SECTION 1

INTRODUCTION

1.1 Forest Response Program

The Forest Response Program, sponsored by Task Group V (Terrestrial Effects) of the National Acid Precipitation Assessment Program (NAPAP), is a national research program initiated by the EPA, the USDA Forest Service, and industry designed to study the effects of acidic deposition and associated pollutants on forest ecosystems. These effects are studied through a combination of field, controlled environment, and laboratory experiments, concomitant modeling, and the integration of research results at a national level. The research program was formulated to answer three policy-related questions:

1. Is there a significant problem of forest damage in North American which might be caused by acidic deposition, alone or in combination with other pollutants?
2. What is the causal relationship between acid deposition, alone or in combination with other pollutants, and forest damage in North America?
3. What is the dose-response relationship between acidic deposition, alone or in combination with pollutants and forest damage in North America?

Research to answer these questions is being conducted within four research cooperatives with the assistance of two support programs. Research cooperatives, defined as interacting

groups of scientists working on integrated, multidisciplinary research projects organized to examine a particular forest type, are based in four geographic areas corresponding to broad forest classes: Spruce-Fir, Southern Commercial, Eastern Mixed Hardwoods, and Western Conifers. Supporting research and monitoring will come from the National Vegetation Survey (NVS) and the Atmospheric Exposure Cooperative (AEC), providing inventory data on forest conditions and air quality monitoring data, respectively (Figure 1.1). National Program Management is also supported by a Quality Assurance Staff and a Synthesis and Integration Staff.

1.2 Quality Assurance

The Deputy National Program Manager is charged with managing the Forest Response Quality Assurance program under the interagency agreement between the EPA and the USDA Forest Service. The responsibility for organizing and managing the Quality Assurance (QA) program is delegated to the QA Officer at ERL-Corvallis who will be supported initially by four trained individuals: (1) a QA Coordinator located at ERL-Corvallis to assist in program implementation and to coordinate QA Staff activities; and (2) three QA Specialists located at Research Cooperative offices to provide QA support to the cooperative and associated researchers. Figure 1.2 displays the organizational structure of the QA Staff.

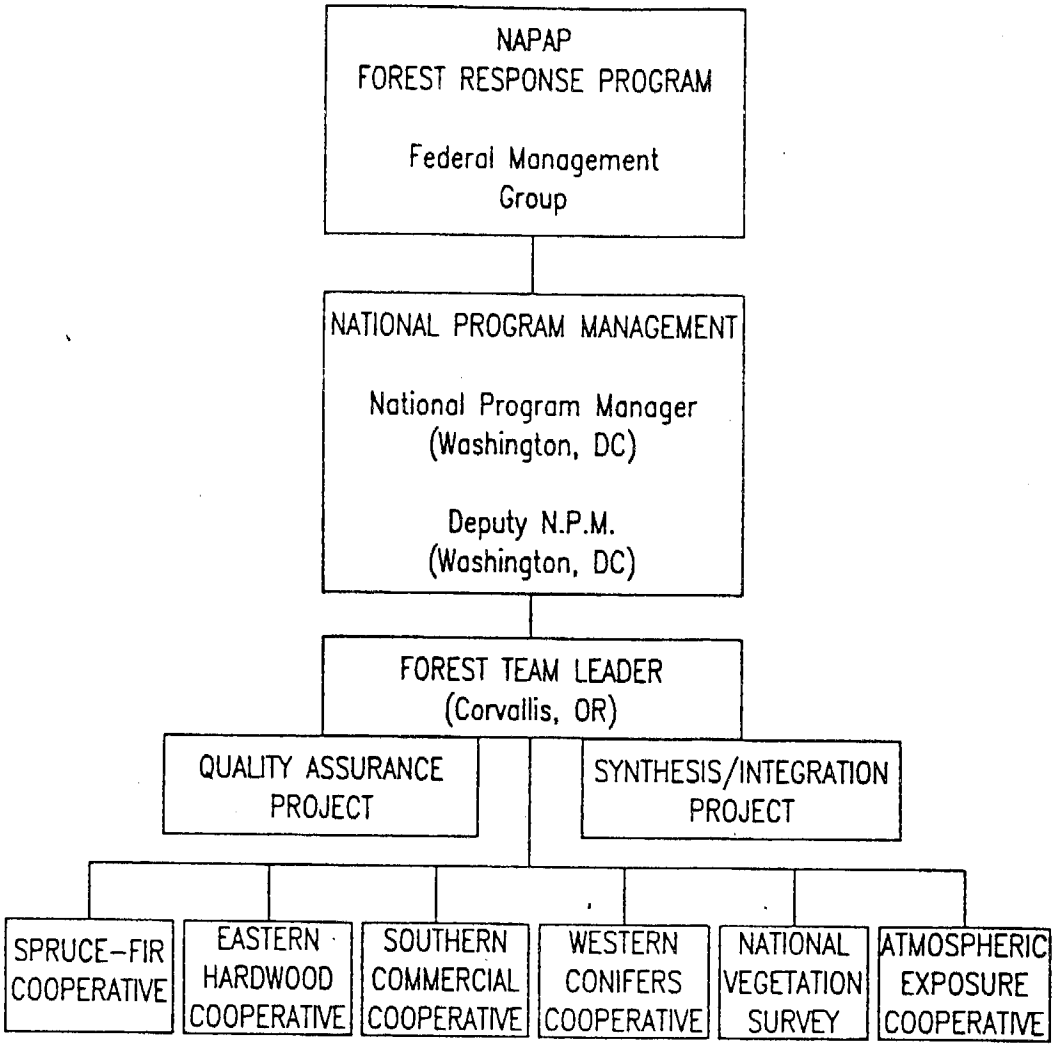
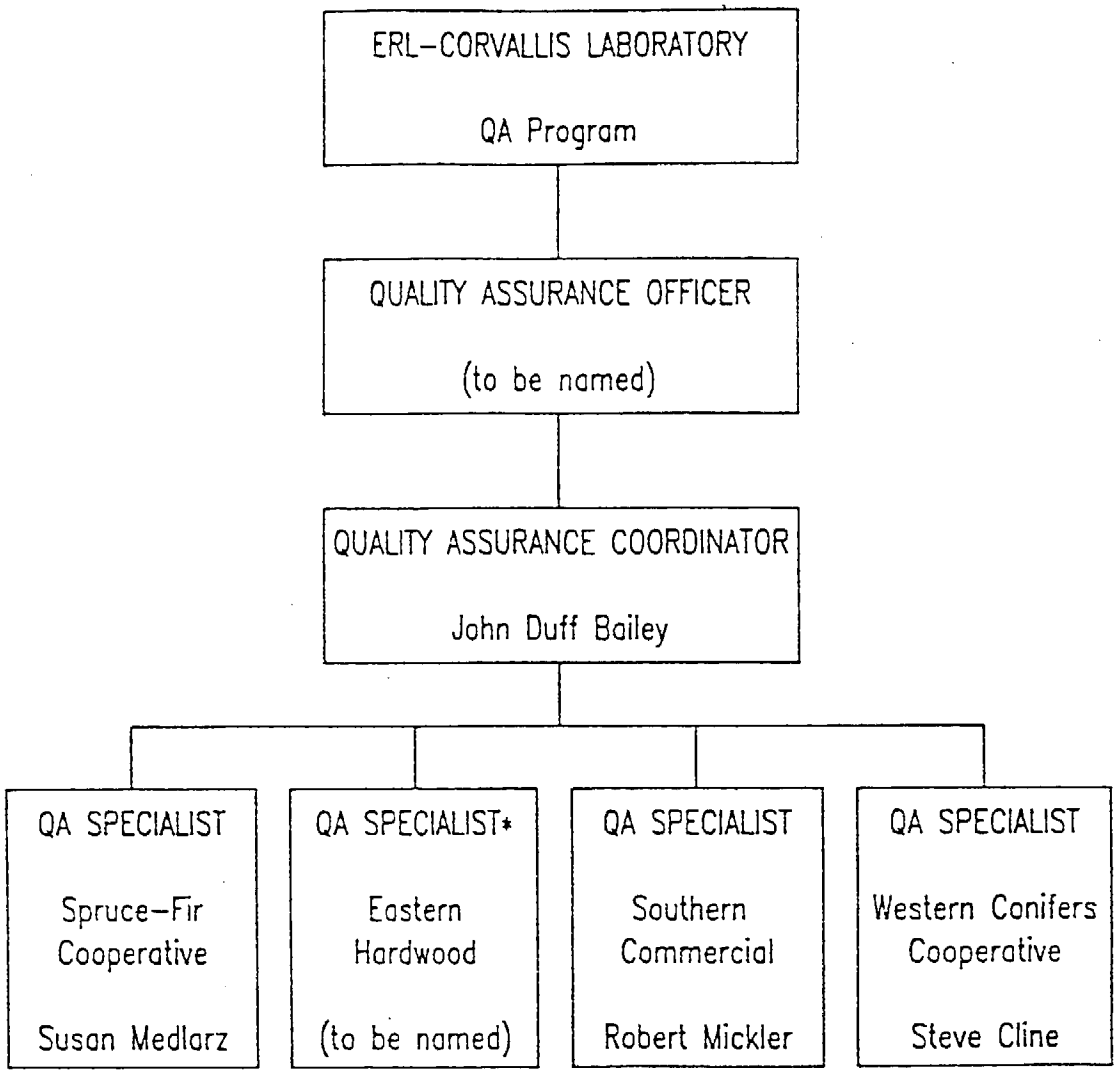


Figure 1.1 Organizational structure for the Forest Response Program showing Quality Assurance as a support function to the Forest Team Leader. The Forest Team Leader maintains line management over the QA and Synthesis/Integration Staffs and programmatic supervision over the Research Cooperatives and Support Cooperatives. The Quality Assurance Staff organization is expanded in Figure 1.2



*responsibilities/duties given to Steve Cline

Figure 1.2. Quality Assurance Staff organization structure expanded from Figure 1. This figure shows direct line management of QA Staff. QA support for the Atmospheric Exposure Cooperative (AEC) is currently functioning as a separate entity through ASRL-RTP. Close coordination with the AEC is anticipated. The ERL-Corvallis QA Staff provides oversight for the Forest Response Program QA Staff. QA for National Vegetation Survey projects is provided by the QA Specialist for each related cooperative.

The QA goal in the Forest Response Program (FRP) is to ensure that Forest Response Program data are of known and sufficient quality to meet their intended use for the syntheses and integration of research results leading to the assessment of atmospheric deposition effects on forest ecosystems. The following objectives are designed to achieve this goal:

1. Provide guidance, reinforcement, and resources to the investigators for the implementation of QA activities;
2. Assure comparability of research and QA activities across sites and over time;
3. Examine, evaluate, and adjust research and QA activities to ensure continued compliance with standard or approved protocols and procedures; and
4. Provide evidence of research data quality through qualitative and quantitative evaluations.

The need exists for monitoring and controlling data quality and standardizing procedures, given the biological nature of Forest Response Program research, the number of sites conducting the research, and the duration of the program. Due to the assessment and (possible) regulatory nature of the work, the results of the research may be challenged by the scientific and legal communities. Full documentation of procedures and results (with accompanying data quality information) will provide a scientifically and legally defensible position during procedures. The QA program will be periodically evaluated under a separate peer review process.

Ideally, an integrated QA program, such as that for the Forest Response Program, begins with the assessment of the intended use of the data and, thereby, a description of the data needed to support a decision. Decision-makers can establish the level of quality needed to make the data usable from this knowledge, stated as Data Quality Objectives (DQOs). Given those, the researchers should design the appropriate systems of methods, protocols, quality control checks, responsibilities, and documentation procedures needed to produce the needed data, the quality of which is documented and sufficient to meet its intended use. This system is documented in a QA Project Plan which, beginning with FY87 projects, must be approved by National Program Management before the project is funded and research begins. DQOs have been specified for the Forest Response Program without an exact assessment of its intended use, but have provided limited guidance to investigators for developing QA Plans. The QA Staff will review research facilities periodically to determine if investigators are following the procedures described and if data are of known and sufficient quality.

The strength of the QA program rests in: (1) establishing appropriate guidance for Data Quality Objectives (DQOs), (2) sufficiently documenting procedures and protocols, and (3) effective auditing. Resources for national planning and management of the QA program, performance evaluation and auditing, and production of documentation were defined by the interagency agreement as an inseparable part of the research

effort. Budgeting by researchers for QA will depend on the extent and nature of QA/QC activities, dependent on the individual research projects. Costs which must be considered when designing QA/QC activities for individual research projects include: maintaining records and documentation, delegating personnel for tracking samples and checking data, and running necessary control samples to allow for estimation of accuracy (inter-laboratory exchange and control samples) and precision (replicates).

The ERL-Corvallis Laboratory QA Staff, managed by Jim McCarty, will oversee and provide guidance to the Forest Response QA Program including reviews of documentation and selected research projects. The QA Implementation Plan, national Data Quality Objectives Document, and QA Methods Manuals will be evaluated by the Laboratory QA Staff. They will periodically review research sites in conjunction with normal FRP auditing procedures to evaluate the implementation of documented procedures. The Laboratory QA Staff will be responsible for ensuring compliance with ERL-Corvallis QA guidelines when feasible within the Forest Response Program.

1.3 Definition of Terms

The following list defines terms and acronyms used in this document as they specifically apply to the QA Program.

Quality Control (QC) -- Quality Control is a set of routine activities conducted during a research effort to maintain quality

in sample collection, analysis, and recording. It is a scientific function performed by research staff.

Quality Assurance (QA) -- Quality Assurance is a program of planned systematic activities conducted before, during, and after a research effort to assure that specified data quality objectives (DQOs) are achieved for a given project. It is a management function which continually evaluates the adequacy and effectiveness of QC activities and provides for correcting problems where necessary. Quality assurance programs include the organization, management, and documentation of quality control activities.

Data Quality Objectives (DQOs) -- Data Quality Objectives are quantitative and qualitative objectives and guidance set by decision-makers before initiation of a research project. These objectives define the accuracy and repeated measurement error tolerance limits and identify sources of error common to the data being collected. Researchers respond to these limits.

Environmentally-Related Measurement -- Any field or laboratory investigation involving (1) assessment of chemical, physical, or biological parameters in the environment, (2) determination of the presence or absence of criteria or priority pollutants, (3) economic assessments and health and ecological effects, (4) conduct of clinical and epidemiological investigation, (5) performance of engineering or process evaluation, (6)

study of laboratory simulation of environmental events, and/or (7) study of measurement of pollutant transport and fate, including diffusion models. Most measurements taken in the Forest Response Program, with little exception, are considered environmentally related.

Standard Operating Procedure (SOP) -- A documented procedure which describes, in detail, an operation, analysis, or action which is commonly accepted as the preferred method for performing certain routines or repetitive tasks (Table 2.1). Standard operating procedures are supported by citations from various published documents that describe relevant procedures.

Repeated Measurement Error (RME) -- The degree to which data generated from repetitive measurements, repeated in time or by other personnel or equipment, are similar to one another. A large RME results in a large variation or dispersion of data points about the true value, assuming no bias.

Accuracy -- Accuracy is expressed as a percent "miss" from the true value. Inaccuracy in measurements, or bias, results in the faulty estimation of true values, the estimation of which may be precise or imprecise. Both bias and imprecision result in poor estimations of true values.

Completeness -- The amount of valid data obtained from a measurement system compared to the amount that was expected to be

obtained under correct normal operations, usually expressed as a percentage.

Comparability -- A measure of the confidence with which one data set can be compared to another, based upon an assessment of the similarities and differences in experimental design, objectives, methods, and analyses.

Representativeness -- The accuracy and precision with which a measurement represents a sample characteristic or a sample represents a population.

Other Acronyms:

ADQ -- Audits of Data Quality
DNPM -- Deputy National Program Manager
FMG -- Federal Management Group
FRP -- Forest Response Program
MSA -- Management Systems Audits
PE -- Performance Evaluations
PI -- Principal Investigator
QAO -- Quality Assurance Officer
QAC -- Quality Assurance Coordinator
QAS -- Quality Assurance Specialist
TSA -- Technical Systems Audits

SECTION 2

QUALITY ASSURANCE PROCEDURES

2.1 Documentation

Documentation for the Forest Response QA Program consists of: a national QA Implementation Plan (revision 1 pending approval), a national DQO Document (in draft), four national Methods Manuals (in revision), and QA Project Plans for Cooperatives (in draft) and individual research projects (various stages). The Implementation Plan provides the overall framework for supplemental documentation, as follows:

2.1.1 Quality Assurance Implementation Plan

The Quality Assurance Implementation Plan, this document, defines and describes quality assurance and quality control policies and responsibilities required by the Forest Response Program. It is designed to assist Forest Response Program researchers in the uniform implementation of QA requirements. This includes initial planning and documentation of: intended use of the data; Data Quality Objectives; sampling, measurement, and analytical procedures; Standard Operating Procedures (SOPs) ; auditing and quality control functions; and reporting requirements.

The Implementation Plan is distributed to all participants in the Forest Response Program at the time of funding. Annual revisions of certain sections are scheduled to coincide with

annual reports to National Program Management in February of each year. The Implementation Plan and overall QA program will be periodically peer reviewed to insure continued appropriateness to the FRP, beginning in May 1987.

2.1.2 Data Quality Objectives Document

Data Quality Objectives (DQOs), are qualitative and quantitative statements of the quality of data needed to support specific research decisions supporting regulatory actions. These objectives are considered an integral part of the overall program to evaluate effects of acidic deposition and associated pollutants on forests since they define the criteria for accepting or rejecting certain hypotheses. DQOs are be recorded at the national level in a DQO document (in draft) consisting of: 1) Experimental DQOs, which will provide minimum data quality levels for general research design in the Forest Response Program, and a consistent reference for researchers; and 2) Measurement DQOs, a listing of variable information for specific investigators which consist of columns for the: variable, measuring technique, measuring units, reporting units, range of expected values, allowable repeated measurement error, and accuracy tolerance limits (percent). Measurement DQOs define the basic "arena" of measurement error within which scientists will test hypotheses.

Quality Assurance procedures are structured to produce data consistent with DQOs while minimizing cost and effort. Should data fail to meet limits established in the DQOs, the research

will be revised and conducted again, or the use of the data will be reassessed. Interim estimates of Measurement DQOs, provided in Appendix A, will be used for variables where information on measurement precision and accuracy is unknown.

National DQOs will be assigned for all parameters which influence the decision-making process concerning effects of acidic deposition and associated pollutants on forest ecosystems. The foundation for the Data Quality Objectives (DQO) Document was generated by the formulation of a national research plan in January 1986, outlining the decomposition of policy questions into research tasks. This meeting and ensuing meetings have produced broad guidelines for establishing specific data quality requirements concerning critical tasks within the research framework.

Estimates of precision and accuracy for measured variables were provided by scientists through an informal but informed process of judgments about acceptable levels of error in measurements and analyses. These estimates were compared to the research framework independently established by decision-makers within the cooperatives and national Synthesis and Integration Project. A draft DQO document outlining the framework for testing hypothesis has been assembled by the QA Staff, with necessary input from all program elements. The QA Officer will handle the development of final DQOs. A DQO document will be peer reviewed when completed (9/87), revised, and submitted to the Federal Management Group for final approval. The DQO

document will be updated annually thereafter and submitted with the annual report.

2.1.3 Quality Assurance Project Plans

All FRP research projects should have approved QA Project Plans (QAPjP) as described in Appendix A, B, or C. Appendix A provides guidelines for developing QAPjPs for projects collecting raw environmental data within an experimental framework (e.g., exposure studies, field surveys, or any experiments). The majority of projects funded within the FRP fall into this category. Appendix B provides guidelines for developing special QAPjPs for projects collecting and synthesizing existing information (e.g., literature reviews and reanalyses of historical databases. Appendix C provides guidelines for developing special QAPjPs for modeling projects.
Such non-data collection require less intensive QA and QC activities. All three types of QAPjPs should be coordinated with project work plans to reduce unnecessary duplication.

All QA material for projects funded after FY86 must be completed and approved by the QA Staff before funding. Projects funded in FY86 and before must submit QA project plans before continuation funding is approved by the QA Staff. Research-level QA Project Plans provide the basis of the QA program since: 1) they describe the fundamental actions taken to produce data of known (and sufficient) quality, and they provide the basis for

project auditing. Complete QA Project Plans ensure correct standardization among FRP projects and smoother audits.

Cooperative Project Plans, being developed by the QA Specialists for FY88, will summarize information available in research-level Project Plans concerning the 8-point QA requirements list in general statements (e.g., "all researchers will use check cruises or plot inspections by trained and experienced personnel to evaluate field crew precision"). In addition, cooperative Project Plans activities conducted at the cooperative-level to maintain data quality (e.g., seedling production and distribution, or data management and security measures).

2.1.4 Quality Assurance Methods Manuals

The QA Staff developed four QA Methods Manuals for the Forest Response Program:

- Exposure Systems and Physiological Measurements
- Site Classification and Field Measurements
- Laboratory Analytical Techniques
- Experimental Design and Data Management

These manuals were developed with input from Forest Response Program personnel involved with the series of workshops held in March 1986. The workshops resolved issues and reached a consensus on what, if any, standardization is needed for variables measured in the Forest Response Program. The workshop structure was based on having Standard Operating Procedures

(SOPs) for each measurement of analysis (Table 2.1). Procedures were written by the workshops' lead-scientists, associated scientists, and cooperative staff and distributed prior to the workshop for review by participants. SOPs were developed for all "priority variables", variables which were measured by more than two researchers in the Forest Response Program and, therefore, required standardization (see Appendix F). The lead-scientists evaluated and adjusted these SOPs prior to the workshop and led the workshop discussion in a method-by-method sequence. As many procedures as possible were included for standardization in the QA Methods Manuals to reduce documentation requirements for investigators.

Each lead-scientist compiled the methods chosen and/or refined during the workshops and distributed draft manuals for review by the respective participants (investigators and other subject matter experts). Final QA Methods Manuals (version 1) were distributed by ERL-Corvallis in July 1986. The QA Staff is currently updating those manuals; first revisions should be available in Summer 1987. The QA Staff anticipates annual updates of the Methods Manuals. Revisions will not, however, sacrifice consistency through time since the development of new procedures hinge on their comparability to established procedures.

Table 2.1 Standard Operation Procedure (SOP) Format.

STANDARD OPERATING PROCEDURE FORMAT

The following eight element format is to be used by all staff when writing a standard operating procedure:

1. Scope and Purpose

2. Materials and Supplies

   2.1 Equipment
   2.2 Chemicals/Reagents
   2.3 Other

3. Procedure

   3.1 Sample Preparation
   3.2 Equipment Operation (including training and QC checks)

4. Preventative Maintenance

5. Calibration Procedures

6. Calculations/Units

7. Error Allowance and Data Quality

8. References

Standard operating procedures are to be prepared using a document control format consisting of information placed in upper right-hand corner of each document page, thus:

Section _____
Revision _____
Date: _____
Page: __ of __

2.1.5 Quality Assurance Status Reports

The QA Staff is responsible for compiling quarterly reports, semi-annual reports, and annual reports of QA activities. Quarterly reports outline the status of research projects with regards to QA and QC activities, and a summary of QA information. The report is presented in a project-by-project summary with an overall summary for cooperative and related National Vegetation Survey projects. The status section outlines the stage of quality assurance activities and products from the quarter, plus an anticipated schedule for further QA activities. The QA section consists of representive QC data, major audit comments, inter-laboratory exchange results, general comments on the QA program, and anticipated QA concerns and recommendations. The quarterly reports are distributed throughout the QA Staff and to the Forest Team Leader, Synthesis and Integration Team Leader, respective Cooperative Director, and the ERL-Corvallis Laboratory QA Coordinator. The Forest Team Leader will relay necessary information to National Program Management.

Reports are prepared semi-annually by the QA Officer for the Forest Team Leader. The report summarizes progress, successes, and deficiencies of the QA program within the Forest Response Program. Identification of specific needs and recommendations on a particular course of action will be a part of these semi-annual QA status reports, distributed in February and August of each year.

In addition, the QA Officer must prepare a QA Annual Report to National Program Management providing information on the general status of the QA program, its strengths and weaknesses, and its successes and failures. This report evaluates the effectiveness of different levels of management and suggests changes for the coming year concerning management, DQOs, other QA documentation, or audit protocols. Predictions for the coming year are given on the basis of the previous year's performance. The annual report will be submitted in February of each year.

2.2 DATA COLLECTION:

2.2.1 Laboratory and Field Notebooks

Notebooks should be periodically reviewed and signed by the investigator. Periodic checks of notebooks may also be made by the QA Specialist and the QA Officer. Investigators should adhere to the following requirements for Forest Response Program research:

1. Project staff should use bound (sewn) pre-numbered laboratory and field notebooks. Alternatively, project staff may use any notebook system which is secure from the loss of pages and can be serially-numbered before use. If it is necessary to use separate data sheets, they are to be consecutively numbered and securely catalogued (using binders) during use and permanently secured before storage. Measures should be taken to ensure that no data sheets are lost or damaged during collection.

2. Entries into the notebook should be made in ink. Mistakes should be crossed out with a single line and initialed. Exception to this rule must be justified by the investigator.

3. Spaces and pages left blank should be crossed out to prevent entries from being made at a later time. Dates of entries must be provided on each page.

4. Supporting records can be included in the laboratory notebook. These records should be attached with glue, tape, or permanently bound in succession and signed and dated.

5. Supporting results and conclusions (e.g., computer print-outs, data sheets, calibration records) should be referenced in sufficient detail to allow retrieval of the record.

6. If project staff are working in a shared notebook, the person responsible for the entry must sign the page.

7. Notebooks are to be reviewed and signed by the investigator, as necessary, based on the intended use of the data.

8. Pages are not to be removed from any notebook.

2.2.2 Automated Data Collection and Processing

The use of automated data collection and processing is strongly encouraged for the Forest Response Program research. Procedures used to 1) prevent entry and translation/transmission errors, and 2) minimize data loss should be carefully documented. Data must be validated according to criteria established in the QA Methods Manuals for Experimental Design and Data Management. It is the responsibility of the investigator to ensure that these procedures are adequate. Documentation for software developed for data processing or analysis must be available in sufficient detail for a complete technical understanding of the method and usefulness of the program. Investigators should test all newly developed software packages, "home-grown" software routines, and internal equipment calculations by hand to ensure that the proper calculations are made, and document the results of those tests.

2.2.3 Quality Assurance Audits

Quality Assurance audits are currently classified into four groups: Performance Evaluations (PEs), Technical Systems Audits (TSAs), Management Systems Audits (MSAs), and Audits of Data Quality (ADQs). These audits are formal reviews of QA/QC practices used by an investigator or cooperative in the program to determine compliance with the QA Project Plan and national documentation. Audit reports provide: (1) reassurance to upper management that quality data are being produced (at a known cost); (2) periodic reports on the status of the program; and (3) identification of modifications and adjustments to data collection and analysis. Audits are planned and conducted by the QA Staff, at least annually. The actual frequency is determined by the stage of the program, past performances, and intended use of the data. Site visits will require at least one full day to review facilities and methods.

2.2.3.1 Performance Evaluations:

Performance Evaluations (PEs) are used to quantitatively evaluate performance of field and laboratory personnel, equipment, materials, and techniques before and during the research effort. Sample replicates and inter-site sample exchanges of standards are used to establish precision and accuracy, respectively, within and among cooperating research sites. Thus, PEs are useful in flagging problem areas before research begins and in confirming consistency during the

research project. Performance evaluations can be conducted without site inspection or laboratory interference. Researchers should have sufficient sample material available to participate in inter-site sample exchanges conducted for performance evaluation.

Performance Evaluations will be conducted on a routine basis to ensure accuracy and comparability cross research sites. PEs are organized by the QA Specialists (within cooperative) or the QA Coordinator (across cooperatives). PEs currently consist of sample exchanges utilizing standard soil and foliar material, and contracted equipment audits utilizing standard gases and analyzer equipment. The QA Staff coordinates the distribution of National Bureau of Standards (NBS) samples, EPA standards, or other PE samples or the implementation of equipment audits among participating sites. The QA Staff will collect data generated by sample exchanges and relay results with necessary reports (process description) to the QA Officer. Results from all Performance Evaluations will be analyzed and interpreted by the QA Officer who will recommend program adjustments, if needed. These activities are independent of routine PE activities conducted by investigators within their own research projects.

The Performance Evaluation protocols established by the QA Staff will ensure complete and consistent sample exchange programs. Investigators have been receptive to the idea of sample exchanges as long as the sample processing burden remains low relative to regular research samples. The goal of Quality

Assurance, and therefore Performance Evaluation, is to enhance the research effort without creating a burden on it; therefore, an appropriate number of PE samples per site per time frame will be carefully reviewed and resolved with investigators' input.

2.2.3.2 Systems Audits:

Technical Systems Audits focus on actual QA procedures used in the measurement, sampling, and analysis of data and entails a thorough site inspection (Appendix D). Areas of concern include: equipment and facilities use, calibration and preventive maintenance records, personnel thoroughness, support systems, control charts, sample handling and sample storage. Audits of Data Quality (ADQs), focusing on validation, movement, synthesis, and analysis of data, can be conducted during the same visit. The ADQs will determine if sufficient information exists with data to support an assessment of data quality (to be evaluated against DQOs). Management System Audits are a general review of the organization and personnel, focusing on communication channels and responsibilities, and can also be conducted during the same visit. These three site audits may be dictated by poor results from Performance Evaluations or internal QC data. Likewise, excellent results from PEs may dictate less frequent site audits.

The number of trips taken per QA staff member will be minimized by combining site visits in a logical and efficient manner. Assuming three site visits per week or per trip (1-week

trips), ten to twenty audit trips per cooperative will be required for fully operational cooperatives. Auditing protocols have been established for four research areas corresponding to the four Methods Manuals: Exposure Systems and Physiological Measurements, Laboratory Analytical Techniques, Field Measurements, and Data Management. Audits will be periodically conducted in groups of two to four individuals, in various combinations, to maintain consistency within the QA Staff.

Figure 2.1 shows the audit frequency for a typical project conducting field, exposure, and laboratory research (including data management).

Less intensive site reviews may be conducted prior to the start of data collection to assure that sufficient facilities, equipment, and services are available for the research effort. These audits are labeled "pre-start" for convenience. Some pre-start audits may not be conducted due to time and resource limitations when the existence of sufficient facilities, equipment, and services can be verified through other means (e.g., similar involvement with other programs or cooperatives). Routine audits, early-stage and late-stage, will be scheduled dependent on research type and particular site. Exposure research equipment should be audited at the beginning and conclusion of exposure period, with concurrent systems audits in the early stages of research. Field research activities should

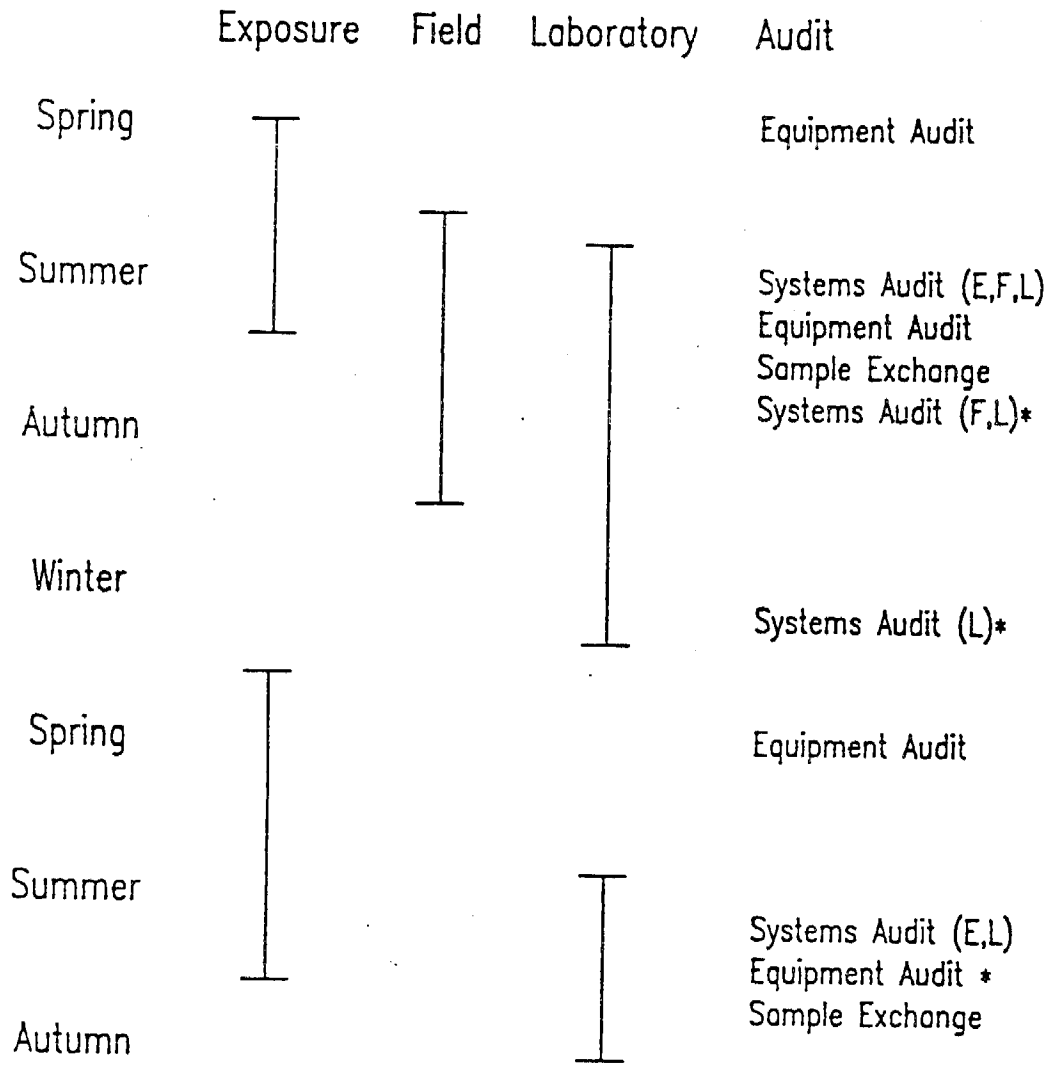


Figure 2.1 Audit frequency for a typical research project involving exposure, field, and laboratory research. Figure shows on-site systems audits and performance evaluations. *denotes optional audit, dictated by need.

be audited once early in the field season; laboratories once early in the sample analysis period. Late-stage systems audits may be dictated by the results of early-stage audits. Multi-year projects will be audited at least annually.

The Forest Response Program should be sufficiently organized in the future for "pre-start" audits to become "pre-award" audits as requested by the Federal Management Group. Pre-award audits will be conducted by the QA Staff. Pre-award audits will follow the same scheme as outlined above.

The distribution list for reports from QA Specialists for specific project audits will consist of the investigator for the project and the QA Coordinator (file copy) only. In addition, the QA Specialist will submit a separate audit report to the appropriate Cooperative Director, summarizing the audit results by project or by group of projects as requested. Specific information could be requested individually for special interests. Any outstanding observations which the QA Staff feels are worthy of further distribution to other program components will be handled on an individual basis as dictated by the particular observation. For example, should an investigator fail repeatedly to take needed corrective action, we will notify the Cooperative Director of the problem and recommended course of action. The Forest Team Leader assumes leadership should the problem be unresolvable at the cooperative level.

The QA Staff can better the working relationship with investigators using this reporting scheme, increasing the level

of confidentiality and communication. Using this approach should avoid problems caused by the misinterpretation of audit reports by external persons or those not well-informed program about the details of a specific project. This will reduce time spent placing comments or actions into context for those persons. The approach will also reduce the large amount of routine QA documentation program management must review. However, this approach will not hamper communication between QA and program management since any important information will be conveyed in a timely fashion and specific material can always be requested.

2.2.4 Adjusting Research and Quality Assurance Activities

Adjusting research and/or Quality Assurance activities in response to concerns developed during the auditing process should be handled by the investigator at the request of the QA Specialist, whenever possible.

A description of major problems (detected either through an audit or other investigation), solutions devised, corrective actions taken, and estimates of the effect of problems on data quality should be developed by the QA Specialist and sent to the QA Coordinator who will communicate the "lesson" to all program levels. The Cooperative Director of each Research Cooperative should establish a system for adjusting research or QA activities for each Research Program, clearly defining the management line of authority for dealing with problems that cannot be resolved between investigators and the QA Specialist. The Cooperative

Director and QA Specialist should hold regular summary briefings to review general QA/QC results and discuss general problems encountered. Should compliance with the Forest Response QA Program be inadequate, intervention from the QA Officer would be necessary to reconcile the problem. Continued failure to comply with overall program requirements may lead to the termination of funding as determined by National Program Management.

2.2.5 Training for Research Staff

The QA Officer will provide for appropriate training, based on perceived needs, for all Cooperative Staff and Research Project Staff to assure that QA responsibilities and requirements are understood at every stage of the project.

2.2.6 Facilities and Equipment

Facilities and equipment which influence data quality and/or integrity should be routinely inspected and maintained. Results from these inspections must be documented in project notebooks. General laboratory and field equipment must be operationally consistent with their intended use to provide for the generation and processing of environmental data having the quality and integrity established in the QA Project Plan. Section 2.2.7 outlines what is required in terms of preventive maintenance for Forest Response Program research.

Because there are numerous support facilities involved in the Forest Response Program, only a general summary of these

facilities will be presented here. More in-depth descriptions are available for review in individual investigators' QA Project Plans. In general, universities and government research installations provide the majority of field, greenhouse, controlled chamber, laboratory, and data analysis support, in varying combinations per site and cooperative. These research facilities own or have access to necessary equipment and services to perform general research in atmospheric deposition. Pre-start and/or early-stage audits will confirm the existence of any project-specific equipment or services. Researchers are experienced in their respective areas of atmospheric deposition research, including: scheduling samples, preparing samples, operating the equipment, and/or taking necessary precautions to ensure data quality.

The individual researchers' QA Project Plans contain necessary information concerning compliance with DQOs and data reporting requirements. Researchers understand that samples will not be collected and measurements will not be taken without proper documentation of QA and QC procedures or some approval to proceed. Investigators are expected to have access to necessary facilities, equipment, and services to adhere to Standard Operating Procedures (SOPs) as described in the four Forest Response Program QA Methods Manuals.

2.2.7 Preventive Maintenance

Facilities and equipment which influence data quality or integrity are to be inspected and maintained on a regular basis. The investigator is responsible for assuring that laboratory and field equipment meet operational requirements based on intended use of the data. The objective of preventive maintenance is to increase measurement system reliability and to assure that data are being generated with a high probability of being of acceptable quality.

Program staff should prepare and implement a preventive maintenance schedule for measurement systems and those facilities affecting such equipment. Where possible, checklists should be used to ensure and document maintenance activities. Documentation of all preventive maintenance activities is essential. Scheduling of preventive maintenance should be predicated on the effect of equipment failure on overall data quality. A detailed description of all major adjustments (including software) and replaced parts should be recorded into laboratory and field notebooks.

Preventive maintenance inherently improves the degree of safety in operation of equipment. In many instances, quality assurance and safety awareness are the means to the same end.

2.2.8 Data Storage

All data associated with research projects, such as raw sampling and analytical data, calibration data, calculations, and

processed data reports should be stored in a secure location as detailed in the Experimental Design and Data Management Methods Manual in absence of such policies, until the Cooperative Director determines that the data are no longer useful. The QA Specialists may elect to house out-dated QA data and documentation after the Cooperative Director determines it useless.

2.2.9 Cooperative Databases

Investigators' data will be placed in a cooperative database for use by the cooperative and Synthesis and Integration Project. Transmission of data to the cooperative database is governed by the guidelines established in the Experimental Design and Data Management Methods Manual. Data must be in standardized format and coding for the Database Administrator to effectively work with data. Formats and codes are defined in the four Methods Manuals; a summary of standardized codes is found in Appendix F. Disposition of data to sources other than the collecting investigator, cooperative staff, QA staff, and S&I staff must be approved by the collecting investigator as detailed in the Experimental Design and Data Management Methods Manual.

SECTION 3

QUALITY ASSURANCE PROGRAM STRUCTURE

The availability of sufficient staffing is crucial to the successful implementation of Quality Assurance in the Forest Response Program. A permanent staff of five individuals with qualifications in related scientific disciplines will administer the QA program (Table 3.1). This staff consists of: (1) an experienced, senior QA officer to provide overall management for planning and implementing the QA program (to be filled); (2) a QA Coordinator to provide assistance to the QA Officer in planning and implementing the program, coordination of QA Specialist activities, with respect to audits, meetings, documentation, and report preparation; and (3) four QA Specialists to provide physical implementation of the QA program at the Research Cooperatives (intersite sample exchanges, performance evaluations, audits, and reports). The QA Officer position is currently being filled; the QA Coordinator is acting in his absence. The QA Staff has a dedicated staffer for clerical and communication support.

The management structure of the Forest Response Program and the QA Staff is shown in Figures 1.1 and 1.2, respectively. These figures show that the Quality Assurance Staff is organizationally separated from researchers involved in data

Table 3.1. Forest Response Program Staffing.

Classification	Affiliation	Qualifications
QA Officer (to be filled)	EPA (Corvallis)	-- PhD or equivalent experience in Biological or Physical Science -- 3-5 years experience in QA desirable -- large scale Program Management experience
QA Coordinator	NSI*(Corvallis)	-- MS or equivalent in Forest Science or related field -- statistical experience -- QA experience desirable
Clerical Support	NSI (Corvallis)	-- general clerical skills -- computer (PC) assisted word-processing and communication experience
QA Specialist	NSI (Cooperatives)	-- MS/BS in Forestry/Forestry Science or related fields -- statistical experience -- QA experience desirable

*NSI: Northrop Services, Inc.

generation. This independence is required of all Quality Assurance programs. The program receives guidance and oversight from ERL-Corvallis Laboratory QA Staff.

The Cooperative Management Staff and Research Project Staffs (including technicians) share the responsibility for implementing QA activities, and they are accountable for those aspects of quality assurance (mainly QC) associated with their specific research project. The QA Staff will only assist in developing and coordinating these activities and oversee their appropriate implementation. Conversely, the QA Staff is responsible for implementing the FRP QA program across projects and must enforce national QA policy. The following sub- sections describe some of the key QA and QC responsibilities of various components of the Forest Response Program.

3.1 Principal Investigator:

The Principal Investigator, charged with a research task, has primary responsibility for the quality of the results generated from the individual task. The researcher prepares both the QA guidelines for the research effort in general (e.g., training programs and documentation guidelines), and the smaller scale quality control aspects of the project (e.g., laboratory spike samples, reference gases, or test plots). Both levels of activities, QA and QC, are obviously interrelated. Following is a summary of key QA and QC responsibilities for investigators:

- Prepare the QA Project Plan
- Negotiate requirements with QA Specialist
- Perform and document preventive maintenance and equipment inspection
- Maintain updated laboratory and field notebooks
- Follow standard or approved procedures/methods including calibrations, necessary training, and QC checks
- Document all other procedures/methods/critical activities; communicate location of this documentation to the QA Specialist
- Conduct internal data quality (QC) checks and analyze/track results
- Deliver QC outputs to QA Specialist when requested
- Report all problems and associated adjustments to the QA Specialist
- Report data quality assessments when reporting results

3.2 Cooperative Director (USFS Program Manager):

The Director is responsible for the performance and coordination of the cooperative research program and the adminstration of grants. The Director, with the assistance of the cooperative's QA Specialist, will develop a section of the Cooperative Research Plan regarding QA that must relate national and cooperative QA guidelines.

3.3 Quality Assurance Specialist (QAS)

The Quality Assurance Specialists are responsible for physically implementing the QA program: providing guidance and assistance to the investigators with regard to QA implementation at research sites, organizing and conducting intersite sample exchanges and performance evaluations, auditing research sites, and reporting to the QA Coordinator. Their main duties are summarized below:

- Assist in the development of Cooperative QA Project Plans
- Negotiate QA requirements and interact with Investigators in the establishment of individual QA Project Plans
- Review QA Project Plans and resolve inadequacies
- Help develop and approve standard operating procedures and protocols
- Conduct audits (Appendix D) and report results
- Periodically review and evaluate researcher's QC data (separate from auditing process) as required
- Arrange for blind samples to test comparability among sites (when applicable)
- Report all possible data quality problems to QA Coordinator
- Prepare brief monthly summary of activities for the QA Coordinator
- Prepare quarterly QA reports

The QA Specialist will organize inter-site sample exchange programs for within-cooperative sample comparison and audit research sites on a routine basis to monitor the QA program. The QA Staff will conduct periodic exchanges and joint audits to establish consistency between cooperatives. QA Specialists are the primary contact with investigators, being located at the respective cooperatives to manage cooperative QA activities and assist investigators.

3.4 Quality Assurance Coordinator (QAC)

The QA Coordinator is responsible for: (1) coordinating the activities of the QA Specialists and maintaining efficiency and independence of QA Staff (unbiased evaluations); (2) creating and maintaining consistency across cooperatives; and (3) assisting the QA Officer in providing guidance to cooperatives, maintaining appropriate documentation, and compiling reports. Some of the QAC's key responsibilities are:

- Assist the QA Officer in the implementation of the QA program including maintenance of documentation and reporting requirements
- Act as the intermediary between QAS and QAO
- Coordinate sample and information exchanges among cooperatives
- Coordinate activities (joint audits, quarterly reports and meetings, and report exchanges) to maintain QA Specialist independence and consistency
- Track the QA activities and results for all research
- Conduct audits and evaluations of Cooperatives
- Evaluate audit reports from QA Specialists and relay necessary information to Program Management
- Compile and distribute quarterly reports on FRP QA.
- Assist in solving QA-related problems at the lowest possible organizational level
- Develop and maintain QA related communication channels

The QA Coordinator is currently serving as the acting QA Officer for the Forest Response Program.

3.5 Quality Assurance Officer (QAO)

The QAO will manage the QA program. He will report to the Forest Team Leader and have primary control over the QA program with the QA Coordinator as an assistant. A major responsibility of the QA Officer is to ensure that all personnel involved in the FRP understand QA requirements and understand their respective QA and QC responsibilities, and that QA Staff maintain appropriate independence from program management. His key responsibilities are summarized below:

- Ensure that QA Program Plan is properly implemented, and annually reviewed and updated
- Ensure that the FRP QA Program meets the requirements of the EPA and ERL-Corvallis
- Ensure that adequate QA plans are developed and implemented for all Cooperatives and Research Projects
- Ensure the maintenance of the QA Implementation Plan
- Ensure the maintenance of the National DQO Document

- Ensure the maintenance of QA Methods Manuals
- Provide for appropriate training of the QA Staff
- Prepare monthly reports to the Forest Team Leader
- Evaluate status of QA implementation and costs
- Recommend required adjustments to the QA program and the Forest Response Program to the Forest Team Leader.
- Prepare a semiannual status report to the Forest Team Leader and annual report to National Program Management.

3.6 Deputy National Program Manager

The Deputy National Program Manager for the Forest Response Program, located in Washington, has overall responsibility for implementing the quality assurance program in accordance with (a) the mandate of the joint EPA/Forest Service Forest Response Program, (b) the EPA's QA mandate (May 30, 1979, and June 14, 1979), and (c) the guidance provided by the Quality Assurance Management Staff (QAMS) under the Office of Research and Development. The authority and responsibility for directing and managing the QA program are delegated by the Deputy National Program Manager to the Quality Assurance Officer. The DNPM will make the final decision(s) on QA-related matters which reach his desk through the QA Officer and Forest Team Leader.

SECTION 4

QUALITY ASSURANCE IMPLEMENTATION REQUIREMENTS

The QA Staff implements the following actions to meet the objectives of the FRP QA program: 1) interaction with other program components, 2) quarterly meetings and other internal exchanges, 3) supplemental training, and 4) internal and external program guidance. These actions are detailed below.

4.1 Interactions

Section 3.3 outlines the QA Specialist's responsibilities for interaction with investigators and Cooperative Directors. This interaction, the sharing of ideas and explanation of program goals, is crucial to the success of the QA program. The QA Coordinator's and QA Officer's interactions with Cooperative Directors and Program Management is also important in relating global QA concerns and the direction of the overall QA program. The concept of "frequent and effective interaction" is second only to the concept of "complete documentation" in the success of QA programs.

4.2 Quarterly Meetings and Internal Exchanges

Quarterly meetings of the QA Staff will be held to facilitate exchanges between Specialists and promote consistency across cooperatives. Quarterly meetings will be held in sequence with quarterly reports. Meetings will consist of a comprehensive

review of the status of QA in each cooperative and the national program, and planning activities for the coming quarter.

Beyond this formal interaction, members of the QA Staff frequently contact each other by telephone and computer with questions and concerns relative to their respective cooperative activities and to share ideas in areas of individual expertise. The QA Staff holds weekly conference calls to insure timely status reports and provide an arena for full team interaction.

4.3 Training for Quality Assurance Staff

The QA Staff was initially trained through a series of workshops on quality assurance and related activities, reviews of literature, and interactions with program staff to provide a solid basis in QA/QC concepts and techniques. The QA Officer and QA Coordinator are charged with assuring that QA Specialists are given appropriate training and support to effectively implement QA within their respective cooperatives. Since much of the work performed in the QA program is adapted to its particular application in the FRP, the use of general QA training courses are limited. The QA Coordinator will, however, provide linkages to other related QA programs for exchanging ideas, and will supply materials to the QA Staff for further professional development.

4.4 Program Guidance

The QA Staff receives guidance from two primary sources: the QA Officer and the ERL-Corvallis Laboratory QA Coordinator. The QA Officer's basic responsibilities are outlined in Section 3.5. including: 1) ensuring that the program is fully implemented and independent of the data collection process; and 2) producing reports to Program Management and national documentation. The ERL-Corvallis Laboratory QA Coordinator, responsible for the implementation of QA across the laboratory, relays guidance to the FRP QA Staff and oversees the program to ensure that it meets ERL-Corvallis and EPA requirements.

4.5 Milestones

Table 4.1 shows major milestones for the implementation of QA in the Forest Response Program. Starred items are considered deliverables for the ERL-Corvallis.

Table 4.1. Milestones for Quality Assurance Implementation.

FY87 Milestone Items	Date
-- Prepare semi-annual report (#1) to Forest Team Leader	Feb 1987
** Prepare annual report to National Program Management	Feb 1987
** Complete revisions of FRP QA Methods Manuals (4)	Mar 1987
** Complete FRP's DQO Document (version 1.0)	Mar 1987
-- Finalize Revision 1 of QA Implementation Plan	Apr 1987
-- QA quarterly report for FRP	Apr/Jul/Oct 1987
-- QA quarterly meeting (internal program review)	May/Aug/Nov 1987
** Peer Review of QA Program and Implementation Plan	May 1987
** Prepare semi-annual report (#2) to Forest Team Leader	Aug 1987

** deliverables

SECTION 5

SUMMARY

5.1 Advantages

The advantages of implementing a QA program such as that described in this document are:

1. It exploits the strengths of the QA program (documentation and auditing).
2. ERL-Corvallis maintains maximum control of the research conducted in the Forest Response Program, producing data of known and sufficient quality, by monitoring:
   - -- methods/protocols
   - -- QA functions
   - -- overall documentation.
3. The QA Staff is better trained and more interactive and communicative by initially and periodically spending time together in workshops, training sessions, meetings, and auditing units.
4. The entire QA Staff has input in the formulation of policies and procedures for the Forest Response Program which they must enforce.
5. By establishing line-management authority from the QA Officer, the QA Specialists will maintain more independence from the cooperative research effort and have QA duties only.
6. The travel costs associated with meetings and audits will be minimized when the QA Specialists are located to the Cooperatives.

7. The QA Specialists can establish effective working relationships with their respective cooperative managers and investigators and will maintain familiarity with the concerns and functionings of their respective cooperatives.

8. By hiring a senior, experienced QA officer, the Forest Response Program can benefit from the extrapolation of their experiences with large-scale research programs to the management of the FRP QA program.

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APPENDICES

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APPENDIX A

GUIDELINES FOR DEVELOPING QUALITY ASSURANCE PROJECT PLAN MATERIAL

GUIDELINES FOR DEVELOPING

QUALITY ASSURANCE PROJECT PLANS

1.0 INTRODUCTION:

All investigators involved with the Forest Response Program (FRP) requesting funding for projects involving environmental measurements and data collection are required to prepare a Quality Assurance Project Plan following the 9-point guidance below. It is the responsibility of the investigators to ensure that the QA Project Plan is prepared and approved before any environmental measurements are made.

The following guidance is revised from the initial 16 point framework used in the FRP to reduce the duplication of material between sections and between the QA Project Plans and technical work plans. The QA Project Plan should heavily reference work plans and other sources (including FRP Methods Manuals) if the necessary information is contained in the reference. However, the QA Project Plan should be a separate, stand alone document which addresses the below 9 points.

The objective of the QA Project Plan is to provide the QA staff with sufficient information about the project for both initial QA interaction and approval and to provide the foundation for auditing. A well developed QA Project Plan saves considerable effort further down the road.

2.0 DEVELOPMENT OF THE QA PROJECT PLAN:

The QA Project Plan should begin with a title page designating the QA Officer for the project and the "contact statistician", the person most familiar with intricacies of the experimental design. QA Project Plans should also contain a Table of Contents, List of References, and appropriate appendices (attachments). The general format for the 9 points is outlined below:

1. Project Description.

The project description should include the following:

* a brief statement of the scope, purpose, and objectives of the research, including the FRP scientific question(s) that the research will address;
* a description of the data which will be produced to address the scientific questions; and
* the research product(s) and a timetable for their completion.

2. Project Organization and Facilities.

The project organization should contain an organizational chart showing individuals within various segments of the research and their responsibilities. If individual responsibilities cannot be clearly delineated in the diagram, a short narrative should be included as a supplement. Special attention should be given to those individuals which manage aspects of the research project of major interest to the quality assurance program:

sample collection, sample custody, sample measurement/analyses, data management, and all quality control (QC) activities.

The project facilities description should include, where appropriate:

a.) a brief discussion about the key support facilities and services used, including the types of computers employed (with their software requirements and integration with related equipment or systems);

b.) a diagram or map showing the location of those facilities, if necessary; and

c.) any limitations to the access of those facilities.

3. Experimental/Sampling Design and Data Analysis.

The experimental and sampling design description should contain or discuss the following items:

a.) the experimental design/analytical model;

b.) the null and alternative hypotheses to be tested (including a-level);

c.) the analysis of variance table, including expected mean squares and appropriate F-tests;

d.) the treatment comparisons;

e.) a complete listing and description of factors and variables (quantitative and qualitative), any hierarchical structure (nesting), random and fixed effects and covariates, any blocks and/or replication;

f.) the number of levels of each factor and the number of blocks and replications;

g.) the population (e.g., species, age, location), with any stratification, and the sampling frame;

h.) the sampling or experimental unit;

i.) sampling site selection criteria and a known sites description;

j.) sample collection methods (which assure representative samples);

k.) sampling equipment with any notation for calibration and preventative maintenance and training;

l.) relevant sampling and measurement dates and intervals (spatial and temporal considerations); and

m.) if modeling, see Appendix C.

Variable names (from e. above), codes, and definitions should be consistent with QA designated nomenclature from the QA Methods Manuals. Any deviations or particular coding schemes (e.g., 01 = treatment 1, 02 = treatment 2) should be explained and justified (see Experimental Design and Data Management QA Methods Manual).

Describe the corresponding data analyses which are planned for the generated data set. In addition, briefly describe any statistical analyses which you plan to perform which are not directly indicated by the experimental design. Innovative procedures are encouraged but require some explanation and justification.

4. Data Quality Estimates.

This section should list all measured variables in a single table with estimates of data quality, such as Table A1. For most types of measured and generated data, precision (or repeated measurement error) and accuracy are useful in describing quality; other types of data are best described in other statistical terms (in this case, define the statistical parameter and data acceptance criteria in one or two sentences).

The table of variables should show supplemental information on measurement technique, measuring units, reporting units, expected range, as well as allowable repeated measurement error at lower and upper limits of its range and accuracy tolerance limits (Table A1). If this information differs from those used in Table A1 from the national Data Quality Objectives, the difference should be identified and justified. Tables should be organized by intended use of data (e.g., environmental condition, treatment factor, response variable).

This section should also contain estimates of the completeness, representativeness, and comparability of data necessary or possible for testing hypotheses or estimating differences due to treatments. This should obviously relate directly to section 3.

Table A1. Measurement DQO table extracted from the national DQO document for the Forest Response Program (continued).

Variables	Techniques	Measuring Units	Reporting Units	Expected Range	Repeated Measurement Error at Lower Limit	Repeated Measurement Error at Upper Limit	Measurement Accuracy Tolerance
Seedling							
Photo-synthesis	gas exchange	$\mu molg^{-1}s^{-1}$	$\mu molCO_2m^{-2}s^{-1}$	•	± 10%	± 10%	15%
Transpir-ation	gas exchange	$\mu molg^{-1}s^{-1}$	$\mu molH_2Om^{-2}s^{-1}$	•	± 10%	± 10%	15%
Stomatal Resistance	gas exchange	•	scm^{-1}	•	•		
Needle Conductance	gas exchange	$\mu molg^{-1}s^{-1}$	$\mu molm^{-2}s^{-1}$	•	± 10%	± 10%	10%
Respiration	gas exchange	$\mu molg^{-1}s^{-1}$	$\mu molCO_2m^{-2}s^{-1}$	•	± 10%	± 10%	15%
Leaf Water Potential	pressure bomb	MPa	MPa	0.2-3.0	± 0.1%	± 1.0%	5%
Osmotic Potential	microvoltmeter	UV/MPa	UV/MPa	6-11	± 5%	± 10%	na
Turgor Pressure		MPa	MPa	0.0-1.5	± 5%	± 10%	na
Leaf Water Content	gravimetric	g	% wt	80-90	± 1.5%	± 1.5%	1%
Leaf Area	photoelectric planimeter	cm^2	0.01 cm^2	0.00-500.00	± 2%	± 5%	5%
Fascicle Length	ruler	cm	cm	0-30	± 5%	± 5%	5%
#Vegetable Buds	count	#	#	1-4	± 1 bud	± 1 bud	na
#Lateral Buds	count	#	#	0-3	± 1 bud	± 1 bud	na
Seedling Height	ruler	mm	0.5 cm	0-50	± 2	± 2	2%
Sapling Height	tape	cm	0.1 m	0.0-3.0	± 5%	± 5%	5%
Leaf Water Content	gravimetric	g	% wt	80-90	± 1.5%	± 1.5%	1%
Leaf Area	photoelectric planimeter	cm^2	0.01 cm^2	0.00-500.00	± 2%	± 5%	5%
Fascicle Length	ruler	cm	cm	0-30	± 5%	± 5%	5%
#Vegetable Buds	count	#	#	1-4	± 1 bud	± 1 bud	na
#Lateral Buds	count	#	#	0-3	± 1 bud	± 1 bud	na
Seedling Height	ruler	mm	0.5 cm	0-50	± 2	± 2	2%
Sapling Height	tape	cm	0.1 m	0.0-3.0	± 5%	± 5%	5%
Diameter	caliper	mm	mm	0-15	± 5%	± 5%	5%
Plant dry Weight	electronic balance	mg	mg	0-1500	± 1	± 1	2%
Root Weight	balance	mg	mg	0-500	± 1	± 1	2%
Stem Weight	balance	mg	mg	0-500	± 1	± 1	2%
Needle Weight	balance	mg	mg	0-500	± 1	± 1	2%
Root Length	ruler	cm	cm	0-1000	± 5%	± 5%	5%
#Non-Myc Tips	count	#	#/cm root	0-1000	± 10%	± 20%	na
Types Myc Tips	count	#	#/cm root	0-1000	± 10%	± 20%	na

Table A1. Measurement DQO table extracted from the national DQO document for the Forest Response Program (continued).

Variables	Techniques	Measuring Units	Reporting Units	Expected Range	Repeated Measurement Error at Lower Limit	Repeated Measurement Error at Upper Limit	Measurement Accuracy Tolerance
Foliar Organic:							
Clorophyll	extraction	absorbance	mg/kg	1-10	± 10%	± 10%	na
Electron Transport	•	•	$\mu molO_2 mgchl^{-1}h^{-1}$	•	•	•	•
Photophosphory-lation	•	counts/min/ mgchl	$\mu molATPmgchl^{-1}h^{-1}$	0.00-100.00	•	•	•
Starch	spec/auto-analyzer	absorbance	.01 mg/g dry tiss.	0.00-100.00	± 10%	± 10%	10%
Total Sugars	spec/auto-analyzer	absorbance	.01 mg/g dry tiss.	0.00-100.00	± 10%	± 10%	10%
C14 Allocation	combustion	•	% of intitial	1-100	± 10%	± 10%	10%
Rhizosphere Dehydrogenase	spectrophe-meter	•	mg/kg	1.0-10.0	± 20%	± 20%	•
Cuticular Wax	gravimetric	mg	mg/kg	0-3000	± 5%	± 5%	na
N-Alkanes Analyses	GLC	absorbance	mg/kg	0-200	± 5%	± 5%	na
Cuticle Thickness	micrometer	µm	µm	0.3-3.5	± 1%	± 1%	na
Cell Wall Thickness	micrometer	µm	µm	2.0-5.0	1%	1%	na
Electrical Conductivity of Leachate	conductance meter	micrombo	micrombo	1.0-1000.0	.001	1.0	2%
Seed							
1000-seed weight	balance	mg	0.1 mg	1.5-6.0	± 0.1	± 0.1	na
embryo length	ruler	mm	0.1 mm	0.5-5.0	± 0.2	± 0.2	10%
germination	count	#	%	1-100	± 1	± 2	5%
germination rate (PV)	count	#	0.1 %/day	0.1-10.0	± 1.0%	± 2.0%	na
germination rate (MGT)	count	#days	days	5-28	± 1%	± 2%	na
electrolyte leakage	meter	amp	amp	30-300	± 2	± 20	na
early seed growth	balance	mg	0.1 mg	0.1-100.0	± 0.2	± 2.0	5%
germ-loss after a.a.	count	#	%	0-75	± 1%	± 2%	na
germ rate loss after a.a.	count	#	0.1 %/day	0.0-8.0	± 1%	± 2%	na
Genetics							
Allele frequency	count	#	0.1%	0.0-99.9	•	•	na
Expected heterozygosity	count	#	%	5-50	•	•	na
Alleles/locus	count	n/locus	0.1 n/locus	1.0-4.0	•	•	na
Fixation index	count	#	0.01%	0.01-0.99	•	•	na
Polymonophism	count	#	%	10-80	•	•	na

Variables	Techniques	Measuring Units	Reporting Units	Expected Range	Repeated Measurement Error at Lower Limit	Repeated Measurement Error at Upper Limit	Measurement Accuracy Tolerance
Foliar Inorganic:							
N (TKN)	autoanalyzer/ C-N-S analyzer	%(wt/wt)	0.1%	0.1-10.0	± 10% (cv)	± 10% (cv)	10%
P	autoanalyzer/ICP	wt/wt	0.01%	0.00-5.00	± 10% (cv)	± 10% (cv)	10%
K	ICP/AA	wt/wt	0.01%	0.10-5.00	± 10% (cv)	± 10% (cv)	15%
Ca	ICP/AA	absorbance	mg/kg	1000-6000	± 10%	± 10%	15%
Mg	ICP/AA	absorbance	mg/kg	400-1000	± 10%	± 10%	15%
C	C-N-S analyzer	absorbance	mg/kg	•	± 5%	± 5%	5%
S	C-N-S analyzer/spec	absorbance	mg/kg	700-1000	± 15%	± 10%	15%
Mn	ICP/AA	absorbance	mg/kg	0-1000	± 10%	± 10%	15%
Zn	ICP/AA	absorbance	mg/kg	0-300	± 10%	± 10%	15%
Fe	ICP/AA	absorbance	mg/kg	0-1000	± 10%	± 10%	15%
Al	ICP/AA	absorbance	mg/kg	0-3000	± 20%	± 10%	15%
Cu	ICP/AA	absorbance	0.1 mg/kg	1.0-100	± 20%	± 10%	15%
B	ICP/AA	absorbance	mg/kg	0-100	± 10%	± 10%	15%
Mo	ICP/AA	absorbance	mg/kg	0-300	± 10%	± 10%	15%
Cd	ICP/AA	absorbance	0.01 g/g	0.0-100.0	± 20%	± 10%	15%
Na	ICP/AA	absorbance	mg/kg	0-30	± 20%	± 10%	15%
Ni	ICP/AA	absorbance	0.01 mg/kg	0.00-100.00	± 20%	± 20%	15%
Pb	ICP/AA	absorbance	0.01 mg/kg	0.00-100.00	± 25%	± 25%	15%
V	ICP/AA	absorbance	0.01 mg/kg	0.0-1.0	± 20%	± 20%	15%
Ba	ICP	absorbance	0.01 mg/kg	0.00-20.00	± 15%	± 10%	15%
Cl	Chloridometer	concentration	mg/kg	0-100	± 5%	± 5%	15%
Cs	ICP	absorbance	0.01 mg/kg	0.10-0.80	± 10%	± 10%	15%
Rb	ICP	absorbance	mg/kg	10-60	± 10%	± 10%	15%
Soluble Nitrate	•	wt/wt	0.1%	1.0-3.0	•	•	•
Soluble Sulfate	ICP	absorbance	mg/kg	10-200	•	•	•

Table A1. Measurement DQO table extracted from the national DQO document for the Forest Response Program.

Variables	Techniques	Measuring Units	Reporting Units	Expected Range	Repeated Measurement Error at Lower Limit	Repeated Measurement Error at Upper Limit	Measurement Accuracy Tolerance
Soil Physical							
Soil Moisture	gravimetric	grams	% mass	0–60	± 5%	± 5%	5%
Soil Bulk Density	core	grams/cc	mg/m^3	•	na	na	na
Water Content	gravimetric	grams	% (w/w)	na	na	na	na
% sand/silt/clay	PSA	time	%	•	10% (cv)	10% (cv)	na
Organic Matter	LOI	grams	%	0–95	± 50% (cv)	± 5% (cv)	5%
Soil Chemical							
pH by H_2O	meter	pH units	0.01 pH units	3.00–7.00	± .01	± .01	na
by $CaCl_2$	meter	pH units	0.01 pH units	3.00–7.00	± .01	± .01	na
by KCl	meter	pH units	0.01 pH units	3.00–5.00	± .01	± .01	na
Adsorption Capacity	•	•	mg/kg	50–100	± 20%	± 5%	5%
Extractable Anions:	extraction	•	mg/kg	20–300	± 20%	± 5%	5%
Orthophosphate	"Bray I" double acid	concentration	mg/kg	•	± 20%	± 5%	na
Sulfate	extraction	gS/ml entr.	mg/kg	•	± 20%	± 5%	na
Exchangeable Bases:							
– Ca	NH_4Cl extract.	µg/ml extr.	.01 ccmole(+)/kg	0.05–20.00	± .05	± 1.00	na
– Mg	NH_4Cl extract.	µg/ml extr.	.01ccmole(+)/kg	0.03–9.00	± .03	± .50	na
– K	NH_4Cl extract.	µg/ml extr.	.01 ccmole(+)/kg	0.05–6.00	± .05	± .30	na
– Na	NH_4Cl extract.	µg/ml extr.	.01 ccmole(+)/kg	0.05–1.00	± .05	± .05	na
Exchangeable Acidity:							
– Al	KCl extract.	µg/ml extr.	.01 ccmole(+)/kg	0.10–18.00	± .05	± 1.00	na
– H	KCl extract.	µg/ml extr.	.01 ccmole(+)/kg	0.10–18.00	± .05	± 1.00	na
Total EA	KCl extract.	µg/ml extr.	.01 ccmole(+)/kg	0.10–30.00	± .05	± 1.00	na
C.E.C.	calculation	na	ccmole(+)/kg	3.00–80.00	± 20	± 4.00	na
Extractable Metals:							
– Fe	HCl extract.	concentration	mg/kg	10–100	± 1	± 5	na
– Zn	HCl extract.	concentration	0.1 mg/kg	1.0–10.0	± 0.1	± 5.0	na
– Cu	HCl extract.	concentration	0.1 mg/kg	1.0–10.0	± 0.1	± 0.5	na
– Pb	HCl extract.	concentration	0.1 mg/kg	0.5–20.0	± 0.1	± 1.0	na
– Cd	HCl extract.	concentration	0.1 mg/kg	0.1–3.0	± 0.1	± 0.2	na
– Ni	HCl extract.	concentration	0.1 mg/kg	0.1–2.0	± 0.1	± 0.1	na
– Mn	HCl extract.	concentration	mg/kg	10–100	± 1	± 5	na
Soil NH_4			0.1 mg/kg	1.0–20.0	± 0.5	± 15%	10%
			0.1 kg/ha/time	10.0–100.0	± 2.0	± 15%	10%
Soil NO_3^-N			0.1 mg/kg	1.0–20.0	± 0.5	± 15%	10%
			0.1 kg/ha/time	1.0–100.0	± 2.0	± 15%	10%
NO_2^-N Loss			0.1 µg/kg/day	0.1–200.0	± 0.1	± 50%	•
			0.1 kg/ha/month	0.1–10.0	± 5.0	± 50%	•

Variables	Techniques	Measuring Units	Reporting Units	Expected Range	Repeated Measurement Error at Lower Limit	Repeated Measurement Error at Upper Limit	Measurement Accuracy Tolerance
Elemental Content:							
- C	elemental anal.	°	mg/kg	100-	± 15%	± 10	15%
- N (TKN)	colormetric	ml/kg	0.01% (w/w)	0.02-2.10	± 10% (cv)	± 10% (cv)	15%
(total)	elemental anal.	°	0.01% (w/w)	0.02-4.00	± 15% (cv)	± 10% (cv)	15%
- Ca	total dissolution	µg/ml dig.	0.1%	0.1-1.0	± 10% (cv)	± 10% (cv)	15%
- K	total dissolution	µg/ml dig.	0.1%	0.5-2.5	± 10% (cv)	± 10% (cv)	15%
- Mg	total dissolution	µg/ml dig.	0.1%	0.0-1.0	± 10% (cv)	± 10% (cv)	15%
- Al	total dissolution	µg/ml dig.	0.1%	0.2-10.0	± 15% (cv)	± 10% (cv)	15%
- Fe	total dissolution	µg/ml dig.	0.1%	0.2-5.0	± 10% (cv)	± 10% (cv)	15%
- S	elemental and total dissolution	µg/ml dig.	mg/kg	100-1000	± 10%	± 10%	15%
- P	total dissolution	µg/ml dig.	mg/kg	500-3000	± 10%	± 10%	15%
- Cu	total dissolution	µg/ml dig.	mg/kg	15-200	± 15%	± 10%	15%
- Mn	total dissolution	µg/ml dig.	mg/kg	50-1000	± 15%	± 10%	15%
- Zn	total dissolution	µg/ml dig.	mg/kg	20-200	± 10%	± 10%	15%
- Na	total dissolution	µg/ml dig.	mg/kg	500-8000	± 10%	± 10%	15%
- Cd	total dissolution	µg/ml dig.	0.1 mg/kg	0.2-5.0	± 15%	± 10%	15%
- Ni	total dissolution	µg/ml dig.	mg/kg	10-100	± 20%	± 10%	15%
- Pb	total dissolution	µg/ml dig.	mg/kg	20-250	± 20%	± 10%	15%
- V	total dissolution	µg/ml dig.	mg/kg	10-100	± 20%	± 10%	15%
Plot							
Slope	chrometer	percent/degrees	percent	0-150	± 3%	± 10%	4%
Aspect	compass	degrees	degrees	0-359	± 5°	± 5°	2°
Elevation	map/altimeter	meters	meters	50-1400	(± 20% of stratum NTE 30m)		na
Latitude	map	degrees minutes	degrees minutes	28-49 0-59	± 3 na	± 3 na	na na
Longitude	map	degrees minutes	degrees minutes	67-125 0-59	± 1 na	± 1 na	na na
Stand							
Basal Area	1) tape 2) prism	tree diameter #trees	sq. m/ha sq. m/ha	2.0-100.0 2.0-100.0	1 tree (any dbh) 1 tree	1 tree 1 tree	na na
Stand Density	visual count	stems/plot	stems/ha	0-11250	1 tree	1 tree	na
Stand Age	estimate	years	years	10-200	± 10%	± 10%	na
% Live B.A.	estimate	percent/plot	percent	0-100	± 10%	± 10%	na
Tree							
DBH	tape	mm	cm	5.0-90.0	(± 2% NTE 0.4cm)		0.1 cm
Height	clinometer	%/dm	0.1 meters	2.0-45.0	± 4%	± 4%	0.4 m
Age	core count	years	years	0-200	± 2 yr	± 2 yr	na
Needle Retention	count	years	years	0-8	± 1 yr	± 1 yr	na
Radial Growth	micrometer	mm	mm	0.1-10.0	± 0.1 mm	± 0.1 mm	0.2 mm
Leaf Area	PE planimeter	sq. cm.	sq. cm.	0-na	± 5%	± 5%	± 5%

5. Sample Custody and Storage.

Describe the procedures for preserving samples integrity, including where appropriate:

a.) sample and sample container identification;
b.) field handling and preparation;
c.) sample transfer;
d.) custody and security;
e.) storage prior to and after analysis (time and conditions);
f.) sample tracking from collection to analysis; and
g.) criteria for rejecting inadequate, inappropriate, or degraded samples.

Where possible, identify personnel responsible for the samples and data of various stages of the research.

6. Sampling and Measurement Procedures.

For this section, we recommend that procedures for sampling and measuring variables, which are not contained in any of the four QA Methods Manuals (see Appendix E), be documented in Standard Operating Procedure (SOP) format (Table 2.1). This format, developed for the FRP and used in the QA Methods Manuals, should be used whenever possible to ensure uniformity, minimum content, and better communication with other field and laboratory units. An effort will be made to incorporate new SOPs into future QA Methods Manuals.

A procedure must be documented prior to its use. Referencing established procedures in published manuals or referenced journals is encouraged, where appropriate. These references should be supplemented with the additional QA material in the SOP

format (e.g., training requirements and QC checks) if absent from the reference.

Many of the methods used in the FRP are documented in SOP format and included in the QA Methods Manuals. If a particular method is generally well established (and/or in a manual), but its use for the specific purpose in this project is new, describe the experiments that will be performed to ensure its applicability. If new methods are being developed, describe the general approach of the method and prescribed evaluation procedures. The QA Program may document recently developed and refined methods in the QA Methods Manuals.

7. Quality Control (QC).

Training:

Supply a short narrative on training requirements necessary for staff to operate facilities and equipment in the respective areas of the research project (e.g., laboratory, or controlled chamber). Training procedures specific to a procedure should be described in the SOP for a given procedure, when using that format.

Quality Control:

Figures A1 and A2 show the interaction of QC activities, research, and possible QA activities in hypothetical laboratory and field situations. For your project, indicate the QC

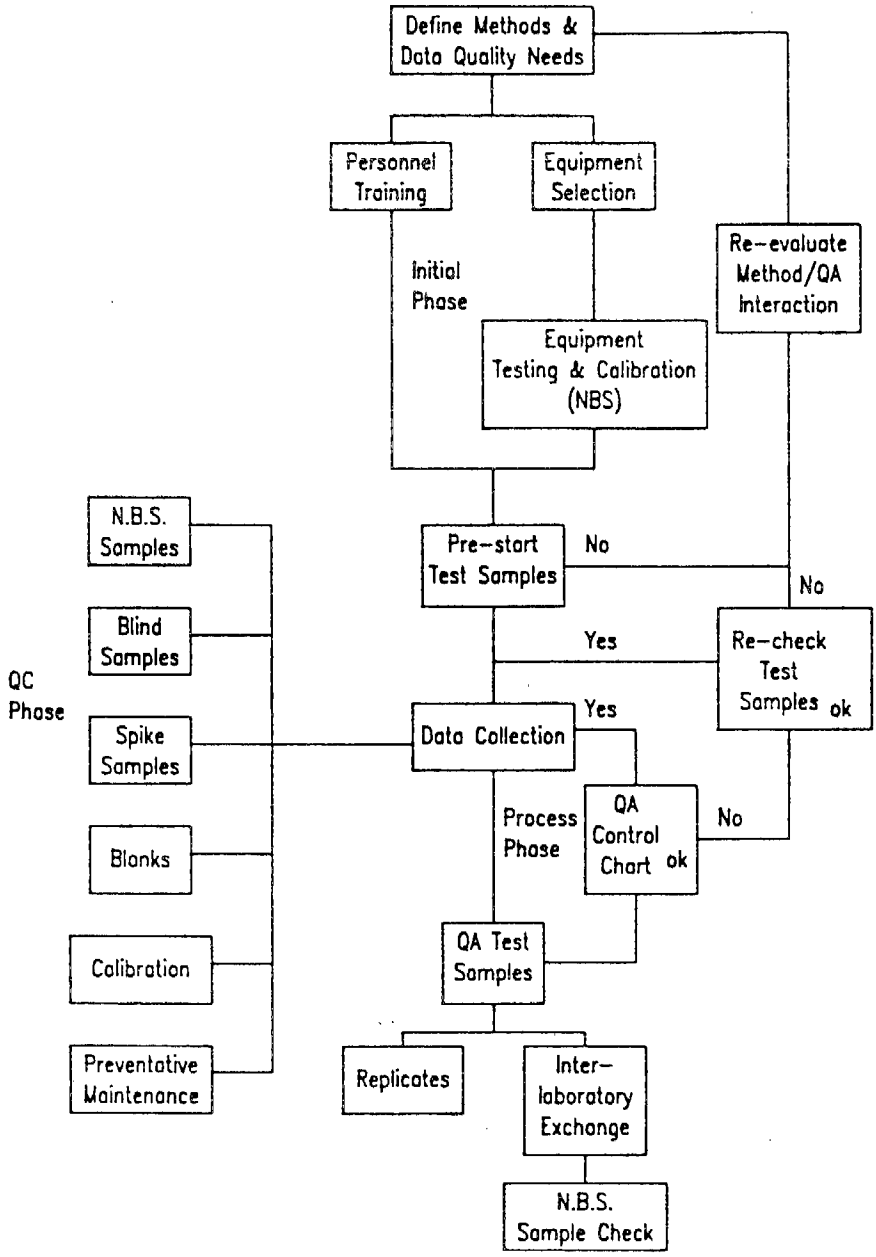

Figure A1. Framework for assuring data quality in the collection of laboratory data. The process phase involves periodic replication and introduction of performance evaluation samples for tracking precision and accuracy, respectively.

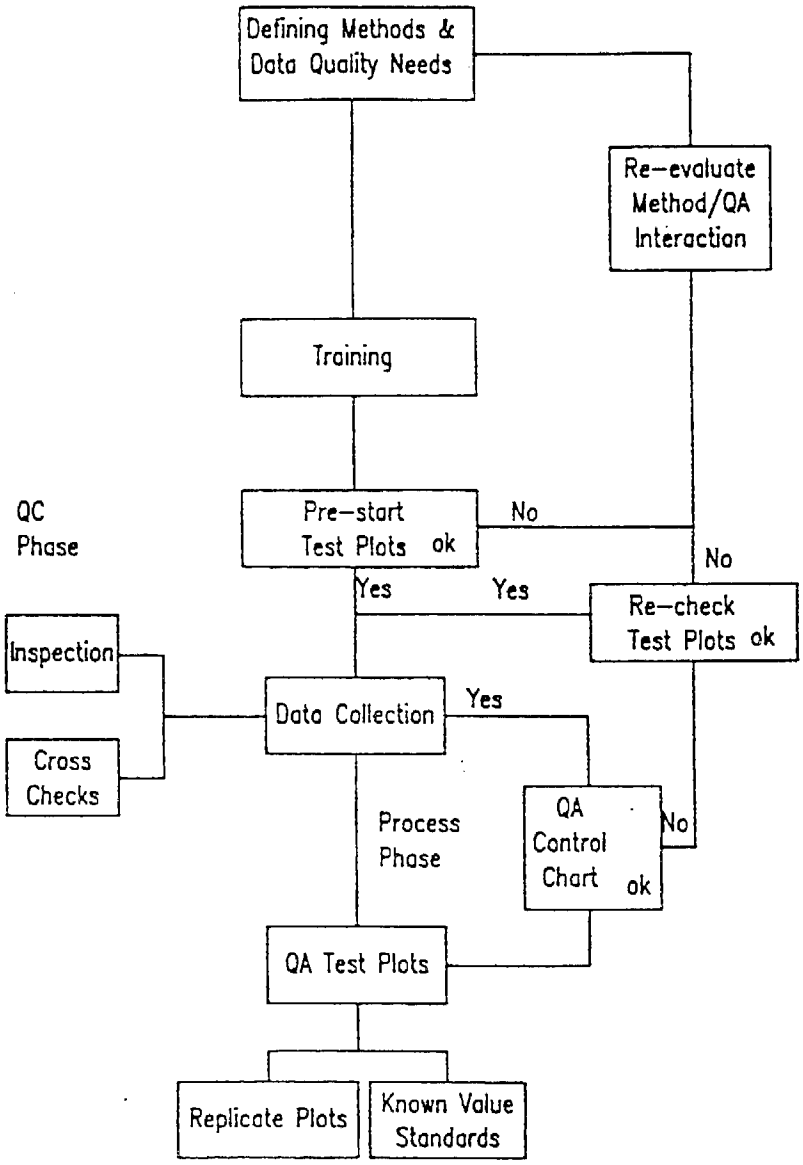

Figure A2. Framework for assuring data quality in the collection of field data. Test plots are select areas where the parameters of interest are of established value (with confidence limits). The measurement crew must show the ability to measure those parameters with a given range about the confidence limits as specified in the Measurement DQOs.

procedures that will be used to control potential sources of error for techniques which are not described in any of the QA Methods Manuals (see Appendix E). QC activities should be described in SOP format for a given procedure, if SOP format is used. Address instrumentation, reagents, laboratory environmental conditions and intra-laboratory comparisons. Explain the source and scheduled frequency of quality control standard. Individuals other than principal investigators who are involved in tracking data quality should be listed.

This section should also be used to supplement the SOPs found in the QA Methods Manuals where necessary. Those SOPs often omit details on QC due the variety of needs and abilities among sites.

Describe the routine procedures to be used to analyze data and thereby track various error sources. Whenever possible, consideration should be given to assessing consistency with other facilities and projects. Control charts or similar graphical representations are strongly recommended; the QA Specialists can help design these mechanisms for tracking QA/QC output. Access to all raw data quality information is required during on-site reviews or on special request from the QA Specialist.

Describe any internal mechanisms for adjusting various aspects of the measurement or analysis procedure in response to problems (e.g., exceeded acceptance limits) discovered with internal QC checks. Mechanisms should be compatible with the

organization as described in Point 1. Procedural changes should be thoroughly documented and reported to the QA Specialist. The new procedure should be compared with the old to quantitatively establish comparability.

Although biological methods are less precise than those of the physical and chemical sciences, project staff are to employ QC measures whenever possible that enhance the reliability of the data or describe the uncertainty surrounding the biological measurements.

Calibration:

Calibration procedures and frequencies should be described for all procedures which are not included in the QA Methods Manuals (see Appendix E). Calibration activities should be documented in SOP format for a given procedure, if that format is used. Procedures for recording and analyzing calibration data should be included (e.g., log books). You should consider stock solutions for preparing calibration standards, concentrations and frequency of analysis of working calibration standards, and criteria for instrument re-calibration in this section.

Preventive Maintenance:

Information on preventive maintenance should be supplied for all equipment not discussed in one of the four Methods Manuals (see Appendix E). Preventive maintenance activities should be

documented in SOP format for a given procedure, if that format is used. Manufacturer's recommendations are strongly recommended with any necessary modifications and can be described simply as such. Remember, preventive maintenance activities must be recorded concurrent with calibration activities. The appropriate schedule for maintenance and responsible personnel should be clearly stated.

8. Data Management.

This section should describe 1) the verification and validation procedures used before and during data analysis; and 2) methods and procedures for maintaining data set integrity. Validation procedures should be comparable to those required in the QA Methods Manual for Experimental Design and Data Management with respect to detecting, evaluating, and correcting potentially faulty points. Validation procedures may include: valid data ranges, outlier detection, and spatial/temporal analyses.

For data set integrity, describe security and archive considerations such as storage medium, conditions, and location. Access by project staff and external personnel (security), record retention time, and protection from demonic forces should be addressed.

9. Quality Assessment and Reporting.

This section should describe planned quality assessment activities. Quality is assessed from the analysis of research

and QC data. Validation data and model/regression testing is particularly valuable in assessing data set quality. In general, however, most information will emerge from the evaluation of QC output (section 7 above). This information should be summarized at the conclusion of the research project and entered/maintained with the data set. Final research reports should present your conclusions about data quality.

3.0 IMPLEMENTATION:

After the first draft QA Project Plan is completed, it is submitted by the investigator to the appropriate QA Specialist for review. This is the first in a series of ongoing interactions between the investigator and QA Specialist. Once reviewed, the QA Project Plan will be approved, or revisions will be requested. If the requested revisions cause disagreements, they will be settled through negotiations between the investigator and QA Specialist. Should they fail to resolve the issue, the QA Officer and Cooperative Director will intervene.

The QA Specialist recommends approval of the QA Project Plan to the QA Officer when all planning requirements have been met. However, the QA Project Plan may require periodic updating based upon the results of system or data quality audits, or changes in research design or methodology.

If you have questions about the guidance offered in this appendix, please contact the designated QA Specialist for the Cooperative. We will assist in QA Project Plan development and

supply copies of appropriate methods manuals or examples of QA Project Plan material upon request.

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APPENDIX B

GUIDELINES FOR DEVELOPING SPECIAL QA PROJECT PLANS FOR LITERATURE REVIEWS AND ANALYSES OF DATA PROJECTS

GUIDELINES FOR DEVELOPING QUALITY ASSURANCE PROJECT PLANS FOR PROJECTS USING EXISTING INFORMATION

1.0 INTRODUCTION

Forest Response Program (FRP) projects commonly use existing information (literature reviews, data collections, and data re-analysis projects) to draw conclusions about past research, support current analyses, and plan future research projects and budgets. Since most of this information was collected without an EPA-type QA program in place, it is mostly of unknown quality. That is, information on its precision, accuracy, representativeness, completeness, and comparability is unreported.

The use of information of unreported quality conflicts with the goal of QA in the FRP: to assure that data are of known and sufficient quality for assessing the effects of atmospheric deposition on forest ecosystems. Furthermore, the certainty of conclusions and analyses based upon information of unknown quality can not be judged, and past and present work cannot be readily compared because the sources and magnitude of errors are undocumented.

These concerns have prompted the development of special QA guidelines for research projects conducting 1) literature reviews, or 2) data collections and/or re-analyses. The guidelines are designed to assist investigators in the preparation of QA Project Plans. The QA Project Plan is a stand alone supplement to the technical work plan. All investigators

requesting funding from the FRP are required to prepare a QA Project Plan.

The specific objectives of the QA Project Plan for projects using existing information are as follows:

1.) to characterize the literature and/or database(s) that will be used, and why they are used;

2.) to document how the information in the literature and/or database(s) will be analyzed and applied; and

3.) to estimate, to the extent possible, the quality of information in the literature and/or database(s), and to evaluate the usefulness of the information to the research project.

Projects which solely use existing information need only follow the format presented below for their QA Project Plan. Projects which use existing information as part of their research design are expected to include points 3 - 5 in addition to the standard guidelines presented in Appendix A of this document. Remember to cite and enclose existing planning documentation (technical work plans, QA Methods Manuals, technical papers, and other manuals) wherever possible and appropriate.

2.0 DEVELOPMENT OF THE QA PROJECT PLAN

2.1 Literature Reviews:

The QA Project Plan should begin with a title page, followed by a table of contents containing entries for the sections outlined below and any supplemental information (literature cited and appendices). The general format of a QA Project Plan for literature reviews is outlined below:

1. Project description.

The project description should include the following:

* a brief statement of the scope, purpose, and objectives of the research, including the FRP scientific question(s) that the research will address;

* the product(s) and a timetable for their completion.

2. Project organization and facilities.

The project organization should include the following:

* a diagram showing the project personnel, their titles and duties/responsibilities, and the lines of authority and information flow among them (see Fig. 1 for examples);

* a short narrative about individual responsibilities, when they cannot be clearly delineated in a diagram.

The description of the project's facilities should include the following, where appropriate:

* a brief discussion about the key support facilities and services used, including the types of computers employed, and their software and uses with related equipment or systems.

* a diagram or map showing the location of those facilities, if necessary.

3. Characterization of literature available.

The purpose of this section is to systematically describe the information used for literature reviews including, where appropriate:

* the name and location of information sources, such as computerized searches or published bibliographies.

* the nature of the information, original reports or review articles.

4. Analysis and application of information.

If information from literature reviews will be used "as is", a statement to this effect should be made. The remainder of this section should then address the specific application of the information, including the importance of that application to answering the FRP scientific question(s) and to the overall success of the project.

In contrast, if the information will be modified or synthesized in a different way, then the procedure should be described (e.g., the procedure for resolving conflicting literary accounts of a similar phenomenon).

5. Assessment of information quality.

The purpose of this section is to evaluate, to the extent possible, the reliability of information. Procedures for determining the reliability of each individual source during collection should be outlined. In many cases, evaluations of information quality will be necessarily based upon qualitative information, judgments, and impressions, because quantitative QC information was unreported. For example, the quality of information gathered during literature reviews may be indicated

initially by these qualitative groups (personal communication, I. Millers, USFS, State and Private Forestry, Durham, NH):

a.) primary sources: personal observations of the author(s) based upon systematic data collection; conclusions based upon quantitative data;

b.) reviews: summaries and interpretations of other research by the author(s); conclusions based upon quantitative data;

c.) conjectures: hypotheses or speculations of others reported by the author(s); no quantitative data provided;

d.) indirect sources: ancillary, secondary references to other research by the author(s) to introduce, justify, explain, or interpret a different, primary subject; no quantitative data provided.

For group a., and possibly group b., the following qualitative items should also be considered, where possible and appropriate:

* there is a difference among peer reviewed journal articles, agency publications, symposia publications, and newspaper articles.

* the sampling/measurement equipment and techniques used to generate the information in the literature may provide insight into data quality (e.g., there are inherent differences in achievable precise and accurate across instruments and techniques). Investigators are not required to go beyond the information presented in the literature, but may find more in-depth searching worthy for crucial pieces of literature.

* evaluate the limitations of the information in the literature due to missing data (e.g., were measurements for a crucial time period or whole treatment missing?) or particular sampling methods or equipment.

In addition, concerns about the representativeness, completeness, and comparability of information should be addressed for the entire project (e.g., is the review itself comprehensive and appropriate?).

2.2 Data Collections and/or Re-analyses:

The QA Project Plan for data collection and/or re-analyses projects follow from that of literature reviews (title page, table of contents, literature cited, and appendices).

1. Project Description. (as in above point 1)

2. Project Organization and Facilities. (as in 2 above)

3. Characterization of the database(s).

The purpose of this section is to systematically describe the database(s), including, where appropriate, the following:

* the name and location of the sources
* the nature of the information, including where appropriate:

  a.) the population or community sampled, including the sampling or experimental unit;

  b.) the sampling methods, including selection, collection, timing, frequency, and equipment;

c.) the measurement variables;

d.) the analytical methods, including key chemical, physical, and biological measurements, equipment, and statistics; and

e.) any QC information associated with these methods, including calibration or standardization methods, schedules for preventative maintenance of instruments and training of personnel, precision and accuracy of measurements, and data verification and validation techniques.

A well-documented database will have much of this type of information readily available in support documentation; if it is missing or unavailable, suspicions might be in order. Items c. through e. might best be incorporated into a table. QC information that is unavailable should be noted as such in the table.

4. Analysis and application of data.

If information from the database(s) will be used "as is", a statement to this effect should be made. The remainder of this section should then address the specific application of the information, including the importance of that application to answering the FRP scientific question(s) and to the overall success of the project.

In contrast, if information from the database(s) will be modified or reanalyzed, or if different types of data summaries are desired, then the analytical procedures should be described. The description should include, where appropriate, the following points:

* the variables reanalyzed;

* the procedures, statistical or otherwise, used to validate, verify, select, and group data;

* any calculations, transformations, or statistics used to modify or describe the data; and

* the specific application of the reanalysis or summary.

5. Assessment of data quality.

The purpose of this section is to evaluate, to the extent possible, the reliability of the existing database(s). Procedures for determining precision, accuracy, representativeness, completeness, and comparability of existing data should be summarized. Ideally, quantitative QC data, will be available to make evaluations of information quality, especially with raw data. However, in many cases, evaluations of data quality will be necessarily based upon qualitative information, judgments, and impressions. Following is a guide to these evaluations:

* precision and accuracy--evaluate the measurement equipment and techniques used to generate the database(s) for inherent precision and accuracy (e.g., how precise and accurate were the instruments and techniques chosen relative to those available?);

* completeness--evaluate the limitations of the database(s) due to missing data (e.g., were measurements for a crucial time period or whole treatment missing?);

* representativeness--evaluate the study sites and the measurement equipment and techniques used to generate the database(s) for uniqueness (e.g., were odd or unusual sites or techniques used that limit the usefulness of the information?); and

* comparability--evaluate the miscibility and applicability of the database(s) for supporting current analyses and answering scientific questions (e.g., do differences in objectives, designs, methods, or analyzes among the studies or database(s) limit their usefulness collectively?).

The QA Project Plan should detail plans for QA reports which summarize the above data quality and associated QA/QC activities. QA/QC data may be requested periodically, and must be accessible to the QA staff during project reviews.

3.0 IMPLEMENTATION:

After the first draft QA Project Plan is completed, it is submitted by the investigator to the appropriate QA Specialist for review. This is the first in a series of ongoing interactions between the investigator and QA Specialist. Once reviewed, the QA Project Plan will be approved, or revisions will be requested. If the requested revisions cause disagreements, they will be settled through negotiations between the

investigator and QA Specialist. Should they fail to resolve the issue, the QA Officer and Cooperative Director will intervene.

The QA Specialist recommends approval of the QA Project Plan to the QA Officer when all planning requirements have been met. However, the QA Project Plan may require periodic updating based upon the results of system or data quality audits, or changes in research design or methodology.

If you have questions about the guidance offered in this appendix, please contact the designated QA Specialist for the Cooperative. We will assist in QA Project Plan development and supply copies of appropriate methods manuals or examples of QA Project Plan material upon request.

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APPENDIX C

GUIDELINES FOR DEVELOPING SPECIAL QA PROJECT PLANS FOR MODELING PROJECTS

GUIDELINES FOR DEVELOPING QUALITY ASSURANCE PLANS FOR MODELING PROJECTS

1.0 INTRODUCTION:

The goal of Quality Assurance (QA) in the Forest Response Program is to assure that data are of known and sufficient quality to meet their intended use for determining the effects of atmospheric deposition on forest ecosystems. The technical work plan is the primary research planning document. The QA Project Plan is a stand alone supplement to the technical work plan. All investigators requesting funding from the FRP for projects involving collection, measurement, and analysis of environmental data are required to prepare a QA Project Plan, which must be approved before research funds are released.

Modeling projects represent a unique QA requirement in that they only require very thorough documentation (no standardized methods). For this reason, we have developed a special set a requirements for the development of QA Project Plans which details activities of modeling projects. As with other QA Project Plans, though, remember to cite and enclose existing documentation where possible and appropriate. For example, the QA Project Plan can and should reference the technical work plan to reduce duplication.

Projects concerned solely with modeling need only follow the format presented below for their QA Project Plan. Projects which develop models only as part of their research design are expected

to include points 3 - 7 in addition to the standard guidelines presented in Appendix A of this document.

2.0 DEVELOPMENT OF THE QA PROJECT PLAN:

The QA Project Plan should begin with a title page, followed by a table of contents containing entries for the sections outlined below and any supplemental information (literature cited and appendices). The general format of a QA Project Plan for modeling projects is outlined below:

1. Project description.

The project description should include the following:

* a brief statement of the scope, purpose, and objectives of the research, including the FRP scientific question(s) that the research will address;
* the product(s) and a timetable for their completion.

2. Project organization and facilities.

The project organization should include the following:

* a diagram showing the project personnel, their titles and duties/responsibilities, and the lines of authority and information flow among them (see Fig. 1 for examples);
* a short narrative about individual responsibilities, when they cannot be clearly delineated in a diagram.

The description of the project's facilities should include the following, where appropriate:

* a brief discussion about the key support facilities and services used, including the types of computers employed, and their software and uses with related equipment or systems.

* a diagram or map showing the location of those facilities, if necessary.

3. Model description.

The model description should include:

(a.) Origin and original function
(b.) Population being modeled
(c.) Spatial extent (tree, stand, regional level)
(d.) Spatial resolution (distance independent, distance dependent)
(e.) Temporal extent (length of modeling period)
(f.) Temporal resolution (time step)
(g.) Model structure (theoretical vs. data driven, stochastic vs. deterministic, structural framework)

4. Model Input/Output.

Describe the form and units of model input and output.

5. Model Application.

Outline any restrictions of model application, including:

(a) Geographical
(b) Population (species, forest type, age, etc.)
(c) Input restriction bounds (minimums, maximums)
(d) Other

6. Model Testing.

Describe what tests will be run after the model is developed or adapted for its current use to assess model reliability.

Include methods for assessing model behavior, including estimates of the bias, precision, and accuracy of the predictions over suitable ranges of the input variables. Show that the input data for the above is independent of model formulation.

Discuss the use of validation data sets, if appropriate, and how they are defined.

7. Computer aspects.

Indicate the following:

(a.) What programming language is used (FORTRAN, BASIC, etc.) and is it ANSI standard?
(b.) What is the extent of model portability?
(c.) What are the core (memory) requirements?
(d.) Required hardware/software for application (monitor, line printer, graphics)?
(e.) Approximate execution time for a typical run?

3.0 IMPLEMENTATION:

After the first draft QA Project Plan is completed, it is submitted by the investigator to the appropriate QA Specialist for review. This is the first in a series of ongoing interactions between the investigator and QA Specialist. Once reviewed, the QA Project Plan will be approved, or revisions will be requested. If the requested revisions cause disagreements, they will be settled through negotiations between the investigator and QA Specialist. Should they fail to resolve the issue, the QA Officer and Cooperative Director will intervene.

The QA Specialist recommends approval of the QA Project Plan to the QA Officer when all planning requirements have been met.

However, the QA Project Plan may require periodic updating based upon the results of system or data quality audits, or changes in research design or methodology.

If you have questions about the guidance offered in this appendix, please contact the designated QA Specialist for the Cooperative. We will assist in QA Project Plan development and supply copies of appropriate methods manuals or examples of QA Project Plan material upon request.

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APPENDIX D
QUALITY ASSURANCE PROJECT REVIEW

QUALITY ASSURANCE PROJECT REVIEW
FOR THE
FOREST RESPONSE PROGRAM

GENERAL INFORMATION:

Research Cooperative: _____

Investigator: _____ Reviewer: _____

Project Title: _____

_____

_____

Intended Use of Data: _____

_____

PROJECT FUNDING:

Contract: _____ Starting Date: _____

Cooperative Agreement: _____ Completion Date: _____

Interagency Agreement:_____

Other _____ Specify _____

- -

QUALITY ASSURANCE PLAN:

Yes No N/A Environmentally-related measurements taken.

Yes No N/A Quality assurance plan has been written for this project.

Yes No N/A Project proposal has been written. The proposal has received peer review (intramural and/or extramural).

Yes No N/A Quality assurance is covered in the project proposal.

Yes No N/A Project staff are aware of quality assurance objectives and perform their job with these objectives in mind.

- -

SAMPLING PHASE:

Yes No N/A The experimental/sampling design has been prepared with the advice and assistance of a statistician. Criteria are provided for sample size and sample selection.

Yes No N/A The experimental design is standard or used by other investigators. Explain:

Yes No N/A Criteria are used to select sampling site(s). Documentation: _____

Yes No N/A Written procedures are available for collecting samples. Documentation: _____

Yes No N/A Written procedures are available for handling and preserving samples (this includes chemical treatment, transfer to the lab, and storage prior to analysis). Documentation: _____

Yes No N/A Data records verify that measurement data are traceable to a specific sample or field site. Documentation: _____

Yes No N/A Sampling equipment use follows accepted manufacturer's instructions or peer review methods. Documentation: _____

Yes No N/A Sampling equipment is checked to assure its proper operation and calibration. How often: _____ by whom: _____

Yes No N/A Samples are free of contamination from exterior sources (road dust, pesticides, or other human influences).

Yes No N/A Field sampling techniques and measurements are "practiced" and coordinated among samplers prior to and periodically during the sampling procedure and are documented.

Yes No N/A Field personnel are aware of the guidelines for quality assurance and understand/respect the purpose of these guidelines.

Yes No N/A Records of instrument inspection, calibration and preventive maintenance follow frequency prescribed in guidelines (manufacturer's specifications, SOP).

Yes No N/A Significant data are recorded directly, promptly, and legibly.

Yes No N/A The standard operating procedures set forth the methods, materials and schedules to be used in the field sampling operations and specify any action to be taken in the event of equipment malfunction.

Yes No N/A Significant deviations from these procedures are noted and approved by the investigator.

Yes No N/A Evidence of project officer review of equipment and maintenance records.

- -

FIELD MEASUREMENT PHASE:

Yes No N/A All measurement techniques are standardized (described in the Methods Manuals) or approved (described in the QA Project Plan) and personnel are familiar with these documents.

Yes No N/A The measurement equipment is used within the accepted range as described by the manufacturer or Methods Manual.

Yes No N/A Significant changes in established procedures are documented and authorized by the Project Officer.

Yes No N/A Proper calibration and preventative maintenance procedures are followed.

Yes No N/A Data are recorded directly, promptly, and legibly.

Yes No N/A Quality control checks are adequately performed, recorded, and evaluated.

Yes No N/A Evidence of Project Officer's review in field data is available.

GREENHOUSE PHASE:

Yes No N/A Appropriate protocols for the operation of greenhouse and controlled chamber are available and personnel are familiar with this documentation.

Yes No N/A Deviations from these protocols are documented and authorized by the Project Officer.

Yes No N/A Monitoring equipment is maintained as required to characterize chamber environment.

Yes No N/A Seedlings are not subjected to unusual conditions outside the prescribed range of treatments.

Yes No N/A Seedling measurements are standardized or approved.

Yes No N/A Quality control information is collected, evaluated, and documented as required by the Methods Manuals or approved documentation.

Yes No N/A Evidence of the Project Officer's involvement in review of greenhouse facilities and data.

- -

LABORATORY ANALYSIS PHASE:

Yes No N/A There is one individual responsible for laboratory sample control. Name: _____

Yes No N/A Sample receipt, processing and storage procedures are followed. Procedures: _____. Samples are consistently stored in the same manner.

Yes No N/A Sample is analyzed within recommended time period.

Yes No N/A Each laboratory area has standard operating procedures and laboratory manuals relative to the procedures being performed. Documentation: _____

Yes No N/A Documentation is accurate and defines the operating procedures currently in use.

Yes No N/A Significant changes in established standard operating procedures are authorized by the project officer.

Yes No N/A Each individual in the laboratory has a notebook for maintaining detailed records. Significant data, except those that are generated as direct computer input, are recorded directly, promptly and legibly into laboratory notebooks.

Yes No N/A Notebooks are maintained in sufficient detail to permit a similarly qualified researcher to understand the original research performed.

Yes No N/A The laboratory conducts routine checking, calibration and maintenance of equipment and instruments. Documentation: _____. Review frequency of calibration.

Yes No N/A The sample is within the range limits of the calibration.

Yes No N/A The calibration is performed under the same instrumental and chemical conditions as those that exist during the measurement process.

Yes No N/A Reagents are properly labeled, stored, and dated.

Yes No N/A Quality control samples exist for the measurements taken in the project.

Yes No N/A Results of the quality control sample checks. Documentation: _____

Yes No N/A Quality control outputs (spiked samples, split samples, internal standards, etc.) are summarized on a regular basis.

Yes No N/A Evidence of project officer review of laboratory data. Documentation: _____

- -

DATA REDUCTION AND STORAGE PHASE:

Yes No N/A Statistical techniques used in the program are documented. Documentation: _____

Yes No N/A Statistical techniques have been developed in conjunction with and approved by a statistician. Name: _____

Yes No N/A Written guidelines are used to prevent errors and minimize data loss. Documentation: _____. Describe procedures which cause data to be flagged.

Yes No N/A When errors in data handling are discovered, a mechanism exists to correct the situation that allowed the error.

Yes No N/A Validation checks (i.e., range checks, outlier checks, relational checks) are routinely performed on all data. Computer or manual?

Yes No N/A Electronic data handling, reduction, storage, and transmission systems are periodically tested with known data that have already been calculated.

Yes No N/A Written guidelines are used for data storage, retention and data access. Documentation: _____

Yes No N/A There is one individual responsible for record keeping. Name: _____

Yes No N/A The software is written and maintained in-house.

Yes No N/A Written guidelines are used for software documentation. Documentation: _____

Yes No N/A When the data are changed for reasons other than entry errors the original values are saved.

Yes No N/A Duplicate copies of data are maintained.

Yes No N/A Data is indexed correctly and retained in an archive of adequate space and design.

- -

PROGRAM REPORTING PHASE:

Yes No N/A A report has been written for this research program. Documentation: _____

Yes No N/A The report describes or references the quality assurance aspects of the project. Documentation: _____

Yes No N/A The report describes or references the evaluation of precision and accuracy. The data quality objectives as stated in the quality assurance plan have been achieved.

Yes No N/A The report includes or references results of quality control outputs.

Yes No N/A The report indicates problems encountered and corrective action taken.

Yes No N/A The report describes the limitations of the data.

- -

Yes No N/A There has been a peer review of this research program. Date of last review. _____

Yes No N/A Does the investigator or the program staff have any problems/concerns/questions concerning the Forest Response QA program as it relates to this research effort?

_____

_____

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APPENDIX E

QUALITY ASSURANCE METHODS MANUALS TABLES OF CONTENTS

EXPOSURE SYSTEMS AND PHYSIOLOGICAL MEASUREMENTS

Section		Pages	Revision	Date	Page
1.	Introduction	3	0	June 1986.	1
	1.1. Exposure Systems				1
	1.2. Physiological Measurements				2
2.	Protocol Narratives for Exposure Systems	8	0	June 1986.	4
	2.1. Wet Deposition - Automatic Rainfall Exclusion with Regular Additions				4
	2.2. Dry Deposition - Open-Air Release (Chamberless) Systems.				5
	2.3. Wet Deposition - Automatic Rainfall Exclusions with Automatic Additions				8
	2.4. Dry Deposition - Open-Top Chambers				8
	2.5. Controlled-Environment Facilities.				9
	2.6. Greenhouse Facilities				9
3.	Protocol Narratives for Pollutant Delivery and Monitoring Systems	8	0	June 1986.	12
	3.1. Wet Deposition				12
	3.2. Dry Deposition				13
4.	Standard Operating Procedure for Measurement of Net Carbon Exchange	11	0	June 1986.	20
5.	Standard Operating Procedure for Plant Water Relations Measurements	10	0	June 1986.	31
6.	Standard Operating Procedure for Measurement of Seedling Leaf Area.	7	0	June 1986.	41
7.	Standard Operating Procedure for Seedling Growth Measurements	6	0	June 1986.	49
8.	Standard Operating Procedure for Determination of Foliar Injury to Seedlings and Saplings	2	0	June 1986.	55

EXPOSURE SYSTEMS AND PHYSIOLOGICAL MEASUREMENTS
(cont'd)

Section	Pages	Revision	Date	Page
9. Standard Operating Procedure for Mycorrhizal Assessments	3	0	June 1986.	57

SITE CLASSIFICATION AND FIELD MEASUREMENTS

Section		Pages	Revision	Date	Page
1.	INTRODUCTION	1	0	July 1986.	1
2.	PERMANENT PLOT ESTABLISHMENT	4	0	July 1986.	2
	2.1 Objectives				2
	2.2 Location				2
	2.3 Design				3
	2.4 Marking				5
3.	PERMANENT SAMPLE POINT ESTABLISHMENT	2	0	July 1986.	6
	3.1 Objectives.				6
	3.2 Location				6
	3.3 Design.				6
	3.4 Marking				7
4.	SITE DESCRIPTION	11	0	July 1986.	8
	4.1 Objectives/Narrative				8
	4.2 Standard Operating Procedure for Measurement of Aspect.				11
	4.3 Standard Operating Procedure for Measurement of Elevation				13
	4.4 Standard Operating Procedure for Measurement of Slope				15
5.	INDIVIDUAL TREE LEVEL MEASUREMENTS	41	0	July 1986.	19
	5.1 Objectives/Narrative.				19
	5.2 Standard Operating Procedure for Measurement of Diameter at Breast Height				21
	5.3 Standard Operating Procedure for Measurement of Tree Height				26
	5.4 Standard Operating Procedure for Field Increment Coring for Tree Age, Site Index, and Dendrochronology				30
	5.5 Standard Operating Procedure for Measurement of Leaf Area				41

SITE CLASSIFICATION AND FIELD MEASUREMENTS
(cont'd)

Section		Pages	Revision	Date	Page
5.7	Standard Operating Procedure for Estimating Tree Vigor				51
5.6	Standard Operating Procedure for Estimating Foliage Vigor/Foliage Discoloration				48
6.	STAND LEVEL MEASUREMENTS	9	0	July 1986	60
6.1	Objectives/Narrative				60
6.2	Standard Operating Procedure for Measurement of Stand Basal Area				61
6.3	Standard Operating Procedure for Measurement of Stand Age				67
7.	SOIL DESCRIPTION	6	0	July 1986	69
7.1	Objectives				69
7.2	Pre-Field Activity				69
7.3	Equipment Required				70
7.4	General Approach				70
7.5	Technical Approach				70
8.	MYCORRHIZAE/ROOT PATHOGENS ASSESSMENT	8	0	July 1986	75
8.1	Objectives/Narrative				75
8.2	Sampling				76
8.3	Ectomycorrhizal Estimation Methods				78
8.4	Ectomycorrhizal Sampling Procedures				79

LABORATORY ANALYTICAL TECHNIQUES

Section		Pages	Revision	Date	Page
1.	GOOD LABORATORY PRACTICES	13	0	July 1986.	1
1.1	Documenting Analysis Procedures.				1
1.2	Maintaining Distilled Water Quality.				2
1.3	Cleaning and Using Glassware and Plasticware				3
1.4	Using Laboratory Reagents, Solvents, and Acids				5
1.5	Maintaining Analytical Standards				6
1.6	Weighing				6
1.7	Maintaining Laboratory Cleanliness				7
1.8	Controlling Laboratory Sample Handling/Custody				8
1.9	Recording and Reporting Data				10
2.	FOLIAR INORGANIC ANALYSIS	47	0	July 1986.	14
2.1	Standard Operating Procedure for Multi-Element Analysis: N (Kjeldahl-N), P Using an AutoAnalyzer				14
2.2	Standard Operating Procedure for Multi-Element Analysis: C, N (Total-N), S Using an Elemental Analyzer.				22
2.3	Standard Operating Procedure for Multi-Element Analysis: N (Kjeldahl-N), P, Ca, Mg, K Using WFT Digestion				25
2.4	Standard Operating Procedure for Multi-Element Analysis: K, P, Ca, Mg, B, Na, Cu, Zn Using Dry Combustion.				31
2.5	Standard Operating Procedure for Multi-Element Analysis: K, Ca, Mg, Cu, Fe, Mn, Zn, Al, Cd, Na, Ni, Pb, V, Ba, Co, Rb Using Dry Combustion.				36
2.6	Standard Operating Procedure for Measurement of Boron				42
2.7	Standard Operating Procedure for Measurement of Chloride				48
2.8	Standard Operating Procedure for Measurement of Sulphur				54
3.	FOLIAR ORGANIC ANALYSIS	35	0	July 1986	61
3.1	Standard Operating Procedure for Determination of Total Chlorophyll				61

LABORATORY ANALYTICAL TECHNIQUES
(cont'd)

Section		Pages	Revision	Date	Page
3.2	Standard Operating Procedure for Quantitative Analysis of n-Alkane Concentration and Total Epicuticular Wax of Red Spruce Foliage.				69
3.3	Standard Operating Procedure for Measurement of Starch and Total Sugars				84
4.	SOIL PHYSICAL ANALYSIS . . . . 34 . . .0. . .July 1986.				96
4.1	Standard Operating Procedure for Sample Preparation				96
4.2	Standard Operating Procedure for Measurement of Soil Moisture Content.				103
4.3	Standard Operating Procedure for Measurement of Organic Matter by Loss-On-Ignition.				106
4.4	Standard Operating Procedure for Measurement of Soil Bulk Density (Core Method)				109
4.5	Standard Operating Procedure for Measurement of Field Water Content (Gravimetric Approach). . .				117
4.6	Standard Operating Procedure for Particle Size Analysis.				122
5.	SOIL CHEMICAL ANALYSIS. . . . .58 . . .0 . .July 1986 .				130
5.1	Standard Operating Procedure for Measurement of pH (DI water, 0.01M CaCl2, 1N KCl-air dry soils)				130
5.2	Standard Operating Procedure for Measurement of Exchangeable Bases (Ca, Mg, Na, K) by 1N, NH4,C1				136
5.3	Standard Operating Procedure for Measurement of Exchangeable Acidity				142
5.4	Standard Operating Procedure for Measurement of Extractable Metals (Fe, Zn, Cu, Pb, Cd, Ni, Mn)				150
5.5	Standard Operating Procedure for Measurement of Extractable Phosphorus ('Bray 1')				156
5.6	Standard Operating Procedure for Measurement of Extractable Sulfate-S				161
5.7	Standard Operating Procedure for Measurement of Total (Kjeldahl) Nitrogen.				168

LABORATORY ANALYTICAL TECHNIQUES
(cont'd)

Section		Pages	Revision	Date	Page
5.8	Standard Operating Procedure for Measurement of Total Carbon/Nitrogen/Sulfur Content Using an Elemental Analyzer				176
5.9	Standard Operating Procedure for Measurement of Elemental Content by Total Dissolution (Ca, K, Mg, Al, Fe, S, P, Cu, Mn, Zn, Na, Cd, Ni, Pb, V)				179

EXPERIMENTAL DESIGN AND DATA MANAGEMENT

Section	Pages	Revision	Date	Page
PREFACE	3	0	July 1986	iv
1. INTRODUCTION	2	0	July 1986	1
2. EXPERIMENTAL DESIGN CONSIDERATIONS	5	0	July 1986	3
2.1 Screening Studies and Surveys				4
2.2 Pollutant Interaction Studies				5
2.3 Dose-Response Studies				5
2.4 Field Studies				7
3. SAMPLING DESIGN CONSIDERATIONS.	2	0	July 1986	8
3.1 Design Selection				8
3.2 Other Quality Assurance Considerations				9
4. DATA ANALYSIS	2	0	July 1986	10
4.1 Types of Error in Hypothesis Testing.				10
4.2 Documentation of Data Analysis.				11
5. DATABASE MANAGEMENT	12	0	July 1986	12
5.1 Goals				12
5.2 Data Type Distinction				13
5.3 Design Rationalization				13
5.4 Products				14
5.5 Management Systems for Internal Data.				15
5.6 Management Systems for External Data.				21
5.7 Data Documentation Files				22
6. DATA MANAGEMENT.	6	0	July 1986	24
6.1 Data Collection and Recording				24
6.2 Data Input and Transmission				25
6.3 Quality Assurance Requirements for the Investigators				25

EXPERIMENTAL DESIGN AND DATA MANAGEMENT
(cont'd)

Section		Pages	Revision	Date	Page
6.4	Guidelines for the Database Administrator				27
6.5	Implementing a Tracking System				28
6.6	Data Archival, Security, and Exchange				28
6.7	Disposition of Data				29

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APPENDIX F

STANDARDIZED VARIABLE CODE NAMES

APPENDIX F

VARIABLE CODES [1]

PHYSIOLOGICAL MEASUREMENTS

Variable Name	Code
Ambient Carbon Dioxide	ECO2
Photosynthetically Active Radiation	EPAR
Relative Humidity	ERHM
Air Temperature	ETMP
Leaf Area Index	LAIN
Leaf Surface Area	LARE
Leaf Conductance	LCND
Leaf Resistance	LRES
Leaf Temperature	LTMP
Leaf Water Content	LWCO
Leaf Water Potential	LWPO
Canopy Conductance	PCCO
Dark Respiration	PDRS
Internal Carbon Dioxide	PICD
Apparent Net Photosynthesis	PNPS
Plan Osmotic Potential	POPO
Photorespiration	PRSP
Specific Leaf Area	PSLA
Stomatal Resistence	PSRE
Plant Turgor Pressure	PTPR
Transpiration	PTRA
Vapor Pressure Deficit	PVPD
Vapor Pressure Gradient	PVPG
Xylem Pressure Potential	PXPP
Soil Water Content	SFWC
Soil Temperature	STMP
Soil Water Potential	SWPO

SITE CLASSIFICATION AND FIELD MEASUREMENTS

Variable Name	Code
Aspect	ASPT
Crown Damage	CDAM
Crown Decline	CDEC

[1] This material represents a tentative list of suggested computer database codes to be used for these variables.

FIELD MEASUREMENTS (cont'd)

Variable Name	Code
Crown Position	CPOS
Crown Ratio	CRAT
Elevation	ELEV
Stand Age	SAGE
Site Index	SIND
Slope	SLOP
Stand Basal Area	STBA
Tree Age	TAGE
Tree Diameter at Breast Height	TDBH
Tree Foliage Discoloration	TFDS
Tree Foliage Vigor	TFVG
Tree Increment Growth	TIGR
Leaf Area	TLAI
Tree Height	TRHT
Tree Vigor	TVIG

LABORATORY ANALYTICAL TECHNIQUES

Variable Name	Code
n-Octadecane	FC18
n-Nonadecane	FC19
n-Eicosane	FC20
n-Heneicosane	FC21
n-Docosane	FC22
n-Tricosane	FC23
n-Tetracosane	FC24
n-Pentacosane	FC25
n-Hexacosane	FC26
n-Heptacosane	FC27
n-Octacosane	FC28
n-Nonacosane	FC29
n-Triacontane	FC30
n-Hentriacontane	FC31
n-Dotriacontane	FC32
n-Tritriacontane	FC33
n-Tetratriacontane	FC34
n-Hexatriacontan	FC36
Total Chlorophyll	FCHL
Extractable Cl	FECL
Extractable Starch	FSTR
Total Sugars	FSUG
Total Foliar Elemental Al	FTAl
Total Foliar Elemental Ba	FTBA
Total Foliar Elemental Ca	FTCA
Total Foliar Elemental Cd	FTCD

LABORATORY ANALYTICAL TECHNIQUES (cont'd)

Variable Name	Code
Total Foliar Elemental Cs	FTCS
Total Foliar Elemental Cu	FTCU
Total Foliar Elemental Fe	FTFE
Soil Kjeldahl-N	FTKN
Total Foliar Elemental Mg	FTMG
Total Foliar Elemental Mn	FTMN
Total Foliar Elemental Na	FTNA
Total Foliar Elemental Pb	FTPB
Total Foliar Elemental Rb	FTRB
Total Foliar Elemental B	FTTB
Total Foliar Elemental C	FTTC
Total Foliar Elemental K	FTTK
Total Foliar Elemental N	FTTN
Total Foliar Elemental P	FTTP
Total Foliar Elemental S	FTTS
Total Foliar Elemental V	FTTV
Total Foliar Elemental Zn	FTZN
Soil Bulk Density	SCBD
pH in 0.01M CaCl	SCPH
Extractable P	SEBP
Extractable Cd	SECD
Extractable Cu	SECU
Extractable Fe	SEFE
Extractable Mn	SEMN
Extractable Ni	SENI
Extractable Pb	SEPB
Extractable Zn	SEZN
Field Water Content	SFWC
pH in 1N KCl	SKPH
Soil Organic Matter: Loss on Ignition	SLOI
Percent Clay	SPCL
Percent Silt	SPSL
Percent Sand	SPSN
Phosphate Extractable S	SPXS
Total Soil Elemental Al	STAL
Total Soil Elemental Ca	STCA
Total Soil Elemental Cd	STCD
Total Soil Elemental Cu	STCU
Total Soil Elemental Fe	STFE
Total Soil Elemental Mg	STMG
Total Soil Elemental Mn	STMN
Total Soil Elemental Na	STNA
Total Soil Elemental Ni	STNI
Total Soil Elemental Pb	STPB
Total Soil Elemental C	STTC
Total Soil Elemental K	STTK
Total Soil Elemental N	STTN

LABORATORY ANALYTICAL TECHNIQUES (cont'd)

Variable Name	Code
Total Soil Elemental P	STTP
Total Soil Elemental S	STTS
Total Soil Elemental V	STTV
Exchangeable Acidity	STXA
Total Soil Elemental Zn	STZN
pH in DI water	SWPH
Water Extractable S	SWXS
Exchangeable Al	SXAL
Exchangeable Ca	SXCA
Exchangeable H	SXEH
Exchangeable K	SXEK
Exchangeable Mg	SXMG
Exchangeable Na	SXNA

APPENDIX III

CONFERENCE AGENDA

APPENDIX III

CALIFORNIA AIR RESOURCES BOARD

FOREST RESPONSE PROGRAM PLAN

CONFERENCE AGENDA

PRECONFERENCE ACTIVITIES:

Saturday, February 21, 1987

Workshop chairs arrive anytime Saturday. The first meal provided is dinner at 6:00 pm (1800). We may have informal meetings Saturday evening.

Sunday, February 22, 1987

0730	Breakfast for Workshop Chairs
0900-1200	Workshop chairs meet to discuss workshop agenda, goals and conduct.
1200-1300	Lunch for workshop chairs
1300-1500	Free time and informal discussions for workshop chairs

CONFERENCE

Sunday, February 22, 1987

1445-1530	Conference Registration
1530-1540	Opening comments, Susan Bicknell, Bill Walker
1540-1550	Charge to participants - John Holmes

Review Papers: Each author will be allowed 20 minutes to present his paper to the conference. This twenty minutes should include five minutes at the end to allow questions and answers from the audience. A strict time schedule will be maintained.

1600	Gary M. Lovett - Atmospheric Deposition: Processes and Measurement Methods
1620	Michael G. Barbour - Forest and Woodland Vegetation of California

1640	Philip W. Rundel - Monitoring Terrestrial Processes in the Long-term Assessment of Forest Effects: a Mechanistic Approach.
1700	William H. Smith - Assessment of the Influence of Atmospheric Deposition on Forest Ecosystems: The Challenge of Differential Effects of Local, Regional and Global Scale Pollutants
1720	Paul R. Miller, (coauthors P. H. Dunn, D. L. Peterson, and M. A. Poth) - Investigating the Effects of Acidic Deposition and Gaseous Air Pollutants on Forest Tree Physiology
1740	**Reception and Dinner**
1900	Richard H. Waring - Distinguishing Pollution from Climatic Effects by the Analysis of Stable Isotope Ratios in the Cellulose of Annual Growth Rings
1920	Joseph E. Barnard's paper will be presented by A. R. Kiester - Review of the State of the Art of Surveying Forest Productivity and Condition over Wide Regions for the Purpose of Long-term Monitoring of Forest Health
1940	John Duff Bailey - Quality Assurance for Forest Ecosystem Research
2000	David F. Grigal - Impacts of Atmospheric Deposition on Forest Soils and Ecosystems, Synthesis and Integration
2020	A. R. Kiester - Synthesis and Integration of Forest Response to Atmospheric Deposition
2040-2100	Opportunity for additional questions and answers over the review papers.

Monday, February 23, 1987

0730-0800 Breakfast

0800-0830 Richard Olson - Presentation of Draft Plan

0830-1200 **Workshops:**

Deposition Support

Chair - John Watson Student Aid - Julie Phillips
Praveen Amar
Neil Berg
Michael Hoffman
John Holmes
John Kadlecek
Gary Lovett

Site Selection and Study Plan for Intensive Studies

Chair - Richard Olson Student Aid - Kim Thorsen
(Joseph Barnard will be unable to attend)
George Ice
Paul Manion
David Parsons
Lou Pitelka
Philip Rundel
Richard Waring

Techniques for Regional Surveys

Chair - Kathy Tonnessen Student Aid - Paul Gibbs
Paul Addison
Michael Barbour
David Burns
Stan Dawson
Malcomb Hughes
Daniel Oswald
John Pronos
Barry Rock
William Smith

Controlled Environment Experiments

Chair - Susan Bicknell Student Aid - Jay Gayner
Bill Bigg
Homero Cabrerra
David Ford
Paul Miller
Harold Mooney
David Tingey
Tony VanCuren

QA/QC/Data Management

Chair -John Bailey, Student Aid - MaryBeth Higgins
Jim Balough
Jeffrey Gordon
Shepard Zedaker
Steve Cline

Synthesis and Integration

Chair -William Walker, Student Aid -Susanne Lemcke
David Grigal
John Harte
Ross Kiester
Paul Schroeder
Jack Winjum

1200-1300 **Working Luncheon**

The purpose of the working luncheon is to allow the members of the several working groups to interchange ideas and progress reports in an informal way.

1300-1500 Workshops reconvene

1500-1730 Free time for most participants while the workshop chairs compare notes and prepare for the evening debate.

1800-1900 Dinner

1900-2200 Presentation of the results of the workshops by the workshop chairs. Formal debate of the strengths and weaknesses of the plan as it stands.

1900 Deposition Support

1920 Site Selection

1940 Study Plan for Intensive Studies

2000 Regional Surveys

2020 Controlled Environment Experiments

2040 QA/QC/Data Management

2100 Synthesis and Integration

2120-2200 Time for final comments and debate.

2200-2400... Workshop Chairs meet to discuss changes to the plan for plan modification and presentation the next morning.

Tuesday, February 24, 1987

0730-0830	Breakfast
0830-1000	Workshop Chairs make final presentation of the plan with changes incorporated from the debate of the previous day.
1030-1100	Time for final comments on the plan.
1200-1300	Lunch
Before 1500	All participants depart.

POSTCONFERENCE ACTIVITIES

1100-1700	Workshop Chairs meet to make any additional adjustments to the plan, and produce a written working draft before leaving the conference center.
1800	Dinner for Workshop Chairs

Wednesday, February 25, 1987

0730	Breakfast for Workshop Chairs
0830-1200	Workshop Chairs meet and complete work on the plan.
1200	Lunch for Workshop Chairs

All Workshop Chairs depart before 1500.

APPENDIX IV

WORKSHOP SUMMARIES AND PEER REVIEWS

APPENDIX IV

FINAL REPORTS OF THE WORKING GROUPS

	PAGE
FOREST CONDITION CHAIR KATHY TONNESSEN	IV-2
ATMOSPHERIC MONITORING CHAIR JOHN WATSON	IV-15
PERMANENT FOREST RESEARCH SITES CHAIR RICHARD OLSON	IV-21
HYPOTHESIS TESTING CHAIR SUSAN BICKNELL	IV-35
QUALITY ASSURANCE AND QUALITY CONTROL CHAIR JOHN DUFF BAILEY	IV-47
SYNTHESIS AND INTEGRATION CHAIR WILLIAM WALKER	IV-55

FINAL REPORT

FOREST CONDITIONS/REGIONAL SURVEYS WORKING GROUP

KATHY TONNESSEN, CHAIR

California Forest Response Program Research Plan Review
Asilomar Conference Center
Pacific Grove, California
February 23, 1987

Members of the Forest Conditions/Regional Surveys Working Group:

Kathy Tonnessen - Chair
Paul Gibbs - Student Aid

Paul Addison
Michael Barbour
David Burns
Stan Dawson
Malcolm Hughes
Daniel Oswald
John Pronos
Barry Rock
William Smith

Summary of Group Recommendations

The morning session of Regional Surveys workshop involved a general discussion of definitions ("forest condition", "ponderosa pine forest type") and the availability of forest inventory information for California. Group members felt that the regional survey plan was inadequate and could not be carried out given the budget figure cited. Discussion then focused on what survey products the CFRP could expect to get for $200,000 and what the focus of that limited survey work should be. The survey workshop group devised a list of variables that should be included in the intensive site characterization in order to maximize the usefulness of the survey data. This list included:

Population parameters:

- mortality
- regeneration/recruitment

Forest performance variables:

- canopy characteristics
- root function

Stand characteristics

- history
- species composition
- basal area
- age structure
- pest/pathogen occurrence

Miscellaneous

- visible symptoms (chlorotic mottling)
- spectral analysis (remote sensing)
- tree core chronology development

During the afternoon session the group revised section 4.0 of the CFRP plan. The time period and funding levels for various projects were agreed on. Optional projects to develop new survey methods were recommended.

The survey work will begin in the first year of the program with the issuing of an RFP ($70,000) to accomplish two tasks: (1) to identify the existing data bases on forest condition in California, and to determine the content and quantity of these data bases, and (2) to convene a four day workshop in March of 1988 to evaluate the usefulness of these data bases. Participants will include those who collected the data and those who will use it. Two inventory projects currently in progress: ARB/ERC forest sensitivity projects and WEST Associates' dendrochronology data base evaluation, will be evaluated at this meeting. Meeting participants will write a follow - up RFP to create a forest condition data base, to analyze these survey data and begin additional forest survey work ($130,000).

Optional projects to be considered if additional money is available include:

(1) Statewide Remote Sensing Survey. This monitoring program would include analysis of Thematic Mapper (TM) scenes every year for five years to detect changes in forest condition. This monitoring work would be linked to a ground based verification program to understand changes in spectral signatures. A concurrent project would include work at the intensive sites to calibrate the TM scenes with known forest condition.

(2) Dendrochronological Analysis of Stand Condition - a full stand analysis of tree rings would be carried out over two years at the intensive sites. This project would

provide a linkage between the survey and intensive site work.

(3) Analysis of Pre-visual Indicators of Stress. Aircraft sensors would be tested to identify pre-visual indicators of stress at the intensive sites. This would help to identify an intermediate pollutant site for additional gradient study work.

Comments on the Draft Plan Section 4: David Burns

4.1 Objectives and Approach (es)

I had trouble understanding exactly what was being planned until I read the other parts of the plan. A reference to other parts of the plan would have been helpful as was done on the last line of page 14. The use of undefined regional survey and gradient study is not clear. How does the gradient study fit into the regional approach?

4.2 Inventory

I doubt if any of the northern California forest data bases have any reference to atmospheric deposition damage. General forest data bases will be different and probably will require a great deal of work to make them compatible.

4.3 Creation of a regional data base.

Creation of a regional data base for ponderosa pine (P. P.) once defined should be relatively easy to complete because of the narrow band of P. P. type. The approach to evaluate at the completion of each step is an excellent way to meet changing needs as long as the objectives are well defined.

4.4 Implementation

Implementation should include the expected DISPLAY that is talked about in Joseph E. Barnard's paper (page 6 or 138).

All through this 4.0 section there should be some projection of time and target dates.

Comments on Draft Plan Section 4: Barry Rock

My review of the portion of the California Forest Response Program Draft Plan entitled "4.0 Forest Condition," follows. It is based on my understanding of the material presented in this portion of the document (pp 14-26) and does not take into account any outside information that I have become aware of through sources other than this draft plan. The review is followed by a list of specific questions that I feel should be addressed during the course of the meetings at Asilomar.

REVIEW

The **Scientific Question 1.2: What spatial patterns exist in forest condition and how do these patterns relate to spatial patterns of pollutant exposure,** needs to be restated at the beginning of the discussion found on page 14 under 4.1 Objectives and Approach. The primary objective then becomes the testing of the implied hypothesis: that a pattern of forest condition does exist in California. The second objective would then be to compare the spatial extent of the pattern of forest condition (if such can be shown to exist) with documented spatial extent of pollutant exposure. The approach to be used would then include; 1) a statewide survey, 2) a regional survey focused on ponderosa pine, and 3) a gradient study of ponderosa pine at three or more intensive sites.

At some point, the term "forest condition" should be defined. Although I was not able to find a definition in the preceding pages, one may exist and simply needs to be restated on page 14. I suspect that the term may have a specific meaning to foresters, but that meaning is not obvious to me. Does the term mean damage?

Some modest reference is made to the use of modeling as part of the integration and synthesis phase of the draft plan; but I think that a more specific statement should be made as to how such a modeling effort might be used. A paragraph on various models and their relative values could be placed here.

The existing Statewide forest data base listed on page 15 may provide insight into the presence or absence of a spatial pattern of forest condition. Many of the cited sources of forest information are unlikely however, to provide such insight. Most of these data sets are from point sources, and will provide spatial pattern information in a disjunct fashion. A survey method, which can be verified by comparison with such point source data sets, must be developed. The use of remote sensing data bases is cited as one type of data set for the purpose of assessing forest condition. A strategy must be developed, however, which makes use of remote sensing as a tool to be used not

just as another source of information, but as the prime data base which will be used to detect, quantify, and map change in. forest condition. In other words, remote sensing **must** be considered as more of a survey tool, rather than one of several data bases. Since I am probably the only one attending the Asilomar meetings who firmly believes this, we will need to spend some time discussing this issue at the meetings.

I understand why ponderosa pine has been selected for focused study as part of the draft plan, based on its relative importance in California. Because the canopy characteristics, as well as the sensitivity to pollutants of ponderosa pine may differ from those of Douglas-fir, white fit, and other species of importance, I think that some time should be spent discussing how the lessons learned from ponderosa pine may or may not be extended to other species of interest in California.

The final comment to be made addresses the use of remote sensing as a means of selecting some of the intensive study sites. The study sites selected for inclusion in the gradient study must be carefully evaluated so that the likelihood of a single variable (pollutant exposure) among sites is improved. Other variables, such as slope, aspect, elevation, soil type, moisture levels, etc. must be considered, and a Geographic Information System (GIS) approach will be invaluable. The use of a GIS as a tool for comparing a number of divergent types of data sets, is really a separate matter, and should not be confused with the use of remote sensing as a survey tool. Remote sensing can be used to select a large number of potential intensive study sites, while a GIS approach to selecting those sites that are the most common, exclusive of pollutant exposure, may then be applied for the purpose of final site selection.

QUESTIONS

1. What is meant by the term "forest condition?" This needs to be defined.

2. What specific models need to be developed so that interactions among research areas may be facilitated? We need to come up with some specific examples.

3. What is the role of remote sensing in the inventory and evaluation of forest condition? Is it merely one of many existing data bases or is it a survey tool as well?

4. What is the likely role of the other sources of forest information (pest-pathogen surveys, dendrochronology, etc.)?

5. How will the various sources of forest information be integrated so that statewide and regional trends and patterns will be seen?

6. Can the lessons learned from ponderosa pine be applied to other species of importance in California? Are the canopy characteristics (needle whorls, canopy openness, number of needles retained, needle morphology, etc.) and relative sensitivity to pollutants similar enough among species, so that survey techniques developed for one species may be applied to another species?

All this leads me to the conclusion that either the statewide analysis has not been taken seriously for some reason or that its objectives and structure have not been thought through (or both!). I therefore propose that the working group pay careful attention to this part of the plan. I am confident that a valuable statewide analysis can be done based on existing data, if properly planned and funded, and have some ideas on what is needed. It is hard to see how CFRP could justify proceeding without such an analysis.

Comments on the Draft Plan Section 4: William H. Smith

A general point before specific comment on Section 4. I would strongly urge that acid deposition and associated air pollutants" be replaced with "regional-scale air pollutants (e.g. oxidants, heavy metals, acid deposition) and global-scale pollutants (e.g. carbon dioxide, halocarbons)." This latter designation is a much more comprehensive and accurate description of the stress factors that need to be addressed by the Forest Response Program.

With regard to Section 4, I have the following specific comments:

1. In order to characterize forest conditions, the proposal seeks to use existing data bases to survey current forest conditions - this appears reasonable.

2. The next step would be to establish permanent plots for continuous forest health survey. These plots would utilize a variety of techniques to continuously track forest health and productivity.

3. Consideration should be given to establishing plots in areas where existing survey data reveal stress impact.

4. Air quality monitoring (rural sites) should be initiated on some sub-set of the permanent plots.

5. The most valuable legacy of the proposed 5-year research program would be a system of permanent sample plots, positioned to track forest responses to regional pollutant deposition and global climate alteration over the next several decades.

Comments on the Draft Plan Section 4: Daniel Oswald

This Draft Section (4.Ø) of the CFRP Plan gives a good general description of the objectives and general approach to be used to assess and characterize the forest condition for the target population, ponderosa pine forests on the western slope of the Sierra Nevada.

An important key to the success in the studies will be the ability to link the gradient studies to the regional ponderosa pine surveys, and in turn to the statewide survey of (I presume) all forests. Ponderosa pine forests or ponderosa pine type with the general qualification of dominance of this species is not enough to adequately target the population; the definition will have to be quantified in the draft plan, but perhaps not in this section of the plan.

A major factor that must be contended with is disturbance. The existing extensive inventories on the western slope and state forests will sample variation not only to exposure, climate, soils, etc., but in both natural and human disturbance. This latter factor can have significant impact on availability of data, and its utility for some types of analyses. It will add complexity to the studies.

It occurred to me that often a first use of extensive inventories in a monitoring sense is as first alarms that something is wrong; they usually have little utility in and of themselves in pinpointing what is wrong. The pine growth decline discovered in the FIA inventories of the Southeastern U. S. is a case in point. These extensive inventories can also tell us that things seem normal, if for instance growth is increasing or stable, and mortality is decreasing or stable. Given this latter finding, perhaps the next step in the investigation process is not needed. We seem to have proceeded beyond this point already in the CFRP. (Just and observation.)

In Section 4.2, FIA and dendrochronological data bases are cited as not being designed to evaluate air pollution affects. But their applicability for use is to evaluate air pollution affects. The extensive inventories hopefully sample the variability in the entire population due to all causal factors; they raise initial red flags on condition changes; and they provide the basis for assessing the impacts population wide of detrimental impacts of deposition, etc. Those data sources should not be singled out, nor should any of the mentioned data sources, as possibly not being applicable. That is the task of the inventory and evaluation of data basis activity.

Some place in this section there should be a discussion of the plans for location, maintenance and accessibility of

the data bases that will support the analyses and studies, once they have been selected or the data collected. Will existing data bases reside with the current custodians? If so, how will they be accessed? Or will they reside with a new central authority, or a consultant/consultants? This is a housekeeping detail, but should be addressed at some point in the planning document.

The discussion about quality standards for data is important. The validity of the studies will rest in substantial part on the data quality issue.

Comments on the Draft Plan Section 4: John Pronos

4.1 In reading this section and just glancing at the others, it is not clear to me what "forest condition" is and how it will be described. Even in Section 6, Table 2, "Forest Condition" is listed as a variable for site classification. What do you measure or estimate to evaluate it?

4.2 Another source of data would be from those who have developed forest stand growth models. There have been tons of data collected in California by the USDA Forest Service, UC-Berkeley, and private consultants to develop these predictive models. One who comes to mind is Dr. Leroy Dolph, Pacific Southwest Forest Experiment Station in Redding, California (Forest Service).

4.3 The mention of "ecological variables" reminded me of a current resource inventory effort being done on various forest types within the National Forests in California. It is called "ecosystem classification" and involves collecting a lot of data to describe the productivity of different lands as far as timber, range, wildlife, etc. The leader of this project is David Diaz, Regional Ecologist at the USDA Forest Service regional office in San Francisco. Phone no. is (415) 556-6446

FINAL REPORT

ATMOSPHERIC MONITORING WORKING GROUP

JOHN WATSON, CHAIR

California Forest Response Program Research Plan Review
Asilomar Conference Center
Pacific Grove, California
February 23, 1987

Members of the Deposition Support Working Group:

John Watson (chair)
Julie Phillips (student aid)

Praveen Amar
Neil Berg
Michael Hoffman
John Holmes
John Kadlecek
Gary Lovett

Affiliations and addresses of group members may be found in Appendix V.

Summary of Group Recommendations

Sections of the plan need to be clarified in the following ways:

5.1 Needs more specific statements of measurement problems, priorities and observables:

1) Ozone and meteorology hourly
2) Fog - hourly
3) Precipitation - hourly
4) Atmospheric concentration of gases, SO2, NH2, NO2, HNO3 and particulates
5) Dry deposition - hourly

The number and location of sites needs to be more specific. We also need to define "exposure regime" and "gradient."

5.2 Needs a table of available data bases including monitoring periods, quality assessment and explanation of how these data were collected and where they are located.

5.3 Needs to specify the requirements for the location of the air quality monitoring equipment. These requirements may be more restrictive that the locations of the permanent research sites themselves. For example, the presence of trees can influence many of the proposed measurements. The air monitoring site will necessarily need to be located in an opening of sufficient size to eliminate these effects.

5.4 Under the constraints of the proposed budget of 100,000 for three sites, the monitoring program could include only ozone and meteorology, one annual audit, no repairs, no spare parts and no backup equipment. The ideal monitoring program should be outlined in this section and its associated costs identified. We need a table of observables, practical averaging times, sampling method, typical concentration ranges, and lower quantifiable limits. This section should also identify any new developments needed and any ongoing development studies ongoing that should be followed for possible inclusion in the CFRP monitoring program. Finally, this section should include a list of other measurement programs and how "piggybacking" might occur for mutual benefit.

Sections 5.5-5.7 are OK as is.

Comments on Draft Plan Section 5: John Kadlecek

In this section several goals are listed which require conversion of a concentration measurement in some way to a deposition flux. In general this must be done in a complex terrain, changing meteorology, and variability in the forests' biological interactions with the atmosphere. Also, the time resolution for each measurement must be greater than the time dependent fluxes capable of influencing plant responses. Even the best models are incapable of doing this for most of the measurements proposed.

Essential to the success of this effort is the requirement that tests of actual deposition, along with measured confidence levels where appropriate, be performed. Included in this list would be continuous liquid water content of clouds/fog, adequate time resolutions in ion chemistry of cloud/fog, throughfall, size dependent aerosols, and precipitation. These measurements will be highly variable across the study region, however, well understood intensive sites are likely to contribute more to the effort. More emphasis in relating canopy inputs (dry, cloud/fog, precipitation) to outputs (well characterized throughfall, stemflow, and evaporation) should be considered. Also strong oxidants (i.e. peroxide) should be added to the list of monitored species.

Comments on the Draft Plan Section 5: M. R. Hoffman

Several questions are raised by reading the CFRP plan. Some of them are as follows:

Why are the proposed studies limited to the Western Slope of the Sierra? If you really intend to study the effects of air pollution and deposition, you should focus on the ponderosa pine in the San Gabriel Mountains and the San Bernardino Mountains.

What aspects of deposition are you interested in characterizing? This is quite nebulous in the current description. Do you mean cloud water impaction, dry deposition, cloud droplet sedimentation, radiation fog deposition, rainfall, etc.? The total task will depend greatly on what avenues will be explored.

Characterization of Forest Exposure should include several tracer studies to determine likely pathways for pollutant transport into forest regions. Research carried out by Shair and co-workers on the transport of San Juaquin Valley air into Sequoia National Park has been quite revealing. Similar studies need to be done across the western face of the Sierra.

The frequency of events such as rain, snow, and fog (impacting clouds) needs to be established at each intensive site.

The Caltech wet deposition monitoring devices would be preferable to the Aerochem Metrics instruments. The Caltech devices will give time resolved samples, preserved aliquots of these samples for special analysis, complete computerized data-logging, automatic wash cycles, and refrigerated storage at $4^{o}C$. The lack of time resolution in the NADP method may lead to unacceptable error when making predictions of total wet deposition. The rain sampler shares many of the same features of the Caltech cloud water sampler.

Comments on Draft Plan Section 5: Neil Berg

Page 17: How detailed will the pollution gradient be specified? Since the direction of post-1989 research is contingent largely upon quantification of the gradient, a statistically rigorous test -- stating an a priori level for gradient identification -- should be instituted.

Page 17: Given that an aim of the CFRP is characterizing the exposure of California forests to air pollution, I'm concerned that available data bases will not allow adequate resolution of this objective. In a short paragraph towards the bottom of page 17 shortcomings of the current network are mentioned. Yet the remainder of the first five chapters of the Draft Plan appears to ignore those limitations. Eight wet fall monitoring stations are listed for the California Acid Deposition Monitoring Network on the western slope of the Sierra Nevada (Table IIIA-1, page III-4 of the 1986 ARB annual report on acid deposition). The three Sequoia National Park gauges are relatively close together and the two additional NADP gauges are also in close proximity to existing CADMP gauges. Two dry deposition monitoring stations are proposed for west slope Sierra Nevada sites (1986 ARB annual report p. III-47). A hard look should be taken at what is needed to adequately characterize "pollution gradients," and for that matter the spatial variability of deposition on the west slope of the Sierra. I would go so far as to argue that it is necessary to know the spatial variability of atmospheric deposition first before a defendable number of sites (for long-term monitoring) can be determined. If the number of sites is economically unfeasible, ARB staff should be willing to "bite the bullet" and request additional funds and/or state that the network is inadequate. If such an assessment has been made, it should be reinforced in the Draft Plan.

Page 19 (mid-page): Criteria listed for the monitoring protocols are appropriate and necessary.

Page 20: Confirmation of ...: One year is potentially too short a time span to base a decision as important as the direction of post-1989 CFRP research. The decision criteria must be rigorously defined and completely thought out. Will it matter if the 1988-1989 period is an "average" precipitation or deposition year for instance? As a fall-back position is a two-year gradient identification period possible?

Page 20: Long-term...: Does "These sites will fill in some of the gaps in the existing network in more remote areas..." mean that location of the three intensive monitoring sites will be determined partially on the basis of the location of existing network sites? If so, it may be

impossible to adequately address what are essentially two separate objectives: expanding the long-term monitoring grid and conducting intensive research as three ponderosa pine sites. Would the objectives of each task be compromised?

Comments on the other sections of the Plan:

Page 6: Policy Question 2: I urge extremely critical thinking go into selection of the three ponderosa pine sites. "Secondary" variables, potentially effecting vegetative behavior (growth, reproduction, etc.) could bias or mask vegetative responses to atmospheric deposition.

Page 6: Policy Question 3: The Draft Plan should address the potential for extension of results from ponderosa pine studies to other species. Is there any chance of such an extrapolation?

Page 6: Policy Question 3: Why only mature trees? From a simplistic viewpoint, it seems like an appreciable proportion of the damage could have already occurred by the time a tree reaches maturity.

FINAL REPORT

INTENSIVE SITE WORKING GROUP

RICHARD OLSON, CHAIR

California Forest Response Program Research Plan Review
Asilomar Conference Center
Pacific Grove, California
February 23, 1987

Members of intensive site working group:

Richard Olson - Chair
Kim Thorsen - Student Aid

Michael Barbour (a.m. only)
George Ice
Paul Manion
David Parsons
Lou Pitelka
Philip Rundel
Richard Waring

Affiliations and addresses of group members may be found in Appendix V.

Summary of Group Recommendations

The intensive site working group was charged with reviewing and revising Section 6.Ø of the California Forest Response Program Draft 1987 Research Plan (version dated February 1987). This section deals with the selection, establishment and operation of permanent research sites as part of the CFRP. Discussion of research to be conducted at the sites was limited to measurement of natural variables and processes. Discussion of experimental manipulations was considered to be the responsibility of the working group reviewing Section 7.Ø (Bicknell, chair).

The major recommendations of the intensive site working group were as follows:

(1) The group concurred with the draft Plan that mechanism-driven whole tree and stand level models should be the major unifying outputs of the CFRP. Research at the sites should be designed to support development of these models and the Plan should be revised to describe more clearly the linkage

between site research and model development.

(2) Implementation of the CFRP Plan should involve three initial steps:

1-review and evaluation of existing tree and stand models

2-a conceptual effort to define the framework of the models to be produced by the CFRP

3-analysis of these conceptual models to determine what data needs to be collected to support their development.

(3) Ponderosa pine is a logical choice for the development of the CFRP tree and stand models.

(4) Permanent research sites are necessary for the CFRP to meet its objectives. Research sites function as:

1-Locations for measurements of forest structure and processes necessary for development of tree and stand models and for comparisons of forest response to different pollutant exposures.

2-Locations for conducting experimental manipulations of seedlings, trees, and other forest ecosystem components.

3-Permanent sites for long-term monitoring of forest condition.

4-Foundation sites for attracting collaborative research efforts.

(5) The Plan should be revised to include the establishment of only two (instead of three) research sites. Since three sites along a gradient have very limited statistical power anyway, the group recommended just looking for differences between sites at the clean and dirty extremes of pollutant exposure. Site selection criteria should include:

1- greater than 80% basal area dominance by ponderosa pine

2- maximum differences in pollutant exposure between sites with ozone as the primary pollutant

3- minimum differences between sites for other site characteristics--site characteristics in Table 2 of draft Plan should be considered in site comparisons with additional emphasis on crown density, understory and pest/pathogen history

4- sites should include stands where height growth has stabilized

(6) The air quality and meteorological monitoring described in Section 5.Ø of the draft Plan is sufficient for the intensive sites if:

1- biologically relevant monitoring protocols are developed in conjunction with the national Forest Response Program Atmospheric Exposure Cooperative

2- incoming short-wave radiation and dew point are also measured

Where possible, pollutant fluxes to the forest should be estimated.

(7) Two of the planned Air Resources Board dry deposition monitoring stations should be co-located at the effects research sites and the money budgeted for CFRP air quality monitoring transferred to effects research.

(8) Two sets of variables should be measured at the intensive sites. The first set (Table 3 of draft Plan) constitutes an initial test of hypothesized differences between sites based on the mechanisms described by the Scientific Questions. To support the CFRP modeling effort, the following variables are recommended for addition to Table 3:

S.Q. 2.1 (2): xylem nitrate concentration

S.Q. 2.2: litter nutrient content

S.Q. 2.3: photosynthetic response curves, components of tissue water relations

The second set of variables will be determined during the initial model review and analysis to be conducted by the CFRP. Once this initial effort has determined what data is needed for development of the final tree and stand models, research at the intensive sites will be designed to supply that data.

(9) The initial model review/analysis and the site selection process should begin concurrently.

Comments on Draft Plan, Section 6: David Parsons

For the most part, Section 6 is straightforward and logical. I support the concept of utilizing intensive sites along a pollution gradient. A few general comments:

-- Does the Sierra Nevada include the San Bernardino and other southern California mountains in this plan?

-- I would encourage the WCRC to consider adding a site or two to the gradient if cleaner sites can be found in Oregon or Washington.

-- I am concerned about the long term commitment aspect. How do you assure the commitment of the land management agency? If possible, site selection criteria should seriously consider this. If the land manager is committed, even to the extent of contributing funding and instrumentation (as would be the case of Sequoia National Park), you have a lot better chance of assuring long term measurement. The RFP should encourage consideration of this.

-- It is worth considering some support or at least some level of formal cooperation with those few sites where long term forest health is already under way even if in a different forest type (e.g., Sequoia National Park)? There are so few sites where such occurs that we should encourage communication, data compatibility, etc.

-- Why not hold off site selection for ARB/DRI site deposition sites so they can be placed at the three intensive sites?

Comments on Draft Plan, Section 6: Lou Pitelka

I strongly endorse the need for a small number of intensive research sites where monitoring of natural forests can be combined with experimental studies of naturally occurring trees and experiments done under even more controlled conditions (e.g., open top chamber experiments). Whether these sites should be selected along a supposed pollution gradient is much less obvious to me. The problem with any gradient study is: How do you make sure that there are not other covarying, confounding factors? It is difficult to identify exactly what these could be until specific sits are suggested, but there are sure to be some. The credibility of a gradient increases as the number of sites is increased. I am particularly concerned about the fact that only three sites are proposed. If one is looking for correlational relation- ships, three sites is the absolute minimum, and spurious correlations are very likely. I can appreciate that compromises are necessary to keep the budget reasonable and also allow intensive study of particular sites, but this is a problem.

In an area as ecologically diverse as California, it will probably be quite difficult to find three or four sites that do arrange themselves along a clear pollution gradient while being as similar as possible in all other aspects. Perhaps we should try to locate the intensive sites along a gradient but be willing to give that idea up if it proves impossible or compromises other needs.

If the sites do end up being along a gradient, it is critical that any observed correlations be tested experimentally. For instance, one could supplement the studies of natural forests to the three gradient sites in a way that would help to confirm or reject the validity of any observed correlations. This could involve a reciprocal transplant/field exposure experiment. Seedlings or saplings (ideally full or half sibs from each site) would be transplanted to the other two sites. These would be grown, at a minimum, in charcoal filtered chambers with natural deposition excluded and in ambient air. This would allow you to separate the effects of: (1) genetic differences in the pines from the different sites; (2) the different ambient pollutant regimes; and (3) other suspected or unknown site differences. Ideally, one could also expose some of these plants to higher than ambient levels of particular pollutants. With so few gradient sites, this sort of controlled field experiment will be essential.

I understand the logic of restricting much of the work to ponderosa pine and to restricting the gradient to the western slope of the Sierra. However, you will then miss situations where deposition levels are greater (e.g., at higher elevations). Thus, certain potential site

differences (effects) may not occur at these lower pollutant levels. You may reject potential mechanisms that actually are important elsewhere. How do you resolve this problem?

I have a few comments regarding testing for the correlations required to support the various different hypotheses or scientific questions. In question 2.3, it will be very hard to detect any significant differences in most of these parameters (Table 3; except visual symptoms) in just three or four years. Question 2.4 may be less relevant for ponderosa pine, because it grows at lower elevations. With regard to question 2.6, with only three sites one might easily get spurious patterns of pest/pathogen occurrences that are unrelated to the pollutant gradient.

A challenge in any effort such as this forest research plan is ensuring that the various components adequately complement each other so that together they meet the goals of the program. This is likely to be a problem if each component of the overall program involves a separate proposal and independent group of investigators. For obvious reasons, scientists are interested primarily only in their own work. If they are not somehow forced to think in terms of the bigger picture they usually won't (even if they said they would in their proposal). There are various ways to get around the problem. One is to have a few major contractors responsible for bigger chunks of the research. They subcontract the separate tasks and experiments but are responsible for seeing that these all fit together. Another is to have required integration meetings involving the individual investigators, the modelers or integrators, and project managers and advisors. These meetings (i.e., the integration process) must start when the research starts. I do not believe it is absolutely necessary to have a mathematical model as the basis or goal for the project, but only some conceptual model. For instance, the deposition and cycling of materials within an ecosystem can help to organize research on forest effects. It can identify important linkage and gaps in information.

General comments on overall plan:

The NAPAP has a good, well thought out plan for studying forest effects. Therefore, it makes sense for California to follow a similar plan. It will increase the ease with which comparisons in results can be made.

From my perspective, one of the unfortunate problems with government supported efforts of this kind is the annual decision making cycle that determines what will be done next, whether a study will continue, whether funds will be committed, etc. It sometimes seems as though some of these decisions do not get made until well into the year in which the research is supposed to be done. It makes it difficult

for the researchers to plan ahead and be adequately prepared to start new work. For instance, on pages 30-31 the plan states that experimental projects will not be started (and presumably the plans will not be finalized) until the third year. And yet, presumably a lot of experimental work is supposed to take place in the third year. How can well conceived, well planned experiments involving trees be planned, proposed, approved, funded, and conducted all in the same year? If you send out an RFP in February for work to be done during the summer, you are already preselecting to some extent both the types of scientists/organizations that will respond and the types of experiments they can propose. Doing good experiments with trees may require a year or more of advance preparation (growing seedlings and acclimating them to the sites, building equipment, etc.). Will this sort of careful advanced preparation be possible within the proposed plan? I appreciate the unavoidable constraints that we have to live with but wanted to bring up the issue.

Comments on Draft Plan, Section 6: Michael Barbour

The selection criteria for study sites will eventually need fine tuning. In a very real sense, the ponderosa pine forest is an ecotone between foothill oak woodland/chaparral and montane mixed conifer forest. Consequently, there can be a moderate amount of variation in overstory and understory strata. It is unlikely that ponderosa pine will provide 100% relative cover in the overstory over a large sample area; consequently, selection criteria should allow for (say) as much as 5% relative cover by other species (oaks, digger pine, incense cedar). More variability will be found in the understory shrubs, and this variation could be a confounding factor if not controlled. For example, Ceanothus species fix nitrogen; deciduous species may provide an N pulse in the soil as they come into, or shed, leaves; prostrate mountain misery may form dense patches and modify throughfall reaching the soil surface; manzanita or chamise may have allelopathic effects on microbiota or other plants. Total shrub cover may affect tree growth via competition for moisture.

So: sample sites must be made relatively similar to each other in terms of total vegetation. How similar, is a good question. No two sites will be identical, so variances of (say) +/- 10% should be adopted as limits for such traits as absolute tree density, absolute canopy cover, etc. Floristic or vegetational similarity can be expressed by simple formulae (e.g., Sorensen's coefficient of community) and limits (say, >50%) can be adopted. Probably, the herbaceous layer can be ignored.

Attention needs also to be paid to the area of each site, and to the number of individual trees or sub-areas to be sampled and followed. It appears that only one site per pollutant zone will be selected, and that site will be subsampled. This is pseudoreplication and statistical tests will lack of power of true replication. This design will also make it difficult to separate pollutant effect from spurious variation in other environmental factors. Rainfall/snowpack will likely not be exactly the same from site to site, even if they are within a few kilometers of each other. Without true replication, how will this confounding factor be eliminated? It is not clear how, and which, environmental factors such as soil moisture, seasonal heat sums, and microenvironmental temperatures will be taken.

These are the same problems faced by most field studies, and they can not be completely solved, but I feel that they must be addressed more closely than the draft plan states. Other problems of quantifying similarity: past fire history (frequency and intensity of last burn), age structure of ponderosa pine population, how to deal with

seedling numbers over a short term study when dealing with a species which has episodic mast years and poor years -- and it is not clear that within that species each population has the same year-to-year timing.

Comments on Draft Plan, Section 6: Richard Waring

Section 6.3. The idea of studying how forests respond to a gradient in pollutants seems reasonable, as does the search for sites with similar soils, climate, and dominant species. The additional requirements that the stocking density and leaf area be initially comparable assumes no impact of pollutants. If one were to search for similar canopy development, one might e forced to seek consistently improving water or nutrient regimes that counterbalanced the suspected effects of increasing pollution. If trees are of similar size, I would expect the stocking density and leaf area to progressively fall as pollutants increasingly stress the forests. Other variables listed in Table 2 such as available P, sulfur, and exchangeable cations would be expected to be altered as a result of pollution.

If you had access to Barry Rock's programs (Rock et al., 1986, Biosci. 36:439-445) for assessing the chlorophyll b to carotenoid pigment ratios in forest canopies using remote sensing techniques, you should be able to identify a number of stress gradients across suspected pollution gradients. Then you could test to see whether the pollution gradients indeed existed. Otherwise, you may be evaluating a recent situation where the effects have yet to develop fully.

Section 6.5. What exactly will long-term monitoring do to confirm the effects of air pollution? If older trees die, young, normally faster growing ones should replace them. If you monitor mortality, you might rank the stand as badly affected; if you monitor growth or capture of pollutants by the canopy, you might conclude the reverse. I think you may want to be to an appropriate mechanistic level fairly quickly and use remote sensing or other less intensive approach to monitor selective aspects of vegetational changes.

The variables listed in Table 3 are generally useful, but many are likely to shift as the canopy opens. Ratios of elements or ions may be informative, but the total flux moving through the ecosystem is strongly affected by hydrology and interception by the canopy, variables expected to change, or already to have been changed following chronic exposure to variable pollutant levels.

Section 6.6. I would like the idea that one group is responsible for the entire gradient. The limitation of what will be measured initially is understandable, but bothers me. The initial group of scientists attracted to this study are likely to be pretty field oriented. Eventually, the explanation is probably going to rest at the enzyme level. The transition may be tough. From what I read in the last 4 issues in the journal Environmental Pollution, most of the

pollutants you are concerned with will cause a decrease in the enzymes fixing carbon dioxide into simple sugars, raise the amino acid concentrations, cause stomata to be less responsive than normal in pollution-sensitive species, and only later breakdown chlorophyll b. Drought can cause some of these responses but not all (stomata become more responsive). I think you are missing a bet by focusing on things that are going to be difficult to unambiguously interpret and that your selected team may be unable to advance to the next level of explanatory measurements.

Additional Comments Provided by Richard Waring

Common Structural Characteristics of Trees Important for Interpreting Process Measurements

R. H. Waring
23 February 1987
Intensive Site Working Group

In any physiological model of how pollutants affect trees, three major categories of responses are involved:

(1) Alterations in photosynthetic capacity

(2) Alterations in maintenance costs

(3) Alterations in how resources are allocated.

Although short-term measurements of photosynthesis, respiration, and resource partitioning may be necessary, they are not sufficient for extrapolating how pollutants may affect overall forest growth and structure. Nor are such physiological measurements possible over a range of sites. We need structural surrogates for the major physiological processes.

Photosynthesis, if adversely affected, should cause leaf nitrogen composition to change with less carboxylation enzyme, less chlorophyll b, and more free amino acids and possibly nitrate. Structurally, the duration of leaf display and amount of leaves displayed should decrease. The amount of leaf area can be estimated from sapwood area at the base of the live crown and that value in turn estimated from sapwood area at breast height knowing taper in the bole dimensions between the two points. The display of leaf area can be estimated at monthly or at longer intervals by using a fish-eye camera loaded with both infra-red and panchromatic film. This film combination allows automatic digitizing by computer assisted programs and provides a way of distinguishing foliage from other structures (boles and branches) that also cast shade. Combined with appropriate meteorologic and climatic measurements, canopy characteristics allow estimates of daily and seasonal photosynthesis, transpiration and interception.

Changes in branch and bole respiration can be estimated by distinguishing how growth is distributed and what fraction of these structures contain sapwood. Because the respirational cost of producing a unit of wood is fixed, measurements from dendrometer bands attached at dbh, base of the crown, and along representative branches can be used to estimate cost of production on a seasonal basis.

Maintenance costs are primarily a function of living cells in the sapwood and cambium. Then maintenance costs can be estimated by knowing the cross-sectional area of sapwood in branches and that in the bole, particularly between breast height and the base of the live crown. Temperature data is important to evaluate actual respiration of the living tissue associated with the sapwood (above 5-8% in pine of the volume).

Depending upon the kind of environmental stress, the normal pattern of carbon allocation is shifted (Table 1). A significant change in the way the wood is deposited along the bole between dbh and the base of the live crown should result if pollutants alter the relative availability of nutrients as expected.

Root growth is difficult to measure using conventional techniques but alterations in starch concentrations and rates of fine-root turnover are expected (Marshall and Waring 1985--Canadian Journal of Forest Research).

References

Landsberg, J.J. 1986. Physiological ecology of forest productivity. Academic Press, London 198pp.

Waring, R.H. 1987. Physiological characteristics of trees predisposed to die. BioSci. (in press).

Waring, R.H. and W.H. Schlesinger 1985. Forest ecosystems: concepts and management. Academic Press, Orlando. 340pp.

Table 1. Changes in carbon allocation patterns associated with various stresses (Waring and Schlesinger 1985).

Stress	Change from normal allocation pattern
Shade	Reduced root growth, reduced stem taper, umbrella-shaped crown
Drought	Increased root growth, increased stem taper, loss of older foliage, and reduced growth of foliage
Mechanical	Increased stem taper, asymmetrical shape of branches, bole, and large roots
Nutrient	Increased root growth, increased stem taper, deficiency reduced growth of foliage
Nutrient	Decreased root growth, decreased stem taper, surplus increased growth of foliage

FINAL REPORT

HYPOTHESIS TESTING WORKING GROUP

SUSAN BICKNELL, CHAIR

California Forest Response Program Research Plan Review
Asilomar Conference Center
Pacific Grove, California
February 23, 1987

Members of Hypothesis Testing Working Group:

Susan Bicknell - Chair
Jay Gayner - Student Aid

William Bigg
Homero Cabrerra
David Ford
Paul Miller
Harold Mooney
David Tingey

(Affiliations and addresses of group members may be found in Appendix V.)

Summary of Group Recommendations

This working group was charged with the task of evaluating Section 7 of the Draft Plan. Section 7 addresses Policy Question 2 and its associated Scientific Questions which propose mechanisms by which acidic deposition and other air pollutants may affect forests. This section proposed an approach by which the many hypotheses could be prioritized and then tested to determine how air pollution influences the forests of the State of California.

This working group spent a considerable amount of time considering the overall strategy of the plan including (a) whether the California Forest Response Program should concentrate on one species, and what that species should be, and (b) the experimental design of the intensive research sites. Although these topics were not in our charge, we were unable to come to grips with the hypothesis testing aspects of the plan without first resolving in our minds these overriding issues. After much discussion, the group arrived at the consensus that:

(1) The CFRP should concentrate on a single species.

(2) Ponderosa pine is a good choice for that single species.

(3) This type of study requires intensive research sites.

(4) A gradient study with research sites arranged along an air pollution gradient would be an effective tool for correlating exposure with damage.

(5) However, ozone is the principle agent of known damage to ponderosa pine. The ozone gradient is elevational and seems to go from east to west, rather than north to south. Pure ponderosa pine occurs at low and mid-level exposures of ozone, while Jeffrey pine occurs at high exposures to ozone. Therefore, to observe the range of ozone exposure, the experiment should ideally include Jeffrey pine and be organized on an east-west gradient. The group felt that ideally, several east-west gradients should be observed at different latitudes in the Sierra. This was considered to be the ideal experimental design, however. Practical considerations persuaded the group to compromise for a much simpler experimental design.

The working group came to a consensus rapidly on the priority for studying hypotheses of damage. They ranked the agents of damage in the following order of importance:

Ozone

Wet deposition in clouds and fog

Accretion of Nitrogen from wet and dry deposition

Others

They made the following recommendations concerning these agents of damage:

(6) The efforts of the CFRP to understand the mechanisms of ozone damage to ponderosa pine concentrate on integration and synthesis of ongoing work since much has been done with ponderosa pine.

(7) The mechanisms of effects of wet deposition through clouds and fog be approached through experimental work, since little has been done with ponderosa pine.

(8) The mechanisms of effects of the accretion of nitrogen should be approached through experimental work since little has been done with ponderosa pine.

(9) Monitoring should be as complete and detailed as possible at the intensive research sites for both wet and dry deposition, as well as meteorological conditions. (See

recommendations of the Atmospheric Monitoring Working Group).

The working group emphasized in their discussions that the most important unifying output of the program should be the process-driven model of growth and physiology for ponderosa pine and its response to air pollution. However, they emphasized that the basic physiology needs to be understood first, before physiological responses to air pollution can be understood. They therefore recommended that the overall strategy of the program be organized around the following three steps:

(10) The first efforts of the CFRP should be to review the state of the art of ponderosa pine process-driven mature tree models. The gaps of knowledge of basic physiology should be identified.

(11) The first experimental efforts of the CFRP should concentrate on basic ponderosa pine physiology to complete the model.

(12) Only after the model runs well and is a good predictor for ponderosa pine growth and physiology (photosynthesis, respiration and allocation), should experimental work begin to determine the changes in ponderosa pine physiology in response to acidic deposition and other air pollutants. The results of these later experiments can then be used to provide the dose-response relationships for the model to predict ponderosa pine response.

The working group recommended two types of experiments to both fill in the gaps in the basic mature tree model, and in the model including the exposure to air pollution:

(13) Experimental manipulations of saplings grown in large containers to enable root response to be determined. This approach was viewed as a reasonable compromise to overcome the weaknesses of seedling exposure experiments, and avoid the problems of mature tree exposure experiments. The group felt strongly that the first and most profound effects of exposure to acidic deposition and other air pollutants would probably occur to the roots.

(14) Experimental manipulations of whole stands by means of fertilization, irrigation, thinning, etc., to provide stand level response information for incorporation in stand-level models of forest growth and dynamics, and stand level models of response to air pollutants.

Comments on Draft Plan Section 7: William Bigg
February 21, 1987

I want to make a few general comments about the overall plan. This plan has a well thought out conceptual base that takes into account the fiscal and time constraints that will ultimately limit the size of the study. Specifically, I believe using one species and doing detailed studies at no more that three sites will make continuous evaluation and modification of the study feasible.

I found three issues that may need to be addressed in more detail. First, it should be considered that the planned framework could prematurely eliminate factors. One of the basic premises is "only those scientific questions need to be examined for which a positive correlation is demonstrated in the context of the gradient study." One example of this concept, "as atmospheric pollution increases, metals in soils are increasingly mobilized." If this correlation were positive, then other studies would investigate specific effects. I visualize this framework as starting at the middle of a circle that is subdivided into sectors. At the narrow end of each sector is a decision point that determines whether or not the sector will be entered. If a wrong judgment is made in the initial evaluation process, then that entire sector would be left unevaluated. This requires absolute faith in the method used to reach this initial decision. Unfortunately, in most cases there will be alternative methods of evaluating the process. For example, "metals in soil" could be tested by an examination of the soil solution. Equally useful could be an examination of the mycorrhizas, roots or leaves to determine if metals have been accumulated by the plant. It might be worth doing more than one evaluation of these key starting point processes.

Second, there may be an overemphasis on the whole tree process. Admittedly, seedling and whole branch experiments are "not directly translatable to mature trees." However, a similar argument could be made that factors like genotype or climate would make the results from site I not translatable to site II. If one basic objective of the overall study is to find the physiological/morphological effects of air pollution on ponderosa pine, then small plants and plant parts will at least indicate what should be examined in the whole tree. If time and money are a factor, then using whole trees will be the more expensive and difficult way to evaluate the problem. Along the same line, it might prove useful to devote more effort to the examination of regeneration. The most sensitive times in the trees life seem to be during establishment and during old-age. Although, the second is more obvious, the first determines the future. Some relatively simple reciprocal studies could be done with seedlings and seed from each of the sites.

This type of study could point out the on-site sensitivity of regeneration to air pollution and could help to tie the three sites together.

Finally, it should be kept in mind that the sampling process needed to gather adequate information about sites and the vegetation could easily become the greatest impact on the study site. Considerable effort should be devoted to a unified statistical design for these studies. In particular, sampling procedures and sample sizes should be carefully evaluated.

Comments on the Draft Plan Section 7: E. David Ford

Second paragraph of the section on Policy Question 3 (page 6): Process driven models for forest response will not give a dose-response relationship in the same way as described for arable crops. A dynamic response is guaranteed. What you are trying to characterize are the components of a dynamic system, the lags, time (?) constants, of the different aspects of forest growth.

"Site selection for intensive monitoring will minimize difference in age, site index, stand density, soil type, and attempt to maximize differences in exposure to sulfur, nitrogen and ozone" (page 23): There are two difficulties with this approach. First, sites can not be analogous over a gradient. Stand histories at different points along an altitudinal gradient, and that is what we are talking about with regard to ozone in California, must vary according to the environment. Second, there is also a strong risk in attempting to standardize, particularly around age and stand density that the critical period when forests show damage may be missed. This assumes that there is a "critical" period. It is based upon the idea that forests show a natural cycle of growth and have a changing vulnerability to stress as they age. Pollutants may be interacting with certain stress factors, and so by selecting stands of just one age, one may happen to choose a particularly vulnerable time in the lives of a stand, or a particularly invulnerable time.

Can simple measurements be made to address scientific questions 2.1 to 2.6?

SCIENTIFIC QUESTION 2.1 - "What is the effect of atmospheric pollutants on forests through the mechanism of:

1) Direct toxicity to roots, mycorrhizae, or soil microbial populations by mobilized metals in acidified soil water? - Simple measurements may be made in water solutions. But whenever a buffering component is added such as organic material, then the time of exposure to acidity is going to play an important role so that measurements must be made.

2) Nitrogen toxicity to mycorrhizae? - Same qualification applies as in number 1.

3) Increased leaching of soil nutrients resulting in reduced nutrient availability? - There does seem to be some good evidence for this, but one does have to measure a range of nutrients and not just a few common ones, perhaps.

SCIENTIFIC QUESTION 2.2 What are the effects of atmospheric

pollutants on forests through the mechanism of increased leaching of foliar nutrients?

Again, time constraints and lags have to be taken into account, and particularly because there are natural trends in nutrient concentration of foliage, which may influence or be related to changes in photosynthetic rate. Measurements of photosynthesis will also be influenced by order of branching, illumination history, water relations and source-sink relationships, all of which will change as a branch ages.

SCIENTIFIC QUESTION 2.3 - What is the effect of atmospheric pollutants on forests through the mechanism of altered photosynthesis, respiration and carbon allocation patterns with possible induction of water and/or nutrient stress?

There are two fundamental difficulties: a) To characterize the relationship between photosynthetic rate and foliage amount which can vary in compensatory ways; b) To determine whether it is source or sink limitations which drive growth rate.

SCIENTIFIC QUESTION 2.4 - What is the effect of nitrogen compounds, possibly in combination with oxidants on forests through the mechanism of delayed cold hardening or early break of dormancy, which result in increased winter damage?

Some of the most illuminating examples of this type of growth have come from provenance transfer. The complete annual cycle has to be studied; not just release from dormancy, but also the duration of time taken to get into dormancy. Measurements are not simple; they involve nutrient concentration, measuring growth rates and growth durations as well as studying the pattern of frost hardiness. Again, if one can use standardized materials, e.g. seedlings all of the same age, then one can get some good repeatable results with experiments. But these may not be applicable to what goes on in mature trees. Dormancy mechanisms in particular are strongly related to aging.

SECTION 7.0 - Hypothesis testing to determine mechanisms of effects.

The assumption is that the hypotheses which are going to be tested will all arise from correlative research. Some of the difficulties about this particular correlative research have been raised, in particular that the range of variation of forest age is not being studies and attempts are being made to minimize that. If you wish to use correlative studies as a preparatory technique from which to generate hypotheses, you must make sure that the data space you examine is sufficiently broad.

Why not, instead of attempting to generate hypotheses from a limited sense of measurement, use the hypotheses which have been developed to describe the natural mortality of ponderosa pine in the environment. There must be a range of hypotheses which operate in different conditions. The question is, how will pollution interact with those mechanisms? Forest growth is not static, its rate varies continuously as a function of the effect which the environment has on the tree, and which the tree itself has on the stand environment.

The plan states that "the first two years of the CFRP will be spent characterizing exposure, characterizing forest conditions and determining if the correlation between exposure and forest condition exists. This uncertainty dictates that any plan of experimental work must be reviewed annually to determine if it is still appropriate." I do not agree with this. I think you can - and should - define some basic physiological objectives. Integrative models are going to require some fundamental understanding of the relationship, for instance, between foliage amount and root amount. These are not well understood. There are a number of hypotheses which have been developed, but field data is scanty, and if the Forest Effects Program does not go out and get this data then nobody will. We will then be left with the problem of trying to interpret what is going on with respect to pollution-tree growth without sufficient physiological information. I am not at all suggesting carte blanche for physiologists. I think one can devise some very rigorous hypotheses about how pollutants influence growth through the photosynthesis mechanism, through leaching nutrients from foliage, etc. which can point one very clearly in the direction of a need to obtain certain aspects of physiological information.

Throughout this plan no attention is given to tree-ring data at the three sites, or tree volume increment, and how this may relate to physiological processes. That seems quite a weakness to me.

Comments on the Draft Plan Section 7: Paul R. Miller
February 17, 1987

This section is explicit. I find no disagreement with the proposed actions. It is really a breakthrough to have sufficient time for planning before collecting new data.

Comments on the Draft Plan Section 7: David Tingey
February 18, 1987

The relationships among the various research elements (7.2, 7.3, and 7.4) is unclear as stated in the plan. As presently written the different elements are independent, but in reality they should be interrelated. The section is too brief and cryptic; greater detail is needed concerning the types of experiments that are needed or envisioned by the CFRP.

Section 7.2: The statement that only Scientific Questions need to examined for which a positive correlation exists is either not clearly stated or wrong. For example, there is a negative correlation between increasing levels of ozone and decreased growth for various plants. In most cases that I can imagine, a negative correlation exists between increased pollutant exposure and decreased plant or system performance. Also I think that it is too restrictive to require that all hypotheses be derived from the Gradient Study; this approach fails to build on the results of other scientific investigations reported in the literature or research conducted in other Forest Response Program research. Because of the variability that exists in field studies it would be reasonable to base some of the field work on the results of controlled environment experiments. These could suggest what measures are appropriate or sensitive and they could be validated by field testing.

Section 7.3: The plan as written states that no work will be done other than the tracking of one study funded by EPRI. I think that this is too limited of a goal; more research is needed to provide the necessary data to support the development of tree and stand models needed for the integration portion of the project. The research that may be developed in this section appears as though it will be developed without consideration of research beyond the CFRP if this is the case it is a mistake. This section needs greater detail about the types of studies that are desired. There are numerous forestry research projects currently under way; it should be possible to use results from their efforts to develop the preliminary experiments that are needed rather than ignore the issue.

Section 7.4: It is not clear that the EPRI study will provide sufficient information to develop and drive a process model for mature trees. The role of modeling and integration within the CFRP needs better definition and focus than the plan presently contains.

Section 7.5: Why does the plan specify that only the Synthesis and Integration Team can develop mechanistic hypotheses. Who are these all knowing people that are omnicapable and where are they located? I think it is

unwise not to involve other scientists in the development of the hypotheses. The coordination implied at the end of this section is not reflected in the rest of Section 7, why?

Comments on Draft Plan Section 7: Homero Cabrerra
March 11, 1987

The listing of potential applications of research results is useful because it concurrently identifies some of the kinds of information needed. The plan identifies, in a general sense, the kinds of experimental methods which may be useful in gathering the necessary information, but does not contain any examples of studies which would provide information about particular pollutants. Developing specific studies will necessitate addressing each pollutant individually, based upon what is believed to be its mode of action and the information available concerning it.

Beginning the controlled experiments with those correlations which can be established on the basis of field measurements has the advantage that resources are not expended identifying responses or effects which are obscured in the field situation by natural environmental variation. On the other hand, some preliminary controlled studies may help determine which responses hold the most potential for being useful in establishing field correlations.

A difficulty which pervades this portion of the plan is the need or the intention to address a broad range of pollutants. The information available on each pollutant of potential interest differs in type and quantity, so it is very difficult in a general plan to present a single set of experiments that can be used to investigate the various pollutants and their effects. The likely results of such an attempt would be that the program would focus either on the "lowest common denominator" without making use of all available information, or that some pollutants would not be adequately investigated.

FINAL REPORT

QA/QC/DATA MANAGEMENT WORKING GROUP

JOHN DUFF BAILEY, CHAIR

California Forest Response Program Research Plan Review
Asilomar Conference Center
Pacific Grove, California
February 23, 1987

Members of the QA/QC/Data Management Working Group:

John Duff Bailey - Chair
Mary Beth Higgins - Student Aid

James Balogh
Jeffrey Gordon
Shepard Zedaker
Steve Cline

Summary of Group Recommendations

The QA/DBM WORKING GROUP for the California Forest Response Program (CFRP) Planning Conference was charged with providing specific recommendations for the revision of the CFRP QA Plan (section 8 of the draft plan). In addition to providing specific recommendations below, the working group offers the general comment that the plan was in relatively good shape and provided a good starting block for their review. The group recognizes and appreciates its inherent dependency on the national FRP QA Plan given the design of the CFRP.

The group, however, felt that the plan could profit from some elaborations and additions, as follows:

1). The working group recommends that an introduction be added to section 8 to provide context for the QA information that follows. Such information should raise morale and defuse the reaction to QA. This would be similar the QA presentation given by John Duff Bailey at the conference.

In addition, the group recommends replacing words such as "audit" at in the introduction with "review" or other less aggressive terminology.

2.) The group recommends that the QA Specialist serve on the S & I Team as 1) a resource of information (project details and status), and 2) a unique point of view about the CFRP and individual projects.

3.) The group recommends the addition of/emphasis on QA for modeling projects (recognizing their importance to CFRP). The QA Specialist will not review modeling details but will ensure:

a.) sufficient documentation of the model;
b.) proper technical review of that info; and
c.) appropriate testing of the model.

4.) The group recommends the addition of details on physical implementation of QA, from Request for Proposals (RFPs) through interactions with the QA Specialist, negotiation of disputes, and final approval of QA plans. This section would contain the "nuts and bolts" chronology of QA implementation, possibly in a flow diagram.

5.) The group recommends the addition of/emphasis on QA for projects utilizing existing data or other information. This would follow the lead of the national FRP QA Implementation Plan:

1). documenting the project uses; and
2). assessing quality of the information. This is crucial for allowing the weighing of past data collection against present "QA'ed" data collection.

6.) The group recommends revising the QA plan (section 8) in reference to discussions of the FRP Methods Manuals and standardization to consistently reflect QA concerns. The group recommends the use of the FRP Methods Manuals for standardizing methods (not standardizing the science) as a tool for integrating the program, providing quality data, and relieving documentation burden on investigators. If deviation is required for whatever reason, investigators should describe the difference, justify it, and provide for comparison with the standardized procedure.

7.) With regards to database design, the group is unable to meet its charge at this time. They recommend that the CFRP pursue a centralized database archive, whether it be a physical entity or a virtual database as planned for the national FRP. They recommend the release of an RFP in '87 to 1) design an appropriate system (obvious connection to S/I members), and 2) communicate with/educate investigators which will use the system. Data availability in '88 forces the development and implementation of the database management system. That system is currently budgeted

strictly as an archive and would require additional funding should S/I desire to use the database resource manager as an analyst or if the CFRP desires a very structured system.

8. The group recommends the adoption of national FRP guidelines for data transfer and data access as documented in national FRP QA Methods Manual for Experimental Design and Data Management. The revised QA plan (section 8) should reflect this recommendation.

9. The group recommends that the QA/DBM support group specified in Figure 2 of the draft plan (page 12), developed to advise the CFRP manager on QA and database issues, be comprised of:

- Steve Cline, the QA Specialist
- the database designer (later, the resource manager); and
- a representative for CFRP investigators.

The QA Officer of the national FRP might serve on that group as an observer/advisor depending on the wishes of the CFRP manager.

That completes the recommendations of the Quality Assurance/Data-base Management Working Group. Questions about these comments should be directed to John Bailey, chairman.

Comments on Draft Plan Section 8: Steven P. Cline

SUMMARY

Overall this section (8) gives a good introduction to the make-up and functioning of the QA project in the FRP and how that program will be incorporated into the CFRP. My comments are editorial in nature.

COMMENT 1 (P. 34). When procedural changes are made QA requires proper documentation. Fine, but is this enough? Should we not also require (strongly recommend?) that the old and new procedures be tested together so that data are comparable at a later date. The principle for this comes from the lab, where old and new standards are routinely compared and adjusted accordingly. Incorporate into QA paper if accepted.

COMMENT 2 (P. 41). The references to appendixes is confusing or wrong. Be clear and consistent. An improvement might be to use numbers for the appendixes in the FRP Implementation Plan (Appendix B). Also, appendix B of Appendix B (see what I mean) is not the QA guidelines for historical databases (missing). Is appendix C (project review) of Appendix B necessary. Finally, the QA guidelines for QA plan development should be marked with a great big DRAFT.

COMMENT 3 (P. 41). Related to COMMENT 1. How do we assure that alternative methods are comparable? This is difficult when methods have no standards reference material against which they can be tested. I would suggest that we be more strict initially about adherence to methods without standards than to methods with standards.

COMMENT 4 (P. 41). I believe criterion (singular) is misused on pages 41 and 43 (maybe other places too). You want criteria (plural) I think.

Comments on Draft Plan Section 8: Geoffrey A. Gordon

The QA/QC project plan derives the bulk of its detail and organization form the EPA National Forest Response Program. This is entirely appropriate in the context of the CFRP. The national QA/QC plan is thorough -- it carefully considers most important aspects of QA/QC and reflects professional excellence in conception and design.

I have two areas of concern: One with the cost of executing the QA/QC plan and one with the psychological aspects of the relationship between the QA/QC plan and the PI's. The cost factor remains a serious concern even after discussing the issue within the QA/QC working group. I believe that the QA/QC working group made some helpful suggestions in the second area, but more attention is needed.

On the cost issue, some thought must be given to the level of effort required to execute the QA/QC plan within the CFRP. More importantly, some guide lines as to the portion of a PI's overall budget that should be allocated to implementation of QA/QC. Careful review of the QA/QC costs relative to the modest level of funding projected for the CFRP as a whole will reveal the need to insure that QA/QC is as efficiently implemented as possible in order for the substantive goals of the project to be realized. It may be beneficial to consider centralizing some of the aspects of QA/QC such as generation of QA/QC statistics and reports. This would relieve the PI's form having to secure technical staff to execute these duties.

On the issue of the psychology of the relationship between PI's and QA/QC, I feel that the QA/QC plan can be presented less like the research "gestapo" and more like a service to the PI. Specific recommendations were made on this within the working group, and this idea should be carried further. Emphasis needs to be made on the fact that the QA/QC plan only requires documentation of QA/QC procedures that most PI's already execute on a routine basis and not a new burden. On the other side of the issue, PI's need to understand that the goals of the CFRP are planning goals and not necessarily scientific goals. The two types of goals are closely related of course, but some broad differences exist between a grant to do research (the usual way a PI view the work) and a contract to conduct research (as with the CFRP). The contract situation is by necessity highly regulated, even to the level of requiring a systematic program of internal review of results, i.e. QA/QC. In a contract setting QA/QC is more than a means to an end -- it is an integral part of the product to be produced.

Comments on Draft Plan Section 8: Shepard M. Zedaker

I have not had time to adequately review Section 8 - QA/QC of the CFRP. I will read it more carefully before the meeting. My general impression of the Section is that it is extremely well written and very complete. Enough detail has been provided for an efficient working document on the QA plan. One point of confusion might be that if an investigator wants to do something different than the specifications in the Methods Manuals, how will it be approved? Also, will the QA specialist grant final approval or just assist in revision and approval? Is there any arbitration plans if there is a major disagreement? Work needs to be done on the data transfer section. PI's are very nervous about this and much more detail on this will be needed if it is not spelled out better in other parts of the plan.

Comments on Draft Plan Section 8: James C. Balogh

Given the brief period provided for review of the extensive CFRP Draft Plan, the following is an outline of initial reactions and comments to the DRaft Plan. The focus of the review is on Section 8, Quality Assurance and Quality Control.

1) The overall draft plan is well structured, ambitious, and has fairly well defined objectives. Success of the CFRP will depend on adherence to these objectives during all phases of project implementation.

2) The QA/QC draft plans are based on plans previously developed by NAPAP, EPA, and Northrup Services, Inc. Have any previous problems been encountered in implementation in the National FRP? Have these problems been eliminated for QA/QC implementation on the CFRP?

3) In the Draft Plan and Appendix B detailed QA/QC objectives, rationale, and intent are discussed in detail. However, discussion of implementation of these plans regarding specific CFRP research is limited. The following questions are immediately apparent:

a) How will specific projects PI's participate in planning and implementation of QA/QC and data management systems?

b) QA/QC must be tailored to the data necessary to answer the scientific questions and stated research objectives. Is the QA/QC system proposed for this project flexible enough to meed the needs of specific research projects. Will the priorities of the QA/QC staff meet the needs of the researchers actually implementing the projects to satisfy project objectives? Will the Data Quality Objectives be established through the mutual cooperation of the project PI's with the appropriate scientific expertise and the QA/QC staff?

c) Who will ultimately make decisions concerning the level of sufficient scientific and legally defensible data?

4) Discussion may be appropriate concerning the methods of maintaining positive attitudes to QA/QC procedures during all phases of research implementation. QA/QC should be designed to enhance the individual projects and overall project integration. Unfortunately, QA/QC is often perceived as a form of research policing or regulation. Rigid QA/QC systems, including cumbersome data management systems, are often detrimental to satisfactory economic and technical implementation of QA/QC.

5) Proper allocation of budget and staff resources is crucial to proper QA/QC. Given the QA/QC requirements of

the CFRP, will PI's be allocated sufficient funds to utilize qualified personnel at critical stages of research design, implementation, and analysis?

6) Data analyses and statistical design is an important component of research design and overall project success. There was limited discussion in the QA/QC draft plan regarding review of analytical techniques (e.g. statistical analyses and model development) and data management strategies. Use of appropriate data, numerical, and model analysis is as important as establishing confidence intervals for laboratory analyses.

7) A critical research intersection in the CFRP is extrapolation of process models, experimental manipulation, and site monitoring developed on the three intensive research sites to the gradient of Ponderosa pine in California. The CFRP has elected to use three intensive research sites as the basis of scientifically and legally defensible data analyses. The QA/QC section has defined a plan to establish data quality objectives and standardized methods. However, the gradient analyses is limited to a total of three sites, each site with research extrapolation, the CFRP is limited to a total of two (2) degrees of freedom and a total lack of 'treatment' replication; not to mention model verification.

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John Wiley and Sons. New York. 257 pp.

Hurlbert, S. H. 1984. Pseudoreplication and design of ecological field experiments. Ecol. Monogr. 54(2): 187-211.

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FINAL REPORT

SYNTHESIS AND INTEGRATION WORKING GROUP

WILLIAM WALKER, CHAIR

California Forest Response Program Research Plan Review
Asilomar Conference Center
Pacific Grove, California
February 23, 1987

Members of the Synthesis and Integration Working Group:

William Walker - Chair
Susanne Lemcke - Student Aid

David Grigal
John Harte
Ross Kiester
Paul Schroeder
Jack Winjum

Summary of Group Recommendations

INTRODUCTION

The synthesis and integration component of the CFRP draft plan was evaluated according to the agenda items outlined below.

I. Establish goals of S&I plan

A. Process driven mature tree model
B. Stand model
C. Expert systems - artificial intelligence

II. Specific objectives

A. Setting program wide and research area priorities
B. Determining the needed research outputs

1. level of detail
2. data compatibility
3. tracking of other research program outputs

III. Hypothesis testing

A. With research proceeding in a concurrent, rather sequential fashion, how can we effectively assimilate data,

analyze it, and then hypothesize or redirect the next level of research?

B. What means should be used for analyzing data? Should new statistical methods be developed?

C. How should data, produced by research at different levels of resolution, be integrated in a manner useful for the various synthesis efforts?

IV. Management and organization

A. How should the S&I team be assembled? How will the members be selected?

B. Who are the policy clients and what policy directives are S&I responsible for?

C. Can S&I related activities be built into RFPs to ensure the appropriate program outputs?

The synthesis and integration workshop participants identified several activities that S&I should be responsible for. The first of these was the immediate generation of summary statements. These summaries are analogous to literature reviews and will cover topics related to the research areas to be started in the first year of plan implementation. Thus they will cover the state and usability of California vegetation survey data, air quality data (particularly atmospheric pollution trends), results of tree seedling research, and the results of forest effects research studies in California and other places.

The summary statements will be useful for developing a complete picture of available data, its usefulness, and its application in directing research important to the CFRP. In addition, collection of the summaries will help provide the rationale behind the intensive site selection, the measurements to be made at the site(s), and the methods needed for extrapolation from intensive site work to regional survey data.

The second activity designated to the S&I team is the establishment of the CFRP's modeling effort. The modeling program should be designed to include the evaluation of existing whole tree models and stand models, the development of new models (if appropriate), the use of models for directing research needs, and the use of models for data integration and evaluation.

The evaluation of existing models should commence immediately prior to the start of the research effort. The models will identify needed research derived inputs as well as the usefulness of available data. In addition, a

thorough model evaluation determines the relative sensitivity and robustness of existing whole tree and stand type models. Decisions regarding the need for the development of new process driven models will be largely based on current model evaluation with emphasis on the suitability of model outputs for addressing both the CFRP's scientific questions and the Air Resources Board's policy directives.

Tracking of other research programs related to the CFRP and establishment of cooperative efforts with suitable programs was cited as another important S&I activity. All appropriate research studies undertaken in the past or currently in effect should be integrated with the CFRP studies to avoid unnecessary duplication of effort and to expand our ability to address the important scientific questions. The WCRC is already engaged in this type of activity which will allow the CFRP to link up with this pre-established network.

With respect to decision making and hypothesis testing, the workshop participants recommended an iterative approach. That is with research proceeding in a concurrent fashion and at different levels of detail, the S&I team will be constantly evaluating research outputs as they are generated in order to set the next level of research. This will necessarily require the close cooperation of the researchers with the S&I team. To ensure this cooperation, as well as to ensure the correct use of and interpretation of data, several P. I.'s will be selected to become a permanent part of the S&I team. This will also lend continuity to the research program, a prerequisite for success.

Finally, the group suggested that several other critical program needs be further evaluated. These included the development of a structure for carrying out the iterative process for research evaluation, the development of assessment methodology suitable for the concerns of the policy clients, and the suggestion that manipulative studies be started as soon as possible in order to aid in model calibration.

Comments on Draft Plan Section 9: David Grigal

"Integration," as outlined on p. 45 of this section, is primarily project administration. This statement is not meant to belittle its importance. There is no question that such duties as facilitating coordination among investigators and support groups and ensuring that the relevant data and information are produced in a timely manner are vital to the project.

I find an examination of the approach to synthesis to be more interesting, in the sense that synthesis will require more scientific imagination and less cajoling and record-keeping.

In that context, I strongly endorse the focus in this draft around a process-driven mature tree model. My review of Kiester's paper indicates some of my concerns with a statistical orientation. I believe that a process orientation is likely to be both more successful in understanding the phenomenon and more useful in either spatial or temporal extrapolation. A model will also provide a necessary focus for other elements of the project.

I also endorse the goal of tracking other studies and of using information either already or currently being collected outside of CFRP. The question of forest response to air pollution is obviously a hot issue, and many organizations are devoting or planning to devote many resources in an attempt to understand the problem. A modest investment by the CFRP could be leveraged many-fold with data being generated in these studies.

I endorse the draft plan. An unanswered question, and perhaps an unasked question, however, is what model or models will be used by CFRP? Has a choice been made? Or has a certain modeling approach, although not a specific model been identified? If not, then I urge that serious consideration be given to how that will be accomplished. Perhaps an RFP should be issued, asking for development of approaches to modeling rather than development of the model itself. Once an approach is agreed upon, then I trust that computer jocks and scientists can work together to flesh out the details. I do not consider that development to be a trivial task, either, but a poor initial approach could waste both resources and more importantly it could waste invaluable time.

In summary, I like this section of the plan.

Comments on the Draft Plan Section 9: Paul Schroeder

Overall, this section is well written. It closely follows the Forest Response Program's approach to Synthesis and Integration with which I have been involved. Several specific comments are listed below:

1. A process-driven mature tree model should be an excellent vehicle to facilitate program integration. It will provide a context and framework for planning and for research. Such a model will make it possible to assess and evaluate the contributions of individual projects to the program as a whole and to assure that all the pieces fit together. I strongly support this approach.

2. Within the CARB program itself, however, this section does not make clear the organization and lines of authority within the program. For example, how do the Central Planning Group and the S&I Team interact and relate to one another? Who approves funding decisions? How will the program "ensure that the relevant data and information needed for synthesis are produced ... in a timely manner?" In some ways these questions pertain to program management, but management and S&I are often very closely linked.

3. Some of the program outputs on page 46 seem redundant. What is the difference between major output 1, intermediate output 1, and intermediate output 3?

4. It is reasonable that the CFRP will not try to produce all of the listed outputs itself and will work closely with other programs. It is not clear, though, how the CFRP will coordinate "... efforts other than those funded directly by the CFRP ..." What happens if some of these other programs do not wish to be coordinated? What happens if other programs fail to deliver critical data or information as expected? Perhaps the CFRP needs to identify those activities and data that are crucial to the program's success and either do them itself or collaborate directly (with funding) with other programs.

5. The project tracking system is another worthwhile idea that has proven very useful to the FRP. Like the FRP, the CFRP must implement a procedure for regularly reporting project progress. Otherwise the tracking system becomes outdated and obsolete almost immediately.

6. The problem of extrapolating the results of seedling growth and physiology studies to mature tree response is a major challenge. The CFRP should begin working with other programs immediately on this question. The methods for accomplishing this extrapolation may have important implications for how the seedling studies should be carried out.

Comments on the Draft Plan Section 9: Jack K. Winjum

After reviewing the CFRP Draft Plan and particularly Section 9 on S&I, I have three comments:

1. Thank you to the writers for producing a readable and well-organized document covering a rather complex subject. Contrary to many recent, research plan documents in this field, the writers wisely refrained from using officious jargon and contrived sentences, and just clearly described the program in sensible language. They are to be commended for professional work.

2. Coming from the state where the first regional-scale case of forest decline caused by air pollution was documented (i.e. San Bernardino National Forest, I find it ironic that a Draft Document for a Forest Response Program for research in California reflects almost a zero knowledge base as a beginning point. I would think you would build on the San Bernardino experience in your planning or at the very least mention it in the draft plan. It already gives you a leg up on the intermediate outputs 1, 3 and 4 (page 46).

Further, Dr. J. L. Kulp, Director of NAPAP, recently pointed out the unique opportunity that the San Bernardino case presents. There the sequence of discovery-implemented corrective measures-forest response (recovery?) has had time for a full cycle. Why would not (should not) it make sense to use some of your research dollars to determine if regional forest decline caused by air pollutants can be reversed by society's control policies. Seems like a leading-edge research opportunity that rightly should be included in the California program.

3. Regarding - Section 9 on S&I, there is no mention of how the CFRP will get from results for ponderosa pine forests to the major program-wide outputs on "California forest" (page 46). By definition on page 2 of the draft plan, forests are "all California forests and woodland vegetation dominated by trees." The draft plan begins by explaining the need to focus on one of the major California forest types in the limited time and resources available. This is understandable. But then the plan has no apparent provision on how ponderosa pine results are extended to "all California forests." Would an effect or no effect for ponderosa pine be true for all regional forests in the state? That is a mighty big decision criterion!

APPENDIX V

BIOGRAPHIES OF CONFERENCE PARTICIPANTS

APPENDIX V

BIOGRAPHIES OF CONFERENCE PARTICIPANTS

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WORKSHOP: Chair-deposition support

Dr. John G. Watson is an Associate Research Professor and Leader of Air Quality Studies in the Energy and Environmental Engineering Center of the Desert Research Institute. He received a Ph. D. in Environmental Science from the Oregon Graduate Center. Dr. Watson is currently the principal investigator for ARB's dry deposition monitoring network and quality assurance officer for the EPA's and NPS's dry deposition monitoring networks.

Dr. Jack Winjum 202-395-5771
NAPAP
722 Jackson Place Northwest
Washington, DC 20503

WORKSHOP: quality assurance and quality control

Dr. Winjum is a forester and forest ecologist with academic training at Oregon State University (B. S.), University of Washington (M. S.) and University of Michigan (Ph. D.), and applied research experience with Weyerhaeuser Co. He is now the Senior Forest Scientist with primary responsibility for developing the forest effects chapter in NAPAP's first interim assessment document. His interest is focused on addressing the management of industrial forest lands.

Dr. Shepard Zedaker 703-961-4855
School of Forestry
Virginia Polytechnic Institute
Blacksburg, Virginia 24061

WORKSHOP: quality assurance and quality control

Dr. Zedaker received his Ph. D. from Oregon State University in Forest Ecology. He is Assistant Professor of Forestry at Virginia Polytechnic Institute. He is the author of the methods manual for the USFS on Field Sampling. His research interests have involved him in the Spruce-Fir Cooperative and include site stand conditions field sampling, growth effects and compositional changes.

APPENDIX VI

LIST OF ABBREVIATIONS

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LIST OF ABBREVIATIONS USED IN THIS REPORT

ADD - ARB'S Aerometric Data Division

AEC - Atmospheric Exposure Cooperative of the NFRP

ARB - (California) Air Resources Board

CARB - California Air Resources Board

CFRP - California Forest Response Program

DBM - Data Base Management

EHC - Eastern Hardwoods Cooperative

EPA - Environmental Protection Agency

EPRI - Electric Power Research Institute

ERC - Energy Resources Consultants

FIA - Forest Inventory Analysis

FRP - (national) Forest Response Program

GIS - Geographic Information System

NAPAP - National Acid Precipitation Assessment Program

NCASI - National Council (of the Paper Industry) for Air and Stream Improvement

NOAA - National Oceanic and Atmospheric Administration

NPS - National Parks Service

NVS - National Vegetation Survey

PM - as in PM10 or PM2.5 is particulate matter

PQ - Policy Question

QA - Quality Assurance

QC - Quality Control

RFP - Request for Proposals

SAI - Science Applications, Inc.

SCE - Southern California Edison

SQ - Scientific Question

TMI - Timber Management Inventory

USFS - United States Forest Service

WCRC - Western Conifers Research Cooperative

WEST - Western Energy Supply and Transmission Associates