

**WATER RESOURCES  
COOPERATIVE PARK STUDIES UNIT  
1991 PROGRESS REPORT**

**Raymond Herrmann, Leader**

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FY 1991  
SUMMARY OF WATERSHED RESEARCH  
NATIONAL PARK SERVICE  
WR-CPSU COLORADO STATE UNIVERSITY

R. HERRMANN, WR-CPSU LEADER

During 1991, the watershed level research and monitoring site activities have contributed to the accumulation of important baseline information on deposition, meteorology, hydrology, ecosystem functioning, and biology. In some cases, important information on biological diversity and biogeochemical processes have been obtained. Activities have ranged from needs identification, to reconnaissance or synoptic analyses, to long-term monitoring and to long term ecosystem research. Forty two (42) publications were written, submitted and published during 1991 based on watershed project results at OLYM, ISRO, SEQI and ROMO. Also 13 presentations on watershed research were highlighted during 1991. Watershed activities now involve 15 parks (APIS, CRLA, DENA, GRSM, ISRO, LACL, NOAT, PIRO, ROMO, SEQI, SHEN, GLAC, OZAR/BUFF and SLBE) and the Oka and Caucasus Reserves of the Soviet Union.

The period 1991-2000 provides for the enhanced understanding of watershed processes within the context of comprehensive natural resources inventory and monitoring. Presently, the watershed program under the direction of the WR-CPSU is implemented at four (4) geographically diverse research watersheds (SEQI, ROMO, ISRO, OLYM). There are also similar cooperating programs at or planned in SHEN, GRSM, EVER, CRLA, GLAC, OZAR/BUFF and DENA. By providing basic site support, including research coordination and cooperation, data management, and scientific and managerial review, the program has attracted external research expertise and research funding greatly exceeding NPS's own investments.

The WR-CPSU and Colorado State University, Watershed Research Studies Program is aimed at developing a hydrologically, geologically and ecologically sound program for collection of long-term baseline data on the state of park ecosystem health. The program is developing a network of representative long-term watershed research sites compatible with and complementary to other agency efforts. Quantification of the hydrologic cycle and chemical flux are major objectives of the NPS watershed program. Such measurements, when combined with other geographic resources data (e.g. geology, land-use, topography, historic and pre-historic records), permits a better understanding of ecosystem-level processes and of how park watershed-ecosystems respond to various natural and human-induced stimuli, and allows one to interpret environmental change as an early indicator of resources impairment for the improved management of NPS watersheds.

From the period 1982-1989, the National Park Service watershed research program was focussed to provide information to detect actual and potential impacts from changing atmospheric chemistry. 1990 was a transition year where emphasis was on finishing those commitments required by the National Acid Precipitation Assessment Program and preparing for implementation of new program emphases. Resources questions currently of direct concern to park resources management may be local, regional, or global. They result from today's modern technological world and can be broadly categorized into four areas: biogeographic changes including translocation, fragmentation,

migration and invasion; land-use changes owing to recreation, industrial development and resource exploitation; climate changes, including temperature change, mean sea level change and change of precipitation patterns and amounts; and, biogeochemical changes such as those caused by acid rain, increased carbon dioxide and increased levels of trace contaminants.

The research strategy is to address these complex experimental issues of the Park Service through a pilot ten-year program involving multi-institutional, interdisciplinary and integrated watershed research studies. The program is meant to develop, test and implement state-of-the-art science methods and procedures for application to future water and land resource management at both the national and international levels. Five broad study goals are being pursued: 1) develop and implement example procedures and protocols to identify, collect, organize, analyze and synthesize selected watershed data within representative watersheds and to interpret for park management the current status and trends in the condition of the park natural resources contained therein; 2) establish baseline conditions for watershed processes against which change can be measured and evaluated including those related to climate change and pollution levels and trends; 3) seek to identify similarities or differences in watershed response to stress and make this new knowledge available to the scientific community and report to management on its significance to the management of park resources; 4) provide in the parks protected watershed sites as part of a national and possibly international system of background sites establishing both the ecological and pollutant baseline against which national and global trends can be measured; and, 5) assess at four study parks a GIS-based watershed condition theme to be implemented within the context of NPS Inventory and Monitoring. Information being developed will permit a methodical description and quantification of the watershed and will be organized to represent key data categories, specific data elements, and their relationship to the watershed.

## WATERSHED STUDIES RESEARCH

Program Leader: Raymond Herrmann

<u>Funding:</u>	<u>Watershed Field Studies</u>	<u>317,000</u>
	CSU Research Support and Administration	34,000
	GIS Watershed Research	<u>8,000</u>
	Subtotal 1991	359,000
	Federal travel	6,000
	Other research project support	30,000
	Subtotal other federal 1991	<u>36,000</u>
	Total 1991	395,000

The U.S. National Park Service (NPS) is faced with direct questions about the condition of park natural resources, park-specific issues of both internal and external origin and a number of general problems of a regional or global nature. These issues have immediate and long-term potential to affect integrity and management of park watersheds. Water and many ecological issues are most conveniently studied and best managed within the theoretically confined system -- the watershed. This unit is more easily comprehended than the generic term "ecosystem". To better address these issues, a program has been developed that recognizes water, as an integrator, transporter, solvent and as an organically and inorganically active substance common to all ecological systems and common to many resource problems.

The watershed approach to long-term study and monitoring of natural, and remote areas within the National Parks has provided important data for detecting both spacial and temporal changes in environmental conditions. These data collections allow the partitioning of cause and effect relationships of ecological change within a given watershed. They also serve to meet both reference and early warning objectives. Success in advancing a number of "acid precipitation" goals has demonstrated the usefulness of these integrated watershed data for inter-ecosystem comparison and for analogy between watersheds. The watershed program owing to the NPS experience provides to park researchers and resources managers the needed tools for dealing with today's complex local, regional and global natural resources issues.

In 1980, the NPS national program of long-term watershed research was proposed to monitor atmospheric inputs and to establish baseline data on climate, chemistry, geology, soils, vegetation, hydrology and aquatic resources. The intent was to provide data on atmospheric inputs, ecosystem condition, system response to acidification and stream outputs. The approach emphasized was understanding the watershed hydrologic cycle and building an information base sufficient to test a number of hypotheses regarding acidification. The study sites chosen from the fourteen NPS Biosphere Reserves, were selected to be biogeographically representative of ecosystems in relatively remote areas, and to span a gradient of sites, impacted and unimpacted by atmospheric deposition. Essential continuity was provided for by developing and employing carefully selected equivalent "core" measurements. The integrated program design, focused each site

toward meeting the programmatic objectives, emphasized the importance of hydrology and incorporated those "minimal core measurements" and "common biotic and abiotic elements of change" needed to analyze and partition cause and effect relationships at the watershed level. Most of these repetitive measurements support a hydrologically driven input-output model.

NPS involvement in integrated watershed ecosystem studies and related research suggests that impacts from externally caused effects to National Parks can be subtle, insidious, chronic and long-term. Proving environmental cause and effect, however, increasingly involves not only detecting component changes, but also detecting significant trends in processes that can be attributed to human sources.

Major changes in plant and animal distributions and abundance, biodiversity, hydrology and water quality, and fire regimes are suspected as the result of processes active at the global scale. At each watershed site, the WRSP is contributing to the accumulation of important baseline information on deposition chemistry, meteorology, hydrology and ecosystem processes. In many cases, important information on both aquatic and terrestrial biological diversity has also been obtained. These data are providing important support to new NPS global change program efforts and to the inventory and monitoring initiative.

#### Program Coordination and Cooperators

NAPAP was a decade-long program for the 1980's. But, while the 1990 Assessment of NAPAP is still being completed NAPAP has been re-authorized. Also, major government and international funding agencies are considering the development and continuation of programs to assess a broad range of impacts to the environment including aspects of both the chemical (acid precipitation and air pollution) and physical (temperature and precipitation). Programs proposed or ongoing, include the EPA's Environmental Monitoring and Assessment Program (EMAP) and Temporally Integrated Monitoring of Ecosystems (TIME); the International Council of Scientific Unions' (ICSU's) International Geosphere Biosphere Program (IGBP), and the US interagency Committee on Earth and Environmental Sciences (CEES) Global Climate Change Program; the USGS, Water Energy and Biogeochemical Budgets (WEBB), Hydrologic Benchmark Network and National Stream Quality Accounting Network (NASQAN) programs; and, the global climate change programs of the USFS, BLM, NASA and the interagency Fresh Water Initiative. These organizations have specifically stated that they wish to include National Park Service watershed sites as prospective sites within their monitoring networks due to the protected nature of parks, the likely sensitivity of parks to environmental impacts, the existing data base and the site support that they can expect. The NPS Watershed Program is working to make this a reality.

#### Program Objectives

From the period 1982-1989, the National Park Service watershed research program, as previously discussed, was designed primarily to provide information to detect actual and potential impacts from changing atmospheric chemistry. The program, as implemented, became part of the National Acid Precipitation Assessment Program in 1982. It incorporated four National Parks (Isle Royale NP, Olympic NP, Rocky Mountain NP, Sequoia and Kings Canyon NP). Two additional National Parks (Great Smoky Mountains NP and Shenandoah NP) had similar but separately

funded studies underway. 1990 was a transition year, finishing those commitments required by the NAPAP and preparing for new program activities having a broadened watershed emphasis.

For the period 1991-2000 the program provides for the broad characterization of watersheds within units of the NPS in order to develop enhanced understanding of relationships between watershed processes and ecosystem health. A primary focus is interpreting watershed information as an early indicator of potential impairment to natural resources. Seven study objectives are being pursued:

- 1) Develop and implement example procedures and protocols to identify, collect, organize, analyze and synthesize selected watershed data within representative watersheds and to interpret for park management the current status and trends in the condition of the park natural resources contained therein.
- 2) Establish baseline conditions of watershed processes against which change in the hydrologic cycle can be measured and evaluated; study issues include pollution levels and trends, global climate, important bio-geochemical cycles and effected ecosystem processes.
- 3) Seek to establish watershed response to stress and make this new knowledge available to the scientific community and report on its significance to the management of park/reserve resources.
- 4) Assist parks to develop watershed sites as part of a national and possibly international system of background sites establishing a hydrological, ecological and pollutant baseline against which national and global trends can be measured.
- 5) Develop and test in at least four pilot parks a watershed research theme to be implemented within the context of NPS Global Climate Change and Inventory and Monitoring.
- 6) Coordinate with similar interagency, inter-institutional and international efforts (viz. WEBB, FWI, Benchmark, MAB, NAPAP, LTER, Forest Effects).
- 7) Develop strong linkages between the NPS Global Climate, Inventory and Monitoring and Watershed Research Programs.

### Program Accomplishments

Potentially significant conclusions, common to most long-term watershed-ecosystem programs and studies, are emerging. First, the testing of germane hypotheses on ecosystem structure and function requires an ecological context which can only be provided through long-term watershed monitoring and understanding of the hydrologic cycle. Second, many of the "index" biological and chemical species studied to detect human-induced change have considerable annual natural variation in occurrence, magnitude and frequency. Separating anthropogenic change in ecosystem structure and function from natural change requires detecting statistically significant trends against what can be very "noisy" baseline conditions. Third, ecosystem studies permit the analysis of processes operating between and among biotic and abiotic components. There is



increasing evidence that understanding the magnitude of variation within such processes can provide an earlier indication of environmental change or trends attributable to human-induced stress. Fourth, the watershed-ecosystem concept better permits assessment of the full magnitude of impact which can serve as a stronger basis for possible mitigation. Fifth, to be effective, studies at the ecosystem level need to be truly multi-disciplinary in design.

The integrated watershed approach of the NPS Watershed Studies Research Program combines research, inventory, and monitoring into a directed program for the collection of data needed to test hypotheses regarding the contribution of human-induced stress to long-term ecological change within parks. The long-term management strategies of the NPS combined with the "protected" nature of Park lands placed the NPS in a unique position among Federal agencies and among international conservation organizations to document relationships between ecosystem effects and anthropogenic influences.

The WRD supports and funds cooperatively with the parks (and often other agencies) four representative long-term watershed research sites at ISRO, OLYM, ROMO and SEKI, that are compatible with and complementary to other interagency sites. Quantification of the hydrologic cycle and chemical flux are major objectives of the NPS watershed program. Cooperative sites included in the NPS watershed network but receiving funds from WRD are SHEN, GRSM, NOAT and the Global Change watershed sites.

In addition to the NPS Watershed Studies Research program, the ARB continues to coordinate with the Acid Rain program and NAPAP, the Global Climate Change Program and technical aspects of the NPS Geothermal Program.

Seven areas now have some watershed research activities: Crater Lake National Park (CRLA), Great Smoky Mountains National Park (NP) (GRSM), Isle Royale NP (ISRO), Olympic NP (OLYM), Rocky Mountain NP (ROMO), Sequoia and Kings Canyon NP's (SEKI), and Shenandoah NP (SHEN). The four sites discussed earlier (ISRO, OLYM, ROMO, and SEKI) have received partial funding through the Watershed Program. Additional major funding for these sites has been from external sources. Currently, all four sites have been designated as part of, and receive funding from, the NPS Global Climate Change Program. The NPS has also supported acid deposition research at SHEN, GRSM (both are now included in the NPS Inventory and Monitoring (I&M) Program along with DENA) and Everglades NP (EVER), and a substantial lake studies program at CRLA (now included in the NPS Global Climate Change Program). New watershed sites included in the NPS Global Climate Change (GCC) Program are EVER, Glacier NP (GLAC), Organ Pipe Cactus National Monument (ORPI), Noatak National Preserve (NOAT) and Buffalo Wild and Scenic River/ Ozarks National River (BUFF/OZAR) (Table 2). Because NPS watershed research was conducted within the context of NAPAP and is now supporting the NPS I&M and the government-wide Global Climate Change Programs, our results will be enhanced by these related research activities.

Herrmann and Stottlemeyer reported, in brief, the status of watershed site activities through 1991 in *Environmental Management and Assessment*: "Sequoia and Kings Canyon National Parks have alpine and sub-alpine watersheds with low buffering capacities within two distinct physiographic regions. At Sequoia, atmospheric inputs at 3 elevations representing 3 major ecosystems (chaparral, coniferous forests and sub-alpine), have been monitored and baseline data on soils, vegetation, and aquatic communities collected. Specific studies include analysis of precipitation chemistry, dry deposition, stream hydrology, aquatic chemistry and biology, soil chemistry, meteorology, nutrient

fluxes, and vegetation structure and function. Emphasis was placed on detection of long-term change of atmospheric inputs and of the effects upon natural ecosystems, across the elevational gradient. Temporary acidification of high elevation lakes and streams of the Sierra Nevada has been documented during spring snow melt and after acidic summer storms. The effects of atmospheric contaminants on forest productivity are being evaluated.

At Rocky Mountain, atmospheric ionic inputs have been monitored in alpine and sub-alpine lakes having low buffering capacity. Baseline data on soils, vegetation and aquatic communities have also been collected. Studies have focused on soil and water chemistry, and have investigated historical changes in pH in Rocky Mountain high elevation lakes. No permanent influence on pH attributable to acid deposition has been observed. In the Lock Vale sub-alpine watershed study site the 7 year biogeochemical study has greatly increased our knowledge of: response of natural systems to stress, sources and types of both wet and dry deposition, bedrock weathering rates and weathering mechanisms, soil characteristics and buffering mechanisms, terrestrial nutrient cycles, and alpine and sub-alpine surface water chemistry, biology and hydrology. Extrapolations are now being considered to other study sites within the southern Rocky Mountain region.

Isle Royale National Park represents an upper Midwest forest ecosystem experiencing increased levels of acid deposition. Seasonal variations in precipitation chemistry have been evaluated as to their effect on small watershed ecosystems. Other questions investigated were the increase of atmospheric loading with elevation above Lake Superior, how vegetation affects the quality and quantity of precipitation, the influence of alkaline glacial till on streamwater quality, the quantification of biogeochemical cycling for specific nutrients, and snowpack quality. Sulfate was found to be minimally adsorbed by soils, suggesting that nutrient leaching is possible in many similar forest systems due to sulfate mobility. This may accelerate ecosystem acidification. Preliminary data show an increase in forest ecosystem nutrient leaching across the region attributable to sulfate in acid deposition.

Olympic National Park represents a relatively pollution free area with substantial maritime influence on terrestrial and aquatic ecosystems. Pronounced differences in the dominant ions in precipitation (sodium and chloride) and streamflow (calcium and sulfate) occur. Research objectives are to develop an understanding of the sources and flux of atmospheric coastal sulfur of marine origin, and their biologic implications.

Great Smoky Mountains National Park in the southeastern U.S is in a mountainous area of high acid deposition. Temporary acidification of streams due to acid precipitation has been documented.

Shenandoah National Park, along the crest of the Blue Ridge Mountains, is an eastern site with high sulfate deposition. At Shenandoah, study was initiated to monitor and characterize stream and soil sensitivity to airborne pollution, and to develop a baseline for determining acid induced change. Research has concentrated on analysis of watershed chemical budgets. Poorly buffered streams have been chronically acidified in the Park and surrounding region."

## 1991 Accomplishments of the WR-CPSU

Continued discussions to develop a NPS network of ongoing programs with watershed research elements (DENA, NOAT, OZAR/BUFF, ROMO, SEQI, ISRO, OLYM, GRSM, SHEN, EVER, CRLA, GLAC).

Based on knowledge obtained from the four NPS watershed research sites (SEQI, OLYM, ISRO, ROMO) established under NAPAP and other NPS sites with elements of an active watershed program, continued support for NPS watershed studies research as part of the new NPS global change program. Global change sites with watershed components are CRLA, GLAC, ISRO, ROMO, and OZAR/BUFF.

Continued coordination with other watershed research agencies (USFS, EPA, USGS, DOE, NSF, NASA, etc.).

Maintained important ties with the NSF, LTER network.

Began assessment of options for NPS watershed research to support improved NPS watershed management as part of the NPS inventory and monitoring program.

Continued support for data collection needed to assess watershed change at 4 NPS sites (SEQI, ISRO, ROMO, OLYM).

Finalized for publication the Lawn Lake Flood Monograph.

Consulted on NPS National Inventory and Monitoring program.

Hosted the annual NPS watershed meeting.

Provided interagency coordination to USGS (NASQUAN, WEBB, Benchmark, and Global Climate Change programs)

Consulted to the NPS inventory and monitoring program

Served as member of the NPS Global Climate Change Program Committee

Reviewed and commented on 23 NPS global climate change research proposals

Represented NPS on the interagency Fresh Water Initiative, Coordinating Council

Participated in Water Quality 2000, an interagency inter-institutional effort to develop a broad consensus on future national water quality goals

Supported and continue to serve as chair of the 1992 Conference "Managing Water Resources During Global Change"

Continued liaison between the watershed research program and other NPS research and monitoring initiatives (I&M, GCCP, Target Parks)



Reviewed research proposals for UCOWR for water resources research under Section 105 of the Water Resources Research Act of 1984.

## **ASSISTANCE TO PARKS AND REGIONS**

### **ARO**

- assessment of interagency cooperative geothermal research at Katmai N.P. and Preserve
- participation on Katmai Science Experiments Review Panel and on the interagency review team for the Katmai EIS
- continued to assistance to ARO and Noatak N. Preserve and Biosphere Reserve with development of US/USSR bilateral research planning activities

### **MAR**

- continued coordination with Shenandoah N.P. with watershed monitoring program

### **MWR**

- reviewed the ISRO watershed research program continued support to Isle Royale N.P. watershed studies

### **PNR**

- continued support to Olympic N.P. watershed studies
- participation with technical review of the Congressionally mandated Crater Lake studies
- assistance with technical support and peer review of the Crater Lake N.P. geothermal studies and review of Congressional reports

### **RMR**

- assistance with interagency coordination and review of Yellowstone N.P. and Corwin Springs Known Geothermal Area research reports and reports to Congress
- continued support to the Rocky Mountain N.P. watershed studies
- co-edited with ROMO staff the Rocky Mountain N.P. 'Lawn lake flood monograph'

### **SER**

- developed in cooperation with WOB and CSU staff the GIS water resources applications project (VIIS will be a demonstration site)

### **WR**

- review and continued support to the Sequoia and Kings Canyon N.P.'s watershed studies

## **PUBLICATIONS**

Herrmann R. 1991. Global Climate Change: Ecological Research and Monitoring for Resources Management, The George Wright Forum 2:42-47.

Herrmann R. and R. Stottlemyer. 1991. Long-term Monitoring for Environmental Change in U.S. National Parks: A Watershed Approach. Env. Monit. and Assessment 17:51-65.

## **PRESENTATIONS**

Allens Park, CO. Protecting Global Natural Resources: Interdisciplinary Biosphere Monitoring and Research, 46th Meeting, Rocky Mountain Hydrologic Research Center.

## LINKAGES BETWEEN ECOSYSTEM FUNCTION AND WATERSHED SCIENCE: US/USSR BILATERAL RESEARCH

Principals: Raymond Herrmann, WR-CPSU, NPS, Fort Collins, CO (303 491-7825)  
Stanley L. Krugman, Timber Management Research, USFS, Washington, D.C. (202 453-9547)

Funding: \$15,000/year (USFS)

Soviet and American scientists, representing multiple disciplines, and multiple agencies and institutions of the two countries, have implemented cooperative watershed/ecosystem level research as a part of the UNESCO Man and the Biosphere (MAB) Programme and the US/USSR Bilateral Agreement for Environmental Protection. Questions asked relate to obtaining better understanding of temperate forests and of ecological effects, including those changes in the hydrologic cycle and biogeochemical cycles, that are occurring globally owing to anthropogenic activities. Program objectives include: development and calibration of a system of measures that provide for base-line monitoring and for comparison of ecosystems; development of plans for monitoring ecosystem change in watersheds of representative biosphere reserves worldwide.

Joint work began in the Oka Biosphere Reserve, USSR, during August 1989 and continued at the Coweeta Hydrologic Laboratory, US, during the summer 1990. These bilateral investigations consider geologic, climatic and hydrologic histories. Measurements have included biological, physical and chemical aspects of air, water, soil, vegetation and forest litter. This analytical approach permits us to better understand ecosystem-level processes, and to test hypotheses regarding global issues. The sampling approach chosen to begin bilateral field studies employs long-term permanent plots on transects across complex environmental gradients (*viz.* topographic, climate and hydrologic). Integration and standardization of measurements at the site level as part of a global network of integrated monitoring and research sites proposed for the biosphere reserves provides for regionally or globally comparable results that are useful for understanding today's multiple resources issues. Thus, observing ecosystem parameters and processes provides an opportunity to study ecological shifts along chosen gradients at several levels of resolution. Results to date confirm that this knowledge is critical to understanding the changes taking place in reserves (natural systems) owing to anthropogenic influences.

Future studies are planned to take place at the Caucasus Biosphere Reserve during 1991, the Hubbard Brook Experimental Forest during 1992, and Sikhote-Alin Biosphere Reserve during 1993. Suggested activities for the next 3 years include paired ecosystem studies, international workshops, joint publications and flexible exchanges for scientists and students.

### Accomplishments

- Continued development of international and bilateral (U.S./USSR) watershed research and monitoring for parks and similar protected reserves.
- Continued support to bilateral paired site exchanges between the US and USSR.
- Continued a leadership role in section 02.05-41 of the U.S./USSR Environmental Agreement and support to bilateral protocols.

- Continued working with the United Nations to develop a pilot network of international monitoring sites in Biosphere Reserves and present concepts on 'Biosphere monitoring and research for understanding global pollution issues.'
- Developed plans protocols for the next 3 to 5 years for US /USSR bilateral studies.
- Made 4 presentations on US/USSR bilateral research (Washington D.C., New Orleans, LA, Miami, FL and Boone,NC).
- Consulted to the US/Poland bilateral

### **PUBLICATIONS**

Herrmann R., Y. Puzachenko, L.R. Boring and A. Sankovsky. 1991. Linkages Between Ecosystem Function, Structure and Watershed Science: US/USSR Bilateral Research in Proceedings of the AWRA 27th Annual Conference, New Orleans, LA. American Water Resources Association, Bethesda, MD: 383-384.

### **PRESENTATIONS**

NPS Seminar, History of US/USSR Bilateral Research, Washington D.C.

US/USSR Bilateral Research: Linkages Between Biodiversity and Ecosystem Function, Assoc. of South Biologists, Boone, N.C.

Linkages Between Ecosystem Function and Watershed Science: US/USSR Bilateral Research, US-Poland Workshop, Miami, FL.

Linkages Between Ecosystem Function, Structure and Watershed Science: US/USSR Bilateral Research, 27th Annual Conference, AWRA, New Orleans, LA.

## GEOTHERMAL MONITORING AND STUDIES PROGRAM

Principal: R. Herrmann

Funding: N/A

The NPS is currently required by PL 99-591 and PL 100-443 to monitor geothermal features in 16 Congressionally listed Parks (viz. MORA, LAVO, JODR, YELL, BELA, GAAR, HAVO, LACL, HOSP, ANIA, WRST, OLYM, HALE, CRLA, BIBE, AND LAME). WRD is coordinating with USGS and NPS regions and Parks to maintain a program to meet the highest priority and continuing long-term data collection needs of the Parks. Monitoring and research needs were identified in 1988. These data will be used to develop the background needed to assess effects of geothermal exploration and development on park geothermal features.

The WRD role in the Geothermal Program is one of national coordination and continued technical assistance. WRD review and coordination is to insure that the data collected meets the requirements of PL 99-591 Section 115 and those of the Geothermal Steam Act (PL 100-443), and that additional program needs continue to be identified for future action. The WR-CPSU provides technical, geological and hydrological support and coordination activities mandated by the Geothermal Steam Act.

### Accomplishments

Coordinated with USGS on Geothermal technical needs and future cooperative activities.

Continued review and assistance to YELL. Reviewed Corwin Springs technical reports and assisted with the NPS report to Congress.

Provided technical support and geological liaison input to activities required by PL 100-443.

Continued to review and to assist ARO with overview of interagency cooperative research at Katmai and to participate as part of Katmai Science Experiments Review panel of NSF.

Served on Katmai EIS proposal evaluation team.

Participated in peer review of CRLA Geothermal Studies. Reviewed final technical reports and NPS report to Congress.

Continued to participate in CRLA Studies peer review process.

## Development and Implementation of Geographic Information System-Based Water Resources Applications

Principal Investigators: Merlyn Paulson - Professor, Colorado State University  
Dean Tucker, Hydrologist - National Park Service  
William Jackson, Chief WOB - National Park Service  
Ray Herrmann, Leader WR-CPSU, CSU/NPS

Funding: \$24,000 (NEW PROJECT) (\$16,000 WOB, \$8,000 Watershed)

The purposes of this project are to develop and implement geographic information system (GIS) -based water resources applications for park units administered by the National Park Service (NPS) and to advance the current theoretical and methodological state of water resources GIS applications. The intent is to demonstrate the effectiveness and efficiencies that can be realized by using GIS to address critical park management water resources issues and concerns and to explore scientific research hypotheses in NPS park units. As an integral part of this effort, several prototype GIS water resources applications will be developed and implemented in selected NPS units. The methodologies and results of these prototypes will be well documented to enable other NPS units, governmental entities and researchers to employ similar or slightly modified techniques.

The use of GIS to describe, prescribe, analyze, and communicate management of natural resources is accelerating quickly in both the public and private sectors. Daratech, a computer graphics marketing research company, determined that the value of the GIS hardware, software, and services market in 1989 was more than \$5 billion and projected it to increase at a compound annual rate of 22% over the next five years. Driving this enormous investment is the increasing diversity and sophistication of GIS applications in real estate, planning, natural resources, industry, government, business, environmental sciences, and other activities with spatially distributed assets. The premiere federal water resources management agencies, the U.S. Geological Survey, Environmental Protection Agency, Army Corps of Engineers, and Bureau of Reclamation, have all made significant financial and personnel commitments to GIS in their respective programs.

The GIS program in the National Park Service has also witnessed tremendous growth. Currently, more than 80 parks have GIS databases. Of these, 40 have in-house GIS capabilities. The NPS GIS Division has set a goal of building at least 5 park digital databases annually. As a consequence, the NPS Water Resources Division (WRD) is becoming increasingly involved in projects or being requested to provide technical assistance to parks that entail the manipulation of digital spatial data and/or the use of GIS to address hydrologic issues and concerns. To accommodate these requests and advance the current state of hydrologic GIS applications in the NPS, the WRD has added an FTE with specific responsibilities in this area as a GIS coordinator. Given the number of projects and technical assistance requests, the diversity of park ecosystems, the vagaries of park hardware and software configurations, the limited resources of the WRD, the sophistication of hydrologic models, and the decentralized nature of the organization, it would be very difficult for any WRD GIS efforts to succeed without cooperative agreements with academic institutions and other government agencies.

Despite the flurry of GIS activity in the NPS and the efforts of other federal water resources management agencies, the pace of water resources GIS applications development has been somewhat slow. Except for delineating "live" water and watershed boundaries, many potential water resources themes are derived by combining and manipulating multiple themes (soil, vegetation, elevation, etc.) or by incorporating input from other analytical models and procedures (erosion

models, runoff models, etc.). The derivation of water resources themes generally requires a more robust database and a sophisticated user. Consequently, there exists a great need to establish GIS water resources applications, standards, and recommendations to ensure proper and efficient treatment of water resources themes, including water rights, water quality, stream channel and riparian condition, watershed analyses, floodplains, ground water, wetlands, wells, springs, and other hydrologic phenomena and issues. As water resources issues are among the most critical problems confronting the NPS and other land managing agencies, there exists a great need to incorporate water resources information into NPS GIS databases and develop water resources application guidelines, based on initial prototypes, to better support natural resources planning and management.

The specific objectives of this project are to: 1. Develop and implement prototype GIS-based water resources applications for NPS units; and, 2. Develop and distribute technical guidance on water resources GIS applications.

Initial prototype water resources GIS applications will be selected from several potential application areas (water quality, watershed, ground water, etc.). Specific applications to be addressed within these subject areas will be identified from WRD projects and technical assistance requests. Of necessity, focus will be directed upon parks with existing or soon-to-be created digital databases. Potential candidate park units meeting these criteria include Indiana Dunes National Lakeshore, Virgin Islands National Park, Cape Hatteras National Seashore, Capitol Reef National Park, and the watershed studies research sites (Eg. SHEN, SEQUOIA, OLYMPIA, ROMO, ISRO). The selected park(s) will work in conjunction with the WRD, NPS Regions, and Colorado State University (CSU) to design, implement, and evaluate the water resources GIS application. An important aspect of each application will be interfacing with appropriate hydrologic models and water data sources such as WATSTORE and STORET.

The development of water resources applications technical guidance will include reports detailing the background of the problem addressed; step by step methodology employed to assess the problem such that others may replicate the procedure; results of the application; discussion of the usefulness of the technique and possible alternative approaches or modifications; and conclusion. These reports will conform to and be published as WRD technical reports. To foster more widespread distribution of the results, variants of the reports could appear in journals, proceedings, or other suitable academic and scientific outlets.

This project, Development and Implementation of Geographic Information System Based-Water Resources Applications, utilizes the basic element of the NPS/CSU Cooperative Agreement. CSU faculty, students, and research associates possess unique expertise in GIS, modeling, water resources, research techniques, and computers. In return for lending their considerable state-of-the-art skills and other contributions, CSU faculty, students, and research associates are afforded the opportunity to apply their theory and textbook knowledge to "real" world water resources problems confronted by the NPS. Use of national park units as applied and basic field research laboratories in which to develop and test theoretical and conceptual knowledge can generate theses, dissertations, and other scholarly publications. Additionally, the applied nature of the research also satisfies the education and extension missions of the University by providing unique "hands-on" educational opportunities for students and improving the practice of environmental and park management throughout the national park system and other natural areas.

## **SITE SUMMARIES**



## ECOSYSTEM AND WATERSHED STUDIES IN OLYMPIC NATIONAL PARK

Principal Investigators: Robert L. Edmonds, Professor, Univ. of Washington  
Kat Maybury, Research Assistant, Univ. of Washington  
Jim Marra, Research Assistant, Univ. of Washington  
Roger Blew, Post-Doctoral Research Associate, Univ. of Washington  
Terry W. Cundy, Assoc. Professor, Univ. of Washington  
John Aho, Chief Research, OLYM

Watershed Funding: \$75,700

The studies described here were conducted in old-growth rainforest ecosystems in the Hoh River Valley, Olympic National Park, Washington. They were initiated in 1984 and funded by The National Acid Precipitation Assessment Program (NAPAP) through the National Park Service's Small Watershed Program. NAPAP was established in the early 1980's to examine the influence of acidic precipitation and other air pollutants on the nation's vegetation and aquatic ecosystems. The Hoh site was one of four National Park Service sites in the Small Watersheds Program; the other sites were Isle Royale (Michigan), Sierra-Kings Canyon (California) and Rocky Mountain (Colorado). NAPAP was essentially terminated in 1990, but the Park Service's Small Watershed Program has continued. The focus of this program is now on assessing the potential impacts of global change.

The program at the Hoh site has involved basic monitoring of precipitation, throughfall, stemflow, soil solution and stream chemistry in the low elevation West Twin Creek watershed (180-850 m). In addition, we have determined vegetation dynamics, ecosystem biomass, annual litterfall rates, litter decomposition rates and monitored tree health, growth and mortality and microclimate at this site. For several years we also conducted studies at Hoh Lake, a mid-elevation site (1250-1525 m) in the Hoh River Valley, where lake chemistry, litterfall rates, vegetation dynamics and tree growth and mortality have been monitored.

The study site is located 32 km from the Pacific Ocean. The watershed ranges in elevation from 180 to 850 m. Annual rainfall averages 350 mm. The chemistry of precipitation in a transect from the Pacific coast to the Park boundary was also monitored. Hydrology data are collected at the weir. Some lake chemistry data have also been obtained from Hoh Lake in the Upper watershed during the study period. All data are rigorously scrutinized using a QA/QC protocol.

Douglas-fir, western redcedar, western hemlock and Pacific silver fir trees in the watershed range in age from 237 to 635, 123 to 600, 71 to 262 and 98 to 248 years, respectively. Maximum tree height is >90 m but the canopy is broken up and very uneven. Ranges of diameter at breast height (dbh) are 10-310, 27-302, 5-270 and 9-190 cm for Douglas-fir, western redcedar, western hemlock and Pacific silver fir, respectively.

Six permanent sampling plots were established on the watershed. Specific research data collected these plots were vegetation characteristics and biomass, litterfall, tree diameters and tree mortality. Tree diameter and mortality data were also collected at the Hoh Lake site. A needle decomposition study using litterbags continues in the West Twin Creek Watershed. A computerized weather station collecting air and soil temperatures continues to operate in the lower watershed.

A long-term (10 year) decomposition study involving leaf and needle litters from Long-term Ecological Research (LTER) sites across the U.S. was installed in lower East Twin Creek watershed in the Research Natural area. Wooden dowels to examine wood decomposition were also installed. This study represents the first national decomposition study to examine factors influencing decomposition processes in a variety of ecosystems types including grasslands, woodlands, and forests.

**Other research being conducted at the site include:**

1. Relating monitoring and research to global change.
2. Decomposition and CO<sub>2</sub> evolution from logs and forest floor.
3. Biodiversity of soil invertebrates; Old-growth versus clearcuts.
4. Fine roots and mycorrhizae
5. Determination of soil solution beneath logs.

The 125 ha Hoh Lake Basin is also located in the Hoh River Valley on the western side of Olympic National Park, 50 km from the Pacific Ocean. Slopes range from 55 to 78% and generally face S to SE. Elevations range from 1250 to 1525 m with the lake at 1390 m. Mean January and July air temperatures are -2.5° and 15° C, respectively. Annual precipitation ranges from 380 to 500 cm with most falling from October to May. Most of the precipitation falls as snow and typical snowpack depths range from 760 to 1300 cm. Soils are formed from marine deposits of grayish green and black sandstones and are classified as cryorthods. Forest floor depth ranges from 4 to 10 cm.

The 58 ha West Twin Creek Watershed is located in the Hoh River Valley on the western side of Olympic National Park, WA, 32 km from the Pacific Ocean. The watershed is a steep (slopes range from 40 to 110%), dissected, first order valley wall watershed. It generally faces SE but many aspects are represented. Elevations range from 180 to 850 m. Mean January and July air temperature at the Hoh Ranger Station (located 10 km E of the site at an elevation of 183 m) are 4° C and 16° C, respectively; annual rainfall averages about 350 cm with most falling from October to May. A winter snow pack may develop above 700 m elevation from December to March. Snow rarely falls at the base of the watershed and generally lasts for only a few days. Bedrock and soils are formed from marine deposits with minor conglomerates and breccias and contain some green and black sandstones. Soils are classified as coarse-loamy mixed mesic typic dystrochrepts.

Monitoring of precipitation, throughfall, stemflow, soil solution and stream chemistry in the 58 ha West Twin Creek Watershed, Hoh River Valley, Olympic National Park has been conducted since this project was initiated in an old-growth rain forest in 1984. The basic monitoring program continued at West Twin Creek in 1991. We focused primarily on descriptions of vegetation patterns, and tree growth and mortality in the West Twin Creek and Hoh Lake watersheds. Data was collected on precipitation, throughfall, stemflow and soil solution and stream chemistry.

## **Objectives**

The primary objectives at the Hoh site were to:

1. Establish long-term monitoring sites in a pristine environment. Data sets for precipitation chemistry and elemental cycling in clean ecosystems provide a baseline for comparison with other sites around the country that are atmospherically impacted.

2. Obtain baseline information regarding the structure and function of terrestrial and aquatic components in the West Twin Creek and Hoh Lake watersheds. We were primarily interested in determining the influence of plant, soil and stream components on the chemistry of solutions flowing through these ecosystems.

The major questions addressed by the program were: (1) what is the chemistry of bulk precipitation (and fog) in a pristine forest ecosystem? (2) what effect does the forest canopy, soil and stream components of West Twin Creek have on the chemistry of solutions flowing through this ecosystem? and (3) what is the microclimate in an old-growth forest?

For 1991 we continued to collect data aimed at understanding the biological implications of the influx of sulfur of marine origin. The specific activities for 1991 included:

1. Analyze tree population dynamics and growth and mortality on permanent vegetation sampling plots at West Twin Creek and Hoh Lake over a 5 year period from 1985-1990.
2. Determine decomposition rates of needle litter in the West Twin Creek watershed relative to microclimate and litter chemistry.
3. Determine carbon dioxide evolution rates from the forest floor and decaying logs in the West Twin Creek watershed.
4. Determine the influence of the forest canopy in modifying precipitation chemistry.
5. Determine precipitation chemistry on a transect from the coast to the edge of the park 32 km inland.
6. Monitor stream chemistry at the weir in West Twin Creek.
7. Collect litterfall in permanent plots in West Twin Creek

### Key Findings

On site measurements continued to yield a good description of site input-output chemistry for 1991. Precipitation pH averaged 5.3. Stemflow (pH 4.0-4.5) was more acidic than throughfall (pH 4.9-5.1). The pH of soil solutions ranged from 5.7 to 6.2 while stream pH averaged 7.1. Dominant ions in precipitation were Na, Ca, Cl and SO<sub>4</sub>. Concentrations of most ions increased in throughfall and stemflow relative to precipitation. Each tree species modified the chemistry of precipitation differently. Dominant ions in the stream were Ca, Na, SO<sub>4</sub>, Cl and HCO<sub>3</sub>.

Studies have also demonstrated, like the earlier studies of DeBell and Franklin, that old-growth forests in the Pacific Northwest are extremely dynamic. Each species behaves differently. We need more information on rates of population change and mortality if succession is to be predicted and management strategies to protect wildlife values are to be developed. Global change can also be expected to influence population structure and mortality rates in these forests.

Western hemlock and Pacific silver fir were the dominant species in terms of stem density in the old-growth stands at West Twin Creek. Pacific silver fir was the dominant species at Hoh Lake. Both of these are shade tolerant species and there were thousands of trees/ha < 5 cm

diameter of both species in the understory. Populations of these species were extremely dynamic in the 5 year period from 1985-1990 with considerable mortality in both species. However, there was higher mortality in Pacific silver fir than western hemlock. Populations of Douglas-fir and western redcedar, which were the largest trees and oldest trees in West Twin Creek, did not change in the 5 year period and no trees died. There was little representation of these species in the understory because they are shade intolerant species. There was some mortality in the Alaska yellow cedar and mountain hemlock populations at Hoh Lake, but it was lower than that of Pacific silver fir.

Most of the mortality was in the lower canopy classes in both watersheds, although some codominants died, particularly Pacific silver firs. The overall annual mortality rate in both watersheds for all species was  $<1.0\%$ , which was similar to the rate found by Franklin and DeBell for old-growth stands in the Cascades. Thus, overall mortality rates are similar in old-growth stands in both the Cascades and Olympics although there were some species differences. The causes of mortality were predominantly suppression, insects and diseases. Wind was also important at West Twin Creek. These conclusions generally support the hypothesis of Franklin et al., who suggested that pathogens, wind, competition and physiological disorders are the dominant causes of mortality in old-growth stands in the Douglas-fir region.

There was considerable basal area growth from 1985-1990 by Douglas fir, western hemlock and western red cedar in West Twin Creek watershed and growth added carbon exceeded mortality carbon lost for these species. On the other hand Pacific silver fir populations at both West Twin Creek and Hoh Lake lost basal area, indicating that mortality was greater than growth for this species. Mountain hemlock and Alaska yellow cedar at Hoh Lake also decreased in basal area from 1985 to 1990.

Dry weights of western hemlock and Pacific silver fir needles remaining in litter bags after 3, 12, and 36 and 60 months are shown for the lower watershed and for the upper watershed. There were no significant differences in decomposition rates between species except that western hemlock decomposed faster than Pacific silver fir after 3 years in the lower watershed. However, there was an overall trend for western hemlock to decompose faster than Pacific silver fir. This is perhaps due to differences in litter chemistry. Western hemlock needles were lower in lignin concentration (11.7%) compared to 17.5% for Pacific silver fir. There was also a trend for needles to decompose faster in the lower watershed than the upper watershed. Maximum temperatures were considerably warmer in the lower watershed than the upper watershed. The decomposition rate of western hemlock needles is apparently controlled more by microclimate than Pacific silver fir needles, which appear to be controlled more by litter chemistry. There is a considerable amount of  $\text{CO}_2$  evolved from logs.

Results from this program have several **management applications**. The functioning of old-growth forest watersheds in the western Olympics is now better understood. Streams in these watersheds are well buffered and will not be significantly impacted by acidic atmospheric inputs. The vegetation has a considerable effect in modifying precipitation chemistry and acidifies precipitation to a considerable extent. The West Twin Creek watershed should also be an excellent site to monitor impacts of global change at the biogeochemical level because it is near the ocean/terrestrial interface.

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## WATERSHED RESEARCH SEQUOIA AND KINGS CANYON NATIONAL PARKS

Principal Investigators: David Graber, Research Scientist, SEKI  
David Parsons, Research Scientist, SEKI  
Annie Esperanza, Research Assistant, SEKI  
Dan Everson, Research Assistant, SEKI

Watershed Funding: \$67,000

The Sequoia watershed research program has been designed as a long term, cooperative, integrated study of ecosystems thought to be sensitive to anthropogenic pollutants. The Park Service projects include the collection of baseline data to assess future changes in atmospheric inputs and their effects on natural ecosystems. Studies, most of them cooperative with other agencies, include measurement of precipitation chemistry, dry deposition, stream hydrology, aquatic chemistry and biology, soil chemistry, meteorology, nutrient fluxes and vegetation structure and function. The potential role of fire, a frequent natural occurrence in the area, in buffering effects of acidic inputs and making its own contributions to stream chemistry is currently being studied.

At the conclusion of the National Acid Precipitation Assessment Program (NAPAP), there remains continued strong interest in watershed processes. External threats to Sequoia and Kings Canyon National Parks in the form of air pollution, development, and increased visitor use drive the need to understand how these threats will affect our ecosystems. In many ways these watersheds become integrators of the overall health of the systems in these Parks.

We have proposed a continuing effort to enhance our baseline inventory of these watersheds, to monitor chemical and biotic changes over time, and to pursue directed research where specific questions important to the systems may arise. These include continued efforts to monitor atmospheric and stream chemistry, to monitor forest dynamics at a frequency sufficient to detect changes in recruitment and mortality, and continue hydrologic and meteorologic records for the existing watersheds. These data sets will only increase in value over time as they will be the logical indicators of trends over time.

### Objectives for 1991

The Watershed Program and Sequoia and Kings Canyon National Parks cooperative research have entered a period of transition as the new global climate change program is initiated.

*Monitoring.* Results for the past decade do not show a critical or changing situation with regard to atmospheric pollutant contributions to precipitation or surface water. Therefore, it is reasonable to reduce the frequency of this sampling as it moves from research to monitoring. The Parks plan to use watersheds as sampling units for a broad array of long-term atmospheric, terrestrial and aquatic monitoring as soon as funding becomes available, and we expect present chemistry monitoring efforts will be integrated. An extensive program of water quality and aquatic ecosystem monitoring has been proposed for funding.

*Hydrodynamics.* The past 5 years have strikingly revealed the importance of water quantity and dynamics, not only the Park ecosystems, but to the State of California's well-being. We hope to

integrate the Watershed Program with existing Global Change research in the region.

*Ecological Research.* Present studies of the links between natural fires, water chemistry, and ecosystem processes will continue. Present vegetation studies in our experimental watersheds will likewise continue for the indefinite future. We will continue to remain receptive to cooperators who wish to extend our knowledge of ecosystem parameters, especially where such research can be integrated into our existing base of knowledge on our long-term study sites.

We have decided to postpone plans to engage a specialist, such as a post-doctoral student, to "wrap up" our data collections to date. Instead, we expect to be discussing possible publications or other uses of NPS data with John Melack (UCSB) and other long-term cooperators.

### Activities

- 1) We have continued stream, precipitation and soil solution sampling on a reduced schedule where appropriate, but will intensify sampling of streams to monitor fire effects on watersheds. All sampling continues to follow established methods.
- 2) Stream gauging stations at Lower Chamise Creek, Tharp's Creek and Log Creek were continued with the updating of existing hydrographs.
- 3) Meteorological stations at the low and mid-elevation sites were continued with a minimum of monthly station checks and an exchange of storage modules for monthly data retrieval. Weather sensors were checked and some sensors were serviced during this fiscal year.
- 4) We continued to participate in laboratory audits with the Environmental Protection Agency (EPA), the California Air Resources Board (CARB) and the US Geological Survey/National Atmospheric Deposition Program (NADP). All of these activities lend a great deal of credibility to our continued quality control efforts.
- 5) Our staff continued to maintain and collect samples as part of NADP, the CARB wet and dry deposition state monitoring network, and the National Oceanic and Atmospheric Administration (NOAA) dry deposition network.
- 6) The Sequoia research water lab in Ash Mountain continued to process and perform initial analysis of stream, precipitation and soil solution samples. Analyses consist of pH, conductivity, alkalinity, and determination of phosphate ( $\text{PO}_4$ ), ammonium ( $\text{NH}_4$ ), and silicate ( $\text{SiO}_3$ ).
- 7) Our staff maintained and extended vegetation, water chemistry, and meteorological databases. Data were provided on request. Particular effort will be as devoted in 1992 to edit and document all datasets to assure their accuracy and maximize their long-term usefulness.
- 8) Our office continues efforts with outside agencies and researchers to maintain cooperation on projects of interest to the Parks.
- 9) We continued to update our list of publications related to acid deposition research done in Sequoia and Kings Canyon National Parks and our acid deposition/watershed bibliography.

10) We participated in and attended meetings as necessary to support long term watershed research.

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## **LONG-TERM STUDY OF BOREAL WATERSHED/LAKE ECOSYSTEMS, ISLE ROYALE AND MICHIGAN'S UPPER PENINSULA**

**Principal Investigator:** Robert Stottlemeyer, Research Scientist, ARB, WRD, NPS  
Darcy Rutkowski, Senior Research Assistant, Mich. Tech. Univ.  
David Toczydlowski, Senior Research Assistant, Mich. Tech. Univ.  
Patricia Toczydlowski, Research Assistant, Mich. Tech. Univ.

**Watershed Funding:** \$97,000 (\$78,400 ISRO research and monitoring; \$19,000 Program laboratory support)

This study essentially began in 1979-80 with a regionwide survey of surface water chemistry for many streams and lakes on ISRO and in Michigan's Keweenaw Peninsula. In 1982, a small subset of these sites became part of the National Acid Precipitation Assessment Program (NAPAP) and in 1991 they became units of the NPS Watershed Studies Program. Most recently, the ISRO site was selected as a unit of the USDOJ Global Climate Program, and a research pre-proposal accepted. A full proposal has subsequently been prepared and submitted.

Surface water chemistry and change in snowpack amount and chemistry were initiated late in 1979 at the Calumet site. This site was selected because of its proximity to Lake Superior and to Michigan Tech, a major factor when considering the intense study associated with the rapid changes which occur in watersheds during spring melt. The site is similar in successional stage and vegetation type to that of Hubbard Brook three decades ago. This site was intensively instrumented and monitored beginning in 1982. Another major upgrade in its instrumentation was made in 1987. Much of the data collected to date are being summarized for submission this spring to Ecological Monographs.

The sites selected for long-term study on ISRO, Wallace Lake and the conterminous Sumner Lake watersheds, were picked because they were vegetated by mature boreal forests, were reasonably accessible (by ISRO standards), and were quite representative of the park based upon the results from the earlier surveys. A major reason for site selection in the ISRO studies was that it is a boreal ecosystem, a system, which, despite its global extent, has been very little studied.

The research for 1991: Continued in-depth study of snowpack chemistry which will continue on the Calumet site. All research will be stopped on the PIRO Legion Lake site, but in cooperation with park staff, watershed and lake chemical monitoring will continue. On ISRO, basic input/output monitoring will be continued along with re-sampling of forest biomass quantity, and the quantity and quality of dead and downed forest vegetation. The latter projects will complete some previous research dealing with the importance of blowdown as a mortality factor on ISRO, a hypothesis which goes back to the classical studies of W. S. Cooper (1913. 1915) on ISRO.

### **Objectives (Basic Questions/Hypotheses)**

#### **1. Ecological Effects of Snowpack and Snowmelt on Surface Water Chemistry**

**Problem:** In this region of contaminated atmospheric inputs, up to 50% of the annual precipitation to Lake Superior watersheds occurs as snowfall. However, there is little information on snowpack spatial and temporal variation and ionic retention. We have found that snowpack accumulation of

moisture and solutes significantly increases with minor gain in elevation above Lake Superior. This results in an increased deposition of anthropic atmospheric inputs into the more sensitive upper portions of watersheds feeding the lake. Fast snowpack ion release could result in a significant spring "pulse" reducing stream pH and possibly increasing ecosystem nutrient loss. Hypotheses: 1) snowpack accumulation of anthropic ions is a significant fraction of annual inputs, but solute retention until spring melt and peak stream runoff does not occur due to periodic thaws and unfrozen soils and 2) the pattern of snowmelt, and especially the occurrence of initial small melts, largely determines the snowpack solute pathway to streams and therefore the potential for solute "pulses." Research approach: A small first-order watershed with uniform slope above Lake Superior has been instrumented for eleven years. Snowfall and snowpack quality and quantity are measured weekly at four stations. Snowpack solute movement is measured by sub-sampling the snowpack along a vertical profile with the results compared to the traditional use of solute change in bulk snowcores. Radiation, snowpack and soil temperature profiles are recorded adjacent snow and soil lysimeter plots designed to quantify snowmelt and solute pathways to the stream. Expected results: First long-term study of snowpack ionic dynamics and assessment of natural variation; long-term comparison of snowpack ionic dynamics and streamwater chemistry; one of very few studies underway regarding snowpack solute pathways in forest soils to streams; multi-year comparison of using vertical profile snowpack sub-samples and bulk snowcores to assess movement of ions within the snowpack; and only long-term database of ionic inputs, outputs, their variation and modification by forest canopy and soil at a site dominated by large lake snow inputs.

## 2. Effect of ecological factors on forest vegetation patterns in national parks of the Great Lakes basin

Problem: Much of the present vegetation in Great Lakes basin national parks is the product of late 19th century anthropic disturbance. There is little understanding of the major ecological factors responsible for vegetation patterns prior to that time. Most of the Great Lakes parks occupy a major ecotone, with fire being more important to the north and climate in the central and southern portions. As opportunities arise to reestablish natural vegetation in the national parks, there is a need to understand the mix of factors likely responsible for vegetation patterns prior to 1850. In particular, the nature and periodicity of episodic events needs to be determined. Research objectives/hypotheses: 1) determine the origin and ecological history of the mature forests in the Great Lakes basin and in specific park units, and relate their present status to the pre-European condition, 2) assemble and analyze existing regional and park-specific data on ecological factors responsible for vegetation patterns, 3) assess the effects of past logging and other anthropic-induced disturbance on present day forests and 4) assess the potential effects of conterminous land use on the restoration of park ecosystems. Research approach: We are attempting to assess the relationship between climatic factors and distribution of species across the ecotone using data from NOAA and the Continuous Forest Inventory. Those factors responsible for local variation in the vicinity of selected national parks will be assessed in more detail. Additional historical data will be obtained by synthesizing the Public Land Survey notes and quantifying by spatial statistics. Expected results: We anticipate this research will significantly qualify the role of fire in some national parks of this region. Research to date indicates that climate and chance are more important factors than generally assumed. This is particularly true for parks south of and including Isle Royale. Hardwood species distribution in the southern portion of the region is probably determined by length of growing season while distribution of species with greater range, as Acer saccharum, is likely determined by longer term climatic change. Distribution of boreal species, particularly conifers, and local distribution of more southern species is a function of chance (topographic and edaphic factors) which modifies fire frequency.

### 3. Role of modeling in better design of inventory and monitoring (study site is Isle Royale)

This effort consists of two components being undertaken for ISRO. First is the re-location and marking of permanent plots from past and ongoing studies. ISRO Resource Management is substantially involved in this effort, and will be preparing the final report on this component. The second component is the assessment of the role modelling might play in inventory and monitoring.

### 4. Characterization and mapping of the soils of Isle Royale National Park

Dr. Stephen Shetron, Professor of Forest Soils, Michigan Technological University, has been the lead on this three-year effort. A draft final report has been prepared and with completion of Soil Conservation review (for classification certification), we will submit a completed draft for publication by NPS. The GLARSU role in this effort was to conduct the sampling and analysis of park soils to characterize their sensitivity to potential impacts as may come from atmospheric contaminants. The hypothesis was that due to their higher soil organic matter content, conifer (spruce-fir) dominated ecosystems would prove more susceptible than hardwood systems to anion ( $\text{SO}_4^{2-}$ ) leaching of soil base cations by atmospheric inputs. This work was completed in our laboratory, the data entered and analyzed for inclusion in the final report. In addition, some of the results, especially on the relationship of soil factors to the ecosystem sulfur budget, have been presented at national ESA meetings (see below). This survey provided us with considerable data especially for the Wallace Lake watershed (see Rutkowski and Stottlemeyer 1991).

### 5. Studies related to global climate change

In the sensitive, southern boreal tension zone, increased atmospheric  $\text{CO}_2$  alone will not increase ecosystem production. Its relative effect will be enhanced by the present and predicted increases in levels of atmospheric N input. This study will further link the C to N cycle and forest succession by capitalizing on data (biomass, litterfall, forest floor) previously collected at the ISRO sites (Wallace Lake and Sumner Lake watersheds), extend its period of record, and be more intensive (Rutkowski and Stottlemeyer 1991). A series of plots at paired watershed sites in VOYA and at the Marcell Experimental Forest will be established in undisturbed forest to assess processes at more continental locations. The research design would be very similar at all three sites, and details of the methods to be employed are contained in the NPS Global Climate proposal.

The present research program is briefly described in the above paragraphs on research questions/hypotheses. The related studies (not funded by NPS Watershed Program) on ecological factors and forest vegetation and the mapping of ISRO soils will be completed in 1991. The former addresses the question of what vegetation changes occurred during the Holocene (paleoecology) and what is the importance of blowdown as a source of mortality on ISRO. The paleoecology study was conducted in cooperation with Dr. Ken Cole, INDU, and further study of this sort has been proposed by Cole et al. for the NPS Global Climate Change program. The question of blowdown as an ecological factor of some significance to the boreal forests of ISRO was first proposed by W. S. Cooper in his 1911-13 classical vegetation ecology research on ISRO. But the question had never been addressed until 1987.

The work on modelling was the precursor to the study of wetlands, and the output of the wetlands study, which will begin in earnest next summer, will be application to and modification of some existing models to predict this ecosystem's possible response to climate change. This study is being done in cooperation with Dr. Paul Barten, Yale University School of Forestry.

The long-term study of snowpack chemistry and hydrologic pathways prior, during, and following snowmelt has been well-published and needs no further elaboration here. We will likely continue the present design during the next year with the hope of using tracers this coming winter to confirm what we already suspect is occurring.

## Key Findings

Lakes and streams of ISRO and most of upper Michigan's Keweenaw Peninsula are moderately well buffered and not directly sensitive to present atmospheric  $H^+$  inputs.

Soils throughout the region were not generally derived on site, but were brought southward and westward by glacial activity. The glaciers picked up limestone as they moved southward and this results in more alkaline soils than the bedrock or vegetation suggest should be present.

Inputs of atmospheric S are on the decline at the research sites, an observation consistent with some regional studies of stream chemistry. However, the decrease was not statistically significant.

Input/output budgets and nutrient cycling studies in all major forest types show these ecosystems are presently saturated with  $SO_4^{2-}$ . The excess  $SO_4^{2-}$  does result in anion leaching of base cations from the forest rooting zone. However, the amount leached is still very small relative to the total soil reservoir of exchangeable base cations.

In contrast to sulfur, the concentration of N species in precipitation is increasing. Computations of N inputs show that the combined inputs of wet and dry deposition (NPS IMPROVE station about 6 km from Wallace Lake) exceed ecosystem requirements. Over 50% of this input is in the form of  $NH_4^+$ , high energy N which may be preferred by conifer species. In the future, the excess  $NO_3^-$  could also contribute to anion leaching of base cations from these ecosystems.

However, in intensive, multi-year studies of the fate of N species, input we have not found evidence of much of it getting below the rooting zone. In short, the forest community appears to be utilizing this excess nitrogen. The likely future effects of this or increased N input could be  $NO_3^-$  leaching of cations particularly under conifer forest, nitrogen toxicity, and most likely changes in species composition due to the application, in effect, of N-containing fertilizer.

We still have no evidence of direct inputs of atmospheric contaminants from the Thunder Bay region despite its high industrial outputs. However, the smell from that output is common on ISRO, which suggests, implicitly, that some atmospheric inputs to the park occur. But any direct evidence would be hard to scientifically defend short of the use of tracer studies.

A major information need is more knowledge of the cycling of C and N in the soil-forest floor interface, and the effect of change in moisture and temperature on the rate of this process.



## PROJECT REPORTS AND PUBLICATIONS

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Stottlemeyer, R. 1991. Nitrogen mineralization and streamwater chemistry, Rock Creek watershed, Denali National Park. Status: Following peer review of first draft, a revised manuscript was resubmitted to ARCTIC ALPINE RES.

Rutkowski, D., and R. Stottlemeyer. 1991. Composition, biomass and nutrient distribution in mature northern hardwood and boreal forests of Upper Michigan. Submitted to AM. MID. NATUR.

Stottlemeyer, R. 1991. An ecosystem approach to long-term inventory and modeling. *The George Wright Forum* 7:31-37.

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**LONG-TERM ECOLOGICAL RESEARCH  
IN LOCH VALE WATERSHED, ROCKY MOUNTAIN NATIONAL PARK**

Principal Investigators : Jill Baron, Research Ecologist, ARB, WRD, NPS  
Robert L. Edwards, Research Associate, Colo. State Univ.  
Dave Clow, Graduate Student, Colo. State Univ.  
Steve Bachman, Graduate Student, Colo. State Univ.  
Jennifer Back, Graduate Student, Colo. State Univ.  
Mike Martin, Graduate Student, Colo. State Univ.

Watershed Funding: \$70,000

The Loch Vale Watershed study in Rocky Mountain National Park was initiated in 1981 to explore the ecological consequences of acidic atmospheric deposition. The objective was to increase understanding of both natural and potentially acidified biogeochemical pathways in the alpine and subalpine environment of Rocky Mountain National Park. The study took an ecosystem approach, attempting to quantify major elemental and pollutant flux, identifying sources, sinks and controls of the major ions. We defined the boundaries of our ecosystem with the physical boundaries of Loch Vale Watershed and adopted the small watershed technique as the overall context for study. Instead of "black-boxing" internal processes while quantifying watershed inputs and outputs, we have attempted to understand and quantify inputs and outputs from each of the major ecosystem components of the landscape: bedrock, soils, vegetation and surface waters (Figure 1). Because so little was known about these components of the alpine and subalpine zones, much early effort went into documenting basic characteristics and processes. Since the study was based upon the threat of acidic deposition, we also explored the airshed (most of the western United States) that contributes both moisture and chemical compounds to Loch Vale Watershed.

Rocky Mountain National Park is sensitive to acidic deposition. Much of the park area is exposed granitic rock, with 147 alpine and subalpine lakes and over 700 stream km. Naturally-reproducing populations of trout are present in 59 lakes. It is well documented in the literature that deposition of strong acid anions can rapidly exhaust the acid neutralizing capacity (ANC) of systems underlain by slow weathering bedrock types, allowing lakes and streams to acidify. The acidity itself, and, more importantly, aluminum, which becomes soluble at pH below 5.0, are extremely toxic to aquatic organisms.

Loch Vale Watershed (LVWS) is a 660 ha northeast-facing basin located in Rocky Mountain National Park about 80 km NW of Denver, Colorado. The watershed ranges in elevation from 3110 m at the outlet of the lowest lake, The Loch, to 4010 m at the Continental Divide. More than 80% of the basin surface consists of bedrock outcrop and active talus slopes. Bedrock consists primarily of Precambrian-aged granitic gneiss and schist. Several permanent snowfields and an active rock glacier, remnants of neoglacial activity, occupy about 1% of the watershed. In areas of relatively gentle slope, the valley floor is covered with glacial till of Pinedale age.

Forest soils have developed on the moraine veneer below 3300 m elevation, covering about 5% of the area of the catchment. Soil pH (1:1 paste) ranges between 3.3 and 5.1. Cation exchange capacity of these soils ranges from 50 to 100 ceq kg<sup>-1</sup>, but base saturations are quite low, with a mean of 23% in the organic surface layers and decreasing to below 10% in the deeper horizons. The exchange complex is dominated by Ca. Soil development is very heterogeneous, varying in depth

from 1 to 50 cm. These soils support a mature forest of Engelmann spruce (*Picea engelmannii*) and subalpine fir (*Abies lasiocarpa*), which covers about 6% of the total land area. Alluvial and bog soils, classified as Cryaquents and Cryohemists, occupy only about 1% of the watershed, but have a disproportionate influence on surface water chemistry due to their position adjacent to stream channels. These highly organic soils are characterized by base saturations of less than 13%.

Accumulation of snowpack in LVWS begins in November of each year, and the melt begins in mid- to late-April. More than 75% of the annual water input to the basin is in the form of snow. Midwinter melting events are extremely rare, and snowpack temperatures remain below 0°C above the "depth hoar" zone from about November through late March. Peak runoff occurs from late May to early June, with 40 to 50% of annual runoff occurring by July 1. Meltwater from the permanent snowfields contributes to stream discharge through August, and baseflow is maintained by groundwater seepage until early winter. From December through February there is little baseflow.

### Objectives (Basic Premise and Questions)

Research in the Loch Vale Watershed Study is based on the premise that the biogeochemistry of the catchment is a defineable and predictable combination of precipitation chemistry, weathering and exchange reactions of soil and parent materials and the chemical products of biological activity. Within that context, the following questions serve as guides to research in LVWS, with most of the work up to the present focusing on the first three.

Question 1. Are current levels of acidity in precipitation falling in Rocky Mountain National Park greater than historical levels? This question is being examined by regular analysis of precipitation to assess current levels, and with the analysis of sediment cores, to assess historical levels.

Question 2. Does buffering of surface waters come from soil processes such as weathering of inorganic soil materials and exchange reactions from soil organic matter? Soils form a small, but significant and potentially active component of the surface material in LVWS.

Question 3. What are the controls of surface water chemical composition? We postulated that the composition of lakes and streams fluctuates over time, primarily influenced by the seasonal patterns of hydrologic processes and their interaction with the products from bedrock weathering, soils, and biota. Pertinent research includes characterizations of bedrock and geochemical weathering, vegetation, and the physical, chemical and hydrologic characterization of lakes and streams within LVWS.

Question 4. What are the likely effects of climate change on the alpine-subalpine areas of the southern Rocky Mountains? Past research has indicated that LVWS is strongly influenced by the volume, chemistry and seasonal pattern of precipitation. Thus, changes in regional climate that affect these parameters may create a fast and significant response in LVWS and similar subalpine watersheds. Proposed research will tie together climate and ecosystem modelling efforts with field data from Loch Vale, in an attempt to quantify effects of possible climate change on similar resources within the National Park system and throughout the Rockies.

Current research in LVWS includes: (1) continuation of the long term monitoring program, (2) several projects addressing specific aspects of alpine flowpaths, weathering of alpine soils, nutrient cycling and decomposition of organic matter, and (3) participation in the WEBB program of the USGS.

The use of Loch Vale as a site in the USGS WEBB program is overseen by John Turk, with research activities coordinated by Norm Spahr and Don Campbell. The WEBB program will provide the resources to allow a more detailed examination of the hydrology of Loch Vale. Three



meteorological stations are being set up to give a better spatial representation of climate in LVWS. Several gaging stations were installed on Icy Brook and Andrews Creek to give a more accurate picture of flow in the upper watershed. Intensive surveys of snow depth and chemistry began in the spring of 1991. These will be coordinated with studies of surface water quality during snowmelt and sulfur sources within the watershed.

A mass balance of Andrews Glacier was begun in 1991. Advances and retreats of Andrews Glacier have occurred (and been documented) several times in this century. Andrews is one of the southernmost glaciers in North America, and it is possible it will be very sensitive to slight changes in either precipitation or temperature. Andrew Fountain, USGS-Denver, is coordinating the mass balance study.

### Key Findings

A detailed review and discussion of research conducted in Loch Vale through 1988 is presented in Baron (1992). Presented here are some general results related to the basic questions listed earlier. Average annual precipitation is not acidified, although individual events may exhibit significant anthropogenic inputs. There is a large difference in precipitation amount and ionic concentrations between Loch Vale and a close (~15km) but lower (672m difference in elevation) site at Beaver Meadows. Loch Vale is less likely to be influenced by anthropogenic inputs from the Front Range urban area east of the National Park than the lower elevation Beaver Meadows site. Loch Vale soils have a limited ability to buffer increased amounts of acidity from deposition. The influence of soil processes on surface water composition is restricted to a short period at the beginning of snowmelt. The major source of ANC appears to come from microcalcite veins in the bedrock, which are exposed to weathering through physical breakdown of primary minerals by freeze-thaw, avalanches, and debris flows. Hydrologic processes exhibit the major influence on surface waters, with concentrations increasing as flow decreases through the winter, and decreasing with snowmelt after the early flush of materials from soil solution.

The annual chemical budgets through 1990 were developed. Outputs are not available for 1989 due to quality control problems with the analytical laboratory results. These are measured inputs and outputs only, not taking into account such things as snow blowing in near the ridge tops and losses due to evaporation. Due to the location of the single precipitation collector and the physical processes dictating collection efficiency, it is likely that the inputs represent an underestimate of actual values. These budgets show a net consumption of  $\text{NH}_4$ , H, and to a lesser degree,  $\text{NO}_3$ , which is balanced by a net production of base cations. Cl appears conservative, with long term outputs balancing inputs. More  $\text{SO}_4$  is exported from LVWS than enters via wet deposition, and sulfur isotope analyses conducted by John Turk suggested a mineral source for some  $\text{SO}_4$ . The presence of sulfur-bearing minerals was confirmed this past summer by locating rocks containing pyrite. Alkalinity and  $\text{SiO}_2$  are not measured in the inputs, and are considered negligible in precipitation. Evaporation from the watershed is calculated, and may account for most of the difference between input and output of water.

## MEETINGS AND PRESENTATIONS

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Baron, J. 1991. An Overview of the Aquatic and Hydrologic Portion of the Colorado Rockies Global Change Program. Climate System Modeling Program Workshop on regional climate and ecological influences, Oct 21-23 Pingree Park.

Baron, J. 1991. An Overview of the Importance of Hydrologic and Aquatic Biogeochemical Studies to Understanding Boreal Forest Processes. BOREAS Planning Workshop, August 18-23, Flathead Lake, MT.

Baron, J. 1991. Sources and Sinks of Nitrate to High Elevation Lakes and Streams. National Center for Vehicle Emissions and Safety Annual Meeting, Sept 3-6, Durango, CO.

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## LOCH VALE WATERSHED PUBLICATIONS

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Edwards, R.L. 1991. Data Quality Report: 1989-1990, Loch Vale Watershed. Natural Resource Ecology Laboratory, Colorado State University, Fort Collins. 22p.

Spaulding, S.A. 1991. Phytoplankton community dynamics under ice-cover in The Loch, a lake in Rocky Mountain National Park. M.S. thesis, Colorado State University, Fort Collins. 149p.



separately. All sediment cores are currently under analyses for the various factors, and we hope to merge some of these data with the lake chemistry and hydrology by late spring 1990. Results will be in a thesis and at least one additional publication.

### Quality Assurance/Quality Control:

The primary purpose of this section is to present an update on our quality assurance/quality control results focusing primarily on laboratory analytical procedures and results. This report updates the last reported QA/QC results and discussion presented in 1987 (Stottlemeyer et al. 1987). The results are broken down into three sections: internal QA which is mostly an internal checking process, external audits, and additional QA checks. This discussion is not exhaustive. Omitted

are those external checks provided by the USGS, the State of California, and the University of California on replicate and split samples which they run as a check of our results on samples analyzed in the GLARSU laboratory for the Sequoia-Kings Canyon NAPAP study.

### Internal QA/QC:

Precision analyses using replicate samples ran within the same block (a block is approximately 150-250 samples ran at the same time ranked according to specific conductance) shows that the mean percentage difference is both positive and negative from the value obtained in the original run (Table 6). These results are for samples ran between October 1987 and September 1989 (Blocks # 73 - 102).

Table 6. Precision based on replicate (duplicate) analysis of samples within analytical blocks, GLARSU MTU laboratory.

Ion	Mean % Diff.	SD	Absolute mean % difference	SD	n
Ca <sup>2+</sup>	0.8	14.0	6.9	12.2	194
Mg <sup>2+</sup>	2.1	33.6	9.8	32.2	195
Na <sup>+</sup>	2.5	32.7	8.9	31.6	207
K <sup>+</sup>	2.9	33.7	9.3	32.5	207
NH <sub>4</sub> <sup>+</sup>	-2.0	30.8	16.1	26.2	159
F <sup>-</sup>	-0.4	2.8	0.7	2.8	103
Cl <sup>-</sup>	4.8	30.8	15.2	27.2	226
NO <sub>2</sub> <sup>-</sup>	-0.7	4.4	1.0	4.3	97
NO <sub>3</sub> <sup>-</sup>	0.8	20.3	7.0	19.1	204
PO <sub>4</sub> <sup>3-</sup>	11.1	106.4	17.8	105.5	117
SO <sub>4</sub> <sup>2-</sup>	0.6	6.2	3.6	5.1	229

### Accuracy (bias):

These results are given as means over the period of analyses. There were some changes in machine configuration during the period principally the use of improved columns. These changes are documented elsewhere such that if it is found necessary to correct values, as low level Ca<sup>2+</sup>, for machine bias it can be done on a block by block basis. The question of accuracy with time (blocks) will be addressed in our final QA/QC report in 1990.

It is evident from these results (Tables 7 & 8) that a machine bias exists for Ca<sup>2+</sup> especially for samples < 0.05 mg L<sup>-1</sup>. Mg<sup>2+</sup> showed a much less but potentially important bias of about 20%. This bias disappears when concentrations become > 2 mg L<sup>-1</sup> for Ca<sup>2+</sup> and > 1.0 mg L<sup>-1</sup> for Mg<sup>2+</sup>. Based upon earlier results, it appears this positive bias for Ca<sup>2+</sup> at low concentrations is independent of column configuration in the IC although precision and level of detection are clearly functions of column design and configuration.

Table 7. Results of EPA performance evaluation samples run over all or part of the analytical blocks October 1987 to September 1989, GLARSU MTU laboratory. Concentrations in  $\text{mg L}^{-1}$ .

	EPA Nutrient #3			EPA Nutrient #4		
	$\text{NH}_4^+$	$\text{NO}_3^-$	$\text{PO}_{43-}$	$\text{NH}_4^+$	$\text{NO}_3^-$	$\text{PO}_{43-}$
EPA mean	0.36	0.62	0.15	2.45	6.33	1.07
95% CI	(.30-.42)(.44-.80)(.09-.21)			(2.2-2.7)(5.7-6.9)(1.0-1.1)		
MTU mean	0.34	0.56	0.16	1.83 <sup>1</sup>	5.86	1.08
SD	0.02	0.04	0.08	0.21	0.52	0.12
n	7	12	12	9	18	18

EPA minerals sample (diluted 10x given concentration strength)

	$\text{Ca}^{2+}$	$\text{Mg}^{2+}$	$\text{Na}^+$	$\text{K}^+$	$\text{SO}_4^{2-}$	$\text{Cl}^-$
EPA mean/10	1.99	0.49	1.97	0.49	1.97	5.18
MTU mean	3.00	0.60	2.03	0.50	1.89	6.24
SD	0.36	0.04	0.16	0.04	0.10	1.04
n	51	52	48	51	75	35
% difference	50.8	22.4	1.5	2.0	-4.1	20.5
EPA mean/2	9.94	2.45	10.0	2.47	9.84	25.9
MTU mean	10.07	2.52	10.56	2.34	9.17	29.31
SD	1.44	0.93	2.90	0.85	1.06	8.6
n	10	10	8	11	13	7
% difference	1.3	2.8	5.6	-5.3	-6.8	13.2

<sup>1</sup> Outside EPA 95% CI.

Table 8. Results from NBS standard reference sample run over all or part of analytical blocks 73 - 102 (October 1987 to September 1989). Ammonium and chloride were not certified. Concentrations in  $\text{mg L}^{-1}$ .

Sample NBS 2694.1

	$\text{Ca}^{2+}$	$\text{Mg}^{2+}$	$\text{Na}^+$	$\text{K}^+$	$\text{NH}_4^+$	$\text{SO}_4^{2-}$	$\text{Cl}^-$	$\text{NO}_3^-$
NBS mean	0.014	0.024	0.20	0.05	-	2.75	0.24	-
+/-	0.003	0.002	0.009	0.007	-	0.05	-	-
MTU mean	0.04	0.029	0.207	0.049	-	2.85	0.23	-
SD	0.02	0.01	0.01	0.01	-	0.23	0.1	-
n	25	26	26	26	-	46	46	-
% difference	207	20.8	1.0	-5.8	-	3.6	-4.2	-

Sample NBS 2694.2

NBS mean	0.05	0.005	0.10	0.11	1.0	10.9	1.0	7.06
+/-	0.01	0.003	0.01	0.00	-	0.2	-	0.15



MTU mean	0.11	0.06	0.40	0.14	0.95	11.52	1.07	6.69
SD	0.103	0.02	0.047	0.06	0.22	0.94	0.18	0.54
n	20	20	22	21	22	27	31	31
% difference	128	21.6	-4.0	32.0	-5.0	5.7	7.0	-5.2

An additional check on accuracy was provided by the NAPAP Terrestrial Effects Program. Our laboratory routinely ran  $\text{SO}_4^{2-}$ ,  $\text{Cl}^-$ , and  $\text{NO}_3^-$  standards provided by the EPA for the period October 1987 - September 1989. These results showed a slight increase in  $\text{SO}_4^{2-}$  bias (to about 9%) relative to our other checks on accuracy, but no clear differences for  $\text{Cl}^-$  or  $\text{NO}_3^-$ .

Still another internal QA check was provided by the routine field analyses of pH and specific conductance in conjunction with the National Atmospheric Deposition Program (NADP), and the additional use of laboratory standards (Table 9).

Table 9. pH and specific conductance comparisons for NADP and MTU standards used within the GLARSU laboratory.

Sample/standard	mean	S.D.
NADP cond. std. (75 $\mu\text{s}$ @ 25 $^\circ$ )	62.84	2.73
NADP correction factor (75/n)	1.2	0.05
Lab (MTU) conductivity std.	65.87	2390
Lab correction factor	1.14	0.05
NADP cond. check sample (21.8 $\mu\text{s}$ )	21.24	0.85
NADP pH check sample (4.30)	4.31	0.02

These measurements were performed at least weekly during the period October 1987 to September 1989, and generally more often.

Since the inception of research in this lab (1979) we have washed and recycled most sample bottles. Initially this decision to recycle was based on economics, and later defended by the reduction in

solid waste through recycling. As a QC step, several bottles are pulled at random from each batch following our bottle wash and drying process. They are filled with DI water of known quality, left soak for at least one week, and then analyzed for change in specific conductance (Table 10). These blanks were also ran on the IC for determination of specific ion concentration (Table 11).

Table 10. Mean specific conductance and range for DI water before and after left soaking in washed bottles.

	Before soaking	After soaking
Min. value	0.55	0.48
Max value	1.56	2.13
mean	0.97	0.92
S.D.	0.16	0.28
n	87 <sup>1</sup>	548 <sup>2</sup>

<sup>1</sup> Number of batches of clean bottles checked.

<sup>2</sup> Number of bottles actually checked.

Table 11. IC results for DI blanks and DI rinse water after soaking in washed bottles for a minimum of one week. Period of comparison was October 1987 to September 1989. Values for  $F^-$  and  $NO_2^-$  were never above detection levels. Concentrations in  $mg\ L^{-1}$ .

DI	$Ca^{2+}$	$Mg^{2+}$	$Na^+$	$K^+$	$NH_4^+$	$Cl^-$	$NO_3^-$	$PO_4^{3-}$	$SO_4^{2-}$
max	0.07	0.04	0.04	0.06	0.03	0.11	0.01	0.0	0.02
mean	0.01	0.003	0.008	0.007	0.003	0.01	0.001	0.0	0.001
S.D.	0.02	0.009	0.016	0.008	0.018	0.003	0.0	0.003	
n	24	24	24	24	24	71	71	71	71

Bottle blanks or DI soak water from routinely washed bottles

max	1.29	0.009	0.026	0.02	0.024	0.128	0.018	0.055	0.056
mean	0.164	0.003	0.013	0.006	0.012	0.06	0.001	0.004	0.018
S.D.	0.42	0.003	0.007	0.009	0.007	0.143	0.115	0.014	0.022
n	9	9	9	9	9	15	15	15	15

In this effort, we found two batches of bottles in 1987 that had to be rewashed. This was due to the occasional occurrence of bottles which appeared to be inadequately rinsed or were missed in the first place.

The specific conductance of DI water used in the laboratory was checked at least each week and normally a number of times each week. The mean value through this period was  $1.00 \pm 0.13\ \mu S$ . There were minor gains in the concentration of  $Ca^{2+}$ ,  $Na^+$ ,  $NH_4^+$ ,  $Cl^-$ , and  $SO_4^{2-}$  in DI soaked in washed bottles relative to that of the DI blanks.  $Ca^{2+}$  showed the largest increase. This likely was reflecting bias and level of detection limitations for this ion. Nevertheless, the IC peaks from the blanks were real. The only other ion showing much gain was  $NH_4^+$ , but this too can be

attributed to the level of detection of the IC for this ion and stripchart digitizing "noise".

External QA/QC:

The GLARSU laboratory participates in a number of external audit programs. These include the EPA Acid Rain Performance Surveys (audit), the USGS/NADP audit, the USGS/Northern Hardwoods round robin audit (part of the NAPAP Terrestrial Effects Program), and the weekly comparison of NADP split samples collected from NADP station M99 and ran at the GLARSU and NADP Central Analytical laboratories. This latter comparison has been underway since 1980. The results from a sampling of these audits are presented below (Table 12).

Table 12. EPA acid rain performance surveys. Three samples, differing in concentration, were ran for each date shown below. Results are expressed as the percent difference between our results and those of the EPA. The mean national percentage difference (MND) is also given for each audit date.

10/87	ph	cond	$SO_4^{2-}$	$NH_4^+$	$NO_3^-$	$Cl^-$	$Ca^{2+}$	$K^+$	$Mg^{2+}$	$Na^+$
	-1.3	4.8	6.3	16.6	-9.5	20.5	32.7	16.6	50.0	-6.7
	-0.7	1.2	9.8	-1.0	-10.6	18.4	-7.7	62.5	45.5	-7.3
	-0.8	2.8	13.5	-3.9	-11.1	3.5	300	62.1	22.0	-7.2
MND	1.7	4.5	14.2	14.3	15.4	11.8	130	44.7	35.1	18.2

05/88

ph	cond	$SO_4^{2-}$	$NH_4^+$	$NO_3^-$	$Cl^-$	$Ca^{2+}$	$K^+$	$Mg^{2+}$	$Na^+$
----	------	-------------	----------	----------	--------	-----------	-------	-----------	--------

	0.9	13.9	0.0	12.5	-9.1	-14.3	20.0	62.5	0.0	26.3
	0.3	-3.8	8.4	2.4	-5.6	27.0	-30.8	30.0	-50.0	9.6
	0.3	0.3	7.6	-4.5	-6.1	18.4	-50.0	300	-50.0	12.8
MND	1.7	14.0	9.6	14.7	19.5	13.3	38.9	19.9	11.1	11.4

10/88

	ph	cond	SO <sub>4</sub> <sup>2-</sup>	NH <sub>4</sub> <sup>+</sup>	NO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	Ca <sup>2+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>
	0.6	-1.0	1.4	4.8	-3.1	7.6	7.7	0.0	2.9	-3.0
	0.4	7.1	-2.2	16.2	-14.7	-11.7	10.6	27.4	10.7	13.4
	0.1	1.8	10.3	-10.7	-6.2	-0.3	41.3	66.2	5.9	8.9
MND	2.0	6.9	15.2	12.9	9.8	13.7	21.2	16.7	16.1	15.8

06/89

	ph	cond	SO <sub>4</sub> <sup>2-</sup>	NH <sub>4</sub> <sup>+</sup>	NO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	Ca <sup>2+</sup>	K <sup>+</sup>	Mg <sup>2+</sup>	Na <sup>+</sup>
	-0.2	-0.8	-4.2	11.2	-15.9	-35.9	140	37.5	30.3	31.3
	1.3	-2.9	/34	-4.6	-13.3	-12.8	54.5	64.3	18.7	20.6
	-0.5	1.3	4.4	-0.4	-12.5	-31.0	5.6	-0.2	-4.0	-1.2
MND <sup>1</sup>	92	91	92	91	88	73	47	47	71	60

<sup>1</sup> In this case NMD equals the percentage of national labs with average percent difference  $\leq 15\%$ .

Event collector (NADP) versus bulk collector (Taylor), Summer:

We analyze a sizable subset of our routine samples using Inductively Coupled Plasma Emission (ICPE) analysis. These samples are ran at the University of California-Los Angeles. QA for these samples has been provided principally by the US Geological Survey. The ICPE is not routinely configured for the analyses of Al, As, Co, Mo, Pb, or Se, and the level of detection for these species is poor. Also we have not generally relied upon the values given for Cr, K, or V from this machine. The primary problem again has been level-of-detection for these chemical species at the concentrations normally found in our samples.

For this comparison, we have been running two bulk collectors within 10 m distance from the NADP collector. One collector (Taylor) is a Lucite raingage commercially manufactured. The other bulk collector is one of our own design made especially for collection of throughfall. Both are equipped with a pre-rinsed ashless filter. Since both styles of collectors are used for summer precipitation collection at our more remote sites, we have been comparing results from all three types of collector for some time (Table 13). Also there is the general question of how bulk collectors compare to event collectors such as the Aerochem Metrics on a seasonal basis.

Other QA/QC in Field Sampling:

Table 13. Test of parameters using two-way blocked ANOVA to see if collector type or time give significantly different results from the NADP event collector. P values are given in columns 2 and 3. Data presented here are for June - September, 1989.

Parameter	Collector type	Time (week)
C <sub>B</sub>	0.05	0.167
c/a	0.0166	0.177
H <sup>+</sup>	0.816	0.136
SO <sub>4</sub> <sup>2-</sup>	0.455	0.644

NO <sub>3</sub> <sup>-</sup>	0.828	0.992
NH <sub>4</sub> <sup>+</sup>	0.335	0.503
Ca <sup>2+</sup>	0.086	0.17
Mg <sup>2+</sup>	0.081	0.148
Na <sup>+</sup>	0.014	0.523
K <sup>+</sup>	0.184	0.417
Cl <sup>-</sup>	0.057	0.568
Amount	0.907	0.015

Table 14. Comparison of NADP event collector at station MI99 with winter bulk precipitation and snowpack chemistry, Calumet Experimental watershed, Keweenaw Peninsula, MI. Data collected January 1, through April 30, 1989.

Al	C <sub>B</sub>	Ca <sup>2+</sup>	K <sup>+</sup>	NH <sub>4</sub> <sup>+</sup>	pH	H <sup>+</sup>	NO <sub>3</sub> <sup>-</sup>	SO <sub>4</sub> <sup>2-</sup> Cl <sup>-</sup>	HCO <sub>3</sub> <sup>-</sup>	C/A
Precipitation										
NADP @ MI99	13	8	1	13	4.6	27	19	22	1	- 1.29
Bulk @ MI99	31	19	2	20	4.6	25	23	27	3	- 1.35
Bulk @ Calumet	20	13	1	15	4.6	27	22	25	3	- 1.29
Snowpack										
C1 - C4	21	14	1	11	4.7	21	19	15	2	- 1.59
C5	17	11	1	11	4.7	21	23	17	1	- 1.56

In general, base cations were higher in the largest diameter bulk collector. The only base cation which had a significantly higher concentration in the Taylor collector was Na<sup>+</sup>.

During winter there generally has been a very strong correlation in precipitation quality between event and bulk collectors. This we attribute largely to the region-wide presence of a snowpack which minimizes local inputs of dust. For example, with precipitation collected in the winter of 1989 (Table 14), R<sup>2</sup>s were >0.8 for all ions. The mean concentration of base cations was higher than that observed in the event collector.

However, H, NO<sub>3</sub><sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, and Cl<sup>-</sup> concentrations were very similar among all collectors. These results are similar to those found in earlier years [Stottlemyer and Rutkowski (in press)].

During the period 1987-89 we had very good agreement when comparing the NADP field pH and specific conductance with the results from the Central Analytical Laboratory (CAL) (Table 15). The reduced pH obtained in our laboratory likely reflects the problem of contamination from the rubber O-ring in the NADP buckets which has a net effect of raising the pH by the time the sample is analyzed at CAL (Bigelow et al. 1989).

Table 15. Comparison of Central Analytical Laboratory pH and specific conductance (μr) readings with those from GLARSU on NADP samples submitted during period 1987-89.

	CAL pH	GLARSU pH	CAL Cond.	GLARSU Cond
min	4.04	3.81	4.1	4.9
max	6.66	5.59	60.9	100.7

mean	4.98	4.66	14.1	16.6
S.D.	0.58	0.35	8.36	12.4
n	88	88	88	88

Paired t test results showed  $p < 0.000$  for both pH and specific conductance differences with only paired data used.

Additional QA/QC testing which involves the GLARSU laboratory have been summarized in the previous QA/QC report (Stottlmyer et al. 1987), and are included in the QA/QC reports from the Sequoia-Kings Canyon NAPAP lake/watershed study sites.

## Status of Core Requirements

**II(1a).** Location of NADP collector at each site standardized with bulk collectors.

NADP station MI97, operating during period of ISRO occupation (May - October) since 1980, continues to operate in the Wallace Lake Watershed conterminous with Sumner Watershed. The station began operation in June 1985. Data are collected according to NADP protocol. The loss of 1987 data because of the shift in laboratories was very unfortunate since we used both the Wallace and Chassell (Michigan Tech) stations for input and concentration evaluations. At Wallace Lake we will continue to use bulk collectors during winter. These are collected monthly January - April. During fall and late spring access to Isle Royale is nearly impossible since there are no landing areas, and funding is not adequate for all-weather helicopter access. All sites are equipped with continuous recording raingages.

We installed a meteorological station at Legion Lake this year. We placed an aerochem metrics unit on site, but elected not to operate it due to the indefinite nature of the record for this site. We already have some bulk collector record, and such a collector continues to be used at this site.

We continue to maintain correlations of chemistry quality for bulk versus wet-only precipitation samples collected during the winter season, and find very good agreement during presence of snowpack. As part of our quality assurance/quality control program we have split

NADP samples from station MI99 for eight years comparing CAL results to those from our lab. Also we are operating additional stations on the NADP protocol as part of the NAPAP Forest Effects Program and for the State of Michigan. Field and laboratory data are kept updated on lab micro files. Some comparisons of these data sets are presented in the above section on quality assurance.

### II(2). Dry Deposition.

The ISRO station continues to operate. Particulates are not sampled during winter since AC power is required. This station is a low-technology filtering instrument, and will sample C, fine particulates, SO<sub>2</sub> and O<sub>3</sub>. This year we began to evaluate the data so far released from this station. This effort was largely done to complement some of our research in the Eastern Hardwoods Consortium assessing a gradient of anthropic inputs across a gradient running from Minnesota to southern Michigan.

**II(3).** Meteorology. A standardized method of data collection involving an automatic recording weather station and data logger will be at each site.

This requirement has been met for the present. The Campbell unit at Wallace Lake should be upgraded especially if aspects of the present research are to be continued. This goes for much of the field hardware in this study. Most of it was only intended for 8 - 10 of service before replacement or significant upgrading.

### II(4) Vegetation Productivity and Phenology.

Most components of this have been completed. Trout Lake still presents some problem due to the extreme height of the mature hardwoods. All plant tissue samples have been processed and analyses completed. Also we intend to finish assessing the contribution of dead wood (by size class) using transects and small paint marks adjacent the permanent plots.

This year we also collected litter and soil samples from the Legion Lake site. This watershed and

seepage lake differ markedly from the Wallace Lake or Trout Lake sites, and a slightly modified data collection protocol is in place.

Data files for this type of information have been formatted to accommodate our existing biomass data sets. As is the case for all laboratory data sets, these data exist as hard copy and on micro computer. We are in the process of putting together two papers on the results to date, and these will be submitted to the Canadian Journal of Forest Research in early spring.

#### II(5). Soils.

b. Soils maps will be produced for each study site.

A soils map of the Wallace Lake watershed has been completed. Samples have been analyzed (see first section of this report). We will complete soil sample analyses for Legion Lake by early spring.

Nothing has yet been done with soil buffer curves for any site. We would still like to do this for the Legion and Wallace sites.

c. Laboratory buffer curves. See above. These still need to be completed.

#### II(6). Surface waters.

b. Describe sources and drainage area. With the exception of a survey of organic debris in streams, all of the original components of this core requirement have been met. A survey of riparian vegetation around the lakes was completed with the study of Legion Lake. The results of the surveys have not yet been fully compiled.

d. Establish stream discharge records at appropriate locations for basin output analysis. At the lower station in each watershed we undertook a number of 24-hour surveys of diurnal change in water quality using a combination of manual and automated water sampling every two hours on site. This was done on a seasonal basis. The objective was related to QA, and we wanted to see if the time of day samples were collected is a possible source of variation during non-storm runoff period.

We have finally given up on the Belfort Sonar stage height recorders. The company has informed us that there is a fundamental hardware

problem which will not be looked at for at least 15 months. The units were returned to Belfort in Baltimore, MD.

All usual computations, as input/output ratios, relationships between discharge and concentration, are done on data sets updated on an annual basis.

II(7). Critical measurements that cannot be funded under current program authorization. See Appendix A, 1985 Annual Report.

#### Research Progress in 1989

Most of the progress made in 1989 is outlined in the following list of reports and publications, and in the above status report. As stated earlier, the focus from now on out will be on testing the above hypotheses.

##### Projects Started in 1989:

There were no strictly new projects initiated in 1988 under this program (see Introduction and subsequent sections). The focus this year was in fully replicating throughfall, litter, and soil solution plots both at Wallace Lake and Legion Lake. Also, at Legion Lake we completed the benthic coring of this lake and three additional ones nearby.

##### Projects Completed in 1989:

##### Leverage Projects

There has been little change since last year's report. The NAPAP - funded Forest Effects research project is fully underway, and the data we are generating will be of considerable assistance in putting our sites in a regional context. Particularly interesting will be their location along the Upper Midwest gradient. This project, as with all other components of NAPAP, will be terminated this year. In addition, the NPS - sponsored study of ecological factors responsible for pre 1850 vegetation will support some of the costs of analyzing the Legion Lake cores. These samples will also be analyzed for variables of value in assessing historical trends in sulfur inputs.

##### Coordination With NPS Science:





# **QUALITY ASSURANCE REPORT**

Loch Vale Watershed Study, 1989-90

Robert L. Edwards

*Natural Resource Ecology Laboratory  
Colorado State University*

May 22, 1991

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## List of Acronyms

ANC	Acid Neutralizing Capacity, equivalent to alkalinity
CAL	Central Analytical Laboratory at the Illinois State Water Survey
DAMS	Data Acquisition and Monitoring Subsystem
DOC	Dissolved Organic Carbon
DQO	Data Quality Objectives
GOES	Geostationary Operational Environmental Satellite
IPD	Ion Percent Difference
NADP	National Atmospheric Deposition Program
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
RSD	Relative Standard Deviation
STL	Soil Testing Laboratory
USGS	U. S. Geological Survey
WEBB	Watershed Energy Biogeochemical Budgets, USGS program

## **Introduction**

The Loch Vale Watershed Study was initiated by the National Park Service in 1980 and has continued as a long term monitoring site since then. The watershed also is currently in the Watershed Energy Biogeochemical Budgets program of the U.S. Geological Survey and is a proposed site for the Global Change research program of the NPS. Data quality through 1987 was assessed in an earlier report [3], and 1988 data was reviewed in the 1988 Annual Report [2].

There are four areas of ongoing long term data collection; meteorology, hydrology, precipitation chemistry, and surface water chemistry. Each of these types of data will be discussed separately below. Additional types of data such as lake bathymetry, soil characteristics, and various student research projects are collected on an individual project basis. Data are reviewed and stored on a Unix based local computer network at the Natural Resource Ecology Laboratory (NREL) at Colorado State University.

A primary objective of the long term program is to detect and interpret trends over multi-year periods, taking into account seasonal and annual variation. To meet this objective, an accurate and regular assessment of data quality is important. This report addresses the quality control procedures and the quality of analytical results for the Loch Vale data from 1989-90.

## **Meteorological Data**

Meteorological data for the Loch Vale watershed are collected by a solar powered remote area weather station. The following parameters are measured; wind speed, wind direction, relative humidity, barometric pressure, solar radiation, air temperature and precipitation amount. Data are gathered every 15 minutes by a Handar 524 data collection platform, and relayed hourly to NOAA's Wallops Island, VA, ground station via the GOES West satellite. Quality assurance is maintained with an annual calibration check performed by Environmental Technology, Inc., to maintain the equipment within published limits. The

Data Acquisition and Monitoring Subsystem (DAMS) at the Wallops Island downlink monitors each hourly data transmission for signal strength (EIRP), frequency offset, modulation index and received data quality [6]. Fifty randomly selected hourly transmissions from the 1990 data were analyzed for each of these parameters (Table 1). All parameters except EIRP were always within the normal range. EIRP is slightly lower than normal in one out of four transmissions, however, in the absence of other problems the observed range does not affect the transmitted signal [6].

**Table 1: Meteorological data signal quality parameters**  
 Summary statistics from 50 randomly selected data transmissions  
 Wallops Island DAMS provides these signal quality measures each hour

	Signal Strength (EIRP)	Frequency Offset (Hz)	Modulation Index	Data Quality
mean	44.1	+47	always Normal ( $60^{\circ} \pm 5^{\circ}$ )	always Normal (error rate $< 10^{-6}$ )
SDs	2.1	41		
normal range	44 to 49	-250 to +250		
# outside normal	12 low	0		

## Hydrological Data

Surface water flow out of the Loch Vale Watershed is gaged in Icy Brook, just below the outlet from the Loch. A Parshall Flume with a stilling well was installed in 1983. Stage height data are collected both electronically and mechanically when there is measurable flow through the flume, typically from May through October. A continuous flow record has been kept since Oct 15, 1983, with an Omnidata electronic stage height recorder and a Leupold and Stevens chart recorder. Field verification of the recorded gage heights occur weekly. Annually, data are approved by comparing the electronic, chart and field data. Any discrepancies are corrected according to the information at hand. These corrections are noted and stored along with the data files at NREL. The data are converted to flow (in  $\text{m}^3 \text{sec}^{-1}$ )



using a rating formula provided by the Thompson Pipe and Steel Co. According to Winter [12], the accuracy of Parshall Flumes is  $\pm 5\%$ . In Loch Vale, it is estimated that an additional 5% uncertainty is introduced by water flowing around or under the flume structure.

## **Precipitation Data**

The Loch Vale Watershed Study participates in the National Atmospheric Deposition Program (NADP), which is responsible for the analysis of precipitation chemistry and the quality assurance of those data. The network has a published quality assurance plan [1] and a report is produced periodically by the Central Analytical Laboratory (CAL) which gives the results of their quality control projects. The NADP goals for laboratory measurements of specific analytes are given in Table 2. The most recent CAL report covers data from 1989 [7]. It states that CAL was meeting these goals through a quality control program of weekly blanks, quality control check samples, blind network sample replicates, and an internal blind audit with artificial samples.

The precipitation data for the Loch Vale site, CO98, have been verified and published by NADP through June, 1990. Nine weekly samples since 1989 have been considered invalid; twice for contamination, once because of a two week sampling interval when a winter storm curtailed field activities, and six times because of insufficient sample volume when there was significant precipitation during the week. The latter cases all occurred in the winter season. The standard Aerochem Metrics Precipitation Collector used by the network is poor for catching dry snow under the windy conditions prevalent in Loch Vale in the winter. This problem has been discussed with the NADP technical staff, but currently there is no known solution.

Field personnel are responsible for measuring pH and conductivity of weekly precipitation samples. Each analysis is accompanied by measurement of a quality control check sample. If pH is not within 0.1 unit and conductivity within 4  $\mu\text{S}/\text{cm}$  of the reported check sample values, the equipment is re-calibrated. The field technicians also participate twice per year in an intersite comparison organized by the USGS. An artificial sample is sent to each NADP site for measurement of pH and conductivity. Measurements are expected to

be within the weekly criteria (above) of the network wide median values. In 1989-90, as in all previous years, lab results met NADP quality assurance criteria (Table 3).

**Table 2: Data Quality Goals for Precipitation Chemistry**  
From NADP/NTN Quality Assurance Plan, 1990 [1]

Analyte	Units	Bias/Precision	Detection Limit
Ca	mg/l	100% at Detection Limit  20% at 10 times Detection Limit  10% at 100 times Detection Limit	.009
Mg	mg/l		.003
Na	mg/l		.003
K	mg/l		.003
NH <sub>4</sub>	mg/l		.02
SO <sub>4</sub>	mg/l		.03
NO <sub>3</sub>	mg/l		.03
PO <sub>4</sub>	mg/l		.02
Cl	mg/l		.03
pH < 5.0		±0.1 / ±0.03	
pH > 5.0		±0.3 / ±0.1	
Specific Conductance			
10 - 100	µS/cm	±10% / ±3%	
>100	µS/cm	±6% / ±2%	

**Table 3: USGS Intersite Laboratory Comparison**  
Artificial sample sent to field sites on dates shown  
Median values from all participating NADP sites  
Measured values from Loch Vale field laboratory

Date	Median pH	Measured pH	Median Conductance	Measured Conductance
3/89	4.68	4.69	8.6	9.3
9/89	4.01	4.04	43.2	44.5
4/90	4.57	4.60	12.3	12.8
10/90	4.85	4.88	6.5	6.6

## Surface Water Chemistry

### Introduction

Surface water samples are routinely collected throughout the Loch Vale Watershed, with a major emphasis on weekly samples from The Loch outlet as long as there is sufficient flow. Specific quality control procedures for the collection and handling of samples before shipment for chemical analysis have been described previously [3] and follow established protocol for low ionic strength waters, e.g. [9]. Chemical analysis of surface water samples was done by the USGS Central Laboratory, in Arvada, CO, through March 1989. With an overlap period starting in Jan 1989, analyses were performed by the Soil Testing Laboratory (STL) at Colorado State University through Aug 1, 1989. It was thought this change would provide more direct oversight of sample analysis, faster turnaround time and lower cost. However, results from this lab were not satisfactory and sample analysis reverted to the USGS Central Laboratory starting Aug 8, 1989.

Each laboratory is responsible for its own internal quality assurance, according to current standards for analysis of low ionic strength natural waters, e.g. [5]. This information is not published, but precision estimates are included in the Services Catalog for the USGS Central Laboratory [4]. Both the USGS Laboratory and the STL participated in a round robin interlaboratory comparison in 1989. A variety of samples were distributed to participating laboratories. Analytical results were compiled by USGS personnel. Ratings were given to each laboratory according to the closeness of its measured values for a series of parameters to the mean values for all laboratories. Both laboratories received satisfactory to excellent ratings, depending on the sample [8,11].

Overall data quality for combined field and lab procedures is assessed through a series of replicate and blank samples. The aim is to meet the same goals already established for precipitation (Table 2), although the laboratories have higher detection limits for surface waters, due to the use of different analytical techniques. Bias and contamination due to field procedures are estimated using blank samples. In LVWS, blank samples are deionized water (conductivity  $< 1.0 \mu\text{S/cm}$ ) which is carried up to the field site, then "sampled" according to standard procedures. Precision is estimated using two types of replicate samples. Duplicate

samples are collected in separate bottles from the same site within minutes of each other. Split samples are collected in a single large bottle in the field, then split during the field lab processing. Both types are treated as separate regular samples for shipment to the laboratory for analysis.

Analytical results are screened to detect problems with individual samples. The difference between the sum of the cations and the sum of the anions, divided by the total ion concentration (ion percent difference, IPD) is used as a general indicator of analytical difficulties. Individual analyte concentrations of samples with IPD > 10% are compared with expected values to identify specific analytical errors, and reanalysis of these analytes is requested if possible.

#### Results from the USGS Central Laboratory

There were eight duplicate pairs, and six split pairs of samples analyzed by the USGS lab in 1989-90 (Table 4). The difference between the duplicate sample means and the split sample means reflects seasonal change. Precision is assessed by examining the difference in measured concentration within sample pairs. A t-test was used to compare the mean difference of duplicate sample pairs against the mean difference of split sample pairs for each analyte. No significant differences were found between the two sample types. Since any differences between the duplicate and split samples would be a result of the field collection procedure, it is concluded that in general, such procedures do not add variability to the surface water data, or in other words, data precision is not affected by the techniques used to collect samples in the field.

The duplicate and split sample results are combined to provide a more accurate estimate of data precision (Table 5). Given a narrow sample concentration range or no relationship between variance and mean, conditions which generally apply to Loch Vale samples [3], the relative standard deviation ( $100 * (\text{std dev}/\text{mean})$ , RSD) is the most useful statistic for comparing precision among different analytes. Both iron and aluminum had single sample pairs with much higher concentration and variance than other sample pairs; those data are not included. Other missing data are due to incomplete laboratory analyses.

For most analytes, the USGS data meet data quality goals for precision. When the RSD is high for an analyte, mean concentration is near the analytical detection limit. The variability of pH measurement slightly exceeded DQO. Dissolved Organic Carbon (DOC) showed the worst RSD, while the mean DOC was more than 10 times the detection limit. Two sample pairs with large differences are primarily responsible for the large standard deviation, indicating a problem with occasional contamination.

**Table 4. Replicate samples analyzed by USGS Central Lab**

Values are for sample pairs collected at same site and time

H<sub>0</sub>: Duplicate pair mean differences are not different than split pair mean differences

Duplicate pair n = 8, Split pair n = 6

Major ions and DOC are in mg/l; Al, Fe, and Mn are in µg/l

Conductivity is in µS/cm, ANC is in µeq/l

	Duplicate pairs			Split pairs			ttest
	mean	SDs	mean diff.	mean	SDs	mean diff.	p =
Ca	2.016	0.027	0.014	1.143	0.043	-0.006	0.522
Mg	0.305	0.003	0.001	0.175	0.007	0.002	0.823
Na	0.815	0.031	-0.007	0.395	0.048	-0.034	0.430
K	0.202	0.006	0.001	0.130	0.000	0.000	0.734
NH <sub>4</sub>	0.008	0.004	-0.001	0.010	0.003	-0.002	0.607
SO <sub>4</sub>	2.454	0.085	0.006	1.410	0.055	0.06	0.404
NO <sub>3</sub>	0.763	0.035	0.031	0.895	0.063	-0.035	0.117
PO <sub>4</sub>	0.007	0.003	0.001	0.009	0.005	0.004	0.378
Cl	0.203	0.021	0.02	0.096	0.000	0.000	0.102
F	0.104	0.012	-0.01	0.094	0.011	0.000	0.296
SiO <sub>2</sub>	1.743	0.005	-0.003	1.454	0.082	0.052	0.703
Al	14.4	4.54	-0.4	39.9	9.32	2.5	0.623
Fe	88.5	12.00	-2.3	141.4	47.60	-21.1	0.473
Mn	9.8	1.67	-0.7	2.2	0.40	0.1	0.226
DOC	2.77	5.785	-3.29	1.64	1.664	-1.28	0.645
ANC	93.2	10.28	-4.7	58.2	13.90	7.3	0.229
Cond	19.8	0.36	-0.04	14.1	0.07	-0.03	0.986
pH	6.692	0.211	0.059	6.543	0.065	0.027	0.814

**Table 5. Overall Precision and Bias for the USGS Central Lab**

Values for pooled duplicate and split sample pairs from Table 4

Units the same as in Table 4

SDs = sample standard deviation

RSD (relative std. dev.) =  $(100 * (\text{std dev} / \text{mean}))$ 

Detection limits as reported in analytical results from USGS Central Laboratory

Average minimum values from all 1987-1990 data excluding outliers

Bias % =  $(100 * (\text{mean blank conc}(\text{from pre-1988 data}) / \text{average minimum}))$ 

† = at or below detection limit

	Combined Replicate Pairs				detection limit	avg. min.	Bias %
	mean	SDs	RSD	n			
Ca	1.652	0.035	2.1	12	.02	1.0	8
Mg	0.251	0.005	1.9	12	.01	.13	22
Na	0.640	0.039	6.1	12	.02	.27	81
K	0.172	0.005	2.7	12	.01	.10	10
NH <sub>4</sub>	0.008	0.004	41.9	12	.003	†	333
SO <sub>4</sub>	2.019	0.074	3.7	12	.01	1.1	2
NO <sub>3</sub>	0.818	0.049	5.9	12	.01	.6	7
PO <sub>4</sub>	0.008	0.004	55.9	11	.003	†	200
Cl	0.158	0.016	10.3	12	.01	.07	30
F	0.100	0.011	11.4	12	.01	.05	36
SiO <sub>2</sub>	1.623	0.053	3.3	12	.01	1.3	14
Al	18.5	3.33	18.0	13	1	13	88
Fe	75.9	5.04	6.6	13	10	23	22
Mn	6.6	1.30	19.7	12	1	†	110
DOC	2.36	4.723	200.2	11	.1	0.8	25
ANC	78.2	11.97	15.3	14		35	14
Cond	17.4	0.28	1.6	14		10	40
pH	6.628	0.165	2.5	14		-	-

The previous Quality Assurance Report examined the bias in Loch Vale samples analyzed by the USGS Laboratory from blank samples collected prior to 1988 [3, Table 3]. No blank samples were sent to the USGS Laboratory in 1989-90. In the earlier blanks, most analytes were close to the detection limits, indicating minimal field contamination. However, calcium, ammonium, silica, aluminum and conductivity had high variances, indicating



occasional contamination. Sodium concentrations were consistently higher than detection limits, indicating a possible bias due either to field or laboratory procedures. Although it is not readily apparent from Loch Vale blanks, chloride values for all samples analyzed by the USGS Central Laboratory prior to 1988 exhibit a small positive bias due to a calculational error. Instructions for correcting this error are forthcoming from the USGS. The percent bias presented in Table 5 is produced by dividing the mean blank concentration by the average annual minimum concentration (from scanning the 1987-1990 data). Most analytes met the data quality objectives (DQO) in Table 2 for bias. Since the average minimum calcium concentration was high, bias was low even though the blank was relatively high. Sodium, silica, aluminium and conductivity biases were greater than DQO. Both ammonium and phosphate also show a large bias, but minimum values were consistently below detection and thus a small blank value had a large effect.

The mean ion percent difference of 1989-90 samples (Figure 1) is slightly more positive than in 1988 data [2, Figure 7]. This may be due to an undermeasurement of alkalinity in 1990 samples. In March 1990, the laboratory building had structural problems which resulted in delayed analysis of samples from March and April. Because it must be performed on unfiltered, unpreserved aliquots, alkalinity is time-sensitive and is difficult to reanalyze accurately. Samples from June-August 1990 were also analyzed with techniques suitable to higher alkalinity waters, which resulted in the underestimation of the significant but low alkalinities of Loch Vale waters. All samples are now flagged for low alkalinity analysis.

### Results from the Soil Testing Laboratory

The results from both paired replicate samples and blank samples sent to the STL are presented in Table 6. Six blank samples were analyzed. Relatively high values for mean and standard deviation were found for calcium, sodium, potassium, chloride, and aluminum. These reflect a few samples with high values, indicating a problem with occasional contamination. Percent bias was still acceptable for calcium, due to a high annual minimum value, and for aluminum, due to a detection limit for STL data ten times that for USGS data. Percent bias

for sodium and potassium was close to, but greater than DQO while chloride clearly exceeded those goals. Ammonium, iron and alkalinity had high mean values with relatively low standard deviations, indicating either consistent contamination or accuracy problems with the analytical methods. All these analytes exceeded DQO for percent bias. Nitrate, phosphate, fluoride and manganese were always at detection limits, which were higher than the corresponding USGS limits. Since annual minima for ammonium, phosphate and manganese

**Table 6. Replicates and Blanks Analyzed by the Soil Testing Lab**

Replicate pairs, n = 7, Blanks, n = 6

Units as in Table 4

SDs = sample standard deviation

RSD = relative standard deviation as in Table 5

Bias % calculated as in Table 5

‡ = STL detection limit higher than USGS, annual minima below detection

	Replicate Pairs			Blanks			Bias %
	mean	SDs	RSD	mean	SDs	RSD	
Ca	1.559	0.079	5.1	0.079	0.083	105.6	8
Mg	0.274	0.005	1.7	0.020	0.000	0.0	15
Na	0.665	0.020	3.0	0.086	0.145	169.4	32
K	0.195	0.033	16.7	0.053	0.093	175.0	53
NH <sub>4</sub>	0.196	0.369	188.0	0.083	0.035	41.9	±
SO <sub>4</sub>	2.764	0.180	6.5	0.040	0.041	103.1	4
NO <sub>3</sub>	0.313	0.085	27.0	0.044	detection limit		7
PO <sub>4</sub>	0.031	detection limit		0.031	detection limit		±
Cl	0.386	0.030	7.8	0.176	0.179	101.8	251
F	0.054	0.007	12.1	0.010	detection limit		20
SiO <sub>2</sub>	1.165	0.043	3.6	0.060	0.060	99.5	5
Al	30.0	5.86	19.5	12.4	15.404	123.9	92
Fe	177.1	25.36	14.3	22.9	17.043	74.6	100
Mn	32.9	0.00	0.0	10.0	detection limit		±
DOC	4.15	4.857	117.0	incomplete lab results			-
ANC	59.9	3.66	6.1	19.6	13.37	68.2	56
Cond	15.4	1.28	8.3	1.6	0.79	50.0	16
pH	6.329	0.065	1.0	-	-	-	-

were at the USGS detection limits, the higher limits for STL data represent a substantial loss of information. Sodium, silica and conductivity were improved from USGS results, although sodium and conductivity still did not meet DQO.

Seven replicate sample pairs were analyzed for an overall estimate of precision. In contrast to the USGS results, ammonium, nitrate and conductivity did not meet DQO, although the latter two were close. Ammonium is difficult to measure at low concentrations and may be expected to give problems for a lab just beginning analysis of low ionic strength waters. The STL analyses of DOC were more variable than desired, similar to the USGS results.

The distribution of IPD for the STL (Figure 2) shows both a greater standard deviation and a substantially lower mean than any previous USGS data. This suggests both a consistent problem with overmeasurement of anions or undermeasurement of cations, and precision problems with regular samples. A specific problem was the time lapse between shipment of samples and receipt of analytical results. This inhibited timely review of the data and subsequent chances for reanalysis.

### Comparison of USGS Central Laboratory and STL Results

Various differences in the quality control samples analyzed by the USGS Central Laboratory or the Soil Testing Laboratory have been covered above. Plots of regular sample concentrations from March 1987 to August 1989 (spanning both the USGS lab and the STL analytical periods) reveal several patterns. For some of the analytes the mean concentrations and seasonal patterns are consistent through both the USGS and STL data (e.g. sodium, Figure 3) though often the STL data don't hold as tightly to the seasonal trends (e.g. DOC, Figure 4). These include DOC, silica, aluminum, iron, alkalinity and pH. STL results for some other analytes follow USGS data quite closely except for a number of outliers, both high (sulfate, Figure 5) and low (magnesium, Figure 6). For ammonium (Figure 7) and manganese, STL's detection limit is too high for Loch Vale waters. Almost all USGS data is below that limit, and STL data occasionally are very high. Nitrate (Figure 8) and potassium

have a large range and no seasonality in STL data compared to the previous USGS analyses. Overmeasurement of anions occurs generally and is especially pronounced in chloride (Figure 9). This is probably what accounts for the low mean and high variability of the IPD data.

In Jan - Mar 1989, six pairs of samples were sent to both laboratories for analysis. A pairwise t-test was used to test whether the mean difference within sample pairs was different from zero (Table 7). If the mean difference is positive, the USGS concentration is higher, a negative value indicates that the STL concentration is higher. Eight analytes showed significant differences. Calcium, sodium and conductance were positive, silica, ammonium, aluminum, manganese and pH were negative. The results for sodium, silica and conductance are consistent with the bias estimates, indicating an improvement in STL over USGS, although this is not clear from the timeplots (Figure 3, for sodium). Ammonium and manganese are also consistent with previously discussed results. The STL produced high values and had high detection limits for these analytes (Tables 5 and 6, Figure 7 for ammonium). Bias estimates and timeplots for calcium, aluminum and pH did not suggest a consistent difference between USGS and STL results, although blanks for aluminum were high for both laboratories (Tables 5 and 6).

## Surface Water Chemistry Overview

A summary of the different data quality measurements for each analyte is presented in Table 8. In general, surface water data for 1989-90 meet or are close to data quality goals. Four analytes exhibited problems in the data produced by both the USGS Central Laboratory and the Soil Testing Laboratory. Sodium, ammonium, phosphate and conductivity field blanks were higher than DQO. Ammonium and phosphate usually occur at very low concentrations in Loch Vale waters. These analyses are particularly sensitive to contamination and in part the problem may be due to the difficulty in removing all ammonium and phosphate from the deionized water used for blank samples. Deionized water with conductance  $< 1 \mu\text{S/cm}$  may have a total electrolyte concentration of .2-.5 mg/l [10]. Contamination in the water used for blanks could easily account for the observed biases if the concentration of ions is not distributed evenly among the chemical species analyzed. The sodium blanks decreased

with the change in analytical laboratories, possibly indicating a relationship to analytical method. High conductance is probably a reflection of the high blanks for other analytes. Poor precision for DOC analysis is due to just a few samples with high values. The duplicate sample standard deviation was much higher than that for split samples (Table 4), although statistically they were not different. Perhaps this indicates that field procedures are the most likely source of occasional DOC contamination.

**Table 7. Pairwise Comparison of USGS and STL Replicated Pairs**

Values are for replicate sample pairs, one of which was sent to the USGS Central Laboratory for analysis, the other sent to the Soil Testing Laboratory  
 $H_0$ : Pairwise mean difference is not different from 0

\*  $p(t) < .05$

\*\*  $p(t) < .01$

		n	Difference		pair-wise t-test		
			mean	SDs	t =	p =	
Ca	mg/l	6	0.332	0.197	4.117	.049	*
Mg	mg/l	6	0.005	0.030	0.415	.695	
Na	mg/l	6	0.122	0.042	7.151	.001	**
K	mg/l	6	0.008	0.051	0.399	.706	
NH <sub>4</sub>	mg/l	4	-0.068	0.012	-11.282	.002	**
SO <sub>4</sub>	mg/l	6	-0.597	1.254	-1.165	.296	
NO <sub>3</sub>	mg/l	5	-0.195	0.195	-2.239	.089	
Cl	mg/l	6	-0.307	0.436	-1.722	.146	
F	mg/l	4	0.038	0.028	2.724	.072	
SiO <sub>2</sub>	mg/l	6	-0.198	0.185	-2.629	.047	*
Al	μg/l	6	-23.7	12.80	-4.529	.006	**
Fe	μg/l	6	-20.7	21.87	-2.315	.069	
Mn	μg/l	6	-4.7	1.86	-6.139	.002	**
DOC	mg/l	6	-0.23	2.836	-0.202	.848	
ANC	μeq/l	6	27.3	36.55	1.827	.127	
Cond.	μS/cm	6	1.9	1.57	2.990	.031	*
pH		6	-0.19	0.13	-3.562	.016	*

The change in analytical laboratories was the most significant event for surface water data quality. Analysis of blanks and replicates indicated that most analytes still met DQO. STL data showed a reduction in bias for sodium, silica and conductivity analyses. However, blanks were worse for potassium, iron, alkalinity and especially chloride. Filtration procedures and analytical methods were slightly changed for STL samples. It is likely these were responsible for the changes in blank values, though it is unknown why the chloride values were so much worse. Precision declined greatly for ammonium, less so for nitrate and conductivity, and was slightly improved for pH. Laboratory handling may be responsible for some of these changes. Clearly there were methodological problems with the ammonium analysis. Some of the results from the interlaboratory comparison samples (Table 7) agreed with the blank sample results (sodium, ammonium, aluminum and conductivity), while others were contradictory (silica) or unexpected (calcium, manganese and pH) compared to the blank samples. The number of samples may have been too small to expect both the blanks and the comparison samples to give congruent results. Plots of concentration versus time for regular samples (Figures 3 - 9) were the most useful method for revealing inconsistencies in the results produced by the different laboratories. The STL data for most analytes was similar to, though more variable than the USGS data. However, a number of analytes varied markedly between the laboratories. Taken all together, the usefulness of the STL data is highly questionable, though with careful screening some of it may be acceptable for certain purposes. Currently all STL produced data are stored separately and not used in the main Loch Vale database.

## **Future Plans**

Quality assurance of long-term data from the Loch Vale Watershed Study is essential. Quality control procedures already implemented will continue for all four areas of data collection. These are seen as adequate for the meteorological and precipitation chemistry data. Through closer association with the U.S. Geological Survey WEBB program, it is hoped that there will be increased accuracy and precision of the hydrological data. Surface water data quality control will continue to require collection of replicate and blank samples,



as well as careful screening of analytical results. This latter aspect will be improved through streamlining of computer data handling procedures and the frequent construction of timeplots for all analytes. It is also planned to coordinate data formats and quality assurance with standards for sites in the Long Term Ecological Research network funded by the National Science Foundation.

**Table 8. Summary of Surface Water Data Quality**

see text for explanation of data quality measures

pre. = precision

? = close to, but exceeding DQO

\* = did not meet DQO

> = USGS values greater than STL values

comments under timeplots refer to STL data compared to USGS data

	USGS		STL		USGS vs. STL	
	bias	pre.	bias	pre.	pairs	Timeplots
Ca					>	
Mg						low outliers
Na	*		?		>>	
K			?			no ann. pattern
NH <sub>4</sub>	*		*	*	<<	high det. limit
SO <sub>4</sub>						high outliers
PO <sub>4</sub>	*		*			high det. limit
NO <sub>3</sub>				?		high & no pattern
Cl			*			high & variable
F						
SiO <sub>2</sub>	?				<	
Al	*				<	high det. limit
Fe			*			
Mn					<	high det. limit
DOC		*		*		more variable
ANC			*			
Cond.	*		?	?	>	
pH		?			<	

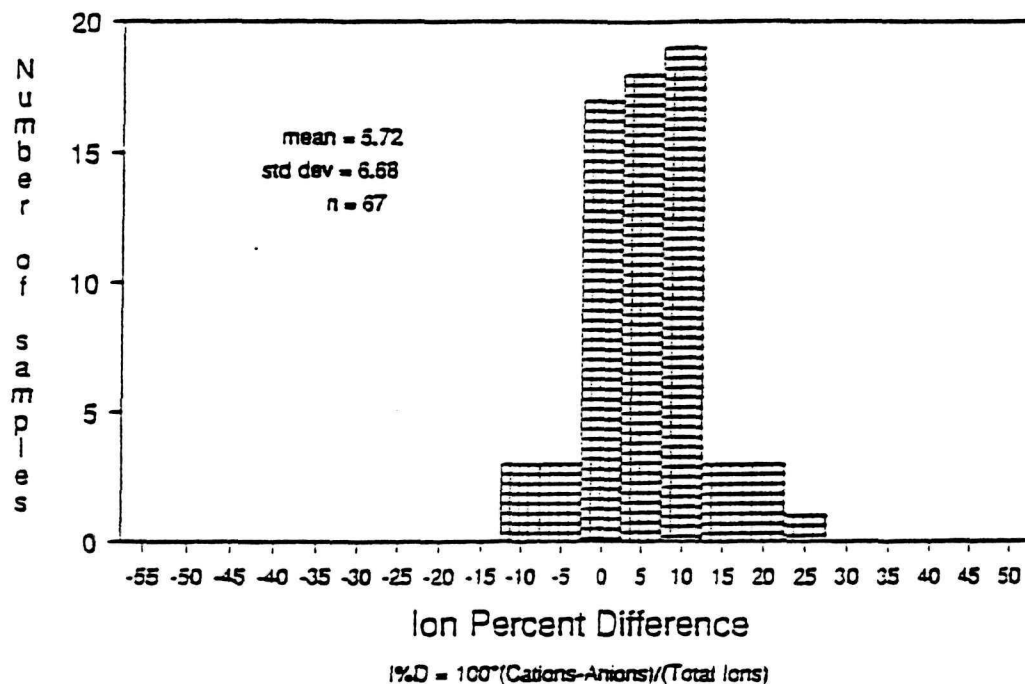
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# Figure 1. USGS Data

1 Jan 1989 - 20 Aug 1990



# Figure 2. STL Data

1 Jan 1989 - 1 Aug 1990

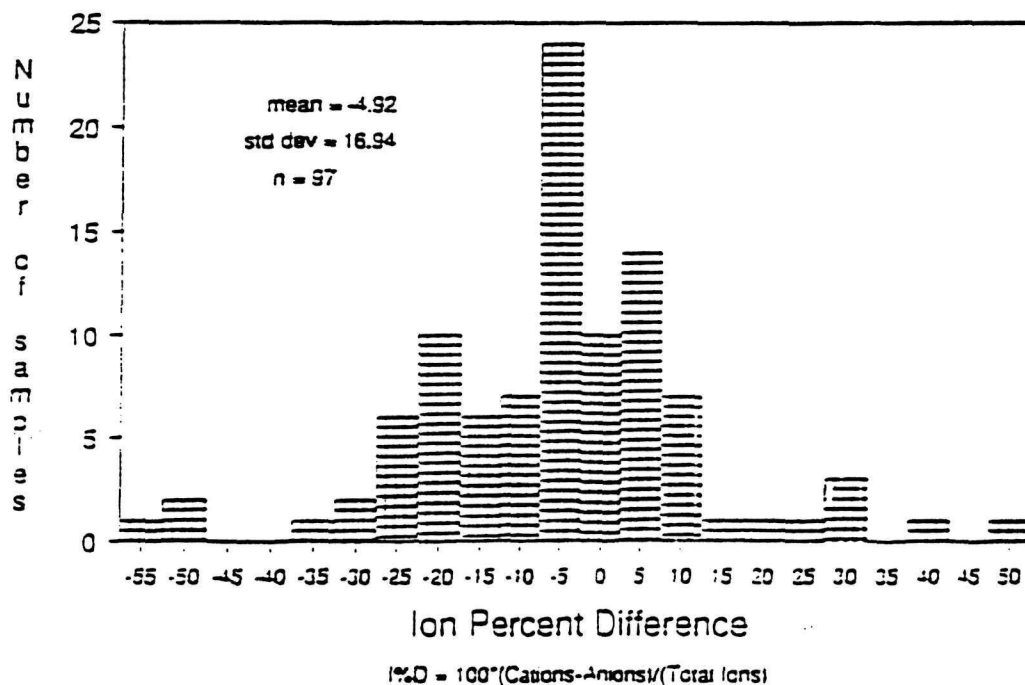


Figure 3.

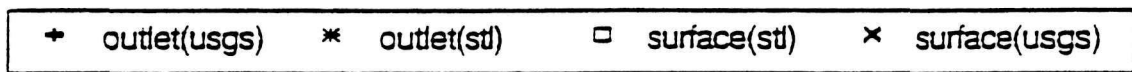
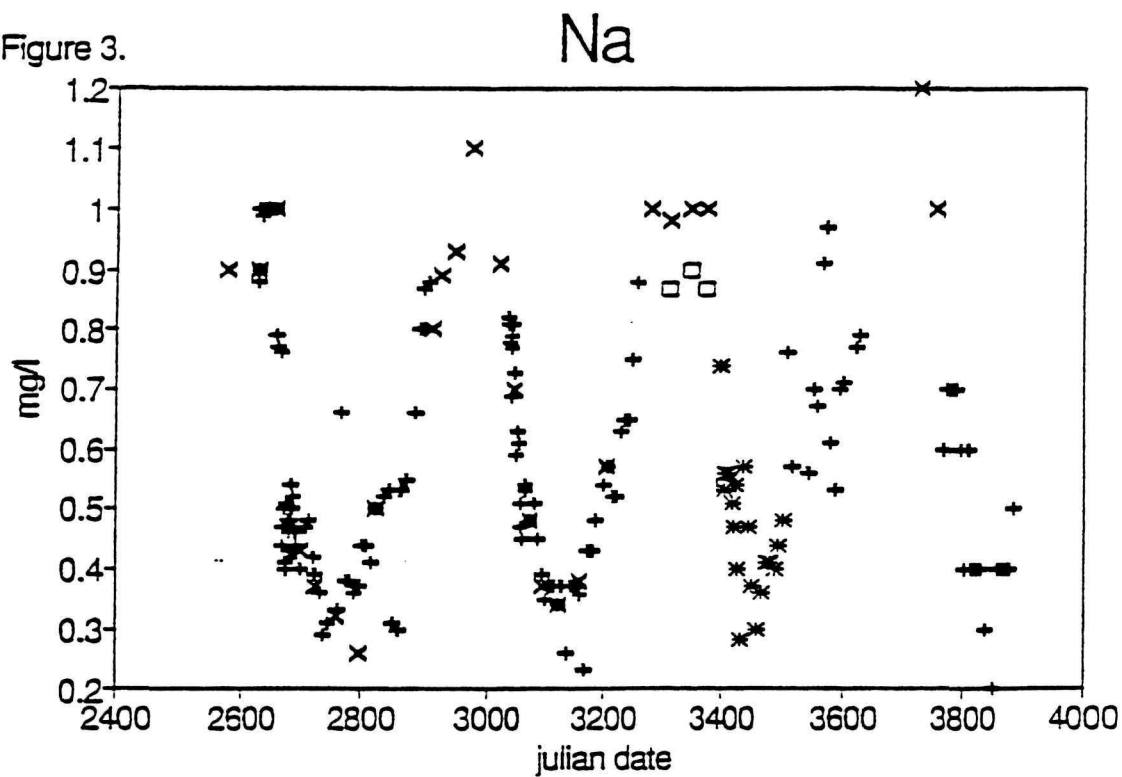
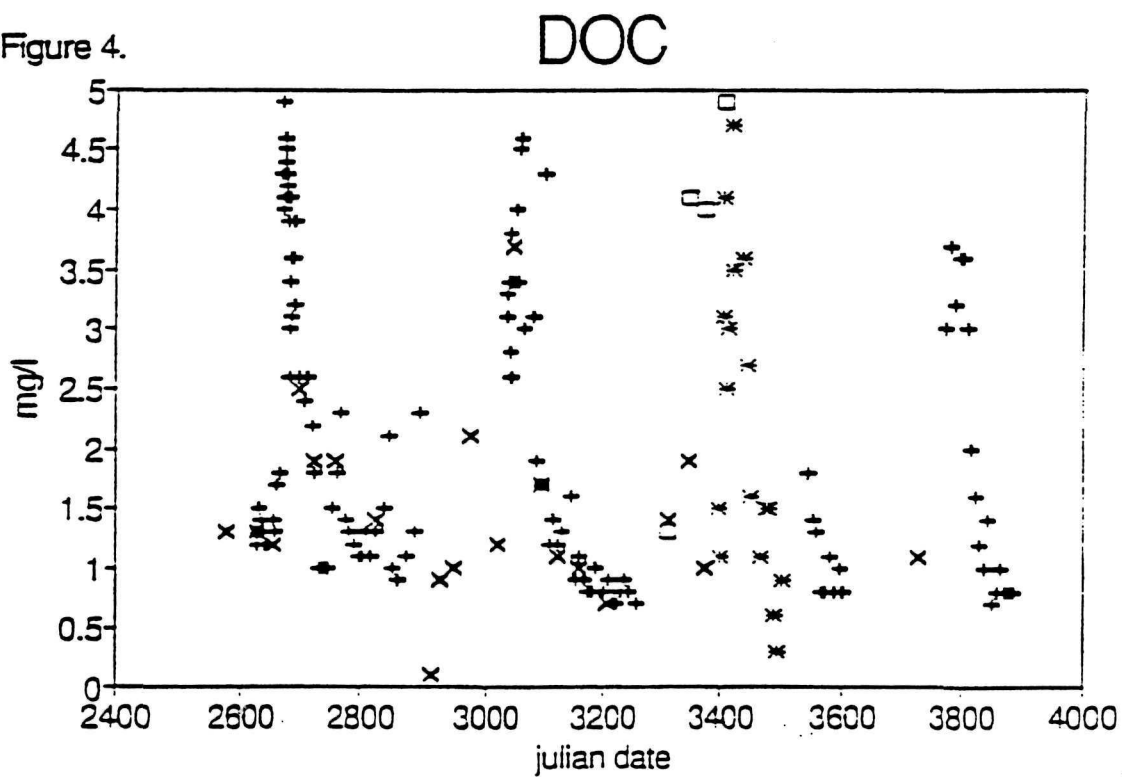


Figure 4.



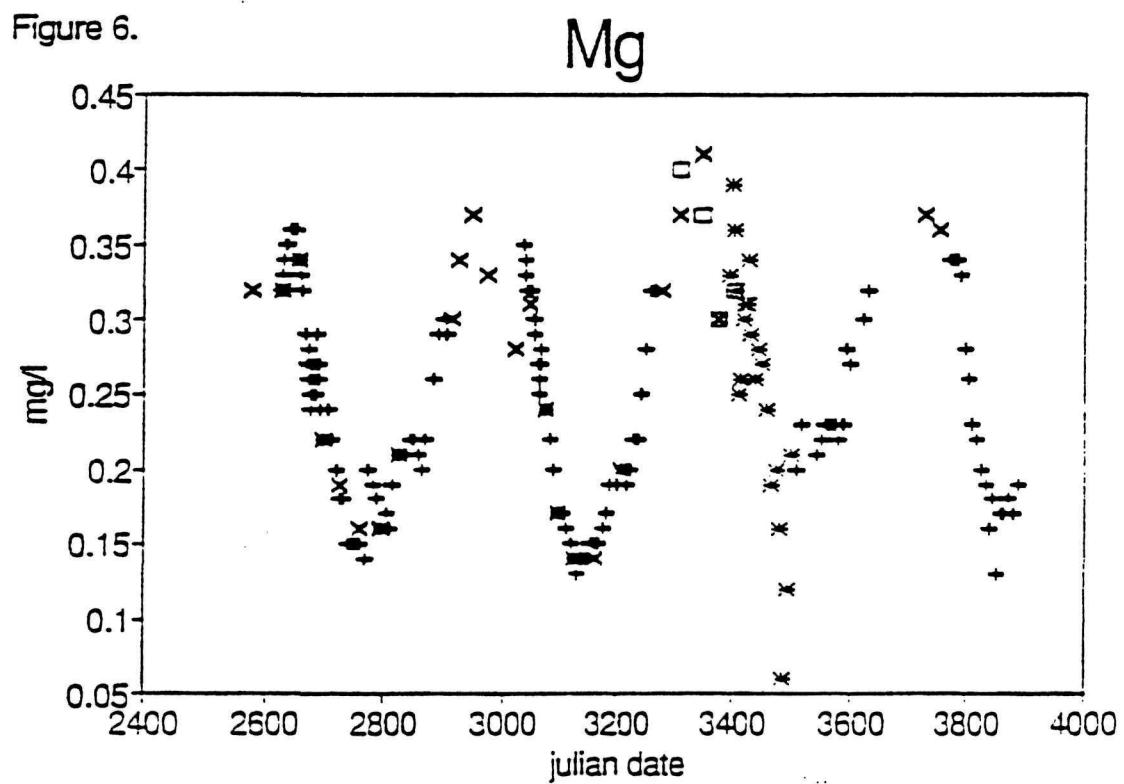
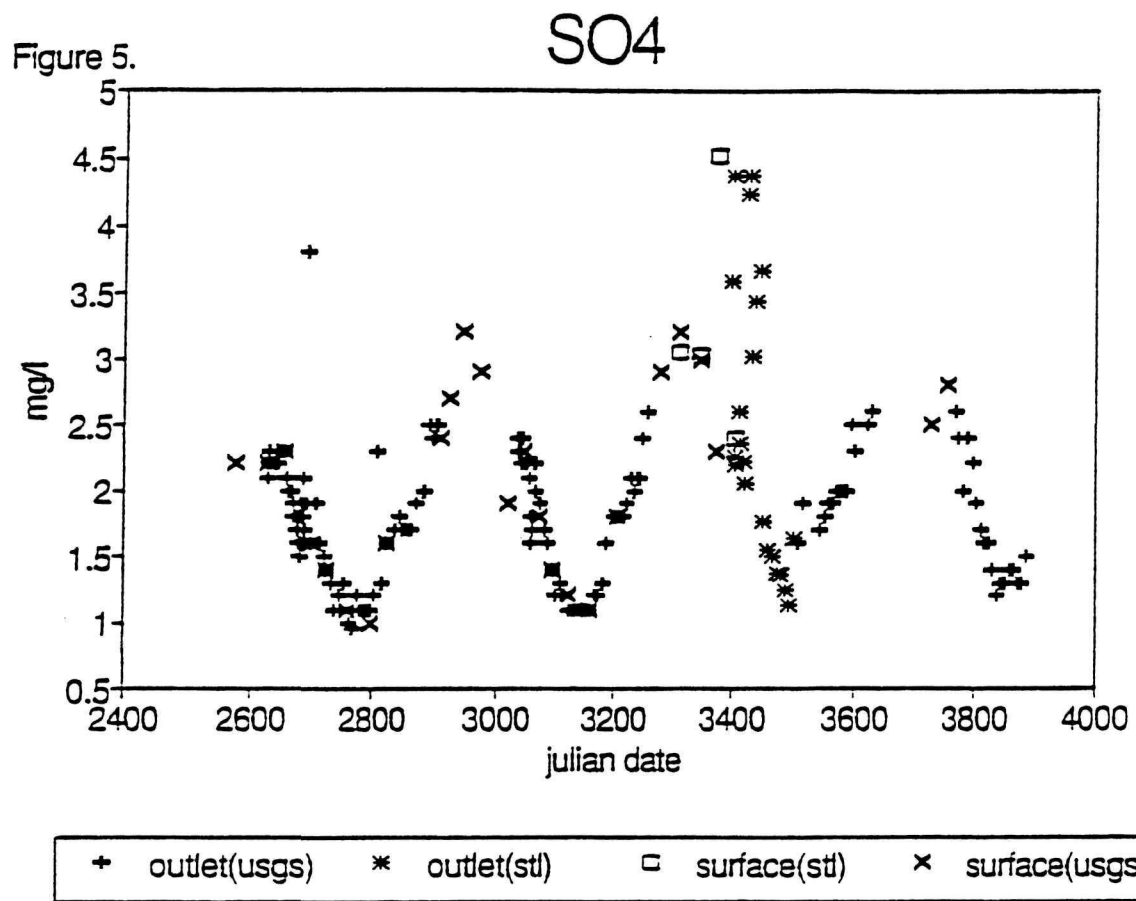




Figure 7.

NH<sub>4</sub>

-.064 = below detection limit

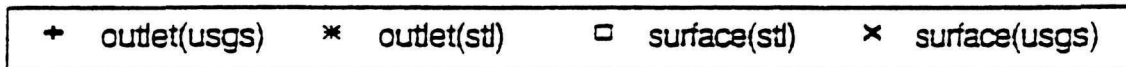
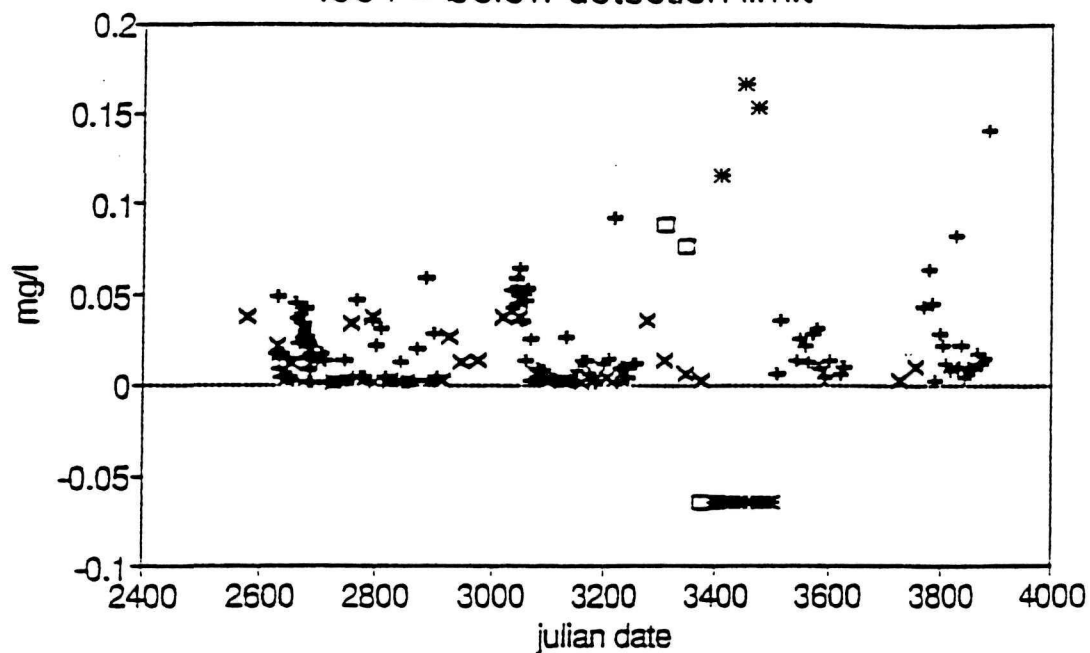


Figure 8.

NO<sub>3</sub>

-.044 = below detection limit

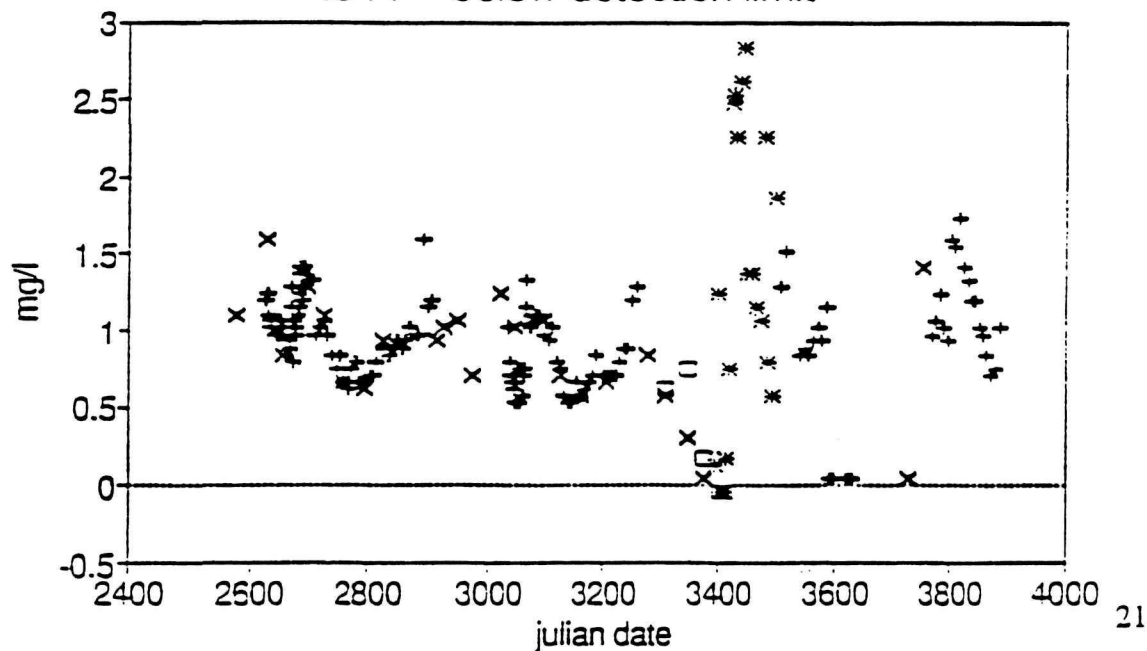
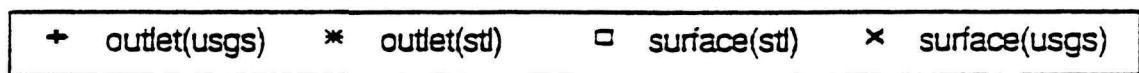
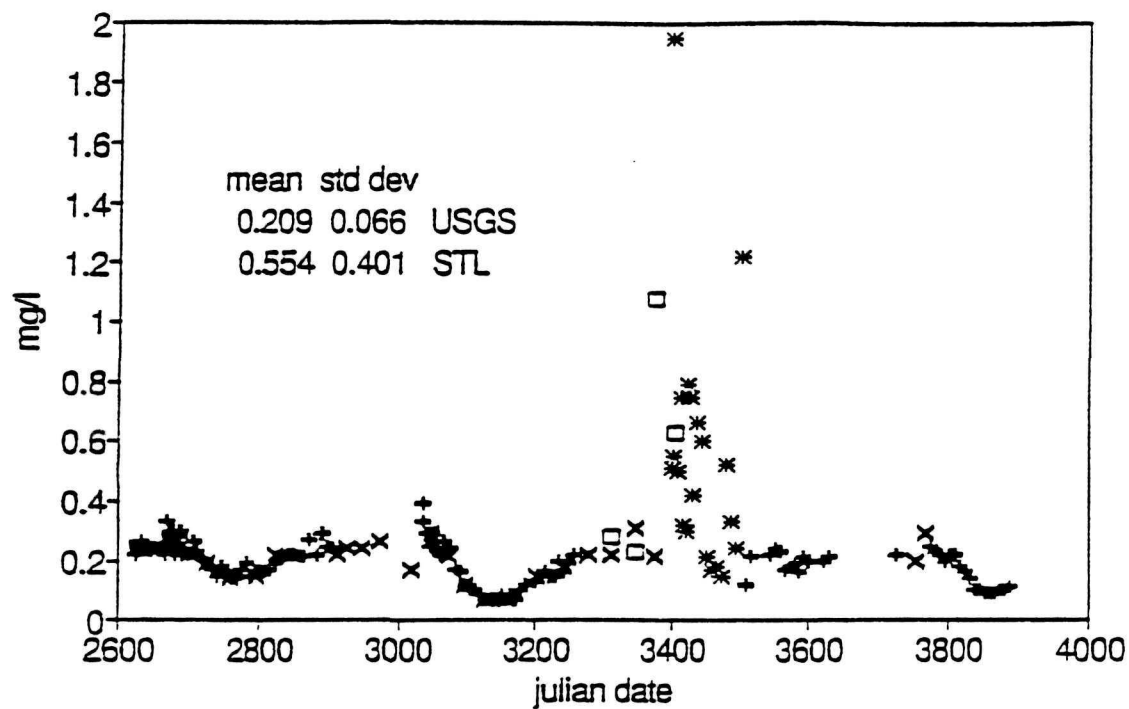


Figure 9.

Cl





**SEQUOIA NATIONAL PARK  
ACID DEPOSITION/ECOSYSTEM STUDIES  
VEGETATION SAMPLING PROTOCOL**

**Revised December 1989**

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ACID DEPOSITION/ECOSYSTEM STUDIES  
VEGETATION SAMPLING PROTOCOL

I. Introduction

Sequoia National Park, in the southern Sierra Nevada of California, is the site of a long-term research program on the potential impacts of acid deposition and associated air pollutants on Park ecosystems. Begun in 1982, primarily under the auspices of the National Acid Precipitation Assessment Program (NAPAP), the research effort focuses on measuring atmospheric input chemistry and on collection of the types of baseline ecosystem data necessary to detect subtle but potentially profound changes in soils, vegetation, and aquatic environments. The program is cooperative effort of federal, state, university, and private investigators.

The purpose of this vegetation sampling protocol is to consolidate sampling methods from various in-house vegetation studies related to the Park's Acid Deposition/Ecosystem Studies project. This protocol should be used in conjunction with other documents. Overall study objectives are detailed in the Briefing Statements as are descriptions of related research studies. General descriptive information on the study sites is located in the Study Site Folders. Detailed information on data organization, analysis, and storage are located in the Data Management Plan. Detailed methods on tangential studies (e.g. litter decomposition and nutrient mobilization, tissue and soil chemical analyses) will be developed in scientific publications.



## II. Elk Creek Area

### A. Overview

1. Introduction: The major goal of the vegetation sampling program at Elk Creek is to establish a long-term, baseline data set that can be used in future years to characterize changes in species composition, density, stand structure, biomass, productivity, and phenology. Our primary objectives are to develop biomass estimating equations for the major shrub species on the site, establish long-term vegetation plots in each of the paired watersheds, establish permanent cover transects, determine litterfall rates, analyze dominant species tissue for macronutrient concentrations, and conduct descriptive phenological measurements of the dominant shrub species.
2. Study Area: The Elk Creek watershed (Fig. 1), ranging in elevation from 680m to 800m, is characteristic of low elevation southern Sierra chaparral. The dry, granitic drainage is dominated by Adenostoma fasciculatum (chamise) and Ceanothus cuneatus. Precipitation at Ash Mountain, 4km to the south, averages 665 mm/yr. The site includes two headwater drainages, Lower Chamise Creek (4.3ha) and Upper Chamise Creek (5.7ha), which serve as paired watersheds. When sufficient pre-burn data on vegetation and hydrology have been collected, the Upper Chamise Creek drainage will be prescribe burned to isolate the effects of fire from the effects of acid deposition in watershed dynamics.

- B. Biomass Estimating Equations: Allometric equations have been developed to estimate above ground biomass for the five shrub species which constitute a significant proportion of stand biomass in the Elk Creek drainage. These are Adenostoma fasciculatum (chamise), Ceanothus cuneatus, Eriodictyon californicum (yerba santa), Rhamnus crocea (coffeeberry), and Fraxinus latifolia (ash).

In developing biomass estimating equations for Ceanothus cuneatus, 25 shrubs were randomly selected, and the diameter of each stem was measured at 15cm above the ground. The shrubs were then harvested and weighed in the field with a spring scale. A subsample of each species was taken to the lab for further analysis. In the lab, the dry weight of each subsample was obtained (48 hours at 100 C, weighed), and the percent foliage was determined by dissecting the shrub and weighing the

foliage. Each shrub's basal area ( $\text{cm}^2$ ), total dry weight (kg), stem dry weight (kg), and foliage dry weight (kg) were calculated. Single variable regression equations were developed to estimate total biomass, stem biomass, and foliage biomass from stem basal area (Stohlgren et al. 1982).

To reduce the amount of destructive sampling, biomass estimation equations for Adenostoma fasciculatum, Eriodictyon californicum, Rhamnus crocea, and Fraxinus latifolia were developed using fewer stems. For each species, the diameter of one stem from each of 18 to 41 randomly selected shrubs was measured at 15cm above the ground (stem diameters of A. fasciculatum were measured at 30cm above the ground to avoid the basal burl tissue). The calipered stem was harvested, and its dry weight was calculated in the laboratory as described above. Eight to ten stems of each species were separated by tissue type to determine percent foliage. Regression equations were calculated similar to those for C. cuneatus so that total shrub biomass could be estimated by summing projected biomass from each of the shrub's many stems (Table 1). For detailed information, refer to Parsons and Stohlgren, 1986.

Because of their similar morphologies, we assume F. latifolia regression equations will be suitable for estimating the biomass of the following species: Quercus dumosa, Arctostaphylos viscida, Cercocarpus betuloides, and Ceanothus leucodermis which are only a minor component of stand biomass in the study area. If other area are studied where these species are important component species, specific equations should be developed.

### C. Long Term Plots

1. Overview: In order to characterize species composition, stand structure, stand density, and demography in the Elk Creek drainage and to estimate above ground biomass and mean annual productivity on a per hectare basis, long-term vegetation plots have been established.
2. Methods: Ten 10m x 10m permanent plots have been randomly located within the boundaries of both the Lower Chamise Creek and Upper Chamise Creek drainages. Plot corners are identified by 1m tall 1.3cm diameter fiberglass posts. The location of each plot has been described and mapped. In order to facilitate the mapping of individual shrubs, each plot was temporarily subdivided into a 2m x 2m grid.

Shrubs have been mapped to the nearest 10cm<sup>2</sup> area on field maps.

The plots will be revisited at five year intervals and each shrub remapped and individual shrubs remeasured for biomass calculations.

Two 10m line intercept cover transects are located along the north-south and east-west borders of each plot. Percent cover by species is measured along these transects (Mueller-Dombois and Ellenberg, 1974).

Annual aboveground productivity is estimated by combining changes in biomass estimates (kg/ha) over time with total litterfall (kg/ha) using the following equation (Parsons and Stohlgren, 1986):

$$\text{MAAP} = \frac{\text{AB at } t + n \text{ yrs} - \text{AB at } t = 0 \text{ yrs} + \text{TL over } n \text{ years}}{n \text{ years}} \quad (\text{kg/ha/yr})$$

Where MAAP = Mean Annual Aboveground Productivity  
AB = Aboveground Biomass  
TL = Total Litterfall  
t = Time

Mean annual aboveground productivity can be calculated similarly for the stem, foliage, and total biomass components of each species.

3. Data Management: Data management objectives are to summarize cover transect data, calculate individual shrub characteristics (i.e. live stem, foliage, and total live biomass, dead biomass, and number and basal area of live and dead stems) from measured stem diameters, and plot biomass, density, and stand structure.

Line intercept cover transect data is input directly from data sheets and summarized by a custom BASIC computer program (cover.bas).

Shrub data (i.e. species code, shrub number, and stem diameters) is also directly entered from data sheets to another customized BASIC computer program (elkplot2.bas) which summarizes the shrub and plot characteristics mentioned above.

#### D. Nutrient Concentrations

Baseline vegetation and soil nutrient pools have been determined for major plant tissue and soil types. The one-time sampling was carried out at the end of the growing season in June, 1983.

Five randomly selected sampling locations were identified for each of the two major soils identified in a soil survey (G. Huntington and M. Akesson, personal communication) of the Lower Chamise Creek watershed. At each location, pooled samples of each tissue type were collected from five individuals of both Adenostoma fasciculatum and Ceanothus cuneatus. Tissue types sampled new leaves, old leaves, new stems, 1 to 2 year stems, old wood, and reproductive tissue. Soil samples from two depths (0 to 5cm and 10 to 15cm) were also collected at each sampling location. All vegetation and soil samples were oven dried (50 C for 24 to 48 hours) and sent to Palmer Plant and Soil Laboratory (University of Alaska, Palmer, Alaska) for analysis of nitrogen, phosphorus, potassium, calcium, and magnesium by standard atomic absorption methods. Vegetation nutrient concentration data will be used in conjunction with the plant biomass to determine the total nutrient pool in the aboveground vegetation.

#### E. Phenology

1. Overview: The objective of this project is to describe the timing of phenological events for Adenostoma fasciculatum and Ceanothus cuneatus, the co-dominant shrub species in the Lower Chamise Creek drainage. Phenology measurements were discontinued as of August 1988. The data has been summarized and is kept in the vegetation drawer. In the event phenology measurements are resumed, the following methods will be used.
2. Field Equipment: A. fasciculatum and C. cuneatus Vegetative and Reproductive Development data sheets, Stem Elongation Measurement data sheet, metric ruler, map of the Chamise Creek drainage, clipboard, pencil.
3. Field Methods: Twenty shrubs of each species, located throughout the drainage are banded and flagged for identification. To minimize trampling of the shrubs, selected individuals are marked at the fire line/site perimeter, and located 2-10m into the stand,

Phenological observations are made on each tagged shrub at two week intervals during the growing season (January-August) and bi-monthly during the dormancy (September-December). An example of the phenology data sheets can be found in Fig. 2.

Of the 20 shrubs selected, five shrubs of each species have subsample branches marked for elongation measurements. Each subsampled plant will be included in the comprehensive phenology observations, but in addition, an outer, middle, and inner canopy branch is measured from the point of the current year's growth initiation to the stem, not leaf tip.

In addition to shoot tip elongation, data on vegetative observations includes branch vegetative stage, leaf maturity, and presence or absence of leaf initiation. Data on reproductive observations includes flower and fruit development stages.

4. Data Management: Data summaries will include the percentage of shrubs in each phenological stage, and terminal branch elongation over time.

Vegetative stage, leaf stage, reproduction phase, and elongation data are summarized (i.e. mean, S.E.) with a commercially available software program (STATPAK). The results are graphed to compare the timing of phenological events for the two species.

#### F. Litterfall

1. Overview: Litter collection in the Elk Creek drainage, initially in the Lower Chamise Creek site only, is aimed at gathering data to help estimate annual productivity of dominant chaparral shrubs.
2. Field Equipment: 20 collection bags, marking pen, repair kit: fine polyester netting, staple gun, staples, hammer, nails.
3. Field Methods: Twenty 41cm x 42cm (inside diameter) paired litter traps are placed at least 2m into the stand around the perimeter of the site. Trap frames are numbered 1-20 without reference to location.

Collections are made four times a year, in January, April, July, and October. As each screen is sampled, the litter is placed in a collection bag that has been labeled with the date, screen location, and initials of the collector. Screen repairs are made following sample collection.

4. Lab Methods: The sampled litter is dried at 100 C to a constant weight (at least 24 hours) in the Sycamore Lab drying oven. A 25% subsample is sorted by species and weighed to obtain net dry weight by species. These data are used to estimate grams/m<sup>2</sup> and kg/ha. Weights are recorded on litter data sheets (Fig. 9).
5. Data Management: Litterfall data are summarized by hand and kept in the Vegetation File Drawer.

G. Pre-Burn Mortality Check:

1. Overview: In preparation for the Upper Chamise Creek prescribed burn in the fall of 1989, a mortality check of tagged shrubs was conducted in the summer of 1989. This will differentiate between natural mortality and mortality due to the fire.
2. Field Equipment: Xerox of reference stand maps, tick suits!!, pencil, clipboard.
3. Field Methods: Tagged shrubs in eight plots (were unable to locate plots #11 and 17) of Upper Chamise Creek were checked for mortality against the reference maps. The numbers of the dead shrubs are recorded in the field.
4. Data Management: This data is currently being stored in the Upper Chamise Creek Pre-Burn Mortality folder in the vegetation drawer. For each plot, the percent mortality of all shrubs and of each type of shrub were calculated and recorded.
5. In September 1989 the decision was made to cancel the Upper Chamise burn due to a lack of stream chemistry data. Monitoring will continue in the Lower Chamise watershed to continue our ecosystem research in the chaparral zone.



### III. Log Meadow

#### A. Overview

1. Introduction: The major goal of the vegetation sampling program at Log Meadow is to establish a long-term data set which can be used in future years to characterize changes in species composition, density, stand structure, litterfall, and understory vegetation. Our primary objectives are to establish long-term vegetation and site characterization plots in paired watersheds, survey each plot tree for incidence of insects, disease, or mechanical damage, estimate relative abundance of seedlings and herbs within plots, and determine plot litterfall rates.
2. Study Area: The study site, located east of Log Meadow, encompasses both the Tharp's Creek (13.1ha) and Log Creek (49.8ha) headwater drainages (Fig. 3). The elevation range extends from 2067m to 2371m. Both creeks emerge from a series of perennial seeps and springs. Running water is not found above 2318m. Average annual precipitation in the area is 1.1 meters, most of which is snow.

Soil depths are moderate (1-2m) over most of the study area. Along the northwest Log Creek watershed boundary, between the Wolverton Cutoff trail and the Trail of the Sequoias, is found the one area of sizable granitic outcrop in the site. A series of small granite exposures exist along the entire length of the sharp, well defined boundary. Slopes are generally steep to moderate, with only the meadow areas and flume sites approaching near level gradients.

The area is, for the most part, uniformly forested with mixed conifer forest. Obvious visual differences are noted in changes of species dominance. The core of the Log Creek watershed is dominated by an arm of the Giant Forest Grove of Sequoiadendron giganteum. The greatest portion of the study area is occupied by extensive stretches of forest dominated by white fir (Abies concolor) and contains sugar pine (Pinus lambertiana). At higher elevations, red fir (Abies magnifica) dominates the forest. On the rock outcrops rimming the site boundaries, Jeffrey pine (Pinus jeffreyi) dominates over the shrub cover of greenleaf manzanita (Arctostaphylos patula), mountain whitethorn (Ceanothus cordulatus), and bitter cherry (Prunus

emarginata). Although small in area compared to the other plant associations, two riparian associations, containing 80% of the species found in the study site, are found along creek banks.

When sufficient pre-burn data on vegetation and hydrology have been collected, the Tharp's Creek drainage will be prescribed burned in an effort to isolate the effects of fire from the effects of acid deposition in watershed dynamics.

#### B. Site Characterization Plots

1. Overview: Forty 0.1ha site characterization plots have been installed in the Log Meadow area in an effort to characterize species composition, stand structure, basal area, shrubs, and herbs. Ten plots are located in the Tharp's Creek drainage and thirty plots are located in the Log Creek drainage.
2. Methods: Plot southwest corners were randomly located. The northwest corner was found by taping 50 meters due north from the southwest corner, and the southeast corner was found by taping 20 meters due east from the same. The southwest and northeast corners of the 20m x 50m plots are marked with 1m tall, 1.3cm diameter fiberglass posts. Each site characterization plot is identified by a number from one to 40. The location of each plot is described and mapped on the site characterization data sheet (Fig. 4).

Plots were then bisected from the plot center to the four cardinal directions. A line intercept cover transect was located along the 50m centerline. The distance along the transect covered by rock and each species was recorded. Species present in the plot but not intersecting the line were also recorded.

In each site characterization plot, the diameters of all trees and snags taller than breast height (1.37m) were measured. Seedlings were tallied by species and recorded.

3. Data Management: Tree data were directly input into DBASE III files (livetree.dbf and deadtree.dbf) and DBASE report forms were developed to summarize basal area and density by species for each stand.

Line intercept shrub transect data were input into a separate file (shrubs.dbf) and summarized with a DBASE command file in tabular form.

### C. Long Term Plots

1. Overview: In order to characterize species composition, stand structure, basal area, and demography in the Log Meadow area, six long term reference stands were installed.
2. Methods: Two reference stands have been installed in the Tharp's Creek drainage, and four have been installed in the Log Creek drainage (Fig. 4). The nomenclature for each stand is derived from the species which comprises its major vegetative component. Tharp's Creek reference stands include: sugar pine (1.125ha) and white fir (1.0ha). Log Creek reference stands include: sugar pine (1.0ha), white fir (1.125ha), Jeffrey pine (1.125ha), and sequoia (2.5ha).

Reference stands were installed according to the technique described by Franklin et al. (1984). Slope corrected plots are laid out along cardinal compass lines and subdivided into 25m x 25m subplots. Perimeters are marked every 25 meters with 1m tall, 1.3cm diameter fiberglass posts. Red circles have been spray painted on granite where posts could not be inserted. Subplot interior points are indicated by 2in2 wooded stakes. Subplot coordinates are assigned x and y values relative to (0,0), the southwest corner of the reference stand. Each subplot is identified by the coordinates of its southwest corner (Fig. 5)

Within each reference stand, each tree is tagged on the midslope side of the tree at breast height (1.37m) with a 4-digit aluminum tag and stainless steel nail. Trees whose breast height diameters are too small to support a tag and nail are tagged at their bases. Individual trees, prominent topographic features, snags, and logs are mapped. (Fig. 5)

Each field season every tree is checked in the field against the map for mortality. If a tree has died, causes attributing to its mortality are determined, and its DBH is taken. These observations are recorded on the Tree Mortality Data Sheet (Fig. 6). In addition to the reference stands mentioned above, mortality checks are made in the five reference stands established by J. Franklin (USFS, currently at UW) in 1982-1983. The trees in these stands will also be remeasured at five year intervals.

3. Data Management: Long Term Plot data are entered into DBASE III files along with vigor coding data (see section IIID).

Tree mortality data for the Franklin (OSU/USFS) Reference Stands are hand tallied and sent to Dr. Franklin each year.

#### D. Tree Damage and Pest Complex Survey (Vigor Coding)

1. Overview: In an effort to detect subtle changes in tree productivity and natural mortality rates, each tree in the long term reference stands is assessed for incidence of insect, pathogen, and mechanical stress.
2. Field Equipment: Tree Damage and Pest Complex Survey Key, Tree Damage and Pest Complex Survey Data Sheets, clipboard, pencil, reference stand maps, diameter tape, calipers, clinometer, binoculars
3. Methods: In order to eliminate the possibility of underestimating the impact of a specific cyclic stress, an entire reference stand should be evaluated in a single field season. Methods should follow precisely those outlined in the Tree Damage and Pest Complex Survey Key (Appendix A). Because the observations are somewhat qualitative and require a calibrated eye, only technicians who have been trained should vigor code. Stands will be vigor coded every five years and generally surveyed for major stresses each season during mortality checks.

A tree is examined both from a distance with binoculars and up close. When viewing a tree from a distance, make certain the entire bole and crown are visible.

Observations are checked against the key and appropriate numerical values are recorded on the data sheet (Fig. 7). If an observation falls into the Unknown/Other category, the tree number and extensive descriptive comments are recorded on the reverse side of the data sheet. Never assume that an insect or disease is present. A sign, direct physical evidence (i.e. fruiting body, larval gallery, mistletoe plant, insect), is the only means of absolute identification. A symptom, physiological response by host tree (i.e. witches broom, branch flagging) should only be used to document the presence of an insect or pathogen if identification is positive. Every effort should be made to identify unknown

agents. An excellent reference source is Bega (1978).

During annual mortality checks, the reference stands are surveyed for severe cyclic stresses. If an obvious outbreak is noted, a more comprehensive evaluation is made using the Tree Damage and Pest Complex Survey Key.

As part of an interagency agreement, the Forest Pest Management Office of the Forest Service will aid in specimen identification (Appendix B).

3. Data Management: Tree Damage and Pest Complex Survey data for each stand are entered into DBASE III files. Information on species composition, basal area, density by species, stand structure, tree mortality, and some stress interactions is being summarized using SPSS. forms.

In the future, multivariate techniques will be explored to analyze pest complexes and the relationship between physical tree attributes and stresses.

E. Five Year Remeasurement of Long Term Vegetation Plots:

1. Overview: As part of the effort to summarize vegetation characteristics in the long term vegetation plots, remeasurement of all trees and accounting for new ingrowth in the plot is conducted every five years.
2. Field Equipment: Tree Damage and Pest Complex Survey Key, Tree Damage and Pest Complex Survey Data Sheets, clipboard, pencil, xerox copies of reference stand maps, diameter tape, calipers, binoculars, prenumbered tags, blank tags, aluminum nails, number tap and die set, hammer, a list of living tree numbers for each subplot.
3. Methods: All vegetation plots are to be remeasured and checked for ingrowth every five years after establishment. The following are the installation dates of each plot:

<u>STAND</u>	<u>ESTABLISHED</u>
Tharp's ABCO	84
Tharp's PILA	84
Log ABCO	87
Log PILA	87

Log PIJE  
Log SEGI

85  
83

For each stand, a list of tree numbers that are currently alive in each subplot should be created. Each previously tagged tree is checked against this list and the maps for mortality; if the tree is still alive, a new dbh is measured and recorded. Trees that are on the map and/or list but have lost their tag should be retagged with the same number. If a tree is found dead and it was not dead in previous years, it is vigor coded on the Tree Damage and Pest Complex Survey Data Sheet (Fig. 7).

Any untagged tree that is taller than or equal in height to breast height (1.37 m) should be vigor coded as ingrowth on a separate Tree Damage and Pest Complex Survey Data Sheet (Fig. 7) and assigned a new number. Prenumbered tags are attached to the tree at breast height with aluminum nails. If the diameter at breast height is too small to support a tag and nail, the tree is tagged at the base.

4. Data Management: The dBASE III files for the vegetation stands are stored in drive F:\VIGOR. These databases are modified for any remeasurement, mortality, or ingrowth that occurs in the stands.

#### REMEASUREMENT:

To enter the newly measured diameters, create a new field, next to the old DBH field, entitled DBHyr (i.e. DBH89 for diameters measured in 1989) and enter the new diameters for each tree number. Instructions for doing this follow. All words in capital letters are typed as shown; underlined, lower case words need to be replaced with actual names.

1. To enter dBASE, type: DBASE.
2. Enter the required database: .USE logpila
3. .MODIFY STRUCTURE
4. Go to one field below the last DBH field
5. <ctrl> N - Adds a field
6. Name this field DBH89 - fill in the appropriate year  
Field type is NUMERIC  
Width is 5 and decimal is 1.
7. <ctrl><end> - to save this new structure
8. <return>
9. Using BROWSE, edit the new field by entering the new dbh's. Be careful in BROWSE - it is easy to alter other data unintentionally.
10. <ctrl> <end> - to save your work



11. .CLOSE ALL - to close all the databases.
12. .QUIT - to leave dBASE.

#### MORTALITY:

In the case of mortality, change the MORTALITY field from -9 to the year of death according to the following instructions.

1. Enter dBASE.
2. Enter the required database: .USE logpila
3. .BROWSE
4. Modify the MORTALITY column
5. <ctrl><end> - to save changes
6. Close all databases and leave dBASE.

#### INGROWTH:

Ingrowths are to be appended to the appropriate database by entering all data from the Tree Damage and Pest Complex Survey Data Sheet. For prior years, when the tree was not at breast height, the DBH field should be filled with -99.

1. Enter dBASE.
2. Enter the required database: .USE logpila
3. .APPEND
4. Enter data from the Data Sheet
5. <ctrl><end> - to save
6. Close all databases and leave dBASE.

#### BACK-UP:

The computer should be backed up on tape as soon as all new information is entered. At the same time, the vegetation back-up floppy disk, kept in the diskholder (marked Acid Rain Back-up Diskettes) in the closet of the GIS computer room in the RC, needs to be updated. While the tape backs up the entire computer drive by drive, this floppy disk is backed up file by file. Update only those files where data has been changed.

#### FILE FOLDERS AND DATA SHEETS:

Tree Damage and Pest Complex Survey Data Sheets for mortality should be filed in the appropriate Mortality folder in the vegetation drawer; those for ingrowth are filed in the appropriate Vigor Coding folder in the vegetation file drawer.



#### F. Mortality Check of Long Term Vegetation Plots:

1. Overview: As part of the effort to summarize vegetation characteristics in the long term vegetation plots, a yearly mortality check is conducted on each tagged tree in all six plots.
2. Field Equipment: Tree Damage and Pest Complex Survey Key, Tree Damage and Pest Complex Survey Data Sheets, clipboard, pencil, xerox copies of reference stand maps, diameter tape, calipers, binoculars, a list of tree numbers that are alive in each subplot, nails, blank tags, number tap and die set, hammer.
3. Methods: All tagged trees in the reference plots are checked against a list of live trees and the stand maps for mortality each year. If a tree is found dead, the Tree Damage and Pest Summary Data Sheet (Fig. 7) is filled out in the field. Should a tag be missing from an already mapped and vigor coded tree, a new tag bearing the original number should be made and attached to the tree.
4. Data Management: The database file needs to be modified only for those tree numbers where mortality occurred. In this case, the MORTALITY field is changed from -9 to the year of death following the instructions below. All commands in capital letters are typed as shown; underline, lower case commands need to be replace with actual names.
  1. To enter dBASE, type: DBASE.
  2. Enter the required database: .USE logpila
  3. .BROWSE
  4. Modify the MORTALITY column
  5. <ctrl><end> - to save
  6. .CLOSE ALL - to close all the databases
  7. .QUIT - to leave dBASE

Once this new information has been entered, the computer should be backed up on tape, kept above the PC in the administration building office, and on the vegetation back-up floppy disk, kept in the diskholder (marked Acid Rain Back-up Diskettes) in the closet of the GIS computer room in the RC. On the floppy disk, only update those files that have been changed; the tape backs up the entire computer.

The Tree Damage and Pest Complex Summary Data Sheet for mortality is filed in the appropriate Mortality folder in the vegetation drawer.

## G. Shrub/Herb/Seedling Plots

1. Overview: In an effort to characterize relative abundance and percent cover by species of understory vegetation and estimate forest tree regeneration, Shrub/Herb/Seedling plots have been established in the six Log Meadow study area reference stands. Plots will be read on a five year cycle.
2. Methods: Using reference stand interior subplot markers as centers, plots 6.65m radius (100m<sup>2</sup>) are laid out (Fig. 5). Each reference stands has as many Shrub/Herb/Seedling plots as subplots. They are numbered according to the coordinate number of the center stake. From plot centers, transect lines are run in each of the cardinal directions.

Eight cover subplots are located along these transect lines. Starting from north, working clockwise, and using a 1m<sup>2</sup> frame, two cover subplots are set out and numbered on each side of the cardinal line (Fig. 5). From the center, looking out, and beginning on the right, the right-hand cover subplot is located at 4-5 meters from center, and the left-hand cover subplot is located at 2-3 meters from center. Ocular estimates of herb, shrub, and seedling foliar cover by species are made within the 1m<sup>2</sup>. Cover is estimated to the nearest 1% up to 10% cover, and to the nearest 5% for cover greater than 10%. Overlapping foliar cover by species is recorded, resulting in total cover of greater than 100% in some cases (Fig. 8). Also recorded is the percent cover of rocks, logs, litter (when it is dense enough to impede plant establishment and growth), and bare ground.

Line-intercept shrub cover transects are run along each plot transect line (11.3m each), with transect A running north-south and transect B running east-west. Measurements are taken to the nearest 0.05m. Overlapping cover by different species is recorded. Rocks and logs are also recorded when they intersect 5 cm or more of the line.

Seedlings and saplings (below 140cm in height) are counted by species in each radial plot. Those 10cm or greater in height are measured for diameter (to the nearest cm), coded for disturbance (1=none, 2=insect damage, 3=animal damage, 4=unknown), and mapped by species. Comments are noted.

Permanent photo points are established at the north and west ends of each transect line, focusing the photograph on the center stake of the radial plot.

3. Data Management: Shrub and herb cover data are directly input into LOTUS 1-2-3 spreadsheets from field data sheets. Frequency and percent cover by species are summarized for each reference stand. Data are printed out in tabular form.

#### H. Litterfall

1. Overview: As a means of estimating mean annual litter production in the Log Meadow study area, litter plots have been installed in each of the five reference stands. Litterfall collections have been discontinued in the reference stands. Should litter collection resume in the future, these methods should be followed.
2. Field Equipment: 2 large grocery bags, an appropriate number (1 bag per subplot) medium grocery bags, calipers, diameter tape, branch shears, spring scale, weighing tarp, data sheets, marking pen, repair kit: polyester screening, staple gun, staples, hammer, nails, duck tape.
3. Field Methods: 5m x 5m litter plots have been systematically installed in each reference stand subplot. Litter plots are centered along the southern subplot border (Fig. 5). In cases where physical obstructions (i.e. boulders) prevented center installation, litter plots were shifted to the east or west and mapped. Litter plot boundaries are marked with 40cm tall cedar stakes which are marked with a three-digit number. The first two digits refer to the reference stand subplot coordinates. The third digit refers to the litter plot corner; numbers run counter-clockwise beginning with the southwest corner. Orange circles have been spray painted on granite where stakes could not be inserted.

After installation, each litter plot was prepared by the removal of all cones and branches 2.54cm to 15.24cm in diameter. Rotten wood, partially buried branches, and bark from logs (downed dead trees) were not initially removed and are not counted during seasonal collections. Bark which has recently sloughed off of trees or snags (standing dead trees) is counted.

Collections of large woody debris (2.54cm to 15.24cm diameter) within the litter plots are made twice a year, post-snowmelt (spring) and pre-snowfall (fall). Debris meeting the above diameter requirements is collected and weighed in the field using a spring scale and weighing tarp. Weights are recorded on the litter collection data sheet (Fig. 9). Only debris inside the plot boundaries is weighed. Portions of debris not meeting diameter requirements of extending beyond the boundaries are cut off with branch shears and discarded from the plot. All cones are tallied on the data sheet by species and discarded from the plot. Once the collection is weighed, a representative subsample is placed in two large grocery bag which has been labeled with date, reference stand name, and collector's initials. The subsample. The subsample is taken to the lab for percent moisture analysis.

Within each litter plot, a litter trap is randomly placed to catch litter and small woody debris (<2.54cm diameter). The 1.0m x 0.5m traps are made of 1mm polyester screening stapled to 2in2 board frames.

Small woody debris collections are made once each spring (post-snowmelt). As each screen is sampled, the litter is placed in a large grocery bag which has been labeled with date, screen location, and initials of collector. Screen repairs are made following sample collection.

4. Lab Methods: Subsampled large woody debris is wet weighed (to the nearest 0.1g) in Sycamore Lab then oven dried at 100 C to a constant weight (at least 24 hours) and reweighed. Weights are recorded on the litter collection data sheet. These data are used to calculate mean dry weight (kg/ha) estimates of large woody debris litterfall.
5. Data Management: Litterfall data are directly input to LOTUS 1-2-3 spreadsheets and summarized by reference stand for each collection period. Factors to correct for percent moisture in large woody debris subsamples are calculated using field wet weight and laboratory dry weight data and applied to all wet-weighed large woody debris. Small woody debris litterfall is separated by species and summarized.

## I. Epiparasite Survey

1. Overview: It has been suggested that certain "epiparasitic" organisms are particularly sensitive to changes in the pH climate of the soil and are therefore possible indicators of ecosystem changes due to acid deposition. The purpose of this survey is to monitor changes in species composition, density, and spatial composition of epiparasites over time. This study will provide yet another parameter in the long term site characteristics of the Tharp's Creek and Log Creek watersheds.
2. Field Equipment: Reference Stand maps, clipboard, pencil, local flora (Weeden)
3. Field Methods: The survey will be carried out by means of a visual census of the reference stands. Observers will walk through each subplot mapping each epiparasite individual by species with the symbol indicated below:

<u>Callorhiza maculata</u>	■
<u>Callorhiza striata</u>	▲
<u>Habenaria elegans</u>	*
<u>Pitypus californicus</u>	★
<u>Pleuricospora fimbriolata</u>	∞
<u>Pterospira andromodea</u>	□

After a thorough search of each subplot, the number of individuals by species is tallied.

Due to differences in phenology and emergence between the various epiparasite species, the census will be performed twice during the summer field season in each of the following reference stands: Tharp's ABCO, Tharp's PILA, Log ABCO, Log PILA, and Log SEGI.

4. Data Management: After each field session, tallies will be made for each reference stand containing the following information: numbers of individuals by species by subplot. The field maps will serve as rough indicators of the distribution of these organisms and the continuity of individuals over time.

Maps and tally sheets for each stand will be kept in labelled files located in the Vegetation File Drawer.

## J. Nutrient Concentrations

1. Overview: Baseline vegetation and soil macronutrient concentrations have been determined for plant tissues

of the dominant tree and shrub species and for major soil types in the Log Meadow area.

2. Methods: Tree species sampled included Sequoiadendron giganteum, Abies concolor, Abies magnifica, Pinus lambertiana, and Pinus jeffreyi. Tissues sampled from these trees included new leaves, old leaves, new stems, old stems, branchwood, bark, heartwood, sapwood, and reproductive tissues. Shrub species sampled included Arctostaphylos patula and Ceanothus cordulatus. Shrub tissues analyzed were the same as for trees but did not include heartwood and sapwood.

Dominant soil types in the area (Pachic xerumbrepts, Lithic xerumbrepts, and Typic haploxerults) were sampled at two depths (0-5cm and 15-20cm) and analyzed for pH, macronutrients (ppm), with total percent N separated into NH<sub>4</sub> and NO<sub>3</sub>. Forest litter above each sample type was also chemically analyzed for macronutrient concentrations. All vegetation and soil samples were oven dried (50 C for 24-48 hours) and sent to Palmer Plant and Soils Laboratory (University of Alaska, Palmer Alaska) for chemical analysis.



#### IV. Emerald Lake Area

##### A. Overview

1. Introduction: The major goal of the vegetation sampling program at Emerald Lake is to establish a long-term baseline data set that can be used in future years to characterize changes in species composition, density, stand structure, litterfall, and understory vegetation. These data will ultimately be incorporated into a comprehensive watershed dynamics model. Our primary objectives are to establish long-term vegetation plots in each area where forest trees are common, survey each plot tree for incidence of insects, disease, or mechanical damage, estimate relative abundance of seedlings and herbs within plots, and determine plot litterfall rates.

2. Study Area: The study site encompasses the upper portion of Emerald Creek, a headwater drainage that is a tributary to the Marble Fork Kaweah River above Tokapah Falls. The elevation range extends from 2804m at Emerald Lake to 3415m at the summit of Alta Peak. Annual precipitation at Emerald Lake may be as much as 2 meters, most of which is snow. Two spurs emanating from Alta Peak form the southern and northeastern boundaries of the 119.6ha watershed (Fig. 10).

Parental material in the drainage is almost entirely granitic. Most of the site consists of exposed rock faces, promontories, and extensive, large angular talus. A major fracture in the granite extends across the Tablelands in a southwest-northeast direction. This fracture was widened by glacial activity and now provides the rectangular basin in which Emerald Lake reposes. Due to weathering along this major fracture, special conditions for plant establishment have occurred. The spacial arrangement of plant associations in the study site reflects the influence of the major fracture and that of Emerald Creek as it flows down the steep topography created by the erosive action of a tributary glacier.

Except for a small area of alpine fell-fields near the summit of Alta Peak, the entire study site is subalpine. Tree species include (in order of relative abundance) Pinus monticola (western white pine), Pinus contorta ssp. murrayana (lodgepole pine), Abies magnifica (red fir), and Pinus jeffreyi (Jeffrey pine). Most trees exhibit a



characteristically subalpine krummholz phenotype. Dominant shrub species include Chrysolepis sempervirens (chinquapin oak), Salix orestera (willow), and Phyllodoce breweri (red heather).

## B. Long Term Plots

1. Overview: In order to characterize species composition, stand structure, stand density, and demography in the Emerald Lake drainage, three long term reference stands were installed.
2. Methods: Due to the sparse, clumped distribution of trees in the watershed, plots were established in the only three area where forest trees are common (Fig. 10). The nomenclature for each stand is derived from the species which comprises its major vegetative component. Emerald Lake reference stands include: salix (1.0ha), western white pine (1.0ha), and western white pine - ridge (1.125ha).

Reference stands were installed according to the technique described by Franklin et al. (1984). Slope corrected plots are laid out along cardinal compass lines and subdivided into 25m x 25m subplots. Perimeters are marked every 25 meters with 1m tall, 1.3cm diameter fiberglass posts. Red circles have been spray painted on granite where posts could not be inserted. Subplot interior points are indicated by 2in2 wooded stakes. Subplot coordinates are assigned x and y values relative to (0,0), the southwest corner of the reference stand. Each subplot is identified by the coordinates of its southwest corner (Fig. 5)

Within each reference stand, each tree is tagged on the midslope side of the tree at breast height (1.37m) with a 4-digit aluminum tag and stainless steel nail. Trees whose breast height diameters are too small to support a tag and nail are tagged at their bases. Individual trees, prominent topographic features, snags, and logs are mapped. (Fig. 5)

Each field season every tree is checked in the field against the map for mortality. If a tree has died, causes attributing to its mortality are determined, and its DBH is taken. These observations are recorded on the Tree Mortality Data Sheet (Fig. 6).

3. Data Management: Long Term Plot data are entered into DBASE III files along with vigor coding data (see section IIID).

C. Tree Damage and Pest Complex Survey (Vigor Coding)

1. Overview: In an effort to detect subtle changes in tree productivity and natural mortality rates, each tree in the long term reference stands is assessed for incidence of insect, pathogen, and mechanical stress.
2. Field Equipment: Tree Damage and Pest Complex Survey Key, Tree Damage and Pest Complex Survey Data Sheets, clipboard, pencil, reference stand maps, diameter tape, calipers, clinometer, binoculars
3. Methods: In order to eliminate the possibility of underestimating the impact of a specific cyclic stress, an entire reference stand should be evaluated in a single field season. Methods should follow precisely those outlined in the Tree Damage and Pest Complex Survey Key (Appendix A). Because the observations are somewhat qualitative and require a calibrated eye, only technicians who have been trained should vigor code. Stands will be vigor coded every five years and generally surveyed for major stresses each season during mortality checks.

A tree is examined both from a distance with binoculars and up close. When viewing a tree from a distance, make certain the entire bole and crown are visible.

Observations are checked against the key and appropriate numerical values are recorded on the data sheet (Fig. 7). If an observation falls into the Unknown/Other category, the tree number and extensive descriptive comments are recorded on the reverse side of the data sheet. Never assume that an insect or disease is present. A sign, direct physical evidence (i.e. fruiting body, larval gallery, mistletoe plant, insect), is the only means of absolute identification. A symptom, physiological response by host tree (i.e. witches broom, branch flagging) should only be used to document the presence of an insect or pathogen if identification is positive. Every effort should be made to identify unknown agents. An excellent reference source is Bega (1978).

During annual mortality checks, the reference stands are surveyed for severe cyclic stresses. If an obvious outbreak is noted, a more comprehensive evaluation is made using the Tree Damage and Pest Complex Survey Key.

As part of an interagency agreement, the Forest Pest Management Office of the Forest Service will aid in specimen identification (Appendix B).

3. Data Management: Tree Damage and Pest Complex Survey data for each stand are entered into DBASE III files. Information on species composition, basal area, density by species, stand structure, and tree mortality will be summarized using DBASE III command files and report forms.

In the future, multivariate techniques will be explored to analyze pest complexes and the relationship between physical tree attributes and stresses.

D. Five Year Remeasurement of Long Term Vegetation Plots:

1. Overview: As part of the effort to summarize vegetation characteristics in the long term vegetation plots, remeasurement of all trees and accounting for new ingrowth in the plot is conducted every five years.
2. Field Equipment: Tree Damage and Pest Complex Survey Key, Tree Damage and Pest Complex Survey Data Sheets, clipboard, pencil, xerox copies of reference stand maps, diameter tape, calipers, binoculars, prenumbered tags, blank tags, aluminum nails, number tap and die set, hammer, a list of living tree numbers for each subplot.
3. Methods: All vegetation plots are to be remeasured and checked for ingrowth every five years after establishment. The following are the installation dates of each plot:

<u>STAND</u>	<u>ESTABLISHED</u>
Emerald PIMO	83
Emerald Ridge	84
Emerald SALIX	83

For each stand, a list of tree numbers that are currently alive in each subplot should be created. Each previously tagged tree is checked against this

list and the maps for mortality; if the tree is still alive, a new dbh is measured and recorded. Trees that are on the map and/or list but have lost their tag should be retagged with the same number. If a tree is found dead and it was not dead in previous years, it is vigor coded on a Tree Damage and Pest Complex Survey Data Sheet (Fig. 7) that is designated for mortalities.

Any untagged tree that is taller than or equal in height to breast height (1.37 m) should be vigor coded on a Tree Damage and Pest Complex Survey Data Sheet (Fig. 7) designated for ingrowth and assigned a new number. Prenumbered tags are attached to the tree at breast height with aluminum nails. If the diameter at breast height is too small to support a tag and nail, the tree is tagged at the base.

Many of the trees in this stand have multiple boles. The remeasurement value that is stored in the computer is that of the tagged bole; the other values are written down and stored in the Vigor Coding folder of the correct site.

4. Data Management: The dBASE III files for the vegetation stands are stored in drive F:\VIGOR. These databases are modified for any remeasurement, mortality, or ingrowth that occurs in the stands.

#### REMEASUREMENT:

To enter the newly measured diameters, create a new field, next to the old DBH field, entitled DBHyr (i.e. DBH89 for diameters measured in 1989) and enter the new diameters for each tree number. Instructions for doing this follow. All words in capital letters are typed as shown; underlined, lower case words need to be replaced with actual names.

1. To enter dBASE type: DBASE.
2. Enter the required database: .USE logpila
3. .MODIFY STRUCTURE
4. Go to one field below the last DBH field
5. <ctrl> N - Adds a field
6. Name this field DBH89 - fill in the appropriate year  
Field type is NUMERIC  
Width is 5 and decimal is 1
7. <ctrl><end> - to save this new structure
8. <return>

9. Using BROWSE, edit the new field by entering the new dbh's. Be careful in BROWSE - it is easy to alter other data unintentionally.
10. <ctrl> <end> - to save your work
11. .CLOSE ALL - to close all the databases
12. .QUIT - to leave dBASE.

#### MORTALITY:

In the case of mortality, change the MORTALITY field from -9 to the year of death according to the following instructions.

1. Enter dBASE.
2. Enter the required database: .USE logpila
3. .BROWSE
4. Modify the MORTALITY column
5. <ctrl><end> - to save changes
6. Close all the databases and leave dBASE.

#### INGROWTH:

Ingrowths are to be appended to the appropriate database by entering all data from the Tree Damage and Pest Complex Survey Data Sheet. For prior years, when the tree was not at breast height, the DBH field should be filled with -99.

1. Enter dBASE.
2. Enter the required database: .USE logpila
3. .APPEND
4. Enter data from the Data Sheet
5. <ctrl><end> - to save
6. Close all the databases and leave dBASE.

#### BACK-UP:

The computer should be backed up on tape as soon as all new information is entered. At the same time, the vegetation back-up floppy disk, kept in the disk holder (marked Acid Rain Back-up Diskettes) in the closet of the GIS computer room in the RC, needs to be updated. While the tape backs up the entire computer drive by drive, this floppy disk is backed up file by file. Update only those files where data has been changed.

#### FILE FOLDERS AND DATA SHEETS:

Tree Damage and Pest Complex Survey Data Sheets for mortality should be filed in the appropriate

Mortality folder in the vegetation drawer; those for ingrowth are filed in the appropriate Vigor Coding folder in the vegetation file drawer.

E. Mortality Check of Long Term Vegetation Plots:

1. Overview: As part of the effort to summarize vegetation characteristics in the long term vegetation plots, a yearly mortality check is conducted on each tagged tree in all three plots.
2. Field Equipment: Tree Damage and Pest Complex Survey Key, Tree Damage and Pest Complex Survey Data Sheets, clipboard, pencil, xerox copies of reference stand maps, diameter tape, calipers, binoculars, a list of tree numbers that are alive in each subplot, nails, blank tags, number tap and die set, hammer.
3. Methods: All tagged trees in the reference plots are checked against a list of live trees and the stand maps for mortality each year. If a tree is found dead, the Tree Damage and Pest Summary Data Sheet (Fig. 7) is filled out in the field. Should a tag be missing from an already mapped and vigor coded tree, a new tag bearing the original number should be made and attached to the tree.
4. Data Management: The database file needs to be modified only for those tree numbers where mortality occurred. In this case, the MORTALITY field is changed from -9 to the year of death following the instructions below. All commands in capital letters are typed as shown; underlined lower case commands need to be replace with actual names.
  1. To enter dBASE, type: DBASE.
  2. Enter the required database: .USE logpila
  3. .BROWSE
  4. Modify the MORTALITY column
  5. <ctrl><end> - to save
  6. .CLOSE ALL - to close all the databases.
  7. .QUIT - to leave dBASE.

Once this new information has been entered, the computer should be backed up on tape ,kept above the PC in the administration building office, and on the vegetation back-up floppy disk, kept in a diskholder

(marked Acid Rain Back-up Diskettes) in the closet of the GIS computer room in the RC. On the floppy disk, only update those files that have been changed; the tape backs up the entire computer.

The Tree Damage and Pest Complex Summary Data Sheet for mortality is filed in the appropriate Mortality folder in the vegetation drawer.

#### F. Shrub/Herb/Seedling Plots

1. Overview: In an effort to characterize relative abundance and percent cover by species of understory vegetation and estimate forest tree regeneration, Shrub/Herb/Seedling plots have been established in the six Log Meadow study area reference stands. Plots will be read on a five year cycle.
2. Methods: Using reference stand interior subplot markers as centers, plots 6.65m radius (100m<sup>2</sup>) are laid out (Fig. 5). Each reference stands has as many Shrub/Herb/Seedling plots as subplots. They are numbered according to the coordinate number of the center stake. From plot centers, transect lines are run in each of the cardinal directions.

Eight cover subplots are located along these transect lines. Starting from north, working clockwise, and using a 1m<sup>2</sup> frame, two cover subplots are set out and numbered on each side of the cardinal line (Fig. 5). From the center, looking out, and beginning on the right, the right-hand cover subplot is located at 4-5 meters from center, and the left-hand cover subplot is located at 2-3 meters from center. Ocular estimates of herb, shrub, and seedling foliar cover by species are made within the 1m<sup>2</sup>. Cover is estimated to the nearest 1% up to 10% cover, and to the nearest 5% for cover greater than 10%. Overlapping foliar cover by species is recorded, resulting in total cover of greater than 100% in some cases (Fig. 8). Also recorded is the percent cover of rocks, logs, litter (when it is dense enough to impede plant establishment and growth), and bare ground.

Line-intercept shrub cover transects are run along each plot transect line (11.3m each), with transect A running north-south and transect B running east-west. Measurements are taken to the nearest 0.05m. Overlapping cover by different species is recorded.



Rocks and logs are also recorded when they intersect 5 cm or more of the line.

Seedlings and saplings (below 140cm in height) are counted by species in each radial plot. Those 10cm or greater in height are measured for diameter (to the nearest cm), coded for disturbance (1=none, 2=insect damage, 3=animal damage, 4=unknown), and mapped by species. Comments are noted.

Permanent photo points are established at the north and west ends of each transect line, focusing the photograph on the center stake of the radial plot.

3. Data Management: Shrub and herb cover data are directly input into LOTUS 1-2-3 spreadsheets from field data sheets. Frequency and percent cover by species are summarized for each reference stand. Data are printed out in tabular form.

#### G. Litterfall

1. Overview: As a means of estimating mean annual litter production in the Emerald Basin long term stands, litter plots were installed in each of the three reference stands. Collection of litterfall has been discontinued. Should collections resume, the following methods should be followed.
2. Field Equipment: 2 large grocery bags, an appropriate number (1 bag per subplot) medium grocery bags, calipers, diameter tape, branch shears, spring scale, weighing tarp, data sheets, marking pen, repair kit: polyester screening, staple gun, staples, hammer, nails, duck tape.
3. Field Methods: 5m x 5m litter plots have been systematically installed in each reference stand subplot. Litter plots are centered along the southern subplot border (Fig. 5). In cases where physical obstructions (i.e. boulders) prevented center installation, litter plots were shifted to the east or west and mapped. Litter plot boundaries are marked with 40cm tall cedar stakes which are marked with a three-digit number. The first two digits refer to the reference stand subplot coordinates. The third digit refers to the litter plot corner; numbers run counter-clockwise beginning with the southwest corner. Orange circles have been spray painted on granite where stakes could not be inserted.

After installation, each litter plot was prepared by the removal of all cones and branches 2.54cm to 15.24cm in diameter. Rotten wood, partially buried branches, and bark from logs (downed dead trees) were not initially removed and are not counted during seasonal collections. Bark which has recently sloughed off of trees or snags (standing dead trees) is counted.

Collections of large woody debris (2.54cm to 15.24cm diameter) within the litter plots are made twice a year, post-snowmelt (spring) and pre-snowfall (fall). Debris meeting the above diameter requirements is collected and weighed in the field using a spring scale and weighing tarp. Weights are recorded on the litter collection data sheet (Fig. 9). Only debris inside the plot boundaries is weighed. Portions of debris not meeting diameter requirements of extending beyond the boundaries are cut off with branch shears and discarded from the plot. All cones are tallied on the data sheet by species and discarded from the plot. Once the collection is weighed, a representative subsample is placed in two large grocery bag which has been labeled with date, reference stand name, and collector's initials. The subsample. The subsample is taken to the lab for percent moisture analysis.

Within each litter plot, a litter trap is randomly placed to catch litter and small woody debris (<2.54cm diameter). The 1.0m x 0.5m traps are made of 1mm polyester screening stapled to 2in2 board frames.

Small woody debris collections are made once each spring (post-snowmelt). As each screen is sampled, the litter is placed in a large grocery bag which has been labeled with date, screen location, and initials of collector. Screen repairs are made following sample collection.

4. Lab Methods: Subsampled large woody debris is wet weighed (to the nearest 0.1g) in Sycamore Lab then oven dried at 100 C to a constant weight (at least 24 hours) and reweighed. Weights are recorded on the litter collection data sheet. These data are used to calculate mean dry weight (kg/ha) estimates of large woody debris litterfall.
5. Data Management: Litterfall data are directly input to LOTUS 1-2-3 spreadsheets and summarized by reference stand for each collection period. Factors

to correct for percent moisture in large woody debris subsamples are calculated using field wet weight and laboratory dry weight data and applied to all wet-weighted large woody debris. Small woody debris litterfall is separated by species and summarized.

#### H. Nutrient Concentrations

1. Overview: Baseline vegetation and soil macronutrient concentrations have been determined for plant tissues of the dominant tree and shrub species and for major soil types in the Emerald Lake basin.
2. Methods: Tree species sampled included Pinus monticola, Pinus contorta, and Abies magnifica. Tissues sampled from these trees included new leaves, old leaves, new stems, old stems, branchwood, bark, heartwood, sapwood, and reproductive tissues. Shrub species sampled included Phyllodoce breweri, Chrysolepis sepervirens, and Salix orestera. Shrub tissues analyzed were the same as for trees but did not include heartwood and sapwood.

Dominant soil types in the area (Typic cryorthents and Lithic cryumbrepts) were sampled at two depths (0-5cm and 15-20cm) and analyzed for pH, macronutrients (ppm), with total percent N separated into NH<sub>4</sub> and NO<sub>3</sub>. Forest litter above each soil sample was also chemically analyzed for macronutrient concentrations. All vegetation and soil samples were oven dried 50 C for 24-48 hours) and sent to Palmer Plant and Soils Laboratory (University of Alaska, Palmer, AK) for chemical analysis.

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Table 1. Elk Creek Biomass Estimating Equations

Stem Basal Area to Total Dry Weight Regression Equations  
for Four Dominant Shrubs

Basal Area =  $x^2/4 * 3.14159$  x = stem diameter  
diameter

Adenostoma fasciculatum  
stem biomass =  $.311 * BA1.28/1000$   $r^2 = .96$   
foliage biomass =  $-2.23 + (.311 * BA)$   $r^2 = .94$

Ceanothus cuneatus  
stem biomass =  $.425 * BA1.17/1000$   $r^2 = .81$   
foliage biomass =  $.140 * BA.974/1000$   $r^2 = .71$

Eriodictyon californica  
stem biomass =  $.120 * BA1.3/1000$   $r^2 = .82$   
foliage biomass =  $.0664 * BA1.03/1000$   $r^2 = .69$

Rhamnus crocea  
stem biomass =  $.295 * BA1.09/1000$   $r^2 = .92$   
foliage biomass =  $.212 * BA.847/1000$   $r^2 = .82$

Stem Diameter to Total Dry Weight Regression Equations  
for Fraxinus latifolia

y = stem diameter  
diameter

Fraxinus latifolia  
stem biomass =  $.003 * y1.93/1000$   $r^2 = .87$   
foliate biomass = same as C. cuneatus equation

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Figure 1. Elk Creek study site

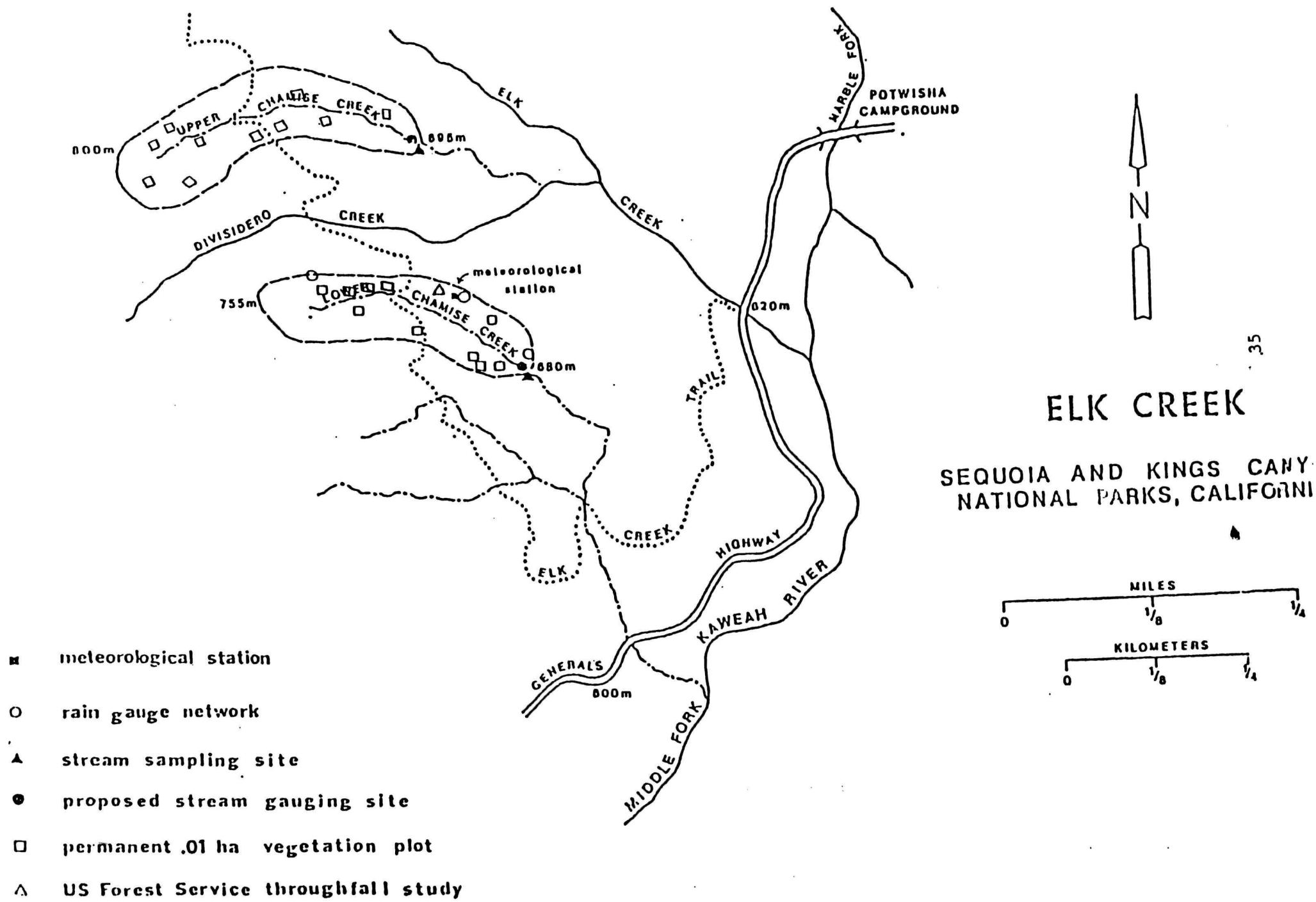




Figure 2. Phenology Data Sheet (pg. 1 of 2)

ELK CREEK PHENOLOGY  
Vegetative and Reproductive Development  
Lower Chamise Site

Date \_\_\_\_\_

Species \_\_\_\_\_

Name \_\_\_\_\_

[illegible]

**Figure 2. Phenology Data Sheet (pg 2 of 2)**

ELK CREEK PHENOLOGY  
Stem Elongation Measurements  
Lower Chamise Site, 1986

Date \_\_\_\_\_

Name \_\_\_\_\_

Species: \_\_\_\_\_

Species: \_\_\_\_\_

[illegible]

FIGURE 3.

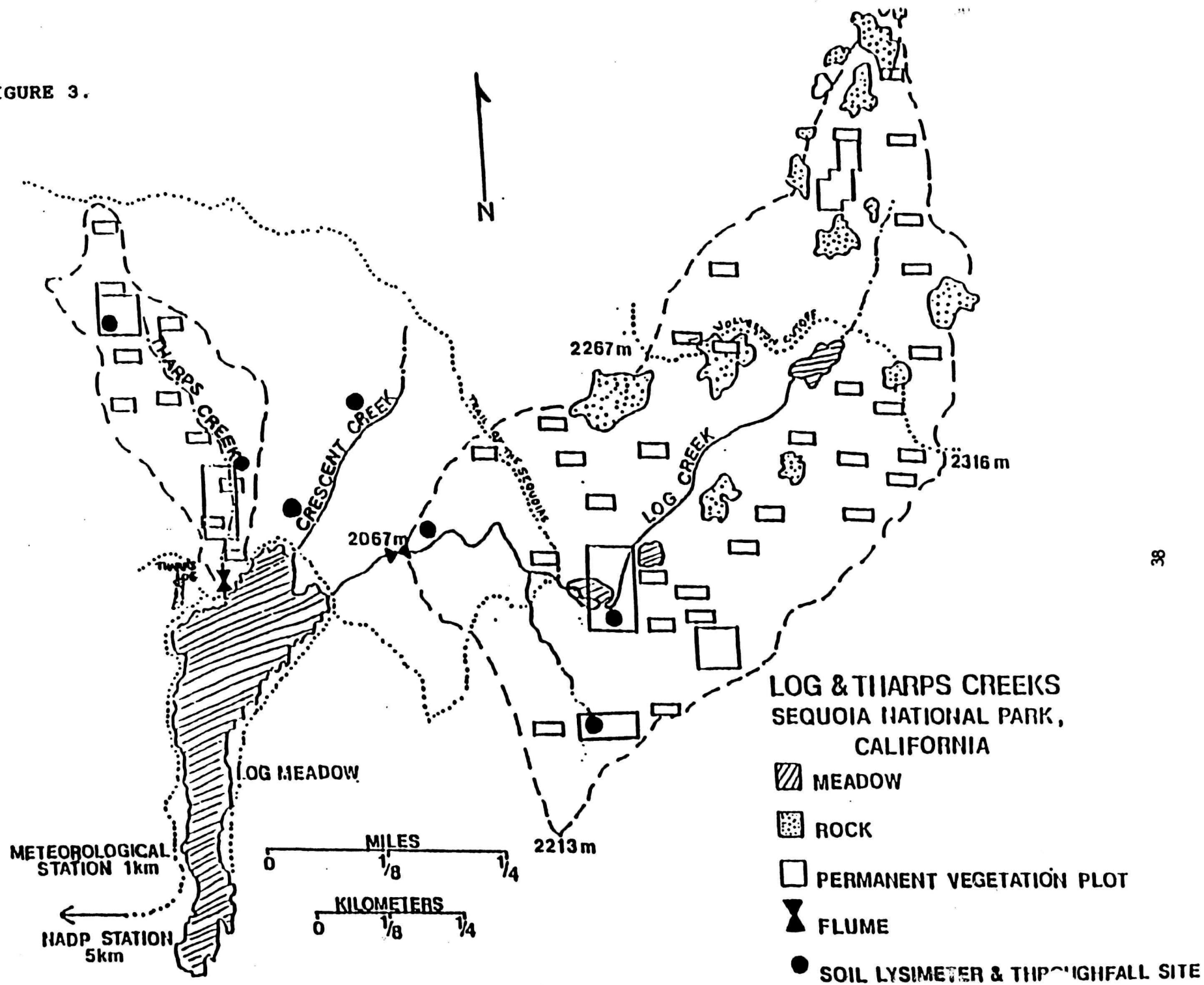


Figure 4. Site Characterization Plot Data Sheet (pg 1 of 3)

VEGETATION PLOTS FOR ACID PRECIPITATION RESEARCH PROGRAM

Observers \_\_\_\_\_

Date \_\_\_\_\_

Random direction \_\_\_\_\_ °

Random distance \_\_\_\_\_ m

Comments \_\_\_\_\_

Plot \_\_\_\_\_

Slope \_\_\_\_\_

Aspect \_\_\_\_\_

Elevation \_\_\_\_\_ ft.

\_\_\_\_\_ m

Plot Location \_\_\_\_\_

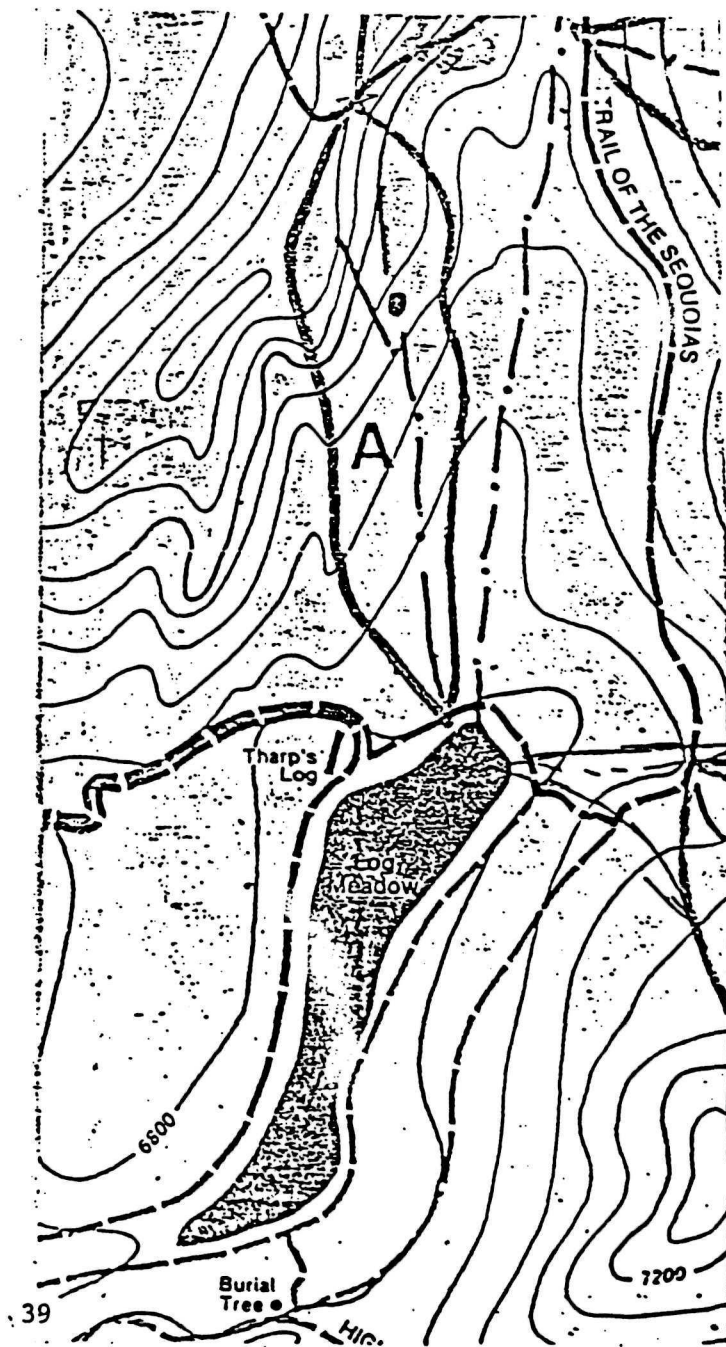
\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_



**SPECIES**

卷三

LINE INTERCEPTS (cm)

TOTAL

[illegible]

SPECIES

(pg 3 pf 3)  
5

10 15 20 25 30 35 40 45 50

(cm)

60 65 70 75 80 85 90 95 100 105 110 115 120 125 130 140 &gt;140

LIVE

DEAD

L

D

L

D

L

D

L

D

L

D

L

D

L

D

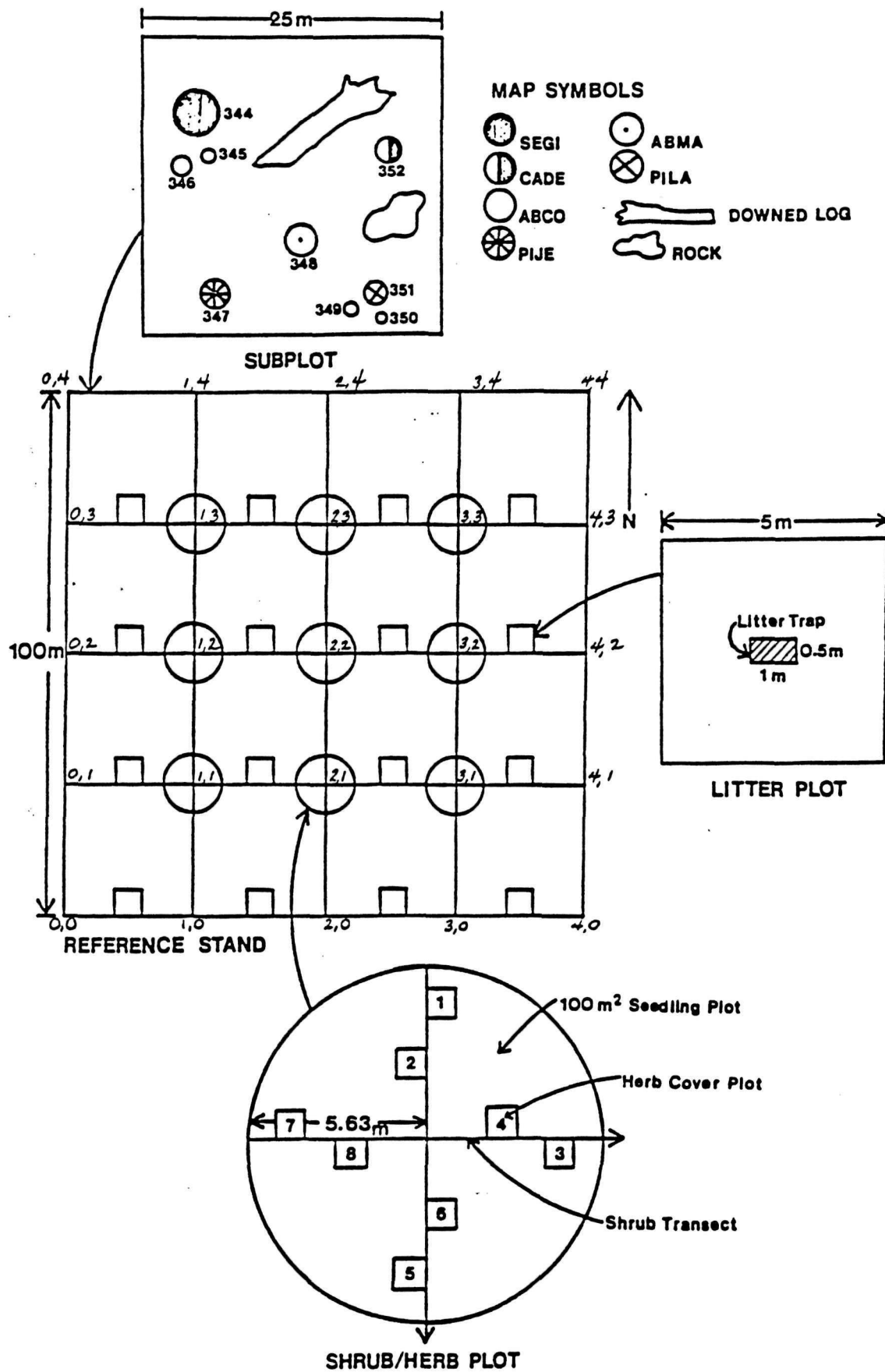
L

D

SEEDLINGS  
20cm - 140cm tall.

41

Figure 5. General layout of a 1 ha long term vegetation plot ("reference stand").





TREE DAMAGE AND PEST COMPLEX SURVEY DATA SHEET

Location: \_\_\_\_\_

Crew: \_\_\_\_\_

Date: \_\_\_\_\_

## \*\*\*\*\* MORTALITY \*\*\*\*\*

TREE NUMBER																			
SUBPLOT																			
SPECIES CODE																			
CANOPY CLASS																			
DBH																			
HEIGHT																			
*****																			
LCR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BROKEN TOP																			
DEAD TOP/LEADER																			
MULTIPLE TOP/LEADER																			
HALF-CROWNED																			
CROOKED CROWN																			
NEEDLE RETENTION																			
BRANCH FLAGGING																			
OTHER																			
*****																			
FORKED BOLE																			
CROOKED BOLE																			
LEANING																			
CANKER																			
FIRE SCAR																			
FROST CRACK																			
LOG FALL SCAR																			
ANIMAL DAMAGE																			
KRUMMHOLZ																			
OTHER																			
*****																			
DMR																			
TMR																			
F ANNOSUS																			
A MELLEA																			
P SCHWEINITZII																			
F PINI																			
F PINICOLA																			
E TINCTORIUM																			
C RIBICOLA																			
P HARKNESSII																			
E DEFORMANS																			
C ABEITIS																			
UNIDENTIFIED/OTHER																			
*****																			
D BREVICOMIS																			
D PONDEROSAE																			
D JEFFREYI																			
D VALENS																			
IPS SPP																			
S VENTRALIS																			
UNIDENTIFIED/OTHER																			
*****																			
MORTALITY YEAR																			

TREE DAMAGE AND PEST COMPLEX SURVEY DATA SHEET

Crew: \_\_\_\_\_

---

	TREE NUMBER	SUBPLOT	SPECIES CODE	CANOPY CLASS	DBH	HEIGHT
	*****					
	LCR					
	BROKEN TOP					
	DEAD TOP/LEADER					
	MULTIPLE TOP/LEADER					
Crown	HALF-CROWNED					
	CROOKED CROWN					
	NEEDLE RETENTION					
	BRANCH FLAGGING					
	OTHER					
	*****					
	FORKED BOLE					
	CROOKED BOLE					
	LEANING					
	CANKER					
Bole	RE SCAR					
	ROST CRACK					
	LOG FALL SCAR					
	ANIMAL DAMAGE					
	KRUMMHOLZ					
	OTHER					
	*****					
	DMR					
	TMR					
	F ANNOSUS					
	A MELLEA					
Pathogens	P SCHWEINITZII					
	F PINI					
	F PINICOLA					
	E TINCTORIUM					
	C RIBICOLA					
	P HARKNESSII					
	E DEFORMANS					
	C ABEITIS					
	UNIDENTIFIED/OTHER					
	*****					
	D BREVICOMIS					
	D PONDEROSAE					
	D JEFFREYI					
	D VALENS					
Insects	SPP					
	S VENTRALIS					
	UNIDENTIFIED/OTHER					
	*****					

DESCRIPTION

PERCENT COVER BY SUBPLOT

TRANSECT E

46

Species, Diam. (cm) ht. (cm) cond., comments

SEU  
CADE  
PIMO  
PIBA  
QUKE

Figure 9. Litterfall Plot Data Sheet (pg 1 of 2)

LITTER PROJECT, SCREEN SAMPLES

SITE:

CREW:

DATE COLLECTED:

DATE WEIGHED:

Coordinants  
or Subplot #

Total Dry Weights

1

### Bag Weights

3

Net Dry Weight

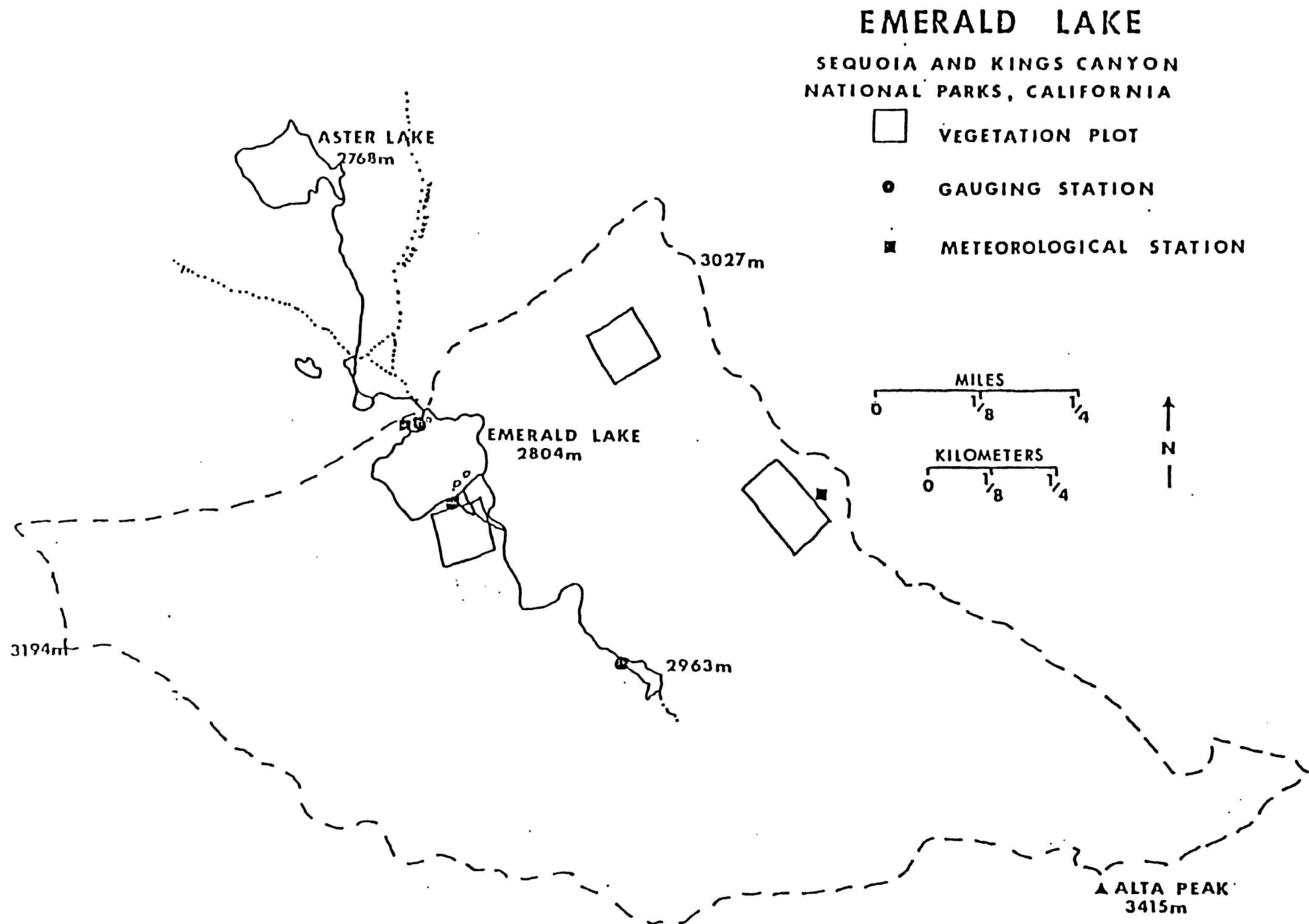
[illegible]



REFERENCE STAND		DATE			CREW			
		1	2	3	4	5	6	7
		1" - 6" dia.						
SUBPLOT #	1	TOTAL WT. (kg)	BAG WT. (kg)	NET WET WT. (kg)	CONES #	species	screen collected	COMMENTS
	2							
	3							
	4							
	5							
	6							
	7							
	8							
	9							
	10							
	11							
	12							
	13							
	14							
	15							
	16							
	17							
	18							
	19							
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	24							
	25							
	26							
	27							
	28							
	29							
	30							
	31							



Figure 10. Emerald Lake study site.



APPENDIX A. TREE DAMAGE AND PEST COMPLEX KEY

REVISED 08-21-85

EXPLANATION OF TREE DAMAGE AND PEST COMPLEX SURVEY DATA SHEET

DATE: enter the six-digit date code corresponding to the date of collection (YR/MO/DA).

CREW: enter the surnames and first initials of personnel collecting data.

LOCATION: enter the name of the drainage and the alpha code of the dominant species.

TREE NUMBER: enter the 4-digit tree number.

SUBPLOT: enter the subplot (coordinated of SW corner) in which tree is located.

SPECIES CODE: enter the number below which corresponds to the tree species alpha code.

1	ABCO	-	<u>Abies concolor</u>
2	ABMA	-	<u>Abies magnifica</u>
3	CADE	-	<u>Calocedrus decurrens</u>
4	PIBA	-	<u>Pinus balfouriana</u>
5	PICO	-	<u>Pinus contorta</u>
6	PIJE	-	<u>Pinus jeffreyi</u>
7	PILA	-	<u>Pinus lambertiana</u>
8	PIMO	-	<u>Pinus monticola</u>
9	PIPO	-	<u>Pinus ponderosa</u>
10	SALIX	-	<u>Salix spp.</u>
11	SEGI	-	<u>Sequoiadendron giganteum</u>
12	QUKE	-	<u>Quercus kelloggii</u>

**CANOPY CLASS:** enter the code indicating the tree's position in the canopy.

- 1 - dominant: tree where canopy occupies space above the co-dominant canopy
- 2 - codominant: tree whose crown is a component of the main stand overstory canopy
- 3 - intermediate: tree whose crown extends both into and below the main stand overstory canopy
- 4 - subcanopy: tree whose crown occupies space below the main stand overstory canopy
- 5 - open grown: tree is growing in an open area

**DBH:** Enter the tree's diameter to the .1 cm. as measured directly above the tree number nail at breast height (4.5 ft or 1.37 m) above the ground on the midslope side of the tree (measure trees tagged at their bases at breast height).

**HEIGHT:** enter the tree's height to the nearest inch

**LCR:** Live Crown Ratio, enter your estimate of the percent of the tree's total height occupies by live crown.

**BROKEN TOP:** entire top or portion of top broken such that section of woody tissue is damaged and inner tree is exposed.

- 0 - top is not broken
- 1 - top is broken, but is occupied by live crown
- 2 - top is broken and the crown in that region is dead or missing

**DEAD TOP/LEADER:** entire top or leader is occupied by dead foliage or free of foliage.

- 0 - top/leader occupied by live crown
- 1 - leader only, dead
- 2 - leader and top portion of the crown are dead

**MULTIPLE TOP/LEADER:** top or leader having more than one terminal growth shoot.

- 0 - single top/leader, or rounded top on mature trees
- 1 - multiple leader only, deformity occurred within approximately last five growing seasons

2 - multiple top and leader, deformity occurred prior to approximately the last five growing seasons

**HALF-CROWNED:** substantial portion of crown on one side of the tree is dead or missing.

0 - tree is full-crowned  
1 - tree is half-crowned due to obvious suppression by neighboring tree or severe winds  
2 - tree is half-crowned for reason other than obvious suppression by neighboring tree or severe winds

**CROOKED CROWN:** the crown or a portion of the crown is not growing in a straight line relative to the rest of the tree. (This does not include trees with a gentle sweep or krummholtz trees.)

0 - crown has no crook  
1 - crown has a crook which is not associated with an open split or wound  
2 - crown has a crook which is associated with an open split or wound

**NEEDLE RETENTION:** the needles comprising the crown are retained and not prematurely cast causing the crown to appear noticeably thin.

0 - tree has acceptable needle retention  
1 - noticeable cast of past years' needles not exceeding 30%  
2 - noticeable cast of past years' needles exceeding 30%, or noticeable cast of present year's needles

**BRANCH FLAGGING:** distinct sections of foliage on branch or entire branch is "flagged" with red or dead needles.

0 - no branch flagging  
1 - less than 10% of branches are flagged  
2 - greater than 10% of branches are flagged

**Bole** - defined as that portion of the tree below the first foliated branch.

**FORKED BOLE:** the main stem of the tree is split creating a fork. (A stem which forks below DBH is defined to be two separate trees.)

- 0 - tree has no fork or is forked below DBH
- 1 - tree is forked and the two stems appear to be similarly vigorous
- 2 - tree is forked and one stem appears much more vigorous than the other (In this case, the attributes of the more vigorous stem should be rated.)

**CROOKED BOLE:** the bole or a portion of the bole is not growing in a straight line relative to the rest of the tree. (This does not include trees with a gentle sweep or krummholz trees.)

- 0 - bole has no crook
- 1 - bole has a crook which is not associated with an open split or wound
- 2 - bole has a crook which is associated with an open split or wound

**LEANING:** the tree is not growing vertically. (This includes trees with a gentle sweep but not krummholz trees.)

- 0 - tree is growing vertically
- 1 - tree has grown in a leaning position throughout most of its life
- 2 - tree has not grown in a leaning position throughout most of its life

**CANKER:** the main stem of branches of the tree have localized swelling and necrosis. (This is often associated with dwarf-mistletoe infection.)

- 0 - tree has no canker
- 1 - stem has a closed canker, or branch has open or closed canker
- 2 - stem has an open or dead-faced canker

**FIRE SCAR:** the lower bole of the tree has been burned.

- 0 - bole has no fire scar
- 1 - bole has a closed fire scar
- 2 - bole has an open fire scar

**FROST CRACK:** after repeated seasons of moisture penetration and freezing, a characteristic seam or scar has formed in the bark.

- 0 - tree has no frost crack
- 1 - stem has a closed frost crack, or branch has open or closed frost crack
- 2 - the stem has an open frost crack

**LOG FALL SCAR:** a neighboring tree has fallen and wounded this tree.

- 0 - tree has no log fall scar
- 1 - tree has closed log fall scar
- 2 - tree has open log fall scar

**ANIMAL DAMAGE:** evidence of animal feeding on tree.

- 0 - no animal damage
- 1 - browse damage or scratching damage
- 2 - cambium feeding or girdling damage

**KRUMMHOLZ:** characteristic growth form of many sub-alpine and alpine trees, stunted growth, irregular form.

- 0 - tree is not krummholz
- 1 - tree is moderately krummholz
- 2 - tree is severely krummholz

## MISTLETOES

Arceuthobium spp.: Dwarf Mistletoe  
Hawthorn Rating System (DMR)

Step 1: Divide the crown into thirds.

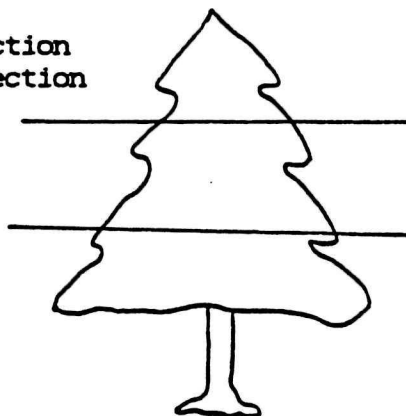
Step 2: Rate each third separately.  
Each third will be given 0, 1, or 2.

- 0 - no visible infection
- 1 - light infection (1/2 or less  
of the total number of branches  
in the third are infected)
- 2 - heavy infection (more than 1/2  
of the total number of branches  
in the third are infected)

Step 3: Add the ratings of each third to  
obtain DMR for tree.

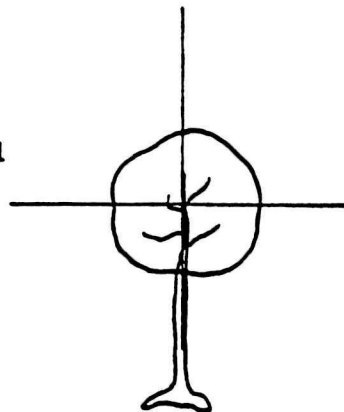
Enter the appropriate code on the data sheet:

- 0 - DMR = 0, no infection
- 1 - DMR = 1-3, light/moderate infection
- 2 - DMR = 4-6, moderate/severe infection



Phoradendron spp.: True Mistletoe

- 0 - no infection
- 1 - plants in less than half of crown
- 2 - plants in more than half of crown or top kill





## PATHOGENS

### Fomes annosus: Annosus Root Disease

- 0 - tree has no signs or symptoms of *F. annosus* and is not located within a suspected center
- 1 - tree is located within a *F. annosus* center; annosus conks have been found in or on trees or stumps inside the center, but no signs or symptoms on this tree
- 2 - tree is within an annosus center and has annosus decay and or resin soaked roots, typical dark wood discoloration at heartwood interface (true fir), or silver-white mycellial pits at cambium/sapwood interface, or *F. annosus* conk on tree

### Armillaria mellea: Armillaria Root Disease

- 0 - tree has no signs or symptoms of *A. mellea*
- 1 - tree is located near a dead oak with *A. mellea* signs, signs or symptoms are present on nearby conifers but not on this tree
- 2 - *A. mellea* mycellial mats under bark or *A. mellea* mushroom and wet stringy white to yellowish rot and black rhizomorphs on or under the bark of roots and root crowns

### Polyporus schweinitzii: Velvet Top Fungus - Red Brown Rot

- 0 - tree has no apparent signs or symptoms of *P. schweinitzii* infection
- 1 - tree has no signs or symptoms, but is located within a suspected center with a *P. schweinitzii* conk nearby and characteristic red-brown cubical heartrot in a nearby stump or butt of snag
- 2 - *P. schweinitzii* conk on or near roots of this tree

Fomes pini: Red Ring Rot or White Pocket Rot

- 0 - F. pini not present
- 1 - F. pini conk present

Fomes pinicola: Red Belt Fungus

- 0 - F. pinicola not present
- 1 - F. pinicola conk present

Echinodontium tinctorium: Indian Paint Fungus

- 0 - E. tinctorium not present
- 1 - E. tinctorium conk present

Cronartium ribicola: White Pine Blister Rust

- 0 - C. ribicola not present
- 1 - infected tree whose closest canker is not less than 4" from the stem, and no cankers are above 1/2 live crown height
- 2 - infected tree has canker within 4" of stem, or cankers are above 1/2 live crown height

Peridermium harknessii: Western Gall Rust

- 0 - P. harknessii not present
- 1 - branch cankers on less than 1/2 of branches
- 2 - branch cankers on greater than 1/2 of branches or stem canker

Elytroderma deformans: Elytroderma Disease

- 0 - E. deformans not present
- 1 - less than 1/2 of branches are infected
- 2 - greater than 1/2 of branches are infected

Cytospora abietis: Cytospora Canker of True Firs

- 0 - C. abietis not present
- 1 - less than 1/2 of branches are infected
- 2 - greater than 1/2 of branches are infected

## INSECTS

### Dendroctonus brevicomis: Western Pine Beetle

- 0 - D. brevicomis not present
- 1 - D. brevicomis present

### Dendroctonus jeffreyi: Jeffrey Pine Beetle

- 0 - D. jeffreyi not present
- 1 - d. jeffreyi present

### Dendroctonus valens: Red Turpentine Beetle

- 0 - D. valens not present
- 1 - less than 2 quadrants below 12" occupied
- 2 - more than 2 quadrants below 12" occupied, or any quadrant above 12" occupied

### Ips spp.: Ips

- 0 - Ips not present
- 1 - Ips present with bark beetle species, or live top
- 2 - Ips present, bark beetle species absent, or dead top

### Scolytus ventralis: Fir Engraver

- 0 - S. ventralis not present
- 1 - tree with old, healed S. ventralis attacks
- 2 - tree with current S. ventralis attacks

# HOST/DISEASE RELATIONSHIPS

DISEASE	HOST CONIFER						
	ABCO	ABMA	CADE	PICO	PIJE	PILA	PIPO
<u>SEGI</u>							
<u>ROOT DISEASES</u>							
<u>F. annosus</u>	X	X	X	X	X		XXX
<u>A. mellea</u>	X	X	X	X	X		XXX
DWARF MISTLETOES	X	X		X	X		XX
TRUE MISTLETOES	X		X				
<u>RUSTS</u>							
<u>P. harknessii</u>				X	X		X
<u>C. ribicola</u>							X
<u>NEEDLE CASTS</u>							
<u>E. deformans</u>				X	X		X
<u>CANKERS</u>							
<u>C. abeitis</u>	X	X					
<u>DECAYS</u>							
<u>F. pini</u>		X	X	X	X		X
<u>F. pinicola</u>	X	X		X	X		XX
<u>E. tinctorium</u>	X	X					
<u>P. schweinitzii</u>	X	X	X	X	X		X
root disease also							

# HOST/INSECT RELATIONSHIPS

INSECT	HOST CONIFER						
	ABCO	ABMA	CADE	PICO	PIJE	PILA	PIPO
<u>SEGI</u>							
<u>CAMBIUM FEEDERS</u>							
<u>D. brevicomis</u>							X
<u>D. ponderosae</u>				X			XX
<u>D. jefferyi</u>					X		
<u>D. valens</u>				X	X		XX
<u>ENGRAVERS</u>							
<u>Ips spp.</u>				X	X		XX
<u>S. ventralis</u>	X	X					

# INDICATORS FOR BARK BEETLES AND ENGRAVERS

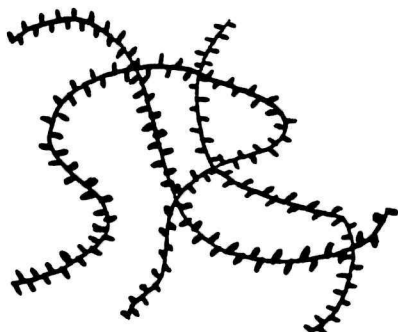
## INSECT

INDICATOR	<u>D. brevicornis</u>	<u>D. ponderosae</u>	<u>D. jeffreyi</u>	<u>D. valens</u>	<u>Ips spp.</u>	<u>S. ventralis</u>
Portion of tree attacked	Entire bole to an 8" top	Entire bole to a 6" top	Entire bole to an 8" top	Generally the basal 3'	Tops of large trees and entire bole of small trees	Tops, patches and entire bole
Resin flow, pitch tubes or boring dust	Pitch tubes (small)	Pitch tubes (medium)	Pitch tubes (medium)	Pitch tubes (large)	Standing trees small pitch tubes & boring dust. Slash - boring dust.	Resin flow
Hosts	PIPO	PICO, PILA, PIPO	PIJE	ALL PINES	ALL PINES	ABCO, ABMA

Gallery patterns  
see next page

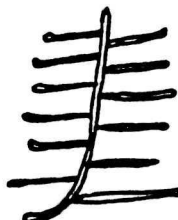
# INSECT EGG GALLERY KEY

Western Pine Beetle  
Dendroctonus brevicomis



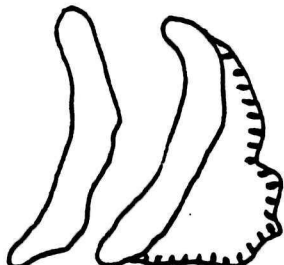
Net-like egg gallery packed with frass. Larvae in bark.

Mountain Pine Beetle  
Dendroctonus ponderosae  
and  
Jeffrey Pine Beetle  
Dendroctonus jeffreyi



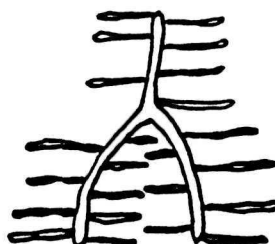
Vertical hockey stick shaped egg gallery, to 3' long. Horizontal larval mines.

Red Turpentine Beetle  
Dendroctonus valens



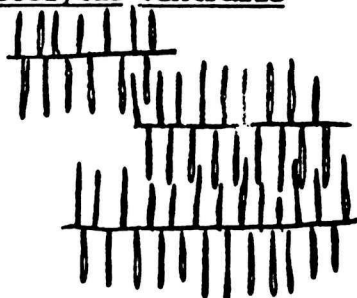
Large egg gallery packed with frass. Larvae clustered in large excavations.

California Fivespined Ips  
Ips paraconfusus



Tuning fork shaped egg gallery free of frass. Xylem is etched.

Fir Engraver  
Scolytus ventralis



Horizontal egg gallery with vertical larval mines. Xylem is etched.



## PEST DETECTION & REPORTING

### Diagnosis

Observation is the key to the detection and identification of pest problems in forest stands and recreation sites. When losses occur, the problem must be accurately identified prior to the formulation of management alternatives. The first priority is to identify the species that is (are) affected. Then the stand conditions should be examined for any abnormalities or changes. This would include environmental conditions and cultural practices. Weather conditions of the recent past (2-3 years) should be evaluated. Cultural practices that have resulted in stump formation, slash buildup, or significant tree damage should also be considered. Correlation of symptomatic trees with site factors often provides useful information, as do observations on the distribution of symptomatic trees, such as grouped or scattered.

Following stand examination, inspection of individual trees can begin. Trees to be examined should include recently dead, dying and symptomatic individuals. Older dead trees often are of little use. When examining trees one should be thorough and look at the entire tree and its surroundings. It is best to start at either the terminal end or the root system and systematically make observations throughout the tree. One should include exposing some roots to examine their condition. In addition to looking for insects and diseases, one should evaluate the progression of symptoms in the tree, terminal growth, foliage color, needle length and retention in conifers, branch dieback, pitch flow, and any other abnormalities. It is best to examine as many symptomatic trees as possible.

Once the necessary observations are completed, analysis of the accumulated information is necessary. One should not stop with the identification process when the first possible causal factor is determined. Much of the mortality in California is a result of the interaction of several factors, often including insects, disease organisms, and the environment. It is necessary to identify all elements of this complex in order to properly prescribe corrective actions.

### Getting Assistance

Situations arise when the person in the field is unable to identify the problem. It is at this time when the Forest Pest Management group can be of assistance. Specimens should be gathered (see below) and sent to FPM in the Regional Office. In situations where significant damage is occurring, a field evaluation may be requested. Personnel with non-federal agencies and private landowners should submit specimens and forms to the CDF headquarters in Sacramento. Accompanying the specimens should be a completed Forest Pest Detection Report (Form R5-3400-1).

### Collecting Specimens

Insect and disease organisms should be collected and sent for identification, if available. However, the collected organisms should be related to the damage that is occurring. Insects observed in the process of causing damage should be collected. Care should be taken not to damage the specimens during collection.

Fruiting bodies of suspected disease organisms should be collected, preferably from damaged tissues adjacent to green tissue.

When no organisms are available, collection of host tissue is required. Symptomatic material, by itself, may not be sufficient because it may simply be an expression of the problem rather than the problem. Material should be green or freshly killed - old dead tissue is not satisfactory. Base your decision on what material to collect on your field observations and experience.

Keep root specimens separate from other specimens to reduce contamination from the soil. Limit the size of specimens - large branches may be split to eliminate unaffected wood. Try to submit several representative specimens. Keep specimens out of sunlight and warm places and send in for identification as soon as possible.

#### Shipping Specimens

Specimens should be packed carefully in a mailing tube or sturdy carton. Sufficient padding should surround the specimens to prevent damage. Fresh specimens, or specimens from which fungal isolations will be necessary, should be put in perforated plastic bags, kept cool and shipped as soon as possible. Schedule shipments so that they will arrive on weekdays. Keep free moisture out of the container to reduce the growth of unwanted organisms.

Immature insect specimens, such as caterpillars, should be shipped in vials containing a preservative such as ethyl or rubbing alcohol. A label, written in pencil, should be included in the vial. Moths and butterflies should be killed by exposing them to toxic vapors in a jar. Such vapors include ethyl acetate (nail polish remover) and sodium cyanide. After the moths are dead, fold their wings together and insert them in envelopes. Mail the envelopes in a carton with sufficient packing material so that the insects are not damaged. Other adult insects, such as beetles, should also be killed by exposure for two to three days to the previously mentioned toxic vapors. The insects should then be placed in a small container with tissue to prevent movement and breakage (no cotton wool please). This container can then be cushioned with packing material in a mailing carton and shipped to the proper office for identification.

## FOREST PEST DETECTION REPORT

## I. FIELD INFORMATION (See instructions on reverse)

COUNTY:		2. FOREST (FS ONLY):		3. DISTRICT (FS ONLY):	
4. LEGAL DESCRIPTION: T. _____ R. _____ S. _____		6. LOCATION:		7. LAND OWNERSHIP: 1. FOREST SERVICE <input type="checkbox"/> 2. OTHER FEDERAL <input type="checkbox"/> 3. STATE <input type="checkbox"/> 4. PRIVATE <input type="checkbox"/>	
5. DATE:					
8. SUSPECTED CAUSE(S) OF INJURY: 1. INSECT <input type="checkbox"/> 5. CHEMICAL <input type="checkbox"/> 2. DISEASE <input type="checkbox"/> 6. MECHANICAL <input type="checkbox"/> 3. ANIMAL <input type="checkbox"/> 7. WEED <input type="checkbox"/> 4. WEATHER <input type="checkbox"/> 8. UNKNOWN <input type="checkbox"/>		9. SIZE(S) OF TREE(S) AFFECTED: 1. SEEDLING <input type="checkbox"/> 4. SAWTIMBER <input type="checkbox"/> 2. SAPLING <input type="checkbox"/> 5. OVERMATURE <input type="checkbox"/> 3. POLE <input type="checkbox"/>		10. PART(S) OF TREE(S) AFFECTED: 1. ROOT <input type="checkbox"/> 5. TWIG <input type="checkbox"/> 2. BRANCH <input type="checkbox"/> 6. FOLIAGE <input type="checkbox"/> 3. LEADER <input type="checkbox"/> 7. BUD <input type="checkbox"/> 4. BOLE <input type="checkbox"/> 8. CONE <input type="checkbox"/>	
11. SPECIES AFFECTED:		12. NUMBER AFFECTED:		13. ACRES AFFECTED:	
14. INJURY DISTRIBUTION: 1. SCATTERED <input type="checkbox"/> 2. GROUPED <input type="checkbox"/>			15. STATUS OF INJURY: 1. DECREASING <input type="checkbox"/> 2. STATIC <input type="checkbox"/> 3. INCREASING <input type="checkbox"/>		
16. PLANTATION ? 1. YES <input type="checkbox"/> 2. NO <input type="checkbox"/>		17. STAND COMPOSITION (SPECIES):		18. STAND AGE AND SIZE CLASS:	
		19. STAND DENSITY (BASAL AREA):		20. SITE QUALITY:	
21. PEST NAMES (IF KNOWN), AND REMARKS (SYMPTOMS AND CONTRIBUTING FACTORS):					
22. SAMPLE FORWARDED ? 1. YES <input type="checkbox"/> 2. NO <input type="checkbox"/>		23. ACTION REQUESTED: 1. YOUR INFORMATION ONLY <input type="checkbox"/> 2. LAB IDENTIFICATION <input type="checkbox"/> 3. FIELD EVALUATION <input type="checkbox"/>		24. REPORTER'S NAME:	
				25. REPORTER'S AGENCY:	
		26. REPORTER'S ADDRESS, ZIP CODE, & PHONE NO.:			

## II. REPLY (Pest Management Use)

27. RESPONSE:			31. FILE NO.
28. REPORT NUMBER:			
29. DATE:		30. EXAMINER'S SIGNATURE:	

**THE COOPERATIVE FOREST PEST DETECTION SURVEY** is sponsored by the California Forest Pest Control Action Council. The Pest Action Council encourages Federal, State, and private land managers and individuals to contribute to the Survey by submitting pest injury reports and samples in the following manner.

**FEDERAL PERSONNEL.** Send all detection reports through channels, and mail injury samples with a copy of the report to:

USDA, FOREST SERVICE, Forest Pest Management  
630 Sansome Street, San Francisco, Ca. 94111.

**STATE PERSONNEL.** Send all detection reports through channels, and mail injury samples with a copy of this report to:

CALIFORNIA DEPARTMENT OF FORESTRY  
1416-9th Street, Sacramento, Ca. 95814.

**PRIVATE LAND MANAGERS AND INDIVIDUALS.** Send all detection reports and samples to:

CALIFORNIA DEPARTMENT OF FORESTRY  
1416-9th Street, Sacramento, Ca. 95814.

**COMPLETING THE DETECTION REPORT FORM.**

**HEADING (BLOCKS 1-7).** Enter all information requested. In Block 6, LOCATION, note distinguishing landmarks and place names so that the injury center can be relocated. If possible, attach a location map to this form.

**INJURY DESCRIPTION (BLOCKS 8-15).** Check as many boxes as are applicable, and fill in the requested information as completely as possible.

**STAND DESCRIPTION (BLOCKS 16-20).** This information will aid the examiner in determining how the stand conditions contributed to the pest problem. In Block 17, indicate the major tree species in the overstory and understory. In Block 18, indicate the stand age in years, and/or the size class (seedling-sapling; pole; young sawtimber; mature sawtimber; overmature, or decadent).

**PEST NAMES (BLOCK 21).** Write a detailed description of the pest or pests, the injury symptoms, and any contributing factors.

**ACTION REQUESTED (BLOCK 23).** Mark "Field Evaluation" only if you consider the injury serious enough to warrant a professional evaluation. Mark "Your Information Only" if you are reporting a condition that does not require further attention. All reports will be acknowledged and questions answered on the lower part of this form.

**REPLY (SECTION II).** Make no entries in this block; for examining personnel only. A copy of this report will be returned to you with the information requested.

**HANDLING SAMPLES.**

Please submit injury samples with each detection report. If possible, send several specimens illustrating the stages of injury and decline. Keep samples cool and ship them immediately after collection. Send them in a screw-top mailing tube or other sturdy container, and enclose a completed copy of the detection report.

**YOUR PARTICIPATION IN THE COOPERATIVE FOREST PEST DETECTION SURVEY IS GREATLY NEEDED AND APPRECIATED.** Additional copies of this form are available from the Forest Service, Forest Pest Management, and from the California Department of Forestry.





SEQUOIA NATIONAL PARK ACID DEPOSITION / WATERSHED RESEARCH  
WATER QUALITY ASSURANCE/QUALITY CONTROL UPDATE

Anne Esperanza, Dan Everson and Hannah Merrill  
Sequoia and Kings Canyon National Parks  
Three Rivers, California 93271

April 1991

INTRODUCTION

The purpose of our quality assurance/quality control (QA/QC) program is to assure that data collected for the Park's Acid Deposition/Watershed Research Program are of such quality that they provide credibility to the research program's results and conclusions. Stringent QA/QC procedures are essential for obtaining representative precipitation, soil solution and stream samples; chemically analyzing samples using consistent and commonly accepted methods; and demonstrating the precision and accuracy of the resulting data relative to data collected for other water quality research programs.

Routine precipitation analysis began in July 1980 after the establishment of a National Atmospheric Deposition (NADP) site at Giant Forest. Expanded precipitation and surface water sampling began in the fall of 1982 as Sequoia National Park received separate National Atmospheric Precipitation Assessment Program (NAPAP) funds to research the effects of acid deposition on Park ecosystems. A standardized data collection protocol, complete with a QA/QC program, was developed and strictly adhered to for all field sampling laboratory analysis and entry.

This report will identify the important aspects of our current and planned field and laboratory QA/QC data on the precision and accuracy of selected water chemistry data. Definitions of terms used throughout this report are shown in Table 1.

CURRENT QA/QC PROCEDURES

Field QA/QC is maintained through sampling standardization, sample preservation and replication, instrument calibration and standardized data entry procedures.

Sample standardization includes consistent preparation for field sampling (checklist of equipment and supplies), standardized procedures for sample collection, filtration, treatment, and storage, routine procedures for shipping samples to the proper laboratories, and carrying backup equipment for each sampling trip.

Sample preservation includes; refrigeration at 4°C of all samples until analyses are performed, short term storage of a refrigerated 60 ml sample (4°C) until chemical analyses and computations are completed, in order to assist flagging atypical data. Samples with atypical values are then reanalyzed. Filtered subsamples (20 ml) are archived (frozen in whirl-pak bags) and have been kept since the beginning of the program.

Sample replicates and split samples are used to estimate the variability or uncertainty in sampling and analysis. This process generally includes split sample analysis of 30% of all NADP and California Air Resources Board (CARB) wet deposition samples and split samples of NPS bulk precipitation samples, true replicate samples of 10% of all stream samples, and split sample analysis for all samples when performing  $\text{NH}_4$  and  $\text{PO}_4$  analysis at the NPS laboratory at Ash Mountain. As of March 1991 we achieved 23% splits of event precipitation and 25% replicate of stream samples.

Field and laboratory notebooks are the most important record for our QA/QC program. At a minimum, they contain the following information; sample date, time, location and type, sampling personnel, equipment calibration efficiency, accuracy or precision, other observations that may assist in interpreting the water chemistry data.

Laboratory QA/QC must be sensitive to the accuracy and precision of each step of the analytical process (see Kirchmer 1983). In general, this means to:

1. Define the determinand, limits of detection and accuracy required.
2. Choose analytical methods with satisfactory small sources of bias and adequate precision. New methods will not be used unless they can be calibrated to the previous techniques. When suitable methods are not available, improved methods will be developed.
3. Ensure that the chosen methods are completely and unambiguously specified and that they will be followed as far as possible by all laboratories.
4. Estimate the standard deviation of analytical results and, if necessary, improve the precision until the target value is achieved. Ensure that standard solutions used by all laboratories are in satisfactory agreement.
5. Establish a control chart and regularly analyze solutions of known concentrations to ensure that precision remains adequate.
6. Estimate the bias of each laboratory and, if necessary, improve until the target value is achieved.

More specifically, the following steps will be taken to ensure within-lab and between-lab accuracy and precision. This includes



precisely following established and accepted standard analytical methods by personnel trained in the following:

- laboratory preparation, calibration of equipment following manufacturers' instructions, cleaning of equipment and supplies (ie. acid washing bottles, glassware, etc.), inventory of supplies needed/used, etc.
- preparation/testing of standard solutions, chemicals (ASC Reagent Grade), reagents and deionized-distilled water as called for by "Standard Methods" (APHA et al. 1981).
- analysis of replicates of splits (10-15% of the total samples) as outlined by "Standard Methods" (APHA et al. 1981).
- use of inter-lab cross checks including participation in the Environmental Protection Agency (EPA) and U.S. Geological Survey (USGS) "audit" programs.

Data base entries also receive rigorous QA/QC so the aberrant and/or erroneous values can be removed or modified. These procedures include data storage on hard copy and computer media in similar format to field/lab notebooks, screening field/lab notebooks, hard copy, and computer data files for errors, systematic entry of data from one format to another (ie. field notebooks to hard copy to computer files), consistent use of units for each variable, adequate training of personnel in data management procedures including use of the computer, routine data back-up, and flagging of questionable or suspect data.

## PROGRESS TO DATE: RESULTS AND DISCUSSION

### General Observations

Our major QA/QC accomplishment to date has been developing and adhering to the "Data Collection Protocol for the Sequoia National Park Acid Precipitation Research Program" (available on request from the Research Office, Sequoia National Park). Beginning in early 1983, we have followed consistent field, laboratory and data management procedures despite slight modifications in methods as the research program developed. Laboratory methods and detection limits are shown in Table 2. These detection limits and estimates of precision and accuracy of pH and conductivity are similar to those of the NADP/NTN wet deposition sampling program.

To ensure accuracy and precision of time-critical variables, time limits are set for each analysis. Sample pH and conductivity are run within six hours of collection. Alkalinity (for stream samples), NH<sub>4</sub>, and PO<sub>4</sub> are run within 24 hours and samples are mailed chilled in coolers with blue ice to the appropriate laboratory within 24 hours, in most cases via express mail services.

Earlier problems centered around generating and maintaining high quality (low conductivity) deionized-distilled (DI) water for bottle washing and chemical analysis. The Sybron-Barnstead 4 liter glass distiller (Fi Stream Model) had required a great deal of maintenance while providing only the minimum of DI water necessary for laboratory operations. In January 1986, a new Barnstead RO NANO-pure II Water Purification System (Type I Reagent-grade water) was installed at the Ash Mountain water quality laboratory and has produced reagent grade water since installation.

QA/QC has grown to become a top priority with the Park research staff. The numbers of replicate and split samples have exceeded original goals. Training of field and laboratory technicians has intensified. Increased laboratory use of conductivity and pH check samples provided by the Central Analytical Laboratory (NADP), the Haagen-Smit Laboratory (CARB), and the Environmental Monitoring and Services Incorporated (EMSI), (only from April 1987 to January 1988). As the rest of this report will demonstrate, efforts are consistently made to evaluate our QA/QC efforts and to improve the program in the future.

#### Quality Control at the Ash Mountain Laboratory

Control charts were developed for  $\text{NH}_4$  and  $\text{PO}_4$  standards and blanks with upper and lower control limits set for spectrophotometer readings (Table 3). If standards or blanks have absorbance values outside the limits, DI water and all reagents are checked and all blanks, standards, and samples are reanalyzed.

As previously mentioned, checks on pH and conductivity meters and electrodes are regularly and routinely made at each use. Equipment has been calibrated and serviced according to the manufacturers' recommendations. We also purchased a new Beckman PHI 40 pH meter (September 1986) with an accuracy of 0.01 pH units. The meter has error indicators for instrument malfunctions, electrode malfunctions, and sample temperature out-of-range. It has the same electrode as our Altex (NADP/NTN) meter. Cross checks between meters with the NADP/NTN 4.30 pH check sample show a mean percent difference of 0.23% (very precise). The new meter will generally be used as a back up to the Altex meter.

#### Audit Programs: Accuracy of Chemical Analysis

Since March 1984, we have participated in the biannual EPA Audit Program. Since March 1985, we have participated in the quarterly inter-laboratory comparisons conducted by the USGS for the NADP. And since 1986, we have participated with the California Air Resources Board acid deposition performance audit. These programs provide an opportunity to compare our analysis results for "blind samples" with known values to results from other labs analyzing similar samples. Results of eight EPA audits of acid precipitation

samples are shown in Table 4. Thus far, our pH values appear quite accurate with less than a 2% difference between EPA and NPS results. This is also better than the national average percent difference reported by the EPA. Conductivity values were more accurate at lower conductivities (<50 umhos) than higher conductivities (>50 umhos). Fortunately, less than 10% of the precipitation and stream samples collected and analyzed thus far have conductivity values greater than 50 umhos. A low level (<1000 umhos) conductivity probe (YSI 3402, k=0.1) was installed in January 1985 to increase accuracy at the more common low conductivity end and a probe with a higher cell constant is available to use for solutions suspected of higher conductivities.

We have had mixed success in NH<sub>4</sub> comparison with EPA samples. There are no consistent results to date. One problem may be the concentration of the standards we commonly use (0.12 mg/l) is inaccurate for concentrated NH<sub>4</sub> analysis. This standard was selected because over 75% of the precipitation and stream samples are under 0.01 mg/l NH<sub>4</sub>, the detection limit of our analysis techniques. Only a small percentage of our samples have NH<sub>4</sub> concentrations >0.6 mg/l. Thus the EPA audit samples do not meet our needs as quality assurance checks. The EPA program does not include audits samples of PO<sub>4</sub>. We will attempt to locate low concentration NH<sub>4</sub> and PO<sub>4</sub> audit samples to better evaluate our accuracy for these ions in the future.

The results of the USGS inter-lab comparisons are shown in Table 5. Our pH and conductivity values are generally very close and improving over time. The improvement in conductivity measurements may be due in part to the new probe discussed earlier. The results of the CARB inter-lab comparisons are shown in Table 6. Our pH and conductivity values have been well within expected ranges of accuracy. We will continue to participate in the EPA, USGS, and CARB audit programs in the future. The NPS laboratory at Michigan Technical University (M.T.U., which currently operates in Fort Collins), where the other ions are analyzed, also participates in audit programs. Those results are not presented here. Analysis of our replicates and splits are currently being updated.

#### PLANNED QA/QC IMPROVEMENTS

Additional improvements in the QA/QC program are necessary to improve and evaluate quality of our data. These include combining the audit program data from M.T.U. and Fort Collins into our next QA/QC report to evaluate the accuracy of our complete water chemistry data set. We also plan to continue participation in inter-lab checks. Our QA/QC program is well entrenched and growing. Expanded QA/QC efforts must remain a top priority in the Park's Acid Deposition/Watershed Research program to maintain and enhance the quality of our research results.

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Table 1. Definition of Terms

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Accuracy:	the total error of a result (from the true value) where accuracy represents the combined random and systematic errors of results and is said to improve as the total error decreases (Kirchmer 1983).
Bias:	systematic error in water analysis due to unrepresentative sampling, instability of samples between sampling and analysis, interference effects, biased calibration, a biased blank correction, and for inability to determine all forms of the determinand (that which is to be determined) (Kirchmer 1983).
Blank solution:	a solution that contains everything in the sample solution except the analyte (O'Haver 1976, Kirchmer 1983).
Control Chart:	a graphic display of individual analytical results, where measured values (ie. concentration found for standard solution in mg/l) are plotted on a chart in which mean +2 standard deviation defines the "warning limits" and mean +3 standard deviation defines the "action limits" (APHA 1981, Kirchmer 1983). In this QA/QC plan, we will use 1 standard deviation as the "action limit."
Detection limit:	the lowest concentration of determinand that the analytical process can reliably detect (Kirchmer 1983).
Precision:	the degree of mutual agreement among individual measurements made under prescribed conditions with a single test procedure (EPA 1979).
Quality Assurance (QA):	the orderly application of procedures to reduce errors during sampling and analysis to improve precision (APHA et al. 1981, Wilhour 1983).
Quality Control:	the application of procedures to ensure the accuracy of results during sampling and analysis (Wilhour 1983).
Recovery:	the difference between the analytical results of spiking compound and multiplied by 100 to convert to percentage (Kirchmer 1983).
Standard solution:	natural water with a known amount of an element or compound (APHA 1981).

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Table 2. Methods and detection limits used for Sequoia National Park precipitation and surface water sampling program.

Constituent	Method	Detection Limit (uEq/l)	
NH <sub>4</sub>	Color spectrophotometry (Indiophenol blue method)	0.56	
PO <sub>4</sub>	Color spectrophotometry (Molybdate method)	0.32	
NO <sub>2</sub>	Ion chromatography	0.22	
NO <sub>3</sub>	Ion chromatography	0.16	
Ca	Ion chromatography	0.50	
Mg	Ion chromatography	0.82	
Na	Ion chromatography	0.43	
K	Ion chromatography	0.26	
SO <sub>4</sub>	Ion chromatography	0.21	
Cl	Ion chromatography	0.28	
		Accuracy Goal	Precision Goal
pH	Altex Model 3500 meter (Beckman probe #39835)	0.3 pH	0.1 pH
Specific Conductance	Beckman Model RC-160 meter (YSI probe 3403 prior to 1/85 YSI probe 3402 after 1/85)	5%	3%
Alkalinity	Gran Titration	5% est.	3% est.

Table 3. Control limits (1 standard deviation from the mean) for spectrophotometer absorbance values for ammonia and phosphate. Samples analyzed between January 1985 and September 1985.

Element	BLANKS			STANDARDS		
	Lower Limit	Observed Means	Upper Limit	Lower Limit	Observed Means	Upper Limit
NH <sub>4</sub> (n)	0	0.0029 (44)	0.0053	0.140	0.168 (42)	0.194
PO <sub>4</sub> (n)	0	0.0029 (38)	0.006	0.114	0.139 (38)	0.165



Table 4. Environmental Protection Agency (EPA) Audit Program  
Results to date

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Date	<u>pH</u>		%Difference
	EPA	NPS	
May, 1984	4.28	4.23	1.17
	4.01	3.96	1.25
	3.55	3.48	1.97
Oct., 1984	4.28	4.31	0.70
	3.88	3.91	0.77
	3.73	3.75	0.54
May, 1985	4.39	4.42	0.68
	4.00	4.06	1.50
	3.56	3.63	1.97
Oct., 1985	4.29	4.27	0.47
	3.92	3.95	0.77
	3.19	3.22	0.94
Oct., 1987	4.27	4.22	1.17
	3.69	3.59	2.71
	3.92	3.83	2.30
May, 1988	4.51	4.54	0.67
	3.91	3.95	1.02
	3.57	3.61	1.12
Oct., 1988	4.40	4.62	5.00
	3.50	3.54	1.14
	3.52	3.52	0.0
May, 1989	3.91	3.77	3.48
	4.27	4.19	1.92
	3.68	3.53	3.95

---

mean = 1.55  
standard error = 1.19

Table 4 continued.

Date	<u>Conductivity</u> (uS/cm)		%Difference
	EPA	NPS	
May, 1984	24.2	24.3	0.41
	50.7	50.0	1.38
	136.2	120.0	11.89
Oct., 1984	24.4	22.0	9.84
	66.0	58.0	12.12
	92.7	78.0	19.86
May, 1985	20.2	20.5	1.49
	53.1	45.0	15.25
	134.3	114.0	15.12
Oct., 1985	24.7	25.0	1.21
	61.6	55.0	10.71
	322.2	300.0	6.89
Oct., 1987	24.5	24.0	2.04
	98.5	94.0	4.57
	65.1	64.0	1.69
May, 1988	16.5	16.5	0.0
	62.8	60.0	4.46
	128.7	123.0	4.43
Oct., 1988	16.5	19.9	20.61
	156.4	156.0	0.26
	130.4	137.0	5.06
May, 1989	66.1	61.9	6.41
	24.08	22.5	6.57
	96.43	92.7	3.87
			mean = 6.92
			standard error = 6.04

Table 4 continued

Date	<u>NH<sub>4</sub></u> (mg/l)		%Difference
	EPA	NPS	
May, 1984	0.083	7.86*	----
	0.626	0.627	0.159
	0.798	0.779	2.381
Oct., 1984	0.075	0.107	42.667
	0.792	1.116	40.909
	0.612	0.946	54.575
May, 1985	0.780	0.098	25.641
	0.612	0.673	9.967
	0.895	0.971	8.492
Oct., 1985	0.080	0.106	32.500
	0.627	0.875	39.553
	0.657	0.928	41.248
Oct., 1987	0.077	0.089	15.584
	0.606	0.810	33.663
	0.342	0.647	89.181
May, 1988	0.108	0.114	5.556
	0.612	0.668	9.150
	0.777	1.100	41.570
Oct., 1988	0.080	0.080	0.0
	0.690	0.830	16.867
	1.070	0.470	127.660
May, 1989	0.335	0.418	24.776
	0.080	0.089	11.250
	0.610	0.781	28.033

mean = 29.22

standard error = 28.54

\*. contaminated sample

-spectrophotometer recalibrated by manufacturer in November, 1985  
and serviced by manufacturer in 1987.

Table 5. National Atmospheric Deposition (NADP) Audit Program results to date. Analysis performed at U.S. Geological Survey Laboratory at Arvada, Colorado and NPS laboratory at Sequoia National Park.

Date	pH			Conductivity (uS/cm)		
	NADP	NPS	% Difference	NADP	NPS	% Difference
Oct 1981	4.29	4.00	6.7	21.6	25.4	17.6
Apr 1982	4.58	4.53	0.6	12.4	12.4	0.0
Nov 1982	4.03	4.10	1.7	38.0	44.1	16.1
May 1983	3.84	3.80	1.0	60.0	62.4	4.0
Nov 1983	4.61	4.61	0.0	10.8	11.9	10.2
Jul 1984	4.12	3.95	4.1	31.8	37.1	16.7
Jan 1985	4.55	4.57	0.4	11.4	18.0	57.9
Apr 1985	4.13	4.14	0.2	30.0	31.5	5.0
Jul 1985	4.80	4.77	0.6	6.6	6.7	1.5
Oct 1985	4.61	4.63	0.4	9.8	9.8	0.0
Jan 1986	4.60	4.58	0.4	10.1	10.3	1.9
Apr 1986	4.96	4.93	0.6	4.4	4.8	9.0
Jul 1986	3.92	3.95	0.7	51.4	50.3	2.1
Oct 1986	4.32	4.34	0.5	21.0	22.4	6.7
May 1987	4.50	4.38	2.7	13.5	14.3	5.9
Oct 1987	4.73	4.74	0.2	7.4	7.4	0.0
Apr 1988	4.40	4.44	0.9	16.9	17.2	1.8
Sep 1988	5.06	5.08	0.4	19.6	18.0	8.2
Mar 1989	4.68	4.62	1.3	8.6	8.8	2.3
Sep 1989	4.01	3.98	0.7	43.2	39.6	8.3
Apr 1990	4.57	4.53	0.9	12.3	12.1	1.6
Oct 1990	4.85	4.78	1.4	6.5	6.1	6.2
mean = 1.19			mean = 8.3			
s.e. = 1.5			s.e. = 12.0			

Table 6. California Air Resources Board Audit Program results.

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Date	<u>pH</u>			<u>Conductivity</u>		
	CARB	NPS	%Difference	CARB	NPS	%Difference
1986	4.32	4.31	0.2	24.1	19.6	5.1
1987 (1)	4.38	4.33	0.1	20.9	21.1	1.0
1987 (2)	4.00	3.89	0.5	54.9	60.5	10.2
1988	3.56	3.52	0.1	133.5	136.8	2.5
1989 (1)	3.92	3.89	0.8	80.8	68.1	15.7
1989 (2)	3.72	3.50	5.9	96.8	88.0	9.1
1989 (3)	3.87	3.62	6.5	96.9	99.7	2.9
1989 (4)	4.34	4.30	0.9	25.6	26.4	3.1
1990	3.72	3.70	0.5	94.1	86.5	8.1

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mean = 1.7  
standard error = 2.41

mean = 6.4  
standard error = 4.47

Table 7. Number of replicates and splits for stream and event precipitation samples from April 1983 - March 1991.

Site	Type	No. Replicates or Splits	Total Samples
<u>Replicates</u>			
Lower Chamise Creek	Stream	20	59
Tharp's Creek	Stream	42	174
Log Creek	Stream	57	281
Emerald Outflow	Stream	59	202
<u>Splits</u>			
Ash Mountain	Event precip.	14	161
Giant Forest	Event precip.	100	327
		Total	292
			1204





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# The Management of Electronically Collected Data Within the Long-Term Ecological Research (LTER) Program

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*A Survey Conducted in January 1992*

Rick Ingersoll and Scott Chapal



Distributed by the Long-Term Ecological Research Network Office  
University of Washington, College of Forest Resources, AR-10  
Seattle, Washington 98195, 206-543-4853, FAX: 206-685-0790/3091

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## INTRODUCTION

The rapid evolution of automated sensing equipment and related computer technologies has been concurrent with the Long-Term Ecological Research (LTER) program's increased reliance on electronically gathered data. Most meteorological data are collected, stored, and/or transferred by electronic means at LTER sites. Although these technologies have freed climatologists and data managers from the tediousness of manual data entry, they also have necessitated quality assurance/quality control (QA/QC) protocol modifications in order to achieve acceptable levels of accuracy, precision, and error in the data. Such modifications (1) require identification of additional sources of poor-quality data, and (2) must account for differences or reductions in human involvement at various stages during and subsequent to automated collection of data. We believe it to be an appropriate time for an assessment of the manner in which the network of LTER sites has coped with problems inherent to modern methods of data collection, since inaccuracies resulting from undetected problems could be subtle enough to mask real variability in the data.

The idea for an electronic data collection survey within LTER originated in QA/QC working group sessions at the August 1991 meeting of the LTER data managers in San Antonio, TX. The objectives of the survey were to (1) obtain detailed information concerning the management of electronically collected data within the program, (2) to summarize that information, and (3) to offer recommendations for the improvement of management of electronically collected data within LTER. A more detailed description of the reasoning behind the survey's origins can be found in the explanatory text accompanying the survey (Appendix 1). The survey was prepared in September and distributed to all LTER sites via electronic mail (email) in October. The responses were compiled and this report was prepared during December 1991 and January 1992.

## THE RESPONSES

The reply rate was favorable, given the amount of detailed information requested on relatively short notice. Responses were received from 14 of 18 LTER sites. Moreover, responses were received from 2 National Park Service (NPS) sites. Although the original intention was for the survey to be LTER specific, it was decided to treat the 2 NPS sites as LTER sites when it became apparent that the responses to individual portions of the survey were qualitatively within the range of responses from the "true" LTER sites. The following sites participated in the survey: H.J. Andrews Experimental Forest (AND), Arctic Tundra (ARC), Bonanza Creek Experimental Forest (BNZ), Central Plains Experimental Range (CPR), Coweeta Hydrologic Laboratory (CWT), Hubbard Brook Experimental Forest (HBR), Harvard Forest (HFR), Jornada (JRN), Konza Prairie (KNZ), North Inlet Marsh (NIN), North Temperate Lakes (NTL), Niwot Ridge/Green Lakes Valley (NWT), Sevilleta National Wildlife Refuge (SEV), Virginia Coast Reserve (VCR), Isle Royale National Park (IRP), and Olympic National Park (ONP).

[The response for El Verde Field Station in Puerto Rico (LUQ) was received too late to be included in the text or tables that follow. Nevertheless, a cursory examination indicated that its inclusion would not significantly alter the content of this report and the response is included in the appendices.]

*Note that "site" as used throughout this document refers to one of the sites above and not to individual measurement locations within those sites. These measurement locations were often referred to as sites within the individual survey responses but for the purposes of this evaluation were "lumped" together and treated as a single site.*

Individual responses were variable both in terms of the detail provided and their formats, although they generally adhered to the specified format. Some of this variability might be attributed to the short notice in conjunction with personnel limitations at the sites. A number of the sites provided supplementary materials not specifically requested. Ten of the responses were received in the form of electronic mail messages, 3 as hard copies only, 2 in word-processing format on floppy diskettes, and 1 was received via binary ftp (file transfer protocol). The individual responses appear in their entirety in Appendices 2-17 and, with the exception of removal of the survey "questions", are unedited. [The LUQ response may be found in Appendix 18.]

## SURVEY SUMMARY

### Caveats

During the initial stages of the evaluation of the responses, it became apparent to the authors that neither could dedicate the time required to conduct as thorough an evaluation as desired. To obtain answers for each of the numerous minor questions that arose would have required an effort that would have been disproportionately larger than the gain in knowledge. Moreover, the "snapshot view" analogy of Foster and Boose (email message, 24 July 1991) is certainly applicable in this case and we felt it important that the snapshot be displayed before it has faded. Thus, we worked with what we had.

Neither of us professes to be experts on all of the hardware, software, and techniques mentioned in this report. Thus, we acknowledge the definite possibility of misinterpretation or outright error. The individual survey responses and contact people should be consulted for further clarification.

The absence of "x" for a given site in any of the summary tables should **not** be construed as indication of lack of applicability of the particular item for that site. The number of "x"s applied to a site in a particular table is to some extent proportional to the amount of detail contained in the response for that site.

The mention of, or comments regarding, commercial products does not constitute any official endorsement by any of the parties involved, i.e. the National Science Foundation, the Long-Term Ecological Research program, the National Park Service, or

the U.S. Forest Service.

## **1. Variables**

Climatological variables are those most commonly measured via electronic means at the 16 sites (Table 1). Air temperature, wind (speed and direction), and solar radiation are monitored electronically at all but one of the sites. At least 75% of the sites use datalogger-type systems to quantify relative humidity, precipitation, and soil temperature. Thus, modern automated technology forms the backbone of climatological data collection within LTER.

## **2. Measurement Periods**

The reliance on electronically collected climatological data within LTER is a comparatively recent phenomenon. If one sums the number of primary variables measured over all sites this becomes readily apparent. In 1979, only 4 primary variables were measured electronically within LTER. In 1991, the number had reached 135, with most of the increase occurring in the mid-1980s.

## **3. Measurement Frequencies**

Details on measurement frequencies may be found in the individual survey responses (Appendices 2-17).

## **4. Hardware**

Dataloggers manufactured by Campbell Scientific Instruments (CSI) were the most commonly used loggers within LTER (Table 2). Versions of these instruments have been used at 14 of the 16 sites, with the CR21X and the CR10 being the most commonly employed models. The only other makes of automated datalogging hardware that have been used at more than one site are Omnidata and Li-Cor.

*Note: Individual site comments are acknowledged parenthetically throughout the remainder of the report.*

Advantages of the CSI dataloggers were reported primarily as being their greater flexibility and programmability (AND, HFR), and the sites that had used these instruments were in general very satisfied (e.g. ONP). Some did not see the need for the additional flexibility provided by the CSI loggers, however, and were more concerned with reliability (BNZ). Advantages of the Li-Cor dataloggers were user-friendliness, retention of data and programs during temporary power losses, low cost, mobility, and durability (IRP, HFR).



**Table 1. Variables measured by electronic means at 14 Long-Term Ecological Research and 2 National Park Service sites.**

Variable	AND	ARC	BNZ	CPR	CWT	HBR	HFR	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
Temperature:																
Air	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Soil	X	X	X	X	X		X	X			X		X	X	X	X
Water		X							X	X	X					
Dewpoint	X															
Wind speed	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Wind direction	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Radiation:																
Solar	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Photosynthetically active		X									X			X		
Light		X			X		X									
Average SW and LW											X					
Relative humidity	X	X	X	X	X	X		X	X		X	X	X	X	X	X
Precipitation	X	X	X	X	X	X		X	X		X		X	X	X	X
Soil moisture	X	X	X	X	X			X					X			
Water depth		X	X						X	X						X
Vapor pressure/evaporation		X	X	X	X											
Barometric pressure		X								X		X				
Snow moisture	X															
Soil salinity			X													
Atmospheric gas concentrations					X											
Conductivity										X		X				

Soil temperature includes surface temperature, temperature at soil-litter interface, and temperature at one or more depths in the soil. Water temperature includes stream, lake, and river temperatures. Precipitation includes both liquid and solid forms. Solar radiation is assumed to be total short-wave radiation. SW=short-wave radiation; LW=long-wave radiation. Light includes lake light, light penetration, and photosynthetic photon flux density. Soil moisture includes soil water content and soil water potential. Water depth includes depth of stream, lake, water table, etc. Note that not all of the Included variables are necessarily measured at a given site. Refer to the individual survey responses for greater detail.

**Table 2.** Electronic data loggers used at 14 Long-Term Ecological Research and 2 National Park Service sites.

Data Logger	AND	ARC	BNZ	CPR	CWT	HBR	HFR	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
<b>Campbell Scientific Instruments:</b>																
CR21X micrologger	X	X		X	X				X		X	X	X	X		X
CR10 micrologger	X	X			X			X			X		X			
CR21 micrologger					X	X									X	X
CR7 datalogger			X													
<b>Omnidata:</b>																
EL824 datalogger			X													
DP211 datapod												X				
DP214 datapod			X													
DP220 datapod			X													
Li-Cor LI-1000 datalogger							X								X	
Interface Instruments M4	X															
Decagon Devices ceptometer					X											
Autodata Acurex 10/5 datalogger								X								
<b>Climatronics Corporation</b>																
IMP803 weather receiver										X						



The LTER program, when viewed as a whole, has amassed a great deal of experience with hardware available for electronic data collection (Table 3). More than 75% of the sites have used CSI temperature/relative humidity probes and 50% of the sites have used CSI wind speed and direction sensors. Greater than 50% of the sites have used Li-Cor radiometers for measuring solar radiation. Precipitation measurements at 75% of the sites have been made using gauges manufactured by Belfort Instrument Company, Sierra-Misco, and Texas Electronic. Soil moisture has been determined using 227 Delmhorst gypsum blocks at greater than 25% of the sites. CSI data storage modules were used at 50% of the sites and CSI cassette interfaces were used at nearly one third of the sites. It was not clear the extent to which the reliance on CSI for peripheral hardware was determined by usage of CSI dataloggers, but factors such as compatibility certainly were mentioned in the surveys.

Although site-specific problems were evident when climatic environment and electronic data collection systems were considered together, the vast majority of problems at most sites have been experienced at several other sites (Table 4).

*Note: Preventative maintenance protocols presented in the survey responses in some cases were interpreted as indicators that the potential for a particular problem existed. Thus the entries in Table 4 do not necessarily mean that a problem actually was experienced at each of the indicated sites, but rather that it either had or was likely to have occurred.*

Power reductions (or losses), the effects of extreme temperature, the impacts of animals and insects, the effects of moisture and condensation, and deterioration of equipment and sensors are each problems that have been reported by at least 50% of the sites. Additionally, problems associated with reading of magnetic tapes, measurement of relative humidity, dirty sensors, and data storage losses were each reported by more than one third of the sites. Obviously, there is "overlap" of the general categories since one problem often generates others. Extremely low temperatures, for example, may affect both power supply and the operation of tape recorders. Nevertheless, given personnel changes, the fact that the survey responses were completed in many cases by more than a single individual, and the lack of detail contained in some of the surveys, it is most likely that these are conservative estimates of the extent to which these problems have surfaced within LTER.

Although the most detailed information concerning these problems and their solutions can be found in the individual survey responses, this is an appropriate place to summarize some of the easier solutions to common problems. Power reduction and loss effects can be minimized by *greatly* exceeding the manufacturer's recommendations for both power reserves and grounding, as well as ensuring that system resistance is kept low (NWT). The effects of low temperature on tape recorder operation have been minimized through the use of thermostatted heat tape (KNZ). Exhalation near tapes and/or tape heads should be avoided during cold weather (AND). Other magnetic tape reading problems have been minimized by elimination of the use of high-quality tapes (less noise) and by matching the heads of the machines used for playback with those used for recording (BNZ). Radio telemetry has been an effective alternative to magnetic

**Table 3.** Hardware peripheral to electronic data collection at 14 Long-Term Ecological Research and 2 National Park Service sites . Computers and data loggers are not included in this list.

Item	AND	ARC	BNZ	CPR	CWT	HBR	HFR	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
<b>Temperature and relative humidity:</b>																
CSI thermistors	X				X			X			X	X	X	X	X	
FE thermistors			X	X								X	X		X	X
CSI probes		X	X	X	X	X		X	X		X	X	X	X	X	X
PCR PCRC-11 RH sensor			X		X							X	X	X	X	X
Li-Cor sensors							X								X	
Vaisalla sensors	X		X													
Omni sensors			X									X				
Brady array RH sensors						X										
WT Humicap 5120 RH probes								X								
Everest infrared thermometers								X								
II silicon diodes	X															
Copper-constantin wires		X	X													
Thermocouples	X							X								
<b>Wind speed and direction:</b>																
CSI M-O windspeed sensors		X		X		X		X	X				X		X	X
CSI M-O wind direction sensors		X		X		X		X	X				X		X	X
RM Young anemometers	X		X								X	X		X		
RM Young windvanes	X										X					
S-M 1036 anemometer and vanes			X													
BIC 5-349A anemometers				X												
WT microresponse anemometers								X								
WT microresponse vanes - 2020								X								

CSI=Campbell Scientific Instruments; FE=Fenwal Electronics; PCR=Phys-Chemical Research; WT=Weathertronics; II=Interface Instruments; M-O=Met-One; S-M=Sierra-Misco; BIC=Belfort Instrument Company. CSI thermistors include but are not necessarily limited to models 107, 107B, and 108B. FE thermistors include but are not necessarily limited to models JB32L1 nonlinear and UUT51J1 thermistors. CSI probes include but are not necessarily limited to models 201, 207, HMP35C temperature/relative humidity, 105T thermocouple, and 101 temperature probes. Vaisalla sensors include but are not necessarily limited to model HMP23U capacitive humicaps. Omni sensors include models ES-60 and ES-110. Li-Cor sensors include models 1000-15 soil and 1000-16 air temperature sensors. CSI M-O windspeed sensors include but are not necessarily limited to model 014A. CSI M-O wind direction sensors include but are not necessarily limited to model 024A. RM Young anemometers include models 6101, 06102, 03001, and 05103. RM Young windvanes include models 05305 and 6301. WT microresponse anemometers refer to model 2030. Refer to the individual surveys for greater detail.

**Table 3 (continued).** Hardware peripheral to electronic data collection at 14 Long-Term Ecological Research and 2 National Park Service sites . Computers and data loggers are not included in this list.

Item	AND	ARC	BNZ	CPR	CWT	HBR	HFR	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
<b>Radiation:</b>																
Li-Cor radiometers		X	X	X			X		X		X		X	X	X	X
Eppley radiometers					X			X			X					
Kipp and Zonnen radiometers	X											X				
Fritschen radiometers				X												
<b>Precipitation and water depth:</b>																
BIC gauges			X	X		X			X						X	
Sierra-Misco, Inc. rain gauges			X								X				X	X
Texas Electronic rain gauges	X	X											X	X		
Druck pressure transducers	X	X	X						X							
Weathertronics gauges								X					X			
Weather Measure gauges						X		X								
SCS snow pillows			X									X				
KAVSG pressure sensors			X													
MRI rain gauges								X								
"Homemade" gauges													X			
Stevens depth transmitters															X	
Instrumentation gauges																X

BIC=Belfort Instrument Company; MRI=Meteorology Research, Inc. Li-Cor radiometers include but are not necessarily limited to pyranometers, radiation probes, and quantum sensors in the following models: 525, 6820, LI-190SA, LI-190SB, LI-190SZ, LI-192SB, LI-200S, LI-200SA, LI-200SB, LI-200SZ, LI-200SCZ. Eppley radiometers include Weathertronics Eppley precision pyranometer model 3015 PSP, Eppley model 8-48 radiometer, Eppley model PSP, and Eppley model PIR. Kipp and Zonnen radiometers include the CM5 thermopile and model CM-11 pyranometer. Fritschen radiometers refer to the RN model B net radiometer. BIC gauges include but are not necessarily limited to models 5915-20 and 5915-12 (with 6071P potentiometer) of weighing and tipping bucket rain gauges, as well as Belfort #900 acoustic depth gauges. Sierra-Misco, Inc. rain gauges include but are not necessarily limited to model 2501 tipping bucket rain gauges. Texas Electronics rain gauges include but are not necessarily limited to model TE525 tipping bucket gauges. Druck pressure transducers include the PDCR 10D and PDCR 930TI models. Weathertronics gauges include models 6032 weighing bucket rain gauges and 6021-D heated rain and snow gauges. WeatherMeasure gauges include but are not necessarily limited to model 6011 tipping bucket rain gauges. MRI rain gauges refer to model 302 tipping bucket rain gauges. Stevens depth transmitters refer to the submersible model SDT-II 2.5. Instrumentation gauges refer to Instrumentation N.W. model PS9002 0-5 PSIG.

**Table 3 (continued).** Hardware peripheral to electronic data collection at 14 Long-Term Ecological Research and 2 National Park Service sites : Computers and data loggers are not included in this list.

Item	AND	ARC	BNZ	CPR	CWT	HBR	HFR	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
<b>Soil moisture:</b>																
227 Delmhorst gypsum blocks	X		X	X				X					X			
Soiltest SM/T cells		X														
Beckman ES-260 sensors			X													
Watermark SM sensors			X													
SMS tensiometers			X													
Omega transducers			X													
Time domain reflectometers					X											
CPNC hydroprobes								X								
<b>Vapor pressure/evaporation:</b>																
WM evaporation gauges		X	X													
Interface lysimeters				X												
<b>Barometric pressure:</b>																
YSI transducers		X														
AIR intellisensors													X			
<b>Snow moisture:</b>																
PM 120-R1-SS pressure pillows	X															
Druck pressure transducers	X															
<b>Soil salinity:</b>																
SME 500-A soil salinity sensors			X													
<b>Atmospheric gas concentrations:</b>																
Thermoelectron monitors					X											
Gas chromatographs													X			

WM=Weather Measure; AIR=Atmospheric Instrumentation Research; PM=Park Mechanical; SME=Soil Moisture Equipment. Soil moisture includes soil water content and soil water potential. The 227 Delmhorst gypsum blocks include but are not necessarily limited to those manufactured by Campbell Scientific Instruments and Soil Moisture Equipment. Soiltest SM/T cells refer to Soiltest soil moisture and temperature cells. SMS tensiometers refer to Soil Measurement Systems tensiometer pressure transducers. Omega transducers refer to Omega PX142005 D 5V silicon diaphragm transducers. CPNC hydroprobes refer to Campbell Pacific Nuclear Corporation model 503 hydroprobes (neutron depth moisture gages). WM evaporation gauges include but are not necessarily limited to Weather Measure model 6844-A evaporation gauges. Interface lysimeters refer to Interface, Inc. AJ-50 load cell lysimeters. YSI transducers refer to YSI model 214 barometric pressure transducers. Druck pressure transducers refer to Druck PDCR10D pressure transducers. Thermoelectron monitors refer to Mod 49 thermoelectron O3 monitors. Gas chromatographs refer to HP and Shimadzu gas chromatographs.

**Table 3 (continued).** Hardware peripheral to electronic data collection at 14 Long-Term Ecological Research and 2 National Park Service sites . Computers and data loggers are not included in this list.

Item	AND	ARC	BNZ	CPR	CWT	HBR	HFR	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
------	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

**Tape and cassette recorders:**

Panasonic recorders			X			X						X				
CSI cassette recorders									X						X	
Memodyne cassette readers	X															
GE 3-50150 recorders			X													
Tandy CCR-82 26-1209 recorders						X										
Realistic CTR-75 tape recorders						X										

CSI=Campbell Scientific Instruments; GE=General Electric. Panasonic recorders include but are not necessarily limited to RQ-8300 recorders. CSI cassette recorders include but are not necessarily limited to RC235 recorders. Memodyne cassette readers refer to model M80 readers.

**Table 3 (continued).** Hardware peripheral to electronic data collection at 14 Long-Term Ecological Research and 2 National Park Service sites . Computers and data loggers are not included in this list.

Item	AND	ARC	BNZ	CPR	CWT	HBR	HFR	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
<b>Miscellaneous:</b>																
CSI data storage modules	X	X			X						X		X	X	X	X
CSI C20 cassette interfaces			X	X								X				
CSI 235 cassette interfaces						X			X							
CSI model SM232 interfaces	X															
CSI model AM32 relay scanners	X															
CSI model MSX10R solar panels	X															
Deep cycle batteries	X											X				
Radiation shields	X															
CSI model A21REL relay drivers	X															
E-PROM data storage packs		X														
Amphenol #MS3101A-14S-6P			X													
Amphenol #MS3106A-14S-6S			X													
Bendix strain reliefs			X													
Tektronix cable testers					X											
Thermoelectron monitors					X											
Li-Cor DTE/DTE cables							X									
Li-Cor gender changers							X									
WT signal condition modules								X								
CSI AM416 relay multiplexers								X								
CSI DC112 1200 baud modems								X								
Li-Cor terminal blocks															X	

CSI=Campbell Scientific Instruments. CSI data storage modules include models 16, SM64, SM192, and SM196. CSI 235 cassette interfaces include models A235 tape terminal and SC235 CR21 cassette connector interfaces. Deep cycle batteries refer to deep cycle marine and golf-cart batteries. Radiation shields are for temperature and relative humidity sensors. Bendix strain reliefs refer to model #MS3057-6C. Thermoelectron monitors refer to Mod 49 thermoelectron O3 monitors. Li-Cor DTE/DTE cables refer to model 1000-03 RS-232 DTE/DTE cables. Li-Cor gender changers refer to model 9900-002 gender changers. WT signal condition modules refer to Weathertronics model 1018/1023 signal condition modules. Li-Cor terminal blocks include models 1000-05 and 1000-06 terminal blocks.

**Table 4.** Problems associated with electronic data collection and encountered at 14 Long-Term Ecological Research and 2 National Park Service sites.

Item	AND	ARC	BNZ	CPR	CWT	HBR	HFR	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
Power reduction or loss	X	X	X			X	X			X		X	X		X	X
Extreme temperature effects	X	X			X	X			X		X	X	X	X	X	
Animal/insect impacts	X	X		X	X			X				X	X	X	X	
Moisture penetration/condensation	X		X		X	X	X			X		X				X
Deterioration of equipment/sensors	X		X		X	X	X				X	X			X	
Magnetic tape reading problems	X		X		X	X			X			X		X		
RH measurement problems			X		X						X	X	X	X	X	
Dirty sensors		X					X	X	X				X	X	X	
Data storage capacity exceeded		X	X			X				X		X				X
Human (user) errors			X			X				X			X		X	
Lightning damage	X					X				X		X				
Wind damage						X				X	X	X				
Poor contacts/shorts/fused switches	X					X							X		X	
Faulty wiring/improper grounding						X				X	X	X				
Frozen anemometer cups	X					X							X	X		
Temperature measurement problems	X		X			X						X				
Inadequate precision/accuracy		X			X							X				
Windspeed sensor bearing failure				X				X			X					
Software/programming problems							X	X							X	
Data logger channel problems						X		X					X			
Communication problems								X	X	X						
Windvane potentiometer failure											X	X	X			
Soil too dry for gypsum blocks	X												X			
Snow accumulation problems	X											X				
Anomalously high wind speeds			X			X										
SR measurement problems						X						X				
Anomalously low wind speeds						X							X			
Broken/cut wiring			X									X				

RH=relative humidity; SR=solar radiation.



**Table 4 (continued).** Problems associated with electronic data collection and encountered at 14 Long-Term Ecological Research and 2 National Park Service sites.

Item	AND	ARC	BNZ	CPR	CWT	HBR	HFR	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
Calibration problems						X						X				
Salt-related corrosion										X					X	
Defective circuit cards	X															
Improperly cleaned circuit boards	X															
LiCl wick contamination	X															
Snow loading problems	X															
Dirty sensors		X														
Ice accumulation problems		X														
Faulty data storage packs			X													
Inaccurate soil thermistor readings			X													
Soil too wet for gypsum blocks			X													
Snow pillow leaks			X													
Tensiometer leaks			X													
Lysimeter load cell failure				X												
Sensors too sensitive					X											
Tipping bucket heater failure						X										
Weighing bucket failure								X								
Improper data logger maintenance								X								
Sympathetic currents (marine air)										X						

tape transfer of data (NWT).

Mammals, and particularly rodents, have chewed on sensors, wires, and other field equipment. Isolation of equipment in PVC conduit (AND) or by burial (BNZ) have been successful tactics. Spider webs have obscured sensor surfaces (JRN), created electrical shorts (SEV), and interfered with the moving parts on some instruments (VCR). Moth balls have been used with success in the latter instance.

The effects of moisture/condensation were best avoided through preventative maintenance, e.g. frequent examination of instruments and replacement of dessicant. Enclosure of sensitive instruments (data loggers and terminal blocks) in picnic coolers have worked at HBR.

Deterioration of equipment and sensors likewise was best avoided through preventative maintenance, specifically by the timely replacement of suspect components. Awareness of a problem common to the electronic measurement of relative humidity (RH) in LTER provided the initial impetus for the current project (Appendix 1). This and many of the other RH measurement problems seemed to be common to the Phys-Chemical Research PCRC-11 RH sensor used in CSI temperature/relative humidity probes. There is evidence that these sensors can become temporarily ineffective (VCR) or even permanently damaged (NWT) when saturated. Moreover, their "reliable" lifetime under even normal conditions has been questionable (BNZ, CWT, NWT, SEV, IRP, ONP). While replacement times have been generally on the order of a year, these sensors were being phased out at several sites (BNZ, NWT, VCR). Alternative replacement sensors and/or probes have been identified at BNZ and VCR. Wind measurement equipment has also been prone to relatively rapid deterioration, with the weakest links being in failure of windspeed sensor bearings (CPR, JRN, NTL) and wind vane potentiometers (NTL, NWT, SEV).

Gypsum blocks were ineffective for the measurement of soil moisture under very dry conditions (AND, SEV), as well as in saturated sandy soil (BNZ).

## **5. Maintenance**

The frequency of maintenance depended on the particular procedure and piece of equipment involved, and varied from daily to biennially. Seasonal differences in maintenance frequency were reported at 6 of the sites.

## **6. Calibration**

Similarly, the frequency of calibration depended on the particular piece of equipment involved, and varied from weekly to biennially. In general, calibrations were less frequent than maintenance procedures. Only 2 sites reported seasonal differences in calibration frequency. Typically individual sensors were replaced rather than calibrated

and large, complex instruments were returned to the manufacturers for calibration.

## **7. Storage, Transfer, and Archival**

Internal memory/solid state were field storage media at more than 50% of the sites (Table 5). Data storage modules or packs also were used at more than 50% of the sites. The latter have minimized data losses through increased storage capacities at a number of sites. Although magnetic tape was used for field storage at only 3 sites, more than one third of the sites employed this medium for transfer of data from the field to the laboratory. Solid state and phone cable were each used at about one third of the sites for data transfer.

All but 2 of the sites reported computer hard disks as archival or storage media (Table 6). Floppy diskette and magnetic tape were the other preferred media, with usage acknowledged by 13 and 9 sites, respectively. Nearly 50% of the sites reported ASCII as a storage or archival format.

## **8. Quality Assurance/Quality Control (QA/QC)**

The vast majority of the sites employed redundant measurement systems and greater than 50% reported regular examination of equipment and/or data as being components of their field QA/QC protocol (Table 7). A variety of commercial software and programs were used, in addition to a number of "homegrown" programs, for QA/QC in the laboratory. In general, these programs performed range checks and or outlier searches, and often produced graphs which were visually inspected for anomalous values. Files were often manually edited, e.g. questionable values were removed or flagged, to improve the quality of a data set.

A number of sites have, at one time or another, attempted to quantify the relationships among redundant measurement systems. In some cases, concurrence of such systems was limited and represented the transition from one data collection system to another. With the exception of dewpoint temperature, correlations between data collected with Interface Instruments M4 (which contained similar sensors to the previous chart recorder system) and those collected by CSI CR21X dataloggers which superseded it were very high (AND). Correlations between chart recorder and CSI CR10 temperatures were also high ( $r^2 \geq .98$ ) (AND). Although differences among redundant measurement systems have been reported as insignificant (JRN), there have been cases of significant differences between datalogger data and those collected by other means (HBR). A detailed comparison of chart recorder, datalogger, and datapod data was recently carried out at NWT. The results indicated that the relationships were complex and frequently nonlinear. Moreover, there is evidence that it is unclear as to what are acceptable differences between the primary and backup/calibration measurement systems (e.g. CWT).

**Table 5.** Hardware and software used for (field) storage and transfer (from field site to laboratory) of electronically collected data at 14 Long-Term Ecological Research and 2 National Park Service sites.

Item	AND	ARC	BNZ	CPR	CWT	HBR	HFR	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
<b>Field storage:</b>																
Internal memory/solid state	X			X	X		X	X	X		X	X	X			X
Data storage modules/packs	X	X	X		X						X		X	X	X	X
Magnetic tape	X					X			X							
Strip chart	X															
None (immediate transfer)										X						
<b>Transfer:</b>																
Magnetic tape	X		X	X		X			X			X				X
Solid state	X				X		X							X	X	X
Phone cable								X	X	X	X		X			
RS 232	X	X														
CSI C20 interface				X								X				
Basic program(s)												X			X	
Portable computer	X															
PC-NFS				X												
Li-Cor program								X								
DTE/DTE cables								X								
Radio telemetry												X				
SMCOM software														X		

CSI=Campbell Scientific Instruments. Li-Cor program refers to the Li-Cor 1000-90 communications utility program. Information regarding manufacturers and models for the items contained in this table may be found in Tables 2 and 3, as well as in the individual survey responses.

**Table 6.** Archival and storage media and formats for electronically collected data at 14 Long-Term Ecological Research and 2 National Park Service sites.

[illegible]

**Table 7. Quality assurance/quality control (QA/QC) approaches and tools used for electronically collected data at 14 Long-Term Ecological Research and 2 National Park Service sites.**

Item	AND	ARC	BNZ	CPR	CWT	HBR	HFE	JRN	KNZ	NIN	NTL	NWT	SEV	VCR	IRP	ONP
<b>Field:</b>																
Redundant measurement systems		X	X		X	X	X	X	X		X	X	X		X	X
Inspection of equipment/data	X		X	X			X	X		X	X				X	
<b>Laboratory:</b>																
Range checks/outlier searches	X		X	X	X	X		X	X	X	X	X	X			X
Visual inspection (eg. graphs)	X		X		X		X	X	X	X	X	X	X			X
"Homegrown" software/programs	X			X		X		X		X			X	X		
Edits (e.g. removal, flags)	X				X	X		X			X	X		X		
Fortran programs	X		X					X								X
SAS routines			X		X				X							
CSI PC208 software								X								X
QuickBasic routines								X						X		
Spreadsheet software							X									
QuattroPro software								X								
SYSTAT 5.0 software												X				
Excel software											X					
Basic programs																X

CSI=Campbell Scientific Instruments. Redundant measurement systems (e.g. charts, duplicate sensors, etc.) may be of variable distance from the primary measurement location. See individual survey responses for more information.

The ability to detect problems quickly is a necessary component of an effective QA/QC program and some newer products may be useful in this regard (BNZ).

## **9. Ideal System**

Although a number of sites complained of inadequate precision or accuracy for some measurements (Table 4), it is also apparent that the sensitivity of some of the instruments was greater than required. A better parameter estimate is likely to be achieved with replication, rather than with more precise instrumentation (BNZ). Greater precision is not without cost and at least one site (NWT) is planning to continue use of chart recorders for some primary measurements.

Greater compatibility among the products produced by the different manufacturers would be desirable (IRP) and would certainly provide greater flexibility in any electronic data collection system.

Photovoltaics (NIN, NWT) were reported as being the ideal power source for remote sites.

Of course, the ideal system would be "something that works all the time and never gets out of 'date'" (KNZ).

## **10. Contact People**

The following names were provided as contact people for clarification of survey responses. Additional information (e.g. addresses, phone numbers, electronic mail addresses) is available in the individual survey responses.

AND	Fred Bierlmaier
ARC	Jim Laundre
BNZ	Phyllis Adams, Bob Schlentner, Mark Klingensmith
CPR	Tom Kirchner
CWT	Barry Argo, Lloyd Swift, Bob McCollum
HFR	Gary Carlton
HBR	Cindy Veen
JRN	Barbara Nolen
KNZ	John M. Briggs
NWT	Mark Losleben, Rick Ingersoll
NIN	Danny Taylor, Scott E. Chapal
NTL	Tim Kratz
SEV	Douglas Moore
VCR	Dave Krovetz
IRP	David Toczydlowski, Robert Stottlemeyer
ONP	Robert Edmonds, Roger Blew, Tina Lipman



## CONCLUSIONS AND RECOMMENDATIONS

During the past decade, the LTER has embraced electronic data collection systems, a young and growing technology, for the measurement of a number of variables. Differences existed among the individual sites in terms of variables measured and hardware, software, and protocols employed. Nevertheless, there was considerable common ground as evidenced by the problems encountered and the solutions employed to deal with those problems.

Climatological variables were measured at virtually every site and, for the most part, these data were being collected by automated electronic equipment. Given the high visibility of the LTER program (and the variety of biomes it represents), increased interest (and opportunity) for data exchange, and rising concern over global climate change, it is likely that the LTER climatological data sets will undergo increasing scrutiny in the coming years. For this reason, and because reliance on a rapidly evolving technology dictates a dynamic situation, it is important *that the evaluation of electronic data collection within LTER be considered an ongoing and regular process.*

The immediate task is determination of the form of that process. The ideas and suggestions contained in the following paragraphs are meant to provide a starting point for a discussion that ultimately leads to a LTER strategy for the regular evaluation of electronic data collection. The suggestions and options are not necessarily mutually exclusive and some aspect of each might be incorporated into such a strategy.

Individual sites and the LTER program as a whole would benefit from more frequent exchange of information on both the inter- and the intra-site level. It seems very likely that the individuals (field personnel) actually involved in the electronic collection of data at the sites often are insulated from one another and are left to their own devices in terms of purchase decisions and solution of problems. While experimentation, experience, and intuition are satisfactory at dealing with these sorts of things, the knowledge of prior success is generally more expedient. A good first step toward information exchange at this level would be for the appropriate personnel to have access to a complete (i.e. including the individual survey responses) copy of this document as soon as possible. **It is therefore recommended that the LTER network distribute a copy of this document to the data manager at each site with instructions to make it known by and available to all field personnel involved in electronic data collection.** In addition, a copy should be made available to each of the two National Park Service sites that contributed responses. The formation of a new group, on electronic data collection technology, within the LTERnet mail forwarding system would provide a means of continued exchange of information, once the bulk of this report has become obsolete.

Superimposed on this is another information gap that probably exists to varying degrees at a number of sites. The field person responsible for the collection of the climatological data, the data manager, and the investigator using the data are, in many

cases, different individuals. These individuals should be encouraged to interact on a regular, if infrequent, basis at each site to ensure that data are of acceptable quality. The LTER Network Office, Climate Committee, and data managers could provide some leadership here. The Standardized Meteorological Measurements for Long Term Ecological Research Sites prepared by the LTER Climate Committee in 1986 was necessarily general and thus did not specifically address electronic data collection. Now that it has become apparent that the large majority of climatological variables in LTER are being measured electronically, the **Standardized Meteorological Measurements for LTER needs to be updated and modified to reflect this awareness.** A section on troubleshooting would be beneficial (ARC).

Since technology has generated the need for a new document in 5 years, it is recommended that **this new SMM for LTER should be in ASCII format and available online** in much the same way that the LTER Personnel Directory is. The Electronic Data Collection Survey could be streamlined and modified so that it could provide much of the information necessary for an annual update of the online SMM for LTER. Checklists (similar to the "items" in the tables in this report) could be provided, for example, to facilitate the completion as well as the evaluation of the survey.

**The LTER should become active in the provision of feedback to the manufacturers of electronic data collection hardware and software.** The survey responses and other sources indicate that the leaders in this industry are generally responsive to the needs of their customers. Presumably, responsiveness would be enhanced if they were approached by an organized group rather than by an individual from one or another site. A working group could be formed that includes representatives from the scientists, data managers, and field technicians within LTER. This group could communicate on a regular basis via email, be involved with distribution and evaluation of the survey, and meet on an infrequent but regular basis (e.g. at All Scientists Meetings or data managers meetings). Moreover, this group would be in contact with the manufacturing industry for the purposes of providing feedback regarding their products. Such feedback should include needs and suggestions, as well as notification of problems. Additionally, interaction with other scientific organizations such as the Department of Energy Research Parks, National Center for Atmospheric Research, National Oceanic and Atmospheric Administration, National Park Service, National Weather Service, U.S. Geologic Survey, etc. could be mutually beneficial.

