that there is much more to atmospheric deposition than just acidity. Chemical constituents in snow and rain water including sulfate, nitrate, ammonium, and basic cations from soil dusts.

Establishing baseline data characterizing the chemistry and quantity of deposition in Wyoming requires data on wet, dry, and occult depositions from representative monitoring stations. Collected data should include measurement of meteorological conditions, quantity of precipitation, and the chemistry of acidic precursors, gases, particulate matter, and ozone. Monitoring stations should be established in great enough numbers to characterize spatial and temporal variabilities in deposition rates. For example, in southwestern Wyoming 3 to 6 stations located 50 to 100 kilometers apart would be necessary. To insure comparability with other or future data sets, data would have to be collected over several years and meet quality control standards. That is, they must be uniformly calibrated against known standards and be reliable.

Dr. Hidy stated that the only deposition data currently available for Wyoming are those collected over the past several years from the Pinedale and Yellowstone areas. These data can be used to characterize western Wyoming and its relationship to surrounding states. In general, pH values of rainwater in western Wyoming are less than what may be expected for these very remote areas, ranging from 5 to 5.2. Concentrations of sulfate in rainwater in the area are about 1 milligram/liter and concentrations of nitrates are about the same by mass. Although spatial differences in deposition of acidity, sulfates and nitrates tend to be very small in the West, relatively higher levels are found in Colorado, with slightly lower levels in Wyoming, and lowest levels in Montana and Idaho. He concluded that there is no evidence of any local industrial impact, based on monitoring data from Wyoming.

Dr. Hidy stated that sulfur deposition rates in the West are about one order of magnitude lower than in industrial areas of the East. One reason for this is that precipitation volumes are much lower in the West, consequently there is less deposition in general. Sulfate and nitrate concentrations in western precipitation are somewhat lower than values in the East, but not as low as is sometimes thought.

Dr. Hidy then reviewed some of the problems and techniques in measuring occult, rime and dry deposition. Research experience with occult deposition is very limited. There is evidence in the East that clouds have higher concentrations of acidic components than precipitation. This makes sense, Dr. Hidy said, because of the dilution effect that occurs as cloud droplets actually grow into rain drops and fall out. There is also evidence that rime ice is different from other ice or snow. Rime ice is formed by freezing super-cooled water into ice crystals on surfaces such as telephone wires or trees. Super-cooled water seems to have a greater capacity to assimilate acidic components. Studying rime ice could also produce useful information on the mechanisms involved in acid deposition. Although measuring techniques for rime ice are not well developed and tend to be controversial, one technique is to collect rime ice on a screen and then heat the screen to get the water for chemical analysis.

For dry deposition, Dr. Hidy said direct measurements are very difficult to make and are very dependent on the space around the monitoring station. Dry deposition is made up of both gases and particles in the air, and factors such as aerodynamics, vegetation, and surface characteristics influence how much is actually deposited.

Cloud water is collected for analysis through a technique called the impaction process. When air flows around an object such as a tree or a collection instrument, cloud droplets present in that air do not follow the diverted flow of air around objects. Instead, they continue in their course, colliding with the object as the air moves on. This is called the impaction process. To make these measurements, researchers use a fan to generate an air flow. A problem with the technique is being certain that collection efficiency is optimum and there is no contamination occurring. This is also a technique that cannot be used in wilderness areas because of the lack of power.

As a result of the current monitoring program in southwestern Wyoming, he expects a greatly improved knowledge on the spatial and temporal variability for wet and dry deposition in the Bridger Wilderness. However, there are two key research needs for Wyoming: 1) to accurately measure dry and "occult" deposition, and 2) to determine if there are higher concentrations of acidic components in precipitation at higher elevations. Another important consideration is research into collection of acidic components during the formation of clouds and rain in the atmosphere. This should include determining the point in these processes where most collection of moisture and acid forming materials occur, and how alternative conditions affect the layer where pollution tends to accumulate in the atmosphere. Current hypotheses suggest that polluted air will remain in the lower levels of the atmosphere, actually going around mountains with very small amounts actually passing over them.

Dr. Hidy said that he thought it was realistic to expect to be able to monitor dry and occult deposition in the near future, but he said not to expect very accurate measurements at first. Measuring occult depositions requires a power source such as a battery. He also said that he would expect the mass of dry depositions to high altitude areas in the Bridger and Fitzpatrick Wilderness to be similar to that of wet depositions.

Ron Surdam asked if comparing Wyoming to the East was a very suitable comparison, considering all of their dissimilarities. Dr. Hidy said that there are plans to expand the western measurement programs in California, Colorado, and Utah and that these programs will provide good data and better opportunities for comparisons to Wyoming.

(Note: Dr. Hidy prepared a review and summary document based on previous Committee meetings and on his knowledge of the literature concerning acid depositions. This document was presented and discussed at the July 23, 1986, round table meeting of the Committee. The complete document is also presented in Section 3 as part of the summary for that meeting.)

Dr. Gale F. Hoffnagle

TRC Environmental Consultants Incorporated
East Hartford, Connecticut

Testimony given on September 11, 1985.

Material supplied to the Committee in support of his testimony:
- a set of 5 graphs showing the relationships that he discusses
- an EPA document that evaluates the effect of Arizona smelters on concentrations and depositions in Colorado

Mr. Hoffnagle outlined several important observations he obtained from research done during 1982 and 1983 in the Rocky Mountain region through the National Acid Deposition Program (NADP). Precipitation in the Rocky Mountains did not uniformly increase with elevation or from south to north, as has been theorized. However, there did seem to be a consistent straight line relationship between increasing precipitation and increasing deposition. He noted that the deposition of sulfur versus elevation tends to be fairly uniform, with equal amounts of sulfur deposited at all elevations sampled. Sulfur concentrations tend to be slightly higher in the south, but tends to be uniform south to north.

Mr. Hoffnagle found the relationship between atmospheric concentrations and precipitation concentrations to be most interesting. Concentrations are relatively uniform over a broad area of the Rocky Mountains, suggesting that these are baseline concentrations and are not affected by local sources or by pollutants transported over long range from any particular direction.

He stated that we are trying to protect mostly high elevation areas that have relatively little vegetation available to collect rime ice and other cloud droplet depositions. Hence, rime ice is probably not as hydrologically important as precipitation in high elevation lake systems. The importance of this form of deposition is the potential damage it can cause trees and other vegetation. He believes that at this point in time, potential forest damage is not of concern to researchers in the western United States.

Mr. Hoffnagle said that dry deposition may have no direct effects on western lakes. This is because acidic components in the atmosphere may be balanced and neutralized by the alkaline particles found in the atmosphere throughout the western part of the United States. Hence, it is important to measure the buffering capacity of dry deposition. A suitable surface for collecting dry deposition, he said, is granite. From dry depositions on granite, good estimates of total dry depositions may be obtained.

Randy Wood asked if it was really possible to draw conclusions using data from sites with locations as widely scattered as used in his graphs. Such diverse sites would be influenced by a number of sources and factors. Mr. Hoffnagle said that would be true, if the sulfate concentrations were all from man-made sources. But, he said, such consistent concentration levels across the area imply that the concentrations are the natural background levels, not due to man-made sources.

Testimony given on November 6, 1985

Mr. Hoffnagle first responded to a discussion that followed Mr. Dailey's presentation. In answer to questions about overestimation of deposition by regulatory models used in Wyoming, Mr. Hoffnagle reiterated that protecting the Wind River Range on the basis of "worst case" scenarios also insures that there will not be unforeseen impacts in other areas from the source in question.

Turning to the modeling of atmospheric transport, Mr. Hoffnagle presented a view of the climatology that might be involved in the long-range transport of pollutants to Wyoming from other areas. He pointed out the difficulties in predicting meteorological conditions at the altitudes at which industrial plumes are moving, based on wind vectors derived from ground stations. In modeling work by Draxler and Heffter at the National Oceanic and Atmospheric Administration (NOAA), the western United States was broken into rectangular areas, or "boxes." Each box was based on upper air stations where wind speed and transport height have been measured in the upper atmosphere over five years and averaged. From this data the percent transport from each box to every other box was estimated. The border box, in western Wyoming, receives a 34% contribution from the Salt Lake City box. The model does not take into account actual emissions from each box, so that figure does not imply that 34% of deposition in western Wyoming comes from Salt Lake City, but that air from that area represents 34% of the air in western Wyoming. In general, the majority of incoming air to the western Wyoming region is from the west. Colorado, Idaho, and Utah were indicated to affect the State as a whole. This model also does not estimate atmospheric movement within boxes, only between boxes. Smaller scale models are needed to predict contributions from within each box. Also, the percentage contributions from various boxes to western Wyoming vary little from season to season.

As a consequence of the year-around eastward transport, Wyoming sources do not have much impact on receptors to the west. Mr. Hoffnagle also showed data on the predicted contribution of smelter emissions in the West to sulfur deposition in Sand Springs and Grand Junction, Colorado, figures that can be calculated if the emission figures are known for contributing boxes. He also presented worst case estimates for the future, but cautioned that economics will probably prevent realization of those situations, since the smelting industry is declining in the West. He also cautioned that since SO_2 and NO_x concentrations vary with no apparent correlation to smelter operations, smelters may not be as pertinent to the Wyoming and Colorado area as has been conjectured.

Mr. Hoffnagle felt the NOAA's model was the best available for long range transport modeling. But for southwestern Wyoming, a smaller scale model would be needed, such as the EPA's Mesopuff model. This model has been used in Minnesota and North Dakota and its attributes and shortcomings are well-known. However, this model requires more upper air data than Wyoming is currently collecting.

The relative contributions of inter- and intrastate sources are to deposition in southwestern Wyoming are unknown, but Mr. Hoffnagle suspected that 25-50% of the deposition is from intrastate sources. Tracer studies would be needed to determine the sources of deposition in Wyoming. Scientifically, radiolabeled sulfur studies would be the best method for this kind of study, but public health considerations prohibit this. Other possibilities for tracer materials, such as arsenic, selenium or trace metals, have technical problems at present. Another method for tracing emissions using calcium to sulfate ratios is being considered in Minnesota, and could be an option for Wyoming.

Mr. Hoffnagle expressed his opinion that at present the permitting approach being used by Wyoming is overly conservative, in that it overestimates the actual depositions that will result from a new facility. He felt that deposition studies and terrestrial and aquatic studies should be given priority to ascertain whether or not there is sufficient deposition occurring to cause damage, and then, if warranted, modeling studies could be intensified. For depositions that are already occurring, monitoring is probably a first priority to determine if any problem exists, but that is of little help in the permitting process.

Mr. Hoffnagle admitted that modeling is currently weak but said that it could give indications for some things. There is a lot more to be done in model research, but model development and validation tends to be very costly. He cited one tracer study that was being considered in the eastern United States for model validation which had an estimated cost of between $180 and $200 million. Much more data are also needed for models. Mr. Hoffnagle believes that a lot of money could be spent on modeling with little to show for it. Committee members thought it might be important to spend the money to help prevent usurpation of the available air resource in Wyoming by other states as has happened with the water in the Colorado River.

Dr. Peter B. Reich

University of Wisconsin
Madison, Wisconsin

Testimony given on January 9, 1986.

Dr. Reich stressed that it is necessary to identify and measure atmospheric depositions in Wyoming before their potential effects on vegetation can be evaluated. Acid deposition consists of both wet and dry depositions, including nitrogen and sulfur acids, NO_x and SO_x gases, and other precursors to acid rain. Other pollutants, such as ozone and heavy metals, are often deposited with acid depositions.

He reviewed two investigative approaches, field research and controlled experiments. The main advantage of field research is that it tends to be realistic. Vegetation can be observed in its typical environment, including other vegetation, climate, and soils. Disadvantages of field experiments include, that they tend to be very expensive, that it can be difficult to separate pollutant effects from natural effects, and that good control systems for comparison to the test system are generally lacking. Also, field studies are often too short in duration; for some forest effects it may take several generations of scientists to study one generation of a forest problem.

In controlled experiments it is easier to create test conditions that focus on specific research questions while excluding natural factors. However, it is impossible to know to what extent the resulting information can be extrapolated to the real world. By eliminating or reducing variations in weather, diseases, competition, water relations, nutrition, temperature, other pollutants, and interactions between these and other possible factors, researchers cannot be certain how accurately their controlled experiments reflect reality. Controlled experiments can be also very expensive and too short. In Dr. Reich's opinion, it is best to combine both types of experiments, looking at overall ecosystems, including soil, site, and climate characteristics, instead of simply trying to identify sensitive plant species.

Based on his review of results from field studies, he reported that tree damage has been observed at high elevations, correlating to high levels of pollutants and natural stresses at high elevations. These natural stresses include high winds, infertile soils, extreme temperatures, drought due to thin soils, and drought due to winter desiccation. The extent of the damage is unknown and opinions differ between scientists. In the United States, forest decline has not been observed at low elevations or in non-montane forests. Some believe forest declines may have natural causes, while others attribute it to atmospheric pollutants, including acid deposition.

Ozone has been cited as one possible cause. Ozone also has been found to be present at higher elevations in much greater concentrations than expected, but Dr. Reich did not think that it is causing the forest dieback observed there. He said that ozone would not cause the kinds of symptoms seen. It may be a factor, however, through interactions with other pollutants, or by adding stress to plants, predisposing them to effects from other diseases or insect infestations.

Nitrogen also has been suggested as a causative agent, possibly through over-fertilization. Affected plants have lower concentrations of magnesium, calcium, and other elements, suggesting that these elements are leached from the soil by acid deposition. However, Dr. Reich emphasized, all of these explanations are circumstantial. Nothing has been proven to date. It is his opinion that forest decline is an interaction among all pollutants present at a site plus natural factors; actual causes are site-specific.

Dr. Reich then reviewed results from various controlled, short-term studies addressing effects of ozone and acid rain on vegetation. In these experiments, no interactions were seen between ozone and acid rain. Experimental acid precipitation, ranging from pH 5.6 to 3.0, was not found to affect photosynthesis. Soils were found to be important in determining how plants respond to similar acid rain treatments.

To examine the role of soil, white pine seedlings were grown in five different soils, ranging from pH from 3.9 to 5.5, collected from the Adirondacks.

Increased growth with the acid rain treatment was observed in the seedlings in the high pH soils, probably due to nitrogen fertilization. This eventually could become a problem, though, as studies have shown that plants having high nitrogen levels do not cold harden well and are prone to damage in the winter at low temperatures. Higher levels of nitrogen could also result in nutrient imbalances that could adversely affect the plant. Acid rain may also make heavy metals more available to vegetation, possibly resulting in toxicity. Increasing acidity also caused significant reductions in growth of plant mycorrhiza, soil microorganisms that benefit plants. The consequences of this effect, however, is unknown.

In experiments with ozone, increased ozone caused decreased photosynthesis. Of seven plant species tested, the three crop species showed a much greater negative response to ozone treatment than did the four tree species. One reason for this is that leaves and needles of trees have smaller stomata than leaves of crop species, resulting in less uptake of ambient ozone by trees. Because growth is directly related to photosynthesis, decreased photosynthesis results in decreased growth. Increased ozone was found to increase in mycorrhizal growths, even when effects on plant growth were not evident. But again, their consequences are unknown.

Dr. Reich emphasized that a major problem with most studies is that they are too short in duration to determine the long-term effects of pollution. Because ozone decays and does not accumulate, short-term ozone studies may extrapolate better to the real world. Very little is known about the long-term consequences of other pollutants, including acid precipitation. This leaves a large gap in the understanding of how acid precipitation affects vegetation.

For Wyoming, Dr. Reich recommended more thorough monitoring of atmospheric depositions, ambient ozone levels, and heavy metal accumulations at both high and low elevations. He said that if levels for all pollutants are consistently as low as indicated by existing data, then the potential for damage to vegetation in Wyoming would appear to be negligible. To maintain an awareness of deposition conditions in the State and their potential effects, it is important to continue monitoring throughout the state, and to stay current about recent scientific finding and political developments regarding pollutants of concern.

In response to a question from Jim Barlow, Dr. Reich said that he did not think dusts from valley soils would have much of an effect on what was happening at higher elevations. If the atmosphere through which pollutants travelled were particularly alkaline, though, this could have an effect. He would not place high priority on such research at the present time.

Dr. William Reiners

Department of Botany
University of Wyoming
Laramie, Wyoming

Testimony given on September 11, 1985.

Dr. Reiners discussed how canopy structure influences the capture of materials from the atmosphere through cloud droplet deposition and dry deposition. He outlined the three classes of deposition. The first is wet deposition, which is the transfer of a substance from the atmosphere to the ground via rain, snow, hail, etc.; the second is dry deposition, which is a process of direct transfer of chemical substances from the atmosphere to the ground surfaces; and the third, although frequently included in either of the first two categories, is cloud droplet or "occult" deposition.

Cloud droplets are deposited on surfaces through impaction. Impaction is the process by which airborne particles collide with an object, rather than being carried around it with air current flows. Variables in the process of impaction in nature include wind speed, size of the impacted object, number of cloud droplets per volume of air, droplet size, momentum of the droplet, temperature, time of year, roughness of the vegetative surface, and characteristic size of the canopy elements. The greater the wind speed, the higher the impaction rate and the greater deposition efficiency. Smaller surface areas such as pine needles in coniferous forests, as opposed to larger leaves found in broadleaf deciduous forests, increase deposition efficiencies. In addition, cloud droplets tend to have very high concentrations of chemicals, compared with raindrops or snowflakes, because the ratio of condensation nucleus material to water is much higher in cloud droplets.

Temperature and time of year also influence processes of cloud droplet deposition. In the summer, cloud droplets are deposited on surfaces as droplets of water that can partially evaporate or accumulate and fall to the ground as throughfall. Lichens, because they depend on moisture in the air during the summer, may be useful indicators of cloud droplet deposition in the summer. In the winter, the cloud base tends to be lower, and more in contact with the earth's surface than at other times of the year. Also during the winter, cloud droplets are usually supercooled, so that when they impact on an object they crystallize forming rime ice. Rime ice, which can develop in substantial amounts, has much higher concentrations of chemicals than snow. Rime ice, however, is not the same as hoarfrost, which is formed by the precipitation of ice crystals in still air through the condensation of vapor, instead of water droplets. Dr. Reiners felt that ice in hoarfrost is probably pretty pure, but some researchers believe it may be important component of the deposition process, particularly on snowfields in the Rocky Mountains.

In a New England study on subalpine forests that Dr. Reiners participated in, up to 47% of the total water input and 40% of the total hydrogen ion input was attributed to deposition of cloud droplets. This finding emphasizes that deposition via cloud droplets can be very important. Dr. Reiners felt that this is true for the Wyoming mountains and should be considered in any monitoring program.

Dry deposition can be separated into two classes: gases and particulates. Gases of concern include ammonium, ozone, SO_2, NO_x, and hydrocarbons. Particulate matter includes soil particles and cloud or mist droplets. The size of a particle is one of the main factors affecting its deposition. Large and very small particles deposit efficiently; they are removed from the atmosphere rapidly when in contact with vegetation. Medium-sizes particles, such as ammonium and sulfate aerosols 1 or 2 um (micrometers) in diameter, are not deposited very efficiently and may remain in the atmosphere for a long time. Thus, in sampling for aerosol content, it is important to the know size distributions for the aerosols to establish necessary deposition velocities.

Dry deposition may be viewed as being a series of steps that particles pass through before being fully deposited. The first is transfer through the turbulent boundary layer between the atmosphere and the canopy. This is the mixing of air as it moves across mountain ranges, and as it mixes down into the vegetation. This rate depends on wind speed and roughness of the canopy. Second, once within the canopy, the gases or particles have to contact a canopy element, such as needles or leaves. Another boundary of resistance is encountered here, which depends on viscosity of the air and the cushion it generates surrounding the complexity of the branches, etc. Gases and small particles can diffuse across this layer; larger particles cross the layer by the impaction process. Third, the particle must stick to the surface. This depends on whether the material is particulate or gaseous, what the gas is, whether canopy materials are wet, and, for some gases, whether the stomata on plant materials are open. At any of the three steps, the dry materials may re-enter the air stream, or the concentration of gases or particulates may build up in the canopy causing no further net movement into the canopy.

Dr. Reiners said that potentials for dry depositions can be appraised by characterizing the resistance of a canopy, often viewed as a series of resistances. The number of canopy resistances defined in the series depends on the type of system (forest canopy, sage brush canopy, grassland canopy), how familiar a researcher is with the system, how well it is has been studied, and the kind of detail desired. Factors to consider when characterizing resistance primarily include wind speed and the height or roughness of the canopy. The slower the wind speed and the lower the vegetation, the greater the resistance, hence, the less the dry deposition rate. When the stomata of the vegetation are open, deposition of some gases can be three-times faster than when the stomata are closed. When the plant surface is senescent, like most of the grasslands in Wyoming during much of the year, resistance is very high. However, if the surface is wet, whether or not the plant is senescent, resistance is very low and deposition of dry materials is very high. Dr. Reiners noted that it is harder to estimate deposition velocity for gases than for particles.

Dr. Reiners concluded his discussion by listing three priorities for Wyoming. First, monitor the chemical composition of gases and particles in the air and classify particulates as to size. Second, gather information on above-canopy wind speeds in several layer, in and above various different vegetative types. Third, develop a set of approximations for dry deposition based on various conditions for the major vegetative types in Wyoming, including alpine tundra, alpine forests, sagebrush, and grasslands. With such relationships researchers would be able to estimate masses of dry deposition impacting individual areas, and then relate these estimates with actual measured concentrations. Such relationships would provide investigators with better estimates of where dry depositions are likely to become a problem.

Dr. Frank Sanders

Wyoming Water Research Center
University of Wyoming
Laramie, Wyoming

Testimony given on March 5, 1986.

Dr. Sanders presented his views on the current situation regarding acid deposition and acidification in Wyoming and discussed the needs for future study. He first asserted that the most important issue for Wyoming is to determine whether impacts will occur at current levels of acid depositions, or will likely occur at predicted future levels. He suggested that baseline data on precipitation chemistry and on sensitivities of aquatic resources to acidification are required to assess this issue. He stated that at present, the distribution of acid sensitive resources in the State is not completely known. Most available data are from the Yellowstone and Wind River areas; more data are required from other potentially sensitive areas, including the Big Horn, Bear Tooth, Snowy Range, and Sierra Madre Mountain Ranges. He suggested that the distribution of acid sensitive areas estimated by the Environmental Protection Agency for Wyoming are crude and probably inaccurate.

Dr. Sanders said that there are nearly 500 lakes in Wyoming at elevations considered susceptible to acidification (>7500 ft), with known trout populations. Historically, salmonid populations have not been present in most of these lakes and very little is known about the current state of these fish populations.

He concluded, based on his review of available data for Wyoming, that there is no evidence of acidification in the State due to acid deposition. However, many areas in the State have waters with low alkalinities that are very sensitive to potential acidification. In addition, acid deposition phenomena at lower elevations have been recorded in Wyoming, although there are few data available for evaluating possible effects of seasonal water chemistry changes such, as snowmelt and rainstorm events. There may be problems in the future. He is currently investigating snowmelt chemistry at high elevations in the Snowy Range Mountains, where he has found pH values depressed to approximately

5.0 in snowmelt waters. He stated that these low pH values may be natural and not due to acid deposition.

Dr. Sanders recommended that Wyoming establish a small research and monitoring program that could receive supplemental funding from federal agencies or industry. This program should inventory sensitive resources, evaluate baseline conditions, and monitor selected sites. Research and other efforts in Wyoming should be coordinated by a committee or person closely associated with the University of Wyoming, and modeled after successful coordinating groups in other states.

Ms. Anna Schoettle

Rocky Mountain Forest and Range Experiment Station
U.S. Forest Service
Fort Collins, Colorado

Testimony given on January 9, 1986.

Ms. Schoettle, a plant physiologist with the U.S. Forest Service, discussed her work with a U.S. Forest Service project investigating potential effects of acid deposition on alpine and subalpine ecosystems. The Forest Service is especially interested in air pollution effects research because the Clean Air Act mandates that the Forest Service, as the federal land manager for wilderness areas, is responsible for protecting Class I areas from any adverse impacts caused from air pollution. The Forest Service has defined air quality-related values that include both biological (terrestrial and aquatic) and physical (soil, water, air visibility, odor, geological formations) components. While there is currently no evidence of damage occurring in the Rocky Mountain region from air pollutants, the Forest Service has initiated a research project, "The Effects of Acid Deposition on Alpine and Subalpine Ecosystems," in an effort to identify potential effects by pollutants on these air quality-related values.

From this project, Ms. Schoettle said they hope to develop baseline data on the ecology and processes that occur in sub-alpine and alpine ecosystems in the West. They are in the process of choosing a representative site for study. The alpine and sub-alpine interface is particularly important because it is the upper limit of environmental tolerance for tree growth. Trees along the timberline are already under extreme environmental stress. Consequently, any added stress, such as atmospheric pollutants, could severely impact species living at this interface.

In addition, Ms. Schoettle said, they intend to conduct a number of dose-response studies, using both wet and dry materials applied to alpine and sub-alpine vegetation types. The sub-alpine vegetation is dominated by Engleman spruce and sub-alpine fir; the sensitivities of these species are currently unknown. For alpine plants, the below-ground biomass can reach as much as 20 to 25 times the mass of the above-ground leafy portion. These large energy reserves help the plants resist short-term stress. Alpine plant communities are especially important in the Rocky Mountains because of their role in maintaining water volumes and water delivery from alpine areas. Because lichens have been shown to be sensitive indicators of air pollution, they will also be included in the study.

It is not currently known if high alpine sites in the West are at risk due to deteriorating air quality. Few data exist on air or precipitation quality in high elevation areas, and most National Atmospheric Deposition Program deposition collectors have been established at lower elevations. In addition, there is very little experimental data demonstrating actual adverse effects of wet deposition on vegetation. But it is difficult to draw conclusions from short-term experiments because impacts may be the integrated result of many years of deposition. For dry deposition, however, such as aerosol or gaseous pollutants, adverse effects on vegetation have been noted in short-term experiments.

Data from an alpine research area at Niwot Ridge, just west of Denver along the front range of the Rocky Mountains, indicate that SO_2 and NO_x concentrations are very low. However, during the summer, ozone at this site can average 55 parts per billion, a concentration shown to reduce productivity and growth in crops. Ms. Schoettle said that it is not clear whether this elevated ozone level is due to the site's proximity to Denver or is indicative of air quality in alpine areas. Alpine communities in the study area are also subjected to augmented chemical inputs of acidity, sulfate, and nitrate. Although the data are still being analyzed, there appears to be very little effect from the chemical additions. This study is ongoing, so they hope to evaluate long-term effects as well as short-term.

Because Wyoming has many high elevation watersheds that are at potential risk due to atmospheric deposition, Ms. Schoettle recommended further monitoring of air quality and wet deposition at high elevations. She suggested the State try to coordinate with Federal efforts to allay expenses.

Dr. Larry Svoboda

Region VIII
U.S. Environmental Protection Agency
Denver, Colorado

Testimony given on November 6, 1985

Dr. Svoboda said EPA Region VIII's emphasis in the western United States is on preventing damage to ecosystems. To date, no evidence indicates that damage has occurred, but that may be due to a lack of data. Without more information, it is impossible know whether there is a problem in the West.

The EPA is promoting and developing research and monitoring programs that will help achieve four basic needs. The first of these is research support for the PSD program and other regulatory programs to facilitate better decision-making on both the local and national level. This research includes development of better regulatory mechanisms for the control of atmospheric pollutants, and better determination of the degree of control needed. Through a policy of allowing no impact in Class I Wilderness Areas, the Clean Air Act provides Wyoming with a way of regulating acid deposition at a local level. Decisions being made under the auspices of this program, however, are being made with an inadequate scientific base. Dr. Svoboda cited a recently issued Chevron oil shale PSD permit. Because the only information available was crude modeling showing a potential for an acid rain problem in a nearby wilderness area, the USFS determined that there would be impacts and conditions were included in the permit requiring extremely costly nitrogen oxide controls.

The second research need is a national assessment of the acid deposition problem. For both scientific and political reasons, current research and attention has focused on the problem in the northeastern United States. EPA Region VIII has been working to increase research programs and funding in the western United States, at least to provide a screening effort in the region.

The third need is basic research. Such research includes improving the measuring and monitoring techniques for both wet and dry depositions. Basic research is also needed to better define source-receptor relationships. This can include defining and mapping sensitive areas based on geology and precipitation measures. Also needed is determination of how meteorological events, such as wind patterns, influence depositions. For a number of years, the EPA has been developing a regional acid deposition model. Unfortunately, there are few good tools available for developing such models; the cost of validation alone has been estimated at about $30 million. Dr. Svoboda thought there are excellent opportunities to learn more about the acid rain situation locally. Sensitive, undamaged ecosystems found in the West are ideal sites for conducting scientific experiments. Also in the West, ambient pollutant levels are low, facilitating development of source/receptor relationships in the area. These could provide further safeguards for sensitive areas.

The final need is the responsible distribution of information to the public. Dr. Svoboda noted that much uninformed material reaches the public, including under- and over-reactions and irresponsible reporting. So, along with the need to broaden the base of knowledge and understanding of the acid deposition problem, is the need to see that the public is accurately informed.

As a part of the effort to coordinate and expand research efforts in the West, the EPA Region VIII office established the Western Atmospheric Deposition Task Force. The primary objective of this group is to facilitate a dialogue between all interested, parties so that a comprehensive and integrated approach to research and monitoring can be developed. Members come from the Environmental Defense Fund, the Western Regional Council, Rocky Mountain Oil and Gas Association, U.S. Park Service, Bureau of Land Management, U.S. Geological Survey, U.S. Forest Service, U.S. EPA and representatives from states in the region. Randy Wood from the Department of Environmental Quality represents Wyoming. The Task Force meets three to four times a year to discuss and review the status of monitoring and research.

A workshop sponsored by The National Acid Rain Research Program was held to identify priority research needs, develop a research plan for the Rocky Mountain Region, and identify regulatory-oriented research programs and public information needs. One resulting program was The National Lake Survey, initiated in September of 1985. Under this program, the EPA and USFS sampled over 1,000 lakes in the western United States. Primary objectives were to identify, at one point in time, the sensitivity of lakes from a broad region, compare the lakes, and then select lakes for future, more intensive studies.

EPA Region VIII is also involved with regional watershed studies, including work with the USFS in the Wind River Mountains. It also supports the State Acid Rain Project, an effort by twelve western states that have collectively organized under the Western Governors Association to evaluate alternative control strategies for the West. In addition to these programs, Region VIII has been planning an emissions inventory for the western United States to better define how individual sources may be impacting sensitive areas. This project is primarily emphasizing policy and development of a model showing what resources are impacted in what areas, that can be used by the PSD regulatory program.

During the question and answer session, Dr. Svoboda stated that the EPA, in an ongoing evaluation of national policy, is evaluating a number of options for reducing emissions at the national level. These options include conservation measures, switching major energy sources from coal to natural gas, and forced air combustion technologies for coal.

Testimony given on November 6, 1985

Dr. Svoboda began by reiterating that the National Lakes Survey did not find any lakes in Wyoming showing evidence of acidification, but that does not mean that episodic events and associated ecosystem impacts are not occurring. The survey was not designed to address that question.

Next, he reviewed the National Acid Precipitation Assessment Program's (NAPAP) approach to the acid deposition problem. NAPAP is involved in organizing acid precipitation research on a federal level in three categories: effects, source-receptor relationships, and control mitigation. Dr. Svoboda's presentation focused on source modeling efforts. Specific goals of these models are to address questions of highly variable atmospheric deposition patterns; the contributions of distant sources to local deposition; the importance of man-made versus natural sources of SO_2 and NO_x; the effects of multiple sources or pollutants; and the amount of emission reduction necessary to yield specific benefits. These models should also help with policy decisions concerning mitigation procedures, linking impacts with specific sources, and cost analyses of various regulatory approaches.

Dr. Svoboda then reviewed three modeling activities EPA is involved with. The first is RADM, a regional acid deposition model being developed by Dr. Julius Chang, at the National Center for Atmospheric Research in Boulder, CO. This model is intended to predict acidic deposition in the northeastern United States from the Ohio Valley, and is extremely complicated, requiring substantial amounts of computer time on large computers. It also has not yet been verified. The lowest cost estimate for validation of the model is $36 million and would require the use of radiotracer materials which do not currently appear to be viable research tools, because of public health risks. Other tracer materials are possible, but will require years to develop. Even when it has been validated, however, it will require reworking for application to the West.

The second modeling activity, a meso-scale model, is a spinoff of RADM. This model is on a smaller scale, geographically, than the RADM and may eventually be useful for regulatory problems. The model would not be available in the near future as it would be dependent upon the validation of the RADM before it could be fully developed. This model, like the RADM, would be most applicable in the eastern United States.

The final modeling activity Dr. Svoboda outlined is the Rocky Mountain Acid Deposition Model. This effort is to review existing operational air quality models and possibly modify them to predict acid deposition more accurately for regulatory use. The goal here is a better regulatory tool, rather than a scientifically validated model. This model would include some spinoffs already developed from the RADM, but would be available sooner than either the RADM or the meso-scale model discussed above.

Section 5

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KEYWORDS: air quality methods
CATALOG #: Ed1-17

AUTHOR: Haddow, Dennis.
YEAR: 198?.
TITLE: Development of atmospheric deposition regulatory programs related to PSD.
SOURCE: Dennis Haddow, U.S. Forest Service.
KEYWORDS: policy/regulations air quality public issues
CATALOG #: Ed2-3

AUTHOR: Herschler, E.
YEAR: 1985.
TITLE: Letter to Dick Cheney, Alan Simpson, and Malcolm Wallop: Wyoming acid rain strategy.
SOURCE: Unpublished letter, Office of the Governor, Cheyenne, WY.
KEYWORDS: policy/regulations recommendations
CATALOG #: Ea2-1

AUTHOR: Herschler, E.
YEAR: 1985.
TITLE: The growing threat of acid rain in the West. Testimony for the record. U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Health and the Environment.
SOURCE: Unpublished testimony. Office of the Governor, Cheyenne, WY.
KEYWORDS: testimony air quality
CATALOG #: Ea8-1

AUTHOR: Heskins, B.J.
YEAR: 1985.
TITLE: Empirical models of fish response to acidification.
SOURCE: Forem 9(1): 6-11.
KEYWORDS: aquatic effects research programs
CATALOG #: Ed1-18

AUTHOR: Hidy, G.
YEAR: 1985.
TITLE: Acidic deposition in Wyoming: A technical summary and perspective.
SOURCE: Prepared for Exxon Company, U.S.A.
KEYWORDS: recommendations general overview policy/regulations
CATALOG #: Ea1-4

AUTHOR: Hidy, G.M.
YEAR: 1984.
TITLE: Source-receptor relationships for acid deposition: Pure and simple?
SOURCE: APCA Journal 34(5):518-531.
KEYWORDS: air quality modeling research review
CATALOG #: Ec1-7

AUTHOR: Hidy, G.M.
YEAR: 1986.
TITLE: Review of summary documents on acid rain.
SOURCE: Unpublished statement submitted to the Wyoming Acid Rain Coordinating Committee.
KEYWORDS: general overview
CATALOG #: D12-1

AUTHOR: Hidy, G.M.
YEAR: 198?.
TITLE: Critique of the report, "The American West's Acid Rain Test."
SOURCE: Prepared for the Utility Air Regulatory Group, c/o Hunton & Williams, Washington, D.C.
KEYWORDS: research review public issues
CATALOG #: Ec7-2

AUTHOR: Hidy, G.M., D.A. Hansen, R.C. Henry, K. Ganesan and J. Collins.
YEAR: 1984.
TITLE: Trends in historical acid precursor emissions and their airborne and precipitation products.
SOURCE: APCA Journal 34(4):333-354.
KEYWORDS: atmospheric deposition processes air quality
CATALOG #: Ed1-19

AUTHOR: Hoffnagle, G.F.
YEAR: 1985.
TITLE: Climatology and modeling of acidic deposition in Wyoming.
SOURCE: Unpublished report submitted to the Wyoming Acid Rain Coordinating Committee.
KEYWORDS: modeling atmospheric deposition processes
CATALOG #: D13-2

AUTHOR: Hoffnagle, G.F.
YEAR: 1986.
TITLE: Research priorities for acidic deposition in Wyoming.
SOURCE: Unpublished report submitted to the Wyoming Acid Rain Coordinating Committee.
KEYWORDS: recommendations research programs
CATALOG #: D13-1

AUTHOR: Hollins, E.F.
YEAR: 1986.
TITLE: Acid rain research in the Intermountain West and the value of potentially impacted resources -- research proposal.

SOURCE: Research Proposal Submitted to the Wyoming Water Research Center, University of Wyoming, Laramie, WY.
KEYWORDS: research programs economics
CATALOG #: Eb1-8

AUTHOR: Homolya, J.B.
YEAR: 1985.
TITLE: Proceedings: First Annual Acid Deposition Emissions Inventory Symposium.
SOURCE: EPA-600/9-85-015, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC.
KEYWORDS: air quality monitoring atmospheric deposition processes
CATALOG #: Ed1-20

AUTHOR: Hulse, R.D.
YEAR: 1986.
TITLE: Testimony of Western Energy Supply and Transmission (WEST) Associates on H.R. 4567, the Acid Deposition Control Act, 1986 before the Health and Environment Subcommittee, U.S. House of Representatives.
SOURCE: Western Energy Supply and Transmission (WEST) Associates.
KEYWORDS: testimony emission control
CATALOG #: Ec8-3

AUTHOR: ICF Incorporated.
YEAR: 1985.
TITLE: Analysis of sulfur dioxide and nitrogen oxide emission reduction alternatives with electricity rate subsidies.
SOURCE: Prepared for National Wildlife Federation, American Forestry Assoc., American Public Power Assoc., Burlington Northern, Inc., Izaak Walton League of America, League of Women Voters of the U.S., et al. by ICF Incorporated, Washington, DC.
KEYWORDS: emission control economics policy/regulations
CATALOG #: Ed1-21

AUTHOR: Interagency Task Force on Acid Precipitation.
YEAR: 1983.
TITLE: Annual Report, 1983.
SOURCE: National Acid Precipitation Assessment Program, Washington, DC.
KEYWORDS: research review atmospheric deposition processes aquatic effects materials damage vegetation effects control technology
CATALOG #: Ed1-22

AUTHOR: Interagency Task Force on Acid Precipitation.
YEAR: 1984.
TITLE: Annual report, 1984.
SOURCE: National Acid Precipitation Assessment Program, Washington, DC.
KEYWORDS: research review atmospheric deposition processes aquatic effects materials damage control technologies vegetation effects
CATALOG #: Ed1-23

AUTHOR: Joyner, K.C., K.A. Davis and B.A. Hood.
YEAR: 1986.

TITLE: Summary report of the Western Atmospheric Deposition Task Force Research Planning Workshop, July 10-12, 1985, Colorado Springs, CO.
SOURCE: The Western Atmospheric Deposition Task Force.
KEYWORDS: atmospheric deposition processes aquatic effects research programs
CATALOG #: Ec1-8

AUTHOR: Kamp, R.
YEAR: 1985.
TITLE: The smelter triangle: An overview of U.S.-Mexico negotiations. Testimony presented before the U.S. Senate Committee on Environment and Public Works.
SOURCE: Smelter Crisis Education Project, Naco, AZ.
KEYWORDS: testimony emission control
CATALOG #: Ec8-4

AUTHOR: Kling, G.W. and M.C. Grant.
YEAR: 1984.
TITLE: Acid precipitation in the Colorado Front Range: An overview with time predictions for significant effects.
SOURCE: Arctic and Alpine Research 16(3):321-329.
KEYWORDS: general overview modeling research programs
CATALOG #: Eb1-9

AUTHOR: Landers, D.H., J.M. Eilers, D.F. Brakke, W.S. Overton, R.D. Schonbrod, R.E. Crowe, R.A. Linthurst, J.M. Omernik, S.A. Teague and E.P. Meier.
YEAR: 1986.
TITLE: Characteristics of lakes in the Western United States. Volume I: Population descriptions and physico-chemical realtionships. Preliminary draft.
SOURCE: EPA-600/(preliminary draft), National Acid Precipitation Assessment Program, U.S. Environmental Protection Agency, Washington, DC.
KEYWORDS: surface water chemistry aquatic effects methods
CATALOG #: Ec1-9

AUTHOR: Lewis, W.M., Jr., M.C. Grant and J.F. Saunders, III.
YEAR: 1984.
TITLE: Chemical patterns of bulk atmospheric deposition in the State of Colorado.
SOURCE: Water Resources Research 20(11):1691-1704.
KEYWORDS: atmospheric deposition processes research programs
CATALOG #: Ec1-10

AUTHOR: Love, J.D.
YEAR: 1984.
TITLE: Rocks--saviors or killers.
SOURCE: Unpublished report.
KEYWORDS: geology and soil water chemistry public issues
CATALOG #: Ed6-1

AUTHOR: Ludwig, G.H., ed.
YEAR: 1986.
TITLE: Acid deposition in Colorado. Volume 1: A summary of current knowledge, ongoing research, and critical research needs. Volume 2: Technical annex.
SOURCE: Colorado Governor Richard D. Lamm's Science and Technology Advisory Council, Acid Deposition Task Force.
KEYWORDS: recommendations general overview research review
CATALOG #: Eb1-10

AUTHOR: Malanchuk, J.
YEAR: 1985.
TITLE: Statement before the U.S. Senate, Committee on Environment and Public Works.
SOURCE: Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC.
KEYWORDS: testimony monitoring
CATALOG #: Ec8-5

AUTHOR: Marcus, M.D., ed.
YEAR: 1987.
TITLE: Lake acidification and fisheries, quarterly report, January to March 1987.
SOURCE: Prepared for Ecological Studies Program, Electric Power Research Institute, Palo Alto, CA.
KEYWORDS: aquatic effects surface water chemistry
CATALOG #: Ed1-25

AUTHOR: Marcus, M.D., H.L. Bergman, C.G. Ingersoll and J.S. Mattice.
YEAR: 1985.
TITLE: A brief summary of surface-water acidification effects on fish.
SOURCE: Prepared for the Air Pollution Control Association, Rocky Mountain States Section, Boulder, CO.
KEYWORDS: aquatic effects research programs
CATALOG #: Ed1-24

AUTHOR: Maryland Power Plant Research Program.
YEAR: 1987.
TITLE: Acid deposition in Maryland: A report to the Governor and General Assembly.
SOURCE: Report No. Ad-87-1. Maryland Power Plant Research Program.
KEYWORDS: general overview legislation research review
CATALOG #: Ee1-3

AUTHOR: McLaughlin, S.B.
YEAR: 1985.
TITLE: Effects of air pollution on forests: A critical review.
SOURCE: Journal of the Air Pollution Control Association 35(5):512-534.
KEYWORDS: vegetation effects research review
CATALOG #: Ed1-26

AUTHOR: Missen, R.
YEAR: 198?.
TITLE: U.S. acid deposition control legislation: A view from the Pacific Northwest.
SOURCE: Pacific Power and Light Co., Portland, OR.
KEYWORDS: recommendations emission control policy/regulations economics
CATALOG #: Ec4-2

AUTHOR: Morton, J. and A.J. Prey.
YEAR: 1986.
TITLE: Evaluation of the impact to Wisconsin's forests from atmospheric pollutants.
SOURCE: Publication No. PUBL-AM-015. Wisconsin Department of Natural Resources, Bureau of Air Management and Bureau of Forestry, Madison, WI.
KEYWORDS: vegetation effects research review recommendations
CATALOG #: Ee1-4

AUTHOR: Motor Vehicle Manufacturers Association of the United States, Inc.
YEAR: 1983.
TITLE: Acid deposition and motor vehicles.
SOURCE: Motor Vehicle Manufacturers Association of the United States, Inc. (MVMA).
KEYWORDS: emission control recommendations public issues
CATALOG #: Ed4-1

AUTHOR: National Acidic Precipitation Assessment Program.
YEAR: 1986.
TITLE: Terrestrial effects--Task Group V -- meeting handout.
SOURCE: National Acidic Precipitation Assessment Program, November 1986 meeting.
KEYWORDS: vegetation effects research programs
CATALOG #: Ed1-27

AUTHOR: National Atmospheric Deposition Program.
YEAR: 1985.
TITLE: National Atmospheric Deposition Program/National Trends Network sites.
SOURCE: National Atmospheric Deposition Program.
KEYWORDS: monitoring
CATALOG #: Ed1-28

AUTHOR: National Forest Products Association and the American Paper Institute.
YEAR: 1986.
TITLE: Air quality and forest health. Testimony presented before the U.S. Senate, Committee on Energy and Commerce, Subcommittee on Health and the Environment.
SOURCE: Unpublished testimony. National Forest Products Association and American Paper Institute, Washington, DC.
KEYWORDS: testimony vegetation effects
CATALOG #: Ed8-3

AUTHOR: National news organizations.
YEAR: 198*.
TITLE: Newspaper clippings and popular articles.
SOURCE: Various news organizations.
KEYWORDS: public issues
CATALOG #: Ed6-2

AUTHOR: National Park Service and American Bryological and Lichenological Sciences.
YEAR: 1983.
TITLE: Symposium announcement: Assessing air quality with lichens and bryophytes.
SOURCE: National Park Service, Air Quality Division.
KEYWORDS: air quality vegetation effects meetings/conferences
CATALOG #: Fb-4

AUTHOR: New York State.
YEAR: 1984.
TITLE: State acid deposition control act as enacted in Chapter 972 and amended in Chapter 973 of the laws of 1984.
SOURCE: State of New York.
KEYWORDS: legislation emission control
CATALOG #: Ee2-1

AUTHOR: New York State Department of Environmental Conservation.
YEAR: 1984.
TITLE: A policy for New York State to reduce sulfur dioxide emissions. Draft environmental impact statement, executive summary.
SOURCE: New York State Department of Environmental Conservation.
KEYWORDS: policy/regulations emission control
CATALOG #: Ee2-2

AUTHOR: Niemann, B.L.
YEAR: 1985.
TITLE: Critical analysis of regional acid deposition source-receptor relationships for smelters in the intermountain West.
SOURCE: Poster paper for presentation at International Conference on Acidic Precipitation, Muskoka, Ontario.
KEYWORDS: air quality atmospheric deposition processes modeling
CATALOG #: Ec1-11

AUTHOR: Office of Technology Assessment.
YEAR: 1984.
TITLE: Acid rain and transported air pollutants: implications for public policy.
SOURCE: OTA-O-204, Office of Technology Assessment, Congress of the United States, Washington, DC.
KEYWORDS: atmospheric deposition processes emission control policy/regulation
CATALOG #: Ed2-4

AUTHOR: Olson, R., P. Schroeder and D. Rambo.
YEAR: 1985.
TITLE: Proposed research plan for the Western Conifers Research Cooperative, preliminary draft.
SOURCE: Wester Conifers Research Cooperative, Forest Response Program, Environmental Research Laboratory, Corvallis, OR.
KEYWORDS: vegetation effects research programs
CATALOG #: Ec1-12

AUTHOR: Ontario Ministry of the Environment.
YEAR: 1985.
TITLE: Acidic precipitation in Ontario study: Annual program report, fiscal year 1984/1985.
SOURCE: APIOS Report No. 023/85, APIOS Coordination Office, Ontario Ministry of the Environment, Toronto, Ontario.
KEYWORDS: general overview research programs
CATALOG #: Ef1-3

AUTHOR: Oppenheimer, M.
YEAR: 1982.
TITLE: The PSD increments and NAAQS for SO2 do not protect against acidification of sensitive environments: Colorado needs an acid deposition standard.
SOURCE: Environmental Defense Fund, New York, NY.
KEYWORDS: policy/regulations air quality recommendations
CATALOG #: Eb4-1

AUTHOR: Oregon Department of Environmental Quality.
YEAR: 1981.
TITLE: Oregon's views on acid precipitation.
SOURCE: Presented by the Oregon Department of Environmental Quality at the California Symposium on Acid Precipitation, January 15, 1981.
KEYWORDS: monitoring recommendations air quality
CATALOG #: Ec4-3

AUTHOR: Perhac, R.M.
YEAR: 1986.
TITLE: Acidic deposition research.
SOURCE: Electric Power Research Institute, Palo Alto, CA.
KEYWORDS: research programs general overview
CATALOG #: Ed1-29

AUTHOR: Pritchett, L.C. and J.A. Cooper.
YEAR: 1985.
TITLE: Aerosol characterization study of Lander and Sheridan, Wyoming: Chemical analysis and source apportionment. Final report, vol. I.
SOURCE: Prepared for Wyoming Department of Environmental Quality, Division of Air Quality, Cheyenne, WY, by NEA, Inc., Beaverton, OR.
KEYWORDS: air quality research programs
CATALOG #: Ea1-5

AUTHOR: Reich, P.B.
YEAR: 1983.
TITLE: Effects of low concentrations of O3 on net photosynthesis, dark respiration, and chlorophyll contents in aging hybrid poplar leaves.
SOURCE: Plant Physiol. 73:291-296.
KEYWORDS: vegetation effects
CATALOG #: Ed1-30

AUTHOR: Reich, P.B.
YEAR: 1986.
TITLE: Impacts of atmospheric pollution on vegetation.
SOURCE: Unpublished report submitted to the Wyoming Acid Rain Coordinating Committee.
KEYWORDS: vegetation effects
CATALOG #: D14-1

AUTHOR: Reich, P.B. and R.G. Amundson.
YEAR: 1984.
TITLE: Low level O3 and/or SO2 exposure causes a linear decline in soybean yield.
SOURCE: Environmental Pollution (Series A) 34:345-355.
KEYWORDS: vegetation effects
CATALOG #: Ed1-33

AUTHOR: Reich, P.B. and R.G. Amundson.
YEAR: 1985.
TITLE: Ambient levels of ozone reduce net photosynthesis in tree and crop species.
SOURCE: Science 230:566-570.
KEYWORDS: vegetation effects
CATALOG #: Ed1-34

AUTHOR: Reich, P.B. and J.P. Lassoie.
YEAR: 1984.
TITLE: Effects of low level O3 exposure on leaf diffusive conductance and water-use efficiency in hybrid poplar.
SOURCE: Plant, Cell and Environment 7:661-668.
KEYWORDS: vegetation effects
CATALOG #: Ed1-31

AUTHOR: Reich, P.B. and J.P. Lassoie.
YEAR: 1985.
TITLE: Influence of low concentrations of ozone on growth, biomass partitioning and leaf senescence in young hybrid poplar plants.
SOURCE: Environmental Pollution (Series A) 39:39-51.
KEYWORDS: vegetation effects
CATALOG #: Ed1-32

AUTHOR: Reich, P.B., J.P. Lassoie and R.G. Amundson.
YEAR: 1984.
TITLE: Reduction in growth of hybrid poplar following field exposure to low levels of O3 and (or) SO2.

SOURCE: Can. J. Bot. 62:2835-2841.
KEYWORDS: vegetation effects
CATALOG #: Ed1-37

AUTHOR: Reich, P.B., A.W. Schoettle and R.G. Amundson.
YEAR: 1985.
TITLE: Effects of low concentrations of O3, leaf age and water stress on leaf diffusive conductance and water use efficiency in soybean.
SOURCE: Physiol. Plant. 63:58-64.
KEYWORDS: vegetation effects
CATALOG #: Ed1-35

AUTHOR: Reich, P.B., A.W. Schoettle, H.F. Stroo, J. Troiano and R.G. Amundson.
YEAR: 1985.
TITLE: Effects of O3, SO2, and acidic rain on mycorrhizal infection in northern red oak seedlings.
SOURCE: Can. J. Bot. 63:2049-2055.
KEYWORDS: vegetation effects geology and soil water chemistry
CATALOG #: Ed1-36

AUTHOR: Remrod, J. and B. Lindevall.
YEAR: 1985.
TITLE: Forest in danger.
SOURCE: The Swedish Forestry Association, Djursholm, Sweden.
KEYWORDS: vegetation effects recommendations geology and soil water chemistry
CATALOG #: Eg1-1

AUTHOR: Rock, B.N, J.E. Vogelmann, A. Vogelmann, G. Hoover, S. Wong and H. Paley.
YEAR: 198?.
TITLE: Spectral characterization and mapping of boreal forest damage suspected of being due to acid deposition (acid rain).
SOURCE: None shown.
KEYWORDS: vegetation effects methods
CATALOG #: Ed1-38

AUTHOR: Rocky Mountain Energy.
YEAR: 1985.
TITLE: The study of the Acid Rain Roundtable conducted by ICF, Inc. for the National Wildlife Federation, et al.
SOURCE: Rocky Mountain Energy, Broomfield, CO.
KEYWORDS: research review economics emission control
CATALOG #: Ed1-39

AUTHOR: Rocky Mountain Oil and Gas Association.
YEAR: 1985.
TITLE: Acid deposition in the Rocky Mountain Region.
SOURCE: Rocky Mountain Oil and Gas Association, Denver, CO.
KEYWORDS: recommendations policy/regulations
CATALOG #: Ea4-2

AUTHOR: Rocky Mountain Oil and Gas Association.
YEAR: 1986.
TITLE: A perspective on acid rain in the Rocky Mountains.
SOURCE: Rocky Mountain Oil and Gas Association, Denver, CO.
KEYWORDS: recommendations general overview air quality policy/regulations
CATALOG #: Eb4-2

AUTHOR: Roth, P., C. Blanchard, J. Harte, H. Michaels and M.T. El-Ashry.
YEAR: 1985.
TITLE: The American West's acid rain test.
SOURCE: Research Report #1, March 1985, World Resources Institute, Washington, DC.
KEYWORDS: monitoring general overview recommendations
CATALOG #: Ec1-13

AUTHOR: Ruby, M.G.
YEAR: 1986.
TITLE: Evaluation of acid deposition control policies for Washington.
SOURCE: Envirometrics, Seattle, WA. 181 pp.
KEYWORDS: policy/regulations emission control atmospheric deposition processes economics
CATALOG #: Ec1-14

AUTHOR: Sanders, F.
YEAR: 1986.
TITLE: Chemical characterization of surface water quality during spring snowmelt in an acid-sensitive Rocky Mountain watershed.
SOURCE: Research proposal submitted to the Wyoming Water Research Center, Laramie, WY.
KEYWORDS: research program surface water chemistry
CATALOG #: Eb1-11

AUTHOR: Schoettle, A.
YEAR: 198?.
TITLE: Federal Land Manager responsibilities.
SOURCE: Unpublished outline submitted to the Wyoming Acid Rain Coordinating Committee.
KEYWORDS: air quality policy/regulations
CATALOG #: D17-1

AUTHOR: Schonbrun, M.K.
YEAR: 1986.
TITLE: Testimony before the Subcommittee on Health and the Environment on H.R. 4567 "Acid Deposition Control Act of 1986."
SOURCE: Unpublished testimony. Denver Metropolitan Air Quality Council, Denver, CO.
KEYWORDS: human health air quality testimony
CATALOG #: Eb8-1

AUTHOR: Science and Policy Associates, Inc.
YEAR: 1986.

TITLE: Protocols for establishing physical, chemical, and biological baselines for high-elevation natural ecosystems. First draft.
SOURCE: Contract No. 28-K5-358, Rocky Mountain Forest and Range Experiment Station, U.S.D.A. Forest Service, Fort Collins, CO. Prepared by Science and Policy Associates, Inc., Washingon, DC.
KEYWORDS: monitoring methods
CATALOG #: Eb1-12

AUTHOR: Shaw, J.W.
YEAR: 1986.
TITLE: Testimony before the U.S. Senate, Committee on Environment and Public Works.
SOURCE: Unpublished testimony. Rocky Mountain Energy Company, Broomfield, CO.
KEYWORDS: testimony economics emission control
CATALOG #: Ec8-6

AUTHOR: Soil Conservation Society of America, New Hampshire-Vermont and Ontario Chapters.
YEAR: 1982.
TITLE: Proceedings of Acid Precipitation: The North American Challenge.
SOURCE: Soil Conservation Society of America, New Hampshire-Vermont and Ontario Chapters.
KEYWORDS: general overview policy/regulations research programs economics
CATALOG #: Ed1-40

AUTHOR: Stanfield, R.L.
YEAR: 1985.
TITLE: Environmentalists try the backdoor approach to tackling acid rain.
SOURCE: National Journal, 10/19/85:2365-2368.
KEYWORDS: legislation public issues implementation emission control
CATALOG #: Ed7-3

AUTHOR: State of North Carolina.
YEAR: 198?.
TITLE: Recommended position on acid deposition.
SOURCE: North Carolina.
KEYWORDS: recommendations public issues emission control
CATALOG #: Ee4-1

AUTHOR: State of Vermont 1983 General Assembly.
YEAR: 1983.
TITLE: Vermont 1983 General Assembly Resolution Number 48.
SOURCE: State of Vermont General Assembly.
KEYWORDS: air quality legislation
CATALOG #: Ee4-2

AUTHOR: State of Washington, Department of Ecology.
YEAR: 1986.
TITLE: Results out from acid rain study.
SOURCE: Baseline 5(9):9, State of Washington, Department of Ecology.

KEYWORDS: general overview public issues
CATALOG #: Ec6-1

AUTHOR: State of Wisconsin.
YEAR: 1985.
TITLE: 1985 Wisconsin Act 296 (vetoed in part).
SOURCE: Wisconsin State Senate.
KEYWORDS: legislation
CATALOG #: Ee2-3

AUTHOR: State of Wisconsin.
YEAR: 198?.
TITLE: Commonly asked questions about acid rain in Wisconsin.
SOURCE: State of Wisconsin public information release. Wisconsin Power Companies, Public Information Release.
KEYWORDS: public issues
CATALOG #: Ee7-1

AUTHOR: State of Wyoming, Office of the Governor.
YEAR: 1985.
TITLE: Statement before the United States Senate Committee on Environment and Public Works.
SOURCE: Unpublished testimony. Office of the Governor, Cheyenne, WY.
KEYWORDS: testimony
CATALOG #: Ea8-2

AUTHOR: Stuart, B.
YEAR: 1985.
TITLE: Quality assurance project plan for the water chemistry and aquatic biology phase of the Air Quality Related Values Action/Monitoring Plan for the Bridger and Fitzpatrick Wilderness Areas.
SOURCE: USDA Forest Service, Bridger-Teton National Forest, Jackson, WY.
KEYWORDS: methods monitoring air quality
CATALOG #: Ea3-1

AUTHOR: Systems Applications Inc.
YEAR: 1984.
TITLE: Technical and institutional foundations for an integrated, interstate control strategy to prevent significant acid deposition in the Western United States: A proposed state acid rain project.
SOURCE: System Applications Inc., San Rafael, CA.
KEYWORDS: emission control research programs recommendations
CATALOG #: Ec1-15

AUTHOR: Systems Applications Inc.
YEAR: 1986.
TITLE: Western states acid deposition project: Technical status report for the period 1 May - 30 June, 1986.
SOURCE: Prepared for Western Governor's Association by Systems Applications Inc., San Rafael, CA.
KEYWORDS: research programs air quality
CATALOG #: Ec1-16

AUTHOR: Systems Applications Inc.
YEAR: 198?.
TITLE: Summary of Project WESCO: Western Emission Source Contributions to Regional Visibility Impairment.
SOURCE: Systems Applications Inc., San Rafael, CA.
KEYWORDS: air quality research review modeling
CATALOG #: Ec1-17

AUTHOR: Taylor, J.W., ed.
YEAR: 198?.
TITLE: The acid test: is Wisconsin threatened?
SOURCE: The Wisconsin Cooperative Acid Deposition Research Program, Wisconsin Department of Natural Resources, Madison, WI.
KEYWORDS: general overview public issues research programs
CATALOG #: Ee1-5

AUTHOR: Temple, Barker and Sloane, Inc.
YEAR: 1986.
TITLE: Economic evaluation of S.2203, the "New Clean Air Act."
SOURCE: Prepared for Edison Electric Institute by Temple, Baker and Sloane, Inc., Washington, DC.
KEYWORDS: economics emission control policy/regulation
CATALOG #: Ed2-5

AUTHOR: The Acid Rain Foundation, Inc.
YEAR: 1982.
TITLE: Acid rain resources directory.
SOURCE: The Acid Rain Foundation, Inc., St. Paul, MN.
KEYWORDS: public issues
CATALOG #: Ed7-4

AUTHOR: The Conference of the New England Governors and the Eastern Canadian Premiers.
YEAR: 1985.
TITLE: Conference proceedings. Intergovernmental Conference on Acid Rain.
SOURCE: Proceedings of the Intergovernmental conference on acid rain, April 10-12, 1985, Quebec. 327 pp.
KEYWORDS: general overview policy/regulations research programs
CATALOG #: Ed1-41

AUTHOR: Theiler, Don.
YEAR: 1985.
TITLE: Acid rain presentation to the Natural Resources Board.
SOURCE: Unpublished statement submitted to Wisconsin Department of Natural Resources, Bureau of Air Management, Madison, WI.
KEYWORDS: policy/regulations recommendations emission control
CATALOG #: Ee2-4

AUTHOR: The Joint Acid Deposition Technical Review Committee.
YEAR: 1983.
TITLE: First annual report on the Wisconsin Acid Deposition Research Program.

SOURCE: The Joint Acid Deposition Technical Review Committee, Wisconsin Department of Natural Resources, Madison, WI.
KEYWORDS: research programs monitoring atmospheric deposition processes aquatic effects
CATALOG #: Ee1-6

AUTHOR: The Joint Acid Deposition Technical Review Committee.
YEAR: 1985.
TITLE: Second interim report on the Wisconsin Acid Deposition Research Program.
SOURCE: The Joint Acid Deposition Technical Review Committee, Wisconsin Department of Natural Resources, Madison, WI.
KEYWORDS: research programs monitoring atmospheric deposition processes aquatic effects
CATALOG #: Ee1-7

AUTHOR: The Petroleum Association of Wyoming.
YEAR: 1986.
TITLE: Acid deposition in Wyoming: A proposal on prioritization of research/monitoring efforts.
SOURCE: The Petroleum Association of Wyoming, Casper WY.
KEYWORDS: research review recommendations monitoring
CATALOG #: Ea4-1

AUTHOR: Thomas, L.M.
YEAR: 1986.
TITLE: Statement of Lee M. Thomas, Administrator, U.S. Environmental Protection Agency, before the U.S. Senate, Subcommittee on Health and the Environment, Committee on Energy and Commerce.
SOURCE: Unpublished testimony. U.S. Environmental Protection Agency, Washington, DC.
KEYWORDS: testimony emission control economics
CATALOG #: Ed8-4

AUTHOR: Toothman, D.A., J.C. Yates and E.J. Sabo.
YEAR: 1984.
TITLE: Status report on the development of the NAPAP emission inventory for the 1980 base year and summary of preliminary data.
SOURCE: EPA-600/7-84-091, Office of Air and Radiation and Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC.
KEYWORDS: air quality monitoring atmospheric deposition processes
CATALOG #: Ed1-42

AUTHOR: Udall, J.R.
YEAR: 198?.
TITLE: Finis Mitchell, lord of the Winds.
SOURCE: None shown.
KEYWORDS: public issues
CATALOG #: Ea6-2

AUTHOR: United States Government.
YEAR: 1987.

TITLE: Annex IV to the agreement between the United States of America and the United Mexican States on cooperation for the protection of the environment in the border area.
SOURCE: United States Government.
KEYWORDS: emission control air quality policy/regulations implementation
CATALOG #: Ed2-14

AUTHOR: U.S.D.A. Forest Service.
YEAR: 1983.
TITLE: U.S.D.A. Forest Service, Bridger and Fitzpatrick Wilderness air quality related values action plan.
SOURCE: Bridger-Teton National Forest, U.S.D.A. Forest Service, Jackson, WY.
KEYWORDS: monitoring research programs general overview
CATALOG #: Ea1-8

AUTHOR: U.S.D.A. Forest Service.
YEAR: 1984.
TITLE: Air quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. March 1984 workshop proceedings.
SOURCE: Air Quality Group, Intermountain Region, U.S.D.A. Forest Service, Ogden, UT.
KEYWORDS: geology and soil water chemistry aquatic effects modeling monitoring atmospheric deposition processes
CATALOG #: Ea1-7

AUTHOR: U.S.D.A. Forest Service.
YEAR: 1984.
TITLE: Workshop announcement: Air Quality and Acid Deposition Potential in the Wind River Mountains, Wyoming.
SOURCE: U.S.D.A. Forest Service, Bridger-Teton National Forest, Jackson, WY.
KEYWORDS: air quality meetings/conferences
CATALOG #: Fb-6

AUTHOR: U.S.D.A. Forest Service.
YEAR: 1986.
TITLE: Atmospheric deposition research in U.S. forests.
SOURCE: Forest Response Research Program, Forest Fire and Atmospheric Sciences Research, U.S.D.A. Forest Service, Washington, DC.
KEYWORDS: vegetation effects research programs
CATALOG #: Ed1-49

AUTHOR: U.S.D.A. Forest Service.
YEAR: 1986.
TITLE: Baseline Protocols for Wilderness meeting.
SOURCE: Rocky Mountain Forest and Range Experiment Station, U.S.D.A. Forest Service, Fort Collins, CO.
KEYWORDS: meetings/conferences research review
CATALOG #: Fb-7

AUTHOR: U.S.D.A. Forest Service.
YEAR: 198?.
TITLE: Atmospheric deposition: Natural ecosystems, western United States.

SOURCE: U.S.D.A. Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.
KEYWORDS: research programs atmospheric deposition processes modeling
CATALOG #: Ec1-19

AUTHOR: U.S.D.I. Geological Survey.
YEAR: 198?.
TITLE: First preliminary data analyses on Fremont and New Fork Lakes near Pinedale, Wyoming.
SOURCE: Water Resources Division, U.S.D.I. Geological Survey, Denver, CO.
KEYWORDS: surface water chemistry monitoring
CATALOG #: Ea1-10

AUTHOR: U.S.D.I. Geological Survey.
YEAR: 198?.
TITLE: Limnological study of selected lakes in the Wind River Range--with emphasis on the potential for acidification from acid precipitation.
SOURCE: Water Resources Division, U.S.D.I. Geological Survey, Denver, CO.
KEYWORDS: aquatic effects surface water chemistry
CATALOG #: Ea1-9

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1979.
TITLE: Research summary: acid rain.
SOURCE: EPA-600/8-79-028, U.S. Environmental Protection Agency, Office of Research and Development, Washington, DC.
KEYWORDS: research review atmospheric deposition processes
CATALOG #: Ed1-43

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1980.
TITLE: Acid rain.
SOURCE: EPA-600/9-79-036, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC.
KEYWORDS: general overview public issues
CATALOG #: Ed7-5

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1984.
TITLE: Acid rain related studies in Wyoming.
SOURCE: U.S. Environmental Protection Agency, Region VIII, Denver, CO.
KEYWORDS: research programs
CATALOG #: Ea1-6

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1984.
TITLE: EPA's program to address acid rain implementation issues: information sheet.
SOURCE: U.S. Environmental Protection Agency.
KEYWORDS: legislation implementation
CATALOG #: Ed3-1

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1984.
TITLE: Terrestrial/aquatic linkages. Draft.
SOURCE: Research Plan FY85-92, U.S. Environmental Protection Agency, Washington, DC.
KEYWORDS: vegetation effects aquatic effects geology and soil water chemistry
CATALOG #: Ed1-44

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1985.
TITLE: EPA episodic response project -- acute effects of acidic deposition on aquatic resources.
SOURCE: U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR.
KEYWORDS: aquatic effects
CATALOG #: Ed1-45

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1985.
TITLE: EPA watershed research program.
SOURCE: U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR.
KEYWORDS: aquatic effects research programs
CATALOG #: Ed1-46

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1985.
TITLE: Responses of forests to atmospheric deposition, preliminary draft.
SOURCE: Research Plan FY85-92, U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR.
KEYWORDS: vegetation effects air quality modeling
CATALOG #: Ed1-47

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1986.
TITLE: Congress compares acid rain control bills as Proxmire-Humphrey joins ranks.
SOURCE: Inside EPA, July 25, 1986:7-9.
KEYWORDS: legislation public issues
CATALOG #: Ed2-6

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1987.
TITLE: Characteristics of lakes in the Western United States.
SOURCE: EPA/600/3-86/054a. Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC.
KEYWORDS: surface water chemistry monitoring research programs
CATALOG #: Ec1-18

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1987.

TITLE: EPA survey finds almost no acidic lakes in West, some have low buffering capacity.
SOURCE: Environmental Reporter 1-23-87:1613.
KEYWORDS: surface water chemistry public issues
CATALOG #: Ec6-2

AUTHOR: U.S. Environmental Protection Agency.
YEAR: 1987.
TITLE: Meeting announcement: EPA/States Forum on Acid Deposition Aquatics Research.
SOURCE: Office of Air and Radiation, U.S. Environmental Protection Agency, Washington, DC.
KEYWORDS: meetings/conferences surface water chemistry
CATALOG #: Fb-5

AUTHOR: U.S. House of Representatives.
YEAR: 1984.
TITLE: Udall/Cheney Acid Rain Control Bill.
SOURCE: Congressional Record 130(43).
KEYWORDS: legislation
CATALOG #: Ed2-7

AUTHOR: U.S. House of Representatives.
YEAR: 1984.
TITLE: U.S. House of Representatives Bill H.R.5370: Acid Deposition Control Act of 1984.
SOURCE: U.S. House of Representatives, 98th Congress, 2d Session.
KEYWORDS: legislation air quality
CATALOG #: Ed2-8

AUTHOR: U.S. House of Representatives.
YEAR: 1986.
TITLE: House of Representative Bill H.R.4567: Acid Deposition Control Act of 1986.
SOURCE: U.S. House of Representatives, 99th Congress, 2d Session.
KEYWORDS: legislation air quality
CATALOG #: Ed2-9

AUTHOR: U.S. House of Representatives.
YEAR: 1986.
TITLE: U.S. House of Representatives Bill H.R.4567: Acid Deposition Control Act of 1986, as reported from Subcommittee.
SOURCE: U.S. House of Representatives.
KEYWORDS: legislation air quality
CATALOG #: Ed2-10

AUTHOR: U.S. Senate.
YEAR: 1986.
TITLE: Acid deposition and sulfur reduction act.
SOURCE: Congressional Record -- Senate, September 12, 1986:S 12454- S 12462.
KEYWORDS: legislation
CATALOG #: Ed2-13

AUTHOR: U.S. Senate.
YEAR: 1986.
TITLE: U.S. Senate Bill S.2203: New Clean Air Act.
SOURCE: U.S. Senate, 99th Congress, 2d Session.
KEYWORDS: legislation air quality
CATALOG #: Ed2-12

AUTHOR: U.S. Senate.
YEAR: 1986.
TITLE: U.S. Senate Bill S.2813: Acid Deposition and Sulfur Emissions Reduction Act.
SOURCE: U.S. Senate, 99th Congress, 2d Session.
KEYWORDS: legislation air quality
CATALOG #: Ed2-11

AUTHOR: U.S. Senate Committee on Environment and Public Works.
YEAR: 1985.
TITLE: Memorandum: U.S. Senate Environment and Public Works oversite hearings on acid rain research.
SOURCE: Committee on Environment and Public Works, U.S. Senate.
KEYWORDS: research reviews public issues
CATALOG #: Ed1-48

AUTHOR: Washington Department of Ecology.
YEAR: 1986.
TITLE: Acid rain program technical report.
SOURCE: Prepared for the Washington State Legislature by the Washington Department of Ecology.
KEYWORDS: general overview research programs
CATALOG #: Ec1-21

AUTHOR: Western Atmospheric Deposition Task Force.
YEAR: 1986.
TITLE: January 24, 1986 meeting of the Western Atmospheric Deposition Task Force.
SOURCE: Western Atmospheric Task Force, U.S. Environmental Protection Agency, Region VIII, Denver, CO.
KEYWORDS: meetings/conferences research review
CATALOG #: Fb-8

AUTHOR: Western Conifers Research Cooperative.
YEAR: 1986.
TITLE: Proposed research plan for the Western Conifers Research Cooperative, preliminary draft.
SOURCE: Western Conifers Research Cooperative, Environmental Research Laboratory, Corvallis, OR.
KEYWORDS: vegetation effects research programs
CATALOG #: Ec1-20

AUTHOR: Western Energy Supply and Transmission (WEST) Associates.
YEAR: 1986.

TITLE: Acid deposition and the West: A scientific assessment.
SOURCE: Western Energy Supply and Transmission (WEST) Associates.
KEYWORDS: general overview research review recommendations
CATALOG #: Ec4-4

AUTHOR: Western Energy Supply and Transmission (WEST) Associates.
YEAR: 198?.
TITLE: Acid rain: Who pays? Who benefits?
SOURCE: Western Energy Supply and Transmission (WEST) Associates.
KEYWORDS: economics public issues general overview recommendations
CATALOG #: Ed4-2

AUTHOR: Western Governors' Association.
YEAR: 1986.
TITLE: Western states programs assess and control acid rain.
SOURCE: Western Report 3:4-5. Western Governors' Association, Denver CO.
KEYWORDS: general overview public issues
CATALOG #: Ec7-3

AUTHOR: Williams, R.
YEAR: 1984.
TITLE: Precipitation chemistry near a large coal-fired power plant. Volume I. Relationship of precipitation chemistry to thunderstorm activity.
SOURCE: Prepared for West Associates, Project AQ82-21, by the Public Service Company of New Mexico.
KEYWORDS: atmospheric deposition processes
CATALOG #: Ed1-50

AUTHOR: Wilson, J.C.
YEAR: 1986.
TITLE: Testimony of James C. Wilson before the U.S. Senate, Committee on Environment and Public Works.
SOURCE: Unpublished testimony. Rocky Mountain Energy Company, Broomfield, CO.
KEYWORDS: testimony emission control economics
CATALOG #: Ec8-7

AUTHOR: Wisconsin Department of Natural Resources.
YEAR: 1985.
TITLE: Results and findings of the Wisconsin sulfur dioxide emission reduction cost study. Final report.
SOURCE: Wisconsin Department of Natural Resources, Bureau of Air Management, Madison, WI.
KEYWORDS: emission control economics
CATALOG #: Ee1-8

AUTHOR: Wisconsin Department of Natural Resources.
YEAR: 1986.
TITLE: Summary of Wisconsin's acid rain legislation.
SOURCE: Wisconsin Department of Administration, Department of Natural Resources, Public Service Commission.

KEYWORDS: legislation public issues
CATALOG #: Ee2-5

AUTHOR: Wisconsin Department of Natural Resources.
YEAR: 1986.
TITLE: Summary of Wisconsin acid deposition research and monitoring, 1979-1986.
SOURCE: Bureau of Air Management, Acid Deposition Section, Wisconsin Department of Natural Resources, Madison, WI.
KEYWORDS: research programs monitoring
CATALOG #: Ee1-9

AUTHOR: Wood, R.
YEAR: 1984.
TITLE: Letter to Governor Ed Herschler: Statement on Wyoming strategy for addressing the potential for acid rain and enforcement.
SOURCE: Unpublished letter. Air Quality Division, Department of Environmental Quality, Cheyenne, WY.
KEYWORDS: recommendations policy/regulations
CATALOG #: Ea2-2

AUTHOR: Wyoming Department of Environmental Quality.
YEAR: 1987.
TITLE: The DEQ annual report, fiscal year 1986.
SOURCE: Department of Environmental Quality, Cheyenne, WY.
KEYWORDS: air quality general overview public issues
CATALOG #: Ea6-3

AUTHOR: Wyoming Game and Fish Department.
YEAR: 1986.
TITLE: Acid deposition, Wyoming.
SOURCE: Unpublished paper. Wyoming Game and Fish Department, Cheyenne, WY.
KEYWORDS: recommendations policy/regulations
CATALOG #: Ea4-3

AUTHOR: Wyoming Game and Fish Department.
YEAR: 198?.
TITLE: Considerations for Commission support relative to acid deposition in Wyoming.
SOURCE: Unpublished paper. Wyoming Game and Fish Department, Cheyenne, WY.
KEYWORDS: recommendations policy/regulation monitoring
CATALOG #: Ea4-4

AUTHOR: Wyoming Heritage Foundation.
YEAR: 1987.
TITLE: Acid rain: a Wyoming perspective.
SOURCE: White Paper, Wyoming Heritage Foundation, Casper, WY.
KEYWORDS: general overview policy/regulations recommendations
CATALOG #: Ea4-5

AUTHOR: Wyoming Newspapers.
YEAR: 198*.

TITLE: Newspaper clippings and popular articles.
SOURCE: Various sources.
KEYWORDS: public issues
CATALOG #: Ea6-4

AUTHOR: Yuhnke, R.E.
YEAR: 1984.
TITLE: Testimony on pending acid rain and toxic air pollution bills presented before the U.S. House of Representatives, Subcommittee on Health and the Environment.
SOURCE: Unpublished testimony. Environmental Defense Fund, Washington, DC.
KEYWORDS: testimony emission control
CATALOG #: Ed8-5

AUTHOR: Yuhnke, R.E.
YEAR: 1986.
TITLE: The West needs acid rain protection too: An acid rain prevention program for the West. Testimony presented before the U.S. House of Representatives, Subcommittee on Health and the Environment.
SOURCE: Unpublished testimony. The Environmental Defense Fund, The Sierra Club, and The Wyoming Outdoor Council.
KEYWORDS: testimony emission control
CATALOG #: Ec8-9

AUTHOR: Yuhnke, R.E., M. Fox and D. Beck.
YEAR: 1985.
TITLE: Testimony on smelters and acid rain in the West. Presented before the U.S. House of Representatives, Subcommittee on Health and the Environment, Committee on Energy and Commerce.
SOURCE: Unpublished testimony. Environmental Defense Fund, Sierra Club and Wyoming Outdoor Council.
KEYWORDS: testimony emission control air quality policy/regulation
CATALOG #: Ec8-8

AUTHOR: Yuhnke, R.E. and M. Oppenheimer.
YEAR: 1984.
TITLE: Safeguarding acid-sensitive waters in the intermountain West: a sulfur pollution strategy for preventing acid pollution damage in the intermountain air shed.
SOURCE: Environmental Defense Fund, Boulder, CO.
KEYWORDS: atmospheric deposition processes emission control policy/regulations recommendations
CATALOG #: Ec4-5

Section 6

Index to Supporting Materials

The materials accumulated by the Wyoming Acid Rain Coordinating Committee are filed according to the following system, and indexed using the terms listed on the following page.

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- Aa. Final Report
- Ab. Draft Report and Comments

B. Unindexed Organizational Materials

C. Wyoming Acid Rain Coordinating Committee Public Meetings
- Ca. Agenda
- Cb. Transcripts

D. Solicited Expert Testimony and Comments
- D1. Ms. Jill Baron
- D2. Dr. Harold Bergman
- D3. Dr. Chris Bernabo
- D4. Dr. David F. Brakke
- D5. Dr. Robert I. Bruck
- D6. Dr. Dale Bruns
- D7. Mr. Bernard Daily
- D8. Dr. Douglas Fox
- D9. Dr. Alan Galbraith
- D10. Dr. James Gibson
- D11. Dr. Michael C. Grant
- D12. Dr. George Hidy
- D13. Mr. G.F. Hoffnagle
- D14. Dr. Peter B. Reich
- D15. Dr. William Reiners
- D16. Dr. Frank Sanders
- D17. Ms. Anna Schoettle
- D18. Mr. Larry Svoboda
- D19. Dr. John Turk
- D20. Dr. Gabor Vali
- D21. Dr. Robert W. Wiley
- D22. Mr. Robert Yuhnke

E. Supporting Materials*
- Ea. Wyoming
- Eb. Rocky Mountain Region
- Ec. Western United States
- Ed. National
- Ee. Eastern United States
- Ef. Canada
- Eg. Europe

F. Other Materials
- Fa. Miscellaneous Unindexed Committee Correspondence
- Fb. Miscellaneous Meetings, Programs and Agendas
- Fc. Miscellaneous Unindexed Correspondence

*Subgroupings under Ea-Eg
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4. Position Statements
5. Fact Sheets
6. Popular Articles
7. Public Issues
8. Testimony

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CATALOG #	TITLE
D17-1	Federal Land Manager responsibilities.
Ea1-3	Acid deposition in the Bridger Wilderness--first year results.
Ea1-5	Aerosol characterization study of Lander and Sheridan, Wyoming: Chemical analysis and source apportionment. Final report, vol. I.
Ea1-7	Air quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. March 1984 workshop proceedings.
Ea1-8	U.S.D.A. Forest Service, Bridger and Fitzpatrick Wilderness air quality related values action plan.
Ea3-1	Quality assurance project plan for the water chemistry and aquatic biology phase of the Air Quality Related Values Action/Monitoring Plan for the Bridger and Fitzpatrick Wilderness Areas.
Ea5-1	Report to the Acid Rain Committee from the Air Quality Division.
Ea6-3	The DEQ annual report, fiscal year 1986.
Ea8-1	The growing threat of acid rain in the West. Testimony for the record. U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Health and the Environment.
Eb1-1	Investigation into the health of forests in the vicinity of Gothic, Colorado.
Eb1-5	Assessment of the cumulative environmental impacts of energy development in northwestern Colorado: Final report.
Eb4-1	The PSD increments and NAAQS for SO2 do not protect against acidification of sensitive environments: Colorado needs an acid deposition standard.
Eb4-2	A perspective on acid rain in the Rocky Mountains.
Eb8-1	Testimony before the Subcommittee on Health and the Environment on H.R. 4567 "Acid Deposition Control Act of 1986."
Ec1-7	Source-receptor relationships for acid deposition: Pure and simple?
Ec1-11	Critical analysis of regional acid deposition source-receptor relationships for smelters in the intermountain West.
Ec1-16	Western states acid deposition project: Technical status report for the period 1 May - 30 June, 1986.
Ec1-17	Summary of Project WESCO: Western Emission Source Contributions to Regional Visibility Impairment.
Ec4-3	Oregon's views on acid precipitation.
Ec7-1	Acid rain in the West? Some points to ponder.
Ec8-1	Testimony of New Mexico Governor Toney Anaya before the U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Health and Environment.
Ec8-8	Testimony on smelters and acid rain in the West. Presented before the U.S. House of Representatives, Subcommittee on Health and the Environment, Committee on Energy and Commerce.
Ed1-2	Characterizing deposition: Background. Overview of NADP/NTN program.
Ed1-4	Air quality monitoring.
Ed1-5	State-operated wet deposition stations.

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Ed1-17	Historic emissions of sulfur and nitrogen oxides in the United States from 1900 to 1980. Volume I: Results.
Ed1-19	Trends in historical acid precursor emissions and their airborne and precipitation products.
Ed1-20	Proceedings: First Annual Acid Deposition Emissions Inventory Symposium.
Ed1-42	Status report on the development of the NAPAP emission inventory for the 1980 base year and summary of preliminary data.
Ed1-47	Responses of forests to atmospheric deposition, preliminary draft.
Ed2-3	Development of atmospheric deposition regulatory programs related to PSD.
Ed2-8	U.S. House of Representatives Bill H.R.5370: Acid Deposition Control Act of 1984.
Ed2-9	House of Representative Bill H.R.4567: Acid Deposition Control Act of 1986.
Ed2-10	U.S. House of Representatives Bill H.R.4567: Acid Deposition Control Act of 1986, as reported from Subcommittee.
Ed2-11	U.S. Senate Bill S.2813: Acid Deposition and Sulfur Emissions Reduction Act.
Ed2-12	U.S. Senate Bill S.2203: New Clean Air Act.
Ed2-14	Annex IV to the agreement between the United States of America and the United Mexican States on cooperation for the protection of the environment in the border area.
Ed8-3	Air quality and forest health. Testimony presented before the U.S. Senate, Committee on Energy and Commerce, Subcommittee on Health and the Environment.
Ee1-1	Northeast damage report of the long range transport and deposition of air pollutants.
Ee2-3	Vermont 1983 General Assembly Resolution Number 48.
Fb-1	Conference announcement: Visibility Specialty Conference.
Fb-4	Symposium announcement: Assessing air quality with lichens and bryophytes.
Fb-6	Workshop announcement: Air Quality and Acid Deposition Potential in the Wind River Mountains, Wyoming.

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CATALOG #	TITLE
Ea1-1	The acid deposition potential for the streams and lakes of the Wind River Mountains.
Ea1-2	Acid deposition in the Wind River Mountains.
Ea1-7	Air quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. March 1984 workshop proceedings.
Ea1-9	Limnological study of selected lakes in the Wind River Range--with emphasis on the potential for acidification from acid precipitation.
Eb1-2	Acid deposition in the Rocky Mountain Area: study needs summary.
Eb1-3	Long-term research into the effects of acidic deposition in Rocky Mountain National Park.
Eb1-6	Effects of atmospheric deposition on alpine and subalpine ecology: A proposed framework for western research.
Ec1-8	Summary report of the Western Atmospheric Deposition Task Force Research Planning Workshop, July 10-12, 1985, Colorado Springs, CO.
Ec1-9	Characteristics of lakes in the Western United States. Volume I: Population descriptions and physico-chemical relationships. Preliminary draft.
Ed1-1	Acid Deposition Symposium: Technical program abstracts.
Ed1-3	Aquatic research and monitoring.
Ed1-6	Lake acidification and fisheries: Project description.
Ed1-10	Acid precipitation in relation to agriculture, forestry, and aquatic biology.
Ed1-18	Empirical models of fish response to acidification.
Ed1-22	Annual Report, 1983.
Ed1-23	Annual report, 1984.
Ed1-24	A brief summary of surface-water acidification effects on fish.
Ed1-25	Lake acidification and fisheries, quarterly report, January to March 1987.
Ed1-44	Terrestrial/aquatic linkages. Draft.
Ed1-45	EPA episodic response project -- acute effects of acidic deposition on aquatic resources.
Ed1-46	EPA watershed research program.
Ed1-51	Summary results from the "Joint Water Chemistry Comparison of Several Quebec and New York Lakes in Relation to Acidification."
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Ee1-7	Second interim report on the Wisconsin acid deposition research program.

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Ea1-7	Air quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. March 1984 workshop proceedings.
Ea4-1	Acid deposition in Wyoming: A proposal on prioritization of research/monitoring efforts.
Eb1-7	Chemical loading rates from precipitation in the Colorado Rockies.
Ec1-2	The third annual report to the Governor and the Legislature on the Air Resources Board's Acid Deposition Research and Monitoring Program.
Ec1-3	The fourth annual report to the Governor and the Legislature on the Air Resources Board's Acid Deposition Research and Monitoring Program.
Ec1-6	A suggested methodology for estimating atmospheric deposition within 200 km of isolated sources in clean air areas. Draft report.
Ec1-8	"Summary report of the Western Atmospheric Deposition Task Force Research Planning Workshop, July 10-12, 1985, Colorado Springs, CO.
Ec1-10	Chemical patterns of bulk atmospheric deposition in the State of Colorado.
Ec1-11	Critical analysis of regional acid deposition source-receptor relationships for smelters in the intermountain West.
Ec1-14	Evaluation of acid deposition control policies for Washington.
Ec1-19	Atmospheric deposition: Natural ecosystems, western United States.
Ec4-5	Safeguarding acid-sensitive waters in the intermountain West: a sulfur pollution strategy for preventing acid pollution damage in the intermountain air shed.
Ed1-1	Acid Deposition Symposium: Technical program abstracts.
Ed1-9	Summary and synthesis.
Ed1-19	Trends in historical acid precursor emissions and their airborne and precipitation products.
Ed1-20	Proceedings: First Annual Acid Deposition Emissions Inventory Symposium.
Ed1-22	Annual Report, 1983.
Ed1-23	Annual report, 1984.
Ed1-42	Status report on the development of the NAPAP emission inventory for the 1980 base year and summary of preliminary data.
Ed1-43	Research summary: acid rain.
Ed1-50	Precipitation chemistry near a large coal-fired power plant. Volume I. Relationship of precipitation chemistry to thunderstorm activity.
Ed2-4	Acid rain and transported air pollutants: implications for public policy.
Ee1-1	Northeast damage report of the long range transport and deposition of air pollutants.

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Ee1-7	Second interim report on the Wisconsin acid deposition research program.

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Ec1-2	The third annual report to the Governor and the Legislature on the Air Resources Board's Acid Deposition Research and Monitoring Program.
Ec1-3	The fourth annual report to the Governor and the Legislature on the Air Resources Board's Acid Deposition Research and Monitoring Program.
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Ed1-23	Annual report, 1984.
Ed2-2	An analysis of issues concerning "acid rain."

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Ed1-21	Analysis of sulfur dioxide and nitrogen oxide emission reduction alternatives with electricity rate subsidies.
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Ec4-5	Safeguarding acid-sensitive waters in the intermountain West: a sulfur pollution strategy for preventing acid pollution damage in the intermountain air shed.
Ec8-1	Testimony of New Mexico Governor Toney Anaya before the U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Health and Environment.
Ec8-2	Statement of Dr. Mohamed T. El-Ashry before the House Subcommittee on Health and the Environment.
Ec8-3	Testimony of Western Energy Supply and Transmission (WEST) Associates on H.R. 4567, the Acid Deposition Control Act, 1986 before the Health and Environment Subcommittee, U.S. House of Representatives.
Ec8-4	The smelter triangle: An overview of U.S.-Mexico negotiations. Testimony presented before the U.S. Senate Committee on Environment and Public Works.
Ec8-6	Testimony before the U.S. Senate, Committee on Environment and Public Works.
Ec8-7	Testimony of James C. Wilson before the U.S. Senate, Committee on Environment and Public Works.
Ec8-8	Testimony on smelters and acid rain in the West. Presented before the U.S. House of Representatives, Subcommittee on Health and the Environment, Committee on Energy and Commerce.
Ec8-9	The West needs acid rain protection too: An acid rain prevention program for the West. Testimony presented before the U.S. House of Representatives, Subcommittee on Health and the Environment.
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Ed2-4	Acid rain and transported air pollutants: implications for public policy.
Ed2-5	Economic evaluation of S.2203, the "New Clean Air Act."
Ed2-14	Annex IV to the agreement between the United States of America and the United Mexican States on cooperation for the protection of the environment in the border area.
Ed4-1	Acid deposition and motor vehicles.
Ed7-3	Environmentalists try the backdoor approach to tackling acid rain.

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Ed8-2	Testimony of Chris Farrand before the U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Health and the Environment.
Ed8-4	Statement of Lee M. Thomas, Administrator, U.S. Environmental Protection Agency, before the U.S. Senate, Subcommittee on Health and the Environment, Committee on Energy and Commerce.
Ed8-5	Testimony on pending acid rain and toxic air pollution bills presented before the U.S. House of Representatives, Subcommittee on Health and the Environment.
Ee1-2	An analysis of acid deposition issues: The impacts of proposed national acid deposition control legislation on Florida.
Ee1-8	Results and findings of the Wisconsin sulfur dioxide emission reduction cost study. Final report.
Ee2-1	State acid deposition control act as enacted in Chapter 972 and amended in Chapter 973 of the laws of 1984.
Ee2-2	A policy for New York State to reduce sulfur dioxide emissions. Draft environmental impact statement, executive summary.
Ee2-4	Acid rain presentation to the Natural Resources Board.
Ee4-1	Recommended position on acid deposition.
Ef7-1	Acid rain: The Canadian control program.
Ef7-3	Acid rain: The statistics.

GENERAL OVERVIEW

CATALOG #	TITLE
D12-1	Review of summary documents on acid rain.
Ea1-4	Acidic deposition in Wyoming: A technical summary and perspective.
Ea1-8	U.S.D.A. Forest Service, Bridger and Fitzpatrick Wilderness air quality related values action plan.
Ea4-5	Acid rain: a Wyoming perspective.
Ea6-3	The DEQ annual report, fiscal year 1986.
Eb1-9	Acid precipitation in the Colorado Front Range: An overview with time predictions for significant effects.
Eb1-10	Acid deposition in Colorado. Volume 1: A summary of current knowledge, ongoing research, and critical research needs. Volume 2: Technical annex.
Eb4-2	A perspective on acid rain in the Rocky Mountains.
Ec1-5	Acid deposition in Utah: An analysis by the Acid Deposition Technical Advisory Committee.
Ec1-13	The American West's acid rain test.
Ec1-21	Acid rain program technical report.
Ec4-4	Acid deposition and the West: A scientific assessment.
Ec6-1	Results out from acid rain study.
Ec7-3	Western states programs assess and control acid rain.
Ed1-8	Acid Precipitation Digest.
Ed1-29	Acidic deposition research.
Ed1-40	Proceedings of Acid Precipitation: The North American Challenge.
Ed1-41	Conference proceedings. Intergovernmental Conference on Acid Rain.
Ed2-2	An analysis of issues concerning "acid rain."
Ed4-2	Acid rain: Who pays? Who benefits?
Ed7-2	ERT Newsletter.
Ed7-5	Acid rain.
Ee1-2	An analysis of acid deposition issues: The impacts of proposed national acid deposition control legislation on Florida.
Ee1-3	Acid deposition in Maryland: A report to the Governor and General Assembly.
Ee1-5	The acid test: is Wisconsin threatened?
Ef1-3	Acidic precipitation in Ontario study: Annual program report, fiscal year 1984/1985.
Ef6-1	The acid rain story.

GEOLOGY AND SOIL WATER CHEMISTRY

CATALOG #	TITLE
D4-1	Acidification and watershed/lake systems: Key processes and a western perspective.
D9-1	Discussion of sensitivity of watersheds in Wind River Mountains to acid deposition.
Ea1-2	Acid deposition in the Wind River Mountains.
Ea1-7	Air quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. March 1984 workshop proceedings.
Eb1-3	Long-term research into the effects of acidic deposition in Rocky Mountain National Park.
Eb1-6	Effects of atmospheric deposition on alpine and subalpine ecology: A proposed framework for western research.
Ec1-4	Characterization of the influence of soil particulates on precipitation chemistry at five sites in the Western United States. Draft report.
Ed1-10	Acid precipitation in relation to agriculture, forestry, and aquatic biology.
Ed1-36	Effects of O3, SO2, and acidic rain on mycorrhizal infection in northern red oak seedlings.
Ed1-44	Terrestrial/aquatic linkages. Draft.
Ed6-1	Rocks--saviors or killers.
Eg1-1	Forest in danger.

IMPLEMENTATION

CATALOG #	TITLE
Ed2-14	Annex IV to the agreement between the United States of America and the United Mexican States on cooperation for the protection of the environment in the border area.
Ed3-1	EPA's program to address acid rain implementation issues: information sheet.
Ed7-3	Environmentalists try the backdoor approach to tackling acid rain.

LEGISLATION

CATALOG #	TITLE
Ec4-2	U.S. acid deposition control legislation: A view from the Pacific Northwest.
Ed2-1	Summary of the Proxmire-Humphrey Bill and comparison with other acid-rain control bills.
Ed2-6	Congress compares acid rain control bills as Proxmire-Humphrey joins ranks.
Ed2-7	Udall/Cheney Acid Rain Control Bill.
Ed2-8	U.S. House of Representatives Bill H.R.5370: Acid Deposition Control Act of 1984.
Ed2-9	House of Representative Bill H.R.4567: Acid Deposition Control Act of 1986.
Ed2-10	U.S. House of Representatives Bill H.R.4567: Acid Deposition Control Act of 1986, as reported from Subcommittee.
Ed2-11	U.S. Senate Bill S.2813: Acid Deposition and Sulfur Emissions Reduction Act.
Ed2-12	U.S. Senate Bill S.2203: New Clean Air Act.
Ed2-13	Acid deposition and sulfur reduction act.
Ed3-1	EPA's program to address acid rain implementation issues: information sheet.
Ed7-3	Environmentalists try the backdoor approach to tackling acid rain.
Ee1-2	An analysis of acid deposition issues: The impacts of proposed national acid deposition control legislation on Florida.
Ee1-3	Acid deposition in Maryland: A report to the Governor and General Assembly.
Ee2-1	State acid deposition control act as enacted in Chapter 972 and amended in Chapter 973 of the laws of 1984.
Ee2-3	Vermont 1983 General Assembly Resolution Number 48.
Ee2-3	1985 Wisconsin Act 296 (vetoed in part).
Ee2-5	Summary of Wisconsin's acid rain legislation.

MATERIAL DAMAGE

CATALOG #	TITLE
Ed1-1	Acid Deposition Symposium: Technical program abstracts.
Ed1-22	Annual Report, 1983.
Ed1-23	Annual report, 1984.

MEETINGS/CONFERENCES

CATALOG #	TITLE
Eb1-4	Acid rain in the Rocky Mountain West -- meeting abstracts.
Fb-1	Conference announcement: Visibility Specialty Conference.
Fb-2	State Acid Deposition Research Conference, list of participants.
Fb-3	Conference announcement: Acid Rain in the Rocky Mountain West.
Fb-4	Symposium announcement: Assessing air quality with lichens and bryophytes.
Fb-5	Meeting announcement: EPA/States Forum on Acid Deposition Aquatics Research.
Fb-6	Workshop announcement: Air Quality and Acid Deposition Potential in the Wind River Mountains, Wyoming.
Fb-7	Baseline Protocols for Wilderness meeting.
Fb-8	January 24, 1986 meeting of the Western Atmospheric Deposition Task Force.

METHODS

CATALOG #	TITLE
Ea3-1	Quality assurance project plan for the water chemistry and aquatic biology phase of the Air Quality Related Values Action/Monitoring Plan for the Bridger and Fitzpatrick Wilderness Areas.
Eb1-12	Protocols for establishing physical, chemical, and biological baselines for high-elevation natural ecosystems. First draft.
Ec1-9	Characteristics of lakes in the Western United States. Volume I: Population descriptions and physico-chemical realtionships. Preliminary draft.
Ed1-11	Recommendations for the determination of pH in low ionic strength fresh waters.
Ed1-15	RM-2153 problem analysis. Problem 1: Protocols for establishing chemical and physical baselines for natural ecosystems have not been established.
Ed1-17	Historic emissions of sulfur and nitrogen oxides in the United States from 1900 to 1980. Volume I: Results.
Ed1-38	Spectral characterization and mapping of boreal forest damage suspected of being due to acid deposition (acid rain).

MODELING

CATALOG #	TITLE
D13-2	Climatology and modeling of acidic deposition in Wyoming.
Ea1-7	Air quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. March 1984 workshop proceedings.
Eb1-2	Acid deposition in the Rocky Mountain Area: study needs summary.
Eb1-9	Acid precipitation in the Colorado Front Range: An overview with time predictions for significant effects.
Ec1-6	A suggested methodology for estimating atmospheric deposition within 200 km of isolated sources in clean air areas. Draft report.
Ec1-7	Source-receptor relationships for acid deposition: Pure and simple?
Ec1-11	Critical analysis of regional acid deposition source-receptor relationships for smelters in the intermountain West.
Ec1-17	Summary of Project WESCO: Western Emission Source Contributions to Regional Visibility Impairment.
Ec1-19	Atmospheric deposition: Natural ecosystems, western United States.
Ed1-47	Responses of forests to atmospheric deposition, preliminary draft.
Ed2-6	Congress compares acid rain control bills as Proxmire-Humphrey joins ranks.
Ed7-1	"Maybe acid rain isn't the villain.
Ee1-1	Northeast damage report of the long range transport and deposition of air pollutants.

MONITORING

CATALOG #	TITLE
D3-1	Letter to R. Wood: Monitoring and research recommendations to the Wyoming Acid Rain Coordinating Committee.
D8-1	Issues and priorities.
Ea1-3	Acid deposition in the Bridger Wilderness--first year results.
Ea1-7	Air quality and acid deposition potential in the Bridger and Fitzpatrick Wildernesses. March 1984 workshop proceedings.
Ea1-8	U.S.D.A. Forest Service, Bridger and Fitzpatrick Wilderness air quality related values action plan.
Ea1-10	First preliminary data analyses on Fremont and New Fork Lakes near Pinedale, Wyoming.
Ea3-1	Quality assurance project plan for the water chemistry and aquatic biology phase of the Air Quality Related Values Action/Monitoring Plan for the Bridger and Fitzpatrick Wilderness Areas.
Ea4-1	Acid deposition in Wyoming: A proposal on prioritization of research/monitoring efforts.
Ea4-4	Considerations for Commission support relative to acid deposition in Wyoming.
Eb1-1	Investigation into the health of forests in the vicinity of Gothic, Colorado.
Eb1-2	Acid deposition in the Rocky Mountain Area: study needs summary.
Eb1-3	Long-term research into the effects of acidic deposition in Rocky Mountain National Park.
Eb1-12	Protocols for establishing physical, chemical, and biological baselines for high-elevation natural ecosystems. First draft.
Ec1-13	The American West's acid rain test.
Ec1-18	Characteristics of lakes in the Western United States.
Ec1-2	The third annual report to the Governor and the Legislature on the Air Resources Board's Acid Deposition Research and Monitoring Program.
Ec1-3	The fourth annual report to the Governor and the Legislature on the Air Resources Board's Acid Deposition Research and Monitoring Program.
Ec4-1	Western smelters and acid rain: Setting the record straight.
Ec4-3	Oregon's views on acid precipitation.
Ec8-5	Statement before the U.S. Senate, Committee on Environment and Public Works.
Ed1-1	Acid Deposition Symposium: Technical program abstracts.
Ed1-2	Characterizing deposition: Background. Overview of NADP/NTN program.
Ed1-3	Aquatic research and monitoring.
Ed1-4	Air quality monitoring.
Ed1-5	State-operated wet deposition stations.
Ed1-15	RM-2153 problem analysis. Problem 1: Protocols for establishing chemical and physical baselines for natural ecosystems have not been established.
Ed1-16	Analysis of acid precipitation samples collected by State Agencies, sampling period: Sept. '83 - Dec. '84.

MONITORING (continued)

CATALOG #	TITLE
Ed1-20	Proceedings: First Annual Acid Deposition Emissions Inventory Symposium.
Ed1-28	National Atmospheric Deposition Program/National Trends Network sites.
Ed1-42	Status report on the development of the NAPAP emission inventory for the 1980 base year and summary of preliminary data.
Ed7-1	Maybe acid rain isn't the villain.
Ed8-1	Statement of Dr. J. Christopher Bernabo before the Committee on Science and Technology, Natural Resources, Agriculture Research and the Environment Subcommittee, U.S. House of Representatives.
Ee1-1	Northeast damage report of the long range transport and deposition of air pollutants.
Ee1-6	First annual report on the Wisconsin Acid Deposition Research Program.
Ee1-7	Second interim report on the Wisconsin acid deposition research program.
Ee1-9	Summary of Wisconsin acid deposition research and monitoring, 1979-1986.

POLICIES/REGULATIONS

CATALOG #	TITLE
D17-1	Federal Land Manager responsibilities.
Ea1-4	Acidic deposition in Wyoming: A technical summary and perspective.
Ea2-1	Letter to Dick Cheney, Alan Simpson, and Malcolm Wallop: Wyoming acid rain strategy.
Ea2-2	Letter to Governor Ed Herschler: Statement on Wyoming strategy for addressing the potential for acid rain and enforcement.
Ea4-2	Acid deposition in the Rocky Mountain Region.
Ea4-3	Acid deposition, Wyoming.
Ea4-4	Considerations for Commission support relative to acid deposition in Wyoming.
Ea4-5	Acid rain: a Wyoming perspective.
Eb4-1	The PSD increments and NAAQS for SO2 do not protect against acidification of sensitive environments: Colorado needs an acid deposition standard.
Eb4-2	A perspective on acid rain in the Rocky Mountains.
Ec1-14	Evaluation of acid deposition control policies for Washington.
Ec4-2	U.S. acid deposition control legislation: A view from the Pacific Northwest.
Ec4-5	Safeguarding acid-sensitive waters in the intermountain West: a sulfur pollution strategy for preventing acid pollution damage in the intermountain air shed.
Ec8-8	Testimony on smelters and acid rain in the West. Presented before the U.S. House of Representatives, Subcommittee on Health and the Environment, Committee on Energy and Commerce.
Ed1-7	The great acid rain mystery (myths and realities in the claims against acid precipitation). Final report.
Ed1-21	Analysis of sulfur dioxide and nitrogen oxide emission reduction alternatives with electricity rate subsidies.
Ed1-40	Proceedings of Acid Precipitation: The North American Challenge.
Ed1-41	Conference proceedings. Intergovernmental Conference on Acid Rain.
Ed2-2	An analysis of issues concerning "acid rain."
Ed2-3	Development of atmospheric deposition regulatory programs related to PSD.
Ed2-4	Acid rain and transported air pollutants: implications for public policy.
Ed2-5	Economic evaluation of S.2203, the "New Clean Air Act."
Ed2-14	Annex IV to the agreement between the United States of America and the United Mexican States on cooperation for the protection of the environment in the border area.
Ee1-1	Northeast damage report of the long range transport and deposition of air pollutants.
Ee2-2	A policy for New York State to reduce sulfur dioxide emissions. Draft environmental impact statement, executive summary.
Ee2-4	Acid rain presentation to the Natural Resources Board.
Ef7-1	Acid rain: The Canadian control program.

PUBLIC ISSUES

CATALOG #	TITLE
Ea6-1	News releases.
Ea6-2	Finis Mitchell, lord of the Winds.
Ea6-3	The DEQ annual report, fiscal year 1986.
Ea6-4	Newspaper clippings and popular articles.
Ec1-5	Acid deposition in Utah: An analysis by the Acid Deposition Technical Advisory Committee.
Ec6-1	Results out from acid rain study.
Ec6-2	EPA survey finds almost no acidic lakes in West, some have low buffering capacity.
Ec7-1	Acid rain in the West? Some points to ponder.
Ec7-2	Critique of the report, "The American West's Acid Rain Test."
Ec7-3	Western states programs assess and control acid rain.
Ed1-7	The great acid rain mystery (myths and realities in the claims against acid precipitation). Final report.
Ed1-48	Memorandum: U.S. Senate Environment and Public Works oversite hearings on acid rain research.
Ed2-1	Summary of the Proxmire-Humphrey Bill and comparison with other acid-rain control bills.
Ed2-2	An analysis of issues concerning "acid rain."
Ed2-3	Development of atmospheric deposition regulatory programs related to PSD.
Ed2-6	Congress compares acid rain control bills as Proxmire-Humphrey joins ranks.
Ed4-1	Acid deposition and motor vehicles.
Ed4-2	Acid rain: Who pays? Who benefits?
Ed6-1	Rocks--saviors or killers.
Ed6-2	Newspaper clippings and popular articles.
Ed7-1	Maybe acid rain isn't the villain.
Ed7-2	ERT Newsletter.
Ed7-3	Environmentalists try the backdoor approach to tackling acid rain.
Ed7-4	Acid rain resources directory.
Ed7-5	Acid rain.
Ee1-2	An analysis of acid deposition issues: The impacts of proposed national acid deposition control legislation on Florida.
Ee1-5	The acid test: is Wisconsin threatened?
Ee2-5	Summary of Wisconsin's acid rain legislation.
Ee4-1	Recommended position on acid deposition.
Ee7-1	Commonly asked questions about acid rain in Wisconsin.
Ef6-1	The acid rain story.
Ef7-1	Acid rain: The Canadian control program.
Ef7-2	Moving ahead on acid rain.
Ef7-3	Acid rain: The statistics.

RECOMMENDATIONS

CATALOG #	TITLE
D3-1	Letter to R. Wood: Monitoring and research recommendations to the Wyoming Acid Rain Coordinating Committee.
D8-1	Issues and priorities.
D13-1	Research priorities for acidic deposition in Wyoming.
Ea1-4	Acidic deposition in Wyoming: A technical summary and perspective.
Ea2-1	Letter to Dick Cheney, Alan Simpson, and Malcolm Wallop: Wyoming acid rain strategy.
Ea2-2	Letter to Governor Ed Herschler: Statement on Wyoming strategy for addressing the potential for acid rain and enforcement.
Ea4-1	Acid deposition in Wyoming: A proposal on prioritization of research/monitoring efforts.
Ea4-2	Acid deposition in the Rocky Mountain Region.
Ea4-3	Acid deposition, Wyoming.
Ea4-4	Considerations for Commission support relative to acid deposition in Wyoming.
Ea4-5	Acid rain: a Wyoming perspective.
Eb1-10	Acid deposition in Colorado. Volume 1: A summary of current knowledge, ongoing research, and critical research needs. Volume 2: Technical annex.
Eb4-1	The PSD increments and NAAQS for SO2 do not protect against acidification of sensitive environments: Colorado needs an acid deposition standard.
Eb4-2	A perspective on acid rain in the Rocky Mountains.
Ec1-5	Acid deposition in Utah: An analysis by the Acid Deposition Technical Advisory Committee.
Ec1-13	The American West's acid rain test.
Ec1-14	Evaluation of acid deposition control policies for Washington.
Ec1-15	Technical and institutional foundations for an integrated, interstate control strategy to prevent significant acid deposition in the Western United States: A proposed state acid rain project.
Ec4-1	Western smelters and acid rain: Setting the record straight.
Ec4-2	U.S. acid deposition control legislation: A view from the Pacific Northwest.
Ec4-3	Oregon's views on acid precipitation.
Ec4-4	Acid deposition and the West: A scientific assessment.
Ec4-5	Safeguarding acid-sensitive waters in the intermountain West: a sulfur pollution strategy for preventing acid pollution damage in the intermountain air shed.
Ed1-11	Recommendations for the determination of pH in low ionic strength fresh waters.
Ed4-1	Acid deposition and motor vehicles.
Ed4-2	Acid rain: Who pays? Who benefits?
Ee1-4	Evaluation of the impact to Wisconsin's forests from atmospheric pollutants.
Ee2-4	Acid rain presentation to the Natural Resources Board.
Ee4-1	Recommended position on acid deposition.
Eg1-1	Forest in danger.

RESEARCH PROGRAMS

CATALOG #	TITLE
D3-1	Letter to R. Wood: Monitoring and research recommendations to the Wyoming Acid Rain Coordinating Committee.
D8-1	Issues and priorities.
D13-1	Research priorities for acidic deposition in Wyoming.
Ea1-1	The acid deposition potential for the streams and lakes of the Wind River Mountains.
Ea1-2	Acid deposition in the Wind River Mountains.
Ea1-3	Acid deposition in the Bridger Wilderness--first year results.
Ea1-5	Aerosol characterization study of Lander and Sheridan, Wyoming: Chemical analysis and source apportionment. Final report, vol. I.
Ea1-6	Acid rain related studies in Wyoming.
Ea1-8	U.S.D.A. Forest Service, Bridger and Fitzpatrick Wilderness air quality related values action plan.
Eb1-4	Acid rain in the Rocky Mountain West -- meeting abstracts.
Eb1-5	Assessment of the cumulative environmental impacts of energy development in northwestern Colorado: Final report.
Eb1-6	Effects of atmospheric deposition on alpine and subalpine ecology: A proposed framework for western research.
Eb1-8	Acid rain research in the Intermountain West and the value of potentially impacted resources -- research proposal.
Eb1-9	Acid precipitation in the Colorado Front Range: An overview with time predictions for significant effects.
Eb1-11	Chemical characterization of surface water quality during spring snowmelt in an acid-sensitive Rocky Mountain watershed.
Ec1-1	Selected research activities related to atmospheric deposition in the Rocky Mountain West.
Ec1-2	The third annual report to the Governor and the Legislature on the Air Resources Board's Acid Deposition Research and Monitoring Program.
Ec1-3	The fourth annual report to the Governor and the Legislature on the Air Resources Board's Acid Deposition Research and Monitoring Program.
Ec1-8	Summary report of the Western Atmospheric Deposition Task Force Research Planning Workshop, July 10-12, 1985, Colorado Springs, CO.
Ec1-10	Chemical patterns of bulk atmospheric deposition in the State of Colorado.
Ec1-12	Proposed research plan for the Western Conifers Research Cooperative, preliminary draft.
Ec1-15	Technical and institutional foundations for an integrated, interstate control strategy to prevent significant acid deposition in the Western United States: A proposed state acid rain project.
Ec1-16	Western states acid deposition project: Technical status report for the period 1 May - 30 June, 1986.
Ec1-18	Characteristics of lakes in the Western United States.
Ec1-19	Atmospheric deposition: Natural ecosystems, western United States.

RESEARCH PROGRAMS (continued)

CATALOG #	TITLE
Ec1-20	Proposed research plan for the Western Conifers Research Cooperative, preliminary draft.
Ec1-21	Acid rain program technical report.
Ed1-2	Characterizing deposition: Background. Overview of NADP/NTN program.
Ed1-3	Aquatic research and monitoring.
Ed1-4	Air quality monitoring.
Ed1-5	State-operated wet deposition stations.
Ed1-6	Lake acidification and fisheries: Project description.
Ed1-8	Acid Precipitation Digest.
Ed1-13	Electric power data base acid deposition project inventory.
Ed1-14	Acidic deposition catalog: Research and development.
Ed1-18	Empirical models of fish response to acidification.
Ed1-24	A brief summary of surface-water acidification effects on fish.
Ed1-27	Terrestrial effects--Task Group V -- meeting handout.
Ed1-29	Acidic deposition research.
Ed1-40	Proceedings of Acid Precipitation: The North American Challenge.
Ed1-41	Conference proceedings. Intergovernmental Conference on Acid Rain.
Ed1-46	EPA watershed research program.
Ed1-49	Atmospheric deposition research in U.S. forests.
Ed1-51	Summary results from the "Joint Water Chemistry Comparison of Several Quebec and New York Lakes in Relation to Acidification."
Ed8-1	Statement of Dr. J. Christopher Bernabo before the Committee on Science and Technology, Natural Resources, Agriculture Research and the Environment Subcommittee, U.S. House of Representatives.
Ee1-5	The acid test: is Wisconsin threatened?
Ee1-6	First annual report on the Wisconsin Acid Deposition Research Program.
Ee1-7	Second interim report on the Wisconsin acid deposition research program.
Ee1-9	Summary of Wisconsin acid deposition research and monitoring, 1979-1986.
Ef1-2	Journee d'information sur l'acericulture.
Ef1-3	Acidic precipitation in Ontario study: Annual program report, fiscal year 1984/1985.

RESEARCH REVIEWS

CATALOG #	TITLE
D5-1	Impacts of acid deposition: Written statement for the Wyoming Acid Rain Coordinating Committee.
Ea4-1	Acid deposition in Wyoming: A proposal on prioritization of research/monitoring efforts.
Eb1-2	Acid deposition in the Rocky Mountain Area: study needs summary.
Eb1-10	Acid deposition in Colorado. Volume 1: A summary of current knowledge, ongoing research, and critical research needs. Volume 2: Technical annex.
Ec1-7	Source-receptor relationships for acid deposition: Pure and simple?
Ec1-17	Summary of Project WESCO: Western Emission Source Contributions to Regional Visibility Impairment.
Ec4-4	Acid deposition and the West: A scientific assessment.
Ec7-2	Critique of the report, "The American West's Acid Rain Test."
Ed1-7	The great acid rain mystery (myths and realities in the claims against acid precipitation). Final report.
Ed1-9	Summary and synthesis.
Ed1-22	Annual Report, 1983.
Ed1-23	Annual report, 1984.
Ed1-26	Effects of air pollution on forests: A critical review.
Ed1-39	The study of the Acid Rain Roundtable conducted by ICF, Inc. for the National Wildlife Federation, et al.
Ed1-43	Research summary: acid rain.
Ed1-48	Memorandum: U.S. Senate Environment and Public Works oversite hearings on acid rain research.
Ee1-3	Acid deposition in Maryland: A report to the Governor and General Assembly.
Ee1-4	Evaluation of the impact to Wisconsin's forests from atmospheric pollutants.
Fb-7	Baseline Protocols for Wilderness meeting.
Fb-8	January 24, 1986 meeting of the Western Atmospheric Deposition Task Force.

SURFACE WATER CHEMISTRY

CATALOG #	TITLE
D4-1	Acidification and watershed/lake systems: Key processes and a western perspective.
D9-1	Discussion of sensitivity of watersheds in Wind River Mountains to acid deposition.
Ea1-1	The acid deposition potential for the streams and lakes of the Wind River Mountains.
Ea1-9	Limnological study of selected lakes in the Wind River Range--with emphasis on the potential for acidification from acid precipitation.
Ea1-10	First preliminary data analyses on Fremont and New Fork Lakes near Pinedale, Wyoming.
Eb1-6	Effects of atmospheric deposition on alpine and subalpine ecology: A proposed framework for western research.
Eb1-11	Chemical characterization of surface water quality during spring snowmelt in an acid-sensitive Rocky Mountain watershed.
Ec1-9	Characteristics of lakes in the Western United States. Volume I: Population descriptions and physico-chemical relationships. Preliminary draft.
Ec1-18	Characteristics of lakes in the Western United States.
Ec6-2	EPA survey finds almost no acidic lakes in West, some have low buffering capacity.
Ed1-11	Recommendations for the determination of pH in low ionic strength fresh waters.
Ed1-16	Analysis of acid precipitation samples collected by State Agencies, sampling period: Sept. '83 - Dec. '84.
Ed1-25	Lake acidification and fisheries, quarterly report, January to March 1987.
Ed1-51	Summary results from the "Joint Water Chemistry Comparison of Several Quebec and New York Lakes in Relation to Acidification."
Fb-5	Meeting announcement: EPA/States Forum on Acid Deposition Aquatics Research.

TESTIMONY

CATALOG #	TITLE
Ea8-1	The growing threat of acid rain in the West. Testimony for the record. U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Health and the Environment.
Ea8-2	Statement before the United States Senate Committee on Environment and Public Works.
Eb8-1	Testimony before the Subcommittee on Health and the Environment on H.R. 4567 "Acid Deposition Control Act of 1986."
Ec8-1	Testimony of New Mexico Governor Toney Anaya before the U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Health and Environment.
Ec8-2	Statement of Dr. Mohamed T. El-Ashry before the House Subcommittee on Health and the Environment.
Ec8-3	Testimony of Western Energy Supply and Transmission (WEST) Associates on H.R. 4567, the Acid Deposition Control Act, 1986 before the Health and Environment Subcommittee, U.S. House of Representatives.
Ec8-4	The smelter triangle: An overview of U.S.-Mexico negotiations. Testimony presented before the U.S. Senate Committee on Environment and Public Works.
Ec8-5	Statement before the U.S. Senate, Committee on Environment and Public Works.
Ec8-6	Testimony before the U.S. Senate, Committee on Environment and Public Works.
Ec8-7	Testimony of James C. Wilson before the U.S. Senate, Committee on Environment and Public Works.
Ec8-8	Testimony on smelters and acid rain in the West. Presented before the U.S. House of Representatives, Subcommittee on Health and the Environment, Committee on Energy and Commerce.
Ec8-9	The West needs acid rain protection too: An acid rain prevention program for the West. Testimony presented before the U.S. House of Representatives, Subcommittee on Health and the Environment.
Ed8-1	Statement of Dr. J. Christopher Bernabo before the Committee on Science and Technology, Natural Resources, Agriculture Research and the Environment Subcommittee, U.S. House of Representatives.
Ed8-2	Testimony of Chris Farrand before the U.S. House of Representatives, Committee on Energy and Commerce, Subcommittee on Health and the Environment.
Ed8-3	Air quality and forest health. Testimony presented before the U.S. Senate, Committee on Energy and Commerce, Subcommittee on Health and the Environment.
Ed8-4	Statement of Lee M. Thomas, Administrator, U.S. Environmental Protection Agency, before the U.S. Senate, Subcommittee on Health and the Environment, Committee on Energy and Commerce.
Ed8-5	Testimony on pending acid rain and toxic air pollution bills presented before the U.S. House of Representatives, Subcommittee on Health and the Environment.

VEGETATION EFFECTS

CATALOG #	TITLE
D5-1	Impacts of acid deposition: Written statement for the Wyoming Acid Rain Coordinating Committee.
D14-1	Impacts of atmospheric pollution on vegetation.
Ea1-2	Acid deposition in the Wind River Mountains.
Eb1-1	Investigation into the health of forests in the vicinity of Gothic, Colorado.
Eb1-6	Effects of atmospheric deposition on alpine and subalpine ecology: A proposed framework for western research.
Ec1-12	Proposed research plan for the Western Conifers Research Cooperative, preliminary draft.
Ed1-1	Acid Deposition Symposium: Technical program abstracts.
Ed1-10	Acid precipitation in relation to agriculture, forestry, and aquatic biology.
Ed1-22	Annual Report, 1983.
Ed1-23	Annual report, 1984.
Ed1-26	Effects of air pollution on forests: A critical review.
Ed1-27	Terrestrial effects--Task Group V -- meeting handout.
Ed1-30	Effects of low concentrations of O3 on net photosynthesis, dark respiration, and chlorophyll contents in aging hybrid poplar leaves.
Ed1-31	Effects of low level O3 exposure on leaf diffusive conductance and water-use efficiency in hybrid poplar.
Ed1-32	Influence of low concentrations of ozone on growth, biomass partitioning and leaf senescence in young hybrid poplar plants.
Ed1-33	Low level O3 and/or SO2 exposure causes a linear decline in soybean yield.
Ed1-34	Ambient levels of ozone reduce net photosynthesis in tree and crop species.
Ed1-35	Effects of low concentrations of O3, leaf age and water stress on leaf diffusive conductance and water use efficiency in soybean.
Ed1-36	Effects of O3, SO2, and acidic rain on mycorrhizal infection in northern red oak seedlings.
Ed1-37	Reduction in growth of hybrid poplar following field exposure to low levels of O3 and (or) SO2.
Ed1-38	Spectral characterization and mapping of boreal forest damage suspected of being due to acid deposition (acid rain).
Ed1-44	Terrestrial/aquatic linkages. Draft.
Ed1-47	Responses of forests to atmospheric deposition, preliminary draft.
Ed1-49	Atmospheric deposition research in U.S. forests.
Ed8-3	Air quality and forest health. Testimony presented before the U.S. Senate, Committee on Energy and Commerce, Subcommittee on Health and the Environment.
Ee1-4	Evaluation of the impact to Wisconsin's forests from atmospheric pollutants.
Ef1-1	Un patrimoine en detresse.
Ef1-2	Journee d'information sur l'acericulture.

VEGETATION EFFECTS (continued)

CATALOG #	TITLE
Egl-1	Forest in danger.
Fb-4	Symposium announcement: Assessing air quality with lichens and bryophytes.

Western Aquatics, Inc.

ENVIRONMENTAL CONSULTANTS

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December 15, 1987

Dr. Victor R. Hasfurther, Acting Director
Wyoming Water Research Center
University of Wyoming
Box 3067, University Station
Laramie, Wyoming 82071

Dr. Vic:

As promised last week, I have enclosed our final report titled "Testimony Summaries and Index to Materials for the Wyoming Acid Rain Coordinating Committee." While completing this project took much longer than I had originally expected, it was also a much larger task than expected. Once we started the project, we decided that what was most appropriate to address the needs of the Committee and the State is the product enclosed. I think you will agree.

In addition to the enclosed report, we have also sorted and cataloged, as shown in the final sections of the report, all of the supporting reference materials compiled by the Committee. These documents are contained in four boxes, which we will keep at our offices until we can arrange transport for them to DEQ, where I assume the files will finally reside. If you or others at the Water Center or if DEQ personnel are traveling between Laramie and Cheyenne, perhaps I can arrange for their passage. Otherwise, I hope to be in Cheyenne after the first of the year and will bring them over then.

Also, Harold Bergman told me that both Dave Park and Ron Surdam had requested to receive copies of the report as I submitted it to you. Due to length of the final report (220 pages) and our very limited budget for this project, I am able to send them only the front end materials, the first two sections, and the first several pages from each of the remaining sections. I assume that you will forward the enclosed full copy to Randy Wood.

Finally, as you requested, our final invoice for $1660 is enclosed. I hope that the delay in this project's completion has not caused any inconvenience.

Sincerely,

Mike

Michael D. Marcus,
President

Enclosures
cc. R. Wood
D. Park
R. Surdam

WYOMING WATER RESEARCH CENTER
The University of Wyoming

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December 18, 1987

Dr. Harold Bergman
Department of Zoology
Biological Sciences Bldg.
University of Wyoming
Laramie, WY 82071

Dear Harold:

Enclosed is a copy of the final report "Testimony Summaries and Index to Materials for the Wyoming Acid Rain Coordinating Committee" for your review. Copies have been transmitted to Randy Wood and Steven Gloss for review as well as those indicated by the Marcus letter.

Please let me know what you feel should be done with the report. Have a Merry Christmas and a Great New Year.

Sincerely,

Victor Hasfurther
Associate Director

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