EPA/620/R-93/002
November 1993

FOREST HEALTH MONITORING

1992 ACTIVITIES PLAN

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NOTICE

The information in this document has been funded in part by the U.S. Environmental Protection Agency under Interagency Agreement Number DW12934170-5 to the U.S. Forest Service, under Contract Numbers 68-D0-0106 (RTP) and 68-C8-0006 (Corvallis) to ManTech Environmental Technology, Inc., under Contract Number 68-C0-0049 to Lockheed Engineering & Sciences Company, under Cooperative Agreement Number CR818526-01-0 to the University of Nevada-Las Vegas, and under Cooperative Agreement Number 58-6645-0-002 to North Carolina State University. It has been subjected to the Agency's peer and administrative review, and it has been approved for publication as an EPA document.

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Proper citation of this document is:

Alexander, S.A. and J.E. Barnard. 1992. Forest Monitoring Monitoring 1992 Activities Plan. EPA/602/R-93/002. U.S. Environmental Protection Agency, Washingtion, DC.

ABSTRACT

Forests, which cover approximately one-third of the United States, are an important part of the U.S. economy, culture, and ecology. In response to legislative mandate and concerns for our environment, several government agencies have been working together to develop a program to monitor the condition of the Nation's forests. This multiagency program is called the Forest Health Monitoring (FHM) program. The U.S. Department of Agriculture Forest Service has contributed to this initiative under the auspices of their Forest Health Monitoring program. The U.S. Environmental Protection Agency has participated through the forest component of the Environmental Monitoring and Assessment Program. Other contributing agencies include the National Association of State Foresters and individual state forestry agencies, the Tennessee Valley Authority, the Soil Conservation Service, the Bureau of Land Management, the Fish and Wildlife Service, and the National Park Service.

This report is designed to serve two purposes for FHM. The first is to provide a description of major FHM activities planned for the fiscal year 1992. These activities range from the initial planning stages of field work to the assessment and reporting activities. The second is to provide background information about the FHM program organization, the indicator development process, and other activities within FHM.

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ACKNOWLEDGEMENTS

The authors thank the external reviewers of this document, Dr. Robert Brooks and Dr. Louis Iverson, for their time in reading the document and their constructive comments.

The following individuals are acknowledged as the EPA Work Assignment Managers: Ralph Baumgardner, Daniel Heggem, and Spencer Peterson.

The authors gratefully acknowledge the additional review comments from Bill McLain and John Vissage.

Appreciation goes to Barbara Conkling and Elizabeth Eastman for their contributions as editors.

Appreciation also goes to the following persons: Leslie Gorr and Cheryl Simmons for their assistance with word processing, and Shirley Burns for her excellent graphics assistance.

ACRONYMS AND ABBREVIATIONS

3-D	-	three-dimensional
AAS	-	atomic absorption spectrometry
AD	-	Associate Director
Al	-	the element aluminum
BA	-	the element baruim
BLM	-	Bureau of Land Management
C	-	the element carbon
Ca	-	the element calcium
CBC	-	calcium binding capacity
Cd	-	the element cadmium
CDF	-	cumulative distribution function
CEC	-	cation exchange capacity
Cl	-	the element chlorine
CNS	-	the carbon, nitrogen and sulfur elemental parameters
Cr	-	the element chromium
Cu	-	the element copper
CV	-	coefficient of variation
DBH	-	diameter at breast height (1.37 meters)
DQO	-	data quality objectives
DRC	-	diameter at root collar
DRIS	-	Diagnosis and Recommendation Integrated System
ELVES	-	Environmental Laboratory Verification and Entry System
EMAP	-	Environmental Monitoring and Assessment Program
EMSL-LV	-	EPA Environmental Monitoring Systems Laboratory in Las Vegas, NV
EPA	-	U.S. Environmental Protection Agency
ERL	-	EPA Environmental Research Laboratory in Corvallis, OR
EQO	-	Ecosystem-level DQO
F	-	the element fluorine
FAA	-	flame atomic absorption spectrometry
Fe	-	the element iron
FAO	-	Food and Agriculture Organization
FIA	-	Forest Inventory and Analysis

FHM	-	Forest Health Monitoring
FPM	-	Forest Pest Management
FS	-	Forest Service
FWS	-	Fish and Wildlife Service
FY	-	fiscal year
GIS	-	geographic information system
GMT	-	Greenwich Mean Time
GPS	-	global positioning system
GSMNP	-	Great Smoky Mountains National Park
Hg	-	the element mercury
ICP	-	inductively coupled plasma
ICP-MS	-	inductively coupled plasma-mass spectrometer
ICP-OES	-	inductively coupled plasma optical emission spectroscopy
ID	-	identification
IM	-	information management
IQO	-	indicator-level DQO
IRC	-	independent regional coordinator
ISEM	-	Intensive Site Ecosystem Monitoring
K	-	the element potassium
LAI	-	leaf area index
LTER	-	National Science Foundation's Long-Term Ecological Research
MEI	-	maximum expression of injury
Mg	-	the element magnesium
MLRA	-	major land resource area
Mn	-	the element manganese
MQO	-	measurement quality objective
MSDR	-	measurement system detection reference samples
MSFD	-	measurement system field duplicate samples
N	-	the element nitrogen
NASF	-	National Association of State Foresters
NCSFNC	-	North Carolina State Forest Nutrition Cooperative
NCSS	-	National Cooperative Soil Survey
Ni	-	the element nickel
NIST	-	National Institute of Standards and Testing
NPS	-	National Park Service

P	-	the element phosphorus
PAR	-	photosynthetically active radiation
Pb	-	the element lead
PC	-	personal computer
PD	-	pilot/demonstration crews
PDR	-	portable data recorder
PEA	-	performance evaluation audits
PL	-	preparation laboratory
PVC	-	polyvinyl chloride
QA	-	quality assurance
QAARW	-	Quality Assurance Annual Report and Workplan
QAC-FHM	-	national Quality Assurance Coordinator for Forest Health Monitoring
QAMS	-	Quality Assurance Management Staff
QAO	-	Quality Assurance Officer
QAPjP	-	Quality Assurance Project Plan
QC	-	quality control
RI	-	retrospective indicator
RQO	-	Resouce Group-level DQO
RTP	-	Research Triangle Park, NC
S	-	the element sulfur
SA	-	selective availability
SAMAB	-	Southern Appalachian Man and the Biosphere program
SCS	-	Soil Conservation Service
SOP	-	standard operating procedure
Sr	-	the element strontium
SRM	-	standard reference material
TD	-	Technical Director
Ti	-	the element titanium
TQM	-	Total Quality Management
TSA	-	technical systems audit
TVA	-	Tennessee Valley Authority
USDA-FS	-	United States Department of Agriculture Forest Service
USGS	-	United States Geological Survey
V	-	the element vanadium
VPI&SU	-	Virginia Polytechnic Institute and State University

VS	-	vegetation structure
XRF	-	X-ray fluorescence spectroscopy
Zn	-	the element zinc

1. Introduction

S.A. Alexander and J.E. Barnard

1.1 Overview

Forests, which cover approximately one-third of the United States, are an important part of the U.S. economy, culture, and ecology. In response to legislative mandate and concerns for our environment, several government agencies have been working together to develop a program to monitor the condition of the Nation's forests. This multiagency program is called the Forest Health Monitoring (FHM) program. The U.S. Department of Agriculture (USDA) Forest Service (FS) has contributed to this initiative under the auspices of their Forest Health Monitoring program. The U.S. Environmental Protection Agency (EPA) has participated through the forest component of the Environmental Monitoring and Assessment Program (EMAP-Forests). Other contributing agencies include the National Association of State Foresters (NASF) and individual state forestry agencies, the Tennessee Valley Authority (TVA), the Soil Conservation Service (SCS), the Bureau of Land Management (BLM), the Fish and Wildlife Service (FWS), and the National Park Service (NPS).

A major impetus behind the development of this program has been increasing concern about documented and potential effects of air pollutants, global climate change, and a variety of insect, disease, and other interacting stressors on forested ecosystems. To help address these concerns, the FHM program is designed to assist resource managers and policy makers in managing the Nation's forest resources, allocating funds for research and development, and evaluating environmental policy for forest resources. The specific objectives of the program are to:

1. Estimate the current status, extent, changes, and trends in indicators of the condition of the nation's forest resources on a regional basis with known confidence,

2. Monitor indicators of pollutant exposure and habitat condition and identify associations between natural and human-induced stresses and forest condition, and

3. Provide periodic statistical summaries and interpretive reports on forest status and trends to resource managers and the public.

The organizational structure for planning, managing, and implementing the FHM program has evolved gradually and is still being developed. An overview of the current organizational structure is provided in Figure 1-1. National Technical Coordinating Committees are or will be established for each major program area listed in the bottom tier of Figure 1-1. In addition, regional coordination of detection monitoring and other field activities will be accomplished through Regional Technical Committees that are being established for each of the four FHM mega-regions: North, South, Intermountain, and West Coast. The National Technical Coordinating Committees and the Regional Technical Committees are staffed by personnel from the FS, EPA, state forestry agencies, and other participating federal agencies.

This report is designed to serve two purposes for the FHM program. The first is to provide a description of major FHM activities planned for the fiscal year 1992. These activities range from the initial planning stages of field work to the assessment and reporting activities. The second is to provide background information about the FHM program organization, the indicator development process, and other activities within FHM. The FHM program includes three levels of monitoring activities which are summarized below and described in more detail in Chapters 2, 3, and 4. Chapter 5 describes the purpose, scope, and plans for each of three field studies (two demonstration

USDA Forest Service
National Forest System
Research
State and Private Forestry

U.S. Environmental Protection Agency
Environmental Monitoring and Assessment Program (EMAP)

Other Agencies
National Association of State Foresters
Tennessee Valley Authority
Fish and Wildlife Service
Bureau of Land Management
Soil Conservation Service
National Park Service

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Figure 1-1. Organizational structure of the FHM National Office.

projects and one pilot study) to be conducted this year. The rest of the chapters summarize plans in the major program areas that support indicator development, field, and assessment activities.

1.2 Forest Health Monitoring Design

Initially, both the FS and EPA, working more or less independently, designed programs to monitor forest health. The programs designed by both agencies are comprised of multiple tiers; each tier constitutes a level or type of monitoring activity related to assessing ecological condition. The FS program identifies three tiers while the EPA EMAP comprises four tiers. The EMAP and FS tier structures are very similar and this has facilitated development of the jointly sponsored FHM program.

Within EMAP, Tier 1 is the broadest level of monitoring and focuses on landscape characterization to estimate the extent, type, and geographic distribution of forests based primarily on remotely sensed data. Tier 2 activities focus on estimating status and trends in forest condition. Measures of chemical, physical and biological indicators are collected from a subset of Tier 1 sites and aggregated to assess the status and trends of forests on a regional basis. The two main functions of Tier 3 are to determine whether or not current conditions warrant additional evaluation and to

diagnose problems in order to recommend appropriate actions. The data needed to accomplish these purposes may be obtained by intensifying the sampling grid in a specific area or by collecting additional data at established plots. Tier 4 is essentially a research component which supports the monitoring activities of Tiers 2 and 3. The objectives of Tier 4 are: (1) to provide a conceptual framework for testing, implementing, and refining forest health indicators for Tiers 2 and 3; and (2) to evaluate experimentally whether or not indicators adequately reflect ecosystem conditions.

In the three-tiered structure developed by the FS, each successive tier represents a more detailed level of monitoring. The three tiers are Detection Monitoring, Evaluation Monitoring, and Intensive Site Ecosystem Monitoring, each of which is described in more detail in the following chapters (2, 3, 4). Detection Monitoring, comparable to the EMAP Tier 2, is designed to collect data on the extent and condition of forested ecosystems, estimate baseline (normal) conditions, and detect changes over time. Data are collected from a network of permanent plots and augmented with information from air and other ground reconnaissance studies. The purpose of Evaluation Monitoring, comparable to EMAP Tier 3, is to determine the extent, severity, specific nature, and, if possible, the causes of unexplained changes found through Detection Monitoring. Studies are conducted to identify causal agents or develop testable hypotheses. Intensive site Ecosystem Monitoring is designed to provide very high quality, detailed information on fundamental processes that shape forest ecosystems. At this level, hypotheses regarding cause/effect relationships are assessed in experimental studies conducted at a small number of sites representing important forest ecosystems. Research on monitoring techniques, is an important component of the FS program and has been a primary focus of the jointly sponsored FHM program during the past two years. Research on the biological, statistical, and analytical aspects of monitoring forest health is a necessary prerequisite for FHM and, in the future, will continue to support all tiers of the program.

Currently, research on monitoring techniques is focused on identifying and selecting indicators of forest condition. An indicator is defined as "a characteristic of the environment that, when measured, quantifies the magnitude of stress, habitat characteristics, degree of exposure to the stressor, or degree of ecological response to the exposure" (Hunsaker and Carpenter 1990). Indicators are categorized depending on their stage of development:

In the first stage of development, **candidate indicators** were identified through a combination of literature review, expert workshops, and interviews with scientists and environmental managers. In the second stage, candidate indicators are evaluated against specific criteria to select **research indicators** -- those that are believed to be the most promising for future evaluation. Procedures for evaluating the expected performance of research indicators include analysis of existing data, simulation studies, and limited field tests or pilot studies.[1] Indicators that pass evaluation for expected performance and, with the concurrence of scientific peer reviewers, are deemed suitable for actual performance testing in regional demonstration projects are called **developmental indicators**. Finally, developmental indicators that are selected for long-term implementation are termed **core indicators** (Hunsaker and Carpenter 1990).

1.3 History of FHM Field Activities

A pilot project, called the Visual Damage Survey, was conducted in 1988 and 1989

[1]Field studies in which data are collected from a subset of FHM plots selected according to the sample design described in Section 7, are referred to "on-frame" or "on-plot" studies. Off-frame or off-plot studies do not use the FHM sample design for selecting plots.

under the auspices of the National Vegetation Survey in the Forest Response Program, part of the National Acid Precipitation Assessment Program. A select group of indicators for determining forest condition were identified in workshops in 1987 and implemented during pilot tests in 1988 and 1989. Visual damage survey plots were established in mixed hardwood forests (128 plots), high elevation spruce fir forests (31 plots), and natural loblolly pine stands in the piedmont (157 plots) and coastal plain (222 plots) regions. The objectives of this project were: (1) to assess the condition of selected areas of the eastern forest through the application of visual and sample collection procedures and evaluations, (2) to determine the proportion of trees that show damage symptoms which might have been caused by exposure to atmospheric pollutants and/or other agents, and (3) to determine the severity of damage as determined and grouped in damage classes of symptoms that may have been caused from exposure to atmospheric pollutants and/or other agents.

Based on the success of these and other studies, forest health monitoring was initiated in six new England states in the summer of 1990. The participating states included Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont. Over 200 plots were established in this project by the FS and state forestry agencies; EMAP-Forests staff provided assistance in quality assurance and information management. Certain visual symptoms indicator measurements, along with standard forest mensuration measurements were made.

A second field project was undertaken during the 1990 field season to evaluate several additional indicators (Palmer et al. 1990). These additional indicators were identified during interagency workshops and peer reviews of the EMAP ecological indicators document (Hunsaker and Carpenter 1990). Twenty plots were established in northern hardwood forests of New England and 20 plots were situated in loblolly pine stands in Virginia on sites that would not become FHM sites. This project is referred to as the 20/20 pilot study. In addition to visual symptoms and growth measurements, indicators of soil productivity, foliar nutrients, vertical vegetation structure, and percent transmitted photosynthetically active radiation (PAR) were measured.

In 1991, detection monitoring was continued in the six New England states and initiated in six additional states: Alabama, Delaware, Georgia, Maryland, New Jersey, and Virginia. As in 1990, standard forest mensuration measurements and selected visual symptoms indicator data were collected.

Two pilot studies were conducted in 1991: one in Georgia and one in Colorado and California. The Georgia pilot study was designed to evaluate indicators related to ecological nutrient cycling (soil chemistry, foliar chemistry, tree core elemental analysis, and the presence and taxonomy of selected root fungi) and to examine relationships between selected field measurements (vegetation and habitat structure and intercepted PAR) and data interpreted from high-resolution aerial photography.

Prior to 1991, most FHM indicators were developed and tested in eastern forests. The purpose of the pilot study in California and Colorado was to develop measurement procedures and evaluate research indicators in western forests.

The FHM staff also began developing detailed plans for Evaluation Monitoring and Intensive Site Ecosystem Monitoring in 1991. A draft plan for Intensive Site Ecosystem Monitoring was prepared and is currently undergoing internal review and revision.

1.4 1992 Activities

Detection Monitoring activities in 1992 will include revisiting the plots that have been established in the 12 participating eastern states and establishing plots in 2 western states, California and Colorado. The same site condition, growth, regeneration, and visual

symptoms indicator data that were collected in 1990 and 1991 will be collected from FHM plots in 1992.

Two demonstration projects and one pilot study will be conducted in 1992 to further develop and evaluate indicators of forest health. The Southeast Regional Demonstration will be carried out in the loblolly/shortleaf pine forest-type group of the Atlantic coastal plain in Virginia, North Carolina, South Carolina, and Georgia. This forest-type group represents one kind of forest ecosystem. The purpose of this study is to test the regional forest health assessment potential of a broad suite of indicators across a major forest type. Indicators that will be evaluated include:

- Standard mensuration measurements.
- Visual crown ratings.
- Soils (characterization and physiochemistry).
- Habitat structure for wildlife.
- Foliar chemistry.
- Tree ring growth and chemistry.
- Lichen diversity.
- Branch evaluation.
- Photosynthetically active radiation (PAR).
- Root diseased evaluation.
- Air pollution bioindicator plants.

The second demonstration project will be conducted in the portions of Virginia, Tennessee, North Carolina, South Carolina, Georgia, and Alabama that comprise the Southern Appalachian Man and Biosphere (SAMAB) region, principally an oak-hickory forest. This study will provide an opportunity to evaluate the developmental indicators listed above and selected research indicators in a second type of forest ecosystem. The pilot study to be conducted in Colorado and California will test a similar suite of indicators in western forests. These three field studies aredescribed in more detail in Chapter 5.

In addition to field studies, other important activities in 1992 are related to:

- Development of a conceptual strategy for selecting and evaluating indicators.
- Design and statistics.
- Assessment.
- Reporting.
- Quality assurance/quality control methods.
- Logistics.
- Information management.
- Use of global positioning system equipment.

The 1992 activities in each of these areas are discussed in separate chapters later in this document.

2. Detection Monitoring
R.C. Loomis

2.1 Overview

Detection Monitoring is the most extensive component of the national Forest Health Monitoring Program (FHM) and it currently is the most developed monitoring level. Detection Monitoring field implementation was initiated in 1990 and is conducted jointly by the USDA Forest Service (FS), the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program for Forests (EMAP-Forests), and state forestry and other federal agencies. The FS, EMAP-Forests, and other partners work together in the following program areas:

- Policy and goal development.
- Assessment endpoint definition.
- Quality assurance and control.
- Logistics.
- Training.
- Indicator development and testing.
- Plot establishment.
- Data analysis and reporting.
- Assessments.

In FHM, Detection Monitoring covers all forested lands and consists of (1) a plot component which is a network of permanent plots, and (2) a survey component which includes aerial and other surveys of forest pest and other stressor effects coupled with reports of forest damage. Together, these two components monitor and report the condition of forest ecosystems by estimating baseline (normal) conditions, measuring changes from those baselines over time, and determining if changes are normal or are cause for concern and warrant additional evaluation. The schedule for implementing Detection Monitoring is developed jointly by FHM partners. The 14 states now participating in FHM Detection Monitoring are Alabama, California, Colorado, Connecticut, Delaware, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, Rhode Island, Vermont, and Virginia.

The FHM program addresses the needs of participating agencies to monitor the status and trends of the Nation's forests. To accomplish this, FHM has identified a number of societal concerns that the long-term monitoring is designed to address. These concerns include:

- Productivity.
- Sustainability.
- Biodiversity.
- Aesthetics.
- Extent.
- Damage.

Societal concerns are described in terms of a number of assessment endpoints which address one or more of the concerns. Assessment endpoints are in turn described by a number of ecological indicators which describe ecological condition. Specific field measurements quantify the ecological indicators.

Proposed ecological indicators are tested and improved in pilot and demonstration studies and must address the following criteria before they are recommended to become "core" indicators for incorporation into FHM long-term monitoring (see Chapter 6):

- Interpretability.
- Quantification.
- Regional responsiveness.
- Index-period stability.
- Signal-to-noise ratio.
- Environmental impact.

To date, two indicators have been provisionally accepted by FHM as "core" indicators. They have been implemented in 12 eastern states (see Chapter 1), and their performance will continue to be evaluated. These indicators are:

- Mensuration:
  - Site condition
  - Stand condition
  - Seedling condition
  - Sapling condition
  - Understory condition

- Crown/bole assessments:
  - Visual Crown Rating
  - Damage Evaluation

A number of proposed indicators have been tested in several pilot studies in the East and one pilot study in the West. These indicators will be further tested in 1992 in two regional demonstration studies in the southeastern U.S. and in a pilot study in the West (California and Colorado). The southeastern demonstration studies include portions of the loblolly/shortleaf pine ecosystem and portions of the oak-hickory ecosystem. The indicators that are being evaluated in these studies are:

- Soils (characterization & physiochemistry).
- Habitat structure for wildlife.
- Foliar chemistry.
- Tree ring growth and chemistry.
- Lichen diversity.
- Damage evaluation (for western conditions).
- Mortality evaluation (for western conditions).
- Branch evaluation.
- Photosynthetically active radiation (PAR).
- Root disease.
- Air pollution bioindicator plants.

In addition to the evaluation of these FHM plot-based indicators, off-plot data are collected and evaluated on pest and other stressor effects, climate, and air pollution.

The FHM design provides for national and regional assessments, although sampling can be intensified to answer more localized questions. The FHM plot selection is designed to link FHM and the FS Forest Inventory and Analysis (FIA) plot networks and to provide data to fulfill FHM partner mandates. Statistical design and ground plot selection are discussed in Chapter 7. There are an estimated 4,000 forested sample plots nationwide. In addition to ground sampling, the initial EMAP strategy includes characterizing land cover and land use in each 40 km^2 hexagon. Work is currently in progress using various forms of remotely sensed data.

2.2 1992 Activities

2.2.1 FHM Plot Network

Twelve eastern and two western states comprise the 1992 FHM program. The eastern states (Alabama, Connecticut, Delaware, Georgia, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, Rhode Island, Vermont, Virginia) have 925 plots on the EMAP sampling frame. Of these, there are 628 forested plots on which remeasurements will be made. The measurements referred to here mean measurements taken on plots which were established in previous years. The western states (California and Colorado) have 1045 plots on the EMAP sampling frame. Of these, there are an estimated 384 forested plots. Western field activities include: (1) determining which plots are forested on the specified one-fourth (262) of the sampling frame plots in accordance with EMAP interpenetrating design specifications, and (2) establishing plots and taking first year measurements on the forested plots.

In the east, field crews are mostly state or state contract personnel who usually work in two-person crews. Field work on an individual plot is normally completed in one day. Western crews will likely need more time to establish the plot and collect initial data. Data are recorded on Portable Data Recorders (PDRs) and periodically downloaded and sent to FHM regional coordinators. Communication with field crew personnel is largely through state coordinators who are also in contact with FHM regional coordinators.

Regional training and certification of field crew members is scheduled for June in Utah, North Carolina, and New Hampshire with additional follow-up training done in individual states. Quality assurance/quality control (QA/QC) checks and remeasurements are made shortly after field activities commence and during the field season as specified in QA/QC guidelines. Field crews and FHM regional and national staff will have post-

season debriefings to identify ways of improving field procedures and coordination for 1993.

Plot establishment and data collection procedures for FHM are specified in the FHM Field Methods Guide (Conkling and Byers (eds) 1992). Eastern remeasurements will focus on the following:

- Trees 5 inches DBH and greater - crown measurements of crown ratio, diameter, density, dieback, and foliage transparency; tree damage measurements; and tree mortality measurements.
- Saplings (trees with DBH between 1.0 and 4.9 inches) - measurements of tree vigor, crown ratio, mortality, and damage.
- Measurements of symptoms of ozone effects on biological indicator plants in the Northeast.
- Soil measurements on a subset of New England plots and in conjunction with pilot and demonstration activities in the South and West.
- Confirmation of 1990 and 1991 data where data were lost due to PDR malfunction or when errors in the data are suspected.

Western plot establishment and initial data collection include all variables specified in the national FHM Field Methods Guide. These variables are listed under the following broad categories:

- Site condition, growth, and regeneration (up to 71 variables).
- Crown classification (up to 16 variables).
- Damage and mortality assessment (up to 23 variables).

2.2.2 Off Frame

Three important factors influencing forest health are measured off the EMAP sampling frame: (1) climate, (2) air quality and deposition, and (3) forest insects and diseases.

In 1992, FHM will support work to improve the consistency, reliability, and usefulness of current forest pest and other forest stressor effects reporting. The eastwide workplan, Integration of Forest Pest Management and Forest Health Protection Activities with Forest Health Monitoring for the Eastern United States (see Appendix B), outlines activities underway to do this. It is based on the FHM national plan for integrating the Forest Pest Management component into FHM.

The eastwide plan identifies two aspects that need updating to improve the usefulness of currently available pest and stressor effect data. The first is survey standardization; the second is establishing reporting standards and guidelines for particular insects, diseases, and other stressor effects.

3. Evaluation Monitoring

R.C. Loomis and W. Burkman

Evaluation Monitoring is being designed to determine or hypothesize likely causal relationships for unusual or unexpected changes in forest health and to recommend management responses. Evaluation Monitoring is activated by Detection Monitoring results and is designed to estimate the extent, severity, and possible causes for changes in forest health status beyond those initially identified in Detection Monitoring.

When Detection Monitoring or other reports identify areas or problems of concern for which more specific information is needed, FHM will assess the situation and determine specific Evaluation Monitoring needs. These could include additional surveys, site- or area-specific evaluations, and more detailed monitoring. In some cases, specific research studies may be required. Evaluation Monitoring project design, planning, and funding is on a project basis. Criteria for project design and selection are being developed by the FHM program.

One example of an evaluation project undertaken by FHM is the continuation of the North American Sugar Maple Decline Project. This project was initiated in 1987 as a joint effort between the United States and Canada because of concern about sugar maple decline in sugarbushes and northern hardwood stands. Initial program management and support in the United States came from the Eastern Hardwood Research Cooperative, the FS Northeastern Forest Experiment Station, and the National Acid Precipitation Assessment Program. This project is now the responsibility of the FS Northeastern Area, and state and private forestry. Program management and support in Canada is provided by Forestry Canada.

The North American Sugar Maple Decline Project is scheduled for review in August 1992. Recommendations from that review will guide future project activities.

4. Intensive Site Ecosystem Monitoring

K.W. Stolte and C.G. Shaw

4.1 Introduction

Intensive Site Ecosystem Monitoring is the third component of the Forest Health Monitoring (FHM) program. Intensive Site Ecosystem Monitoring (ISEM) will provide high-quality, detailed information on ecosystem structure and processes through long-term monitoring at a limited number of sites representing important forest ecosystems. Intensive Site Ecosystem Monitoring is defined in the FHM program as:

> Intensive, continuous measurement and analysis of forest ecosystem attributes and processes at selected biologically representative sites. The purpose of this monitoring is to provide detailed baseline information on key components of the selected ecosystems and to further our understanding of the processes and mechanisms responsible for adverse or unexpected changes in forest health.

Intensive Ecosystem Monitoring Sites are very similar to the concept of the National Science Foundation's Long-Term Ecological Research (LTER) sites. Information from Intensive Ecosystem Monitoring sites can be augmented with additional short-term measurements or it can be expanded by measuring new variables during specific studies.

The primary goals of Intensive Site Ecosystem Monitoring are to:

1. Understand the natural variability of forest ecosystems, and
2. Understand the response of forest ecosystems to human environmental influences.

Intensive Site Ecosystem Monitoring will accomplish these goals by:

- Developing hypotheses of cause-effect relationships.
- Providing information to interpret the baseline and trends in forest condition observed in the Detection Monitoring component of FHM.
- Confirming or refuting causes of change indicated in the Evaluation Monitoring component of FHM.
- Supporting mechanistic research to identify, describe, or model tree and forest processes.
- Enhancing the understanding of the mechanisms underlying change in forest ecosystems by developing a sufficient understanding of forest ecosystem structure and function to enable explanation of ecosystem processes and their relationships to changes in forest health over time.

Intensive Site Ecosystem Monitoring has five purposes:

1. To help anticipate changes in forest health,
2. To increase basic understanding of causal relationships,
3. To provide long-term, detailed measurements that will support experimental research conducted by programs external to FHM at the Intensive Ecosystem Monitoring Sites,
4. To provide indicators and methods for Research on Monitoring Techniques that will enable explanations or projections of observations, and
5. To provide the understanding necessary to develop management responses to adverse or unexpected changes.

Intensive Site Ecosystem Monitoring will provide long-term data and the sampling infrastructure that will facilitate research onmechanisms and processes that shape forest ecosystems, such as:

- Genetic selection and diversity.
- Compartmentalization of carbon and other nutrients.
- Forest community succession.

Indicators of forest ecosystem health and the specific measurements to be made as part of ISEM remain to be developed during future planning meetings. The following general indicators are considered important to address:

- Forest fertility.
- Forest composition.
- Physical environment.
- Aquatic systems.

The Forest Health Monitoring Program is concerned literally with ecosystems in which trees comprise a significant part of the dominant vegetation. Sixteen criteria were identified to guide in the selection of specific Intensive Ecosystem Monitoring Sites representing important forest ecosystems:

1. Site integrity,
2. Representative of an extensive forest ecosystem,
3. Sensitive to change in environmental conditions,
4. Maximally different from other sites in ISEM,
5. Availability of existing long-term data sets,
6. Potential to support multidisciplinary team research,
7. Supported financially, logistically, and philosophically by host facility,
8. Politically supported (Federal, State, University, etc.),
9. Accurate site history information,
10. Ecotonal (related to #3; in conflict with #2),
11. Maximum within-site variability,
12. Capability to identify and track changes in ecosystem conditions,
13. Representative of an important forest ecosystem,
14. Freedom from inertia of existing programs at site,
15. Provide information on near-term effects of global change, and
16. Potential to attract support external to the Forest Service.

4.2 Intensive Ecosystem Monitoring Sites

The study of ecosystems poses a challenge because no convenient, specific component or process exists to form the basis of observation and study. In ISEM, the organism to be monitored is a purposefully selected, intensively monitored site. Each site represents the abstract concept of a particular kind of forest ecosystem, and becomes the basis for making the repeated observations necessary to understand the structure and function of that ecosystem.

There has been considerable discussion about whether the Intensive Ecosystem Monitoring Sites should be chosen to:

- represent the modal conditions of particular ecosystems (the "basics" of the ecosystems) where processes observed most commonly occur in the ecosystem or

- represent ecotones (the "edges" of ecosystems) where processes are in a less stable equilibrium and are therefore more responsive to environmental changes.

The ISEM plan opts for a design that captures the desirable features of all of these approaches. By evaluating modal and ecotonal sites in important forest ecosystems, it will be possible to:

1. Characterize the conditions that are most representative of each ecosystem,
2. Characterize the range of conditions inherent in each ecosystem, and
3. Identify ecosystem conditions and processes that are most sensitive to change.

4.3 Implementation Schedule and Budget

Intensive Site Ecosystem Monitoring will be conducted at 20 regional groups, composed of the modal and ecotonal sites and identified by the core site of each group. These 20 regional groups will be selected according to site-selection criteria and phased in over time. Because ISEM will initially involve only 20 regional groups, the number of forest ecosystems covered will be limited.

Full funding of ISEM will be $500,000 (estimates are in 1990 dollars) per core group per year. This includes the core site and any associated satellite sites (modal or ecotonal). The total operational funding is $10 million for the full 20 regional group network. The recommended implementation schedule is (in 1990 dollars):

• 1992	No funding.	Review, revise, and complete plan.
• 1993	$0.42 million	Initiate 2 regional groups at 40% funding
• 1994	$3 million	Implement 2 regional groups at 100% funding. Initiate 6 regional groups at 50% plus funding.
• 1995	$8 million	Implement 8 regional groups at 100% funding. Initiate 6 funding groups at 50% plus funding.
• 1996	$10 million	Implement 20 regional groups at 100% funding.

4.4 Relationship with Other Programs

Many Forest Service research programs are closely related to forest health and, therefore, to the Forest Health Monitoring Program. All components of Forest Health Monitoring and especially ISEM, will support these other programs, (e.g., the Global Change Program) by providing long-term data sets and logistical infrastructure for experimental research.

4.5 1992 FHM ISEM Activities

The ISEM plan will be finalized in 1992. The plan has been internally (primarily within USFS) reviewed twice by a group of participants that first outlined the plan at a workshop in Salt Lake City, Utah, in 1991. A third draft of the plan is scheduled for completion and internal and external peer review in July 1992. The external peer review group will consist of other federal land managers, other federal agencies, university personnel, and industry personnel. An internal/external peer review workshop is scheduled for late July 1992 to provide an interchange of information on unresolved issues of the plan.

The initial implementation plan will involve funding of two regional groups in 1992-1993 (FY93). The funding will be allocated among the potential sites (core and satellite sites) within the site groups according to a consensus of station directors representing the sites:

Year 1993 - Regional Group 1:
Core Site: Hubbard Brook Experimental Forest (NH)
Satellite Sites: Howland, Mt. Mansfield (VT)

Year 1993 - Regional Group 2:
Core Site: Coweeta Hydrologic Laboratory (GA)
Satellite Sites: Great Smoky Mountains National Park (TN), Clingman's Dome (NC)

Comments on the ISEM plan should be directed to:

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Deputy Program Manager, Research
FOREST HEALTH MONITORING PROGRAM
Southeastern Forest Experiment Station
Forestry Sciences Laboratory
3041 Cornwallis Road
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DG-K.Stolte:S29L03A

5. Indicator Evaluation

R. Kucera, C.J. Palmer, and E.R. Smith

5.1 Southeast Loblolly / Shortleaf Pine Demonstration Summary

The objectives of the Loblolly/Shortleaf Pine Demonstration objectives are:

1. To demonstrate the regional forest health assessment potential of selected indicators through the application of statistical and interpretive methods, and

2. To demonstrate the ability to measure selected indicators across a major forest type.

5.1.1 Design--Plot Selection and Location

The selection of the hexagons and plots has been made (see Section 7 for a more detailed description of plot selection and design). The Demonstration will be conducted in the region that includes the entire states of Virginia (VA), North Carolina (NC), South Carolina (SC), and Georgia (GA) over a 2-year period (1992 and 1993). The plots selected for measurement in 1992 are those which are characterized as forested (stocked and with at least 10 cubic feet of trees), "loblolly/shortleaf" forest types of the 1991 and 1992 rotation of the EMAP Tier I Sample Frame within the states of VA, NC, SC, and GA. The plots to be selected for measurement in 1993 are those which are characterized as above and included in the 1992 and 1993 rotations of the interpenetrating design within the four states.

The locations of the plots are at regular intervals in a regular grid which overlays the EMAP Tier I hexagons. The plots have been located by geographical information system (GIS) computer applications. The GIS has printed out correctly scaled overlay maps showing the plots. These maps have been used to directly transfer the locations to planimetrically correct aerial photographs and topographic maps (see Section 7). Implementation of the demonstration requires field activities of reconnaissance, pretraining, training, field measurements, and debriefing.

5.1.2 Organization

Forest Health Monitoring (FHM) staff develop the required documentation of the QA project plan, methods guides and handbooks, and the Activities Plan. The FHM staff train field personnel and facilitate technical direction and quality assurance; cooperating agencies assist in procurement of personnel, transportation, and equipment. Planning and implementation of the demonstration is a cooperative effort.

Forest Health Monitoring develops agreements with State and Federal agencies to structure and fund the logistical requirements of staffing, transportation, and purchasing. Forest Health Monitoring cooperators arrange to employ personnel, obtain and pay expenses for transportation, and obtain equipment. The Technical Director for FHM has approved the strategy of developing agreements with FHM cooperators in the Southern Appalachian Man and Biosphere (SAMAB) program. The Tennessee Valley Authority (TVA) currently serves as the FHM liaison for the SAMAB committee with contacts for the USDA Forest Service National Forests in NC, USDA Forest Service Region 8 Forest Pest Management, the TVA, and the National Park Service (NPS) being emphasized. The states of NC, GA, VA and SC are important to the Demonstration as cooperators and are currently participating at different levels on a state-by-state basis through their state forestry agencies.

From 65 to 75 plots will be measured between June 15 and August 21, 1992.

The measurements which will be made require a crew which consists of two foresters, a botanist, a soil classifier, tree climber, and an

aide. One crew member will be designated as the crew leader responsible for on-plot and day-to-day coordination of the crew activities. An operational goal is to complete all of the measurements on a plot in one day. Plans are to travel and work for ten consecutive days in two weeks and take four days off at the home station. With the crews measuring plots at an average rate of 7.5 in the 10-day periods, 75 plots can be measured by two crews in a 10-week field season.

A pretraining workshop is scheduled March 30 to April 3 in the Duke Forest and Research Triangle Park, NC. The workshop will provide a field test of the portable data recorders, field methods guide, and field crew activities.

Reconnaissance is required in NC and SC on approximately 60 plots in each state. It was expected that approximately 20 plots in each state would be identified as loblolly/shortleaf pine plots through the reconnaissance process. The state of NC has agreed to establish the plots, identify their forest type classification, and obtain landowner permission for the plots which require measurement. Other cooperators could utilize their field operational capabilities to conduct these activities in SC.

Training will be conducted the week of June 8, 1992, at the Bent Creek Experimental Forest in cooperation with the USDA FS Southeastern Forest Experiment Station and the Region 8 Forest Pest Management Unit as well as FHM staff and contractors. Two crews of the demonstration field personnel will be trained.

There will be a debriefing and quality assurance measurement workshop in Asheville, NC, after the field season.

5.1.3 Personnel

Forest Health Monitoring will create two crews for the field measurements taken as part of the Southeastern Demonstration project. Each crew will consist of a lead forester, another forester, a botanist, soil classifier, a tree climber, and an aide.

At least two and preferably 4 to 8 foresters will develop files of aerial photography, maps, and diagrams for plots located in NC and SC. These people will locate the plots and obtain landowner permission to make measurements prior to the field crew's arrival.

The personnel for the demonstration will be obtained by the most effective means. The personnel, their qualifications, and the options for their employment are:

- Lead forester - a veteran, graduate forester; services to be obtained via agreement with state, the Soil Conservation Service (SCS), EPA Region, the National Park Service (NPS), or consultant.

- Forester - a senior forestry student or graduate; services to be obtained via agreement with state, SCS, EPA Region, NPS, or consultant.

- Botanist - a senior botany student or graduate; services to be obtained via agreement with state, SCS, EPA Region, NPS, or consultant.

- Soil classifier - a soil scientist able to classify soils of the region; to be obtained via agreement with SCS or consultant.

- Tree climber - experienced individuals with ability to climb trees without spikes, and capable of using overnight mail services, and computerized data recording and data transfer procedures; to be obtained via contract with tree surgery company by EPA.

- Aide - A forestry (or related discipline) student capable of using overnight mail services, and computerized data recording and electronic data transfer procedures; to be obtained via agreement with the Tennessee Valley Authority.

There is an FHM staff and working group of scientists who develop different aspects of the program. The demonstration is utilizing technical information from:

- QA Specialist - G.E. Byers/C.J. Palmer

- Logistics - R. Kucera, R.L. Tidwell.
- Indicator Leads - S. Cline, R.D. Van Remortel, B. McCune, K.W. Stolte, W. Burkman, W. Bechtold, R.L. Anderson, W. Hoffard, S.A. Alexander, T. Martin, T.E. Lewis, T. Droessler.
- Statistics - D.L. Cassell, J. Hazard.
- Reporting - B.L. Conkling.
- Assessment - K. Riitters (with team).
- Information Management - C.I. Liff, T. Hastings, V.C. Rogers, B. Cordova.

5.1.4 Communications

A chain of communications will be established to allow consistent technical communication of procedures and to allow timely communication between employees. Electronic mail and phone communications will be used predominantly.

5.1.5 Sampling Schedule

- Reconnaissance. April 3, 1992, to June 8, 1992.
- Pretraining. March 30, 1992, to April 3, 1992.
- Training. June 8, 1992, to June 12, 1992.
- Field Season. June 15, 1992, to August 21, 1992.
- Debriefing. August 23-25, 1992.

5.1.6 Site Access and Reconnaissance

In GA and VA the demonstration plots were established in 1991. In NC and SC the plots to be measured will be established during reconnaissance in 1992. The sequence of field activities is outlined in Appendix C.

5.1.7 Procurement

- PDRs, laptop computers, printers, bar code readers from EMSL-LV.
- Indicator measurement and general forestry equipment and supplies will be purchased by:

  a. FHM USDA Forest Service Southeastern Forest Experiment Station.
  b. States.
  c. Other cooperators.
  d. EPA.
  e. ManTech Environmental Technology, Inc.

5.1.8 Lab Operations

Several measurements require shipment of samples to analytical laboratories. Laboratory operations will be arranged by contract by FHM staff at EMSL-LV.

5.1.9 Information Management

The FHM Information Management Coordinator would like regional and state cooperators to develop the necessary skills and provide assistance with the PDRs and telecommunications.

5.1.10 Quality Assurance

A QA plan is being written and will be managed by the FHM QA Technical Coordinator. Discussions have indicated that the field QA would consist of measurements and remeasurements at training and debriefing and of field audits on the plots.

5.2 Western Pilot Summary

5.2.1 Background and Objectives

The decision by the FHM program to begin detection monitoring in California and Colorado in 1992 has provided an opportunity for indicator testing during this field season in conjunction with the establishment of FHM plots. This study has been named the "Western Pilot."

The Western Pilot will be an on-frame pilot since measurements will be made on the FHM plots being established on the sampling frame. The purpose of the pilot will be to provide key information to the indicator evaluation process with respect to design, logistics, spatial and temporal variability, and effectiveness of

measurement techniques. An on-frame pilot has the advantage of providing a representative sample of the range of conditions that will be ultimately encountered on FHM plots. The Western Pilot will provide the first opportunity to evaluate many of the FHM indicators in an operational mode for forest types in the western United States. A second advantage of an on-frame pilot is that portions of the pilot data collected this year may be used for assessment purposes over time. Several of the pilot indicators have been tested in other regions and may ultimately become core indicators.

In anticipation of the Western Pilot, an off-frame pilot was conducted at seven sites in California and seven sites in Colorado during August of 1991 (Papp et al. 1992). Due to limited funding and the limited timeframe given to implement that study, the objectives were to conduct a logistics and feasibility study for a variety of indicators and establish training plots and demonstration areas for future FHM efforts. Several indicators, including soil microbiology, root sampling and branch extraction, were determined not to be ready for further testing due to feasibility problems. These will be developed in additional off-frame studies in 1992 and 1993. Some suggestions for improving indicators resulted from the study. For example, the understory vegetation indicator was found to underrepresent the species composition on the plots. This method has now been improved for the 1992 pilot study.

Logistical issues were found to be very important in the 1991 study. One recommendation was that a party chief be made available to support the field crews and that a logistics person assist crew members with on-plot and off-plot responsibilities (e.g., data handling and sample shipping). Improved training of field crews was also suggested, particularly for the portable data recorders. All of these suggestions are being implemented in the 1992 Western Pilot.

The objectives of the 1992 Western Pilot are:

1. To obtain information for the evaluation of FHM research indicators in western forest types, and
2. To foster multi-agency participation in the establishment of the FHM program in the West.

5.2.2 Design and Indicators

5.2.2.1 Plot Selection and Location

The Western Pilot will be conducted on all FHM plots established this year in California and Colorado. In summary, the one-fourth EMAP interpenetrating grid was used to select candidate 635 km^2 hexagons for monitoring. In these hexagons, the nearest Forest Inventory and Analysis (FIA) photo point to the hexagon center will be evaluated for the presence of a forest. If a forest is present, an FHM plot will be established. It is expected that, following this protocol, about 70 and 40 plots will be identified in California and Colorado, respectively. Since both states have two crews, contingencies have been developed to reduce the number of plots in California and augment the number of plots in Colorado.

The first step in locating a plot is determining the location of the FIA photo point nearest to the center of a candidate hexagon. The landowner or government agency responsible for this location is then contacted and permission requested for access to the plot location. When permission is granted, the photo point is visited and if criteria are met regarding the presence of a forest, a plot center established. The photograph, along with plot access instructions, is then given to the field crews.

5.2.2.2 Indicators

The following indicators will be evaluated in the Western Pilot:

- Soils.
- Tree crown assessments.
- Tree damage - insect, disease, and other indicator plants.
- Photosynthetically active radiation (PAR).

- Understory vegetation.
- Lichen communities and chemistry.
- Tree mortality.

Additional research will be encouraged in off-plot pilot modes to enhance methodologies for specific aspects of the following indicators: root disease, understory vegetation sampling, soil microbiology, PAR, tree height, dendrochronology, branch extraction, foliage sampling, and soils. This research will be separate from the Western Pilot and is discussed further in Appendix D.

5.2.3 Organization

The Western Pilot is a cooperative study. Funding for the study is being provided from the research, state and private, and National Forest System components of the Forest Service. Funding is also being provided through the EMAP-Forests program of the Office of Research and Development in the U.S. Environmental Protection Agency (EPA), the Colorado State Forest Service, and the California Department of Forestry. The Bureau of Land Management (BLM) and the Soil Conservation Service (SCS) are providing one crew member on each crew through interagency agreements with EPA.

Each state has established an FHM coordinating committee. The leader of the California FHM project is Vernon (Jim) LaBau from the Anchorage Forestry Sciences Laboratory of the Pacific Northwest Research Station. The leader of the Colorado FHM project is Bill McLain from the Forest Inventory group at the Intermountain Research Station in Ogden, Utah. Each of these leaders has prepared a detailed operations plan for their states (see Appendices E and F). Input from other agencies is being coordinated by Craig Palmer (EPA), Don Perkins (California Department of Forestry), Mike Schomaker (Colorado State Forest Service), Jim Francis (BLM), Carol Wettstein (SCS-Colorado), and David Smith (SCS-Colorado).

Training of field crews will be conducted June 1 to 5 in Logan, Utah. A pre-training workshop will be held the previous week to establish training plots and provide crew leader training. Additional state-specific training will be conducted in California and Colorado June 8 to 12. Training of the crews will be the responsibility of national indicator leads. Training has been planned so as not to conflict with the training of crews for the Loblolly/Shortleaf Pine and SAMAB demonstrations. A debriefing session is planned for the last week in August in Logan, UT.

5.2.4 Personnel

Each state will have two crews. The basic crew consists of a lead forester, a forester (forest pest specialist), a botanist, a soil scientist, and an aide. In Colorado, the basic crew will be supplemented by two additional forest pest specialists conducting pest surveys near the FHM plots. The required qualifications for these individuals are identified in Section 5.1.3.

The field crews are supported by a national FHM team. In addition, the California crews will be supported by three foresters with previous experience in FHM. These individuals will be responsible for plot reconnaissance, crew coordination, and quality assurance.

5.2.5 Communications

Each crew will be supplied with three PDRs and a portable computer. The logistics crew member will be responsible for downloading data to the FHM data base. Updating of crew status and requirements will be the responsibility of the crew leader.

5.2.6 Sampling Schedule

• Reconnaissance	Apr. 3 - June 1.
• Crew Leader Training	May 27 - May 29, Logan, UT.
• Training: Joint	June 1 - June 5, Logan, UT. CA and CO June 8 - June 12.

- Field Season June 15 - Aug. 28.
- Debriefing Session Aug. 29- Aug. 31.

5.2.7 Site Access and Reconnaissance

Site access will be requested by the Forest Service reconnaissance staff in each state. Assistance will be provided by federal and state staff for access on government lands.

5.2.8 Procurement

Major indicator and information management equipment is being provided by the EPA. Funding for minor equipment is being provided by the Forest Service and EPA and will be purchased according to local agreements.

5.2.9 Laboratory Operations

Soil and lichen samples will be sent overnight in coolers to the FHM sample preparation laboratory in Las Vegas, NV. After preparation, soil samples will be sent for analysis to qualified analytical laboratories. Lichen samples will be forwarded to Dr. Bruce McCune at Oregon State University.

5.2.10 Information Management

Information management protocols have been established for all data collection efforts in the FHM program. These protocols will be followed in the Western Pilot. Individuals from each state monitoring activity will receive special information management training in Asheville, NC, during mid-May.

5.2.11 Quality Assurance

A quality assurance (QA) plan has been prepared for the overall FHM program by the FHM QA Technical Coordinator. Key components of this plan include the establishment of measurement quality objectives, methods guide, and training, auditing, remeasurement, and debriefing requirements. Each national indicator lead is responsible to see that these QA requirements are met for measurements in the Western Pilot.

5.3 Southern Appalachian Man And Biosphere (SAMAB) Demonstration

The Southern Appalachian Man and Biosphere (SAMAB) Forest Health Monitoring (FHM) Demonstration planned for the summer of 1992 will be a multiagency effort made possible largely through personnel, equipment, and monetary contributions from the SAMAB member organizations. As such, indicator selection is based upon resource availability rather than a prioritization of the candidate indicators.

Five states will be participating in the SAMAB Demonstration: Virginia, Tennessee, North Carolina, South Carolina, and Georgia. Twenty-five plots are spread among these five states.

The indicators which will be used in the SAMAB Demonstration project will be the same as for the Southeast Loblolly/Shortleaf Pine Demonstration project, with the exceptions that root samples will not be collected in the SAMAB region and an on-frame pilot using photosynthetically active radiation (PAR) measurements will be conducted. The project logistical information presented in section 5.1 above can be referenced for more details.

There will be one field crew participating in the SAMAB Demonstration. The crew will consist of:

- Two foresters - TVA.
- One botanist - TVA and NPS.
- One soil scientist - TVA and SCS.
- One tree climber - by contract with the FS.
- One aide - TVA.

The required qualifications for these individuals are identified in Section 5.1.3.

6. Indicator Development

This chapter is organized so that each major section contains a different indicator discussion and has the author's name(s) associated with it.

6.1 Indicator Selection, Evaluation, and Conceptual Strategy

T. Droessler

6.1.1 Introduction

On October 3, 1991, the Forest Health Monitoring (FHM) Indicator Selection Committee was formed in Asheville, North Carolina, to discuss a process for selecting indicators to be used in 1992 field work. The assigned goal was to provide an objective process for selecting indicators for a demonstration project in the Southeast. Potential indicators were subsequently evaluated using a prioritized list of selection criteria that were agreed upon in Asheville. These criteria, presented by Knapp et al. (1991) in The Indicator Development Strategy For The Environmental Monitoring And Assessment Program, include:

1. Unambiguously interpretable,
2. Simple quantification,
3. High signal-to-noise ratio,
4. Regionally responsive,
5. Index period stability, and
6. Low environmental impact.

6.1.2 Target Population

The FHM target population is defined as the areal extent of a forested ecosystem about which estimates of conditions will be made. Target populations can be defined by a region or attribute. For example, the population of interest might be the forests of the Northeast as defined by the Forest Service Forest Inventory and Analysis (FIA) units, only high elevation spruce-fir forests, or all stands of sugar maple in New England. At the broadest level, the target population for FHM is all forest ecosystems in the United States (Palmer et al. 1991).

The implication of the target population is that any field measurement must be aggregated up to and be interpretable at the subplot, plot, hexagon, and regional level. A measurement that is only informative at the individual tree level is not appropriate as an indicator for FHM. The FHM program is interested in monitoring at the regional scale to provide quantitative and unbiased estimates of the status and trends in ecological condition (Palmer et al. 1991). For example, a mean subplot diameter, a mean diameter by species, a diameter distribution by species, or basal area by species are all appropriate aggregations. Once measurements are aggregated to the subplot or plot level, they can be taken to a regional level through expansion factors.

6.1.3 Critical Criteria

6.1.3.1 Unambiguously Interpretable

The indicator must be related unambiguously to a policy-relevant assessment endpoint or relevant exposure or habitat variable that forms part of the ecological resource group's overall conceptual model of ecological structure and function. An assessment endpoint is a forest feature in which a U.S. Environmental Protection Agency (EPA) or Forest Service client or the general public is interested. A conceptual model of ecological structure and function for FHM is currently being developed.

There must be a way for each indicator to aggregate all measurements up to plot level. Plot level data will be used in cumulative distribution functions (CDFs) and graphs in the assessment reports. A method for determining a nominal/subnominal boundary for the CDF should also be included.

6.1.3.2 Simple Quantification

Each indicator must be quantified by synoptic monitoring or by cost-effective automated monitoring.

It should be possible to collect the measurements for the indicator in one day (or to gather them in one day for later analysis). An alternative would be a cost-effective automated monitoring method to gather the data over time. Related considerations include:

- Reliability of the instruments.
- Complexity/difficulty of the measurement process.
- Time required to collect measurements.
- Measurement error.

Measurement error in this context is the total amount of expected variability in repeated measurements on the same material. Measurement error in the visual symptoms indicator is usually attributable to differences between observers. Measurement error for PAR is related to both instrument variability and cloud conditions. Measurement error for soil chemistry is the combination of variability due to sampling protocol violations, preparatory laboratory variability, and analytical laboratory variability.

The subject of measurement error must be carefully considered, since measurement error decreases the accuracy of measures of current status and extent, adds biases to the tails of CDFs, and decreases the ability to detect changes and trends over time.

6.1.3.3 High Signal-to-Noise Ratio

Each indicator must have sufficiently high signal strength (when compared to natural annual or seasonal variation) to allow detection of ecologically significant changes within a reasonable time frame (which may vary among the indicators). It is important to determine whether or not the natural annual variability of the indicator will mask an important shift in the value of the indicator. Documentation for each indicator should address the indicator's ability to detect a trend or change, the amount of change that the indicator can detect, and the period of time over which that change would occur.

With repeated visits over time, site-to-site differences do not matter nearly as much as annual variability. Repeat visits allow analysis analogous to a paired t-test or a repeated measures analysis. With a large number of sites, the ability to detect a trend regionally is different than the ability to detect a change at one site.

As an example, consider the desire to detect a mean change of 10 percent in a measurement that has a remeasurement error of 20 percent. For a single site at two different times, there is no chance of detecting a change. For 35 sites with the same change and remeasurement error, a mean change can be detected with a significance level of 0.05 (analogous to a 95 percent confidence interval) and a power of over 80 percent. For 200 sites, a change of 10 percent and a remeasurement error of 50 percent, a mean change can be detected with a significance level of 0.05 and roughly the same power.

6.1.3.4 Regionally Responsive

Each indicator must reflect changes in ecological condition, pollutant exposure, or habitat condition, and respond to stressors across most pertinent habitats within a regional resource class. This criterion refers to the importance of a strong relationship between the field measurement and the environmental index. A difference in the value of the indicator must reflect a difference in site characteristics, either across time or space. This difference does not have to be independent of external variables such as climate. A visual crown rating that shows regional increases in defoliation during drought years is not defective. It is showing real climatic effects. As long as climatic information is available, the difference can be explained.

6.1.3.5 Index Period Stability

Each indicator must exhibit low measurement error and stability (low temporal variation) during an index period. The index period is the window in which samples will be collected. For example, if data are collected between June and August, then the indicator needs to be relatively stable during that time window. Diurnal and seasonal variability are both important considerations. Effects on the indicator measurements due to phenologic and climatic changes during the sampling period also affect index period stability.

High index-period variability adds noise to the indicator, thus making it more difficult to accurately assess current status or to detect trends over time. In addition, high index-period variability, like measurement error, causes biases in the tails of the CDFs to be used in assessments.

Individual measurements need not be stable over the same period. For example, a measurement of PAR that does not exhibit diurnal or seasonal effects would rate more highly on this criterion than a PAR measurement that is very sensitive to sun angle. Available data from studies or the literature can be used in documenting an indicator's index period stability.

6.1.3.6 Low Environmental Impact

Documentation for each indicator should address the environmental impact of all data collection and sampling procedures. All potential impacts on the site and other indicators, even trampling of the understory, should be considered. The goal is for measurement of indicators to cause the least amount of environmental damage possible.

6.1.4 Evaluation Procedure

In December 1991, indicator leads submitted evaluations of their indicators using existing or manufactured data and relevant literature to demonstrate how their indicator met the above criteria. An indicator selection panel reviewed and rated each candidate indicator using the criteria described above. The process was intended to be tractable and provide an objective process for selecting or rejecting indicators for field use and re-evaluating indicator performance following demonstration studies.

6.1.5 Conceptual Strategy

The FHM program has implemented an indicator selection and development strategy proposed by Knapp et al. (1991), "... conceptual models are an important tool for formalizing possible relations among indicators, assessment endpoints, and stressors, and for identifying data or knowledge gaps that could be filled through the selection and development of additional indicators."

A primary goal is to develop a theoretical framework for indicator selection, integration, and interpretation and to quantitatively link each field measurement to a public value. The conceptual model should identify components of the forest ecosystem with interdependencies, duplication, etc. One strategy is to include all energy pathways so that critical energy flows and implications of interruptions due to environmental pollution and disturbances can be identified. Any number of above- or below-ground factors affect energy flow, including nutrient deficit or surplus and drought. Using this strategy, indicators suitable for monitoring the condition of critical energy flows would be the most useful for monitoring.

6.1.6 Towards a Draft Tree-Level Conceptual Model

Trees are the most conspicuous aspect of a forest ecosystem. While trees are necessary, they are insufficient for defining the ecosystem. A "stand" is an arbitrary delineation often imposed for operational harvesting, but usually represents a contiguous group of trees with some homogeneous characteristics. The use of stands and their dynamics is appropriate

for monitoring and assessing impacts on trees for the following reasons (as given by Kiester 1988):

1. The stand is an important integrator of most biological effects of pollutants on forests (see Assmann [1970] for a comprehensive discussion)
2. The stand may be the only level of organization at which an effect can be detected in the field. Regardless, the interaction between stand processes and pollutant effects must be disentangled before any claim of effect can be made (Hyink and Zedaker 1987).
3. The stand is an important economic unit. One can predict the volume a stand can produce, but one cannot predict it (with any certainty) from trees considered as noninteracting entities. Most of the theory of forest economics deals with stands because of the first reason.
4. The stand is customarily the unit used in assessing the effects of other deleterious environmental processes such as the action of disease and pests. Meineke (1917 and 1928) was an early proponent of stand-level analyses in forestry pathology research. A tree and stand of trees can be divided into the components of canopy, bole and roots. The associated functions and processes of each can be detailed as shown in Figure 6.1-1.

The production of biomass in forests depends on the interception of light by leaves and on the conversion of intercepted light energy into carbohydrates. The efficiency of this conversion depends on the availability of water since leaves under drought stress intercept light, but fail to produce carbohydrates. The productivities of forests

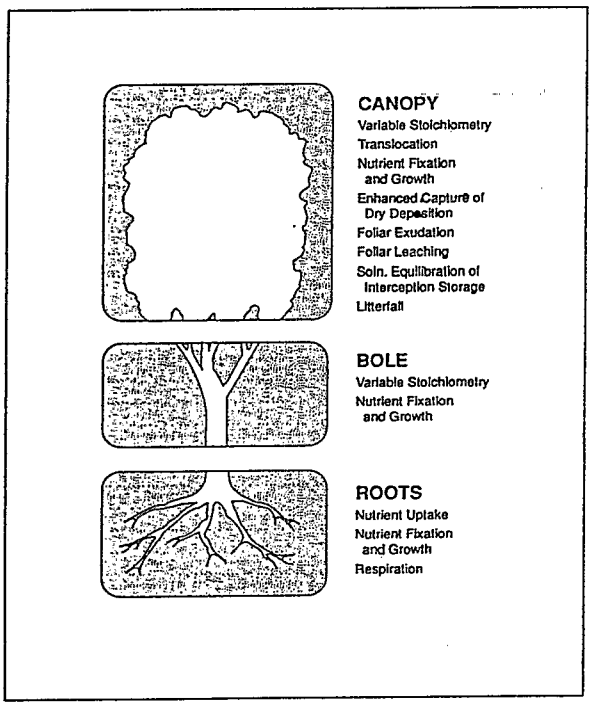

Figure 6.1-1. Tree components and processes associated with those components (see Gherini et al. in Kiester et al. 1990).

differ because of differences in stand leaf area and resultant light interception and in the efficiency of producing carbohydrates from intercepted light. These differences depend on climate, soils, species composition, and history of such factors as disturbance. (Binkley et al. in press).

6.1.7 Current Indicators and the Draft Conceptual Model

Using Figure 6.1-1 as a guide, current indicators cover aspects of the forest canopy, bole, and roots. The visual condition rating, photosynthetically active radiation, and foliar chemistry indicators describe physical, spectral, and chemical aspects of the canopy. The DBH increment and wood chemistry indicators measure physical and chemical features of the bole. The root disease and soil indicators measure structural, biological, and chemical aspects of the rooting environment.

The vegetation diversity indicator describes the vertical and horizontal distribution of floral and faunal habitat. The vegetation diversity indicator is not comprehensive in its attempt to define potential habitat for all species.

6.2 Site Classification, Growth, and Regeneration Indicator

6.2.1 Introduction

Site classification, growth, and regeneration includes 113 measurements and other data to describe plots and plot vegetation as part of the Detection Monitoring phase of the FHM program.

6.2.2 Indicator Evaluation

The site classification, growth, and regeneration measurements were chosen for initial use based on research results, the Forest Service Forest Inventory procedures, and the consensus of experienced foresters. The measurements are being evaluated using the indicator evaluation process described in Section 6.1 and a more detailed presentation of how these indicator measurements meet the selection criteria will be included in the next revision of this document.

6.2.3 Field Measurements

The following tables provide a complete listing of all variables currently measured in Detection Monitoring. The tables show the different variables collected for plot identification (Table 6.2-1), condition classification (Table 6.2-2), point description (Table 6.2-3), boundary information (Table 6.2-4) microplot understory vegetation (Table 6.2-5), microplot seedlings (Table 6.2-6), microplot saplings (Table 6.2-7), subplot trees (Table 6.2-8), and sequoia/redwoods (in California) (Table 6.2-9).

TABLE 6.2-1. PLOT IDENTIFICATION

Measurement Variable
State
County
Plot Number
Measurement Type
Old Plot Status
Current Plot Status
Photo Year (West)
Month
Day
Year
Elevation
Terrain Position

TABLE 6.2-2. CONDITION CLASSIFICATION

Measurement Variable
Condition Class
Land Use Class
Forest Type
Stand Origin
Stand Size
Past Disturbance 1
Disturbance Year 1
Past Disturbance 2
Disturbance Year 2
Past Disturbance 3
Disturbance Year 3
Site-Tree Species (WEST, SE)
Site-Tree Height (WEST, SE)
Site-Tree Age (WEST, SE)
Stand Age (WEST, SE)

TABLE 6.2-3. POINT DESCRIPTION

Measurement Variable
Slope Correction
Percent Slope
Aspect
Microrelief
Subplot Condition List
Subplot Center Condition
Microplot Center Condition
Subplot Offset
Microplot Offset

TABLE 6.2-4. BOUNDARY INFORMATION

Measurement Variable
Plot Type
Offset Point
Contrasting Condition
Left Azimuth
Left Distance
Corner Azimuth
Corner Distance
Right Azimuth
Right Distance

TABLE 6.2-5. MICROPLOT UNDERSTORY VEGETATION

Measurement Variable
Percent Moss
Percent Lichens (West)
Percent Ferns
Percent Herbs
Percent Shrubs
Percent Seedlings

TABLE 6.2-6. MICROPLOT SEEDLINGS

Measurement Variable
Species
Condition Class
Crown Class
Seedling Count

TABLE 6.2-7. MICROPLOT SAPLINGS

Measurement Variable
Tree Number
Offset Point
Old Tree History
Current Tree History
Species
Old Diameter at Breast Height (DBH)*
Diameter at Breast Height
Diameter at Breast Height Check
Old Stem Count
Stem Count
Old Diameter at Root Collar(W)
Diameter at Root Collar(W)
Old Diameter Largest Stem(W)
Diameter Largest Stem(W)
Horizontal Distance
Azimuth
Mortality Year
Condition Class
Crown Class
Tree Height (CA)

* DBH is the diameter measured at a height of 1.37 m.

TABLE 6.2-8. SUBPLOT TREES

Measurement Variable
Tree Number
Offset Point
Old Tree History
Current Tree History
Species
Old Diameter at Breast Height
Diameter at Breast Height
Old Stem Count
Stem Count
Diameter at Breast Height Check
Old Diameter at Root Collar(W)
Diameter at Root Collar(W)
Old Diameter Largest Stem(W)
Diameter Largest Stem(W)
Horizontal Distance
Azimuth
Mortality Year
Ground Year
Condition Class
Crown Class
Tree Height (CA)

TABLE 6.2-9. SEQUOIA/REDWOOD TREES (CALIFORNIA)

Measurement Variable
Tree Number
Offset Point
Old Tree History
Current Tree History
Species
Old Diameter at Breast Height
Diameter at Breast Height
Diameter at Breast Height Check
Old Diameter at Root Collar
Diameter at Root Collar
Horizontal Distance
Azimuth
Mortality Year
Ground Year
Condition Class
Crown Class
Tree Height

The FHM program is working toward remeasurement of all variables on plots on at least a 4-year cycle. This is consistent with the EMAP interpenetrating design (see Chapter 7). Full remeasurement includes reconciling all land use changes, remeasuring diameters for growth, and remeasuring the plots for ingrowth, cutting, and mortality. In areas where annual measurements are made, as part of detection monitoring (eastern United States), the crown ratings are the focus. Complete remeasurement will be done only every 4 years.

6.2.4 Data Analysis

Data are verified, validated, and made available to analysts on both regional and national scales. The data are used in regional reporting activities and appear in the annual FHM national Statistical Summary. Information about stand characteristics appears in these reports. The plot identification data are archived for use at the next remeasurement visit. Data from previous years are also used as part of the quality assurance and quality control procedures by means of the portable data recorders (hand-held computers) that are used for recording data. The portable data recorders can also store and display a limited amount of data from previous years.

6.2.5 1992 Activities

Site classification, growth, and regeneration data will be collected on the new Detection Monitoring plots which will be established in California and Colorado. Selected crown and damage measurements will be taken on established plots in the 12 participating states in the eastern United States (Alabama, Connecticut, Delaware, Georgia,

Maine, Maryland, Massachusetts, New Hampshire, New Jersey, Rhode Island, Vermont, and Virginia) (see Chapter 2 for more details). These measurements will also be collected as part of the Southeast Demonstration project (participating states are Virginia, North Carolina, South Carolina, and Georgia) and the SAMAB Demonstration project (participating states are Virginia, North Carolina, Tennessee, South Carolina, and Georgia).

6.3 Crown Classification

R. Anderson and W. Burkman

6.3.1 Introduction

The crown classification indicator consists of several measurements which are combined when evaluating the status of seedling, sapling, and tree crowns. The measurements may be evaluated individually or combined using a visual crown rating model (Anderson et al. 1992). The five crown variables can be aggregated into the visual crown rating. This is accomplished by defining good, average and poor classes for each variable, aggregating the variables, and subsequently defining good, average, poor and very poor ratings for each tree. Tree level data are then averaged to give a plot-level score. Each of the individual measurements are discussed separately in the following sections.

6.3.2 Indicator Evaluation

This section discusses the indicator selection criteria described in Section 6.1 as they apply to the measurements for the crown classification indicator.

6.3.2.1 Crown Ratio

Crown ratio is the percent of total tree height that supports live green foliage that contributes effectively to tree growth. The crown ratio is determined by the ratio of crown length to total height of the tree. Crown length is determined from the top of the crown with the last live branch to the base of the obvious live crown. When live branches occur below the obvious live crown, these branches are included only if their diameter at the base is larger than 1 inch and they are located within 5 feet of the obvious base of the crown or the previous branch above used for this determination. The point on the main bole is perpendicular to the foliage on the last branch included in the crown estimate. The base of the crown is determined by the foliage and not the point of branch intersection with the main bole. Dead branches in the top of the crown are not included in the ratio estimate.

Crown ratio is recorded in 5-percent classes from 0 to 100. The ratio is estimated by two field crew members to the nearest 5-percent class. The highest class, 100 percent is recorded as 99-percent class. A tree with no obvious crown is recorded as a 0.

All the crown raters must participate in annual crown-rating training and must provide quantitative evaluation of their ability (such as a test) that they can perform at an acceptable level. Visual standards and written definitions are provided to reduce annual drift in rating values. Two persons are required to rate a tree from opposite sides; the two estimates are averaged and recorded in the 5-percent class.

Interpretability --

Recorded measurements must be within 2 percentage classes ($\pm$10 percent) when remeasured. Greater differences are considered errors; however, a third measurement is required to determine which measurement is in error. The error frequency must be 10 percent or less for the data to be acceptable unless confirmation is made that the original measurements were correct (i.e., the remeasurement was in error).

Measurement errors may occur from several sources. The top of the tree may not be clearly visible, or when rounded, clearly identifiable. The branch structure of some trees is such that a clear "obvious' base of the crown is difficult to establish. One should also be aware that a small tree, with a 5-inch diameter at breast height (DBH) tree, such as hemlock after a clear-cut, might have a high crown ratio, while a large oak in a dense stand may have a small crown ratio.

Live crown ratio can be directly related to tree vigor and DBH growth. For example, the larger the ratio is, the greater the diameter growth of the crown. What effect it has on total volume growth of trees is not certain. The

reduction of growth due to declining crown ratio may be the result of increased distance between the bottom of the live crown and the DBH area where growth is measured. It is known that diameter growth declines as the distance increases.

Quantification --

This measurement can be collected for all trees on a plot in one day. The measurements are an estimation to the nearest 5 percent of the total tree height that is in live crown. Clinometers are used to measure test trees for training purposes. The instruments are accurate to the nearest foot, but it is often hard to see the top of the tree. Data from training in 1991 show the crew measurements were within ±10 percent of the instrument measured value 94 percent of the time and they were never more than 20 percent off in the remaining 6 percent. The estimate is easy to make and takes 2 to 3 minutes per tree.

Signal-to-Noise Ratio --

The signal-to-noise ratio is very high for this indicator. Estimates of crown ratio are relatively easy to make and determination of live crown gives a definite indicator (signal) of the vigor of the tree crown.

Regional Responsiveness --

This indicator is very responsive at the local, state, and regional level. An example is that crown ratio typically changes with stand density. At the state or regional level, it would be possible to identify species and areas that had different average crown ratios. There are considerable data which show that the growth rate and vigor of a tree are related to its crown ratio.

Index Period Stability --

The estimates are very stable for the same person evaluating the same tree and for different people rating the same tree. Unless the tree is damaged by storms, for example, the variable is very stable. This measurement has almost no change from June to August and little change from year to year. The live crown ratio is a clear, specific measure that is not confused by other factors.

This measure is very stable during the day and over the sampling season. Crown ratio, however, may decline for many reasons. The base of the crown may move upward or the top be lost, thus decreasing the crown length. Common causes for this are:

1. Self-pruning with increasing age, characteristic of a particular species,
2. Shading from neighboring trees as a result of increasing crown closure,
3. Mechanical damage from adjoining tree branches,
4. Defoliation caused by loss of lower branches, and
5. Loss of tree top from breakage or mortality.

Crown ratio normally changes slowly and the usual trend is to decline, unless some mechanical pruning or damage occurred. Changes may go in either direction. Increasing stand density is likely to reduce crown ratio, while opening of a stand, coupled with vigorous growth, could increase the ratio.

Environmental Impact --

This measurement only has minor impact and is of short duration. Minor damage to the understory may result from two people, approximately one tree-length away from the tree, making their estimate.

6.3.2.2 Crown Diameter

Crown diameter is measured on the perimeter of the crown, or the dripline. Two measurements to the nearest 1 ft (± 3 ft) are taken, one at the widest point and another on a line perpendicular to the widest point line. The two measurements are averaged for the crown diameter.

The expected use is to classify trees into three to four groups, such as large, average, moderate, and poor crown diameter. Crown

diameter is measured vertically down from the branches spaced furthest apart in the crown. The second measurement is taken at a perpendicular angle, again at points vertical to the out-most branch tips. The two measurements are recorded and then the average crown width calculated on the computer by finding the average of the two instruments.

All crew members who rate crowns must participate in annual crown-rating training and must provide quantitative evaluation of their ability (such as a test) that they can perform at an acceptable level. Visual standards and written definitions are provided to reduce annual drift in measurements. A second person standing back to confirm vertical lines down from branches or the use of a device to measure a vertical line from the ground to crown edge is recommended.

Interpretability --

Measurement errors may originate from several sources. The side branches may be intermingled with the neighboring trees or shielded by lower canopy, making it difficult to determine the end of the branch. The vertical line may not be correct, giving an incorrect distance between branch tips.

Crown diameters are associated with vigor and DBH growth of loblolly and shortleaf pine. Simply stated, the larger the crown is, the more growth expected. This assumption may not be valid for mature and over-mature trees that have slowed growth, but may be developing wider, short crowns. Data are needed to compare young and old trees of various species.

Crown diameter measurements are sometimes related to crown density measurements. When two trees are close together, one side also tends to have a reduced or even non-existent crown. As a result, one crown measurement may be one-half of normal. A similar reduction is recorded in crown density for the missing one-half of the crown. Indirectly, crown diameters are related to crown position because of the effect of stand density on crown diameter growth.

Quantification --

This measurement can be collected in one day. A tape, accurate to the nearest inch, is used to measure the distances. For training, a clinometer is used to determine the point on the ground to measure the crown width. It is accurate to the nearest degree. Data from training studies show that the crew measurements were within ± 3 feet of the tree crown diameter for 95 percent of the time. The remaining time their measurements were within ± 5 feet. The measure is easy to make and takes about 3 minutes per tree.

Signal-to-Noise Ratio --

The signal-to-noise ratio is very high for this indicator. Crown diameter can be directly related to the growth of tree species (Frances 1986; Sprinz and Burkhart 1987). In an analysis of 14,296 trees, crown diameter was always highly correlated ($r > 0.60$) with bole diameter at breast height measurments for most tree species (Stolte et al. 1992).

Regional Responsiveness --

This indicator is very responsive at the local, state, and regional level. An example is that crown diameter normally changes with stand density. At the state or regional level, it would be possible to identify species and areas that had different average crown diameters. Data from our loblolly pine studies show that there is a correlation between crown diameters and tree vigor, expressed in growth at DBH.

Index Period Stability --

The estimates are very stable for the same person making remeasurements on the same tree and for different people rating the same tree. Unless the tree is damaged by storms, for example, the measures are very stable. It has almost no change from June to August and change slowly from year to year.

This measure is very stable during the day and over the sampling season. Crown diameters are likely to increase as a tree assumes higher canopy position and with

decreasing stand density where space is available for lateral branch growth. Crown diameters decline with increased competition with neighboring trees. Mortality of lower branches from competition, snow and ice damage, or insect or disease damage reduces crown diameter. Shock response after logging and similar disturbances may result in loss of large branches. Crown diameters are not likely to change from one year to the next unless some injury has occurred. Measurements every 5 to 10 years may be needed to detect significant changes.

Environmental Impact --

This measurement only has a minor impact and is of short duration. Minor damage is caused to the understory when two people hold a tape under the tree to determine the crown diameter.

6.3.2.3 Crown Density

Crown density estimates the condition of the tree crown in relation to a normal, healthy forest-grown tree and also is an indicator of expected growth in the near future. Crown density represents the amount of branches, foliage, and reproductive structures that block light visibility through the crown. This measurement was devleoped on loblolly and shortleaf pines where growth correlations were observed.

Crown density is recorded in 21 5-percent classes. The recorded value is the average of two estimates made by observers from opposite sides of the tree, upgraded to the next full 5-percent class. The lowest class, 0 percent, is recorded when the tree does not have a defined crown (live branches larger than 1 inch at the base). The highest class, 100 percent, is recorded as the 99-percent class.

Interpretability --

Recorded measurements must be within 2 percentage classes (±10 percent) when remeasured. Greater differences are considered errors; however, a third measurement is required to determine which measurement is in error. The error frequency must be 10 percent or less for the data to be acceptable unless confirmation is made that the original measurements were correct (i.e., the remeasurement was in error).

Measurement errors may occur from several sources. The major cause of variation is the assumed normal symmetrical crown of the tree and then the estimated branch area missing, particularly for a tree closely adjoining another tree. The top of the tree or sides may not be clearly visible at the same time and errors may occur from "piecing the crown together" from various viewing points. The branch structure of some trees is such that a clear "obvious" base of the crown is difficult to establish.

Crown density relates to vigor and DBH growth on loblolly and shortleaf pine. Although not confirmed, one suspects that crown density has similar relationships with growth for all trees. Although the measurements are recorded in 5-percent classes, the most likely use of the data is broader groupings which indicate good, average, and poor crown.

Crown density includes several other crown characteristics measured separately:

1. Branch transparency as influenced by changes in foliage abundance; however, the woody parts, branches and twigs remain to reduce light penetration,

2. Dieback as reflected by complete absence of foliage, and

3. Crown diameter as influenced by changed crown shape from neighboring trees.

Quantification --

This measurement can be collected for trees on a plot in one day. The measurements are an estimation to the nearest 5 percent of the density of foliage, branches, and reproductive structures in the crown. A density card is used to make the estimates.

Photographs of examples are also provided to the crews. Data from the 1991 training shows the crews were within ±10 percent of the predetermined estimate 90 percent of the time and they were never more than 20 percent off crown density in the remaining 10 percent of the time. The estimate is easy to make and takes 2 to 3 minutes per tree.

Signal-to-Noise Ratio --

The signal-to-noise ratio for this indicator is relatively good, but not as good as for crown ratio and diameter. Low crown density can indicate low numbers of branches with full foliage or high numbers of branches with thin foliage. The latter would probably affect tree growth to a greater rate.

Regional Responsiveness --

This indicator is very responsive at the local, state, and regional levels. An example is that the crown density typically changes with site quality. At the state or regional levels, it would be possible to identify species and areas that had different average crown densities. Data from our loblolly and shortleaf pine studies show a relationship between crown density and tree growth at DBH (r^2 of 0.37 to 0.61 depending on stand age and species).

Index Period Stability --

The estimates are very stable for the same person evaluating the same tree and for different people rating the same tree. Unless the tree is damaged by storms or defoliated, the variable is very stable. It has very little natural change from June to August and changes slowly from year to year. For conifers, the measures change little from summer to winter. This measure is specific to the crown of the tree. Overlapping branches can cause some measurement errors.

Normally, crown density is expected to decline over time as a result of competition in the stands and aging of the tree. Occasionally, however, crown density may improve (increase) when disturbances in the stand occur such as:

1. Increased growing space as a result of death or removal of neighboring trees,
2. Rebuilding crown structure after loss of major branches,
3. Increased foliage after a poor foliage year, and
4. Loss of branches causing redefinition of crown perimeter, such as dead branches in the top of the tree, or death of widely separated branches in the lower crown.

Various damages, changes in stand density, and reduced growth associated with aging may cause a decline in crown density:

1. Loss of branches from mortality or breakage, creating gaps in the crown,
2. Increased transparency from poor foliage production or from defoliation,
3. Shading of branches by neighboring trees when stand density increases,
4. Foliage stunting that accompanies injury or follows refoliation,
5. Crown form changes as a result of increased stand density, and
6. Gaps increase with age of trees.

Crown density usually changes slowly as the stand density changes. Defoliation may change crown density within a growing season, but repeated defoliation followed by branch dieback is needed for permanent change in crown density. Branch mortality, such as wind and ice damage, creates rapid change in crown density.

Environmental Impact --

This measure has only a minor impact and it is of short duration. The minor damage is caused to the understory as two people distance themselves approximately one tree-length away from the tree to make their estimates.

6.3.2.4 Crown Dieback

Crown dieback is defined as branch mortality that begins at the terminal portion of the branch and proceeds toward the trunk. When whole branches are dead in the upper crown, without obvious signs of damage such as animal damage or breakage, the branch is assumed to have died from the terminal down. Dead branches in the center and lower portion of the crown or below the live crown are assumed to have died from competition or shading and are not considered crown dieback.

Crown dieback estimates reflect the severity of recent stresses on the tree. A tree with increasing crown dieback is likely to have reduced growth. However, a tree may be recovering from past stresses as growing conditions improve. Therefore, the measurement serves as an early indicator of tree response to environmental stresses or damage. The probable use of the measurements is aggregation into several crown dieback severity classes.

Interpretability --

Crown dieback is recorded in 21 5-percent classes in multiples of 5, with the code being the upper range of the class. The zero-class was created to indicate total absence of crown dieback. One dead twig seen in the crown is recorded in the 5-percent class. When all the branches are dead, but the tree is still alive, class-99 is recorded. The percentages are based on the estimated size of the affected area in relation to the total crown. Estimates are made by two crown raters on the opposite sides of the tree. Then the percentages are averaged and recorded in the 5-percent classes.

Measurement errors may occur from several sources. The top of the tree may not be clearly visible, or when rounded, clearly identifiable. The branch structure of some trees is such that a clear "obvious" base of the crown is difficult to establish. Heavy defoliation (foliage transparency greater than 50 percent), makes it difficult to separate dead twigs and living branches that have been defoliated.

Recorded measurements must be within 2 classes when remeasured. Greater differences are considered errors; a third measurement is required to determine which measurement is in error. The error frequency must be 10 percent or less for the data to be acceptable, unless confirmation is made that the original measurements were correct.

None of the other crown attributes are included in the crown dieback measurements. Crown dieback is included in the crown density measurement. Extent of crown dieback may affect crown ratio, because of loss to the top of the crown.

Increase in crown dieback is a disease symptom in response to severe stresses. It may be initiated from damage to the roots, damage on the trunk that interferes with water and nutrient transport to the crown, and direct injury in the crown. Complete defoliation of conifer twigs is likely to cause immediate crown dieback. Likewise, some hardwoods respond to severe defoliation with crown dieback, but the time of the growing season when it occurs seems to be important. Excessive seed production on some species causes crown dieback of small twigs. Frequently, hardwoods released from competition, such as after logging, have crown dieback. A few hardwoods left after a commercial clearcut may have a period of severe crown dieback.

Quantification --

This measurement can be collected in one day. Advanced or specialized education is not required for this measurement, although training is required. In fact, high school students have successfully collected this data for the North American Sugar Maple Decline Project.

All the crown raters must participate in crown rating training and must provide quantitative evaluation of their ability (such as a test) that they can perform at acceptable levels. Training is required annually. Visual standards and written definitions are provided to reduce annual drift in rating values. Two persons are required to rate a tree from

opposite sides; the two estimates are averaged and recorded in the 5-percent classes.

Remeasurement data from 1990 in New England, show that 92 percent of the remeasurements were within the measurement quality limits (Burkman and Alerich in press). Data from the North American Sugar Maple Decline Project show a 97 percent agreement (Burkman 1990) for 1989 results.

Signal-to-Noise Ratio --

Crown dieback directly indicates an external stressor to the tree originating in the soil, air, or from pathogens. It is a direct estimation of loss of the upper portions of a tree crown that does not occur on trees under optimal conditions.

Regional Responsiveness --

This indicator is very responsive at the local, state, and regional level. In 1990 FHM results, this measurement related to the presence of the beech-bark disease complex on American Beech (Fagus grandifolia Ehrh.) in New England (Brooks et al. 1991).

Index Period Stability --

This measure is very stable during the field season except during situations of high wind or excessive, heavy rainfall. Small dead twigs do not persist very long and may drop annually. Larger dead branches persist longer. Therefore, annual fluctuations of crown dieback are expected, unless severe stresses cause large amounts of branch mortality that require many years of recovery. Crown dieback can decrease through the loss of the dead twigs and branches. Trees frequently rebuild their crowns after dieback unless continuation or additional new stresses impact the trees.

Environmental Impact --

This measurement only has a minor impact on site conditions. The impact on the site is related to the traffic on the site to make the measurement and will only affect the microplot measurements. This effect can be reduced by collecting this measurement after the collection of the microplot information.

6.3.2.5 Foliage Transparency

Foliage transparency is defined as the amount of skylight visible through the foliated portion of the crown or branch. On closed crown trees, foliage transparency is estimated for the whole crown, excluding large openings where foliage can not be present because of the absence of branches. On open crown trees, foliage transparency is measured on the foliated portions of the branches. The primary purpose of the measurement is to standardize measurements of foliage loss from disease or insect defoliation. Tree species and age seem to affect foliage transparency because of characteristic branch overlap and foliage placement on the branches. Poorly growing trees also have sparse branches and foliage.

Foliage transparency is used as a measurement of defoliation. Usually, serious adverse effects on the tree are not expected until more than one-half of the foliage is lost. Thus, broad classes are used to describe stresses from defoliation.

Interpretability --

Foliage transparency is recorded in 21 5-percent classes in multiples of 5, with the code being the upper range of the class. Foliage transparency is estimated from several sections of the crown and averaged. Estimates are made by two crown raters on the opposite sides of the tree, then percentages are averaged and recorded in the 5-percent classes. Complete defoliation is recorded in the 99-class.

Measurement errors may occur from several sources. Portions of the crown may not be clearly visible. As defoliation increases, branches and seeds may interfere with foliage estimates. Some variation occurs from judgement when to include or exclude holes, areas without branches, in the overall estimate.

Recorded measurements must be within 2 classes when remeasured. Greater differences

are considered errors; a third measurement is required to determine which measurement is in error. The error frequency must be 10 percent or less for the data to be acceptable, unless confirmation is made that the original measurements were correct.

Foliage transparency does not include any other crown measurement. However, it is included in the crown density estimate. Since foliage blocks transmission of light through the crown, the attribute measured in crown density, it contributes heavily to the measurement.

Quantification --

This measurement can be collected in one day. Advanced or specialized education is not required for this measurement, although training is required. In fact, high school students have successfully collected this data for the North American Sugar Maple Decline Project.

All the crown raters must participate in crown rating training and must provide quantitative evaluation of their ability (such as a test) that they can perform at acceptable levels. Training is required annually. Visual standards and written definitions are provided to reduce annual drift in rating values. Two persons are required to rate a tree from opposite sides; the two estimates are averaged and recorded in the 5-percent classes.

Remeasurement data from 1990 in New England, show that 87 percent of the remeasurements were within the measurement quality limits (Burkman and Alerich in press). Data from the North American Sugar Maple Decline Project show a 92 percent agreement (Burkman 1990) for 1989 results.

Signal-to-Noise Ratio

Crown transparency is a direct estimation of defoliation of the tree crown. Therefore, the signal-to-noise ratio for this indicator is high. Reductions in crown transparency indicate loss of foliage.

Regional Responsiveness --

This indicator is very responsive at the local, state, and regional level. In the North American Sugar Maple Decline Project, this measurement was highly associated with areas of drought during the summer of 1988 in Wisconsin, Michigan, and Ontario (Allen and Barnett unpublished data).

Index Period Stability --

Foliage transparency is potentially one of the most rapidly changing variables measured in the crown of the tree. Wind, frost, and hail can change foliage transparency within hours. Insect defoliation changes may be measurable days apart. Diseases may contribute to steady decline of foliage during a growing season. Defoliation of evergreens may contribute to foliage transparency change for more than a year. Foliage transparency may be associated with poor sites and persist for the life of the tree.

Most frequent changes occur from direct damage and removal of foliage. Foliage transparency increases, that is, foliage is reduced from:

1. Insect defoliation,
2. Diseases,
3. Previous stresses may reduce foliage production in the following year,
4. Declining tree vigor reduces foliage abundance (logging, drought, etc.),
5. Decreased needle retention of conifers,
6. Decreased size of leaves or needles from previous stresses, and
7. Loss of branches decreases foliage overlap.

Foliage transparency may decrease with reduction of stand density and followed by addition of new branches to create branch overlap. Of course, foliage transparency will increase following previous defoliation if the tree does not die.

Environmental Impact --

This measurement only has a minor impact on site conditions. The impact on the site is related to the traffic on the site to make the measurement and will only affect the microplot measurements. This effect can be reduced by collecting this measurement after the collection of the microplot information.

6.3.3 1992 Activities

Crown classification measurements will be made as part of Detection Monitoring activities in the 12 eastern states, as part of the Southeastern and SAMAB Demonstration projects, and as part of the Western Pilot project.

6.4 Damage and Mortality Assessment

W. Hoffard, V.J. LaBau, and M. Schomaker

6.4.1 Introduction

Damage caused by diseases, insects, air pollution, and natural and manmade activities can affect the growth and development of the forests. Any of these agents, either singly or in combination, can cause significant decline in forest tree health. Identification of such agents can provide valuable information concerning the status of forest condition and indicate possible causes of deviation from the expected norm. Signs and symptoms are recorded if, in the estimate of the observers, the damage could kill the tree, cause growth reduction in the tree, or provide entry points for other damaging agents.

Mortality caused by agents as discussed above can also affect the structure and development of forests. Identification of such agents is important in monitoring forest health. Combined with damage information, it will be possible to piece together the events that ultimately lead to the death of a tree.

6.4.2 Indicator Evaluation

This section discusses the indicator selection criteria described in Section 6.1 as they apply to damage and mortality assessment.

6.4.2.1 Interpretability

Damage assessment describes current stresses such as defoliation, broken limbs, and other damage. All these stressors can affect the growth and development of trees and forests. Alone or in combination, they can cause significant declines in forest tree health. Signs and symptoms are recorded if, in the opinion of the recorder, the causal agent could kill the tree, cause growth reduction, or provide entry points for other destructive agents such as fungi.

The tree is observed from all sides and any identifiable symptoms and signs of damage noted. The procedure allows for the coding of up to three different damages in any of nine all-inclusive locations. If the symptoms and signs are attributable to specific causal agents, they are recorded also.

All data collectors must participate in damage coding training consisting of both indoor (35-mm slide show) and field sessions. Trainees are tested, and error frequency must be ≤ 10 percent before trainees are certified as data collectors.

Measurement error may occur from several sources. Portions of the trees (especially tops) may not be clearly visible. Damage causal agents can sometimes be difficult to determine, even for professional pathologists and entomologists. Seasonality influences the frequency and abundance of several insects and diseases, especially defoliators. (This shortcoming is largely offset by spring plot visits which are designed to capture early spring data which may be difficult to discern later in the growing season.) Finally, "significant" is a highly relative term. Some data collectors may consider a causal agent significant, whereas others may consider it unworthy of mention.

6.4.2.2 Quantification

The measurements are collected in one day. Occasionally, binoculars are used to achieve a better view of the crowns and high limbs. The biggest challenge to crews is to decide whether or not to record the damage. Damage recording is a relatively simple process and requires no more than three minutes per tree. Data from the summer of 1991 shows crews were within the 90 percent accuracy requirement.

6.4.2.3 Signal-to-Noise Ratio

The estimates are very stable for the same person evaluating the same and different trees, but can vary between people. The damage classifications have a very high ability to detect trends over a given physical range of forests.

6.4.2.4 Regional Responsiveness

This indicator is very responsive at the local, state, and regional level. An example would be an outbreak of orange-striped oakworm such as recently occurred in northern Georgia. These epidemics often cover millions of acres and would evidence themselves in a number of Forest Health Monitoring (FHM) plots throughout the outbreak region.

6.4.2.5 Index Period Stability

Measurement stability varies from high to low, depending on the time frame in question. On a daily basis, it is high, but this consistency diminishes due to longer term phenological effects. For example, insect life cycles are typically linked with flowering or budbreak. Climatic effects such as storm damage can influence data or invalidate information collected earlier in the sampling season.

6.4.2.6 Environmental Impact

The measurement has minimal impact over a relatively short time frame. Most impact is confined to trampling of vegetation as crews maneuver for position and circle the tree for optimum views of the various tree structures.

6.4.3 Field Measurements

The following damages are recorded:

- Dead (describes part of a living tree).
- Closed wounds.
- Small holes or pinholes.
- Cracks and seams.
- Broken.
- Conks.
- Removed or missing (other than defoliation by insects).
- Defoliation (from insect feeding).
- Resinosus.
- Bleeding.
- Crook or sweep severe enough to impede growth or survival.
- Swelling (greater than ½ the diameter of the stem).
- Excessive branching (indicator of past injury such as top kill).
- Abundance of epicormic branching.
- Rotten branch stubs.
- Stunted or dwarfed.
- Deformed, twisted, curled.
- Embedded foreign objects.
- Leaning from partial windthrow.
- General discoloration.
- Pale green foliage.
- Yellow-green foliage.
- Spotted leaves.
- Damaged leaves.
- Distorted foliage.
- Stunted foliage.
- Dwarfed foliage.
- Other.

These damages are recorded and coded for the following locations: crown stem, upper bole, lower bole, roots, whole trunk, branches, buds and shoots, foliage, and whole crown.

The purpose of damage coding is to explain probable causes for mortality and growth impact. The mere presence of damage should not necessarily be recorded. Multiple damage coding should not occur frequently.

For mortality, the cause of death is recorded for all saplings 1.0-inch in diameter at breast height (DBH) and larger on the microplot and all trees with a 5.0-inch DBH and larger on the subplot that were recorded as live trees during the previous inventory.

In addition, in California a full-hectare cruise is used on all plots to tally mortality and "fader" trees 10 cm and larger. Mortality and "fader" trees, trees with green but fading needles or leaves resulting from such causes as insects, disease, and drought, less than 10 cm measured at DBH or root collar are recorded only on the four sub-plots.

6.4.4 1992 Activities

Damage and mortality assessments will be made as part of Detection Monitoring activities, for the Southeast and SAMAB Demonstration projects and as part of the Western Pilot project.

6.5 Branch Evaluation

K.W. Stolte

6.5.1 Introduction

The evaluation of the condition of tree crowns is performed in FHM by estimation of crown variables (ratio, density, transparency, dieback, diameter - see Section 6.3) made visually by ground observers. These remote estimations of crown condition are complemented by evaluation of tree branches obtained from the upper crowns of dominant or codominant trees in the same condition class as found in the subplots. The purpose is to obtain more specific tree vigor data and identify early crown symptoms caused by air pollutants, disease, or insects that require close-up examination of foliage. The method of evaluation described here is based on procedures developed and tested at The Pennsylvania State University for the Eastern Hardwood Research Cooperative (Nash et al. 1989), the Visual Damage Survey for the National Vegetation Survey (Alexander and Carlson 1989), and the Western Pine Plot Workshop (Stolte and Miller 1991).

On four randomly selected trees in the annular section of two subplots (see Section 7), two branches exposed to direct sunlight are extracted from the upper tree crowns by tree climbers or by severing with shotguns or pole pruners (forest with lower canopies). These branches are brought to the ground and are measured for growth parameters and examined for damage symptoms. This method of leaf collection provides excellent control for sample selection. Climbers can be directed to a particular branch. Leaves collected by this technique provide samples that are in excellent condition. Many insects can be recovered following falls from heights in excess of 25 m (Nash et al. 1989). This collection method provides branch material for examination. In addition, climbers are able to report or sample any unusual symptoms, insects, or diseases that are encountered during the climb. The major disadvantages to this system are that (1) some trees are not safe to climb, (2) the weight and bulk involved with the climbing gear, and (3) any tree injury caused by climbing and severing branches.

The variables measured or evaluated by a trained crew person are wood and foliage damage, number of leaves (representative shoot on deciduous species) or whorls of needles or foliated length of branch (conifers), needle and leaf length, and length of previous year's branch node. After visual evaluation of the branch, the branch is then labeled, bagged, and mailed to the preparation laboratory for foliar chemistry analysis (see Section 6.7).

Evaluation of branch growth addresses the societal value of forest productivity, and evaluation of branch damage addresses forest contamination and sustainability.

6.5.2 Indicator Evaluation

This selection discusses the indicator selection criteria described in Section 6.1 as they apply to branch evaluation.

6.5.2.1 Interpretability

Branch evaluations are highly interpretable because measurement of growth variables gives direct indication of foliage production and wood (branch) growth. Also, estimation of damage variables gives direct indication of the condition of the wood (branch) and foliage. Growth measurements (previous year's node length, number of leaves or whorls of needles, leaf length, previous year's modal needle length) give definitive information on how well the branches are growing and producing foliage. Damage estimates (branch and foliage) give definitive information on the condition of the branches and foliage including descriptions and severity of symptoms, and suspected causal agents.

Aggregation to the Plot Level --

The branch growth measurements can be aggregated into an index of growth by the following formulas, where the maximum score

possible for a branch is 100. The scores are based on scaling the measurement of each variable to the 90th percentile of the population value for each variable. The variables are weighted in each branch growth determination. Formulas vary for branches from deciduous trees, conifers with distinct whorls of needles, and conifers without distinct whorls of needles.

The general form of the growth index for each branch type is:

$$BG_{deciduous} = NL(45) + NLVS(45) + LL(10)$$

$$BG_{conifers\ w/whorls} = NL(40) + NW(25) + FL(25) + NDL(10)$$

$$BG_{conifers\ w/o\ whorls} = NL\ (40) + FL\ (50) + NDL\ (10)$$

where	BG	=	branch growth
	NL	=	node length
	NLVS	=	number of leaves
	LL	=	leaf length
	NW	=	number of needle whorls
	FL	=	foliated length of branch
	NDL	=	needle length
	( )	=	weighting for each variable

The damage estimates for the branch and foliage can be aggregated in some cases within forest types and species. This aggregation would depend on the symptoms observed and the tree species selected for evaluation.

Cumulative Distribution Functions and Nominal-Subnominal Boundaries --

Identifying nominal and subnominal proportions of the population will be possible for the growth index of this indicator. We will set concern thresholds at a plot-level index score of 50, which will proportion the population into the nominal (>50) and subnominal (<50) classes. We will divide the nominal class by setting an optimal threshold at an index score of 75, producing a nominal subclass ($50 < x < 75$) and an optimal subclass ($75 < x \leq 100$). Similarly, we will divide the subnominal class by setting a poor threshold at an index score of 25, producing a subnominal subclass ($50 > x > 25$) and a poor subclass ($25 > x \geq 0$).

A more narrow delineation of the population with respect to branch and foliage damage is possible since the damages are recorded in three classes (1 = highest injury; 2 = moderate; 3 = slight). The highest plot-level injury class will be considered poor, the second highest subnominal, and the lowest injury class will be considered nominal.

6.5.2.2 Quantification

The growth variables for this indicator are readily quantifiable with the use of a ruler to measure internode length, length of foliage on the branch, and needle or leaf length. Quantification of the number of whorls and number of needles is done through counting. These measurements are relatively simple and require very little time to make.

The damage estimations are also relatively easy to quantify. Foliar damage is more precise than branch damage, since it is based on the percentage of leaf area affected (in 3 broad classes based on Horsfall and Barratt [1945]. Damage on branches is more subjective, and involves an estimation as to whether the observed damage threatens the survival of the branch (damage1), injures the branch but is not likely to kill it (damage2), or is present on the branch but does not appear to be impeding any biological processes (damage3).

6.5.2.3 Signal-to-Noise Ratio

The signal (branch growth/damage)-to-noise (unrecognizable nodes, whorls, etc./unknown damages) ratio is relatively high for this indicator. The growth variables selected are generic for any species of tree and consequently can be measured readily, and the damage assessments on the branch and foliage are broad and include categories for unknown symptoms or causal agents. The scaling of the growth variables to the 90th percentile for the population enables a relative comparison of an individual of any tree species

with other individuals of the same species. The damage determinations are relatively direct; either damage is present on the branch or foliage or it is not. What is undetermined at this time is the representativeness of the signal from two branches on a tree compared to the signal from the whole tree.

6.5.2.4 Regional Responsiveness

This indicator is regionally responsive since branch growth and damage are two variables that respond to changes in environmental or biological conditions and can be monitored over large areas. Branch and foliage damage have been shown in a number of Forest Pest Management and air pollution studies (Stolte et al. 1992; Pronos et al. 1978) to be responsive over large areas. Although branch growth may not have been demonstrated previously for regional responsiveness, some of the components of branch growth (number of whorls retained, needle length) have been shown to respond to environmental influences over large areas (Duriscoe 1990; Pronos et al. 1978).

6.5.2.5 Index Period Stability

Growth measurements are relatively stable over the index period (May to September) when measurements are taken. We specifically selected growth measurements that would not change over the growing season, for example last year's internode length and needle length of previous year's whorl of needles. These variables are likely to be 'fixed' and change very little, if any, over the summer season. Other variables such as number of needle whorls and length of foliage on branch (conifers), and number of leaves (deciduous trees) may change slightly over the summer as new leaves are added or old conifer needles are abscised. In general, however, these variables are not likely to change greatly after the spring initiation of leaves and needles and prior to the fall abscission of leaves and needles. Most, if not all, of the field work is conducted between these phenological events.

Estimates of damage to foliage are likely to have lower index period stability than growth measurements. Insects, diseases, air pollution, and physical damage (e.g., wind) are likely to be either episodic or cumulative events that will affect damage estimates over the summer season. Estimates of damage to branches (wood) may be seasonally more stable than for foliage because of the more systemic nature of some branch stressors (e.g., fungus, mistletoe).

6.5.2.6 Environmental Impact

The environmental impacts from measuring this indicator are relatively minor, but some damage might occur to the tree due to branch extraction. Tree climbers may cause some damage, although all climbing is done without spikes. Branch extraction, by pole pruner or shotgun, will cause some minor damage to the tree, but since only two branches are taken, the overall effects on tree vigor are expected to be negligible. Some trampling of the understory vegetation will also occur as branches are collected, analyzed for growth and damage variables, and packaged for mailing for chemical analysis.

6.5.3 Field Measurements and Data Use

Branch growth measurements and damage estimations are intended to quantify the condition of the wood and foliage on the branch. Procedures rely on the in-hand evaluation of branch samples to conduct a detailed examination of wood and foliage condition. Branches of conifers obtained for visual symptom evaluation, whether extracted by tree climbers, firearms, or pole pruners, should contain a full complement of annual needle whorls; for deciduous trees, the branches should contain a full complement of leaves of all ages. In practice this means small terminal or side branches will suffice for an adequate sample. Branches should be kept in the shade until on-site visible symptom evaluation can be performed.

Growth of branches is measured by recording the number of annual needle whorls of conifers (>25 percent of fascicles retained equals a whorl present), the length of a branch

of conifers with foliage (to nearest centimeter), length of needles in previous year's whorl (to nearest centimeter), length (petiole axis) of deciduous leaf (to nearest centimeter), and the length of previous year's internode growth (to nearest 0.5 centimeter). These measurements are recorded separately and are aggregated into a plot-level value for branch growth for each species using the methods described above in Section 6.5.2.1.

Damage to branches is recorded separately for wood (branch and side shoots) and foliage (leaves or needles). The wood symptoms are recorded in order of severity, with "wood damage 1" indicating damage symptoms that are likely to cause death of the branch (e.g., canker), "wood damage 2" indicating symptoms that are impeding normal branch processes but are not likely to result in branch mortality (e.g., animal damage), and "wood damage 3" indicating symptoms that are present but not likely to cause branch mortality or impede normal process (e.g., healed wound). There are eight possible damage codes, including "none", and an additional ninth code for "other" that can be written in. Damage on foliage is recorded as a percentage of the total leaf surface area affected. The damage estimates are divided into three broad classes: 1-25 percent; 26-50 percent; and >50 percent. Twenty-two foliar damage codes, including "none", and a 23rd code for "other" can be described. In addition, there are seven foliar discoloration codes, including "none" and an eighth "other" code. There are seven probable causes possible for both branch and foliar symptoms, and an eighth "other" code. This information is analyzed as described above in Section 6.5.2.1.

In addition to the data collected on the branches and foliage, information is collected on the tree and its immediate environs. Species, crown position, crown and bole condition variables, and DBH information is collected similarly to the trees in the subplots detection monitoring (see Section 6.2). Data are also collected on the microrelief characteristics where the tree is growing (planar, convex, concave, complex), percent bare rock in a radius (20 times the DBH of the tree) around the tree, and associated vascular plant species. This information can be used to help to interpret conditions or trends observed in the branch samples. For example, poor needle retention may be due to the site having poor soil moisture, at the site. Soil moisture can be determined by looking at the percentage of bare rock surrounding the tree and by examining the composition of the vascular plant community in the immediate vicinity.

6.5.4 1992 Activities

The branch sample indicator will be part of the Southeast and SAMAB demonstration projects.

6.6 Soil Classification and Physiochemistry

R. D. Van Remortel

6.6.1 Overview

In its infancy, the soils indicator documentation consisted of general fact sheets that provided a rationale for monitoring "soil nutrients" and "soil toxins" (Hunsaker and Carpenter 1990). These "exposure-category indicators" were intended for use in documenting the status and trends of regional forest soil condition and in identifying associations with other types of indicators. Since that time, the scope has broadened to facilitate the integration of all essential soil-related parameters influencing forest condition or health. This concept of "soil productivity" is an appropriate and useful strategy for addressing the Forest Health Monitoring (FHM) program objectives.

The primary focus has been on those parameters which have been determined by consensus to be important for assessing soil productivity with respect to forest health, and which are also economically and logistically feasible at this initial stage of implementation. Although limited research has been devoted to identifying the effect of these individual soil-related components on forest ecosystems, considerable advances have been made on identifying the soil processes that are important in vegetative response (Bouma 1989). The necessary components, however, have not yet been brought together into an index or model that is suitable for regional or national monitoring. This lack of a suitable model is primarily because of the limited number of forest soil data bases that contain detailed exposure and response data upon which to build. Ultimately, the interpretive goals for regional evaluation of status, trends, and associations are the driving factors in the continuing development of appropriate assessment tools.

There are many reasons to monitor soils as part of forest health assessment. For example, assessment scenarios of possible relevance for soil monitoring in the diverse forested regions of the U.S. demonstrate interest in soils as:

1. The essential mechanism for ensuring sustainable nutrient cycling, forest sustenance, and soil productivity into the future; linkages with other nutrient cycling indicators; for habitat/response assessments,
2. A key linkage, e.g., with respect to buffering effects, for monitoring acidic deposition, cation leaching, other water quality concerns; for exposure/response assessments,
3. A comprehensive predictor of risk or susceptibility, and a means for assessing regional abatement strategies; for stressor/exposure/habitat/response assessments,
4. A sink for airborne metal contaminants or deleterious organic compounds; for exposure/response assessments, and
5. A primary classification medium for EMAP tiers 1 and 2 landscape characterization and geographic information system (GIS) layering; for exposure/habitat assessments.

A combined examination of these scenarios is important to establish a solid baseline characterization of soils for assessing forest health.

As implied in the scenarios described above, some of the necessary soil measurements are intended primarily for ancillary Environmental Monitoring and Assessment Program (EMAP) classification needs, while others are intended for long-term evaluation and interpretation of status and trends in forest health. Hence, the soil productivity indicator has been subdivided into two main categories to address the different EMAP categories of indicators (Hunsaker and Carpenter 1990) where appropriate. The two categories are: "Soil Classification for Habitat/Exposure" and "Soil Physiochemistry for Exposure/Response," as described below in

subsections 6.6.2 and 6.6.3, respectively. In these subsections the rationale for measuring these indicator categories is specified according to the six indicator selection criteria described in Section 6.1.

6.6.2 Indicator Evaluation--Soil Classification for Habitat/Exposure Assessments

This category encompasses a widely accepted baseline field characterization and sampling procedure that is deeply rooted in the soils literature. Included in soil classification are methods regarding plot and hole location, soil excavation, profile description, sample collection, and plot restoration (Van Remortel 1992). As many as 25 measurements of field site, pedon, and horizon characteristics are made, when appropriate, on each plot (see Table 6.6-1). This soil classification category also includes soil sample preparation steps and certain soil physical analyses. The measurements are intended to define specific physical properties of the organic and mineral soil samples collected in the field, such as forest floor biomass on a mass per unit area basis, particle size (sand, silt, and clay), and bulk density of replicate core samples collected in the field (see Table 6.6-1).

Soil physical characteristics are unlikely to vary in any significant manner on a within-season, among-season, or among-year basis in the short term, so repeat-cycle measurements will not need to be made for at least a decade. Hence, all soil classification measurements can be considered to be one-time baseline measurements.

6.6.2.1 Interpretability

Classification information must be collected which is ancillary to FHM needs but important in the assessment of forest soil health from habitat and exposure standpoints. This process logically begins with field soil measurements and sample collection for later analysis. Detailed taxonomic information is a necessary step in properly classifying soils for descriptive and interpretive purposes, and is essential if FHM is to be a long-term program established on a permanent set of plots. Regardless of whether the intent is for soil data to serve as inputs to a stressor-, exposure-, habitat-, or response-category assessment, field soil characterization and the preparation and physical characterization of soil samples are fundamental baseline activities that will support all other FHM measurements.

Physiographic features such as slope, aspect, and elevation have been incorporated successfully into models to predict stand composition (Fralish 1988) and have been shown to influence Douglas-fir growth responses (Steinbrenner 1963). It is not unexpected that these parameters would affect forest growth response because they contribute to the overall hydrologic characteristics of a site. Soil drainage characterization, along with other moisture characteristics, has long been recognized as vital information in estimating soil productivity (Green et al. 1989; Hamilton and Krause 1985; Mader 1976; Storie and Weislander 1948). Physiography, forest floor biomass, particle size, and bulk density are important parameters in estimating the hydrologic contributions of runoff and lateral water flow (Hewlett 1961) and for their effects on nutrient availability (Mader 1976; Carter and Lowe 1986), aeration (Mader 1976; Steinbrenner 1963), and root distribution (Hillel 1980; Blanchar et al. 1978), all of which directly affect vegetative response.

Long-established, well-documented, and unambiguous protocols (SCS 1983, 1984, 1985) established for the National Cooperative Soil Survey (NCSS) serve as the basis and justification for the field measurements (Van Remortel 1992). Suggested changes have been incorporated where necessary as a result of experience gained from previous pilot and demonstration studies in New England, Virginia, Georgia, California, and Colorado.

TABLE 6.6-1. SOIL CLASSIFICATION PARAMETERS FOR HABITAT/EXPOSURE

Field Parameters

Taxonomy: series, order, suborder, great group, subgroup, particle size class, mineralogy class, reaction class, temperature regime, other class, moisture regime
Major land resource area
Slope: percent, shape, geomorphic position, hillslope position, aspect
Physiography: regional and local
Water table: depth, days, kind
Land use class
Surface stoniness class
Hydraulic conductivity class
Drainage class
Parent material: bedrock inclination, mode of deposition, origin, bedrock fracture
Hydrologic group
Water erosion class
Water runoff class
Flooding frequency
Ponding frequency
Particle size control section depths
Diagnostic feature: depths, kind
Horizon: depths, discontinuity, master and suffix designations
Moist color: location, percent, hue, value, chroma
Boundary: distinctness, topography
Texture: class, modifier
Structure: grade, size, shape
Mottles: quantity, size, contrast, hue, value, chroma
Field property: quantity, kind
Roots: quantity, size, location
Pores: quantity, size, continuity, shape
Concentration: quantity, size, shape, kind
Rock fragments: volume percent, roundness, kind, size

Laboratory Physical Parameters

Core bulk density: the oven-dry density of the <2-mm soil fraction (minus rock fragments) from replicate core samples, measured gravimetrically; (mineral soils only).
Forest floor biomass: total mass of organic constituents in a given area of forest floor, measured gravimetrically and by loss-on-ignition; (organic soils only).
Total sand: particle diameter between 0.05 mm and 2.0 mm, determined by wet sieving; (mineral soils only).
Total silt: particle diameter between 0.002 mm and 0.05 mm, determined by pipetting; (mineral soils only).
Total clay: particle diameter less than 0.002 mm, determined by pipetting; (mineral soils only).

Good accuracy and precision are ensured when the measurements are made by soil scientists experienced in these protocols. The codes used to describe soil characteristics are uniformly applied across the U.S. With the exception of the biomass measurement, long-established and unambiguous protocols exist for sample preparation and physical analyses (Byers and Van Remortel 1991). These methods can also be applied uniformly across the U.S.

A nationwide network of data bases, part of the interagency soil survey coverage, assures good comparability and interpretability with respect to other soils programs. Aggregating to the plot level is very straightforward when the entire suite of component depth, gravimetric, and volumetric measurements are made; thus cumulative distribution functions (CDFs) can be derived easily. Appropriate nominal/subnominal boundaries for particular responses are easily defined for all parameters. Around the world, the methods can be universally extended across regional (and ecosystem) boundaries by virtue of comparable National Cooperative Soil Survey/Food & Agriculture Organization (NCSS/FAO) frameworks.

6.6.2.2 Quantification

The data collection phase is detailed, yet straightforward and cost-effective. The proposed field characterization data can be collected in a standard 6-hour day on the plot, as demonstrated in the pilots and demonstration work of the past 2 years. A minimum of one soil scientist, regionally experienced in NCSS procedures and the

Forest Health Monitoring field guide protocols, is needed to perform soil measurements and sampling on each plot. On some plots, assistance from another crew member is required to excavate the holes and transport the soil samples from the plot. The use of a uniform set of NCSS descriptive codes applied in a consistent and repeatable manner ensures that the field data are easily quantifiable and comparable. Consistent application of descriptive codes will constrain measurement uncertainty to a minuscule part of the overall data uncertainty. (NOTE: The term "uncertainty" describes the sum of all quantifiable errors associated with a particular portion of a measurement system or population of interest [Byers and Palmer 1992].)

Organic matter measured by loss-on-ignition and, subsequently, forest floor biomass, are easily quantified using specific field measurements in conjunction with data collected at the soil sample preparation laboratory (Ballard and Carter 1985; David 1988; Byers and Van Remortel 1991; Van Remortel 1992). Bulk density estimated from core samples consists of a straightforward sample collection technique (Van Remortel 1992) and a simple gravimetric measurement procedure at the preparation laboratory (Byers and Van Remortel 1991). The determination of particle size is straightforward and may possibly be undertaken at the preparation laboratory using a hydrometer method; alternatively, a more detailed particle size analysis can be performed at the analytical laboratory (Byers and Van Remortel 1991). These procedures require preparation laboratory staff on a seasonal basis. One or more analytical laboratories may be needed on a seasonal basis for sample particle size analysis.

Measurement uncertainty in the field phase is controllable and quantifiable. Estimates of this uncertainty may be derived by using existing field quality assurance (QA) data for regional soil surveys (Coffey et al. 1987; Kern and Lee 1990). In these studies, observer differences were minor and, in almost all cases, considered to be nonsignificant. This finding can be attributed to the capability and experience of the participating SCS soil scientists. Similar high quality in FHM can be expected if the staffing specifications are satisfied. Estimates of measurement uncertainty for the laboratory parameters may be derived by using existing QA data for regional soil surveys in which the data passed stringent QA acceptance criteria (Van Remortel et al. 1988; Byers et al. 1989; Papp and Van Remortel 1990; Byers et al. 1990). For each of these measurements, an average coefficient of variation (CV) of 10 percent or less is typical for replicate samples introduced at the laboratory. The expected laboratory bias is ± 5 percent or less of the reference value. For the sample measurement system as a whole (e.g., sampling, preparation, and analysis), an average CV of 20 percent or less is typical. Careful collection, preparation, and analysis of samples will minimize measurement uncertainty relative to overall measurement uncertainty.

6.6.2.3 Signal-to-Noise Ratio

The field and laboratory measurements for soil classification have few if any interferences (see Section 6.6.3.3). There is very little unexplained or uncontrolled variability in the classification properties at a particular sampling site. The laboratory measurements have negligible interference from instrumentation and stock solutions. Hence, the signal-to-noise ratio is very high. Previous assessments of soil scientist precision and accuracy during EPA field activities of the last decade support this conclusion (Coffey et al. 1987; Kern and Lee 1990). Variability is generally contingent on the spatial form and distribution of the specific parameter in a specific landform or region, or on the ability and experience of the scientist making the measurements. In either case, this variability is readily quantifiable.

Within the soil sample measurement system, there can be variability due to among-scientist, within-run, among-run, within-batch, among-batch, or among-laboratory differences. Each of these possible sources of uncertainty can be kept within acceptable bounds. It is highly likely that noise may be further reduced by adjusting the data for climatic effects (e.g., available soil moisture in a growing season) or for covariate parameters (e.g., particle size).

6.6.2.4 Regional Responsiveness

The soil classification component measurements are particularly useful and regionally responsive for classification and aggregation purposes and may also be sensitive to different regional environmental stresses. A repository of soil characterization data such as the USDA-SCS Soil Pedon File data base exists for over 20,000 phases of soil series across the United States. The data base includes comparable information on organic matter, bulk density, rock fragments, and particle size fractions. Using this data base and others such as the U.S. Environmental Protection Agency (EPA) Direct/Delayed Response Project data bases (Church et al. 1989), it is possible to provide a characterization basis for simulation and geostatistical interpretation within and among regions. The data report from the 1990 20/20 pilot study (Riitters et al. 1991b) shows that the sample design used for soil sampling satisfies cost-benefit optimization criteria set by the FHM team and that the measurements are appropriate for a regional monitoring program of this nature.

6.6.2.5 Index Period Stability

Except for the seasonal fluctuations characteristic of soil water tables, all of the field and laboratory physical measurements are extremely stable (within ±1 percent) throughout the projected index period. For interpretive purposes, soil sampling should be performed concurrently with any vegetative measurement or sampling on the plots.

6.6.2.6 Environmental Impact

Compared with many other types of soil sampling, FHM field soil characterization procedures have a minimal effect on the long-term integrity of plots. All soils work is carried out in an annular zone well outside the vegetative measurement areas of a plot. Each soil hole is neatly and carefully backfilled in the original order of horizons excavated. Future soil holes may be excavated without danger of contamination from the previous holes. Other indicators will not be adversely affected by the presence of the holes.

The laboratory analyses have a negligible environmental effect as the result of strict controls on the handling of stock solutions and the disposal of sample material.

6.6.3 Indicator Evaluation--Soil Physiochemistry for Exposure/Response Assessments

The proposed soil physiochemical parameters (see Table 6.6-2) have been identified as a result of an intensive review of laboratory methods in collaboration with researchers and laboratory chemists across the United States, Canada, and Europe. The recommendations of many previous committees and investigators relating to similar types of projects have also been incorporated (Anderson 1987; Blume et al. 1990; Morrison 1988; NCASI 1983; Robarge and Fernandez 1987; SCS 1984; UN-ECE 1987).

All soil physiochemistry measurements should be made during the first plot visitation cycle to assess baseline condition. Detectable changes in soil chemical characteristics may be significant on an intraseason, interseason, or interannual basis in the short term; thus repeat-cycle measurements of the surface soil horizons should be considered.

6.6.3.1 Interpretability

Historically, soil pH data have been incorporated into response studies with species such as jack pine (Conyers and Davey 1990; Hamilton and Krause 1985; Pawluk and Arneman 1961) and Douglas-fir (Green et al. 1989). A measure of electrical conductivity is useful for estimating the ionic strength of the soil solution (Griffen and Jurinak 1973). Ionic strength is used to calculate the activity of ions in solution, allowing the monitoring of chemical equilibria in soil samples and modeling of long-term chemical weathering of soil minerals (Lindsay 1979). Changes in carbon sequestering may also occur in some forests as a result of heavy disturbance (Harmon et al.

TABLE 6.6-2. SOIL PHYSIOCHEMISTRY PARAMETERS FOR EXPOSURE/RESPONSE ASSESSMENT

Soil Reaction and Elemental CNS Parameters

Electrical conductivity and pH: determined in deionized water using 1:1 mineral soil to solution ratio (1:4 organic), measured with an electrical conductivity meter and a pH meter with combination electrode, respectively.

Total elemental carbon, nitrogen, and sulfur: determined by rapid oxidation through dry combustion followed by infrared or thermal detection using an automated CNS analyzer.

Soil Exchange and Extraction Chemistry Parameters

Exchangeable calcium, magnesium, potassium, and sodium: determined in a buffered (pH 7.0) 1M ammonium acetate solution using a 1:13 mineral soil to solution ratio (1:52 organic) by atomic absorption spectrometry or inductively coupled argon plasma atomic emission spectrometry.

Cation exchange capacity: determined in a buffered (pH 7.0) 1M ammonium acetate solution using a 1:13 mineral soil to solution ratio (1:52 organic); this is the effective CEC which occurs at approximately the field pH when combined with the acidity component; samples are analyzed for ammonium content by one of three methods: automated distillation/titration; manual distillation/automated titration; or ammonium displacement/flow injection analysis.

Total exchangeable acidity: determined in a buffered (pH 8.2) barium chloride triethanolamine solution using a 1:30 soil to solution ratio and a back titration procedure.

Effective exchangeable acidity and exchangeable aluminum: determined in an unbuffered 1M potassium chloride solution using a 1:20 soil to solution ratio and a direct titration procedure;

Mineralizable nitrogen: a predictor of soil nitrogen availability due to biological activity; an incubation technique is specified for the determination of anaerobic nitrogen as ammonium-nitrogen.

Extractable phosphorus: determined in a Bray & Kurtz No. 1 extractant (acid soils only) using a 1:13 mineral soil to solution ratio (1:52 organic) and a colorimetric procedure and autoanalyzer.

Extractable sulfate: determined in a deionized water extractant and in a sodium phosphate extractant using a 1:20 soil to solution ratio by ion chromatography.

Soil Total Elemental Chemistry Parameters

Total elemental phosphorus, calcium, magnesium, potassium, sodium, iron, manganese, copper, zinc, boron, chromium, aluminum, lead, cadmium, nickel, vanadium, arsenic, and mercury: determined by initial microwave digestion followed by dilution and multi-elemental readout by inductively coupled argon plasma atomic emission spectrometry (organic soil horizons only).

1990). Total carbon, nitrogen, and sulfur can be used to characterize soil organic matter which is a critical component of nutrient cycling within the forest ecosystem (Mader 1976; Wilde 1964).

Soil productivity in forests is affected by the sufficiency or deficiency of essential plant-available nutrients (Edmonds et al. 1989). In the Douglas-fir forests of the Pacific Northwest, for instance, available nitrogen is the nutrient most likely to limit site production (McNabb et al. 1986). Productivity can also be disrupted by a decline in the population of certain microorganisms essential to biological cycling processes within the forest floor nutrient reserve zone. These effects may be caused by long-term natural perturbations or short-term changes due to human activity, either of which can be manifested in low-level plant stress. For instance, whole-tree harvesting in commercial forests can affect macronutrient cycling (McColl and Powers 1984; Johnson et al. 1988). Likewise, a low ambient level of magnesium in some localized forest soils is an example of a naturally-occurring stress that potentially could be aggravated by certain management practices (Ballard and Carter 1985). Timber harvesting can aggravate the depletion of nutrients on already nutrient-poor

sites (Entry et al. 1987; Schulze 1989). Forest floor disturbances can interfere with nitrogen cycling (Peterson et al. 1984). Burning (Debano and Klopatek 1988) and disruption of the soil mycorrhizal fungi on tree roots (Vogt and Persson 1990) are other known stresses.

Parameters such as the exchangeable cations, cation exchange capacity, available phosphorus, and exchangeable acidity have historically been incorporated into acid deposition studies (Church et al. 1989) and into response studies with species such as jack pine (Hamilton and Krause 1985; Pawluk and Arneman 1961) and Douglas-fir (Green et al. 1989). Extractable sulfate and phosphate are important constituents of the soil solution and can be measured easily on the same extract using ion chromatography. These measurements, together with electrical conductivity, can be used to estimate ionic activity of the soil solution (Griffen and Jurinak 1973).

Soil productivity can also be affected by micronutrient availability and by the presence of toxic substances and contaminants in the soil (Smith 1991). The latter presence can indicate exposure to potentially detrimental chemical compounds and elements possibly resulting from land use practices (e.g., application of pesticides, mine spoils, sewage sludge), atmospheric deposition (e.g., aluminum mobilization resulting from acidic precipitation), or naturally occurring phenomena (e.g., overabundance of magnesium in serpentinitic parent materials). Iron, manganese, copper, zinc, and boron are essential to tree growth and should be measured (Bonneau 1991). However, iron and aluminum, as well as lead (Johnson et al. 1982), cadmium, nickel, chromium, and vanadium, can damage root systems and are detrimental to plant growth and forest systems as a whole (Driscoll et al. 1983; Johnson and Henderson 1989; Ulrich et al. 1980). Plant metabolic processes can be disrupted either directly, through uptake of the substances, or indirectly, through impairment of soil nutrient availability (Zedaker et al. 1987). In the first case, the substances can affect physiological processes and internal physical structure, thereby lowering the rate of photosynthesis, growth, and resistance to secondary stresses (McLaughlin 1985; Miller 1983). In the second case, mobile substances bind with soil nutrients and migrate to subsurface soil horizons.

Chemical toxicity can also reduce the number and variety of soil decomposer microorganisms, thereby decreasing the rate at which nutrients become available for plant uptake (VDIKRL 1987) and effectively lowering site productivity. This phenomenon has direct implications for management considerations with respect to mineral extraction, pesticide applications, and atmospheric emissions. The degree of toxic effects on plant tissues and growth is related to the duration of exposure, concentration, exposure regime, and chemical dynamics of forested systems. Discovery of such substances in the soil could warrant close monitoring of areas exhibiting exposure. Monitoring the concentrations of ions, both those known to be nutrients and those which act as toxic substances, is an important measure of the potential for good forest nutrition (Edmonds 1989). However, factors which influence soil moisture imports and exports must be evaluated because of their effects on the availability of nutrients and toxic substances. Evaluation of these factors is a developmental aspect of FHM soil monitoring because it requires the use of sometimes scanty ancillary moisture, climate, and exposure data from sources other than FHM.

Soil characterization using the parameters in Table 6.6-2 is a fundamental baseline activity that gives a broad, if incomplete, picture of soil physiochemical "status" and is particularly useful for soil habitat, exposure, and response assessments. These measurements are essential to any serious classification effort for risk assessment, monitoring soil as a sink for metals, evaluation of soil "potential," or other interpretive purposes, and if this program is to be carried out long-term on a permanent set of plots. The parameters are of critical importance in monitoring nutrient cycling characteristics of forest soils. The total elemental parameters are proposed for measurement in foliage and

stemwood samples as well as soils to increase interpretive power.

Soil pH, electrical conductivity, and the total elemental parameters are easily and unambiguously interpretable for the purposes of baseline soil chemistry characterization. The proposed methodology is accepted internationally and has been tested and used in FHM. Also, the results of many large-scale surveys of the recent past (e.g., EPA acid deposition studies such as the Direct/Delayed Response Project [Church et. al. 1989]) and research-level surveys can be used to establish reference data for comparability purposes. When the measurements are made by laboratories experienced in the protocols and subject to strict QA guidelines, good accuracy and precision can be achieved.

It can be argued that the soil exchange chemistry parameters are somewhat ambiguous because of the dizzying array of soil exchange and extraction chemistry methods. However, the proposed FHM extraction methods are generally accepted by a large cross-section of the soil chemistry community, and have already been tested and used for previous FHM soil analyses. Recent efforts to establish standard or reference methods has made the selection process much more coherent. Following more methods comparisons, the above list of exchange and extraction parameters can probably be consolidated into fewer extraction steps thus reducing the cost of analysis without sacrificing interpretability.

Aggregating to the plot level is very straightforward; hence, cumulative distribution functions can be derived. Appropriate nominal/subnominal boundaries for particular responses can be defined. Worldwide, most of these parameters can be extended across regional and ecosystem boundaries by virtue of comparable methods. In a few cases, between regions of the eastern U.S. and western U.S., different soil methods are necessary to address acid/alkaline soil extraction efficiencies. This difference in methods is easily manageable.

6.6.3.2 Quantification

The specified instrumentation used to measure the soil physiochemistry parameters is well documented in the literature. A detailed, but straightforward, computer program containing algorithms organizes, quantifies, and reports all of the laboratory data. The program has been used successfully in several previous EPA-sponsored analyses (e.g., DDRP and EMAP/FHM). As a result, only limited refinements will be needed as FHM progresses. Specific step-by-step protocols are available for each parameter (Byers and Van Remortel 1991). A major benefit of the total elemental analysis is that a large amount of data can be collected for numerous parameters using only one or two instrument loadings. Staffing needs are minimal and include a soil scientist experienced in the field guide protocols to perform seasonal soil sampling on each plot; a preparation laboratory staff to process samples on a seasonal basis; and one or more analytical laboratories to perform sample analyses on a seasonal basis.

6.6.3.3 Signal-to-Noise Ratio

Overall variability is low to moderate for the proposed physiochemistry parameters, although chemical concentrations can vary within seasons, within years, between years, within plots, and between plots. Temporal or spatial variability is generally contingent on the form, mobility, and concentration range of the parameter. Each of these possible sources of uncertainty can be controlled to varying degrees. By virtue of the inherent destructive nature and unrepeatability of soil sample collection, temporal and spatial uncertainties are usually confounded, and cannot be strictly partitioned and controlled individually.

Within the sample measurement system, there can be variability due to between-crew, within-run, between-run, within-batch, between-batch, and between-laboratory differences. Each of these possible sources of uncertainty can be controlled within acceptable and known limits. Estimates of measurement uncertainty for the physiochemistry parameters may be

derived using soil survey data that have satisfied especially stringent QA criteria (Van Remortel et al. 1988; Byers et al. 1989; Byers et al. 1990; Lewis and Byers 1992). For replicate samples introduced at the analytical laboratory, an average CV of 5 percent or less is typical for each of the soil reaction and elemental carbon, nitrogen, and sulfur (CNS) parameters and 10 percent or less for each of the soil exchange and extraction parameters and the other elemental parameters. The expected laboratory bias is ± 5 percent or less of the reference value. For the sample measurement system as a whole (e.g., sampling, preparation, and analysis), an average CV of 10 percent or less is typical for each of the soil reaction and elemental CNS parameters and 20 percent or less for each of the soil exchange and extraction parameters and the other elemental parameters. Careful collection, preparation, and analysis of the samples will constrain measurement uncertainty to be a minuscule part of the overall data uncertainty.

Interferences will be controlled through the application of strict protocols and selection of the best available instrumentation. It is highly likely that noise may be further reduced by adjusting the data for climatic effects (e.g., available soil moisture in a growing season) or for covariate parameters (e.g., carbon and nitrogen).

6.6.3.4 Regional Responsiveness

The soil physiochemistry measurements are responsive to regional changes in condition or exposure and can be extremely sensitive to different environmental stresses (Smith 1991). Repositories of soil characterization data, e.g., the USDA-SCS Soil Pedon File data base, exist for thousands of soil series across the United States. Using this data base and others such as the EPA Direct/Delayed Response Project data bases (Church et al. 1989), it is possible to provide a characterization basis for simulations and geostatistical interpretation within and among regions. Several research-level data bases are available which contain significant amounts of data documenting heavy metal depositional gradients.

To date in the FHM program, evidence for regional responsiveness in soils is being gathered through evaluation of the Diagnosis and Recommendation Integrated System (DRIS) (Beaufils 1973; Walworth and Sumner 1987) techniques using soil chemistry and dendrochronology data from a Southern Appalachian spruce-fir data base (Kelly and Mays 1989; Van Deusen 1988). Previously, an acidic deposition gradient data base from the north-central United States (Ohmann et al. 1989; Riitters and Van Remortel 1991a) was evaluated using DRIS techniques. Exploratory DRIS evaluations have been done on the 1990 20/20 pilot study soil, foliar, and mensuration data to examine nutrient cycling assessment scenarios.

6.6.3.5 Index Period Stability

It is extremely difficult to verify the temporal patterns of soil chemical variability in forest systems because it is virtually impossible to resample soils (with any certainty) from a destructively sampled zone. Any such estimates of variability are confounded and generally cannot be attributed to temporal versus other sources of variability. Based on some research studies taking *in situ* measurements with lysimeters, temporal variability within a seasonal index period is expected to be within ±10 to 15 percent. Among years, variability is expected to be ±5 to 10 percent for any given annual increment. Some of the more mobile soil nutrients such as N-fractions may be more variable. The potential effect of temporal variability can be minimized by remeasuring each plot at about the same time within the index period.

6.6.3.6 Environmental Impact

Under the present FHM field plot design, the soil sampling activities have little or no effect on the vegetative measurement subplots and, therefore, on the long-term integrity of the plots. Furthermore, all soil sampling work is carried out in an annular zone well outside the vegetative measurement areas of a plot. Any resampling in future years will be conducted a sufficient distance away from the original soil holes to aviod contamination.

The laboratory analyses have a negligible environmental effect due to strict controls on stock solutions and sample disposal.

6.6.4 Selection of Measurement Parameters by Assessment Scenarios

If funding is insufficient to measure all soil classification and physiochemistry parameters, it may be useful to prioritize the assessment scenarios presented in Table 6.6-3 to determine which data to collect. It should be noted and understood that certain data of importance or relevance to the data users may be unavailable if all parameters are not selected for measurement. Also, Table 6.6-3 does not present an exhaustive list of appropriate soil parameters or possible scenarios that have relevance. The present list of parameters for baseline forest monitoring is lean, but comprehensive.

6.6.5 1992 Activities

Soil samples will be collected as part of the Southeastern Demonstration, SAMAB Demonstration, and Western Pilot projects. Chemical analyses will be performed as described previously in this section. Classification measurements will be taken on the same plots from which soil samples are collected.

TABLE 6.6-3. POSSIBLE SOIL ASSESSMENT SCENARIOS FOR FHM

1. Soil as the essential mechanism for ensuring sustainable nutrient cycling, forest sustenance, and soil productivity into the future; linkages with other nutrient cycling indicators; from a habitat/response standpoint. To make this assessment, data must be collected for all of the measurements under both the soil classification and physiochemistry categories.
2. Soil as a key linkage, e.g., with respect to buffering effects, for monitoring acidic deposition effects, cation leaching, or certain other water quality concerns; from an exposure/response standpoint. To make this assessment, data must be collected for all of the measurements under the classification category, and the soil reaction/CNS and soil exchange/extraction measurements under the physiochemistry category.
3. Soil as a comprehensive predictor of risk or susceptibility, and as a means for assessing regional abatement strategies; from a stressor/exposure/habitat/response standpoint. To make this assessment, data must be collected for all of the measurements under the classification category and the soil reaction/CNS measurements under the physiochemistry category.
4. Soil as a sink for airborne metal contaminants or deleterious organic compounds; from an exposure/response standpoint. To make portions of this assessment, we will need to collect data for all of the measurements under the classification category and the soil total elemental chemistry measurements under the physiochemistry category.
5. Soil as a primary classification medium for Tier 1 & 2 landscape characterization and GIS layering; from an exposure/habitat standpoint. To make this assessment, data must be collected for all of the measurements under the soil classification category.

6.7 Foliar Chemistry Indicator

T.E. Lewis

6.7.1 Introduction

Foliar chemistry is the quantitative and qualitative measurement of the levels of micro and macronutrients, as well as certain trace elements in foliage. These measurements indicate the nutritional or pollutant status of a forest stand. In previous Forest Health Monitoring (FHM) studies, foliar chemistry consisted of two separate parts, "foliar nutrients" and "foliar contaminants," the latter encompassing elements not considered essential to plant growth. Since both indicators are based on analyses of the same foliar tissue samples, the two will henceforth be referred to as the foliar chemistry indicator.

Foliar chemistry is an exposure-habitat indicator. This class of indicator is designed to quantify stressors which may be associated with changes in forest condition. The foliar chemistry indicator is also a key component in the suite of indicators that addresses the nutrient cycling assessment endpoint. Foliar analysis can be used as an indicator of the current nutritional status of a stand, elements available in soil, and atmospheric deposition. Foliar nutrient levels can be influenced by factors other than availability. These influences may include site factors, availability of other nutrients, genotype, and sampling protocol.

6.7.2 Indicator Evaluation

The rationale for measuring foliar chemical attributes is addressed in light of the six indicator selection criteria described in Section 6.1.

6.7.2.1 Interpretability

Foliar chemistry is subject to many sources of variability such as time of year when samples are collected, crown position on the tree, and available water regime. Considering single nutrient levels at one point in time provides little information about nutrient status or growth dynamics. However, by determining some type of index, such as the Diagnosis and Recommendation Integrated System (DRIS) index (Beaufils 1973), that considers all nutrients in harmony, a relationship between nutrient status and growth (e.g., basal area growth) may be established.

The DRIS indices were calculated for the loblolly foliar chemistry data obtained from the FHM 1990 20/20 pilot study. The DRIS indices were calculated for each sample tree by comparing the 20/20 data to a reference population using DRIS norms from Needham et al. (1990) for 4-year old loblolly pine growing in the South Carolina and Georgia Piedmont. These DRIS norms are shown in Table 6.7-1.

The DRIS index for each nutrient was calculated by first determining intermediate functions for each nutrient ratio, using N/P as an example.

$$f(N/P) = ([(N/P)/(\mathbf{N/P})] - 1)\ (100/CV_{N/P}) \quad \text{if } N/P > \mathbf{N/P} \qquad (1)$$

$$f(N/P) = (1 - [(\mathbf{N/P})/(N/P)])\ (100/CV_{N/P}) \quad \text{if } N/P < \mathbf{N/P} \qquad (2)$$

where the boldface type refers to the Needham et al. (1990) reference-population nutrient ratio, regular type refers to the 20/20 sample population being compared, f is the functional relationship between the sample and reference population values, and CV is the coefficient of variation of the nutrient ratio of the reference population.

TABLE 6.7-1. THE DRIS NORMS FOR ASSESSING THE NUTRITION OF 4-YEAR-OLD LOBLOLLY PINE GROWING IN THE SOUTH CAROLINA AND GEORGIA PIEDMONT (FROM NEEDHAM ET AL. 1990).

Nutrient ratio	Mean	Standard Deviation	Coefficient of variation
N/P	10.426	1.209	11.6
N/K	2.361	0.427	18.1
Ca/N	0.154	0.037	24.5
Mg/N	0.066	0.026	24.5
P/K	0.227	0.037	16.6
Ca/P	1.589	0.452	28.4
Mg/P	0.696	0.197	28.5
Ca/K	0.362	0.126	35.2
Mg/K	0.158	0.050	25.25

The DRIS index for each nutrient was calculated as follows:

$$\text{N index} = \frac{f(N/P) + f(N/K) - f(Ca/N) - f(Mg/N)}{4} \quad (3)$$

$$\text{P index} = \frac{-f(N/P) + f(P/K) - f(Ca/P) - f(Mg/P)}{4} \quad (4)$$

$$\text{K index} = \frac{-f(N/K) - f(P/K) - f(Ca/K) - f(Mg/K)}{4} \quad (5)$$

$$\text{Ca index} = \frac{f(Ca/N) + f(Ca/P) + f(Ca/K) + f(Ca/Mg)}{4} \quad (6)$$

$$\text{Mg index} = \frac{f(Mg/N) + f(Mg/P) + f(Mg/K)\ f(Ca/Mg)}{4} \quad (7)$$

The data compared in Table 6.7-2 demonstrate that the sampling strategy employed during the 20/20 study provided foliar chemistry data that were directly comparable to those reported in the literature for loblolly pine. There is close agreement between all values except for potassium (K), which was considerably higher in the DRIS derivation. In theory, DRIS-derived optimum nutrient levels should be slightly higher (about 10 percent) than traditionally derived critical levels because of differences in their definition.

The question remains: how does the FHM sampling strategy compensate for or reduce the variability due to seasonal variability and crown-position effects? While individual foliar nutrients are known to vary temporally and spatially on the bole of the tree, the use of an index, such as DRIS, may reduce such sources of variability. Intraseasonal foliar nutrient concentrations and contents in conifers depict a pattern similar to deciduous trees, with seasonal maxima occurring in the current-year foliage in the summer followed by generally stable or slightly decreasing levels in the autumn (Nommik 1966; Nommik and Popovic 1968). Foliar sampling in FHM is performed during the summer months.

From an interpretative standpoint it may at first seem convenient to sample during the time of year when nutrients are most stable, autumn and winter for conifers and one month prior to autumn coloration for deciduous species.

TABLE 6.7-2. COMPARISON OF DRIS-DERIVED OPTIMA AND CRITICAL LEVELS FOR LOBLOLLY PINE FOLIAR-NUTRIENT CONCENTRATIONS FOR THE 20/20 STUDY WITH THOSE REPORTED IN THE LITERATURE

	Foliar nutrient concentration (g/kg dry weight)			
Parameter	N	P	K	Mg
nutrient level when DRIS index = 0	11.3[1] 12.0[2]	1.1[1] 1.2[2]	4.6[1] 5.2[2]	0.7[1] 0.8[2]
DRIS optimum	12.0[2]	1.1[2]	5.2[2]	0.8[2]
critical levels	11.0[3] 12.0[4]	1.0[3] 1.0[4] 1.1[6]	3.5[3] 2.6[5]	0.7[3] 0.8[5]

[1]Based on foliage collected in the summer of 1990 during the 20/20 Study in Virginia; DRIS optima and critical levels could not be calculated from such a small sample.
[2]Needham et al. (1990)
[3]Hockman and Allen (1989)
[4]Fowells and Krauss (1959)
[5]Sucoff (1961)
[6]Wells and Crutchfield (1969)

However, the biological justification for such an index period is tenuous. This dormant period follows translocation of the mobile nutrients out of the foliage in preparation for next year's growth and deposition of the nonmobile elements. Thus, measuring foliar nutrients at the most stable time of year does not provide any information as to the nutritional status of the plant at the most physiologically important use period (Armson 1965). By sampling during the most physiologically active period, as is currently done in FHM studies, critical nutrient demands may be more detectible than during dormant periods. It is also logistically easier to collect foliage samples at the same time all other measurements are made on the plot.

Table 6.7-3 compares the average ratios and coefficients of variation from the 20/20 Study with those from Needham et al. (1990) and Hockman and Allen (1989). The authors sampled previous-year growth loblolly foliage in February and December and January, respectively. In the 20/20 Study previous-year growth loblolly foliage was collected in June and July. Despite the differences in index period between the three studies, the nutrient ratios are similar (Table 6.7-3). When evaluated within the context of the DRIS approach, seasonal differences may be factored out by comparing all nutrient ratios simultaneously.

DRIS has also been applied to deciduous species. Lozano and Huynh (1989) examined DRIS indices for sugar maple. They found that DRIS diagnoses were identical irrespective of sampling date (month) and nearly identical diagnoses were made by DRIS irrespective of the position on the crown where foliage was collected.

6.7.2.2 Quantification

Foliage can be collected from each plot in a single day by either a tree climber, rifle, or pole pruner. Analysis of foliar tissue for micro- and macronutrients and trace elements has been performed for decades. Advances in microwave digestion and analytical instrumentation have improved accuracy and

TABLE 6.7-3. COMPARISON OF AVERAGE NUTRIENT RATIOS AND COEFFICIENTS OF VARIATION FROM THE 20/20 STUDY WITH LITERATURE REPORTED VALUES FOR LOBLOLLY PINE

nutrient ratio	means			CV[1]		
	20/20	N[2]	HA[3]	20/20	N	HA
N/P	12.363	10.426	10.909	26.8	11.6	--[4]
N/K	2.143	2.361	3.076	24.3	18.1	--
Ca/N	0.161	0.154	0.133	43.2	24.5	--
Mg/N	0.060	0.066	0.075	31.5	24.5	--
P/K	0.183	0.227	0.282	32.5	16.6	--
Ca/P	1.973	1.589	1.545	49.3	28.4	--
Mg/P	0.739	0.696	0.818	39.2	28.5	--
Ca/K	0.343	0.362	2.437	49.7	35.2	--
Mg/K	0.125	0.158	0.231	32.0	31.9	--
Ca/Mg	2.770	2.355	1.778	40.4	25.3	--

[1]Coefficient of variation
[2]Needham et al. (1990)
[3]Hockman and Allen (1989)
[4]Authors did not report CV

precision. The use of National Institute of Standards and Testing (NIST) and in-house audit samples will also improve within-batch and between-batch precision and accuracy. The calculation of DRIS ratios and norms from the foliar chemistry data is a simple arithmetic operation.

6.7.2.3 Signal-to-Noise Ratio

The foliar nutrient ratios observed from the 1990 20/20 Study are in agreement with those reported by Needham et al. (1990) and Hockman and Allen (1989). This is despite the fact that the loblolly in the 20/20 Study were sampled during the summer, when nutrient levels are known to fluctuate, and the other two studies collected foliage in the winter. The CVs are greater for the 20/20 Study data due to large variability in the analytical procedures. The variability in foliar nutrient ratios and their relative magnitudes are not different from those reported by other investigators studying nutrient status in loblolly pine (Table 6.7-3). It should be reiterated that in equations 1 and 2 the DRIS nutrient ratios are weighted by the inverse of the CV. Thus, for those ratios exhibiting greater CVs in the 20/20 Study loblolly data set, the resulting intermediate function is given less weight in the DRIS index. This weighting procedure serves to increase the signal-to-noise ratio.

6.7.2.4 Regional Responsiveness

Needham et al. (1990) obtained foliage from 504 randomly selected 4-year-old loblolly pines in 8 plantations in the South Carolina and the Georgia Piedmont. The sites represented diverse cultivation practices. Hockman and Allen (1989) collected foliage from loblolly pines spanning 11 states and 52 soil series from 3 control plots of the North Carolina State Forest Nutrition Cooperative regionwide trial series. Geographically, their study extended from Delaware to southern Georgia and west to Louisiana and Arkansas. Loblolly pine and loblolly pine-hardwood forest types were sampled in Virginia during the 1990 20/20 Study. These stands occurred primarily in the Atlantic coastal plain and Piedmont.

Table 6.7-2 compares the DRIS optima, critical levels, and foliar nutrient concentrations

when DRIS indices = 0 from the three studies. The values obtained from the 20/20 Study, notwithstanding its inherent problems with limited regional representativeness and analytical shortcomings, compared quite remarkably to the literature reported values. These similarities indicate that, at least on a species level, comparisons can be made with respect to the major nutrients in loblolly pine foliage. Some fine tuning of the DRIS norms may be necessary to obtain estimates that are more physiogeographically representative. Greater trend detection accuracy and sensitivity would be obtained if region- or soil-group specific DRIS norms are developed.

How is foliar chemistry regionally responsive to air pollutants such as ozone, sulfate deposition, heavy metal deposition, organics, pests, and other regional stressors? Trees are one of the greatest interceptors of contaminants because of their large surface area. The surface area of the above ground parts usually far exceeds the surface area of the ground in which they are growing. The leaf surface area represents the bulk of the surface area both in herbaceous and woody plants, and leaf area indices up to 20 have been observed (Schulze 1982). Since most leaves have a lower and upper surface, there may be up to 40 m^2 leaf surface area on every m^2 of soil. Therefore, most airborne pollutants will be intercepted by leaf surfaces rather than by the soil surface. The use of plant material that accumulates pollutants is convenient for demonstrating the geographical distribution of a stressor. The levels of trace elements in the 20/20 Study were generally at or below the method detection limit. This is useful information regarding the deposition of trace elements in plots sampled during the 20/20 Study. Obviously, no regional estimates of trace element deposition can be made from the small sampling conducted during the 20/20 Study. However, the data indicate that, for the area sampled, heavy metal deposition was low.

Foliage has been demonstrated to be an excellent integrator of inorganic pollutant exposure (Blauel and Hocking 1974; Hogan and Wotton 1984). Recently, the impact of organic contaminants on forest ecosystems has become a matter of concern. From leaf area indices and area weights of cuticles, Riederer and Schonherr (1984) estimated that, for most plant stocks, the quantity of lipophilic cuticle per hectare amounts to between 180 and 1,500 kg. The quantity of cuticular mass in forests is probably greater, suggesting that lipophilic compounds accumulate in significant amounts in forests (Sherby and Gould 1990). Lipophilic compounds include PCBs, PAHs, chlorinated pesticides, and volatile organic compounds (e.g., trichloroethane, perchloroethene).

6.7.2.5 Index Period Stability

It is apparent from a cursory review of the literature that foliar nutrients fluctuate over the course of the growing period and even during the dormant period. However, if sampling protocols are standardized so that foliage is collected at approximately the same time of year, from the same position on the crown, and from the same age class, then trends in foliar chemistry can be detected. By linking the FHM data base with other data bases that are available for similar species, DRIS indices may be computed and compared with reasonable confidence using analyses of foliage collected within the index period. Furthermore, the study on sugar maple by Lozano and Huynh (1989) suggest that DRIS indices are stable during the entire growing season.

DRIS indices are not limited to nutrient ratios. Other influential factors such as leaf area index, fascile weight, available water, temperature, and toxic elements (e.g., Ca/Al ratio) can be incorporated into the DRIS equations.

6.7.2.6 Environmental Impact

The amount of foliage collected from the sample trees during FHM surveys is not considered to affect the health of the tree, given a 4-year interval for resampling. The foliar sampling activities do not adversely affect other indicator or potential indicator measurements. Tree climbers do not use spikes when obtaining foliage from the crown.

6.7.3 Summary of Foliar Sampling and Analysis

In brief, samples are collected from four trees on each plot by collecting current leaves of deciduous species and previous year (one-year old) needles from coniferous species from the upper third of the live crown of dominant or codominant trees. Specimens are obtained by one of three methods: (1) climbing the tree with ropes and ascenders (e.g., jumars, gibbs), (2) pole pruner, or (3) rifle. Most reputable tree companies prohibit the use of climbing spurs or spikes except when the tree is to be felled. Spikes will not be used on any sample tree.

The specimens are shipped to the preparation laboratory where the samples are oven dried, ground to less-than-one-millimeter particle size, homogenized, and shipped to the analytical laboratory. The samples are analyzed using methods described in Part IV of the FHM Analytical Methods Handbook (Byers and Van Remortel 1991). The dried foliar material is analyzed for the following groups of analytes:

Group I. *Micro- and macronutrients and trace elements* -- Block digestion of foliage and forest floor litter followed by elemental analysis of the digest by inductively coupled plasma optical emission spectroscopy (ICP-OES) for the following micro-and macro-nutrients and certain trace elements:

	ICP	
Aluminum	Boron	Cadmium
Calcium	Chromium	Cobalt
Copperlron	Lead	Magnesium
Manganese	Molybdenum	Nickel
Phosphorus	Potassium	Sodium
Strontium	Sulfur	Titanium
Vanadium	Zinc	

Group II. *Mercury* -- by cold vapor ICP. Forest floor samples to be analyzed only.

Group III. *Arsenic*--by hydride generation ICP. Forest floor samples to be analyzed only.

Group IV. *Total N*--combustion of the foliar material in the furnace of total CNS analyzer.

6.7.4 Data Analysis

The DRIS approach will be used to aggregate data down to the plot level. Macronutrient, and possibly micronutrient, ratios will be produced and DRIS indices calculated using literature-reported DRIS norms for "healthy" species. If literature values are not readily available for certain species, then FHM or FIA growth-related measurements will be used to segregate foliar nutrient ratios into nominal and subnominal populations for calculating DRIS norms.

For trace elements such as Pb, Cd, and Hg, cumulative distribution frequency (CDF) plots will be generated to illustrate the regional trends in contamination levels of these elements. Comparisons will be made to literature values for similar species growing in contaminated and "pristine" environments. Foliar, soil, and stemwood elemental concentrations will be compared to detect correlations between elemental trends in the various forest ecosystem components. Ultimately, a compartmentalized model will be constructed to assist in the interpretation of regional trends in trace element deposition and cycling in various forest types.

6.7.5 1992 Activities

The foliar chemistry of samples collected during the Southeastern Demonstration will be measured. This will include samples from the Georgia Demonstration conducted in 1991 and samples collected during the 1992 Southeastern Demonstration. An off-frame pilot study will be conducted in Portland, Oregon, to develop an optimal branch extraction procedure that uses rifles. The use of rifles will reduce the costs of tree climbers and allow easier implementation of the foliar chemistry indicator in other regional demonstrations and pilots.

6.8 Stemwood (Tree Core) Chemistry Indicator

T. E. Lewis

6.8.1 Introduction

Stemwood chemistry is the quantitative and qualitative measurement of the levels of micro- and macronutrients, as well as certain trace elements, in stemwood that indicates retrospective changes in uptake and translocation. Stemwood chemistry is an exposure-habitat indicator. This class of indicator is designed to quantify stressors which may be associated with changes in forest condition. The stemwood chemistry indicator is a key component in the suite of indicators that address the nutrient cycling assessment endpoint.

Stemwood chemistry is also a retrospective indicator (RI). The RIs place current observations, such as soil chemistry, foliar chemistry, leaf area index, and basal area, into the context of a longer time frame, thereby providing the opportunity to evaluate slowly operating processes, past cyclic changes or unusual events, disturbance regimes, and historically constrained phenomena (Schoomaker and Foster 1991). Many of the current Forest Health Monitoring (FHM) indicators are nonretrospective. They provide extensive geographic coverage, but lack the temporal aspect of evaluating seasonal, annual, decadal, or longer trends. Current measurements of foliar or soil solution chemistry cannot indicate historical changes in dynamic equilibrium of soil chemistry. The current FHM indicators operate in a wait-and-see context. The first year of monitoring yields a reference point, but not a baseline indicative of long-term trends. With historical data gathered from chemical analysis of tree cores, future trends starting at current values of non-retrospective indicator measurements can be predicted. The stemwood record from any particular position is essentially a summary of the changes in the chemistry of the sap in contact with the wood at that position. The greatest value in the use of this record is to indicate the direction and the comparative rate of change in sap chemistry (Bondietti et al. 1990). This is distinct from the direct measurement of branch sap chemistry, which provides a useful picture of nutrient availability at the moment of sampling. The chemistry of branch sap depends on the time of day and position of the branch in the crown, as well as nutrient availability in the soil (Stark et al. 1985).

The analysis of elemental concentrations in tree cores may provide evidence of historical trends in nutrient cycling. Most studies of elemental chemistry of tree cores have examined distinct tracers of anthropogenic origins (e.g., lead (Pb) from leaded gasoline, strontium-90 (^{90}Sr) from atomic weapons testing, heavy metal emissions from smelters). Following is a summary of the results of some of these studies.

The initial observations of Ault et al. (1970) demonstrated distinct increases in Pb content in the more recently formed annual growth rings which could be related to parallel increases in traffic density. Ward et al. (1974) produced a more detailed study on Pb content of annual growth rings. Distinct patterns in Pb content were observed. The authors reported that changes in Pb levels could be correlated with changes in traffic density, even with changes in levels of a Pb anti-knocking agent in gasoline marketed in New Zealand during World War II.

Bondietti et al. (1990) found that trends in ^{90}Sr levels in tree cores approximated historical deposition patterns in the biosphere during aboveground testing of atomic devices.

Close correlation between elemental patterns in shortleaf pine stemwood and historical sulfate emissions from the Copper Hill Smelter in eastern Tennessee (Baes and McLaughlin 1984) provided early evidence that changes in tree ring chemistry reflect changing inputs of regional pollutants in forests. Increasing levels of iron were found in those tree cores during the 50 years of open pit

smelting operations (1860 to 1910). After emissions were reduced to preindustrial levels in 1910, levels of iron were significantly lower for 40 years. The levels of iron have again increased during the last 30 years, in response to increasing acidic deposition. Bowers and Melhuish (1988) observed a similar pattern in tree cores collected from loblolly and red oak growing near the Chromasco Smelter outside of Memphis, Tennessee.

Examining the relationship between tree ring chemistry and changes in soil chemistry during the life of a tree is a more recent approach (Legge et al. 1984; McClenahen et al. 1987; Guyette and McGinnes 1987; Bondietti et al. 1989). Bondietti et al. (1989) observed a significant increase in the ratio of aluminum (Al) to calcium (Ca) in tree rings of red spruce and eastern hemlock in the Great Smoky Mountains of Tennessee. The increase was attributed to increased mobilization of Al and leaching of Ca in the soil as a result of acidic deposition. The increased ratio of Al to Ca corresponded to a decrease in the radial growth of the species. Bondietti et al. (1990) also sampled red spruce and other species in New England and North Carolina. The researchers observed an increase in divalent cations present in red spruce wood formed in the mid-1900's that was coincident with rapid increases in sulfate and nitrate deposition in eastern North America and with increases in radial growth. A decrease in divalent cation content was noted in the red spruce wood formed in the late 1900's with a concomitant decrease in radial growth. Shortle and Smith (1988) have proposed that increasing Al to Ca ratios in soil solution and stemwood may be partly responsible for the regionally expansive decline in red spruce in the Northeastern United States.

6.8.2 Indicator Evaluation

The rationale for measuring stemwood chemical attributes is addressed in light of the six indicator selection criteria described in Section 6.1.

6.8.2.1 Interpretability

Dendrochronological analysis coupled with chemical analysis of stemwood samples provides a valuable method for gauging forest responses to temporal and spatial changes in atmospheric deposition of pollutants and climate change (Lepp 1975; Scherbatskoy and Bliss 1982; Baes and McLaughlin 1984; McLaughlin 1985; Holdaway 1991).

Two factors are believed to affect the interpretation of trends in elemental concentrations in tree cores: (1) translocation may occur across rings, and (2) calcium binding capacity (CBC) is reduced by changes in sap solution pH and by innate composition of wood formed at increasing distances from the pith. These factors require care in the interpretation of trends in elemental levels in tree increment cores. However, various researchers have made adjustments in analytical procedures and data evaluation to compensate for these factors. It should be stressed that stemwood chemistry is a relativistic detection monitoring tool. It does not provide absolute values for elemental concentrations in a single year's growth ring.

The issue of translocation and how it may add ambiguity to the interpretation of trends in stemwood chemistry is addressed in the following discussion. One perspective of how red spruce stemwood records reflect changes in cation availability can be obtained by considering the fallout of ^{90}Sr, a calcium analog, with a known input history into soils. Bondietti et al. (1989) examined the ^{90}Sr concentration in red spruce stemwood samples collected from the Great Smoky Mountains National Park. The deposition of ^{90}Sr began around 1954. Although strontium appeared in tree rings prior to the beginning of the fallout period, both the number of rings affected and the amount of ^{90}Sr present were relatively small. This and other measurements of ^{90}Sr in different tree species indicate that 5- to 10-year increments are reasonable intervals for digestion and subsequent instrumental analysis for determining changes in cation availability (Bondietti et al. 1989). The maximum level of

fallout occurred about 1964. High levels of ^{90}Sr were measured in wood formed 10 years earlier and a few years after. However, relative trends in ^{90}Sr are easily discernable given 5- to 10-yr increments. The questions remain, how can the high levels of ^{90}Sr in wood predate the period of maximum fallout and how can ^{90}Sr levels be found in wood as far back as 1920? The answer is that xylem transport of solutes from the soil solution occurs in wood as old as approximately 30 years. Thus, when the initial releases of ^{90}Sr occurred in 1954, the actively transporting sapwood would have extended back to around 1924. The continued increase in ^{90}Sr after steadily decreasing fallout levels indicates that ^{90}Sr is still available for uptake from soil.

The way in which samples are prepared for chemical analysis by inductively coupled plasma (ICP) or inductively coupled plasma-mass spectrometer (ICP-MS) will compensate for the apparent translocation of elements. Five- to 10-year increments are digested and provide evidence of relative increases or decreases over time in macro- and micronutrients, as well as trace elements.

The second factor believed to contribute uncertainty in the interpretation of stemwood chemistry data is the decrease in CBC from the pith to the cambium. Interpreting the historical record of successive equilibria between sap chemistry and stemwood elemental levels requires recognition that the availability of ion exchange sites decreases with increasing radial distance from the pith (Momoshima and Bondietti 1990). They found a decrease in the CBC of red spruce bolewood as a function of the year the wood was formed and the radial distance from the pith. The CBC was highest near the pith and decreased toward the cambium. The similar CBC values near the center of the trees indicate that the number of binding sites was similar and that production of binding sites is independent of environment, since trees grew at sites in Tennessee, North Carolina, and Maine. The decline in CBC is apparently more a function of radius than chronological age. Red spruce from the Great Smoky Mountain National Park Site #32 (GSMNP-32 site) had slightly higher CBC values, but declined with the same slope as the other trees from other sites.

Presently, the reason for the decrease in CBC is not fully understood. Since CBC shows a geometric dependency, changes in tracheid morphology may be involved. Tracheids become longer with increasing tree radius (Bailey 1957), allowing an increase in the amount of water movement to accommodate the higher demand and capillary lift in mature trees. Tracheid elongation is accompanied by an increase in the number of tracheid end connections per unit weight. The radial decline in CBC compensates for what otherwise would be a geometric increase in calcium and other divalent cation storage in the bole if CBC and pH were constant. The decrease in CBC in the outer radius allows more transport of cation nutrients to the upper portions of the mature tree. Recognizing this phenomenon, Bondietti et al. (1990) plotted CBC and the actual divalent cation concentration in individual red spruce wood from trees sampled in New Hampshire and Maine. Divalent cation concentrations paralleled the trend of CBC for the New Hampshire trees during the 1960s, followed by a sharp decrease relative to the CBC from the early 1970s through to 1985. The Maine trees showed a parallel relationship between cation concentration and CBC up until the 1980s, where a sharp decrease was observed. The sharp decreases in divalent cation concentration may be due to leaching of nutrients from the rooting zone of the trees by acidic deposition (Bondietti et al. 1990). Analysis of changes in wood chemistry from samples across several sites in the eastern United States (Bondietti et al. 1990) indicates that over the past 30 to 40 years there have been some substantial departures from the expected linear decrease in CBC and expected Ca accumulation patterns in wood.

A study by Arp and Manasc (1988) is an example of how the decrease in CBC with increasing radius from the pith may not contribute to ambiguity in the interpretation of stemwood chemistry data. They examined the yearly trend in nutrient and trace element concentrations in red spruce stemwood sampled near a coal-burning power plant.

Trees were separated into two groups--trees greater than 35 years old and trees less than 35 years old. At any point in time, the tree ring in a mature tree (greater than 35 yr) corresponding to a given year's growth would be at a greater distance from the pith than the same year's ring in a younger tree (less than 35 yr). The older tree's ring would thereby have a lower CBC than the younger tree's. Even with the CBC phenomenon reported by Momoshima and Bondietti (1990) acting on elemental uptake and translocation, similar trends are noted in young and mature trees. Relative trends can be discerned, notwithstanding differences in CBC with increasing radial distance from the pith for mature and young trees. During FHM studies an increment core can be collected from a younger tree of the same species as the dominant or codominant tree. An estimate of the change in CBC with distance from the pith can be obtained by analysis of both a mature and young tree.

6.8.2.2 Quantification

Increment boring of trees is a simple procedure that can be performed by trained field technicians. Cores are collected presently in FHM for dendrochronological evaluation. All cores are collected at breast height to standardize the procedure across plots and regions.

Baes and McLaughlin (1984) have shown accuracy and precision to be very good for stemwood elemental analysis. Trees were sampled with increment borers at several sites near Oak Ridge, Tennessee and in the Great Smoky Mountain National Park, and multielement analysis was performed by inductively coupled plasma-optical emission spectrometry (ICP-OES) (Baes and McLaughlin 1984). For most elements, analytical accuracy was at least 80 percent. Their recovery of iron (46 percent) and aluminum (71 percent) from National Institute of Standards and Testing (NIST) standard reference materials (SRMs), (i.e., citrus and orchard leaves and pine needles), was incomplete. Since their study, a new microwave digestion procedure has become available which has made recoveries for most metals nearly 100 percent efficient. Baes and McLaughlin (1984) found precision to be very good for all metals in their study. Because precision was good and because temporal patterns of trace elements in wood were very similar among trees of a stand, confidence in temporal patterns was high. With use of the new microwave digestion procedure (Sah and Miller 1992), accuracy will be considerably increased.

6.8.2.3 Signal-to-Noise Ratio

Year-to-year (ring-to-ring) variability will be reduced by compositing 5- to 10-year increments for ICP or ICP-MS analysis. Bondietti et al. (1989) have shown that this increment size is appropriate for detecting trends in trace element (e.g., ^{90}Sr) and nutrient (e.g., Ca) concentrations in stemwood samples. Arp and Manasc (1988) discerned elemental trends in greater than 35-year-old and less than 35-year-old red spruce by compositing 5-year increments.

Periods of growth decline, both recent and historical, often correspond to increased concentrations of metals such as iron (Fe) and titanium (Ti) in stemwood (Baes and McLaughlin 1984). The increase may be due to a decrease in the amount of tissue laid down in a given year. This noise can be factored out by multiplying elemental concentration and growth rate (microgram of element per gram of wood x gram of wood per year = micrograms of element per year), yielding "xylem accumulation rates" of elements into ring segments. This measure represents annual ring content or burden (total annual accumulation) and is useful in evaluating historical patterns.

Baes and McLaughlin (1986) found that Al levels in wood began increasing in the mid-1900s in conifers sampled in the GSMNP. Concentrations of alkaline earth elements, particularly Ca, were often declining during this same period. When the Al:Ca ratios were calculated (Bondietti et al. 1989), the 1940s stood out as a period when wood Al usually began increasing at various high-elevation locations in the park. The use of Al:Ca ratios normalizes fluctuations in cation

concentrations and accentuates periods when polyvalent cations changed at different rates from, for example, calcium, thereby increasing the signal-to-noise ratio.

The Diagnosis and Recommendation Integrated System (DRIS) has been used successfully for fertilizer treatments to achieve high yields. It was employed by Hockman and Allen (1989) and Needham et al. (1990) to evaluate nutritional status of loblolly pine by foliar analysis. Recently, DRIS has been applied to yet another plant tissue, stemwood, for determining forest health (Riitters and Van Remortel 1991). The DRIS techniques use the inverse of the coefficient of variation (CV) to weight each of the intermediate elemental functions. Thus, if an element exhibits large variability in concentration over a region, its contribution to the DRIS index of any given element is reduced. This weighting procedure serves to increase the signal-to-noise ratio.

6.8.2.4 Regional Responsiveness

Bondietti et al. (1989) found that the Al:Ca ratio measured in the stemwood of trees growing at the GSMNP have increased in the last four decades. However, the same trends in Al:Ca ratios have been observed in other regions and in different species: New Brunswick red spruce (Arp and Manasc 1988), red spruce and sugar maple in Vermont (Matusiewicz and Barnes 1985), shortleaf pine in Tennessee (Braker et al. 1985; Baes and McLaughlin 1984), and hickory in North Carolina (Berish and Ragsdale 1985). What factors other than increased Al availability due to increased mobilization could account for this trend? Cation concentration in wood could increase as more exchange sites are produced or if sap chemistry changes. Increased numbers of exchange sites and increased total cation concentration occur in wood that is wounded (Shevenell and Shortle 1986). However, the widespread, simultaneous occurrence of these anomalies in the Al:Ca ratios argue against synchronous episodes of physical wounding, including damage by fire. Also, fungal infections that would have resulted from wounding typically are associated with large increases in potassium (K). Elevated levels of K were not observed. Site-specific phenomena such as fire or other disturbances that affect soil chemistry have not occurred simultaneously throughout the region. The chemical analysis of stemwood from several species of trees collected by many different investigators throughout the region all indicate a similar pattern in the Al:Ca ratio. Stemwood chemistry is obviously regionally responsive. However, the cause of this trend cannot be definitively determined from stemwood chemistry data alone. In conjunction with other indicator data, such as soil chemistry, a possible link to acidic deposition could be established. Guyette (1991) found a significant inverse relationship between Ba and Mn trends in red cedar tree rings and soil sulfate activity. The Ba/Mn signal in stemwood may be useful in differentiating between changes in soil acidity due to anthropomorphic sulfur emissions and those due to natural, non-sulfate, acidification processes such as climate, base cation sequestering in woody vegetation, fire supression, and species change. This technique may not be applicable to sites with pH values close to 7 and high soil Ca levels.

6.8.2.5 Index Period Stability

Stemwood chemistry is distinct from the direct measurement of branch sap chemistry, which provides a useful picture of nutrient availability at the moment of sampling. The chemistry of branch sap depends on the time of day and position of the branch in the crown, as well as nutrient availability in the soil (Stark et al. 1985) which will vary seasonally. Thus, in the cambium, changes in sap chemistry may be detected when stemwood samples are collected and analyzed. However, since 5- to 10-year increments are composited, this source of variability during the index period will be smoothed out. In conifers, most wood cations are bound to uronic acid polymers in various structures in the cell wall. Saka and Goring (1983) used energy-dispersive X-ray analysis to show that the middle lamella, torus, and other structures in black spruce wood contained the highest concentrations of calcium and other cations. The secondary walls of tracheids contained lower concentrations but accounted for the bulk of the cation inventory.

A coniferous stem can thus be thought of as a renewable ion exchange column in which sap cations are in continuous equilibrium with the walls of the functioning tracheids (Momoshima and Bondietti 1990). Only a small percentage (1 percent to 5 percent) of the bound cations in the wood are in an exchangeable form. Any short-term temporal changes in soil solution chemistry will have a minor influence on the total percentage of nonexchangeable, bound forms in the tracheids that are actively involved in nutrient transport in the outer rings (cambium back 10 years). As tracheids in the annual rings lose function (i.e., greater than 10-yr old), they in effect isolate a relative record of sap chemistry. Thus, short-term temporal variability will not have any effect on the older rings during the index period (i.e., June to August) in which the trees are sampled during FHM surveys.

6.8.2.6 Environmental Impact

The collection of increment cores is not thought to affect the tree health. Although the wound caused by boring can provide an entry point for bacterial and fungal infection, the risk of infection appears to be minimal for most tree species (Phipps 1985)(see also Section 6.9.2.6). Trees which have a living bark layer such as aspen may be affected. These species will not be bored during FHM surveys. Also, small diameter trees may be harmed by boring. Only trees over 5 inches in diameter at breast height (DBH) are sampled in FHM studies.

The collection of increment cores does not interfere or adversely affect any other indicators currently in use in FHM surveys.

6.8.3 Summary of Foliar Sampling and Analysis

In brief, the procedure calls for the sampling of two trees on each of two of four subplots (subplots 2 and 4), i.e., 4 trees on each plot. Two increment cores are collected from deciduous or coniferous species of dominant or codominant trees. Specimens are obtained by pushing and turning an increment borer into the sample tree at breast height (1.37 meters above ground). An extractor is used to remove the core from the bit, while the bit is still in the tree. The core is placed in a plastic straw for storage and shipment to the preparation laboratory. Samples are prepared for subsequent ICP or ICP-MS elemental analysis.

6.8.4 Data Analysis

Relative changes in elemental concentrations will be plotted over time to detect regional trends. Low calcium-to-aluminum ratios have been exhibited by red spruce undergoing a decline in growth (Shortle and Smith 1988). This ratio will be examined in relation to certain growth parameters such as increment growth and basal area growth at the plot level.

Riitters et al. (1991a) have examined DRIS indices in stemwood samples. This approach will also be used in the Southeast Demonstration and Western Pilot studies to detect trends in elemental ratios.

6.8.5 1992 Activities

Stemwood samples for stemwood chemistry analyses will be collected during the Southeast Demonstration and Western Pilot (California and Colorado) studies. The same procedures and data analysis approaches will be used in each study.

6.9 Dendrochronology Indicator

T. Droessler

6.9.1 Introduction

Dendrochronology is the systematic study of growth rings in trees to date past events that affect growth. The growth rings are obtained by extracting one or more cores from a tree at a fixed height, usually 1.37 meters, using an increment borer. The sample tree selection and core extraction site protocols are dependent on the goals of the sampling and critical to the success of the sampling (e.g., for tree core chemistry; contamination, and for dendrochronology; dominant or codominant tree). The cores are usually stored in labelled straws and the straws stored in a tube until they can be slowly dried in the laboratory. The preparation includes drying, stabilizing the core by mounting it in a wood strip, and machine and hand sanding of the core so the growth rings are clearly visible on an even, flat surface. Stokes and Smiley (1968) present a formal description of tree core preparation. Cook and Kairiukstis (1990) contains several sections dealing with core handling.

6.9.2 Indicator Evaluation

This section discusses the indicator selection criteria described in Section 6.1 as they apply to the dendrochronology indicator.

6.9.2.1 Interpretability

The policy-relevant assessment endpoints are diameter or volume growth trends. Further, growth and volume relate directly to economic value (timber production, biomass). Annual or periodic growth is measured directly from the cores from raw ring widths. Volume can be calculated if a local growth/yield model is available. A typical volume equation is:

$$\text{Volume} = aD^bH^c$$

where D is diameter at breast height, H is total tree height and a, b, and c are regression coefficients. Tree height may be estimated using a local height model (usually a function of diameter at breast height [DBH] and age). As long as the pith is located on the core, tree age at DBH can be reliably obtained. Total tree height will also be collected for the current year. These data can also be used to test the height estimates from a height growth equation for the current year.

Aggregation to plot level --

If the cores are from the same species and are approximately equal in age and subject to similar growing conditions (evident from the growth trends), the increment data can be pooled and an average annual increment for the plot and species calculated. Master chronologies are frequently developed by pooling data from many trees over a small geographic region. The merits of pooling must be considered on a case by case basis; there is always a danger of confounding a real but weak trend in one or two cores by averaging with cores that do not show the trend.

Cumulative distribution functions and nominal/ subnominal boundaries --

Identifying nominal/subnominal boundaries over a tree core record may be possible. High and low frequency trends are characteristics often used to delineate growth patterns in a tree. Low frequency growth trends occur over several decades, most often associated with stand dynamics (gap dynamics) and long-term trends in climate. High frequency trends are year-to-year changes in growth, most often associated with year-to-year variation in climate. Nominal and subnominal, however, must be considered over decades and centuries of growth records. The benefit of tree core records is that they often cover decades to centuries.

6.9.2.2. Quantification

A record of annual tree growth over the life of the tree can be obtained from one sampling

(assuming a solid core to the center of the tree can be extracted).

Obtaining good quality cores can dramatically improve measurement accuracy and precision and save considerable time and expense. Common quality defects in most increment cores are:

1. Rough, broken core surfaces because of dull borers,
2. Corkscrewing for the first 1 to 2 cm near the bark from a wobbly, free-hand start and directional change, often resulting in broken cores and missing outer rings, and
3. Discoloration and decay because of improper storage.

Dramatic improvements in core quality are possible by following simple instructions, provided the information is comprehensive and includes increment borer selection, the anatomy of increment borers, the basics of the coring procedure, maintenance, and sharpening (Jozsa 1988). Comprehensive training is the key.

A sharp borer, a starting aid, and a core storage container that is easily labelled for each core help minimize the field sampling time and effort required. Two cores 180° apart should be extracted from each sample tree.

The tree ring measurement equipment may vary. The following describes a typical incremental measuring machine used for tree ring width measurement. The measuring equipment consists of a moveable stage on which the mounted, sanded, and crossdated core is placed. Stage movement is controlled by turning a dial. A combination binocular microscope and video camera with cross hairs allows magnification on a monitor screen to aid alignment with the beginning of a growth ring.

The starting position is automatically recorded through a RS232 connection to a personal computer. The stage is moved by turning a dial until the cross hairs align with the end of a growth ring. The end of the growth ring is recorded and the stage travel distance is computed and recorded as the ring width. The end of one growth ring forms the beginning of the next and measurement proceeds until the core is measured from pith to bark.

Cleaning and lubrication of the incremental measuring machine will ensure smooth stage movement for locating beginning and ending ring width positions. Smooth stage movement can improve measurement accuracy and precision and save considerable time and expense.

Standard descriptive statistics will be calculated for each chronology. These include:

1. Mean ring width,
2. Percent missing rings,
3. Standard deviation of ring-width indices,
4. First order autocorrelation (a measure of correlation between adjacent indices), and
5. Mean sensitivity (a measure of relative difference in index values of adjacent rings).

6.9.2.3. High Signal-to-Noise Ratio

Trend detection --

Tree cores can be used to document forest disturbance history and growth trends and interpret recent growth trends as an indicator of forest condition. The interpretation of growth trends includes identification of periodic (low-frequency), yearly (high-frequency), and disturbance patterns. Disturbance can be classified as endogenous and exogenous. Within-stand competition (gap dynamics) or disturbance that causes asynchronous changes in short-term or long-term growth trends is classified as endogenous. Region-level disturbances such as logging, fire, insect, and disease outbreaks that result in synchronous changes in ring width throughout the region are classified as exogenous.

Undisturbed tree growth follows expected growth trends based on age and stand dynamics. Departures from expected growth trends may indicate a change in the condition of the forest. Disturbances also modify expected growth trends of trees and need to be documented before interpretations of departure from expected growth trends can be made.

Disturbance histories have only recently been recorded for many stands and it will take decades before a long disturbance history can be compiled for interpretation of growth trends. Tree cores provide an immediate, long-term disturbance record which allows disturbance effects to be identified as well as interpretation of departures from expected growth trends. Tree growth can be correlated with climate, management, and other disturbances (positive and negative correlation and the subsequent growth patterns that follow).

Natural Annual and Seasonal Variability --

Trends in annual increment are commonly correlated, for example, with stand dynamics, temperature and moisture patterns, and disturbances. Tree rings are often used to reconstruct temperature and moisture patterns.

6.9.2.4. Responsiveness

If there is a common regional signal that affects growth, such as drought or high ozone, the pattern should be present in trees across the region. Much work has been done in reconstructing climate from tree cores, especially in arid and polar regions. A regional climate signal is recorded in tree rings and has been exploited for a variety of species in several regions (Jacoby and Cook 1981; Jacoby and D'Arrigo 1989; Lev 1987; Swetnam et al. 1985).

Climate is known to limit tree species distribution and growth (Ritchie 1985; Currie and Paquin 1987). Limiting climatic factors may vary, but light, moisture, and heat or their interactions are often discussed (Arno and Hammerly 1984; Zeide 1980). A striking and sensitive example of climatic control of species distribution is altitudinal and latitudinal tree line.

Tree rings provide chronologies useful for detecting growth changes in response to climate. The annual variation of radial increment, expressed as the variation coefficient or mean sensitivity, increases in higher latitudes and reaches a maximum at the tree line (Mikola 1962). Garfinkel and Brubaker (1980) used ring-width sequences of white spruce to define climatic limitations on radial growth at the tree line and to reconstruct past climatic variables for Fairbanks, Alaska. Jacoby and D'Arrigo (1989) reconstructed annual northern hemisphere surface temperature departures for the last 300 years using 11 tree-ring chronologies from high-latitude, boreal sites in Canada and Alaska. Hari and Arovaara (1988) document growth changes in northern Finland. Edwards and Dunwiddie (1985) used balsam popular (Populus balsamifera) chronologies from the north slope of the Brooks Range to study response to climate. Lev (1987) used cores from balsam popular from three sites in Alaska, including tree line in the Brooks Range, to relate diameter increment to temperature and precipitation. LaMarche et al. (1984) present tree-ring evidence for growth enhancement in natural vegetation in alpine environments in the western United States.

6.9.2.5. Index Period Stability

An increment core is stable over a day for all but the current year's growth. Dendrometer studies have shown that trees shrink and swell (millimeter) over a day as a response to moisture availability (dendrometers are instruments that record instantaneous growth). Since the current year growth is not measured or used in data analysis, the diurnal variability is not a problem.

An increment core is stable over a growing season for all years except the present. The current year increment would not be measured (or, if measured, not used in data analysis or interpretation). All previous annual increments are fixed, so the current year variability is not a problem.

6.9.2.6. Low Environmental Impact

Increment boring is not a completely harmless sampling technique. The general consensus is that healing of the sample tree progressed satisfactorily when holes were left unplugged. The first stage of the healing process is almost immediate through resin exudation. Next, callus tissue will be formed over the wound with new growth. The dimpled

surface of the stem will become more straight grained with each succeeding growth increment. Repeat borings, however, even years apart, may have a cumulative effect and should be avoided (Jozsa 1988) (see also Section 6.8.2.6).

6.9.3 1992 Activities

The dendrochronology indicator will be used in the Southeast Demonstration project, the SAMAB Demonstration project, and the Western Pilot project.

6.10 Root Evaluation Indicator

S.A. Alexander

6.10.1 Introduction

Root diseases are significant contributors to the decline and mortality of forests. Growth loss due to root diseases has been demonstrated in both conifers and hardwoods (Bradford et al. 1978; Skelly 1974). The pathogens that cause root disease may act alone or in combination with other factors such as drought, insects, and air pollution. Trees under stress are more susceptible to invasion by certain root pathogens (James et al. 1980; Wargo and Houston 1974). A regional increase in root disease over time may indicate widespread environmental or habitat changes. For this reason it is important to establish baseline values for the prevalence of root disease in forests. Unlike aboveground pests, root pathogens are difficult to detect and are often overlooked as contributors to forest condition.

6.10.2 Indicator Evaluation

The following discussion considers the indicator selection criteria described in Section 6.1 as they apply to the root evaluation indicator.

6.10.2.1 Interpretability

Root disease plays an important role in the decline and mortality of forest trees. Trees under stress are more susceptible to invasion by certain root pathogens (James et al. 1980) and an increase in root disease may indicate the occurrence of a long-term environmental stress such as air pollution.

6.10.2.2 Quantification

Root disease is quantified on a stand or plot basis as the proportion of sample trees from which the pathogen is isolated.

6.10.2.3 Signal-to-Noise Ratio

There is no background noise in this indicator. Presence of a root pathogenic fungus within root tissue is an unequivocal indication of disease. There is virtually no seasonal or annual variation associated with root disease in forest trees.

6.10.2.4 Regional Responsiveness

Trees under stress from air pollution or defoliation have been shown to be more susceptible to attack by root disease pathogens (James et al. 1980; Wargo and Houston 1974). Regional increases in root disease incidence over time may indicate widespread environmental or habitat changes.

6.10.2.5 Index Period Stability

Cultural isolation of root disease pathogens is not dependent on seasonal fruiting or sporulation. The vegetative mycelium from which the isolations are made is present throughout the year.

6.10.2.6 Environmental Impact

Some soil disturbance is caused by root excavation. Wounds made on the root during sampling of healthy trees will heal.

6.10.3 Field Measurements

The following method, adapted from Alexander and Skelly (1974), has been used to determine the presence of root disease in a survey mode from 1988-1991 in the Visual Damage Survey and the Forest Health Monitoring (FHM) program (Alexander and Carlson 1988, 1989, 1991).

The two-root method involves direct sampling of two roots of a sample tree. Root samples are collected from one pair of sample trees at each of two sub-plots per hexagon. The sample trees are the same trees from which increment cores, and branch and foliar

nutrient samples are taken. Two root samples from each of two roots per tree are collected.

Two primary roots on opposite sides of the tree are excavated to a length of one meter. The bark is examined for signs and symptoms of disease and injury which are recorded. A knife is used to peel back several 2.5-cm sections of bark so the wood underneath can be examined and symptoms recorded. If symptomatic roots are found, a wedge of wood approximately 3 x 3 x 3 cm is taken from the symptomatic area. If no symptoms are found, the samples are taken 15 cm and 30 cm from the root collar. The equipment is disinfected with a bleach solution between each tree. All soil removed from the roots is replaced. The root samples are bagged, labeled, and shipped, on ice, to the Forest Pathology Laboratory at Virginia Polytechnic Institute and State University (VPI&SU).

6.10.4 Data Analysis

Root samples are logged in when received at the Forest Pathology Laboratory at VPI&SU and refrigerated until processed. Samples are washed for five minutes under running tap water to remove dirt and debris. Blocks of wood 1 x 1 x 1 cm are aseptically removed and plated onto general and specific media. After 21 and 60 days of incubation, the plates are examined for root pathogens.

6.10.4 1992 Activities

Plans for the 1992 field season include sampling approximately 70 plots during the 1992 Southeast Demonstration project.

6.11 Photosynthetically Active Radiation (PAR) Indicator

J.G. Isebrands and S.J. Steele

6.11.1 Introduction

Measurements of solar radiation intercepted by the canopy are fundamental to the interpretation of the productivity and function of plant communities (Norman and Campbell 1989). Photosynthetically active radiation (PAR) is the quantity of light between the 400-700 nm wavelengths of the spectrum, and is the part of the spectrum used by plants for photosynthesis. The percentage of PAR transmitted by a plant canopy can be estimated by the ratio of PAR under the canopy to ambient incoming PAR. This ratio can be related to canopy condition and combined with growth measurements to estimate growth efficiency, an important indicator of forest health (Waring and Schlesinger 1985). Photosynthetically active radiation can also be combined with companion measurements of vegetation structure (VS), crown transparency, and/or remote-sensing data to assess canopy condition with a multivariate indicator approach.

In the past, reliable measurements of transmitted solar radiation were difficult to achieve on the ground, and were typically characterized by significant temporal and spatial variability. For example, ambient PAR measurements can vary depending upon cloud conditions, time of day, and solar angle (i.e., location and season). However, this variability can be minimized by following a protocol that consists of a narrow sampling window combined with adjustments for cloudiness.

6.11.2 Definitions

Photosynthetically active radiation (PAR) is the visible portion of the light spectrum between 400 - 700 nm and is that part of the spectrum utilized by plants for photosynthesis. PAR is expressed in umol $m^{-2}s^{-1}$ (SI unit).

Transmitted PAR is the quantity of PAR measured under the canopy divided by the quantity of PAR measured in the open (or above the canopy). Transmitted PAR is expressed as a percentage, and is the percentage of incoming radiation transmitted through the canopy.

Beam fraction is defined as 1 minus (shaded PAR in the open/unshaded PAR in the open). Beam fraction is used here as an index of cloudiness.

Leaf area index (LAI) is the quantity of leaf surface area of a plant canopy per unit of land area. LAI is expressed in m^2/m^2 (or without units). The LAI is often used in ecological modeling as a quantitative measure of canopy structure.

6.11.3 Summary of Method

Photosynthetically active radiation is measured with specialized quantum sensors that measure solar radiation in the 400-700 nm waveband. Ambient PAR is measured with two independent quantum sensors placed in a nearby open area and connected to a datalogger. One quantum sensor is shaded, and one is left in full sun. The shaded quantum sensor measures diffuse PAR used to determine beam fraction, an indicator of cloudiness. Under-canopy PAR is measured with the Ceptometer, which has a wand with a linear array of 80 quantum sensors coupled to an internal integrating datalogger. Under-canopy and ambient PAR are measured in synchrony in order to estimate transmitted PAR and leaf area index.

The PAR measurements are made during a standard sampling window from 1100 hrs to 1300 hrs (standard zone time, i.e., 1200 and 1400 daylight time). This measurement window ensures accurate measurement of the percentage of transmitted PAR that depends on solar angle and is a function of time of day.

The PAR measurements are made on a grid of sample points on a 4 fixed area subplot cluster (Figure 6.11-1) for several

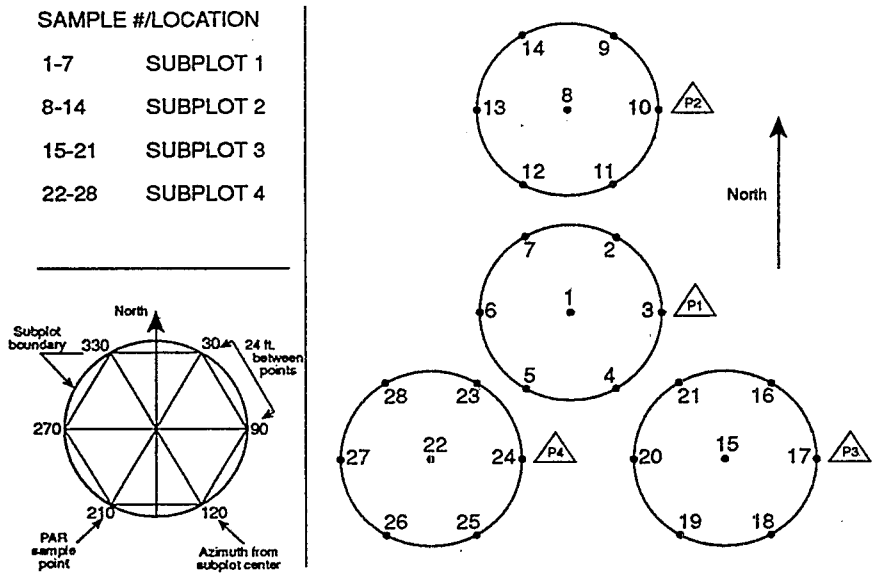

Figure 6.11-1. PAR sampling scheme for Western Pilot Study in 1992. Subplot example on left shows sampling point layout according to azimuth. Diagram on right shows 7 point grid for each subplot of the 4 fixed area subplot cluster. A total of 28 points will be sampled per location.

reasons. First, a grid allows remeasurement of sample points for quality control (QC) comparisons. Second, other indicator measurements such as VS are made at the same grid locations so that these different measurements can be compared and correlated. The grid system also allows the estimation of spatial and temporal variability of PAR, and scaling up from the subplot level to the plot level.

6.11.4 Indicator Selection Criteria

6.11.4.1 Interpretability

Transmitted PAR as defined above (hereafter, PAR) is a very versatile indicator in that it can be used as an indicator of canopy condition and to estimate LAI, an indicator of crown structure (Burton et al. 1991). In addition, PAR can be combined with a suite of canopy indicators to produce a "canopy condition index". Photosynthetically active radiation has also been used as an indicator of "growth efficiency" on plots that are remeasured during subsequent years (Waring and Schlesinger 1985).

Photosynthetically active radiation is easily aggregated to the plot level, but also has utility for assessing variability on a site through examination of subplot means and variances. Photosynthetically active radiation is useful in assessing canopy condition related to stressors such as air pollution, water stress, insect and diseases, wind, and other crown-related stresses. Any increase in transmitted PAR over time at a subplot or plot level signals a change in canopy condition.

6.11.4.2. Quantification

Photosynthetically active radiation is measured with fully automated data logging equipment on a minute-by-minute basis for a 2 hr measurement window in one day. Transmitted PAR, expressed as a percent, is easily calculated by dividing PAR measured with a ceptometer under the canopy by PAR measured in the open (ambient) with a quantum sensor and multiplying by 100

(Russell et al. 1989). The two independent measures of PAR are measured synchronously on site and then transferred to a data file at the end of the day. In fact, transmitted PAR and its variance could easily be available at the end of each sample day using a simple software program.

Photosynthetically active radiation equipment is reliable when standard factory equipment is used. Audits of PAR during the 1991 Georgia and Western Pilots showed that measurement error is 10% or less when an auditor remeasured PAR immediately after the crew member. Some of this error may be related to temporal differences. Potential errors in PAR are associated with variable cloudiness, but PAR values can be adjusted for cloudiness and sun angle to improve data reliability. Photosynthetically active radiation, however, cannot be measured in heavy rain.

6.11.4.3. Signal-to-Noise Ratio

Presently, transmitted PAR has a high signal-to-noise ratio when standard factory equipment is used during the 12:00 to 2:00 p.m. measurement window on clear days during the standard field season between June 1 and September 1. However, cloudiness and sun angle affect PAR over an annual cycle. Cloudiness effects, which may vary with site depending upon the quantity of diffuse light, and sun angle effects are well documented (Larcher 1980). Cloudiness index is automatically measured with the ambient PAR station by simply integrating ambient PAR over the measurement period. This index can be used as a covariate for analysis or regression can be used to adjust PAR to improve signal-to-noise ratio. Another avenue greatly reduces signal-to-noise ratio. This approach uses transmitted PAR, beam fraction (Figure 6.11-2) (a measure of cloudiness) and sun angle to estimate LAI for each Forest Health Monitoring (FHM) plot. The LAI is an important measure of canopy structure that can be used to assess stressor effects on canopies (Norman and Campbell 1989). We have investigated using an estimate of LAI for a diurnal and annual cycle in off-frame studies and found that LAI estimated from PAR is very stable over the day and season and with different cloud conditions (see Tables 6.11-1, 6.11-2, 6.11-3, and 6.11-4).

6.11.4.4. Regional Responsiveness

In 1991 PAR was tested on-frame on a large number of forest types in Georgia in the Landscape Pilot Field Study and in the Western Pilot Study in Colorado and California (see attached supporting data). It was also studied in Wisconsin, Michigan, North Carolina, Tennessee, and Idaho at interregional off-frame research sites. Standard PAR equipment was reliable at all of the above sites. Adjustments for cloudiness and sun angle make PAR responsive to all locations in the country at any time during the field season. Photosynthetically active radiation can be quantified easily at the subplot, plot, state, subregional, or regional levels. Similarly, LAI estimated from PAR can be aggregated to any of these levels.

6.11.4.5. Index Period Stability

Presently, PAR is measured between 12:00 and 2:00 p.m. to ensure stability over the "index period". The window centered around solar noon ensures minimal sun angle effects on the PAR measurements. Measuring PAR between June 1 and September 1 may be necessary to ensure that full canopy development has occurred for the season. Any indicator of canopy condition will naturally have to be measured during the summer field season to minimize effects of autumnal leaf abscission. If one measures transmitted PAR outside the daily and seasonal index periods, errors can result.

6.11.4.6. Environmental Impact

The PAR indicator measurement has minimal environmental impact, except where the PAR crew member tramples the understory vegetation while making the measurement. In 1991 there were 19 sampling points per

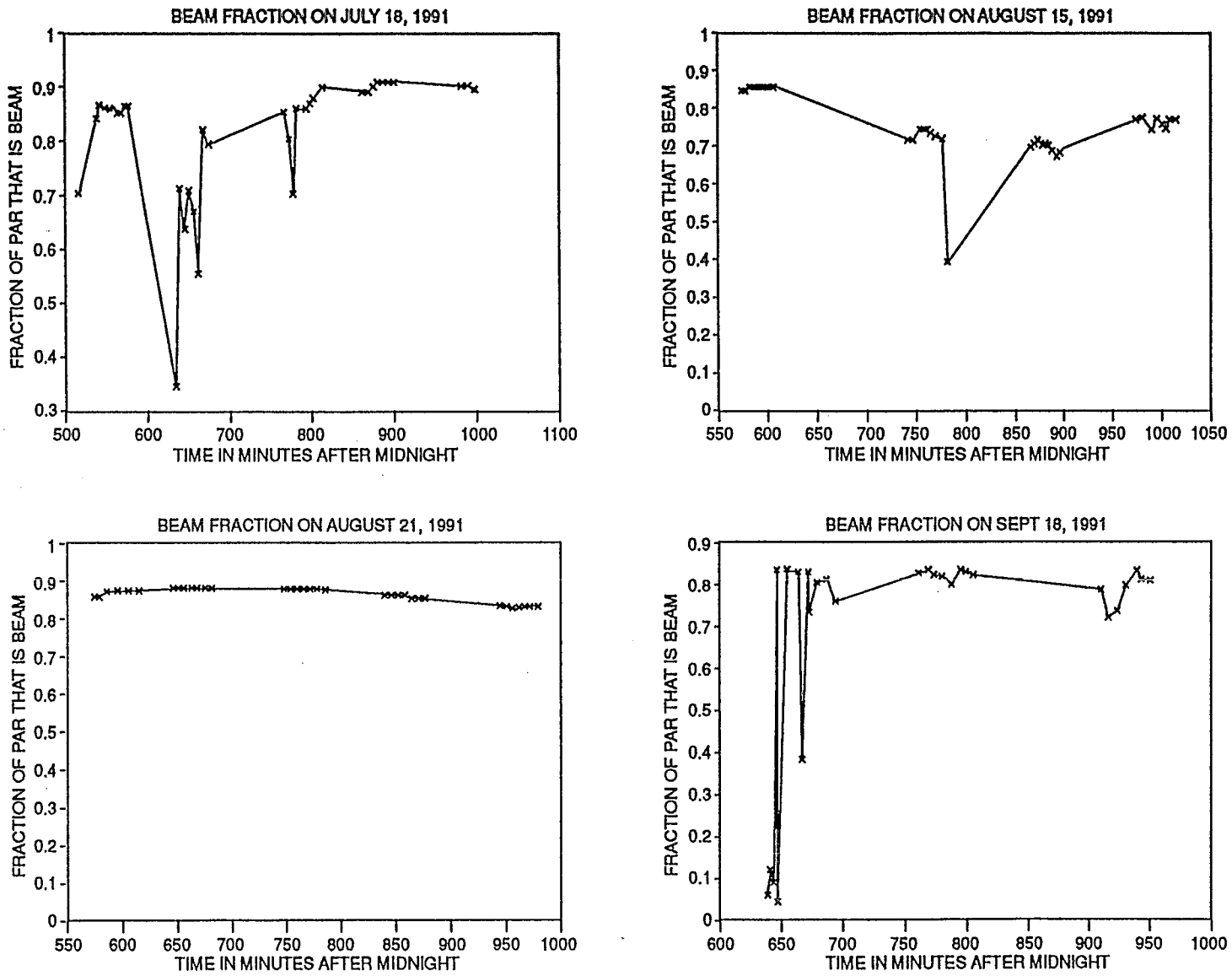

Figure 6.11-2. Beam fraction for four different dates.

TABLE 6.11-1. PLOT SUMMARY FOR PAR INDICATOR-EMAP FHM 1991 GEORGIA PILOT

PLOT #	HEX #	DATE SAMPLED	NEAREST TOWN	FOREST TYPE	CLOUDINESS INDEX INTEGRATED PAR/HOUR 1200-1400 HRS
1	3408521	6-17	Wax, GA	Oak-Gum-Cyp	102585
2	3408435	6-19	Canton, GA	Oak-Pine, Oak-Hickory	69524
3	3308385	6-25	Bogart, GA	Oak-Pine, Oak-Hickory	44172
4	3308481	6-30	Lilburn, GA	Loblolly	57274*
5	3308476	7-1	Lithia Spr., GA	Oak-Pine, Oak-Hickory	103845*
6	3308563	7-2	Budapest, GA	Loblolly	98646
7	3308318	7-8	Forsyth, GA	Oak-Gum-Cyp.	57513
8	3208365	7-9	Huber, GA	Loblolly	112296
9	3208571	7-13	Jones Crossroads, GA	Loblolly	73166
10	3108368	7-19	Doles, GA	Loblolly	114347
11	3108551	7-22	Bluffton, GA	Loblolly	82615*
12	3108431	7-23	Greenough, GA	Oak-Pine, Oak-Hickory	89370*
13	3008467	7-24	Recovery, GA	Oak-Pine, Oak-Hickory	71676

*Ambient station on less than 1 hour - value extrapolated to 1 hour

TABLE 6.11-2. EMAP-FHM-1991 GEORGIA PILOT MEANS OF % TRANSMITTED PAR (19 Pts vs 7 Pts)

Plot #	No. of Sample Points	Sub-plot 1[1]	Variance[8]	Sub-plot 2	Variance	Sub-plot 3	Variance	Sub-plot 4	Variance	# Of Points	Total Plot	Variance	Sky Cond.[9]	Forest Type Group[10]
1	19 7	49.1 (6.1) 45.9 (14.0)	[1252.3] [1372.5]	7.9 (1.0) 7.7 (1.6)	[19.2] [17.1]	14.4 (5.9) 10.6 (5.3)	[657.9] [196.6]	92.7 (1.4) 91.4 (2.6)	[38.1] [45.4]	76 28	41.0 (4.6) 38.9 (7.4)	[1624.1] [1549.7]	2	600
2	19 7	13.1 (3.7) 15.6 (8.7)	[258.3] [535.3]	14.5 (2.8) 14.7 (4.0)	[144.1] [114.1]	19.2 (2.0) 16.1 (2.6)	[77.7] [46.2]	20.3 (3.3) 22.5 (6.7)	[203.5] [315.3]	76 28	16.8 (1.5) 17.2 (2.9)	[173.6] [234.8]	2	400/ 500
3	19 7	5.8 (0.1) 6.0 (0.2)	[0.3] [0.2]	4.6 (0.1)[2] 4.8 (0.1)[3]	[0.1] [0.1]	7.8 (0.2) 7.2 (0.4)	[0.7] [1.1]	9.6 (0.4) 8.3 (0.4)	[2.5] [1.1]	70 26	7.2 (0.3) 6.7 (0.3)	[4.4] [2.3]	3	400/ 500
4	19 7	4.7 (0.4) 4.8 (0.6)	[2.4] [2.3]	6.2 (0.4) 5.4 (0.5)	[2.6] [1.8]	[11]		4.4 (0.2)[4] 4.4 (0.4)[5]	[0.5] [0.9]	54 20	5.1 (0.2) 4.9 (0.3)	[2.5] [1.7]	2	300
5	19 7	30.9 (5.5) 37.4 (8.7)	[573.4] [531.6]	4.5 (0.5) 5.7 (1.1)	[5.2] [8.7]	19.3 (3.7) 14.9 (6.5)	[259.3] [298.4]			57 21	18.2 (2.6) 19.3 (4.6)	[387.6] [437.6]	2	400/ 500
6	19 7	17.7 (3.2) 19.3 (6.0)	[190.4] [247.5]	8.8 (1.6) 4.4 (0.5)	[45.5] [1.9]	30.5 (5.4) 44.1 (8.6)	[542.9] [509.0]	21.1 (4.6) 28.2 (8.7)	[393.9] [526.3]	76 28	19.5 (2.1) 24.0 (4.2)	[343.0] [500.7]	2	300
7	19 7	4.7 (0.3) 4.7 (0.5)	[1.4] [1.6]	6.9 (0.2) 6.6 (0.4)	[1.1] [1.3]	5.6 (0.3) 5.6 (0.3)	[1.6] [0.6]	7.5 (0.2) 7.4 (0.2)	[0.5] [0.4]	76 28	6.2 (0.2) 6.1 (0.3)	[2.3] [1.9]	2	600
8	19 7	53.9 (9.0) 65.7 (14.3)	[1538.1] [1428.9]	23.5 (3.8)[4] 22.2 (6.9)[3]	[225.4] [237.9]	54.6 (9.5)[6] 45.0 (13.5)[3]	[1092.4] [914.8]	23.8 (5.0) 27.6 (11.4)	[477.0] [916.6]	66 24	38.0 (4.0) 41.2 (6.9)	[1030.6] [1133.0]	2	300
9	19 7	26.6 (3.8) 18.6 (3.4)	[268.2] [81.45]			19.5 (1.0) 20.5 (1.8)	[18.4] [22.1]	9.0 (0.6) 10.2 (1.1)	[7.7] [8.5]	57 21	18.4 (1.6) 16.4 (1.6)	[148.0] [54.2]	2	300
10	19 7	47.5 (5.2) 48.3 (5.1)	[513.3] [183.0]	48.5 (6.2) 45.2 (10.8)	[734.9] [818.9]	66.8 (5.2) 70.1 (8.7)	[508.3] [524.7]	80.0 (8.0)[7] 85.0 (14.4)[3]	[959.4] [1041.8]	72 26	59.6 (3.4) 60.4 (5.5)	[809.3] [787.0]	2	300
11	19 7	40.2 (4.3) 40.1 (9.3)	[349.7] [599.5]	28.0 (3.4) 32.3 (8.0)	[216.3] [448.0]	46.9 (2.8) 41.2 (3.1)	[153.2] [68.2]			57 21	38.4 (2.3) 37.9 (4.1)	[293.3] [351.3]	2	300
12	19 7	41.4 (5.9) 40.3 (9.9)	[666.5] [692.1]	30.2 (4.8) 27.3 (2.7)	[434.8] [49.2]	43.3 (5.0) 54.9 (8.4)	[475.1] [488.2]	26.1 (4.0) 25.3 (5.2)	[300.0] [185.5]	76 28	35.3 (2.6) 37.0 (4.1)	[504.2] [459.7]	1	500
13	19 7	78.5 (4.0) 75.3 (9.4)	[308.4] [619.2]	93.6 (2.8) 89.1 (5.6)	[144.7] [219.4]	54.6 (3.1) 49.1 (5.7)	[184.1] [229.2]	68.8 (2.6) 70.8 (3.9)	[124.0] [106.8]	76 28	73.9 (2.3) 71.1 (4.1)	[387.4] [474.2]	3	400/ 500

[1] Number in parenthesis is the standard error of the mean
[2] # of Sample Points = 13
[3] # of Sample Points = 5
[4] # of Sample Points = 16
[5] # of Sample Points = 6
[6] # of Sample Points = 12
[7] # of Sample Points = 15
[8] Number in brackets is the variance of the mean
[9] Sky Condition Codes: 1 = clear, 2 = some clouds, 3 = overcast
[10] Forest Type Group: 300 = loblolly/shortleaf pine; 400/500 = upland hardwoods; 600 = oak/gum/cypress
[11] Nonforest plot

TABLE 6.11-3. EMAP FHM 1991 WESTERN PILOT--PLOT SUMMARY

PLOT #	HEX #	DATE SAMPLED	NEAREST TOWN	FOREST TYPE	CLOUDINESS INDEX INTEGRATED PAR/HOUR 1200-1400 HRS
1	9111111	8-1	Georgetown, CA	Ponderosa Pine	118849
2	2222222	8-2	Georgetown, CA	Mixed Evergreen	117367
3	3812062	8-5	Kirkwood, CA	Jeffrey Pine	118184
4	3812041	8-7	Kirkwood, CA	California Red Fir	120801
5	3812021	8-9	Strawberry, CA	Ponderosa Pine/ California Black Oak	114586
6	3711983	8-12	Tioga Pass, CA	Lodgepole Pine	46474
[1]	3333333	8-13	Crane Flat, CA	Sequoia	40735
7	3710731	8-20	Pagosa Springs, CO	Ponderosa Pine	116360
8	3710724	8-21	Piedra, CO	Doug.Fir/Pond. Pine	116677
9	3710743	8-22	Vallecito, CO	White Fir	17305
10	3710844	8-23	Delores, CO	Ponderosa Pine	121678
[1]	3710832	8-26	Mancos, CO	Aspen/Scrub Oak	--
11	3710728	8-27	Durango, CO	Pinyon Pine	125792
12	3710799	8-28	Purgatory, CO	Spruce/Fir	24427

[1]Complete PAR not measured.

subplot for a total of 76 sample points per plot, thereby creating the potential for understory damage. In 1992 the number of PAR sampling points has been reduced to 7 per subplot and a total of 28 per plot without seriously affecting the estimate (see attached supporting data). This change will substantially reduce the amount of time spent making PAR measurements and greatly reduce the number of sample points affected.

6.11.5 Data Analysis

Photosynthetically active radiation is a promising indicator. It is attractive because it can be used simultaneously as an indicator of canopy condition in the form of transmitted PAR or it can be used to estimate LAI while taking into account cloudiness and sun angle. The LAI estimates can be used as ground truth for aerial photography or remote-sensing data. Photosynthetically active radiation can also be used to estimate growth efficiency if there is remeasurement of sites in subsequent years. Another promising approach might be to combine PAR with other crown-related indicators such as vegetation structure, crown transparency, or mensurational variables to produce a "crown index" indicator of forest health.

6.11.6 1992 Activities

The PAR indicator will be a part of the SAMAB Demonstration project and the Western Pilot project.

TABLE 6.11-4. EMAP-FHM-1991 WESTERN PILOT MEANS OF % TRANSMITTED PAR (19 Pts vs 7 Pts)

Plot #	No. of Sample Points	Sub-plot 1[1]	Variance[2]	Sub-plot 2	Variance	Sub-plot 3	Variance	Sub-plot 4	Variance	# Of Points	Total Plot	Variance	Sky Cond.[3]	Forest Type Group[4]
1	19	17.8 (4.4)	[374.3]	27.7 (7.4)	[1025.7]	22.7 (5.0)	[472.3]	10.3 (1.9)	[71.6]	76	19.8 (2.6)	[508.6]	1	000
	7	14.2 (6.1)	[259.3]	30.8(13.4)	[1258.5]	30.9 (8.9)	[548.8]	11.1 (2.2)	[33.9]	28	21.8 (4.5)	[554.1]		
2	19	5.8 (1.4)	[35.4]	8.1 (2.8)	[143.4]	25.1 (5.5)	[572.7]	19.9 (5.2)	[503.5]	76	14.7 (2.2)	[366.4]	1	990
	7	5.7 (1.5)	[15.4]	12.5 (7.4)	[381.0]	27.2 (11.0)	[847.5]	28.4 (12.7)	[1135.9]	28	18.5 (4.7)	[625.2]		
3	19	86.9 (5.6)	[594.9]	46.6 (8.1)	[1231.6]	47.7 (7.6)	[1105.4]	36.9 (8.2)	[1262.1]	76	54.5 (4.3)	[1378.7]	1	000
	7	93.6 (2.0)	[29.1]	39.7 (14.6)	[1485.8]	38.9 (10.3)	[735.0]	34.6 (15.6)	[1711.1]	28	51.7 (7.3)	[1492.2]		
4	19	14.6 (4.7)	[412.6]	33.4 (7.8)	[1147.6]	19.9 (4.7)	[422.5]	21.4 (2.8)	[607.9]	76	17.8 (4.2)	[333.5]	1	100
	7	24.2 (11.8)	[976.4]	29.5 (14.4)	[1447.9]	16.6 (6.8)	[318.7]	19.9 (9.6)	[649.5]	28	22.6 (5.3)	[778.1]		
5	19	58.3 (8.5)	[1355.4]	15.8 (2.6)	[127.5]	62.5 (7.6)	[1105.6]	50.7 (8.6)	[1391.4]	76	46.8 (4.1)	[1298.5]	1	000
	7	66.9 (15.5)	[1673.5]	20.7 (6.2)	[265.3]	42.1 (12.7)	[1134.9]	53.0 (15.0)	[1578.4]	28	45.7 (6.9)	[1329.0]		
6	19	36.4 (1.2)	[27.06]	72.4 (3.7)	[254.8]	35.9 (2.0)	[75.6]	74.1 (4.8)	[434.9]	76	54.7 (2.7)	[539.3]	3	000
	7	36.4 (2.2)	[34.04]	69.6 (7.2)	[361.1]	38.1 (4.4)	[134.6]	70.6 (10.4)	[754.4]	28	53.7 (4.5)	[565.2]		
7	19	36.6 (7.0)	[942.5]	38.7 (6.9)	[903.1]	52.7 (8.5)	[1383.6]	43.8 (7.4)	[1051.2]	76	42.9 (3.8)	[1066.5]	1	000
	7	30.6 (12.0)	[1003.4]	44.0 (11.7)	[950.2]	43.8 (13.3)	[1237.3]	43.2 (12.7)	[1121.9]	28	40.4 (6.0)	[991.4]		
8	19	33.4 (6.4)	[771.9]	22.4 (5.2)	[510.2]	20.2 (2.9)	[159.8]	26.1 (4.9)	[464.3]	76	25.5 (2.5)	[482.6]	1	100
	7	39.1 (10.1)	[718.5]	33.2 (12.4)	[1081.2]	22.6 (5.7)	[223.2]	21.8 (8.8)	[539.4]	28	29.2 (4.7)	[624.5]		
9	19	51.1 (3.6)	[244.8]	41.8 (3.2)	[193.2]	29.1 (1.8)	[59.2]	72.8 (2.9)	[154.9]	76	48.7 (2.3)	[414.6]	3	100
	7	50.7 (6.9)	[333.0]	44.1 (6.0)	[252.6]	29.6 (3.8)	[103.5]	70.5 (6.4)	[289.3]	28	48.7 (4.0)	[441.4]		
10	19	40.9 (6.0)	[673.5]	36.5 (7.1)	[961.9]	74.2 (6.6)	[830.1]	46.7 (7.3)	[1013.4]	76	49.6 (3.7)	[1052.5]	1	000
	7	44.1 (12.0)	[1008.0]	41.7 (12.2)	[1044.7]	73.3 (12.1)	[1018.2]	50.9 (13.5)	[1280.3]	28	52.5 (6.4)	[1127.6]		
11	19	72.7 (5.3)	[531.5]	73.6 (4.6)	[400.3]	74.1 (5.3)	[529.2]	83.7 (2.7)	[137.2]	76	76.0 (2.3)	[403.9]	1	000
	7	72.4 (11.2)	[884.9]	69.3 (10.4)	[753.3]	66.2 (11.6)	[936.3]	86.4 (2.1)	[32.1]	28	73.6 (4.8)	[641.2]		
12	19	22.0 (1.0)	[19.3]	24.2 (1.8)	[62.2]	26.2 (1.6)	[47.2]	19.8 (2.0)	[77.4]	76	23.1 (0.9)	[55.2]	3	100
	7	21.3 (1.4)	[13.0]	24.3 (3.4)	[81.8]	27.0 (2.9)	[57.5]	24.1 (4.0)	[109.8]	28	24.2 (1.5)	[62.5]		

[1] Number in parenthesis is the standard error of the mean
[2] Number in brackets is the variance of the mean
[3] Sky condition codes: 1 = clear, 2 = some clouds, 3 = overcast
[4] Forest Type Group: 000 = pine, 100 = spruce/fir, 990 = mixed evergreen

6.12 Vegetation Structure Indicator

S. Cline

6.12.1 Introduction

Development of a vegetation and habitat structure indicator is part of an ongoing effort to select, develop, and test indicators of the status and trends of biodiversity in US forests. Biodiversity refers to the identity (composition) of biotic and abiotic elements and their structure (abundance and spatial arrangement), and the associated ecological processes (functions) at several levels of biological organization (genetic, population and species, community and ecosystem, and landscape and region) (Noss 1990, Figure 6.12-1).

Biotic diversity is at risk from six major types of threats:

1. Direct population reduction;
2. Physical alteration of habitats;
3. Chemical and solid waste pollution;
4. Global atmospheric change;
5. Introduction of alien species; and
6. Cumulative or multiplicative effects of interactions among these major threats (U.S. EPA 1990).

Monitoring effects on biotic diversity due to physical alteration of habitats is an initial focus of Forest Health Monitoring (FHM) because physical habitat alteration is an immediate concern (it was identified as the greatest threat to bird diversity [U.S. EPA 1990]), and may exacerbate the potential impacts of future climate change.

Initial efforts to develop and test biodiversity indicators for FHM have focused upon the plant kingdom and in particular upon vegetation structure and its role as a component of habitat structure. Vegetation structure is defined as the composition of vegetation (e.g., species, growth forms, forest type) and its structure (e.g., relative abundance as cover or area and spatial arrangement such as vertical stratification, canopy height and cover, or patch configuration). Habitat structure is the physical arrangement of biotic and abiotic elements in the environment that influences the distribution and abundance of animals at a particular scale (McCoy and Bell 1991). For example, a forest structure of oak-gum-cypress in the southeastern United States would indicate a swamp or wetland forest habitat containing moisture-sensitive flora. This forest structure, plus the presence of standing water and snags near water, would constitute a habitat structure potentially suitable for the prothonotary warbler.

An initial ecological risk assessment model of the effects of physical alteration of habitats on vegetation and habitat structures has been developed (Figure 6.12-2). In this model, heterogeneity and complexity of vegetation is the assessment endpoint for the environmental and societal value of biodiversity. The model shows that habitat alteration affects several organizational levels and, consequently, numerous candidate indicators might legitimately be measured depending upon the scale of assessment (Table 6.12-1). Figure 6.12-2 also shows that these scales are linked hierarchically. For example, a species-rich, multilayered forest may not have long-term biotic integrity if it exists as a forest patch surrounded by agricultural land; likewise a large area of forest cover may be biologically impoverished if it is dominated by young age classes of single-species plantations.

6.12.2 Indicator Evaluation

Although a comprehensive assessment of biodiversity requires measurements at several levels of biological organization (Table 6.12-2), this section focuses upon the evaluation of ground-based measurements. Even though one may be able to substitute some remote-based measurements of vegetation and habitat structure for ground-based measurements, some ground-based measurements will probably always be needed to: (1) supply data on response indicators that cannot be assessed remotely (e.g., species identification is unlikely using remote data, especially in the forest understory where most of the species are concentrated); and (2) to provide ground-truth as relationships between

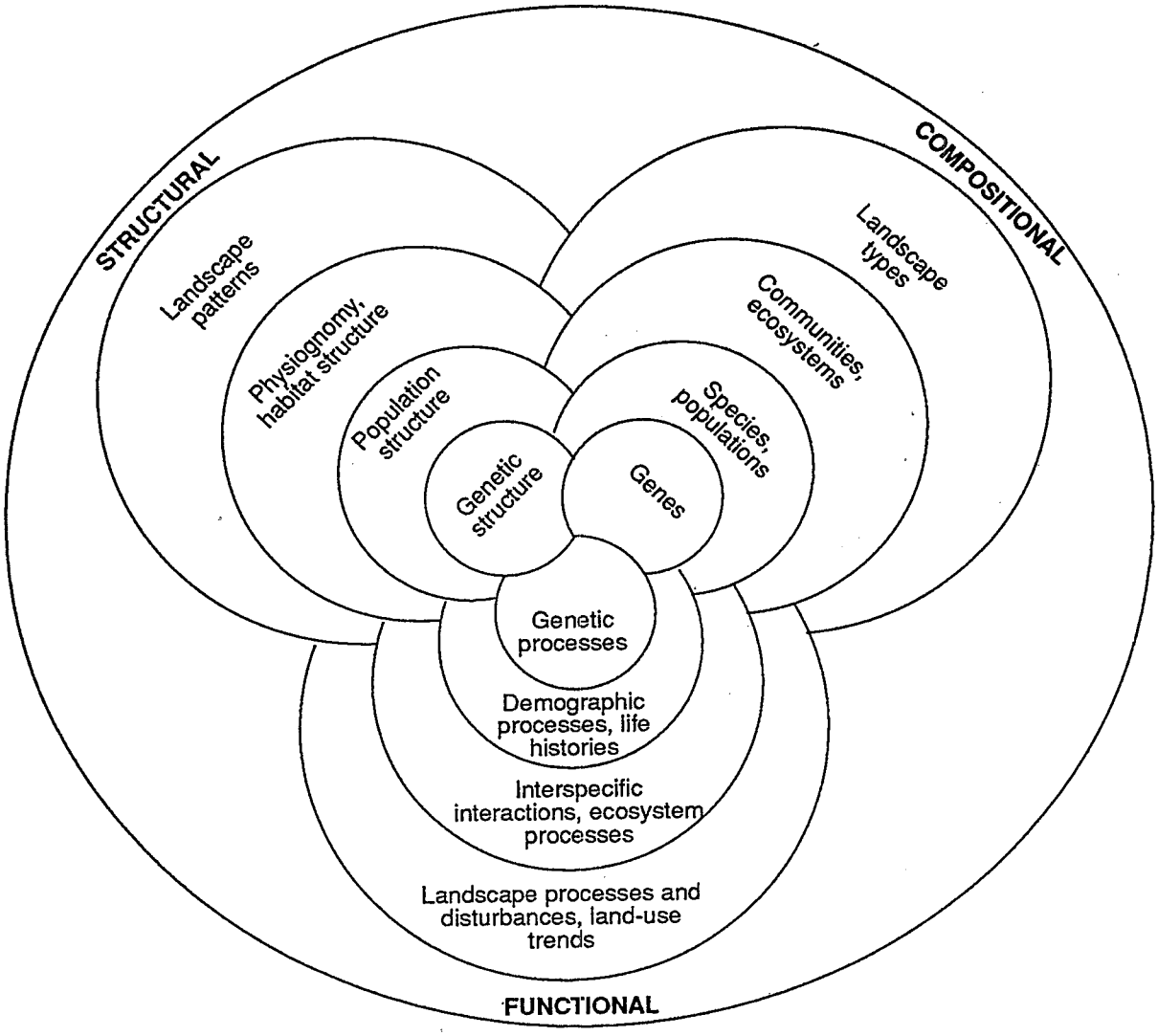

Figure 6.12-1. Biodiversity defined at several levels (Noss 1990).

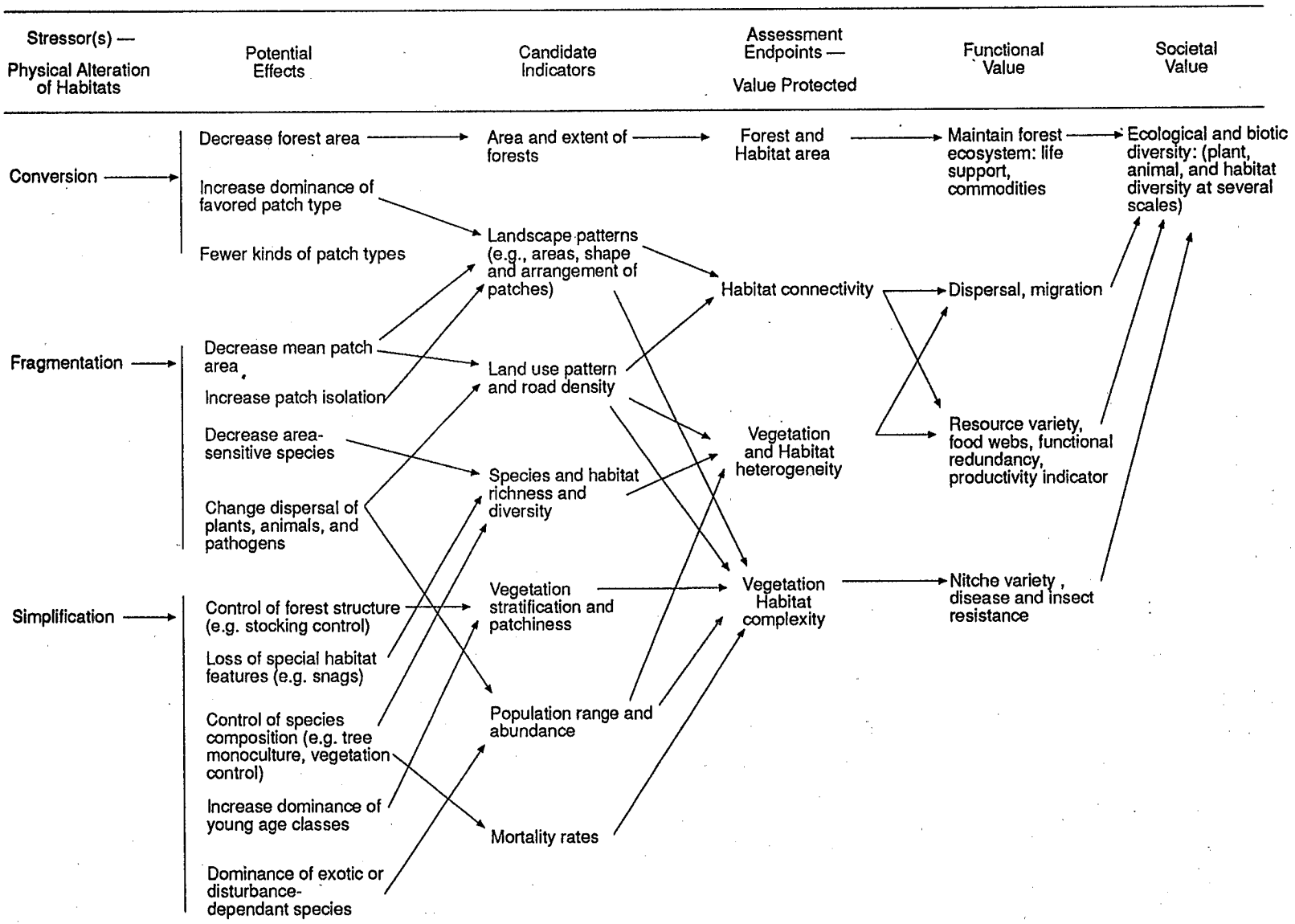

Figure 6.12-2. Forest health monitoring ecological assessment model for biotic diversity.

TABLE 6.12-1. RESPONSE INDICATIORS OF BIOTIC DIVERSITY

A. **Course patch delineation** - Landscape and Region level (by source and person/organization)
Remote-based variables (from small-scale [1:45,000] photos, EPA Environmental Photographic Interpretation Center)

- Forest area by class (conifer, deciduous, mixed).
- Land area by use type.
- Landscape pattern (area, shape, juxtaposition, and conductivity of patches).

B. **Fine patch delineation based on external features** - Community and Ecosystem level (by source and person/organization)
Remote-based variables (from large-scale [1:16,000 or 12,000] photos/EPA Environmental Photographic Interpretation Center)

- Subdivision of patches by forest type.
- Subdivision of patches by tree density and height.
- Overstory cover, roughness, and patchiness.
- Location and area of ecotones.
- Number of vertical strata.

C. **Fine patch characterization based on internal features** - Population, and species level (by source and person/organization)
Ground-based variables from 24-ft radius subplots, FIA

- Tree species.
- Tree diameter and basal area.
- Tree density.

Ground-based variables from pole and quadrat methods

- Profile of understory vegetation cover.
- Patchiness of understory vegetation cover.
- Canopy cover.
- Species and growth-form composition.
- Species richness.

remote and ground measurements are developed.

The following discussion considers the indicator selection criteria described in Section 6.1 as they apply to the vegetation structure indicator.

6.12.2.1 Interpretability --

Maintenance of the heterogeneity and complexity of vegetation and habitats is a socially relevant assessment endpoint because significant homogenization and simplification of vegetation structure within a region would have a negative influence on biodiversity conservation (Figure 6.12-2). Conservation and maintenance of animal and plant species diversity has been identified as an important public value. The connection between diverse vegetation structure and diverse wildlife communities is reflected in numerous existing public laws. Notably, maintenance of diverse habitats in the form of plant communities and

special habitat elements figure prominently in most wildlife conservation laws (DeGraaf and Rudis 1983).

Changes in the value of the vegetation structure indicator (response indicator) will be used to track the status and trends of the heterogeneity and complexity of vegetation and habitats (assessment endpoint). This response indicator is closely connected to the assessment endpoint. For example, the elements of heterogeneity and complexity of vegetation include:

- Richness (the number of different plant species and habitat elements per sample).
- Evenness (the relative abundance of species and habitats within the sample).
- Diversity (i.e., heterogeneity, synthetic measures that are sensitive to both richness and equitability).
- Pattern diversity (the amount of cover and its vertical [stratification] and horizontal [patchiness] arrangement).

Field measurements made for the vegetation structure indicator provide the new data to quantify each of these elements of heterogeneity and complexity of vegetation. This is very close to meeting the recommendation of Chapman (1991) that measurement endpoints (essentially response indicators) and assessment endpoints be the same.

The vegetation structure indicator provides evidence of a relevant and meaningful ecological condition (heterogeneity and complexity of vegetation) and is subject to environmental and anthropogenic stress. Vegetation composition and profile is an element of the diversity of plant communities and is positively correlated with animal and plant species richness and diversity (e.g., MacArthur and MacArthur 1961; Willson 1974; Dueser and Shugart 1978; August 1983). Moreover, structurally simple forests are less tolerant of biotic stresses such as disease and insect attacks (Schmidt 1978; Knight and Heikkenen 1980). Furthermore, vegetation structure is commonly exposed to and changed by anthropogenic stresses such as air pollution, land use changes, and forest management practices. For example, under high ozone doses, ponderosa pine ecosystems have been simplified in species composition and converted to more resistant seral stages with little vertical stratification (Miller and McBride 1975). Forest profile is also routinely manipulated by forestry practices such as logging, plantation establishment, thinning, prescribed fire, scarification, and herbicide application. In some situations forest structure may be greatly simplified, such as when mixed-species forests are cleared and replaced by pine plantations, resulting in impoverished flora and fauna relative to native forests (Atkeson and Johnson 1979; Repenning and Labisky 1985; Childers et al. 1986; Felix et al. 1986). Finally, understory compositions have been used extensively as indicators of environmental gradients (moisture, temperature, nutrients) and site productivity under both undisturbed and disturbed conditions (Archambault et al. 1989).

Table 6.12-3 summarizes the formulations and methods of generating plot-level values of richness, equitability, diversity, and vertical stratification and horizontal patchiness. All calculations can be made from basic data on the amount and location of plant cover by species. The indices offer great flexibility in application across communities, ecosystems, and biotic regions and in the type of measurement data that can be substituted in the formula. For example, Romme (1982) used similar indices to estimate landscape diversity by using plant communities as species taxa and the area of plant communities for abundance. It is important to interpret index values cautiously, because communities with similar values may vary significantly in composition (Peet and Christensen 1982). Index values can be interpreted more reliably in conjunction with other vegetation data and site information.

Interpretations based upon individual plant species or ecological species groups may be particularly fruitful because the reaction of plants to different environmental factors, competition, and disturbance varies on a species-specific basis (Daubenmine 1959). Once a reliable determination of plant species

TABLE 6.12-2. RELATIONSHIP OF RESPONSE INDICATORS FOR DIFFERENT ORGANIZATIONAL LEVELS OF BIOTIC DIVERSITY

	Organization Level		
	Landscape/Region	Community/Ecosystem	Population/Species
Purpose	Provide extrapolation units for region	Provide check of representativeness of plot data for coarse patches Provide extrapolation unit for internal features of fine patches	Provide ground-truth for external features based on large-scale photos Provide data not accessible from remote sources Provide data to develop relationship between internal and external patch features
Focus	Coarse patch delineation and arrangement	Fine patch delineation based on external features of overstory	Fine patch characterization based on internal features of overstory and understory
Data source	Satellite and small-scale photo imagery	Large-scale photo imagery	Ground measurements on plots
Response indicators	See Table 6.12-1	See Table 6.12-1	See Table 6.12-1

TABLE 6.12-3. DEFINITION AND CALCULATION OF PLOT-LEVEL VALUES FOR EACH ELEMENT OF HOMOGENEITY AND COMPLEXITY OF VEGETATION

Elements	Definition	Formula	Aggregation to Plot-level Value[a]
Richness	The number of species sampled in an area	$\bar{S}$ = average number of species sampled per unit area	Count number of tree species sampled per quadrat (n=12); average
Evenness	The distribution of abundance among the species in a community	p_i = relative abundance of species i; n_i/N	Sum cover by species per quadrat (n=12); divide by total cover
Diversity	Synthetic measures that are sensitive to both richness and evenness. Related to the uncertainty of identity of an individual randomly selected in an area. Uncertainty increases with richness and evenness.	$H' = -\Sigma p_i \ln p_i$ (Shannon and Weiner 1949) $c = \Sigma p_i^2$ (Simpson 1949)	Use p_i values generated for plots. Note: $e^{H'}$ and $1/c$ = the number of equally common species required to produce the same uncertainty as the sample.
Equitability	Relative diversity of sample in relation to maximum possible diversity of a community of S species	$J' = H' / H'_{max}$	Use H' and H'_{max} generated for plots. Note: $H'_{max} = H'/\ln S$
Pattern diversity	Variation due to the spatial arrangement of plant cover	Stratification = variability, as coefficient of variation, in total cover per strata Patchiness = variability, as coefficient of variation, in total cover of each sample	Sum cover/strata (n=4); calculate $\bar{X}$, S, CV Sum cover/quadrat (n=12); calculate $\bar{X}$, S, CV

[a] Assumes FIA condition code is the same on all 4 subplots. If condition code changes, then average the subplots separately by condition code.

composition, including cryptogams, has been made, one can derive structural and functional aspects of vegetation based upon the species present (Mueller-Dombois and Ellenberg 1974). Finally, more plant species and assemblages can be examined as potential ecological indicators when the species composition of sites is adequately measured. The most abundant plant species at a site, while greatly influencing biomass production and nutrient cycling, are not necessarily the most sensitive indicators of environmental conditions, stress, or change (Poore 1955; Daubenmire 1968).

Detection monitoring is predicated on the concept of tracking ecosystem characteristics that are relatively easy to measure and sensitive to environmental and anthropogenic stresses of interest. More detailed evaluation monitoring is triggered if and when predetermined levels of change are exceeded. It is one thing to determine if ecological condition is changing (detect a trend) and quite another to determine the quantitative boundary between a good and bad ecological condition (set a nominal/subnominal boundary). Setting such a black and white boundary for regional biodiversity indicators is fraught with problems, among them a lack of theoretical and experimental guidance on one hand and the range of human emotions regarding species extinction on the other. Consequently, while no definitive boundaries have been set for the vegetation structure indicator to date, establishment of these types of boundaries remains as an objective of the biodiversity indicator development process.

6.12.2.2 Quantification

Measurement of vegetation structure (i.e., sessile organisms) is relatively easy and inexpensive (i.e., completed in one visit by one person in one day). Pole measurements (using a telescoping height pole) can be completed in approximately 2 hr per plot and quadrat measurements in made within a 1m^2 quadrat in 4 hr per plot. (Complete measurement methods are found in Section 11 of Conkling and Byers, 1992.)

One source of error for the pole method is leaf and branch flutter during windy conditions. Errors induced by windy weather are not unique to the pole method as a photographic or laser method would experience similar difficulties under similar conditions. The only really effective way to limit this type of error is to suspend data collection during poor weather conditions. During both the 1990 20/20 and the 1991 Georgia pilot studies, this conclusion was necessary on several occasions.

Play in the fully extended pole is a potentially more serious source of error that we have tried to limit by leveling the pole with the aid of a bubble level and positioning the bubble level to the north to assure that pole play is consistent among points. Results of point remeasurements made during the 1990 training are shown in Table 6.12-4. For any height level ± 1 hits is equivalent to ± 6 percent since there were 16 points (1/16 = 6.25 percent) per subplot in the 20/20 study. This result was judged to be satisfactory performance for pilot testing.

The total variation in measurements of response indicators will greatly influence the usefulness of indicators in detecting changes in forest condition. Regional, temporal, within-plot, within-subplot, and measurement variation are important components of total variation. A preliminary estimate of the relative contribution of measurement variation to the total variation of pole measurements of vegetation structure can be estimated from the 1990 20/20 study data. Measurement variation was less than 20 percent of total variation in the first 5- or 6- foot levels, and usually 20 to 30 percent above 6 or 7 feet up to 30 feet. These ratios must be interpreted with caution because a realistic estimation of total variation has not been calculated. Total variation will undoubtedly increase because no temporal variation was included, and regional and within-plot variation were underestimated since the plots in each region were from a relatively small geographical area and the subplots were

TABLE 6.12-4. RESULTS OF POLE POINT REMEASUREMENT DURING 1990 TRAINING

Variable	Cumulative frequency of no difference	±1 hits	N (No. of pairs)
Total hits recorded	61%	93%	41
Assignment of height class	71%	96%	51

rotated into the same homogenous stand condition. In contrast, the measurement variances are probably robust, since the estimates were based upon a large sample size, and procedural improvements have been and will continue to be made. Consequently, there is every reason to believe that the relative contribution of measurement error to total variation will decrease for the pole method, and easily meet Taylor's (1987) ±10 percent guideline for an acceptable level of measurement error.

Data quality for the vegetation structure indicator depends greatly upon hiring qualified personnel. This is especially true for plant species identification. Botanists familiar with regional flora are required to meet data quality requirements.

6.12.2.3 Signal-to-noise Ratio

How responsive is the vegetation structure indicator to forestry treatments such as thinning or planting? Can this response to anthropogenic stress be differentiated from natural cycles and trends due to forest type and age? This issue has been addressed initially by examining the shape of vegetation profiles of major forest cover types on 3,100 plots in the Georgia Piedmont in relation to known natural factors (site and stand conditions) and anthropogenic stresses (forestry practices) (Cline et al. 1990). The vertical structure of forest vegetation is one element of the vegetation structure indicator. Preliminary results suggest that the vegetation profile changes in predictable ways during normal stand development. For example, as expected, stand age, in 10-year age classes, had the strongest influence upon vegetation profile, with most mean age class profiles differing significantly from each other. In addition, mean profiles of similarly aged loblolly pine and oak/hickory stands are reasonably distinct (Figures 6.12-3 and 6.12-4). These patterns of forest profiles might be useful as a "baseline" from which to judge future changes in vegetation profile across the region.

Even with these strong natural trends in profile slope, the effects of forestry practices can still be detected. When mean profiles from similarly aged stands were compared, the effects of forestry practices were quite apparent (e.g., Figure 6.12-5, natural versus planted loblolly pine, and Figure 6.12-6, unthinned versus thinned loblolly pine stands). These results suggest that observed changes in the types and distribution of vegetation profiles could then be used to indicate the homogenization and simplification of vertical structure across a region with respect to expansion or intensification of forestry practices.

While these results make us cautiously optimistic about the value of vegetation profile as an indicator of some anthropogenic stresses, we realize the analyses to date have a limited scope. Expanded analyses are planned to include changes in vegetation composition of each profile in relation to forestry practices and to examine temporal variation across the Georgia Piedmont region. Until these analyses are complete, vegetation

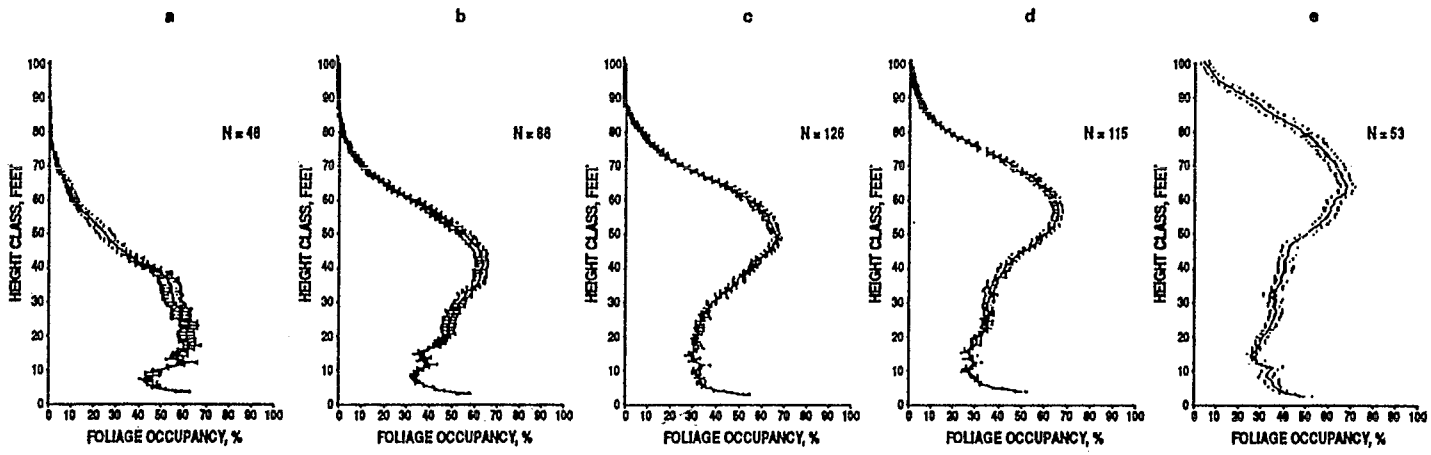

Figure 6.12-3. Mean age class forest profiles of naturally regenerated loblolly pine stands, combined data set. All plots untreated and undisturbed since 1982. (a) 10-19 years, (b) 20-29 years, (c) 30-39 years, (d) 40-49 years, and (e) >50 years.

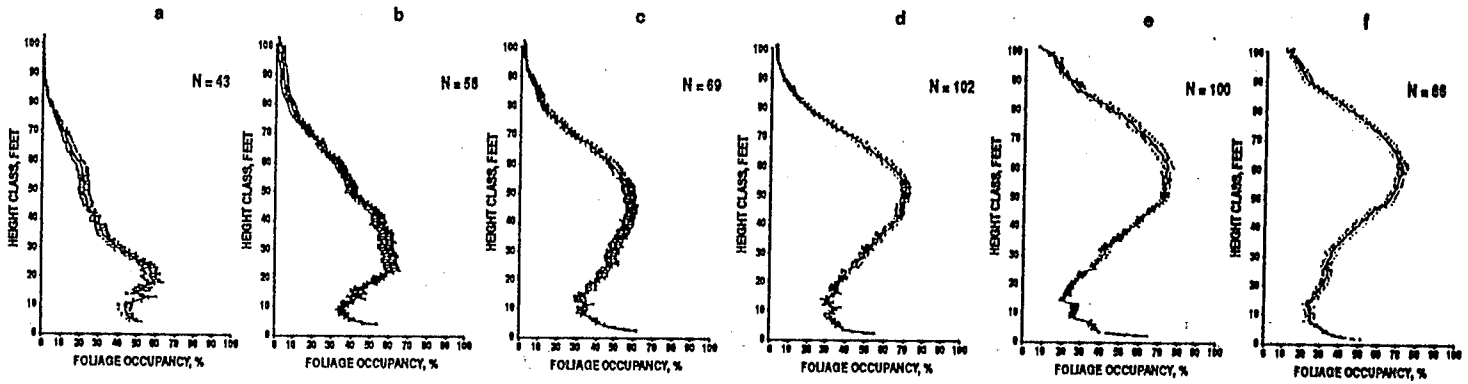

Figure 6.12-4. Mean age class forest profiles of naturally regenerated oak/hickory stands, combined data set. All plots treated and undisturbed since 1982. (a) 10-19 years, (b) 20-29 years, (c) 30-39 years, (d) 40-49 years, (e) 50-59 years, and (f) >60 years.

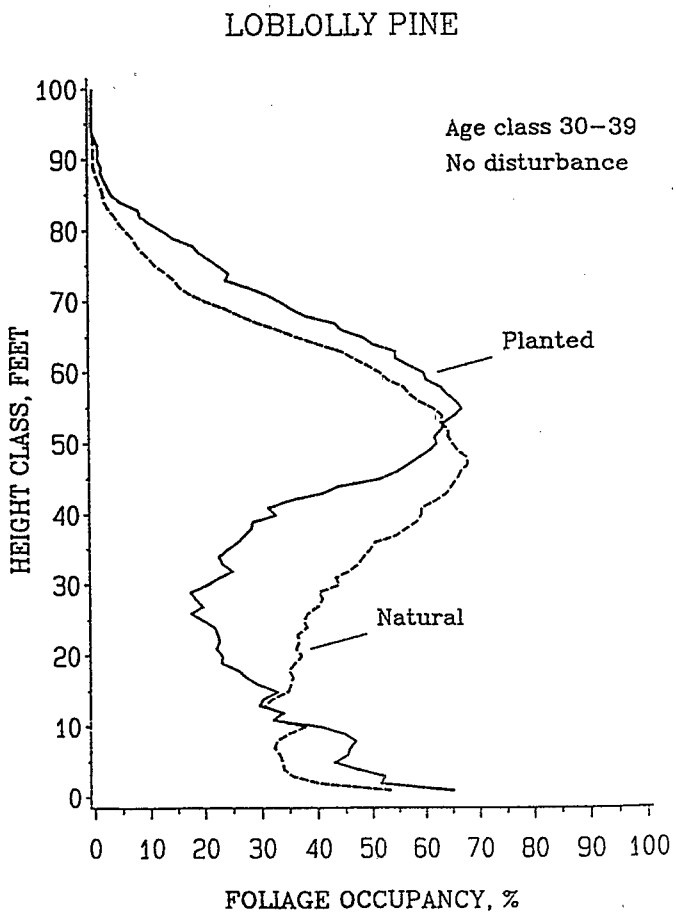

Figure 6.12-5. Height class versus % foliage occupancy for age class 30-39 with no disturbance on planted and natural loblolly pine sites.

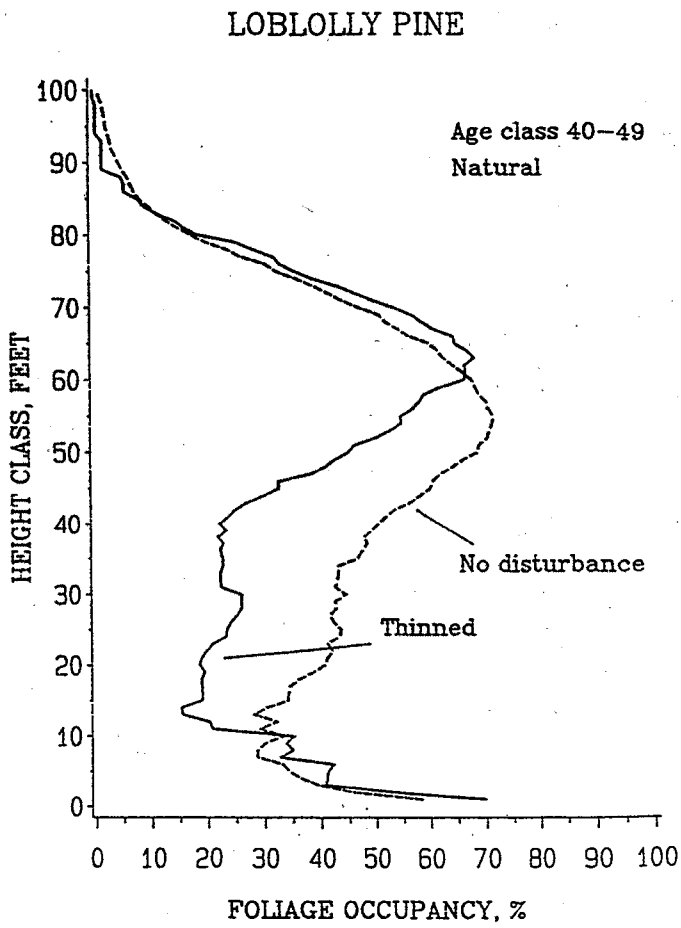

Figure 6.12-6. Height class versus % foliage occupancy for age class 40-49, natural on planted and natural loblolly pine sites.

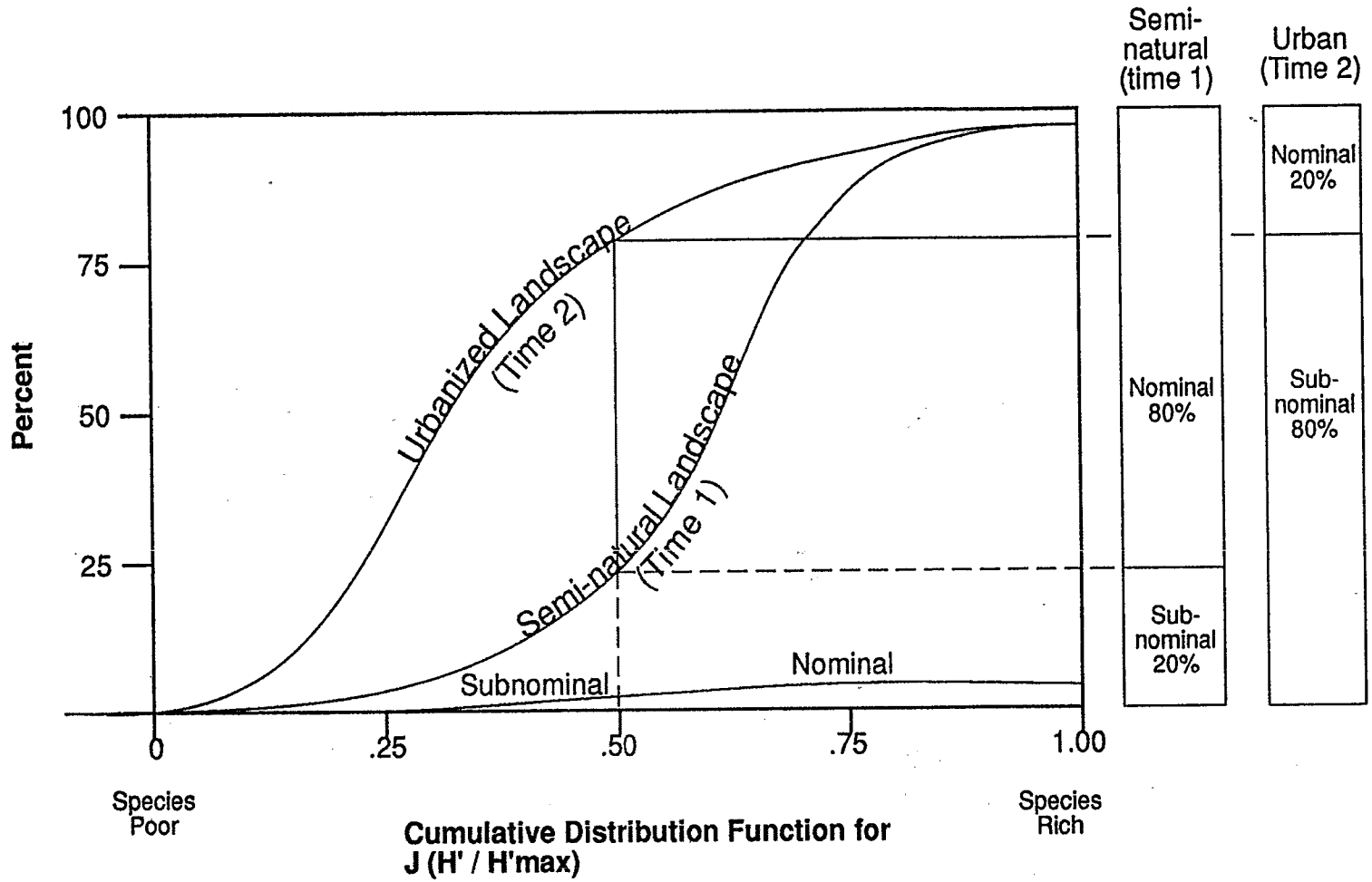

Figure 6.12-7. Hypothetical response of plant communities (as measured by equitability [J']) to expanding human population. The hypothetical nominal/subnominal boundary is 0.5 (50% of maximum possible plant species diversity). Between time 1 and 2 more of the region becomes urbanized, increasing the percentage of subnominal sites from 20% to 80%.

profile cannot be fully evaluated as an indicator and remains subject to being dropped. Part of the concern is the large, inherent variation of vegetation profiles and thus the large number of plots that would need to be tracked to pick up changes. This concern is lessened somewhat by the knowledge that compared to the pole method, the ocular method used by the Southeast FIA to measure forest profile is much more imprecise (CV of 31to 44 percent for cover estimates between 3 and 18 ft [Cost and Craver n.d.]).

6.12.4 Regional Responsiveness

The conservation of biodiversity is threatened by the overharvest of populations, physical alteration of habitats, pollution of water, air, and soil, climate change, introduction of alien species, and the cumulative or interactive effects of these major threats (U.S. EPA 1990). These threats or stresses are often closely related to expansion of the human population and associated economic development, including agriculture, industrialization, and urbanization. Typically the ecological resources in an area are simplified and homogenized by exposure to one or more of these anthropogenic stresses. For example, compared to native forests, forests today are younger, less extensive, more insulated, subject to fewer wildfires, more accessible by road, and more structurally simple (the extreme being monoculture). The area impacted by these stresses continues to increase.

Urban sprawl creates a gradient of impacts on the heterogeneity and complexity of vegetation structure. Moving from urban-suburban to rural to semi-natural to wild settings, the following trends are expected:

- Fewer buildings and roads.
- Decreasing management intensity (less cultivation, less energy and nutrient inputs).
- Increasing extent of natural vegetation cover (fewer cultivars, horticultural varieties, exotics and aliens).
- Increasing size and irregularity of vegetation patches.

The response of plant communities, as measured by one element (equitability) of the vegetation structure indicator, to this stress gradient is illustrated in Figure 6.12-7. Analyses of the number and dominance of exotic or naturalized plants or the presence of plants with known fidelity in relation to moisture, light, and disturbance might also be particularly revealing.

6.12.2.5 Index-period Stability

The stability of the vegetation structure indicator will be influenced most by annual phenological patterns, which are regulated by local weather conditions. Cover estimates will vary until tree, shrub, and herbaceous leaves are fully expanded. A June start date for sampling should be adequate in this regard, except perhaps in mountainous regions. Analysis of patterns of species presence or absence may be informative for regional assessments of biodiversity and overcomes problems associated with interannual changes in plant cover. Flower and fruiting patterns are also phenologically variable, and this has more serious implications as most plant taxonomy keys are based upon flowers, and to a lesser extend fruits, of plants. Thus, while a plant may be fully expanded vegetatively at the time of sampling, it may be in a nonreproductive state, making it difficult to identify positively to species. This effect may be lessened somewhat because many plants have distinct vegetative features useful for species identification, and a botanist knowledgeable of the regional flora would likely be able to use them. In addition, many of the more common species can be identified without flowers. Plant specimens will be collected in the field for all unidentified species and each "known" species. These will be identified or verified by qualified taxonomists and archived for documentation.

6.12.2.6 Environmental Impact

Measurement methods used for the vegetation structure indicator have little impact beyond the disturbance from walking. There is no impact, as long as walking is confined to areas outside points and plots to be measured. People making the vegetation measurements

are trained to minimize their own impact, but the impact of other crew members is hard to control. Experience indicates that people measuring visual symptoms and heights of trees move about the plots the most, so this is the greatest potential impact on understory vegetation. Also, photosynthetically active radiation (PAR) measurements directly over the pole points have affected vegetation occasionally. In 1992, the vegetation sampling plots will be marked as early as possible during each field day so as to minimize disturbance. Plant specimen collection is done off-plot and requires only plant pieces, not whole plants.

6.12.3 Field Measurements

Vegetation structure measurements will be made in small permanent quadrats systematically laid out on each subplot (3 per subplot or 12 per plot). The objective of the procedure is to identify all plant species present in the sample quadrats and to measure the amount and spatial pattern of their canopy cover individually and collectively. On each quadrat five basic types of data will be recorded:

1. Plant species identification,
2. Reliability of plant identification,
3. Vegetation strata of plant,
4. Plant cover, and
5. Phenological status of plant.

In addition, canopy cover measurements will be made at each subplot center and shrub stem density will be determined within each regeneration microplot. Specimens of unknown and representative known plant species will be sampled off-plot and pressed. "Unknowns" will be uniquely coded in the field so that the data base can be updated after identification. All data will be recorded using the portable data recorder. See Section 11 of the 1992 Forest Health Monitoring Field Methods guide for complete details of the vegetation structure measurement method.

6.1.4 Data Analysis

Verified and validated measurement data on the amount and spatial location of plant canopy cover by species will be used to calculate plot-level indices of vegetation heterogeneity and complexity using standard formulas (Table 6.12-3). These values indicate the floristic and structural diversity of vegetation, an important element of biodiversity.

Collectively, the indicator values will be used to establish baseline levels of vegetation complexity and heterogeneity by region. Plot remeasurements over time will be used to determine changes in vegetation structure indicator values and to track regional trends in the heterogeneity and complexity of vegetation and habitats in relation to natural and anthropogenic stresses (e.g., Figure 6.12-7).

6.12.5 1992 Activities

The vegetation structure indicator will be measured on ground plots in the Southeast Demonstration and in the Western Pilot in Colorado and California.

6.13 Wildlife Habitat Indicator and Bird Population Estimates

T.E. Martin, D.R. Petit, and L.J. Petit

6.13.1 Introduction

Animal populations are important assessment endpoints because the public and scientific communities perceive the presence of certain animal species to be indicative of ecosystem health (Hunsaker and Carpenter 1990; Finch 1991). Measurements of bird populations can be especially useful in determining ecosystem health because birds exhibit a high degree of habitat specialization and are closely associated with specific vegetation features. Changes in vegetation features due to human-induced or natural disturbance, therefore, will have direct impact on suitability of habitat for birds. In addition, the mobility of birds enables them to react to changes in habitat quality in a measurable way, allowing assessment of changes in ecosystem health.

The wildlife habitat indicator consists of measures of vegetation structure and floristics that predict the presence and absence or relative abundance of forest bird species or guilds. The majority of the vegetation measurements are collected as part of other indicators such as vegetation structure and site classification, growth, and regeneration.

Ecosystem health in terms of wildlife habitat suitability is important to the public. In particular, much public concern focuses on the decline of neotropical migratory birds, most of which inhabit forests. Thus, attempts to monitor forest health must incorporate measures relevant to wildlife. The wildlife habitat indicator is based upon vegetative characteristics that are currently being measured for other FHM indicators and, thus, integrates directly into the current plan for forest health monitoring. This indicator also adds an important component to the current suite of FHM indicators by providing direct biological relevance of vegetation measurements with respect to bird populations.

6.13.2 Indicator Evaluation

The following discussion considers the indicator selection criteria described in Section 6.1 as they apply to the wildlife habitat indicator.

6.13.2.1 Interpretability

The wildlife habitat indicator is highly interpretable because birds exhibit a high degree of habitat specialization and are closely tied to specific vegetation features. Measures of vegetation structure and floristics within a forest sampling unit can be related to types and numbers of birds present. Predictive models can be generated from these bird-habitat relationships to determine suitability of the forests for particular bird species as indicators of forest health.

6.13.2.2 Quantification

All vegetation measurements are straightforward and easily quantifiable by field crews after minimal training. Methods are patterned after standard methods for measuring bird habitat (James and Shugart 1970).

6.13.2.3 Signal-to-Noise Ratio

Noise for this indicator should be relatively low, as natural variation in stem densities and vertical distribution of foliage within a forest stand is typically low. Signal effects, however, are high compared with natural variation among years or sites. In 1991, variation between human-disturbed sites and undisturbed sites was significantly greater than within undisturbed sites. Thus signal-to-noise ratio is high for this indicator.

6.13.2.4 Regional Responsiveness

Bird-habitat relationships and vegetation characteristics are relatively consistent within regional forest resource subclasses. Thus, predictive models of wildlife habitat should be regionally responsive, so long as local variability is incorporated into the model during development and validation.

6.13.2.5 Index-period Stability

Bird abundances are correlated with relatively gross features of the environment. Therefore, low measurement error and temporal variation of this indicator are readily attainable because of the spatial scale and level of resolution at which vegetation structure and composition are measured. Thus, the indicator has high index-period stability.

6.13.2.6 Environmental Impact

Sampling techniques for the wildlife habitat indicator have minimal environmental impact, mainly involving soil compaction and some trampling of herbaceous vegetation when walking within the sampling plot. There is no destructive sampling of vegetation.

6.13.3 Field Measurements

Relative bird abundance will be measured on each of the Forest Health Monitoring (FHM) Demonstration plots. An expert in bird identification will enumerate all birds heard or seen within an unlimited-radius point count centered on the center of each plot. Only birds detected within 50 m will be used in the initial development of the wildlife indicator. Twenty-minute censuses will be conducted on each plot to increase accuracy of bird counts.

Vegetation measurements for the wildlife habitat indicator are similar to those being collected for the vegetation structure indicator as well as to core measurements collected by FHM personnel. Measurements used for these indicators include percent canopy cover, foliage cover at different height strata, tree and shrub species composition, tree and shrub densities, and distribution of tree diameter size classes. Data are collected as part of the other indicators and then used as part of the wildlife habitat indicator assessment.

6.13.4 Data Analysis

The approach for the wildlife habitat indicator is to develop models of bird-habitat relationships that allow us to predict the occurrence of bird species that are associated with varying levels of disturbance in forest ecosystems. Thus, the indicator being developed has two components: (1) bird populations and (2) vegetation measurements. Implementation of the indicator into FHM would include only vegetation measurements.

Changes in vegetation structure and plant species composition due to disturbance have direct implications for the quality of forests as habitats for birds. Measures of vegetation structure and floristics within a forest sampling unit can be related to types and numbers of bird species present. Predictive models generated from these relationships can be used to determine general suitability of forest habitats (based upon vegetative features) for particular bird species as an indication of forest health. The predictive models can be generated by logistic regression, which estimates the probability of a particular bird species occurring at a given sampling location based upon vegetation characteristics at that site. Probabilities of occurrence can be estimated for a wide diversity of species known to be indicative (both positively and negatively) of forest health. An overall index of condition (similar to the Index of Biotic Integrity of Karr and Dudley [1981]) then can be computed based upon vegetation characteristics and the health status (nominal, marginal, subnominal) assigned to each site. Classification of forest health, therefore, is based directly on vegetative features and indirectly on bird species occurrence.

Results from the FHM 1991 pilot study in the eastern United States indicated that

logistic models based on vegetative characteristics had high predictive ability in classifying forest stands as nominal and subnominal. Overall, 80 percent of stands that were known previously to be nominal or subnominal (based on observed disturbance levels) were correctly classified by derived logistic models. This high predictive ability was achieved even though the range of disturbance levels sampled in the pilot study was narrow.

Predictive capability will improve with incorporation of (1) a wider gradient of habitat disturbance levels, (2) more intensive sampling of bird populations (i.e., 20-min instead of 8-min counts), and (3) measures of landscape features around forest sampling units (e.g., percent cover types, perimeter-to-area ratio, connectivity).

6.13.5 1992 Activities

Data for the wildlife habitat indicator will be collected in the Southeast Demonstration project. Additional data will be collected off-frame on sites in Arkansas and Ohio for model development and validation.

6.14 Air Pollution Bioindicator Plants Indicator

K.W. Stolte

6.14.1. Introduction

Vascular plants have been used as bioindicators of ozone and other air pollutants when fumigation or field studies have identified species that are sensitive to ambient levels of an air pollutant and respond to the air pollutant with a distinct visible foliar injury symptom. Foliar injury symptoms are often visible on the upper leaf surface as distinct patterns of discolored stipples or lesions (see Skelly et al 1988 and Jacobson and Hill 1970 for symptom descriptions and photographs). Affected leaves often age rapidly and acceleration of senescence occurs. Since ozone is the only regional gaseous air pollutant that is frequently measured at known phytotoxic levels, the focus of this indicator in detection plots will be on ozone only.

The societal values addressed by this indicator are contamination (air pollution impacts), productivity (potential reduction in carbon fixation), aesthetics (discoloration of foliage, accelerated senescence of foliage, reduction in density and live crown ratio of tree crowns), and biodiversity (loss of pollution-sensitive genotypes; change in composition of plant communities).

6.14.2 Indicator Evaluation

We will examine ozone injury by selecting suitable sites (open areas in the east and mesic areas in the west) where the injury, if it occurs, will most likely be found. At these sites the presence or absence of foliar injury, above a 5 percent threshold level, will be recorded by in-hand evaluation of the foliage of 30 plants of each ozone-sensitive species. The detection plot will be scored as positive or negative for ozone injury. Plants must be in full sunlight part of the day (greater than 2 hours) in the east. Herbs and shrubs must be in mesic areas in the west. All areas must be free of major disturbances such as herbicide use. Each of the plants selected at the site must have at least 25 percent of the foliage that can be touched. In the east, blackberry, black cherry, tulip poplar, sweetgum, milkweed, and white ash will be evaluated. In the west, ponderosa pine, Jeffrey pine, California black oak, ninebark, aspen, and Rhus sp. will be evaluated.

Since the incidence and severity of ozone injury has been shown to increase over the summer season in the northeast and southeast, reference plots (two types) will be established in different physiographic regions to evaluate the effectiveness of the detection plots to meet the stated objectives. Each year the reference plots will be used to determine the onset of ozone injury and the maximum severity of injury in the region. Previous pilot studies have shown that foliar injury symptoms first appeared in June, and the best time to survey for the symptoms was July 15 to August 15. During this period, symptoms had developed distinctly and there was no statistical change in the severity of symptoms recorded. The reference plots come under the scope of research on monitoring techniques or evaluation monitoring and, as such, are not a part of detection monitoring.

The following discussion considers the indicator selection criteria described in Section 6.1 as they apply to the air pollution bioindicator plants indicator.

6.14.2.1. Interpretability

Air pollution indicator plants are highly interpretable as an indication that phytotoxic concentrations of ozone are occurring when sensitive species are vegetatively active. These species are selected for high sensitivity to ozone, have unique and discernible foliar symptoms that are indicative of ozone injury, are evaluated at sites (on or near the detection plot) where ozone injury is most likely to occur if phytotoxic levels of ozone are present in the area, and can be quantified with one plot-level average.

Aggregation to the plot level --

This indicator is reasonably aggregated to the plot level by quantification of the incidence (percentage) of injured individuals at the site or stand level. Thirty individuals of a sensitive species have been shown to provide a reasonable estimate of the degree of air pollution stress at a site (Duriscoe 1988). This indicator is evaluated by giving a "plus" or "minus" score for ozone injury to each plant. If 5 percent or greater of the surface area of any one leaf on a plant has discernible ozone symptoms, then the plant is scored as positive for ozone injury. In the West, the plot-level average is the number of plants injured and is expressed as a percent of injured plants for each plot. In the East, we do not yet understand the effect of different size canopy openings on the percentage of plants injured. In the East, plot-level averages are 0 or 1 ("plus" or "minus") for ozone injury.

Cumulative Distribution Functions and Nominal-Subnominal Boundaries --

Cumulative distribution functions (CDFs) and the delineation of the population into nominal-subnominal properties can be calculated for this indicator in the West. The CDFs for western species are calculated as the percentage of plants injured in or near each detection plot (X) per the frequency of occurrence in the population (Y). The frequency of occurrence in the population is adjusted by the representativeness of the sample at the detection plot (number of plants evaluated) and the inclusion probability for the plot.

The percentage of injured plants per plot is expected to range from 0 to 100 percent, with the frequency distribution skewed towards low injury per plot. Distribution of nominal and subnominal classes from the CDF for the population will involve setting three thresholds: poor, concern, and optimal. The poor threshold will be set at 50 percent or more of the plants injured. Concern thresholds will be set at 0 percent plants injured. The rationale for setting a stringent concern threshold is recognizing that once ozone exposures reach the point where sensitive species are injured near the ground, crowns of dominant and codominant trees may be experiencing even higher ozone exposures in the upper canopy.

In the East, no calculation of CDFs will be possible at this time until the effect of site opening size on the number of plants injured can be determined. Alternately, we consider the plot as plus or minus for injury based on one or more plants at the plot showing 5 percent or greater foliar injury. Nominal proportions of the population are those having 0 percent injured plants, and subnominal proportions of the population are those showing 1 percent or more of the population with injury. In this way, comparisons of ozone injury through number of plots injured between eastern and western bioindicator populations can be partially drawn.

6.14.2.2. Quantification

This indicator can be quantified with a high degree of accuracy. The number of plants evaluated per species is designed to minimize variability at the plot level. The determination of severity of foliar injury is reduced to two classes: plants having 5 percent or more surface area with foliar injury and plants having less than 5 percent foliar injury. This determination is readily done since Horsfall and Barratt (1945) showed that the highest precision with foliar estimates was obtained at high and low degrees of injury (1 to 6 percent and 94 to 100 percent).

6.14.2.3 Signal-to-Noise Ratio

The signal (ozone injury on foliage)-to-noise (confounding foliar symptoms; lack of response to ambient ozone) is very high for this indicator since we have selected plant species that have demonstrated sensitivity to ambient concentrations of ozone. These plant species were also selected because these plants are common (widespread distributions) and easily identifiable. These plants have distinct foliar injury symptoms that are readily recognizable and it is relatively easy to determine where foliar injury is more than 5 percent of the foliar surface area.

The signal-to-noise ratio is reduced for this indicator in years where drought lessens the physiological activity of the ozone-sensitive species. Drought will be quantified through the off-frame climatic data that is reported in FHM.

6.14.2.4 Regional Responsiveness

This indicator is very responsive at state and ecosystem regional levels. Surveys and long-term monitoring plots have shown that ozone-sensitive species are very good at delineating the spatial distribution of ozone over large regions (Duriscoe and Stolte 1989; Pronos et al. 1978; Miller and Millecan 1971). By evaluating an adequate number of plants (10 to 50) at each survey point or plot, areas receiving high ozone exposures can be delineated. The responsiveness of ozone-sensitive species to ambient ozone exposures has recently been quantified by studies where ozone-sensitive species are evaluated near ambient ozone monitors (Stolte et al. 1991).

6.14.2.5 Index Period Stability

Air pollution injury does increase over the summer season (May to September), and consequently the response of deciduous species is stable only through a proportion of the summer (in some years this period was from July 15 to August 15). This is true for both incidence and severity of injury. Although we would like to describe the incidence of injury (number of plants affected), we will have to limit our determinations at the detection plots only to whether sites have any ozone-injured plants. With coniferous plants, the incidence of injury is not as likely to change over the summer, since the injury is cumulative over years. Thus incidence of injury on conifers in the West will be relatively stable over the summer field season.

The onset of injury on deciduous plants each summer will be determined by a combination of reference plots and plants evaluated at the detection plots. The reference plots are selected so that conditions are favorable for the formation of ozone injury (large opening, mesic conditions). Once ozone injury is observed on a species (verified by specialists), then evaluation of that species at the detection plots is considered valid. Prior to the onset of injury at the reference plots or the detection plots, plots evaluated as negative for ozone injury will be considered as uncertain in the analysis at the end of the season. This indicates that we have evaluated the plot before ambient ozone levels have reached phytotoxic levels. This onset-of-injury point must be determined for each species evaluated.

6.14.2.6 Environmental Impact

The evaluation of this indicator should have minimal environmental impact. Most evaluations are done without removing any foliage; voucher specimens (a few leaves or a small branch) are collected by the crews to verify symptom identification, once for each species (until the proper diagnosis is made). The only damage will be from crews walking around to observe plants, and in many cases this will occur out of the detection subplots or even the 1-hectare detection plot.

6.14.3 Field Measurement and Data Use

The guidelines are intended for the evaluation of ozone air pollution injury on sensitive vascular plant species. The focus is determination of the presence of ozone air pollution symptoms on sensitive plant species in suitable sites in or near the FHM detection plots. Suitable sites are defined as those where air pollution injury is most likely to be found if phytotoxic concentrations of ozone are occurring near the FHM detection plots. A suitable plot is generally determined by the habitats favored by sensitive species, the spatial conditions that allow intrusion of ozone, and environmental factors that favor plant response to air pollutants. Consequently, the definition for suitable plots will be different for different regions of the country. In the East, (northeast and southeast), suitable sites are those where openings in the tree canopy allow substantial intrusions of ozone (openings greater than 0.5 acres) and environmental factors (particularly radiation) are not found to

limit pollutant uptake. Suitable sites in the West, California and Colorado to date, are mesic areas (riparian, meadows, and slope bottoms) where summer drought conditions are somewhat ameliorated. This is true especially for ozone-sensitive herb and shrub species. Conifers (particularly) and deciduous trees (somewhat) in the West can be evaluated at a broader range of sites and are not limited only to mesic habitats.

Species evaluated are those that have been determined through field and laboratory studies to be highly sensitive to ozone air pollution. The sensitive species must have a distinct response to ozone, such as a distinct foliar injury symptom. The plant species proposed for this indicator are those that have a relatively consistent sensitivity to ozone and a distinct foliar injury symptom that is not difficult to diagnose. Within a species, differences in genetics between individuals often results in differential sensitivities to air pollutants. It is not uncommon to find an individual of a species with severe air pollution injury growing immediately adjacent (i.e., same soil, light, moisture) to another individual of the same species with few or no symptoms. This is the norm rather than the exception. Only when air pollution concentrations become high are many individuals affected, and even then there will be gradients of injury among the individuals.

Symptoms are used to determine whether or not an individual plant or a sensitive species is injured. If more than 5 percent of the upper leaf surface area is covered with symptoms, then the plant is considered "symptomatic" and is tallied as positive (+) for injury. No other quantification of injury severity is required. For example, plants with leaves with 6 percent to 100 percent foliar injury are grouped in one class and the plants are scored as positive for injury. Of equal importance to the type of symptom observed on the foliage is the pattern of foliar injury over the whole plant. Since gaseous pollutant injury is dependent on stomatal conductance as a normal part of the photosynthesis process, the age of the leaves (position on the stem, branch, or rosette) affects the susceptibility to gaseous air pollutants. If an air pollutant is the cause of an observed foliar injury, then the pattern of the injury should be consistent with the developmental pattern of the foliage on the plant. This can be very helpful in distinguishing air pollution injury from other abiotic and biotic symptoms. Glater et al (1962) provided an excellent illustration of the effect of leaf position and air pollutant response with their work with tobacco. Stolte (1982) observed a similar distinct pattern of leaf position and symptom development due to ozone stress on a chaparral shrub species. The pattern of air pollution injury should be consistent with the sensitivity of leaves according to leaf position. In general, leaves at 75 percent full expansion are the most sensitive and would tend to show symptoms most definitively toward the center of the leaf. Older leaves would show symptoms more widespread over the leaf surface, while younger leaves would show symptoms more commonly near the leaf tip. It is unlikely that only one or a few leaves would show severe symptoms without other leaves being affected (this result may happen if the injury on one or a few leaves is very slight). Also, if leaves on one branch in the sun are affected, then leaves at a similar leaf position on another sun-exposed branch should be affected, especially for branches on the same side of the plant under similar environmental conditions (sun or shade leaves).

Voucher specimens (pressed leaves with symptoms) are collected for each species the first time symptoms are found on a plot. These vouchers are pressed and mailed to the appropriate QA/QC person (e.g., the trainer for this indicator) to ensure proper symptom identification. Once a species is verified for symptom identification, no further voucher specimens are required for that species. Additional QA/QC measures (reference plots) will be initiated to gauge the efficiency of this method in detection monitoring.

6.14.4 1992 Activities

The air pollution bioindicator plants indicator will be a part of the Southeast and SAMAB Demonstration projects, the Northeastern detection monitoring, and the Western (California and Colorado) Pilot project.

6.15 Lichen Communities and Elemental Content Indicator

B. McCune

6.15.1 Lichen Communities

A lichen community is the assemblage of species of lichenized fungi present at a site. The FHM program restricts the lichen community to macrolichens occurring on living or standing dead woody substrates. Microlichens (i.e., crustose lichens) are excluded because they are poorly known taxonomically and often difficult to differentiate in the field. Only standing woody substrates are included to standardize the measurements to a class of substrates that can be found on all sites. Lichens are commonly abundant and diverse on rocks, but many FHM plots will not have exposed rock as an available substrate. This component of the lichen flora, however, may be added in the future, particularly in dry western forests.

Lichen communities are clearly indicative of several key assessment endpoints, including contamination of natural resources, biodiversity, and sustainability of timber production. Hundreds of papers worldwide (chronicled in the series "Literature on air pollution and lichens" in the Lichenologist) and dozens of review papers and books (e.g., Hawksworth and Rose 1976), published over the last hundred years, have documented the close relationships between lichen communities and air pollution, especially SO_2. In a comparison of biological responses between areas near and far from a coal-fired power plant, lichens gave a much clearer response (diversity, total abundance, and community composition) than either foliar symptoms or tree growth (Muir and McCune 1988). The lack of ambiguity is largely due to the possibility of standardizing the substrate (e.g., bark or bark of a particular group of species). Much of the sensitivity of epiphytic lichens apparently results from the lack of a cuticle and a total reliance on atmospheric sources of nutrition.

To the extent that air pollution affects long-term sustainability and biodiversity of forests, lichens are also indicative of trends in those assessment endpoints. In addition, lichens in themselves form a large portion of the macrophytic species in many forests. For example, in Abies grandis forests in western Montana, the number of macrolichen species in a stand is comparable to the number of vascular species (Lesica et al. 1991). In many forests lichens have key roles in nutrient cycling (especially nitrogen fixation in moist forests; Pike 1978) and food webs. For example; a main component of the diet of spotted owls is flying squirrels (Dawson et al. 1987), and flying squirrels eat epiphytic lichens during the winter (Maser et al. 1986; Maser et al. 1985). Epiphytic lichens are also a primary food for the endangered mountain caribou in Idaho (Rominger and Oldemeyer 1989; Servheen and Lyon 1989).

Various community parameters at the plot level can be calculated from lichen species abundance data (also collected at the plot level, but the data are aggregated from individual species to the community). The most commonly used are:

- Species richness - the total number of species recorded in the sampling unit (plot).
- Total abundance - the sum of the abundance classes across species.
- Score on compositional gradient - the score is calculated as (1) a weighted average across species for a given sample unit, the species weights being derived from a measure of sensitivity to air pollution or any other gradient (see McCune 1991 for a discussion of the available methods) or (2) scores derived from equations based on ordination of samples varying in the quantity to be indicated (i.e., an "assessment endpoint," e.g. air pollution).

6.15.1.1 Indicator Evaluation

The following discussion considers the indicator selection criteria described in Section

6.1 as they apply to the communities part of the lichen indicator.

Interpretability --

All of these community parameters have been shown to be related to air quality (e.g., McCune 1988). Total abundance and species diversity are simple and fairly effective, but do not incorporate specific information on indicator value of different species. In the only study to compare all three approaches, compositional scores gave the strongest correlations with air quality data ($r^2 > 0.7$; McCune 1988).

Lichens are also well known to be sensitive to climatic differences. In general, however, lichen species are more widespread over diverse climatic regions than are terrestrial vascular plant species. Over very long periods, one should also anticipate successional changes in lichens, as the forest structure changes. These changes should be separable from changes induced by air pollutants because of the species involved. Certain lichen species are known to be sensitive to air pollutants, others are pollution tolerant (see lists in Wetmore 1983 and Ryan and Rhoades 1991), and still others are known to increase or decrease with forest succession (examples from North American literature: McCune and Antos 1981, 1982; Lesica et al. 1991). Thus changes in lichen communities will reflect changes in climate, the structure of forest communities, and air quality.

In the most important case, that of air quality, nominal/subnominal boundaries can be drawn by comparison of known polluted areas with otherwise similar but remote areas. Locally polluted areas occur in essentially all forested ecosystems of North America and the nominal/subnominal boundary can be varied and calibrated throughout the continent.

Quantification --

Lichen community data can be straightforward, rapid, and inexpensive to collect. The ultimate example of this (Gilbert 1974) is a map of SO_2 pollution zones in the British Isles that was prepared from data collected by schoolchildren! The principal difficulty with lichen community data is reliable identification of species. If one includes all of the macrolichens, significant lichenological training is needed to name the species. In the case of the British schoolchildren, a subset of easily recognized indicator species was used, along with user-friendly training materials. We propose to solve this problem by having field personnel collect a specimen of each species at each plot, to be mailed to a lichenologist for identification. In the 1991 FHM western pilot, field work per plot required about one hour for one person.

Quantification of lichen communities has taken various forms (McCune 1991), all of which have been effective to some degree. The simplest is to record the presence or absence of indicator species. More commonly, and to distinct advantage, cover or abundance classes are assigned by visual inspection of large plots. Higher accuracy at more expense is possible by quantitative subsampling. These methods have been shown to provide estimates of community parameters that are strongly related to long-term means of air pollutants (McCune 1988; Nimis 1990).

The primary potential cause of measurement error will be observers. We propose to minimize and quantify this error. Observer error will be minimized by (1) 2-day training sessions for field personnel, (2) using professional lichenologists for identifying routinely collected vouchers, mailed to them by the field personnel, and (3) frequent field audits. We also propose to measure the size of this source of error by a QA study to be completed before the 1992 field season.

Signal-to-Noise Ratio --

The high signal-to-noise ratio is evident in the overwhelming body of literature demonstrating strong relationships between air quality and lichen communities, even with crude measures (see discussion under "Interpretability".) This signal comes through both spatially and temporally. There are hundreds of papers using lichen communities

as indicators of local pollution gradients (e.g., McCune 1988). There are many similar papers related to regional scale (e.g., de Wit 1976 and other papers listed below under "Regional responsiveness").

Temporal responsiveness has been demonstrated both for degrading air quality (hundreds of studies) and for improving air quality (Rose and Hawksworth 1981; Showman 1981).

The signal can be enhanced by statistically controlling other variables. For example, Muir and McCune (1988) and McCune (1988) used covariates based on tree characteristics to enhance the air pollution signal of epiphytic lichens. Multivariate data reduction can be used to isolate trends related to specific assessment endpoints (e.g., air quality, Muir and McCune 1988).

Regional Responsiveness --

Regional responsiveness of lichen communities has been demonstrated and utilized by national monitoring grids in other countries; for example:

Country	References
England	Looney and James (1990), Wolseley and James (1990)
France	Van Haluwyn and Lerond (1988)
Netherlands	de Wit (1976- see Figure 6.15-1, 1983)
Switzerland	Ammann et al. (1988), Liebendorfer et al. (1988)

All of these studies have demonstrated moderate to strong relationships with directly measured air quality data.

Index Period Stability --

Lichen communities are an ideal long-term indicator because they show little or no variation at time scales from diurnal to year-to-year (in the absence of catastrophic environmental fluctuations, e.g., fire). There is essentially no seasonal or diurnal variation in lichen communities. Lichen species vary little in how apparent they are. There are no macroscopically apparent phenological changes. Their reproductive structures are stable and perennial, allowing the same opportunities for discriminating among species throughout the field season (and throughout the winter, for that matter). Short-term differences in climate will cause no apparent change in individual lichens, and thus, lichen community data should be independent of short-term weather anomalies.

Environmental Impact --

Environmental impacts of the field work will be negligible. Only one specimen per species per plot is needed for vouchers to be sent to specialists. This sampling activity will have very little effect on the lichen populations in the plot. Since lichen species are collected only off subplots, no trampling of subplot vegetation will occur.

6.15.1.2 Field Measurements

The objective of this task is to determine the presence and abundance of macrolichen species on trees in each plot. Samples will be collected and mailed to lichen experts.

The method has two parts and these are performed at the same time.

1. Make a collection of voucher specimens, for identification by a specialist, that represents the species diversity of macrolichens on the plot as fully as possible. The population being sampled consists of all macrolichens occurring on woody plants, excluding the 0.5-m basal portions of trees and shrubs.
2. Estimate the abundance of each species. Note that the crew member responsible for this task need not be able to accurately assign species names to the lichens (that is done later by a specialist), but must be able to make distinctions among species.

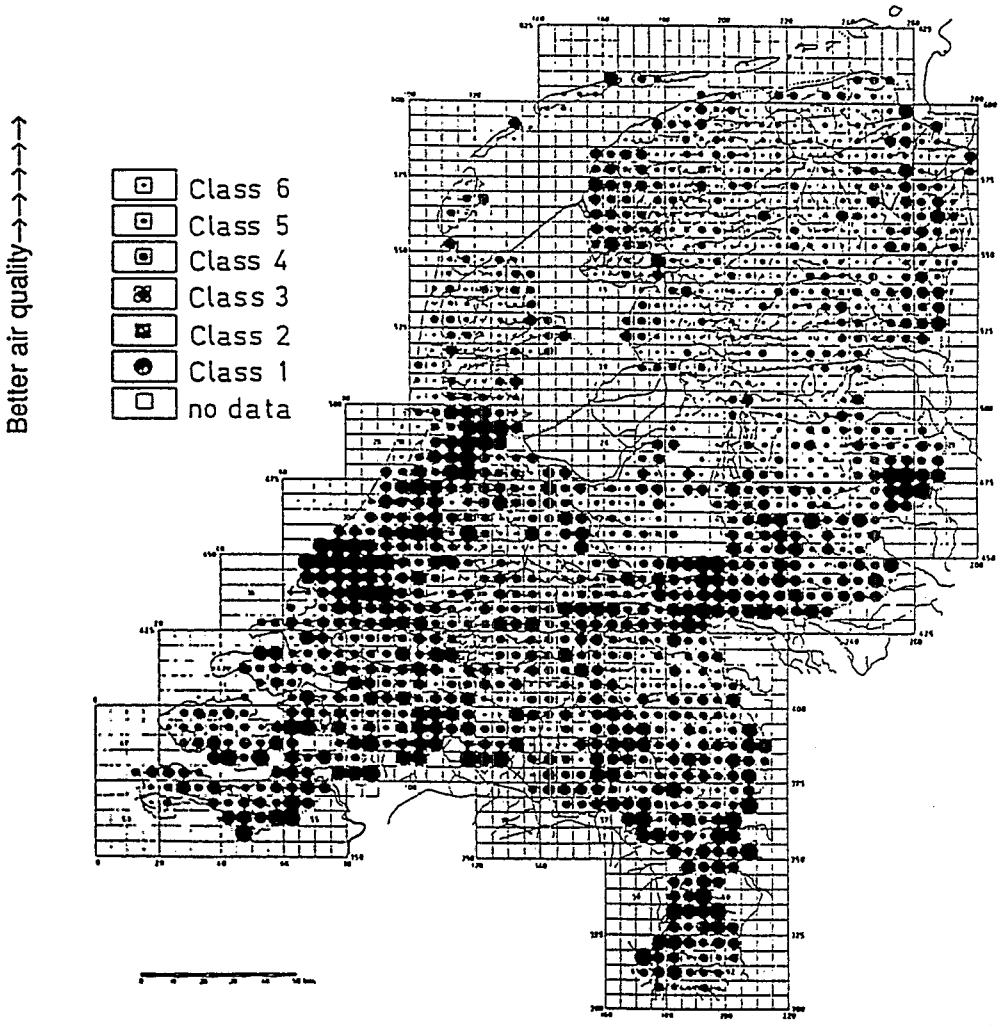

Figure 6.15-1. Final map of the epiphytic lichen vegetation in the Netherlands (based on classification T_4 (de Wit 1976).

6.15.1.3 Data Analysis

Data analysis will consist of:

1. Analysis of data quality by using data from audited plots. Data collected by the field personnel and the auditors (lichen specialists) will be compared.
2. Derivation of synthetic composite variables representing the major components of variation in lichen communities. This multivariate analysis will be done within bioclimatic regions.
3. Description of regional patterns of lichen community parameters.
4. Establishment of nominal/subnominal boundaries for indications of air quality by comparison of known polluted areas with otherwise similar, but remote areas. Locally polluted areas occur in essentially all forested ecosystems of North America, and the nominal/subnominal boundary can be varied and calibrated throughout the continent.
5. Analysis of the relationship between lichen community parameters and various off-frame spatial data (e.g., pollutant emission data) using standard analytical procedures provided by the FHM statistics group.

6.15.1.4 1992 Activities

Lichen communities will be included as an indicator in the Southeast Demonstration and possibly in the Western Pilot.

6.15.2 Lichen Elemental Content

Elemental content refers to the proportion (ppm or percent on dry weight basis) of various selected elements. Elements are selected for analysis based on the likelihood of detectable enrichment from anthropogenic sources. Typically, these include S, Pb, and as well as various other elements such as Ca, Cr, Cu, Fe, Mn, Ni, Pb, Ti, V, Zn. Each sample must contain only one lichen species and be free of dirt, bark, and other contaminants. Species are standardized by using regionally common species as much as possible to maximize the comparability among sites.

The lichen material is pooled in the field collection process thus yielding data collected directly at the plot level.

Elemental content has been determined by various methods, most commonly flame or furnace AA, ICP spectroscopy, and neutron activation analysis. A 10- to 20-g sample is adequate for splitting into 2 to 3 analyses for most methods. The method of processing the samples depends on the analytical method. However, samples are typically rinsed, oven-dried, then ground. Dried material can be stored indefinitely as a means of testing between-laboratory or within-laboratory variation over a period of years.

Lichen elemental content is clearly indicative of a key assessment endpoint: contamination of natural resources. Measuring a suite of elements allows differentiation among sources of contamination (e.g., fossil fuels, saltwater aerosols, agricultural dusts).

6.15.2.1 Indicator Evaluation

The following discussion considers the indicator selection criteria described in Section 6.1 as they apply to the elemental content part of the lichen indicator.

Interpretability --

Lichens are effective absorbers of soluble and insoluble minerals from their surroundings, including both wet and dry deposition (Nieboer et al. 1978). Extracellular ion-binding sites have been demonstrated that allow lichens to accumulate large quantities of potentially toxic cations without serious metabolic effects. Lichens tend to accumulate greater concentrations of metals than the foliage on the trees on which they grow (Bargagli et al. 1987) and consequently may more clearly demonstrate changes in deposition of atmospheric pollutants.

The total sulfur content of lichens is correlated to wet and dry sulfate deposition (typically $0.26 < r^2 < 0.64$; Takala et al. 1985; Zakshek et al. 1986). Elevated levels of many trace elements can be ascribed to coal-fired power plants (Showman and Hendricks 1989). General reviews of studies of elemental contents of lichens can be found in Bargagli 1989, Nash 1989, Nieboer et al. 1978, and Tyler 1989.

The rate of accumulation of elements varies by the element (see above reviews) and it varies by species (S, Takala et al. 1985; Ti, Takala and Olkkonen 1985). However, for a given species and a given element, the elemental content is a good indicator of atmospheric deposition of that element (see references in preceding paragraph). Thus the interpretability is maximized by focusing as much as possible on a small number of species and by analyzing the same combination of elements over broad regions.

Elemental content can be expressed for individual elements or for suites of covarying elements, just as is commonly done for direct measurements of atmospheric deposition (e.g., Hooper and Peters 1989). The latter case often strengthens the signal in the data by synthesizing information from covarying elements, the covariance resulting from

different elements having common sources. This correlation structure can be fairly strong (e.g., Rhoades 1988) and can be extracted by various techniques, especially principal components analysis. Plot scores on the principal components represent the importance of particular atmospheric sources, e.g. combustion of fossil fuels, saltwater aerosols, and agricultural dust and fertilizers. Each principal component is a linear transformation of original elemental contents into a synthetic score of the form:

score = a(E1) + b(E2) + c(E3) ... + m(EN)

where the Es represent content of a particular element and the small letters represent coefficients that maximize the variance explained by that equation. A series of such equations is produced by eigenanalysis. Typically, the first several such equations contain much of the variance in elemental content and are interpretable with reference to particular types of sources of atmospheric contaminants.

Nominal/subnominal boundaries can be drawn by comparison of known polluted areas with otherwise similar but remote areas. Locally polluted areas occur in essentially all forested ecosystems of North America, and the nominal/subnominal boundary can be varied and calibrated throughout the continent. In addition, elemental analyses of epiphytic lichens have been used in many areas of North America and form a substantial data base for different elements and different lichen species. These data could be synthesized and used to establish tentative nominal/subnominal boundaries.

Quantification --

Collecting samples for analysis of elemental content is quite simple and should take 10 to 30 minutes per plot. In the 1991 FHM western pilot, field work per plot required about 1 hour for one person for this task and the lichen community sampling.

Minimal training is needed to recognize certain target species. A small reference collection of target species can be prepared before training so that the collector is familiar with the target species. This reference collection can be consulted in the field by the collector.

There do not appear to be any large problems with contamination of samples in the process of field work or in laboratory handling, provided certain basic precautions are taken. Protocols for analysis should be the same as for any other plant tissue samples analyzed for FHM.

Measurement error should be small. Measurement error will be quantified by field splits and laboratory splits.

Signal-to-Noise Ratio --

Lichens rely directly on atmospheric sources of nutrition and lack a cuticle. For these reasons, their elemental content is very sensitive to changes in atmospheric chemistry. The signal-to-noise ratio is greatly enhanced by standardizing the target species and substrate (e.g., bark, or bark of a particular group of species).

Temporal responsiveness of elemental contents in concert with known changes in industrial emissions has been shown by Perkins et al. (1980), Showman and Hendricks 1989, and Walther et al. (1990). Lichens transplanted from areas with low air pollution to areas near coal-fired power plants had higher contents of certain elements (e.g., Cr, Ni) within 1 year (Garty 1987).

The biological mean residence time for most elements in lichens is 2 to 5 years (Nieboer and Richardson 1981; Walther et al. 1990). Thus one can anticipate some smoothing of an abrupt change in elemental deposition. However, lichens would be expected to show a reduction in elemental content within 1 to 2 yr of a decrease in emission from an industrial source (Nieboer and Richardson 1981).

Regional Responsiveness --

Elemental analysis of lichens has been useful in mapping regional air quality, providing greater detail than is possible from the sparse networks of direct air quality data. Some examples of national or regional programs of elemental analysis of lichens are listed below.

Region	References
Eastern Canada	Zakshek et al. 1986
Finland	Takala et al. 1985, Takala and Olkkonen 1985
Southern Louisiana	Thompson et al. 1987, Walther et al. 1990
Southwest US	Nash and Sommerfeld 1981
Switzerland	Ammann et al. 1988, Liebendorfer et al. 1988

The total sulfur content of lichens is correlated to wet and dry sulfate deposition (typically $0.36 < r^2 < 0.64$; Takala et al. 1985, Zakshek et al. 1986). Fewer data are available for other elements in regional studies because of the sparseness of direct deposition data for metals. However, many studies of metal contents around local pollution sources have readily demonstrated corresponding spatial differences in elemental content in lichens (e.g., Nieboer et al. 1972; Tomassini et al. 1976; Beckett et al. 1982).

Figure 6.15-2 illustrates the pattern of sulphur content in a reindeer lichen, Cladina rangiferina, in eastern Canada (Zakshek et al. 1986). In this case, the correlation coefficient between lichen S content and wet deposition was 0.6. The authors felt the correlation would have been higher had the sample sites been co-located and had dry deposition also been included (since lichen S reflects both wet and dry deposition).

Index Period Stability --

Lichen elemental contents have sufficient temporal stability over the short term to be reliable indicators of long-term changes. Good evidence of this is the easily-observed responsiveness of elemental contents to changes in regional pollutant emissions, (e.g., Perkins et al. (1980), Puckett (1985), Showman and Hendricks (1989), Walther et al. (1990)) and retrospective studies (based on herbarium specimens) reviewed by Lawrey (1984).

Seasonal and short-term variability have been studied in detail by Boonpragob and Nash (1990) and Puckett (1985). These studies found no consistent seasonal variation in elemental contents of lichens. In some cases, however, occasional significant departures from the norm occur (e.g., Al in reindeer lichens sampled monthly over three years showed occasional high spikes; Puckett 1985). There is no reason to expect diurnal variation in elemental content.

The material is rinsed before analysis, differences in elemental content due to time elapsed since heavy, cleansing rains should have little or no effect on the elemental content.

Lichens are phenologically stable throughout the year; i.e., there are no macroscopic phenological changes in lichens (such as development and shedding of leaves).

Environmental Impact --

Environmental impacts of the field work will be negligible. In almost all cases, the amount of material collected for elemental analysis will be only a small fraction of that available in the plot, simply because target species will be chosen partly on the basis of their abundance. Since lichen species are collected only off subplots, no trampling of subplot vegetation is likely to occur.

6.15.2.2 Field Measurements

Lichen samples, collected to determine the elemental content of selected lichen species in each plot, will be used to establish site baseline for toxic elements and determine

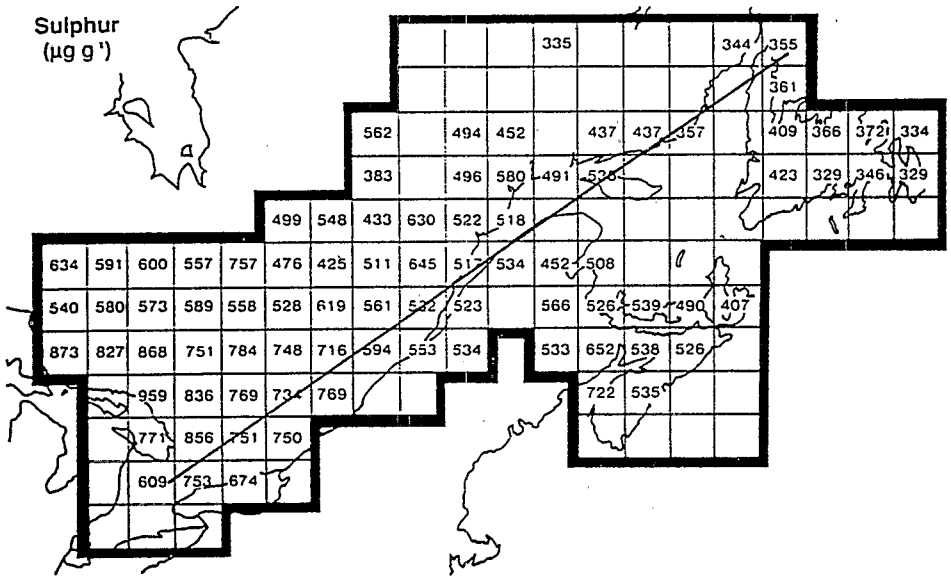

Figure 6.15-2. Sulphur concentrations in C. rangiferina in eastern Canada. Data are the mean value of 5 replicates (Zakshek et al. 1986).

regional toxic element profiles. Desirable attributes of species to be collected for elemental analyses are: regionally abundant, commonly present on the plot, and easy to collect 20 to 50 g dry weight of tissue. No lichens are collected from within the subplots.

The samples are processed first by a lichenologist and then sent to an analytical lab for determination of elemental content. The lichen specialist processes the sample by first checking to see that it is thoroughly air dried, identifying the species contained in the sample, and verifying that the sample contains only one species. The samples are then mailed to the laboratory where they will be cleaned, ground, and analyzed.

6.15.2.3 Data Analysis

Data analysis will consist of:

1. Analysis of data quality by comparing results from field splits and laboratory splits.
2. Derivation of synthetic composite variables representing the major components of variation in elemental content of selected species. This multivariate analysis will be done within bioclimatic regions.
3. Description of regional patterns of elemental content.
4. Establishment of nominal/subnominal boundaries for indications of air quality by comparison of known polluted areas with otherwise similar but remote areas. Because locally polluted areas occur in essentially all forested ecosystems of North America, the nominal/subnominal boundary can be varied and calibrated throughout the continent.
5. Analysis of the relationship between lichen community parameters and various off-frame spatial data (e.g., pollutant emission data), using the standard analytical procedures provided by the statistics group.

6.15.2.4 1992 Activities

The relatively late consideration of lichen elemental content analysis as an indicator has precluded its inclusion in the 1992 field work to date. Meanwhile, development of supporting documentation will continue.

7. Design Overview

D.L. Cassell

The U.S. Forest Service has a developing Forest Health Monitoring program. The Environmental Monitoring and Assessment Program (EMAP) is a program of the U.S. Environmental Protection Agency (EPA). As previously discussed in this document, these two agencies have combined their efforts with other agencies interested in evaluating the health of our nation's forests.

7.1 The Forest Health Monitoring Design

The FHM program objectives can be stated as follows:

1. To estimate the current status, extent, and trends in indicators of the condition of the nation's forest resources. Furthermore, this is to be done on a regional and national basis, with known statistical confidence in the estimates,
2. To monitor indicators of pollutant exposures and habitat condition and identify associations between human-induced stresses and forest conditions, and
3. To provide yearly statistical summaries and (non-annual) interpretive reports on forest status and trends to resource managers and the public.

Specific design features are essential to achieve FHM objectives. One feature is the use of probability samples to provide a consistent representation of environmental reality. In addition, all ecological resources and environmental entities must be represented. The design must be sufficiently flexible to accommodate post-stratification and aggregation for many alternative subpopulations, such as states or special areas of interest. There must be inbuilt capacity to respond quickly to a new question or issue. The spatial distribution of any sample must reflect the population distribution of the resource. Finally, periodic revisiting of all sampling sites is required.

These requirements led directly to the EMAP FHM design (Overton et al. 1990). This design has been subjected to extensive peer review. The American Statistical Association has a special peer review panel to evaluate the EMAP design, as well as all the resource group designs, including that of FHM. This peer review committee has found that the EMAP design is a good choice for achieving the goals of FHM. Furthermore, the FHM design was favorably reviewed by Forest Service statisticians in early 1991.

7.1.1 The Monitoring Grid

The EMAP monitoring grid design uses a triangular grid so that the nation is tesselated with hexagons, each covering approximately 635 square kilometers. Within each 635 square kilometer hexagon, a hexagon of approximately 40 square kilometers represents a 1/16th sample of the resource. Each such "40-hex" represents the tier I sample which will be characterized using remote sensing. Within a 40-hex, a point can be located on the ground. A ground plot then represents the support for that point. Measurements are made for indicators of exposure, habitat, and response. In the national design, measurement visits are made on a 4-year cycle on specific subsets of the grid that preserve the spatial structure, so that samples are distributed over time and space. In statistical terminology, this arrangement of sites across space and time is often referred to as an 'interpenetrating' design. This permits analysis using traditional Horvitz-Thompson estimation (Horvitz and Thompson 1952: Overton et al. 1990).

7.1.1.1 The Triangular Grid

The grid yields approximately 12,600 hexagons, of which approximately 4,000 will have forested ground plots. Ground plots are classified as forest according to standard Forest Service FIA procedures. The hexagons

represent a systematic grid with a random start; the centers of these larger hexes are randomly located by selecting a single random point in space and moving the entire pattern so that a hexagon center is on that point. Then a random point is located within a large hexagon, and the entire systematic grid of 40-hexes is fixed by locating one 40-hex center on that point.

The triangular grid is preferable for the FHM project because it is spatially compact, it provides uniform spatial coverage, and it is very flexible for altering the grid density. In addition, a triangular grid is less likely than a square grid to coincide with anthropogenic features.

Regular spacing of points generally leads to population estimates with smaller variance than simple random sampling. With uniform spatial coverage, resources in the landscape are sampled in proportion to abundance, area, spatial pattern, and grid density. If the interpenetrating sampling scheme and the 4-year cycle are used, this is achieved every year. The triangular grid allows a wide variety of grid enhancements and reductions, as well as other options for special cases, such as subpopulations of special interest.

7.1.1.2 Evaluating Status and Change

There are several key issues in monitoring across both time and space. Current status is best measured by including as many population units as possible since greater coverage enhances the identification of subtle subpopulation differences. Detection of trends, however, is best achieved with repeat observation of the same units over time, with the interval between observations related to the signal-to-noise ratio of the measurements. In addition, observer effects can be a problem; too long a time between visits may mean that field measurements cannot be properly calibrated, while too short a time between visits may lead to environmental impacts, such as trampling of the understory.

The EMAP solution adopted by FHM is an interpenetrating design that distributes samples across both time and space, so that each year's sample preserves the spatial structure of the real resource, and sampling is always proportional to the areal extent of the resource. The interpenetrating design is a special form of a class of statistical sampling designs that are also known as rotating panel designs in the (sociological) survey sampling literature.

For faster detection of trends in the first 4 years, a simple improvement was developed by the EMAP-Design staff. If desired, approximately 10 percent of the sites can be visited annually for the first 5 years of the project. By the beginning of the second cycle, the statistical advantage of annual revisits to sites is negligible. Furthermore, revisiting more than about 10 percent of the sites, even in the first cycle, is not cost-effective. The extra cost and effort is not rewarded by a corresponding improvement in trend detection ability. If there are ecological reasons for visiting sites more often, they need to be established scientifically as part of FHM pilot studies.

Alternate methods for improving detection of trends and speeding assessment of current status involve taking larger subsets of the grid in the first field season. For example, if one visits all sites in the first year and then each following year visits only the standard interpenetrating one-quarter, then each estimate for years two through four consists of replacing the first year's matching one-quarter of data with the latest year's one-quarter and updating the estimates of status and extent. In such an approach, by year five, one would be back to the standard interpenetrating cycle. A smaller 'jumpstart' can be achieved by doing more than the standard one-quarter but less than all sites in the first year. The design is flexible enough to allow any desired level of intensity for visiting ground plots.

To answer questions about the condition of forest ecosystems, it is necessary to specify the area of interest explicitly. This is the target population, the areal extent of forested ecosystem about which estimates of conditions

will be made. Subpopulations can be defined for any region or attribute. Subpopulations can serve two major purposes: (1) increasing the precision of estimates of condition and trend by reducing extraneous variation; and (2) targeting specific sets of resources for assessment and reporting.

7.1.1.3 Stratification

No stratification of the resource is being performed. There have been discussions about appropriate stratification methods for the effective evaluation of status and trends in forests, but no clear choice of stratification method has emerged. In fact, it may be that stratification on current resources would provide distinctly nonoptimal sample designs for future study of the dynamic forest resource.

In many cases, insufficient prior data would be available to perform stratification at the desired level. Furthermore, misclassification errors of as little as 20 percent would invalidate any potential gains in precision from stratification.

7.1.1.4 Higher Grid Densities

Increasing the grid density is recommended for increasing the sample size for any subpopulation. For specific forest types of special interest, it appears that higher grid densities than the standard EMAP grid would be needed. As an example, high-elevation spruce/fir forest occurs only in specific elevation contours. Based on the standard EMAP grid density, it is estimated that less than five high-elevation spruce/fir forest sites would be obtained. Another case applicable to FHM is the special interest of particular states. For the 1990 FHM field season in New England, the state of Rhode Island asked for a denser grid to be overlaid on their state so that they could obtain enough sites to make statistical evaluations.

In each case, it will be necessary to use an iterative process to select such a tier II sample (see Section 1.2 for a definition of the tiers). The first step will be to determine the desired tier II sample size. If the standard grid will not produce a sufficient number of sites, then the density of the grid can be iteratively increased until the desired sample size is obtained. The FHM design is flexible enough to meet this need without serious problems.

7.1.2 The Field Sampling Design

Field sampling involves the collection of tier II measurements for specified indicators. The key features are the statistical selection of ground plots and the design of ground plots for multiple categories of measurements.

7.1.2.1 Selection of Ground Plots

A crucial step in collecting indicator measurements is selecting the field plots to ensure that the data represent a probability sample. The current method of tier II site selection is equivalent to selection of a single Forest Inventory and Analysis (FIA) photo point. This method permits a statistical linkage to the FIA program. The FIA photo point grid for a region is overlain on a 40-hex. Then the closest FIA photo point to the center of the 40-hex is selected. In cases where the selected photo point is already an FIA plot, the FHM plot is offset from the photo point.

In areas where FIA photo point grids do not exist, the FIA has been willing to extend the systematic photo point grids to cover all forested lands.

There are other alternatives as well. With modern GIS software, a planimetric (equal-area) grid can be laid over a base map to locate ground plots and accurately determine latitude and longitude. The selected points can then be photointerpreted along with the FIA photo points, so that links with the FIA program are maintained.

Another, less preferable, alternative is feasible in places where FIA photo points are not currently available. The ground plot can be located at a random offset from the center of the 40-hex, and these points can then be added to the list of FIA photo points for photointerpretation.

7.1.2.2 Ground Plot Structure

The design of FHM field plots was developed jointly by the Forest Service and the EPA. The original plot design resulted from research on optimally cost-effective plot designs for FIA mensuration measurements (Scott 1991). This design includes a circular 1-hectare plot with four fixed-radius subplots for field measurements (Figure 7-1). The 24-foot-radius subplots are arranged in an equilateral triangle with an additional subplot at the center of the triangle. The centers of the outer subplots are 120 feet from the center of the central subplot.

The plot design has been evaluated for all indicators that have reached the pilot and demonstration stages (Riitters et al. 1991b). This evaluation used sampling theory formulas (Cochran 1977) to estimate optimal numbers of plots, subplots, and observations within subplots. Current research suggests that the plot design is adequate for all current FHM indicators in previously studied regions.

The fixed-radius plots provide several key advantages over variable-radius plots. Although variable-radius plots are slightly more efficient for measuring current status for characteristics correlated with basal area, fixed-radius plots are preferable for estimates based on variables uncorrelated with basal area, such as the majority of FHM measurements. In addition, fixed area plots are easier for measuring change over time.

Extractive measurements on trees are performed in a 36-foot wide ring around each subplot, with soil samples taken at the junctures of these four rings. The subplots and destructive sampling zones are laid out so that there are statistical and ecological linkages between indicators.

7.2 The Flexibility of the FHM Design

The flexibility and responsiveness of the FHM design is reflected in the design variations used in the pilot, demonstration, and implementation projects being organized across the country.

7.2.1 The Southeast Region

In the Southeast region, a combination of the standard design method and slight variations has been used. The 1991 demonstration and pilot projects in Georgia used the standard interpenetrating one-quarter of the grid, while growth, mensuration and visual crown ratings were performed in all the hexes with forested ground plots. The extra plots measured in 1991 will allow earlier evaluation of change and trend earlier than if no plots were revisited before the fifth year.

The 1992 Southeast demonstration project has a slightly different objective than standard implementation monitoring, and hence has a slightly different design. This is a 2-year demonstration. The focus of the project is the loblolly and shortleaf pine forest types in a four-state region. Thus, the subpopulation of interest is that area of forest in loblolly pine or shortleaf pine forest type; the domain is the forested region bounded by the borders of the four states.

Since the goal of this demonstration is not all forest types in the region, early reconnaissance will categorize the forest types at all ground plots. Plots with loblolly and shortleaf forest types will be visited by field crews during the field season. This is equivalent to a poststratification, since it is logically equivalent to visiting all the plots and only reporting on the forest types of interest.

In planning the Southeast demonstration, it was calculated that at the baseline grid density and using the one-quarter interpenetrating schedule, only about 30 plots would be sampled. This is not sufficient for all the analyses planned. Therefore, several alternatives were examined. The alternative that will provide the most gain and still maintain the grid density is to visit more than one quarter of the plots. Since this is a 2-year project, the most effective way of subsetting the grid is the sampling during the 1992 field

Distance between points is 120 ft.

Azimuth 1-2 360°
Azimuth 1-3 120°
Azimuth 1-4 240°

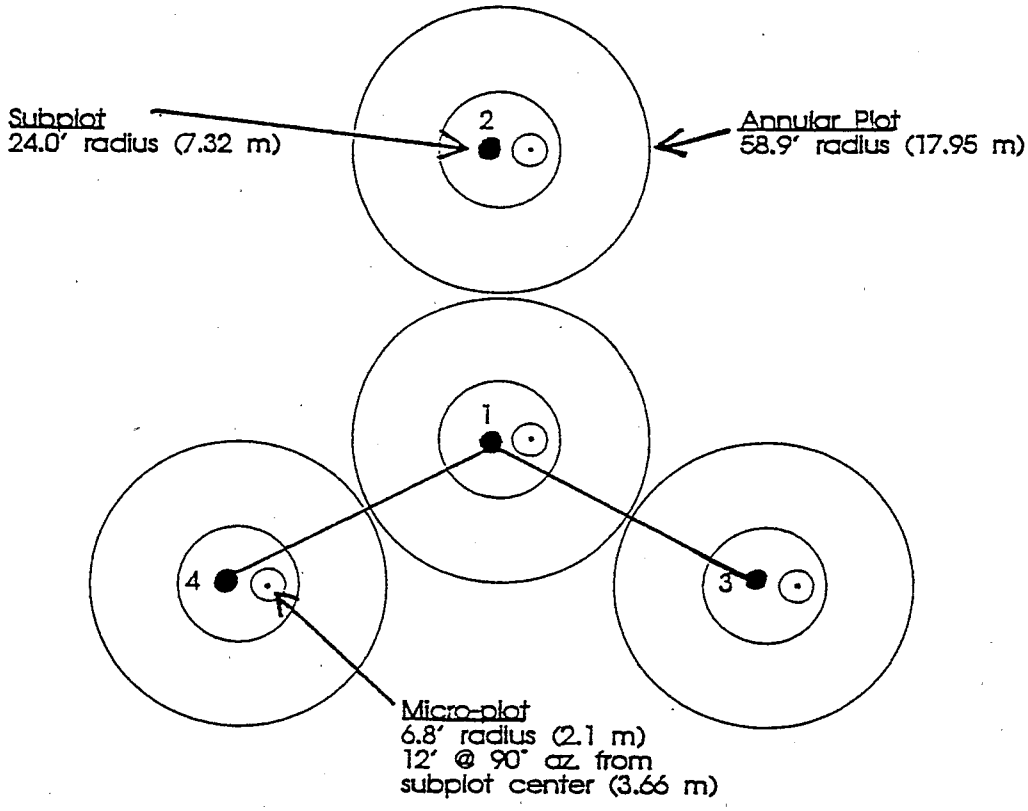

Figure 7-1. The FHM field plot design.

season of both the 1991 and 1992 quarters of the interpenetrating schedule and to sample both the 1992 and 1993 quarters of the interpenetrating schedule in 1993.

With this design, approximately 65 ground plots will be visited in 1992 and in 1993, and approximately 33 plots will be visited in both years. This will permit the generation of yearly statistical reports in both years of the study, as well as evaluation of short-term change and inter-annual variability.

Logistical problems led to the use of a planimetric grid in place of the FIA photo point grid for locating plots in North and South Carolina. The photo point grid was not available for South Carolina in time for field work. Hence, a planimetric grid of the same density as the FIA photo point grid was laid over the two states and ground plots were selected as discussed in Section 7.1.2.1.

7.2.2 The Southern Region

In the Southern region, the state of Alabama participated in pilot activities in 1991. This state was not able to use current photo point grids, and so they used the previously discussed (Section 7.1.2.1) alternative of locating each ground plot at a random offset from the hex center.

7.2.3 The Western Pilot and Detection Monitoring Activities

In the Western pilot and detection monitoring activities, the original plan was to use the standard one-quarter of the interpenetrating design. However, fiscal and logistic considerations led to problems that the overall design was flexible enough to handle.

In California, due to budget constraints, it appears that not all of the hexes in the standard one-quarter of the interpenetrating schedule can be visited this year. Altering the grid density or changing the length of time between revisits are not reasonable options given the need for states to be compatible with regional analyses. A simpler approach was developed that preserves the grid density and the interpenetrating schedule.

A spatially clustered subset of the standard one-quarter of the grid was selected. In essence, this process divides the hexes within the standard one-quarter in the state into contiguous groups of four hexes each. Three of the four hexes in each cluster are randomly chosen to be visited. This reduces the number of ground plots to an affordable level, while preserving the spatial structure of the grid and the four-year cycle. In addition, this design permits easy expansion to the original schedule.

A different problem arose in planning for Colorado. The crews may be able to complete their field work in less time than has been allotted. Planners asked for approximately ten additional plots to be visited in case of early completion of the planned field work.

Extra plots for Colorado were selected so that, if they were visited in 1992, they would be revisited in 1993 for estimation of interannual variability in the region. A fraction of the standard one-quarter of the interpenetrating grid for 1993 was selected, so that these sites are a reduction of the grid. This preserves the spatial characteristics of the FHM grid so that the sample is taken proportional to the area of the resource.

7.2.4 The Northeast Region

In the Northeast region, all ground plots are currently visited annually. That is, all four quarters of the tier II interpenetrating schedule were visited in 1990 and 1991 and will be revisited in 1992. However, only visual crown ratings were taken in 1991 and only these measurements will be taken in 1992. Under normal circumstances this design is not a cost-effective approach and could ultimately lead to impacts from repeated visits.

The design, however, is flexible enough to permit analyses with this schedule. In the Northeast there is serious concern about annual variability in tree crowns. In addition,

FHM in the Northeast does not have sufficient remote sensing capability to replace the annual ground visits. For these reasons current plans to continue the annual visits for measurement of visual crown ratings until more effective approaches are available.

In addition, the Northeast has intensified the baseline grid density in some areas. In 1990, EMAP-Design group developed an intensification of the standard grid for the state of Rhode Island, so that state foresters would have enough ground plots to make state-level estimates. Similar plans are currently underway for the state of Delaware.

7.2.5 The Ground Plot Design

In addition to these extensions of the monitoring network design, the ground plot design also permits flexibility and alterations in measurements. The ground plot design has proved to be flexible enough to incorporate measurements of lichen community, stemwood chemistry, and wildlife habitat. The adaptability of the design has permitted alterations in the measurements for vegetative structure. In addition, the plot design is flexible enough to allow extensions of the ground plot design to incorporate off-plot measurements on air pollution bioindicator plants and off-plot FPM measurements.

8. Assessment Overview

FHM National Assessment Group

8.1 Introduction

Assessment is the process by which data from Forest Health Monitoring (FHM) and other sources are converted into useful information. The immediate purpose of FHM is to prepare forest health assessments (provide useful information) needed by those concerned with forest environmental and management policy. The process of assessments in forest health monitoring can serve a larger purpose, enabling forest health studies and assessments by a set of users extending beyond the sponsoring federal agencies. This chapter reviews critical elements of the FHM assessment process and describes FY92 activities.

The background and prototype approaches to forest health assessments are discussed elsewhere (e.g., Palmer et al. 1991; Riitters et al. 1992). The logical, multiphase and multidimensional research approach taken is consistent with recent National Research Council recommendations for monitoring and forest research (NRC 1989, 1990a, 1990b) and will not be reviewed in detail here. In comparison to other forest health assessment processes, an exciting and unique feature of the FHM approach is the "environmentalist" paradigm (e.g., Leopold 1949) as recommended by the NRC (1990b) to permit responses to emerging public concerns about forest health (without locking into any "preferred observer" status). Another important feature is the early formation of a truly cooperative assessment group with responsible individuals from each participating agency.

Current assessment reports are severely limited by the amount of data presently available from the program; only about 20 percent of the total number of plots have been installed, only a few measurements are made on those plots, and only 1 year of data is typically available. These facts have led to the current emphasis on developing assessment tools (hardware, software, infrastructure, team-building, and communications). As data accumulate over time, the assessment "machine" will be developed that can analyze the data and to prepare increasingly relevant assessment reports. In the meantime, reports are being prepared based on available data. Well over half of the assessment effort is directed towards incorporating other data bases, such as air pollution, climate, and forest pest management, that will be absolutely necessary for understanding the statistical status and trends that the plot network identifies.

8.2 Regional Forest Health Monitoring Assessments

By mutual consent of the U.S. Environmental Protection Agency (EPA) and the U.S.D.A. Forest Service (FS) (July 1991), regional reports of forest health will be prepared by regional FS staffs. Details of these reports may be obtained from the FHM national program managers or from the regional FS assessment leaders. It is expected that the regional reports will be consistent with each other in terms of tabular formats and units of measurements. Annual releases of regional reports are scheduled for January for data collected during the preceding field season.

At present, however, there is no mechanism to guarantee that the regional assessments will be consistent in format or units with any multiregional or national reports. As a practical matter, individuals from each region participate as part of the National assessment group (see Section 8.4), and it is expected that some elements of regional and national reports will ultimately be standardized for the program as a whole. Also, the regional groups can utilize all of the data bases and analyses that have been developed for the national assessment machine, thus increasing overall program efficiency. Both the regional and national groups will improve assessments at a faster rate by working together. Current

administrative difficulties related to reconciling national and regional reports, responsibilities, and timelines has been brought to the attention of the Technical Director and national program manager. A new interagency agreement is the mechanism that will resolve these potential problems.

8.3 National Forest Health Monitoring Assessments

To ensure that the assessment process that is developed is workable, real data from the 1992 field season (12 states in 2 regions) are being analyzed, and a prototype statistical summary report is in preparation. The scheduled release is September 1, 1992. The report will consider measures of forest condition that are currently made on FHM plots (visual symptoms of tree health and tree diversity), and selected auxiliary data from other sources (forest pest incidence, climate and weather, and air pollution). In addition, each plot in the existing network will be characterized according to key attributes to give an indication of the types of forests that have been sampled.

Analyses of FHM plot data will utilize any statistical technique which has been peer-reviewed for the FHM sampling design (Overton et al. 1990). This basic toolbox of techniques enables the creation of a statistical summary document. Depending on what is revealed by the preliminary analyses, further studies of associations among measurements may be made. Depending on the power of the basic techniques, other statistical techniques may be developed and demonstrated by this report.

The 1992 report will contain one section for each major type of data that is analyzed. It will also contain an overall summary section, written for the policymaker, that attempts to show the importance of the findings for a "typical" policymaker in either the EPA or the FS. This format, like the assessment process, is being tested in the 1992 report and may be modified later depending on reader feedback.

In summary, the regional and national 1992 reports are test-beds for assessment procedures, communications, and reporting formats, given the current status of the operational monitoring data collection system. Assessments will become increasingly important as the program moves from a data-collection mode into a mode of data analysis, assessment, and discussion of findings.

8.4 The Forest Health Monitoring National Assessment Group

The first meeting of the national FHM assessment group took place in December 1991. A "manifesto", prepared during the meeting of about 20 individuals, was approved by the FHM Technical Director and national program manager. The document is reproduced below because it is an assessment plan that has the consent of both the group and the program managers. Note that the plan is not complete; part of our plan is to be flexible, to try what has been suggested, and to later modify the process to make it more workable over time.

The second meeting of the national group took place at the end of March 1992. Preliminary indications are that preparing a useful statistical summary will require the majority of the authors' efforts, and, therefore, the report will not contain very much biological interpretation of results. The majority of information will in fact come from the non-plot data sources such as forest pest management and climate. In most instances, the major constraint appears to be a lack of time available to participants to complete their assessment responsibilities. The group will recommend a solution during its self-evaluation that is planned for later in the year.

From "Summary of the 12/10-11 forest assessment meeting (Section 1: Introduction and statement of purpose)":

"Forest assessments are important to the program. There is not enough time or resources to do the job we'd like to do, so the scope and content of the 1992 report will be commensurate with what is available. We believe that the 1992 report will demonstrate at least some of what can be done at the national scale with forest monitoring and ancillary data. The process of producing the report will help identify bugs in the assessment system and may force the resolution of key issues that are beyond our control.

"The forest assessment group is open to participation by anyone who brings to the group: scientific rigor, a willingness to cooperate and contribute, and an orientation towards producing reports for the monitoring program (rigor, responsibility, relevance). The group is limited by available data; participants must have data to make a contribution. The group will grow over time as more measurements are implemented, as more ancillary data bases are made available, as the scope of inquiry increases, and/or as more agencies and organizations begin active participation in the monitoring program.

"This group fills the niche of national scope and national scale. We are not responsible as a group for sub-national reports, even though some of us participate in other groups to produce those reports. We use the data that are presented to us by the monitoring program, and we add value by constructing a view of those data with a national scope and scale, by adding ancillary data, by exploring associations among data. We serve any clients that require such value added.

"The reports made by this group are a subset of all program reports. This group does not produce plans, manuals, database reports, QA reports, or specific policy analyses. We provide statistical summaries and biological interpretations of the monitoring and ancillary data.

"In 1992, we intend to produce a statistical summary of the available data, and to push as far as possible in the direction of interpretation of those data.

"Within our group, we distinguish subgroups for "the system", "on-frame" data, and "off-frame" data. The systems group will make an engine (software, hardware, infrastructure) that will enable a semi-automated production of an annual statistical summary report. The engine will be improved over time according to the program's ability to agree upon the minimal standard and peer-reviewed set of analysis procedures. The on-frame group will assess the data that are flowing from the program's field efforts, using the engine to facilitate analyses and ensure comparability and consistency. The on-frame group size is in direct proportion to the number of assessable measurements that are presented to the group by the program. The off-frame group will assess selected ancillary data that are flowing from other programs' efforts, matching their outputs to the input needs of the engine. The size of this group will be in proportion to the number of off-frame data bases that are available for assessments.

"There is or will be a separate group of reviewers and commentators who may attend group meetings, but who will not be responsible for producing any parts of the reports.

"Although the current path to statistical assessments will be readily apparent (by examining the engine), the path to interpretive assessments depends on where the assessors steer

the engine. The interpretive paths cannot always be predicted, and the assessors cannot always say they will arrive somewhere, but it is the group's intention to request the managers put gas in the engine (funding) and the assessors behind the wheel (assignment). At a minimum, each assessor will always provide a minimal interpretation of any statistical summary, where "minimal" implies peer-acceptable.

"At this time, the group has no control over who participates in the group. Participation is by appointment by Sam Alexander or Joe Barnard [the national FHM managers]. Each member of the group negotiates separately with Sam or Joe to ensure that resources are available to meet individual commitments to the group. The group raises this issue with Sam and Joe: There is a need and desire to broaden the participation in our group with at least state representation and also other agencies and organizations. The criteria of rigor, relevance, and responsibility should apply to the appointments."

8.5 Relationship to Field Pilot and Demonstration Projects

The regional and national assessment groups are not responsible for reporting the results of field pilot and demonstration projects, per se. This is so because pilot and demonstrations projects need not have "assessments" as a primary goal. However, if any field pilot or demonstration project offers a data set that is useful either for an assessment or for improving the assessment process, then the assessment groups will consider how to bring the project data into the ongoing assessment process. The point is that, from the groups' points of view, the ongoing assessment process has a higher priority than the report from any single pilot or demonstration project.

9. Reporting Overview

B.L. Conkling

Reports are an important vehicle for sharing the data collected and the information learned, both within and outside of the Forest Health Monitoring (FHM) team. A variety of documents can be produced in association with a demonstration project, beginning at the planning stages and continuing through assessment. Reporting, along with assessment, is a growing area of emphasis within FHM. A general outline of reporting can be found in Chapter 11 of The Monitoring and Research Strategy for Forests (Palmer et al. 1991).

Reporting includes the planning, preparation, review, and final production of documents. Because reports and other documentation are needed or required in most phases of pilot, demonstration, and implementation projects, many of the FHM team members are actively participating in one or more report-writing activities. A brief discussion of anticipated documents associated with FHM project is given below.

9.1 Activities Plan

The Activities Plan contains the objectives, rationale, and logistical plan for conducting the projects. The chapters, written by FHM team members for their respective areas of responsibility, include objectives, design, logistics, quality assurance, information management, indicator rationale, assessment, and reporting.

9.2 Quality Assurance Project Plan

The Quality Assurance Project Plan (QAPjP) (Byers and Palmer 1992), contains a description of how each indicator will address QA/QC concerns. A further description of the QAPjP can be found in Chapter 10 of this document.

9.3 Methods Guides and Manuals

All methods guides and manuals are actually part of the QAPjP. Because of their importance, however, and for convenience, the methods documents will be discussed separately.

Two methods documents will be used in 1992 activities, the field methods guide and the preparation and analytical laboratory methods handbook. The Forest Health Monitoring Field Methods Guide (Conkling and Byers [eds.] 1992) documents the field methods used for all indicators to be used in 1992 activities. Each indicator lead contributes the complete field methods for his or her indicator. The Field Methods Guide will be available to FHM participants in several versions. A National Guide documents all procedures to be used in all regions of the country. In addition, regional versions will be prepared for detection monitoring crews in the Eastern United States, for the Southeast/SAMAB Demonstration projects, and for the Western Pilot project.

The EMAP-Forests: Handbook of Laboratory Methods for Forest Health Monitoring (Byers and Van Remortel [eds.] 1991) documents the complete methods for sample preparation and any analytical procedures performed on samples collected in the field as part of any FHM field work. Each indicator lead contributes the methods to be used by the contracted preparation and analytical laboratory(s), including quality assurance/quality control requirements.

9.4 Statistical Summaries

Statistical Summaries are annual reports which present the data for the previous field season in a way which is useful to the readers.

These are intended to be systematic data presentations which communicate the current status of the forests which were measured during the previous field season. Indicators which are part of either implementation or demonstration projects in the 1992 field season will probably be included in Statistical Summaries in 1993. Currently, the Statistical Summary including 1991 data is being prepared using available data from previous field seasons. Assessment leads have access to various off-frame data such as climate, wet and dry deposition, landscape characterization and remote sensing, geographic information system data, and data from the Forest Pest Management Program (see Chapter 8).

Regional reports will also be prepared as necessary.

9.5 Demonstration and Pilot Reports

Additional reports for demonstration and pilot projects will be prepared which will focus on indicator development. These reports will be prepared by the indicator leads in conjunction with the Indicator Development Coordinator for FHM.

9.6 Miscellaneous Possible Reports

Various other reports are expected to be prepared after the end of each field season. These reports include the Quality Assurance Project Annual Report and Workplan and the Logistics Report. The Quality Assurance Project Report and Workplan, prepared by the FHM QA coordinator, is the end-of-year QA report. It reports how well the various parts of the project met the QA/QC objectives. This report not only presents the results of the work just completed, but also is an important planning document for the next year's work. The Logistics Report is the end-of-year report of what was successful and what needs modification in the areas of logistics and general project operations. An important part of this report is the notes from the field crew debriefings which are held at the end of field season. Any notes or suggestions from crew members, crew leaders, coordinators and other FHM team members can be included in this report. This is an important documentation of the field season just completed and a vital planning document for the next year.

Other reports are possible which are not well-defined at this time. An example is quality assurance reports written by assessment leads and sent to the participating preparation or analytical laboratory(s). Various reports or documentation may also be requested by the Technical Director, Program Manager, or other management personnel within FHM or EMAP.

10. Quality Assurance Overview

G.E. Byers and C.J. Palmer

As discussed in the Introduction (Chapter 1) of this document, both the USDA Forest Service (FS), via the forest health monitoring program, and the U.S. Environmental Protection Agency (EPA), via the Environmental Monitoring and Assessment Program (EMAP), are key participants in the Forest Health Monitoring (FHM) program. As part of the EPA Office of Research and Development, EMAP will participate in the Agency's mandatory quality assurance program (Stanley and Verner 1985). Accordingly, FHM will develop an appropriate quality assurance (QA) program to ensure that resulting data and information are of known, acceptable, and documented quality.

The FHM program is designed as a major environmental data collection effort and, as such, will operate within the guidelines of the EPA Quality Assurance Management Staff (QAMS). Utilizing a statistically robust design, the FHM program will collect data across large geographic areas over long periods of time for multiple ecological resources. The purpose of the QA program is to ensure that the resulting FHM data bases will yield scientifically valid and unbiased information related to the principal hypotheses being addressed in the project.

10.1 Quality Assurance Documents

The Quality Assurance Program Plan, being prepared by the EMAP QA staff is the major reference document for quality assurance for all resource groups within EMAP. It contains descriptions of quality assurance objectives, policies, procedures, planning, assessment techniques, and communications. The "Monitoring and Research Strategy for Forests-Environmental Monitoring and Assessment Program" (Palmer et al. 1991) describes the FHM QA program and organizational structure. The FHM policies, objectives, and functional responsibilities designed to achieve data quality goals are described in detail. The QA section of that report includes discussions on quality assurance related to policy, total quality management, organizational responsibilities, data quality objectives, documentation, and reporting. Other QA-related FHM documents used as reference material are Burkman and Mickler (1990), Dwire et al. (1990) and, Knapp et al. (1991). Approval of several QA documents is also required by QAMS prior to the field season. These include the QA Project Plan (QAPjP) and two methods manuals describing standard operating procedures for field and laboratory activities. (see Section 10.6.1 of this chapter).

10.1.1 Quality Assurance Project Plan for FHM

As part of the FHM QA program, a quality assurance project plan (QAPjP) was prepared for 1991 and is being modified to reflect continuing and expanded activities for 1992. The purpose of the 1992 QAPjP is to describe the FHM program, its organization and objectives, and the QA activities needed to satisfy the 1992 data quality requirements. The QAPjP will also describe the QA activities and assessment criteria that will be implemented to ensure that data bases will meet or exceed the FHM data quality objectives (DQOs). The QAPjP will identify all environmental measurements for each indicator and address specific processes within each measurement that could introduce error or uncertainty in the resulting data. Data uncertainty could arise during the initial field measurement phase, sampling, preparation, or analysis. Methods, materials, and schedules for assessing the error contributed by each process will also be addressed. In addition, the QAPjP will define the criteria and procedures for assessing statistical control for each measurement parameter.

Each of the 14 indicators for 1992 is, in effect, a separate data acquisition activity or "project" and, technically, requires a separate and complete QA project plan. Therefore, each indicator is discussed in its separate section within in the QAPjP using a standard format. One reason for this approach is that the choice of indicators is an evolutionary process. Some of the indicators are in the dynamic stage of a pilot or demonstration mode, while others are more refined and tested. Also, constraints due to logistics and budgetary considerations impinge on the indicator planning and testing process. As indicators are added, modified, or withdrawn from the FHM program, corresponding sections can be added, modified, or deleted without affecting other sections of the document. Another important effect of the structure of the QAPjP is that 13 of the required QA items (Simes 1989; Simes 1991a; Simes 1991b) for each of the indicators, are contained in each indicator section rather than distributed within a general discussion for all indicators. Thus, the QAPjP for FHM will continue to be a "living" document.

The QAPjP will be revised as necessary to reflect changes in procedures that result from continuous improvement and will undergo a complete revision annually. All project personnel, especially indicator leads, should be familiar with the policies and objectives outlined in pertinent sections of the QAPjP to ensure proper interactions among the various data acquisition and management components.

10.1.2 Methods Manuals for Standard Operating Procedures

Standard operating procedures (SOPs) have been written for all FHM field and laboratory activities for 1992. These SOPs are included in a Field Methods Guide (Conkling and Byers 1992) and a Handbook of Laboratory Methods (Byers and Van Remortel 1991). The Guide includes standardized SOPs with formats approved by the EMAP Methods Coordinator for all indicators included in the 1992 field activities and will be used by all field crew personnel. The Handbook contains standardized SOPs for those indicators that have field sampling, sample preparation, and analytical components. These SOPs are used for contract preaward assessment of analytical laboratories and during the laboratory analysis phase. The use of written SOPs helps to ensure consistency in planning, implementation, and analysis.

10.2 Quality Assurance Responsibilities

For the organizational structure of EMAP, lines of communication, and responsibilities, see the Quality Assurance Program Plan.

10.2.1 Agencies

The success of the FHM program depends on the willingness of all participating agencies to cooperate as full partners. It is important that roles and responsibilities be clearly identified to encourage cooperation and successful implementation. These duties have been outlined in Table 10-1. In general terms, EPA is responsible for preparing planning documents. Field activities will be coordinated by the Forest Service. Evaluation of results will be a shared activity. The key individuals who are most responsible for the success of this project are the indicator leads, regardless of the agency from which they come.

10.2.2 FHM Personnel

There are many key individuals involved in or in charge of the various activities in the FHM project related to quality assurance. Subcontractors whose services are important in coordination and sample analysis are also included. In addition, there are several documentation activities important to the success of the project, such as the preparation of guidance documents. See Table 10-2 below for a list of persons responsible for these various activities.

TABLE 10-1. AGENCY RESPONSIBILITY IN 1992 FHM ACTIVITIES HAVING QUALITY ASSURANCE CONCERNS

	Agencies							
Responsibility	FS	EPA	States	FWS	SCS	NPS	TVA	BLM
Planning								
Strategy Document	C	L	C	C	C	C	C	
Activities Plan	C	L	C	C	C	C	C	
QA Project Plan	C	L	C	C	C	C	C	
Field Methods Guide	C	L	C	C	C	C	C	C
Laboratory Methods Handbook	C	L	C	C	C	C	C	C
PDR Programmer's Guide	C	L						
Implementation								
Pretraining/Training Workshops	L	C						
Crew Staffing	L		C	C	C		C	
Field plot Activities	L		C					
Audits	C	L	C	C				
Evaluation								
Debriefing Workshop	L	C	C	C	C			
Methods Manuals Revisions	C	L	C	C	C			
QA Annual Report & Work Plan	C	L						
Integration and Assessment Report	C	L	C	C	C	C		

FS= Forest Service (USDA)
EPA= Environmental Protection Agency
States= AL,GA,NC,SC,VA,MD,DE,NJ,ME,NH,VT,MA,RI,CT,CA,CO (16 total)
FWS= Fish and Wildlife Service (USDI)
SCS= Soil Conservation Service (USDA)
NPA= National Park Service (USDI)
TVA= Tennessee Valley Authority
BLM= Bureau of Land Management (USDI)

L = Lead Agency
C = Contributing Agency

TABLE 10-2. FHM 1992 PERSONNEL RESPONSIBILITIES RELATED TO QA CONCERNS

Preparation of Activities Plan	B. Conkling, North Carolina State University(NCSU), Raleigh, NC
Preparation of EMAP QA Program Plan	Linda Kirkland, EPA, Washington, D.C.
Preparation of FHM QA Project Plan	G. Byers, Lockheed-ESC, Las Vegas, NV C. Palmer, EPA, EMSL-LV
Preparation of Methods Manuals:	
Field Methods Guide	B. Conkling, NCSU, Raleigh, NC G. Byers, Lockheed-ESC, Las Vegas, NV
Laboratory Handbook	G. Byers, Lockheed-ESC, Las Vegas, NV R. Van Remortel, Lockheed-ESC, Las Vegas, NV
PDR Programmer's Guide	C. Liff, Harry Reid Center for Environ. Studies (HRC), UNLV, Las Vegas, NV
Plot Reconnaissance:	
Southeast	B. Smith, TVA, Knoxville, TN
South	J. Vissage, USDA-FS, Starkeville, MS
West (California)	S. Phillips, Portland, OR
Training Workshops:	
National Pretraining (Durham, NC)	R. Kucera, AREAL, RTP, CC M. Baldwin, VPI, Blacksburg, VA
Regional Pretraining/Training	
Northeast	W. Burkman, USDA-FS, Radnor, PA I. Millers, USDA-FS, Durham, NH M. Miller-Weeks, USDA-FS, Durham, NH
Southeast (Asheville, NC)	W. Bechtold, USDA-FS, Asheville, NC W. Anderson, USDA-FS, Asheville, NC W. Hoffard, USDA-FS, Asheville, NC
South (Starkeville, MS)	D. May, USDA-FS, Starkeville, MS J. Vissage, USDA-FS, Starkeville, MS
West (Ogden, UT)	J. LaBau, Univ. Alaska, Anchorage, AK W. McLain, USDA-FS, Fort Collins, CO M. Schomaker, USDA-FS, Ft Collins, CO
State Training	
California (Blodgett NF, CA)	J. LaBau, Univ. Alaska, Anchorage, AK
Colorado (Durango, CO)	W. McLain, USDA-FS, Fort Collins, CO
Indicator Development Coordinator	T. Droessler, ManTech, Corvallis, OR
Indicator Leads:	
Group 1 1. Site Characterization, Growth, Regeneration*	W. Bechtold, USDA-FS, Asheville, NC
2. Crown Classification*	R. Anderson, USDA-FS, Asheville, NC
3. Damage and Mortality*	W. Hoffard, USDA-FS, Asheville, NC
Group 2 4. In-hand Branch Evaluation*	K. Stolte. USDA-FS, RTP, NC
5. Soil Characterization/Physiochem.*	R. Van Remortel, Lockheed-ESC, Las Vegas, NV
6. Foliar Chemistry*	T. Lewis, Lockheed-ESC, Las Vegas, NV
7. Stemwood Chemistry*	T. Lewis, Lockheed-ESC, Las Vegas, NV
8. Dendrochronology*	T. Droessler, ManTech, Corvallis, OR
9. Root Disease Evaluation*	S. Alexander, EPA, RTP, NC
10. Photo. Active Radiation (PAR)	J. Isebrands, USDA-FS, Rhinelander, WI
11. Vegetation Structure	S. Cline, Mantech, Corvallis, OR
12. Wildlife Habitat	T. Martin, U. of Ark., Fayetteville, AR
13. Air Poll. Bioindicator Plants	K. Stolte, USDA-FS, RTP, NC
14. Lichens*	B. McCune, OSU, Corvallis, OR
Global Positioning System (GPS)	K. Hermann, ManTech, RTP, NC
Design	J. Hazard, Stat. Cons. Serv., Bend, OR D. Cassell, ManTech, Corvallis, OR
Information Management	C. Liff, HRC-UNLV, Las Vegas, NV
Landscape Characterization	K. Hermann, ManTech, RTP, NC
Integration and Assessment	K. Riitters, ManTech, Inc., RTP, NC

* Indicator also includes an analytical laboratory component (field sampling, sample preparation and analysis)

10.2.3 Quality Assurance Personnel and Responsibilities

Several personnel are in key positions in the structure of the QA staff for FHM. In addition, the indicator leads play an important role in planning and implementing quality assurance for their respective indicators (see Table 10-2 above and Figure 10-1 below). These QA personnel include:

- Quality Assurance Coordinator for EMAP
  L. Kirkland, EPA Quality Assurance Officer (QAO) Washington, DC

- Technical Director for EMAP-Forests
  S. Alexander, EPA, Research Triangle Park (RTP), NC

- Deputy Technical Director for EMAP-Forests
  C. Palmer, EPA, Las Vegas, NV

- Forest Service FHM National Program Manager
  J. Barnard, USDA Forest Service, RTP, NC

- Quality Assurance Coordinator for FHM
  C. Palmer, EPA, Las Vegas, NV

- Regional Quality Assurance Officer for FHM
  C. Barnett, USDA Forest Service, Radnor, PA

- Quality Assurance Officer for EPA EMSL-LV
  L. Williams, EMSL-LV, Las Vegas, NV

- Methods Coordinator for EMAP
  G. Collins, EPA QAMS, Cincinnati, OH

The national QA coordinator for FHM (QAC-FHM) interacts closely with the Quality Assurance Coordinator for EMAP, the Regional FHM QA officers (see Figure 10-2 for 1992), indicator leads, Forest Service staff, and other FHM participants in coordinating QA activities for 1992. The QAC-FHM is responsible for QA in all FHM activities and reports directly to the FHM technical director. The Eastern FHM QA officer will coordinate specific QA tasks with individuals on the Forest Service technical staffs who are best qualified to perform them successfully. For 1992, one regional QA Officer has been appointed for the eastern U.S. to represent the Northern, Southeastern, and Southern regions of the Forest Service. For specific responsibilities and roles, see the QA Project Plan (Byers and Palmer [1992]) and the EMAP QA Program Plan.

The FHM Technical Director is responsible for determining which 1992 activities require SOPs and ensuring that they are developed, reviewed, and implemented. The QAC-FHM will work with the technical director, the regional QAO, and especially the indicator leads in the SOP process. The QAC-FHM also has responsibilities in SOP identification, interorganizational consistency, elevation to method or protocol status, and the need for training. The QAC-FHM will write the QA Project Plan for 1992. Figure 10-1 identifies the proposed organizational structure for the FHM quality assurance participants now that the FHM program is becoming national in scope.

The QAC-FHM staff will coordinate the technical systems audits (TSAs) and the performance evaluation audits (PEAs) at the project level for 1992. A TSA is an on-site visit to a field plot or laboratory used to verify conformance to the QA Project Plan, the use of good laboratory and field practices to generate the environmental data, and to ensure adherance by all data collection participants to protocols in a consistent manner. Indicator leads will be responsible to develop and conduct these TSAs. A PEA assesses laboratory (and field in some cases) analyses based on results achieved in the analysis of blind samples. These audits provide the basis for assessing the success of a QA program, and aid in determining whether the QA Project Plan and the field and laboratory manuals are being fully implemented and if they are currently adequate to satisfy the

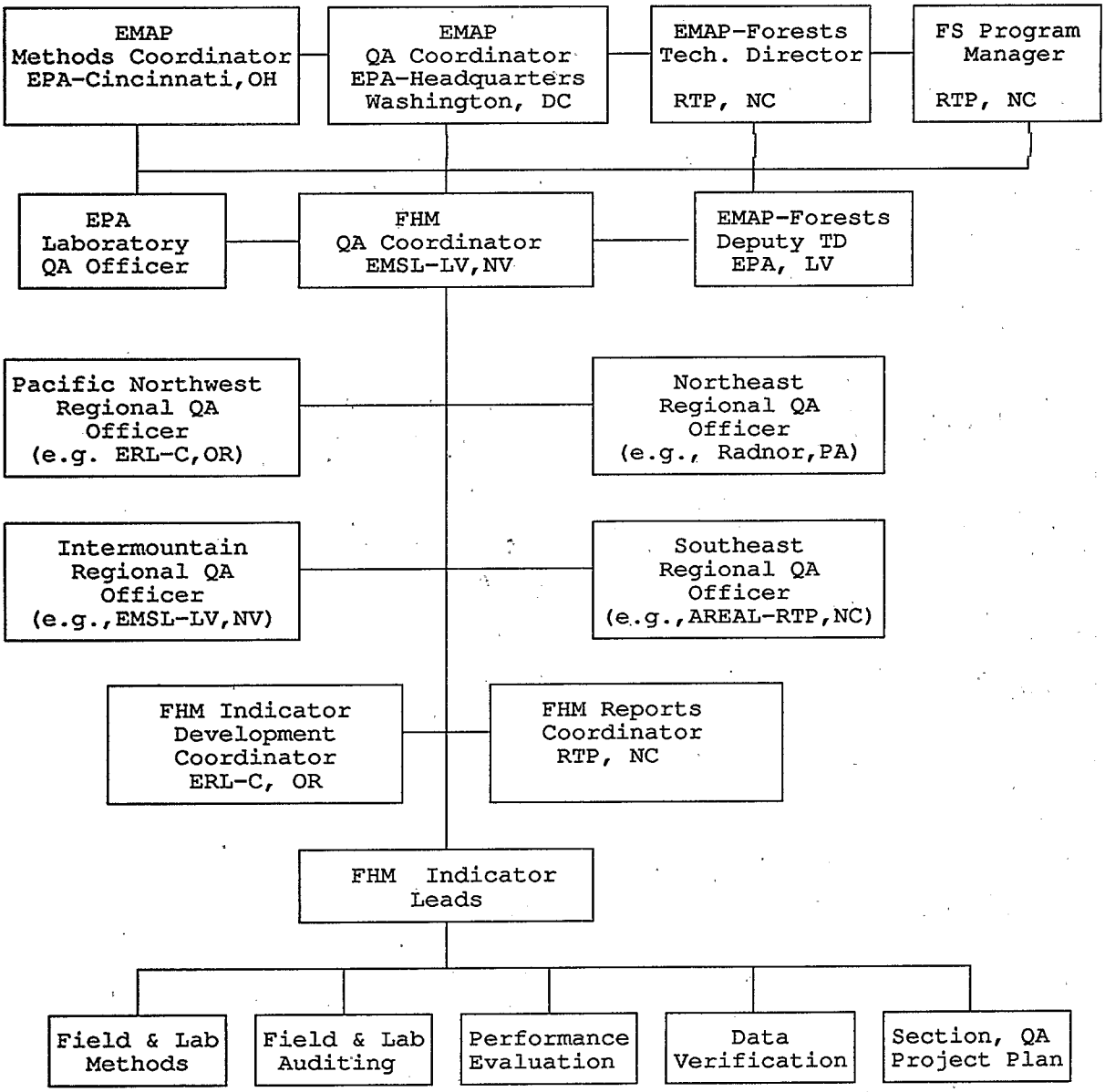

Figure 10-1. Proposed organizational structure for FHM quality assurance staff.

objectives of the project. Audits are conducted for all data collection measurements. Indicator leads will be responsible for developing and conducting these audits. The Technical Director is responsibile for verifying corrective action for any major discrepancies documented in the audit reports. The QAC-FHM is responsible for tracking the corrective actions in these cases. A Memorandum of Intent identifies the problems and/or discrepancies, the corrective action(s) taken, and the remedial effects.

10.3 Data Quality Objectives

At present, data quality objectives (DQOs) are considered to be specific statements of the level of uncertainty a data user is willing to accept in environmental data with respect to the kind of scientific or policy question that motivated the data collection activity. The DQOs are definitive, quantitative, or qualitative statements developed jointly by data users (e.g., indicator leads, other scientists, managers, policy makers, interest groups) in conjunction with the QA staff.

10.3.1 Measurement Quality Objectives

Data quality, and therefore DQOs, may be defined for several levels of FHM data collection. The first level represents the measurement-level DQOs, called measurement quality objectives (MQOs), for specific measurement parameters within each indicator. The MQOs are estimated using existing or initial baseline data. Generally, at present, the MQOs have been established by the indicator leads. However, MQOs for plot establishment, characterization, and mensuration were established independently of FHM based on historical data. In FHM, these MQOs are being established for several levels of data collection, e.g., sample measurement system, measurement parameter, or indicator level for various indicators. The MQOs define acceptance criteria in field and laboratory measurement data (Byers et al. 1990) for four quantitative attributes: detectability, precision, accuracy, and completeness. Also included are two qualitative attributes; representativeness, and comparability. Representativeness criteria have been established a priori by the plot design and plot sample selection procedure established for 1991. Completeness and detectibility criteria have been established for some of the components of the implementation indicators and for some indicators requiring laboratory analysis, e.g., soil analysis. Other DQOs are recognized at a higher ecosystem level, but they are yet to be addressed seriously (e.g., indicator-level DQOs (IQOs), resource group-level DQOs (RQOs), and ecosystem-level DQOs (EQOs).

Common types of data generated by different methods across regions within a resource group and by different resource groups must be compatible, especially over time. Emphasis must be placed on data base flexibility because of issues, unknown now, which may arise in future years of this multi-year program. Acceptance criteria established during the DQO-development process serve as benchmarks for satisfying data user requirements. For a discussion on the hierarchy of DQOs for EMAP, and the DQO setting process, see Palmer et al. (1991). For MQOs for each of the 14 indicators, see the QA Project Plan, Part II, Sections 2 through 15 (Byers and Palmer 1992).

10.3.2 QA Activities in the Field for 1992

Several issues are of concern for the field activities for 1992 that are related to QA for all indicators. Their satisfactory resolution for 1992 is based partly on logistical and budgetary constraints. The issues are:

- How to assess and satisfy MQOs for detectibility, precision, accuracy, and completeness within and among regions for field crews and trainers.
- What are the logistical constraints using different crews on the application of QA techniques within and among the relatively large regions or on a national scale.

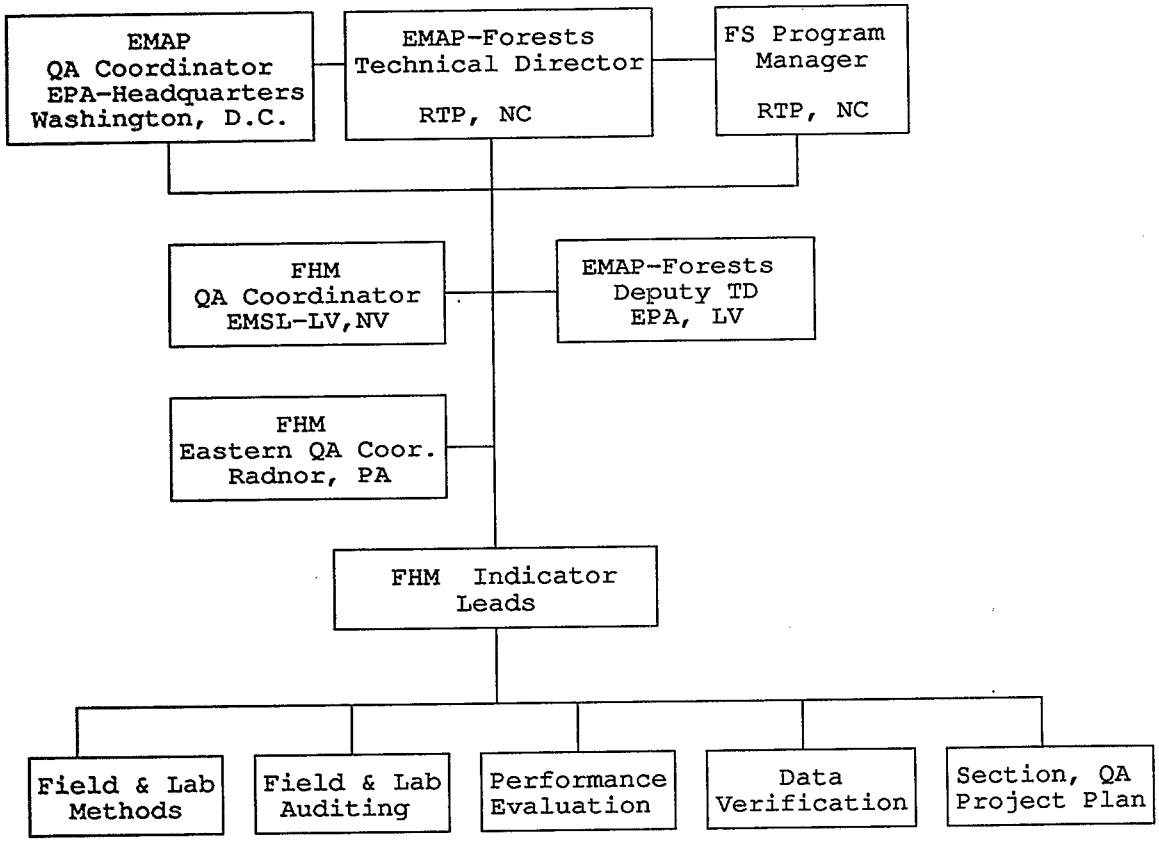

Figure 10-2. The organizational structure for FHM quality assurance staff for 1992.

- How beneficial and cost-effective will be the different possible QA techniques.

10.3.2.1 Field Crews

For the eastern U.S. (Northeast, Southeast, and South regions), approximately 30 field crews of two persons each will be used for collecting field data for all of the Group 1 indicators (see Table 10-2) for the Forest Service's Forest Inventory Analysis Program. This measuring of indicators 1, 2, and 3 (see Table 10-2) is called Type 1 measurement. For plots that were visited in 1991 only measurements performed for the indicators 2 and 3 (as given in Table 10-2), called Type 2 measurements, will be made in 1992. Three field crews of five to six persons each will be used for collecting field data (and samples, in some cases) for all the pilot and demonstration indicators (Group 2 indicators), and for the Group 1 indicators for the loblolly/shortleaf pine Demonstration Project in the southeastern U.S. in 1992. For the Western U.S. (CA and CO)

four field crews of five persons each will be used for collecting field data (and sampling in some cases) from all plots for all indicators in the West. The list of indicators for East and West does not completely coincide. For additional information on these indicators, see Section 6. For additional information on the crews, see Section 11. An adequate number of field and pilot/demonstration crews will be established in the East and West to ensure that the planned 1992 FHM program can be successfully implemented.

10.3.2.2 Trainers

Expert trainers will be used for crew training purposes (Group 1 indicators) for each of the FS regions for 1992. Accuracy standards will be established for all measurements for the Group 1 indicators by a small team of experienced USDA Forest Service personnel. For the Group 2 indicators, the indicator leads will serve as the expert trainers in establishing data standards for training purposes. The trainers will be present at pretraining sessions to establish and characterize the reference plots and test trees prior to training the field and pilot/demonstration crews. To ensure a consensus in the data standards and agreement on training techniques, the trainers for the Group 1 indicators will "cross over" into other regions (e.g., Northeast and South to Southeast; East to West; California and Colorado to Utah) for training together at the pretraining workshops. All data for each trainer will be documented as well as the consensus value for all measurements. Agreement among expert trainers on all measurements is a QA issue in itself, because of their impact on the field crews.

10.3.2.3 Check Crews for Auditing and Accuracy

A check crew is a selected expert crew composed of two well-trained experienced Forest Service personnel (not generally including trainers), that will check field and pilot/demonstration crews during the field season. Check crews attend pretraining and training workshops for certification. The check crews for 1992 serve two purposes: (1) to "audit" each field and pilot/demonstration crew within 2 weeks after commencement of the field season and (2) to measure independently one plot already measured by a field or pilot/demonstration crew for accuracy purposes after the auditing phase. In the first case, the check crew separates into two individual "auditors." No field data are taken by the auditors during this phase. Each auditor visits preselected field plots during measurement activities by field and pilot/demonstration crews, assesses the crew's performance, discusses deviations from protocol where and when they occurred, and provides input to the field crew to reduce inaccuracy and imprecision in the measurements. This audit visit is actually a post-training assessment of all field and pilot/demonstration crews to ensure that they are performing as trained and that all data and sample collection protocols are being followed as specified in the Field Methods Guide. A report by the audit crew will be made for all sites visited and filed with the QAC-FHM.

In the second case, for field accuracy, the reassembled two-person check crew will perform the same Group 1 measurements on a selected field plot which has been previously measured by a field or pilot/demonstration crew. Check crews serve, in effect, as mobile reference standards in this case. The plot data from the check crew are compared with the data generated independently by the field crew. The field crews are unaware of which of their plots the check crew will remeasure. In the East, approximately 20 of the 30 two-person field crews will have one of their plots checked in this manner; all three pilot/demonstation crews will be checked on one of their plots. In the West, all four pilot/demonstration crews will have one of their plots checked. All data taken by the check crew are documented for later assessment.

10.3.2.4 Audits by Indicator Leads

For the Group 2 indicators, each indicator lead will perform one technical systems audit (TSA) of each of the three pilot/demonstration crews in the East and the four pilot/demonstration crews in the West during

the field season. An audit report for all visits to crews will be filed with the QAC-FHM.

10.3.2.5 Reference Plots

Reference plots (also called standard plots or accuracy plots) will be selected, characterized, measured, and documented at each of the training sites in Durham, NH (for the Northeastern Region), Asheville, NC (for the Southeastern Region), Starkeville, MS (for the Southern Region), and Ogden, UT (for the Western Region). All FHM field and PD crews will perform their suite of measurements on these reference plots as part of the 1992 training program. The trainers together will carefully measure and document these specific reference sites; consensus among trainers in the standard data sets is essential. All crews will be judged on their post-training performance on the reference plots using these standard data sets. Establishing the reference plots at the training workshops assures availability of all crews for training and assessment of accuracy and thus accreditation. Already established in 1991, the reference plots serve as unique discrete temporal standards at each regional location for the FHM program.

10.3.2.6 Training and Test Trees

Test and training trees will be used for training and testing the field crews, the two foresters on the pilot/demonstration crews (in the East), and the two foresters on each of the four crews in the West for two of the Group 1 indicators (crown classification and damage and mortality). The expert trainer team will select approximately 40 trees at each training site that possess a broad range of visual damage conditions found in the forests. These trees are not contained within the reference plots. The field and pilot/demonstration crews will be trained using the training trees with supplemental classroom instruction. Then the field crews will be tested as a crew on another set of 20 test trees, and as individual crew members on an additional set of 10 trees. All testing data will be documented and used for crew certification and later for QA assessment statistically.

10.3.2.7 Field Plot Remeasurement

Precision presents itself in the field asa remeasurement issue for the field and pilot/demonstration crews. Asking a field crew to remeasure one of its own previously measured field plots does not supply definitive precision because of possible memory recall by the field crew, i.e., a field plot is not a blind sample. However, no other approach has been brought forward for estimating within-crew variability in the field. In 1992, as in 1991, each field and pilot/demonstration crew will remeasure a previously measured plot within 2 weeks after commencement of the field season. This will result in two sets of data for estimation of within-crew variability in the field. Assuming that the index window is not a factor in changing forest conditions, a second set of within-crew variability data will result from the two visits made to the reference plots by each field crew. The plot to be measured will not be identified to the crew until just prior to remeasurement. This approach will ensure that the field crews will not know what plot to "do better at."

10.3.2.8 Training and Debriefing Workshops

Several levels of training workshops will be used to ensure that crew training, assessment, documentation, and certification by experts is acceptable to address accuracy, precision, and comparability. These are:

- A national pretraining workshop for indicator leads and trainers in early April.
- Regional pretraining workshops for trainers, indicator leads, and crew leaders in mid-May.
- Regional training workshops for field and pilot/demonstration crew in late May/early June.
- In a few cases (e.g., California and Colorado) brief state training sessions for specific measurements (e.g., insect damage) in early June just prior to going to the field.

Information management personnel will also conduct several programmer training workshops during this March through May period. In addition to these prefield season workshops, there will be postfield season

(debriefing) workshops held in several of the regions. The latter workshops serve several purposes. For example:

- Documentation of field and pilot / demonstration crew remeasurements of a reference plot and the test trees for 1992 statistical analysis and reports.
- Post-season assessment of success and short comings of the 1992 program overall.
- Feedback from crew members, crew leaders, indicator leads and management in improvement for 1993.
- Review of logistical, QA, and information management performance and documentation.

Interregional comparability is also of great concern from a quality assurance viewpoint. The debriefing workshops will also be used in 1992 for assessing comparability between trainers and crews for accuracy and precision. Each field crew will remeasure the test trees and reference plots again at the debriefing in September. Several crews from comparable regions, e.g., the southern northeastern region and southeastern region, will also remeasure the test trees and reference plots at the debriefing in Asheville. This process will establish a basis for comparability among crews among regions.

The above approaches address the QA concerns for accuracy, precision, and comparability for field crews, pilot and demonstration crews, trainers, and inter-regional comparability issues.

For further discussion on field accuracy, precision, and comparability, see the 1992 QA Project Plan (Byers and Palmer 1992). The 1991 data for the field remeasurement and training and debriefing workshops for the northeastern, southeastern, and southern regions are currently being assessed statistically. A report on the conclusions and trends in the data will be incorporated in the 1991 Statistical Summary.

10.3.3 QA Activities in the Laboratory

The same issues discussed in Section 10.3.2 can be raised for laboratory analysis. Field sampling, sample preparation, and laboratory analysis are required for six of the Group 2 indicators in Table 10-2. (soil characterization and physiochemistry, root evaluation, foliar chemistry, stemwood chemistry, dendrochronology, and lichens). A sample preparation laboratory has been established in Las Vegas for preparation of the 1992 soil and foliar samples and some preliminary analyses with appropriate QA. Indicator leads have established analytical MQOs for the remaining indicators. See Conkling and Byers (1992) for field sampling protocols for these indicators. For sample preparation, analysis, and MQOs for these indicators, see Byers and Van Remortel (1991) and Byers and Palmer (1992). Sample analyses for most of the above indicators will be contracted to laboratories after a performance evaluation and contract award process. Stringent criteria using QA and QC samples and procedures for verification and validation will be followed.

10.4 Documentation of Data Collection

Effective documentation will ensure that data quality information are available for scrutiny for all measurement activities of the FHM program. The scope and duration of EMAP will certainly require re-examination of data, methods, and conclusions as the program progresses. Thorough documentation is essential in establishing the flow of information, possible alternatives, and a basis for conclusions and decisions which form the basis for new activities or require the revision of previous conclusions based on new methods and information.

Verification determines and controls the quality of data. Verification can be accomplished manually, electronically, or through remeasurements. A systematic

approach to data verification will ensure that all data are subjected to basic standards of accuracy that verify the authenticity, but not necessarily the validity, of the data. Verification is accomplished by comparing data at each level of processing to established data quality criteria. Verification is discussed within each indicator section in the QA Project Plan. See also the section on information management in the QA Project Plan. Verification is also discussed in detail in the logistics plan, e.g., related to the use of PDRs.

A systematic approach to data validation will confirm that environmental measurements, processes, and products are within acceptable bounds of accuracy and validity with respect to the population of interest. Validation is also discussed within each indicator section.

10.5 Quality Assurance Reports to Management

Reports to managment about quality assurance fall into several categories.

10.5.1 Major Documents for 1992

Current versions of the following quality assurance-related documents will be produced during 1992 for the FHM program. These documents, in addition to the Quality Assurance Program Plan and the FHM Activities Plan for 1992 will be disseminated among all appropriate FHM participants and cooperating organizations:

- Quality Assurance Project Plan for EMAP-Forest s for 1992
  (Byers and Palmer 1992)

- FHM Field Methods Guide
  (Conkling and Byers, editors, 1992)

- Handbook of Laboratory Methods for FHM
  (Byers and Van Remortel, editors, 1991)

10.5.2 Audit Reports

Technical systems audits for field and laboratory activities are stand-alone reports and will be delivered through specified channels to the QAC-FHM on an ongoing basis during 1992. Performance evaluation audits will be summarized and submitted to the QAC-FHM. The QAC-FHM is required to report the audit results to the QAO for EMSL-LV, and Technical Director for FHM.

10.5.3 Quality Assurance Annual Report and Workplan

The FHM Quality Assurance Annual Report and Workplan will include a discussion of project activities (e.g., DQOs, QA Project Plan and SOP implementation, total quality management training and implementation, corrective actions, audits and reviews, and resources used during the prior fiscal year). Recommendations for changes in QA policy for 1993 (with appropriate justifications) will also be addressed. The work plan component of this report will describe all major QA activities for 1993 including DQO developments and refinements, deliverables, audit schedules, changes in the QA program, resource requirements, active projects and tasks involved in data generation, and approved changes in the QA project plans and SOPs. The QAC-FHM is responsible for this report and its submission to the QAC for EMAP in early February.

10.6.4 Statistical Summary

A statistical summary report of all 1991 field and laboratory activities will be made in August 1992. A description of the QA activities and accompanying statistical summaries for the year for all indicators will be included as a chapter in this report.

11. Field Logistics Overview

R. L. Tidwell and R. Kucera

Two main types of field crews will be used for Forest Health Monitoring (FHM) 1992 activities: (1) implementation crews, and (2) pilot/demonstration crews. The implementation field crews will consist of two foresters. The pilot/demonstration crews will be comprised of several foresters, one soil scientist, one botanist, and other members such as a logistical aide, a tree climber, a soil microbiologist, or a forester from Forest Pest Management (FPM) taking off-plot measurements for FPM. More detailed plans for 1992 are presented in Appendices C, E, and F of this document.

During a day of sampling, there are a number of activities or operations that occur which are the responsibility of certain individuals. The following table presents an example list of field operations and the persons responsible for the activities. These operations are discussed in the following subsections under the heading of the person or persons responsible for this activity.

11.1 Field Crew Leader

The field crew will be supervised by a designated crew leader. The crew leader will supervise all field operations and, if necessary, resolve all discrepancies or issues at the site. The field crew leader has the responsibility of:

- Maintaining sampling schedule.
- Assembly of field crew.
- Transportation to the sampling site.
- Ensuring adherence to sampling protocols.
- Ensuring proper use of field equipment.
- Maintaining site and sample integrity.
- Data transfer.
- Daily communication.
- Safety.

TABLE 11-1. EXAMPLE OF OPERATIONS AND RESPONSIBILITIES

Operation	Responsibility
Sampling schedule	Field crew leader
Crew assembly	Field crew leader
Transport to site	Field crew leader
Site location	Foresters
Plot establishment	Foresters
Sampling	Field crew
Sample maintenance	Logistical aide
Sample transfer and shipping	Logistical aide
Equipment maintenance	Field crew and Logistical aide
Data transfer	Logistical aide
Daily communication	Field crew leader and Logistical aide

11.1.1 Sampling Schedule

The field crew leader will be responsible for sampling a certain number of plots within an index period. The crew leader will have the responsibility to meet this sampling quota while maintaining the quality of the measurements and samples and following standard protocol. The field crew leader must be attentive in assessing field crew morale and creating a sampling schedule to maintain an adequate level of morale.

11.1.2 Assembly of Field Crew

The field crew leader is responsible for assembling the field crew each morning at an appropriate time. The field crew leader will also determine rendezvous points to assemble crews after scheduled time-off (e.g., after weekends, holidays).

11.1.3 Transportation to the Sampling Site

The field crew leader will be responsible for providing and maintaining adequate transportation to the site. Crews must make efficient use of vehicles.

11.1.4 Ensuring Adherence to Sampling Protocol

The field crew leader is expected to have a basic knowledge of all sampling procedures and be able to determine whether field crew members are adhering to sampling protocols. If protocols appear to be inconsistent or are being misinterpreted, the field crew leader should address the inconsistency during the daily communications update. Problems should be rectified by the next day.

11.1.5 Ensuring Proper Use of Field Equipment

Some field equipment such as PDRs, ceptometers, laptop computers, and bar code readers will require special care and proper use. The field crew leader should observe the use of equipment and if necessary instruct crew members in the proper use. Field crew members will inform the crew leader of equipment that is damaged or in need of repair. The field crew leader is responsible for addressing the equipment problems in the note section of the daily communication update.

11.1.6 Maintaining Site and Sample Integrity

During sampling, flagging will be placed around the site to mark various sampling points (soil holes, vertical vegetation, and PAR measurement points). Soil holes will be dug and branches will be sampled. The field crew leader will be responsible for maintaining plot integrity and anonymity when sampling is completed.

A number of samples will be collected at the sampling site. These samples will be prepared and analyzed and incur significant cost related to collection, analysis and interpretation. It is imperative that the integrity of these samples is maintained. Some samples require cooling and transportation to laboratory facilities as soon as possible. The field crew leader is responsible for ensuring adherence to sample maintenance protocol.

11.1.7 Data Transfer

Data from PDRs and ceptometers must be uploaded to laptop computers and transferred to the EPA VAX. The field crew leader and logistical aide will be responsible for this data transfer.

11.1.8 Daily Communication

Communication will take place electronically through the laptop computers or phone system. The field crew leader fills in an "update" screen that requests the following information:

- Field crew ID.
- Hexagon sampled that day.

- Hexagon expected to be sampled following day.
- Additional personnel with field crew (e.g., auditor, EPA personnel).
- Field crew location (hotel name, address, Phone number).
- Expected location of the crew during the next day.
- Comments or Problems.

The field crew leader or the logistical aide is expected to fill in the update and send it out electronically, each day, whether or not data are being transmitted. This update will be electronically sent to the EPA VAX which will then be used to update Data General and E-MAIL accounts of appropriate individuals in the program.

11.2 Foresters

The foresters will be responsible for locating the sampling site, establishing the plot, and the data collection activities involved with the site classification, growth, and regeneration; visual crown assessment; and damage and mortality indicators.

11.2.1 Sampling Site Location

In most cases, FIA photopoints will be used for the sampling plots. Information pertaining to the sites will be available at the training session. Foresters will follow standard FIA protocol in locating sampling sites.

11.2.2 Plot Establishment

The foresters will be responsible for establishing the plot. It is very important that the plot establishment be accomplished in a sequence that (1) maintains plot integrity for other measurements (i.e., regeneration measurements before vertical vegetation / PAR measurements), and (2) allows all field crew members to start data collection activities as soon as possible in order to finish sampling within a reasonable timeframe. To accomplish this, a plot layout procedure should be developed. Figure 11-1 is an example of a plot layout procedure. This figure includes sampling by foresters 1 and 2 when required to maintain plot integrity. This procedure should be used as an example. As the field crew becomes familiar with the sampling methods, they may adjust the plot layout procedure as necessary.

11.3 Field Crew

The field crew, as a whole, will be responsible for sampling activities. The field crew and the logistical aide will share responsibility for equipment maintenance and equipment inventory. The logistical aide will aid the crew with resupply requests, sample shipment, and other administrative duties. These administrative duties may include calling in and reporting labor hours, sending or receiving messages, and moving personnel gear to the next hotel location.

11.3.1 Sampling

The foresters will be working together for the majority of the day. The tasks of plot layout, mensuration, and regeneration and visual crown rating measurements are expected to take a full day. The soil scientist will be working independently, with the exception of assistance in excavating soil holes during the morning. The botanist will be responsible for measurements for bioindicator plants, vegetation structure, and PAR, which must be sampled within a specific time period. Therefore, an efficient sampling schedule should be developed.

11.3.2 Equipment Maintenance

During training each field crew member will be provided equipment and an inventory list of the equipment they receive. If equipment is damaged during field activities, the item should be identified on the inventory list and the service or repair that may be required should be specified. The field crew member will inform the field crew leader and the logistical aide about the damaged equipment. The logistical aide is responsible for communicating this information through the daily crew update.

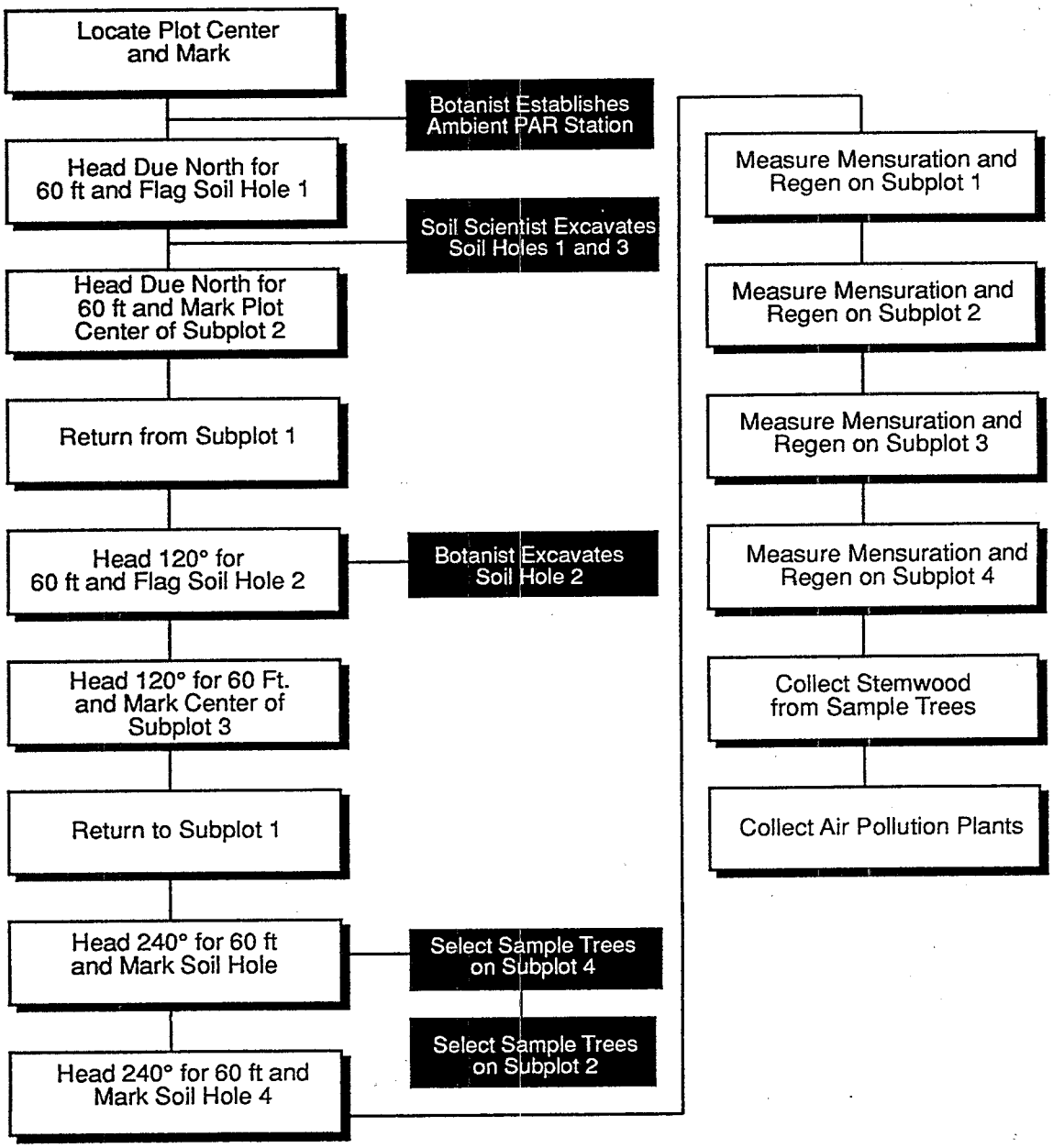

Figure 11-1. Example of a plot layout procedure.

At the end of the field season, the field crew will return all equipment to the logistics lead. The logistics lead, logistical aide, and field crew member will check off each item on the inventory list that is provided at the beginning of the field season to each field crew member. All items must be returned. Items will be inspected for damage and their condition recorded.

11.4 Logistical Aide

The logistical aide will be responsible for the following activities:

- Sample maintenance.
- Sample transfer and tracking.
- Sample shipping.
- Equipment maintenance.
- Equipment inventory.
- Data transfer and communication.
- Administrative duties.
- Assisting with field measurements.

11.4.1 Sample Transfer and Tracking

As samples are transferred from the field crew to the logistical aide, the number and type of samples must be recorded in a manner that will allow for the tracking of these samples. This process will assure that all the samples collected in the field have been transferred to the logistical aide and it will allow tracking of samples throughout the preparation, sample analysis, and archive phases of the program. Two types of techniques will be used for recording and tracking samples: (1) bar code scanning and (2) hard copy recording.

11.4.2 Sample Shipping

Shipments can occur daily or when required by the logistical aide. The EPA will provide prelabeled overnight shipping forms for use in shipping samples. The express mailing forms will be used in order and all unused forms returned.

12. Information Management Overview

C.I. Liff and J.E. Teberg

The mission of the Forest Health Monitoring (FHM) information management system is to provide data of known quality to analysts in a timely manner. Information management is a crosscutting activity that interacts closely with logistics and quality assurance and quality control (QA/QC) in fulfilling its mission. Data are collected in the field on portable data recorders (PDRs), then transferred to a laptop computer. The data are then sent via modem to the VAX computer system at the Environmental Monitoring Systems Laboratory-Las Vegas, Nevada (EMSL-LV), for processing and distribution. Once the data have been through the QA/QC procedures, data bases are created for use by the FHM assessment and reporting groups. Figure 12.1 shows the FHM data flow.

12.1 PDR System

The PDRs contain several data collection programs. In 1992 data for the following indicators will be collected on the PDR:

- Growth (mensuration).
- Visual crown rating suite of measurements.
- Soils data.
- Vegetative profile.
- Wildlife habitat.
- In-hand branch evaluation (sample tree).
- Root evaluation (sample tree).

Programs to record bioindicator plant data and the 1-hectare mortality data have not yet been developed and these data will not be collected on the PDR.

Various QA/QC checks will be performed on the data as they are entered on the PDR. Checks include valid-value checks of a variable and logic checks between a number of variables. Performing these checks in the field greatly improves the data quality.

For those crews performing annual crown update measurements, certain data are downloaded on the PDR. These data include variables necessary to relocate the trees tallied in the previous survey (distance, azimuth, diameter at breast height [DBH], and species) as well as items that need to be reconciled in this survey (e.g., previous tree history). The downloaded data are for display purposes only. The crews are not to change those data except for gross errors (e.g., a transcription error).

For activities requiring sample collection, the sample identification, obtained from a bar code label, will be entered on the PDR. This starts the sample tracking process.

If space is available on the PDR, the PDR will maintain backup copies of all data recorded throughout the field season.

Each demonstration and pilot crew will have three PDRs: one for the foresters, one for the soil scientist, and one for the botanist.

12.2 Laptop PC Systems

Each pilot or demonstration crew will be equipped with a laptop computer. This computer will not be taken into the field, but will remain in the hotel room or vehicle if en route to a new location. The following sections describe the functions performed on the laptop.

12.2.1 Data Transfer from PDR

Data are transferred from the PDR to the laptop computer at the end of each day on which measurements at a plot are completed. The data are maintained on a hard disk and a backup copy on a floppy disk.

12.2.2 Data Transfer from PAR Equipment (West and SAMAB Regions Only)

The volatile data from the ceptometer and the Li-Cor quantum sensor are transferred after every completed plot.

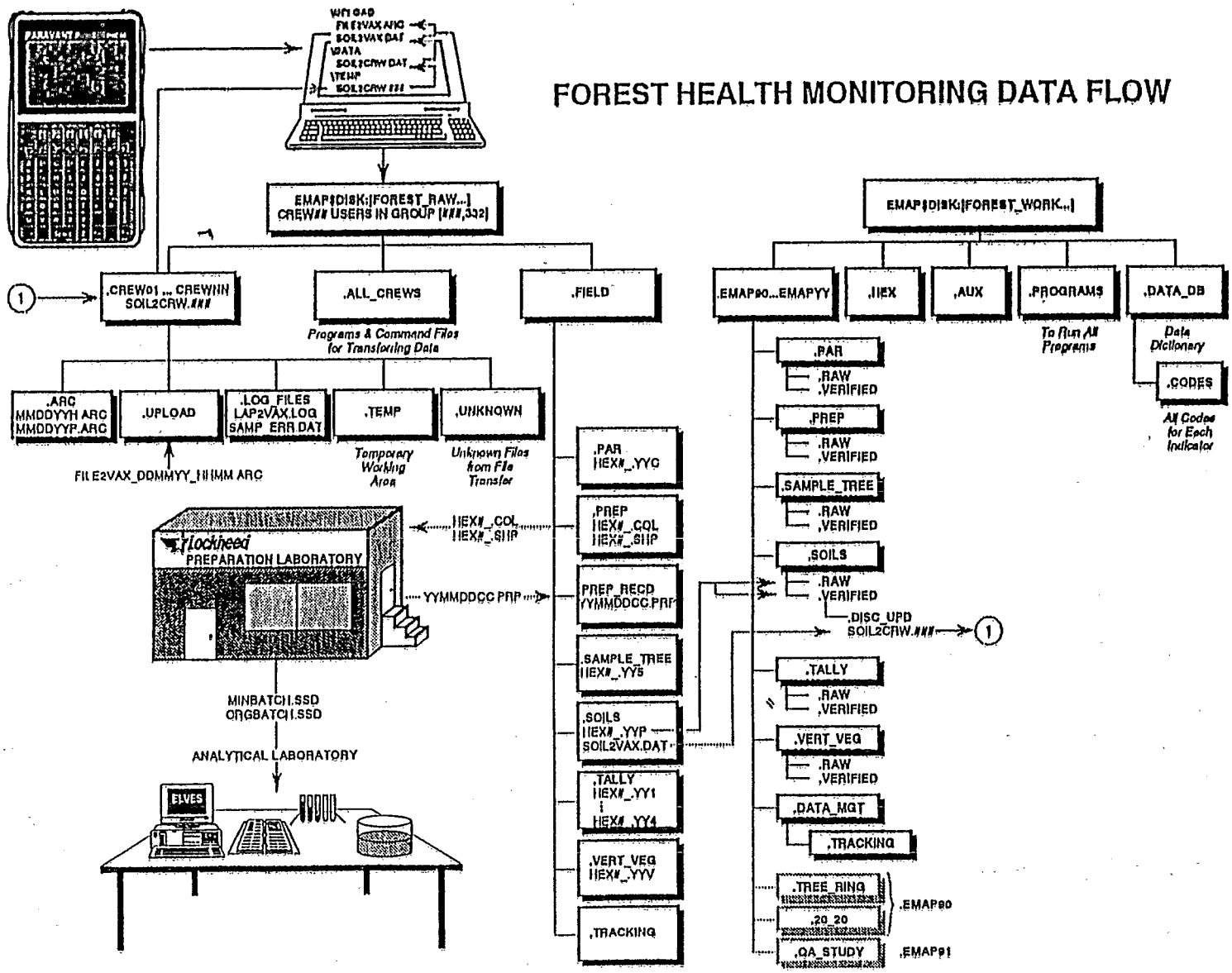

Figure 12-1. Forest Health Monitoring data flow.

12.2.3 Sample and Shipment Tracking

Bar coded samples that are packed for shipping are scanned with a laser bar code reader. Those data are checked against the data that have been recorded on the PDR to increase the likelihood that all samples collected in the field are packed for shipment.

12.2.4 Printing Data

The crew has the option to print all data files and any electronic mail messages that have been received.

12.2.5 Soil Discrepancy Resolution

The field soil scientist will have an opportunity to resolve problems with the soils data. This system is described in detail in section 12.4.

12.2.6 Communications with the EMSL-LV VAX Computer Cluster

The laptop is equipped with a modem and a program that allows access to the EMSL-LV VAX computer. This communications link allows:

- Data Transfer - Field data are sent to the VAX computer. The data are then catalogued and processed. The crew can be notified electronically of problems with the data.

- Electronic mail Communications - The crew can send and receive electronic messages to and from FHM staff members. The crew will also send information about their present and future locations.

12.3 VAX System

Once the data are received on the VAX, they are parsed into the appropriate directories (see Figure 12.1). The data are available to indicator leads either through the EPA network or via internet mail for users off the EPA network. The data are reviewed for verification errors by the indicator leads and problems are flagged.

Tracking data bases are maintained on the VAX and updated each time a crew communicates with the VAX. The following types of information are tracked on the VAX:

- Crew tracking -- including crew location, plots sampled by the crew, and messages from the crew.
- File tracking -- by crew, hex, data type, and date.
- Sample and shipment tracking data from the field and the laboratories -- samples are computer tracked from the field and through the preparation and analytical laboratories.

The tracking data bases will be used to generate daily and weekly reports on progress throughout the field season. Problems with data collection can be identified with the tracking data bases and appropriate action taken.

12.4 Soil Discrepancy System

This system allows for quick identification and resolution of errors in the soils data that are collected in the field. The soils data are entered in the PDR. These data are uploaded to the laptop computer and sent to the VAX. Once on the VAX, a series of programs are run to produce a file containing inconsistencies in the data. This file is reviewed by the soils indicator lead and then a copy is sent electronically back to the field crew. The crew reviews the discrepancies, makes corrections to the discrepancy file, and sends the file back to the VAX. The corrections are reviewed by the indicator lead and the soils data base is updated with the approved corrections. This particular system epitomizes the functionality of the FHM information management system.

12.5 Preparation Laboratory System

The preparation laboratory system tracks and manages samples received from the

field. Three types of samples are expected: soil, foliar leaf, and tree core samples.

The preparation laboratory system is part of the overall sample tracking system and also maintains a data base for data generated at the preparation laboratory.

12.5.1 Sample Receipt

When the preparation laboratory receives a shipment of coolers, the shipment and sample information are recorded in the preparation laboratory data base. The data are transferred to the EMSL-LV VAX, then parsed into a "receive" data base. Finally, the samples that were received by the preparation laboratory are compared to the list of shipped samples prepared by the field crew and any discrepancies are resolved.

12.5.2 Preparation Laboratory Data Procedures

The samples are prepared in the preparation laboratory for shipment to analytical laboratories. Any soil sample measurements such as moisture, bulk density, and loss on ignition are entered into a data base. Verification programs used with the data base, adds flags to incomplete, invalid, and improbable data. The preparation laboratory manager receives a print out and is responsible for resolving problems.

In preparation for analytical analyses, the samples are stored until they can be separated into batches. The preparation laboratory system keeps track of the samples in storage.

As part of the QA/QC process, audit samples are prepared in the preparation laboratory. These data are also entered in the preparation laboratory data base. Batch numbers are assigned before shipment to the analytical labs. The batch numbers are related to the field sample numbers and are tracked throughout the procedure.

Measurement results and tracking data are uploaded to the VAX computer and appropriate data bases are updated at periodic intervals.

12.6 Analytical Laboratory System

For samples sent to an analytical laboratory for chemical analysis, the tracking and analytical data are stored and managed on the Environmental Laboratory Verification and Entry System (ELVES) at EMSL-LV . This system allows one to enter new data, runs QC and QA checks, checks chemical relationships, checks expected ranges of the data, and allows one to correct errors or update a set of data if a batch is reanalyzed.

The laboratory sends an ASCII file of their analysis results to EMSL-LV. These data are loaded into the ELVES data base. Verification programs check the data and a report is generated for the indicator leads who decide whether or not to accept the batch of data. If the batch is not accepted, the problems with the data are corrected. After the batch is accepted, a final version of the data with the sample IDs and final calculated chemical result is stored in the system as well as uploaded to the EMSL-LV VAX.

12.7 Field Software Testing

All software to be used in the field will be thoroughly tested. The initial versions of the software were sent to a group of testers the first week of March 1992. Based on review comments, the computer code is being updated. The updated software will be sent out for further review the last week in March. Additionally, a "dress rehearsal" of field operations will be held at Duke Forest, North Carolina, during the first week in April. This will allow software testing under actual field conditions. A last round of software changes will be made after the field test.

12.8 Training and Support

A field information management support team will be trained to provide assistance to the field crews. This team will consist of Forest Service and state personnel. A support team training session will be held at the FHM office in RTP the second week of May.

The support team will assist in the training sessions. A self-guided PDR manual is planned for completion in early May. This manual and PDRs will be distributed to crew members before training to familiarize them with the PDR program in advance of the training session.

13. Global Positioning System Overview

K. Hermann

Global positioning system (GPS) technology will be used to determine accurately the location of Forest Health Monitoring (FHM) plots. The geodetic coordinates (latitude, longitude, and elevation) will be determined for the field plot center or, if the plot center is inaccessible, for a reference point related to the plot center by survey measurements.

The geodetic coordinates of plot centers will be useful for several reasons. First, accurate coordinates help field crews relocate the plot in future years and are an important aid in acquiring aerial photography. The GPS-determined coordinates will also satisfy the requirements of the EPA Locational Data Accuracy Policy for the information management purpose of accurate sample location. Finally, GPS coordinates will provide a reliable measure of where measurements were taken versus where the design determined location was.

Accurate GPS coordinate determination requires simultaneous operation of both a base station GPS receiver and a remote, or field, GPS receiver. A base station will operate on a known set of geodetic coordinates at the same time that a remote receiver is utilized by a field crew member to record GPS measurements at the plot center and reference point locations. The data from each of the receivers will be run through a set of programs in a postprocessing mode for differential correction at the EPA Atmospheric Research and Exposure Assessment Laboratory. This dual operation and postprocessing technique yields more accurate results than simply operating a single unit. The base station operation will be coordinated through already established base stations.

In addition to determining the location of the FHM plot centers, GPS technology can assist field crews in determining where plots will be established. The field GPS unit can locate the vicinity of the specified coordinates.

Finally, GPS can be employed to determine coordinates for other important FHM locations, such as starting points and photo/ground control points for high-resolution aerial photography. Starting points will be determined using GPS in situations where good visual references are lacking.

The photo/ground control coordinates will be used to rectify high resolution aerial photography to obtain a planimetrically correct interpretation which will be accurately defined to a datum. Photo/ground control locations will be referenced to visible features or reference points. The photography rectification procedure, done with an analytical stereo plotter, will enable the accurate capture of the characterization delineations and their subsequent entry into a geographic information system (GIS).

In the spring and summer of 1992, GPS measurements will be taken in three separate FHM projects--the Southeast Demonstration, the SAMAB Demonstration, and the Western Pilot (Colorado). As a component of the Southeast Demonstration project, GPS measurements of the FHM plot center locations will be taken in conjunction with the plot establishment activities during the spring in North Carolina. It is anticipated that plot center GPS measurements will continue in the Southeast Demonstration region during the fall and winter.

In the SAMAB Demonstration project, plot center locations will be determined with GPS measurements taken during the summer field sampling efforts.

In the Western Pilot project, plot center locations and ground/photo control locations in Colorado will be determined during the summer field sampling efforts. The USFS Methods Applications Group will acquire 1:6000 scale aerial color infrared stereo photography for the Colorado FHM plots in August. The photo/ground control coordinates will be used

in registering and rectifying interpretations from the photography.

13.1 Objectives

Objectives for using GPS technology for the FHM project include:

1. To accurately determine and record the geodetic coordinates (latitude, longitude, and elevation) of FHM field plot centers,

2. To satisfy the EPA Data Locational Accuracy Policy, and

3. To accurately determine and record the geodetic coordinates of photo/ground control locations to be used in the rectification of aerial photography interpretations.

13.2 Design

The GPS coordinate determinations of the FHM plot centers will accurately determine the geodetic position for each plot. If a dense canopy prohibits reception of satellite signals, coordinates will be determined for the nearest available opening. The starting point may provide a suitable alternative location. Surveying measurement techniques will be employed to link this alternate location and the plot center.

In the Colorado GPS effort, coordinate determination is made for photo/ground control locations. A minimum of eight ground control locations will be established for each FHM photographic plot. These ground control locations will be distributed about a 100-hectare circular area around the plot center. This 100 hectare area will be photointerpreted from the 1:6000 scale photography. At least four ground control locations will be placed towards the perimeter of the 100-hectare circle in an effort to achieve adequate point distribution over the area. The locations of the ground control points should be near existing roads or trails for easy accessibility.

13.3 Logistics

13.3.1 Field Personnel Requirements

One field crew member will take GPS measurements with the remote GPS unit at the plot center. In the Colorado portion of the Western Pilot project, GPS measurements will also be taken at each of the photo/ground control point locations. If surveying is required, an additional crew member may need to assist. The GPS operator should be familiar with the basic surveying techniques of determining azimuth, distance, and inclination.

The base stations to be utilized in each of the three GPS projects are already established sites. Coordination with those base station operations will ensure that the base station is operational at the same time as the GPS field activity.

13.3.2 Training

All GPS operators should receive special training in the proper use of GPS equipment. Training requires a minimum of 1 1/2 days including field time.

13.3.3 Estimated Time on Plot

The operation of the field GPS receiver will require about 15 minutes to determine plot center coordinates. An additional half hour may be required if some surveying is necessary from a reference location to the plot center due to canopy interference with GPS reception at the plot center site. The estimated time required to record photo/ground control locations is 4 hours per day. The base station operator will need to operate the base station GPS receiver continuously for 6 hours to coincide with the field operations.

13.4 Information Management

All GPS recordings will be captured on the GPS Polycorder device for each day's reception. Each point location will be stored in a separate file on the GPS Polycorder.

The GPS field and base reception of coordinates in 3-D (latitude, longitude, and elevation) are recorded on the GPS Polycorder. Field notes are made on the time, location, and conditions of GPS measurements. At the end of each day, the collected data are transferred to the laptop computer, using specific naming conventions, and then backed-up on 3.5 inch floppy diskettes. Nightly recharging of the GPS Polycorder and receiver is required.

Plot center coordinates are confidential information. Therefore, public access should not be given to the coordinates.

A personal computer (model 80286 or better) with appropriate software is required for determining satellite availability, for post processing the data, and for datum conversions.

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Appendix A. National Plan Forest Pest Management and Associated State Component National Forest Health Monitoring Program, January, 1992

NATIONAL PLAN
FOREST PEST MANAGEMENT AND ASSOCIATED STATE COMPONENT
NATIONAL FOREST HEALTH MONITORING PROGRAM
JANUARY, 1992

Forest Pest Management
State and Private Forestry
USDA Forest Service
P.O. Box 96090
Washington, DC 20090-6090

National Plan
Forest Pest Management and Associated State Component
National Forest Health Monitoring Program
January 1992

Problem Statement:

The health of the Nation's forests is increasingly in the news. Current issues include concern about management activities, deforestation, habitat loss, air pollution, global climate change, and damage from a variety of forest insect and disease problems. The USDA Forest Service (FS), U.S. Environmental Protection Agency (EPA), and other Federal and State agencies must evaluate and respond to these issues. Timely response requires credible forest conditions information based on data which can be compiled, analyzed, and interpreted to evaluate forest health. The National Forest Health Monitoring Program (NFHM) integrates Federal and State monitoring activities to provide this forest health information.

Congressional Direction:

Congress has provided the FS, through the Secretary of Agriculture, authority, direction, and funding to establish a national forest health monitoring program. Within the FS, Forest Pest Management (FPM) in State and Private Forestry (S&PF), Research, and the National Forest System (NFS) are involved in developing and implementing the initial phases of forest health monitoring.

From the FPM and State perspective, amendments to the Cooperative Forestry Assistance Act of 1978 (P.L. 95-313) by the Food, Agriculture, Conservation, and Trade Act of 1990 (P.L. 101-624) are important because **forest health monitoring is explicitly authorized**. Section 5 of P.L. 95-313, Insect and Disease Control, is redesignated Section 8, Forest Health Protection. Section 8(b)(1) directs the following: "Conduct surveys to detect and appraise insect infestations and disease conditions and man-made stresses affecting trees and establish a monitoring system throughout the forests of the United States to determine detrimental changes or improvements that occur over time, and report annually concerning such surveys and monitoring."

From the Research perspective, the Forest Ecosystem and Atmospheric Pollution Research Act of 1988 (P.L. 100-521) is particularly important because it authorizes a 10-year program of research and monitoring to better understand the relationships between forest health and air pollutants and recognizes the need for long-term monitoring.

Forest Health:

Within NFHM, forest health is considered with respect to effects of both naturally occurring factors such as fire, forest pests, forest succession, site, drought, and weather extremes, as well as unnatural biotic and abiotic factors such as introduced pests, air pollution, and global warming changes. For FPM, the term forest health denotes forest ecosystem resilience and productivity relative to a specified set of values, needs, and expectations. Thus, forest health can be defined by different standards which relate to differing management objectives for particular forested areas. There is an expectation that forests are healthy when biotic and abiotic influences do not threaten the attainment of management objectives

now or in the future. Although forest condition can be specified and measured objectively, forest health carries an element of subjectivity, as it is a value judgement.

Program Cooperation and National Coordination:

Forest Service, EPA, and States are responding to forest health concerns by initiating a National Forest Health Monitoring Program designed to describe regional and national forest conditions and to detect changes, determine causal relationships, and predict consequences. The NFHM success depends on participation by FS, EPA, and States. The NFHM conceptual design incorporates recommendations from the FS Forest Response Research Program (part of the National Acid Precipitation Assessment Program), the FS Forest Health Strategic Plan, and the EPA Environmental Monitoring and Assessment Program. The NFHM design builds on existing FS programs. The FS Staff units most involved have been Forest Fire and Atmospheric Sciences Research (FFASR); Forest Inventory, Economics, and Recreation Research; Forest Pest Management (FPM); Timber Management; and Watershed and Air Management. A number of other FS Staffs will likely become more involved both in NFHM and in related aspects of EPA's Environmental Monitoring and Assessment Program.

Forest Service Washington Office (WO) coordination includes (1) discussions among the NFHM Program Manager and representatives from participating staffs in Research, S&PF, and NFS; (2) the NFS Environmental Health Technical Group; (3) coordination discussions among WO Staff Directors and their staff specialists; (4) weekly teleconference calls originated by NFHM; (5) the September 1990 memorandum defining FS Research and State and Private Forestry roles and responsibilities; and (6) FPM's National Forest Health Monitoring Plan.

NFHM Program Design:

Although FS Research, through the NFHM Program Manager, has the overall lead for NFHM design, implementation, and reporting, FS FPM and participating States have direct responsibility for designing and implementing the FPM/State components of NFHM. These responsibilities are discussed in the following pages.

The National Forest Health Monitoring Program is a three-tiered, long-term process to provide regional (multi-state) and national information on forest health status and trends. Each successive tier requires progressively more detailed information. The tiers are:

> **Detection Monitoring** -- to detect deviation of key monitoring elements from established base line conditions or trends. This is the first and most extensive level. Within the FS, FPM and Research share responsibility for initial design and implementation of this tier which consists of (1) a plot component (Research) -- a geographically-based network of permanent plots distributed throughout the Nation's forested areas; and (2) a survey component (FPM) -- forest pest and other stressor effects surveys and reports of forest damage. Detection Monitoring will discover and describe changes in forest health conditions. The FPM Responsibility section which follows outlines FPM's contribution to Detection Monitoring.
>
> **Evaluation Monitoring** -- to determine or hypothesize likely causal relationships and to recommend management responses. This is the second level, it is FPM's responsibility to initiate, and is activated by Detection Monitoring results. Evaluation Monitoring is the process for determining causes for changes in forest health status beyond that initially obtained in Detection Monitoring. The FPM Responsibility section outlines FPM's contribution to Evaluation Monitoring.

Intensive-Site Ecosystem Monitoring -- to define basic relationships sufficient to predict consequences. This is the third level and provides the most detailed, long-term data for ecosystem research to determine causal relationships, predict rates of change in forest conditions, and identify management responses. Forest Pest Management has little or no responsibility in Intensive-Site Ecosystem Monitoring.

FPM Goal:

Discover if there are large-scale episodes of forest pest and other stressor effects that are not related to historical or normal cycles of forest growth, decline, and stressor activity. This includes effects from (1) known agents; (2) changed activity of known agents; (3) new agents; and (4) unknown agents.

FPM Program Objectives:

1. Document status and change in large-scale effects on forests of forest pests and other stress agents. This includes temporal and spatial change in extent, severity, duration, frequency, host, and cause.

2. Conduct forest stressor effects surveys, provide training, and provide technical assistance in support of the NFHM plot network.

FPM/State Responsibility:

Forest Pest Management and States are responsible for providing Regional and State forest pest/stressor effects information and for addressing how forest health may be affected. Data must be adequate to evaluate and interpret the relationship between forest pest and stressor effects and forest health changes.

Information from both the survey component of Detection Monitoring and from Evaluation Monitoring is essential for describing overall forest health conditions. Data from the plot component of Detection Monitoring will describe important aspects of forest health based on a number of forest health indicators including damage by some insects, diseases, and other stressors. The survey component will more accurately describe forest pest and other stressor effects in the general forest area than can be done from plot data alone. This information is needed to draw proper conclusions about these effects on overall forest condition.

Forest Pest Management and States have four specific responsibilities in NFHM:

1. Conduct surveys to discover, confirm, quantify, and map significant forest pest and other stressor effects over the general forest area so that:
(a) change in overall annual pest and other stressor effects on forests can be incorporated systematically and quantitatively in NFHM reporting, and (b) NFHM ground plot data can be interpreted with knowledge of broader forest stressor activity and history. Although forest pest detection surveys are a traditional FPM and State responsibility, a change in focus is needed to meet NFHM analysis and reporting requirements. A description of the traditional FPM program emphasis as compared to forest health monitoring emphasis is outlined in Appendix 1.

2. Provide NFHM plot support. This includes (1) technical support such as assisting with plot survey design and planning, pest and other stressor identification, tree vigor classification, pest-related data management, and training for NFHM plot survey crew; and (2) supplemental aerial and ground surveys as needed to determine forest pest/stressor effects on NFHM plot measurements. Surveys on and in the vicinity of NFHM plots provide data for effects which would not be noticed or recorded

during regularly scheduled plot visits by Research or State personnel.

3. Evaluate specific reports of forest damage to determine cause, extent, severity, trend, and likely result of forest pests and other stressor effects on forest health. The need for evaluations may be determined from Detection Monitoring results from plot data, survey information, and reports from other sources.

4. Meet FPM, State, and NFHM reporting needs.

FPM Component Design and Implementation:

Regional and Area FPM staffs, in conjunction with Research Stations and States, are responsible for Regional and Area FPM component design and implementation within the context of NFHM Program and national FPM direction. To improve design and implementation coordination among NFHM, Regions, Area, and States, FPM-WO has done the following:

1. Funded a NFHM Applications Deputy Program Manager position to be the national focal point within NFHM for (1) FPM-related design, coordination, implementation, and reporting; and (2) integrating both the FPM/State component of Detection Monitoring and Evaluation Monitoring in NFHM.

2. Established a national FPM Forest Health Monitoring Work Group to identify and address specific FPM design and implementation questions. Regional and Area work group representatives are listed in Appendix 2.

This national work group identified the following sequence of FPM/State activities in NFHM.

1. Find forest pest and other stressor effects (use mix of sensing techniques).

2. Document and quantify pest and other stressor effects (use mix of sensing techniques). Establish quality assurance and quality control standards and guidelines. Verify performance.

3. Document and quantify change in effects.

4. Report change in effects.

5. Explain change.

6. Interpret and report forest health consequences.

7. Consequences that influence management and regulatory decisions.

The draft Eastern Forest Health Monitoring Plan, prepared jointly by R-8 and NA, describes regional application of the national plan. This regional plan outlines a process which employs local reporting networks to detect and report occurrence of effects. These networks include surveillance by field personnel, incidental reporting from all sources, and selected aerial surveys. This may be followed or supplemented by one or more of the following: (1) planned surveys to assess scope and severity of effects noted in local reports; (2) planned surveys of known problems, hazard areas, or areas of particular interest; (3) systematic use of Forest Inventory Analysis (FIA) data to assess scope and severity of effects from selected forest pests/stressors; and (4) planned surveys coupled with ground plot data to quantify scope and severity of stressor effects not readily measured by remote sensing techniques. Ground plot data could come from FIA, FHM, or other plots.

Unresolved issues include: (1) regional differences within the context of a nationally consistent design -- the western plan(s) have yet to be designed and written; (2) statistical soundness of approach for measuring effects and change in effects; (3) agreement on data elements and data collection standards and guidelines; and (4) process for data management, analysis, and reporting.

FPM Reporting and Data Management:

The NFHM Program guidelines will need to be developed on (1) annual forest health reporting requirements; and (2) procedures for integrating information from the survey and plot components of Detection Monitoring. It is anticipated that Regions, Area, and Stations will collaborate on regional reports which will be aggregated by the NFHM Program Manager for the national forest health report. The Regional, Area, Stations, and State contributions to the forest health report are to report status and changes in forest stress agent effects and to explain relationships between stress agent effects and forest health. Initial NFHM forest health monitoring indicators include forest growth, mortality, distribution and structure, canopy condition, and soil condition. Forest health may eventually be described in terms of **Assessment Concerns** such as forest productivity, forest resiliency, forest biodiversity, forest distribution and structure, and forest pest status.

Forest Pest Management, WO will continue both the annual and five-year "Forest Insect and Disease Conditions in the United States" reports in accordance with Chapter 40 of FSH 3409.11. The objective of these reports is to report on pest outbreak status and trends. Some of the data used for the Conditions Reports will be used in NFHM reports.

Regional, FPM-related forest health monitoring reporting will be coordinated by Region/Area FPM staff. Specific direction will need to be developed on how data are to be managed, analyzed, interpreted, and reported by each Region/Area in cooperation with Stations, States, and the NFHM Program Manager. National forest health reporting will be coordinated by the NFHM Program Manager.

Forest Pest Management will focus on reporting changes in forest stressor effects both in the general forest area and on or in the vicinity of NFHM plots. Forest Pest Management and State reporting requires (1) a nationally consistent design; (2) core data elements with standards and guidelines for each; (3) standards and guidelines for data collection; and (4) analysis and reporting guidelines. The FPM's national Forest Health Work Group will be the forum to further develop program design as well as data element, data collection, and reporting standards and guidelines.

Although reporting guidelines are under development, there is consensus that FPM should document temporal and spatial change in large-scale effects on forests due to forest pests and other stress agents. This information needs to be of sufficient quality and proper format so that it can be integrated with forest resource and other data for analysis, interpretation, and NFHM reporting. Initial NFHM reporting will probably describe (1) known forest health risks; (2) trends in forest pest/stressor effects; (3) current year status of forest pest/stressor effects; and (4) significant changes in status and trends of resource risks and effects.

In addition to documenting large-scale effects in the general forest area, stress agent effects on NFHM plots will need to be documented in order to determine possible effects on plot measurements.

National core data elements and related measurements which are being considered to provide the basis for reporting include:

1. EFFECT -- Forest Pest/Stressor Effect Type (defoliation, dieback, mortality, discoloration, growth loss, and other symptom).

2. LOCATION -- State, County, NFHM Plot, Coordinates, and other.

3. HOST(S) -- Tree Species and Forest Type.

4. STRESS AGENT -- Forest Pest/Stress Agent Name.

5. SCOPE -- Acres Affected.

6. SEVERITY -- Volume of Mortality/Acre, Trees/Acre, Intensity (high, medium, and low).

7. DATE -- Year and Month.

8. OWNERSHIP -- Federal and Other.

Evaluation Monitoring:

When Detection Monitoring reports identify areas or problems of concern for which more specific information is needed, FS Forest Pest Management, WO and the NFHM Program Manager will assess the situation and determine specific evaluation needs. These could include additional surveys, site- or area-specific evaluations, and more detailed monitoring. In some cases specific research studies may be required. These would be a FS Research responsibility. Criteria for Evaluation Monitoring project design and selection are to be developed by FPM in cooperation with States and the NFHM Program Manager.

Coordination with Research:

Forest Service Research, through the NFHM Program Manager, has the overall lead for NFHM design, implementation, and reporting. Forest Pest Management has direct responsibility for providing forest pest and other stressor effects information in Detection Monitoring and for initiating Evaluation Monitoring activities. Both Detection and Evaluation Monitoring activities conducted by FPM and States will be coordinated with the NFHM Program. Forest Health Monitoring program and budget planning are coordinated among participating FS staff units.

Deputy Chief, S&PF and National FPM Staff Director, will provide policy direction and oversight to the FPM component of the NFHM program. The NFHM Applications Deputy Program Manager responsibilities include NFHM program implementation and coordination with S&PF, NFS, other Federal agencies, and States. This position will be the national focal point for FPM-related activities in NFHM. Duties are similar to those outlined for Subject Area Managers in the May 1991 Memorandum on Fiscal Year 1992 Forest Pest Management Technology Development. These duties include:

1. Provide management oversight to FPM component of NFHM.

2. Lead and serve on work group/steering committees to address national NFHM design, implementation, and reporting questions.

3. Assist Regions/Area in preparing annual accomplishment and monitoring reports.

4. Review Evaluation Monitoring project proposals.

Regions, Area, and Stations, in concert with the National FHM Program Manager, will need to specify coordination procedures applicable to their particular situations and to the States involved.

Coordination with States:

Forest Service Forest Pest Management and States will jointly design, plan, and implement the FPM/State component of Detection Monitoring and Evaluation Monitoring in each State. To avoid duplication of effort and confusion, FPM staff will work with Research Station and State staff and the NFHM Program Manager to establish the protocols and coordination mechanisms needed to enlist State involvement in NFHM. Specific State responsibilities will be developed and documented on a State-by-State basis.

Coordination with NFS and Other Federal Agencies:

As technical staff to National Forest System and other Federal resource managers, FPM staff will have an important role in helping plan and execute the NFHM Program on National Forest and other Federal lands. Regional and Area FPM staff have direct responsibility for implementing the FPM component of NFHM on National Forest and other Federal lands.

Implementation Schedule for State and Private Lands:

Forest Health Monitoring began in Fiscal Year 1990 in the 6 New England States (CT, ME, MA, NH, RI, and VT). Six additional eastern States are included for Fiscal Year 1991 -- DE, NJ, MD, AL, GA, and VA. The FS plans to fully implement NFHM over the next 5 to 10 years. For purposes of fiscal year 1992 planning, FPM expects to (1) continue FPM's part of NFHM in the 12 above-noted States; and (2) initiate FPM's component in CA and CO. Depending on budgets and NFHM program direction, other priority States to add in Fiscal Years 1992 and 1993 include NC, SC, MN, and WV.

Continued progress in gradually expanding NFHM will depend on when States are able to enter the program and on continued Federal budget support. The NFHM Program Manager, FS, EPA, and State cooperators will review and update State implementation priorities annually. Implementation priorities are based on the following considerations: (1) develop regional blocks of States and forest ecosystems for sampling and analysis; (2) select States able and willing to participate in NFHM; (3) spread workload among different FS Regions and Experiment Stations; and (4) involve new Regions to gain monitoring experience under different conditions. The Forest Health and Research Committees of the National Association of State Foresters (NASF) are currently surveying States to gain information on State readiness to participate in NFHM. This information will help determine implementation priorities.

Initial priority for expanding NFHM follows. This will be updated in response to technical, budget, and NASF information on State priorities.

1. For Fiscal Year 1994, eleven more States -- MS, LA, TX, TN, AR, FL, OK, PA, NY, OH, and KY.

2. For Fiscal Year 1995, eight more States -- previously considered but not implemented States plus OR, UT, WY, MI, and WI.

3. For Fiscal Year 1996, eight more States -- previously considered but not implemented States plus WA, ID, MT, MO, IN, IL, and IA.

4. For Fiscal Year 1997, eight more States -- previously considered but not implemented States plus ND, SD, KA, NB, NV, NM, and AZ.

5. For Fiscal Year 1998, seven more States -- previously considered but not implemented States.

Implementation Schedule for Federal Lands:

Forest health monitoring on Federal lands will generally follow the State implementation schedule as determined by the NFHM Program Manager. Specific implementation schedules and procedures will be coordinated among the NFHM Program manager, Regions, Stations, Area, and other Federal agencies. Other Federal agencies likely involved are those in the U.S. Department of the Interior, Tennessee Valley Authority, and the Department of Defense.

FPM Implementation Plans and Field Methods Manuals:

Forest Pest Management Regional and Area implementation plans and field guides will be developed by Regions/Area and will be consistent with (1) NFHM Program direction; (2) Forest Pest Management national program direction; and
(3) Regions/Stations/States NFHM implementation plans. Coordination among Regions/Area FPM staffs to develop plans and manuals is essential and is encouraged by the National FPM Staff Director. This coordination will be facilitated by the National FPM Program Director and the NFHM Program Manager.

FPM Quality Assurance Plans and Procedures Manuals:

Quality assurance plans and procedures guides will be developed by each Region and Area FPM staff in accordance with NFHM Program requirements. Coordination among Regions/Area FPM staffs to develop plans and manuals is essential and will be facilitated by the National FPM Staff Director and the NFHM Program Manager.

FPM Budget Development:

Forest Pest Management will need to supplement this plan with a long-term budget plan. The FPM budget plan will be developed in coordination with the NFHM Program Manager and States, and will reflect NFHM program and budget planning. The FPM budget plan will show estimated annual funding increments required to reach the fully implemented NFHM Program. Actual annual budgets will be developed at the National level based on Regional and Area input, and cost records where monitoring has been implemented.

Forest Pest Management's funding for NFHM is provided in the appropriation to State and Private Forestry. Research funding is in a separate appropriation. Budget requests for FPM's component of NFHM are incremental additions to the S&PF/FPM Federal Forest Health Management (Fed FHMgt -- formerly Fed S&TA) and Cooperative Forest Health Management (Coop FHMgt -- formerly Coop S&TA) line items. These line items include funding for monitoring as well as other FPM program activities. Fiscal Years 1991 and 1992 budget requests provide for (1) FPM Detection Monitoring and Evaluation Monitoring under the Fed FHMgt line item; and (2) FPM Detection Monitoring under the Coop FHMgt line item.

FPM Funding Process:

Funds for Detection Monitoring will be allocated on a program basis by FPM-WO. Funds for Evaluation Monitoring will be allocated on a project basis by FPM-WO. Detection Monitoring funds will be allocated to Regions, Area, and States based on annual proposals submitted to the National FPM Staff Director. Once the program is fully implemented, annual proposals may no longer be needed and Detection Monitoring allocations would be provided in the Initial Advice (Program Budgeting and Management Information (PBMI)). Both Federal and State Evaluation Monitoring will be funded annually on an individual project basis.

Regions and Area will annually submit to the National FPM Staff Director
(1) progress reports of Detection and Evaluation Monitoring work already under way; and (2) specific Detection and Evaluation Monitoring budget requests for continuing and new work in the NFHM Program. Evaluation Monitoring proposals must be (1) an FPM responsibility; (2) distinguished from other FPM Fed FHMgt and Coop FHMgt program activities; and (3) submitted by FS Regions/Area who are responsible for project management, implementation, and oversight.

The NFHM Program Staff will assist the National FPM Staff Director in reviewing Evaluation Monitoring proposals for conformance to NFHM and FPM Program guidelines and for technical merit. The National FPM Staff Director will make the final decision on which proposals will be funded. Funding will be provided to Regions, Area, and States on a project basis. Some funds may be held in reserve to meet unanticipated Evaluation Monitoring needs. FHM funding levels depend on annual appropriations and program and budget direction.

Limitations on Use of FPM Funds:

Region and Area FPM staffs will use FPM funds to carry out only those Detection and Evaluation Monitoring activities for which they are responsible, as described in this plan. The NFHM plot establishment and annual plot visits are a Research responsibility, and will be funded by Research.

FPM Implementation and Funding Guidelines:

General forest health monitoring implementation and funding guidelines follow:
I. Forest Pest Management's part of NFHM will expand to additional States in concert with the NFHM Program.

2. Detection Monitoring **continuation** in participating States has funding priority over Detection Monitoring **initiation** in additional States. Initially, Detection Monitoring has priority over Evaluation Monitoring.

3. Regions/Area will not assess Cooperative Forest Health Program (CFHP) funds for overhead costs. Previously CFHP was called the Cooperative Forest Pest Action Program (CFPAP). All allocated funds will be provided to participating States.

4. Federal cost-share with each State for Detection Monitoring supported by Coop FHMgt funds will be 100 percent for first year participation, 80 percent the second year, 75 percent the third year, and 50 percent thereafter. This will allow States time to adjust budgets to meet priority NFHM needs.

5. Evaluation Monitoring project proposals considered in NFHM must be in response to Detection Monitoring results, submitted to the National FPM Staff Director, and be coordinated with the NFHM Program Manager. Evaluation Monitoring is currently limited to the Fed FHMgt line item. Fed FHMgt funds may be used on State or private lands as part of evaluations involving Federal lands or as otherwise needed in the National interest. The Federal/State cost-share for these projects will be determined on a case-by-case basis, as they are not subject to predetermined cost-share requirements.

6. Forest health monitoring funds will be provided to the State agencies participating in the Cooperative Forest Health Program (CFHP). Forest Pest Management's contribution to NFHM is a new initiative which will be conducted as an integral part of CFHP. Forest health monitoring funds are provided to meet the additional reporting and evaluation responsibilities FPM and States have in the NFHM program. Traditional FPM detection and evaluation activities will continue as in the past. National Forest Health Monitoring is not a substitute for CFHP. Information from CFHP will supplement

Detection and Evaluation Monitoring in NFHM. Table 1 compares traditional FPM program emphasis with the additional requirements of NFHM.

7. Although NFHM reporting is designed to provide regional-level information, the forest pest component of Detection Monitoring and Evaluation Monitoring may have sufficient detail to allow State-level reporting.

Forest Plan Monitoring Linkage:

Although Forest Plan monitoring and NFHM have distinctly different objectives, NFHM provides an opportunity to improve forest pest data collection, management, analysis, and reporting to better respond to both. Regions and Area are encouraged to adapt, to the extent possible, NFHM forest health reporting to meet other Regional needs.

Chapter 6 of the FS Land and Resource Management Planning Handbook -- FSH 1909.12 -- describes three levels of Forest Plan monitoring: **Implementation Monitoring**, **Effectiveness Monitoring**, and **Validation Monitoring**. As technical support staff to National Forest resource planners and managers, FPM is directly involved with the Forest Planning process. Now that the National Forest Planning Regulations, FSM, and FSH are being revised, it is anticipated that the monitoring phase of Forest Planning will receive more emphasis. Forest Pest Management will continue to be directly involved in the process of identifying monitoring needs and for collecting the forest pest data required at each monitoring level.

For FPM, the link between Forest Health Monitoring and Forest Plan Monitoring is the damage/stressor agent conditions, trends, and effects information provided to each. It is expected that the basic Regional and Area pest data bases will support both monitoring activities. Initially, NFHM summary information will likely be most applicable to Validation Monitoring. However, Regional and Area pest data bases may have site-specific information useful in Implementation Monitoring and Effectiveness Monitoring.

Additional Follow-Up Needed

Additional follow-up is divided into two parts -- technical and management. Target accomplishment dates and responsible person, organization, or staff are noted.

Technical Follow-Up

1. Specify annual forest health reporting required from FPM to NFHM. (Robert Loomis, FPM Forest Health Monitoring Work Group [FHMWG]) June 1992.

2. Design a nationally consistent program for measuring forest stressor effects and change in effects. This includes:

a. Nationally consistent design which accommodates regional differences (Robert Loomis, FHMWG) September 1992.

b. Core data elements with standards and guidelines (Robert Loomis, FHMWG, Regions, and Area) September 1992.

c. Data collection standards and guidelines draft (Robert Loomis, FHMWG, Regions, and Area) March 1993.

d. Data management, analysis, and reporting guidelines draft (Robert Loomis, FHMWG, Regions, and Area) September 1992.

e. Regional implementation plan development and coordination(Robert Loomis, FHMWG, Regions, and Area) East -- May 1992, West -- draft February 1993.

f. Quality assurance and quality control plan development and coordination (Robert Loomis, FHMWG, Regions and Area) National -- draft March 1993, Regional -- draft supplements December, 1993.

3. Design the process by which off-plot data and NFHM plot data can be integrated for analysis and reporting. This includes off-plot data such as forest pest and other stressor effects, weather, and air pollution.
(Robert Loomis, NFHM, and FHMWG) September 1992.

Management Follow-Up

1. Specify Evaluation Monitoring project selection process and criteria. (Robert Loomis, FPM, and NFHM) September 1992.

2. Document State responsibilities and program expectations in NFHM (Regions and Area) annual update and as States enter program.

3. Implement the October 1991 and March 1992 NFHM Program Review action plans (NFHM, FPM, FFASR, and others).

APPENDIX 1

Traditional FPM Program Compared to NFHM
(Detection and Evaluation)

TRADITIONAL PROGRAM EMPHASIS FOCUS	TRADITIONAL PROGRAM PLUS NFHM
Pest Conditions	Forest Conditions (damage/stress agent trends for major episodes of effects such as mortality, dieback, defoliation, discoloration, and growth loss)
Major Pests	All Major and Potentially Important Damage Agents and Abiotic Stressors (insects, biotic and abiotic diseases, and other natural and anthropogenic stressors)
Localized Data	National, Regional, State Data
Timber	All Resources -- recognize intrinsic value of forests independently of commodity production
Short-Term Use (supression)	Long-Term Use (analysis/interpretation of stress agent effects on forest health for strategic planning and prevention)
Short-Term Trends	Long-Term Trends
Data Management - Reports/Maps	Data Management - GIS
Survey Design/Timing Variable Within and Among Regions	Survey Design/Timing Planned and Consistent Among Regions/Area

APPENDIX 2

Forest Pest Management
Forest Health Monitoring Work Group
Regional and Area Representatives

REGION 1	JIM BYLER	J.BYLER:R01A
REGION 2	DAVE JOHNSON	D.JOHNSON:R02A
REGION 3	BORYS TKACZ	B.TKACZ:R03F04A
REGION 4	RALPH WILLIAMS	R.WILLIAMS:R04F02A
REGION 5	JOHN DALE	J.DALE:R05A
REGION 6	JERRY BEATTY	J.BEATTY:R6/PNW
REGION 8	BOB ANDERSON	R.ANDERSON:S29A
REGION 10	KEITH REYNOLDS	K.REYNOLDS:R10F04A
NA	BILL BURKMAN	W.BURKMAN:S24A
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Appendix B. Working Plan, Integration of Forest Pest Management and Forest Health Protection Activiteis With Forest Health Monitoring for the Eastern United States, June 25, 1992

WORKING PLAN

INTEGRATION OF FOREST PEST MANAGEMENT AND FOREST HEALTH PROTECTION ACTIVITIES WITH FOREST HEALTH MONITORING FOR THE EASTERN UNITED STATES

Prepared by Northeastern Area Forest Health
Protection and Region 8 Forest Pest Management

June 25, 1992

This eastwide work plan is designed to build upon the Washington Office National Plan for the Forest Pest Management Component of the National Forest Health Monitoring Program.

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INTRODUCTION

The public's concern for the "health and productivity of forests in the United States" resulted in federal legislation authorizing "such surveys as are necessary to monitor long-term trends in the health and productivity of domestic forest ecosystems". Monitoring forest health is an integral part of the USDA Forest Service (FS) Research Forest/Atmosphere Interaction Program proposed under the Forest Ecosystems and Atmospheric Pollution Research Act of 1988 (PL 100-521). This legislation authorizes a 10-year program of research and monitoring to better understand the relationships between forest health and air pollutants, and recognizes the need for long-term monitoring. Subsequent legislation ("Farm Bill" of 1990, PL 101-624) encouraged the USDA FS State and Private Forestry to work in partnership with the state foresters or state agencies to "monitor forest health". The result is the implementation of a National Forest Health Monitoring (FHM) Program to determine and annually report on the condition of the nation's forests.

Congress has provided the USDA FS, through the Secretary of Agriculture, authority, direction, and funding to establish a national forest health monitoring program. From the Forest Pest Management/Forest Health Protection (FPM/FHP) view, amendments to the Cooperative Forestry Assistance Act of 1978 (P.L. 95-313) by the Food, Agriculture, Conservation and Trade Act of 1990 (P.L. 101-624) are important because forest health monitoring is explicitly authorized. Section 5 of P.L. 95-313, Insect and Disease Control, is re-designated Section 8, Forest Health Protection. Section 8(b) (1) directs the following: "Conduct surveys to detect and appraise insect infestations and disease conditions and man-made stresses affecting trees and establish a monitoring system throughout the forests of the United States to determine detrimental changes or improvements that occur over time, and report annually concerning such surveys and monitoring".

Currently, the USDA FS gathers data on the forest resource and forest pests in various ways. The two most notable activities are the periodic FIA surveys conducted on most forest lands by the FIA Projects; and insect and disease surveys conducted by FPM/FHP on federal forest lands and together with state agencies on state and private forest lands.

The National FHM Program is a cooperative venture with the U.S. Environmental Protection Agency (USEPA) Environmental Monitoring and Assessment Program (EMAP) Forest Program; State Forestry and Agriculture Agencies; USDA FS Forest Inventory and Analysis (FIA), FPM/FHP, Experiment Stations, and National Forests; and a broad spectrum of government, research, and private interests. Monitoring can be defined as the repeated measurement or sampling of pertinent data for comparison to a reference system or identified base line. It always involves the determination of changes over time, usually interpreted against a base line. Its ultimate value comes when the information that is collected, analyzed, and interpreted is used in making management decisions. The FHM program utilizes the expertise of these groups in a coordinated fashion, to collect, archive, analyze, interpret, and report on forest conditions. The initial objective is to develop a base line on the health and condition of forests with permanent plots and forest effect surveys in every State. This base line will be used yearly to monitor forest health, detect deviations, evaluate deviations, and direct research to explain deviations.

The FPM/FHP program objective is to detect, evaluate, and report changes in forest damage--the effects of forest insects, biotic and abiotic diseases, and other natural and anthropogenic stressors on forests; and explain the relationships between forest health changes and these effects.

These objectives will provide needed information to guide management activities which can improve forest health.

Forest conditions will be described by the measurement and reporting of data from several "health" indicators from a permanent plot network and from off-plot information. For the plots, five current indicator groups are currently being measured or are planned to be measured in the future:.(1) growth and mortality; (2) tree condition and symptoms; (3) soil physical characteristics, nutrients, and toxins chemistry; (4) foliar nutrients and toxin chemistry; and (5) landscape characterization, vegetative structure, and diversity. Individual measurements may support one or more indicators. Measurements will be made and indicators characterized on a periodic basis; annually for those that change frequently (e.g., foliage transparency) and on a 4-year or greater cycle for those that change less frequently (e.g., soil chemistry). Other indicators will be added as necessary. The measurements will be monitored to establish a base line and to detect any changes in forest condition. In addition, analyses of spatial variability can be used to determine regional forest health conditions.

For the effect surveys, specific data will be collected and compiled on the effect types identified in the section on FPM/FHP survey support of FHM. Data will also be collected on other pests judged to be of significance for a particular region or state. These data will be used to show the current condition and change over time.

FHM PROGRAM STRUCTURE

Although USDA FS Research, through the National FHM Program Manager, has the overall lead for FHM design, implementation, and reporting, USDA FS FPM/FHP and participating States have direct responsibility for designing and implementing the FPM/FHP/State components of FHM. These responsibilities are discussed in the following pages.

The National FHM Program is a three-tiered, long-term process to provide regional (multi-state) and national information on forest health status and trends. Each successive tier requires progressively more detailed information. The tiers are:

> **Detection Monitoring** -- to detect deviation of key monitoring elements from established base line conditions or trends. This is the first and most extensive level. Within the USDA FS, FPM/FHP and Research share responsibility for initial design and implementation of this tier which consists of (1) a plot component (Research) -- a geographically-based network of permanent plots distributed throughout the nation's forested areas, and (2) a survey component (FPM/FHP) -- forest pest and other stressor effects surveys and reports of forest damage. Detection Monitoring will discover and describe changes in forest health conditions. The FPM/FHP Responsibility section which follows, outlines FPM/FHP contribution to Detection Monitoring.
>
> **Evaluation Monitoring** -- to determine or hypothesize likely causal relationships and to recommend management responses. This is the second level and is the responsibility of FPM/FHP to initiate and is activated by Detection Monitoring results. Evaluation Monitoring is the process for determining causes for changes in forest health status beyond that initially obtained in Detection Monitoring. The FPM/FHP Responsibility section outlines FPM/FHP contribution to Evaluation Monitoring.
>
> **Intensive-Site, Ecosystem Monitoring** -- to define basic relationships sufficient to predict consequences. This is the third level and provides the most detailed, long-term data for ecosystem research to determine causal relationships, predict rates of change in forest conditions, and identify management responses. FPM/FHP has little or no responsibility in Intensive-Site, Ecosystem Monitoring.

The detection plot network will be visited annually and managed by FIA and state cooperators. The extensive network of permanent locations is selected to correspond to a systematic sampling grid (40.6 sq. km; 10,030 acres; or 15.7 sq. mi. hexagons located on a triangular grid) developed by the USEPA for EMAP. Periodic measurements relating to the functioning of a forest, will be made on a series of plots, which are linked to the FIA inventory system.

Each location consists of a cluster of four subplots. All trees, including seedlings and saplings, are located, marked (not seedlings), and measured. On, or adjacent to the location, openings in the forest are searched for bio-indicator plant species known to be sensitive to ozone. At each location, data are collected on the geographic and topographic position and physiographic description of the location; tree species, diameter, crown position, crown condition, and damage; other vegetation; and foliar symptoms on bio-indicator plants.

Collection of off-detection plot information can be used to attempt to explain deviations of detection plot information. The off-detection plot information includes insect and disease effect and distribution surveys, weather and climate data, pollutant deposition information, and fire incidence and severity data. The forest pest condition reporting system will provide state and region-wide information on effects from major insects, pathogens, forest damages, and fire incidence and severity to supplement data collection on the detection plot network. The weather, climate and pollutant deposition information will be assembled and reported by the EMAP.

Evaluation monitoring will focus on specific forest types, tree species, and/or regions that have deviations from established base lines as identified by detection monitoring activities. This activity will be coordinated by the National FHM Deputy Program Manager. The investigations will attempt to explain the specific cause-effect relationships between the deviations and forest stressors such as insects, pathogens, weather, and climate data or combinations of the stressors. If specific cause-effect relationships can not be determined then identification of a research hypotheses will be developed for ecosystem monitoring activities.

Ecosystem monitoring will focus on intensive forest ecosystem measurements to improve the understanding of ecosystem functions and cause-effect relationships. This level of FHM will occur on a small number of sites that represent major forest types.

Another area which will support all levels of monitoring will be research on monitoring techniques. This area will focus on the development and refinement of measurement procedures for all levels of FHM.

COOPERATING GROUPS AND RESPONSIBILITIES

1. The USDA FS Research (primarily the FIA projects) has the lead responsibility for plot measurement, data management, national and regional reporting, indicator development (through research on monitoring techniques), and ecosystem monitoring.

2. State Forestry and other State Agencies will have the overall responsibility for field crews and field measurements on the plots, plus statewide effect/pest surveys. These groups will also be involved in the planning and coordination of FHM. (A field guide is being developed to establish comparable/standardized survey procedures and reporting codes for effect/pest surveys.) The states will also have the responsibility to provide the information in time for an annual report, as well as prepare an annual state forest health report. The states will also be involved in the planning and organization of FHM through the National Association of State Foresters.

3. The USEPA is working with FHM as part of its broader EMAP program aimed to monitor, evaluate and report on long-term status and trends of the nation's ecological resources. Forests are one of six ecological resource categories of interest to USEPA. USEPA-EMAP's contribution to FHM includes the overall sampling grid for locating and establishing permanent monitoring plots; indicator variables for measurement that have been agreed to as valid by the scientific community; technical assistance with quality assurance (QA); weather, climate, and air pollution information; data management support; and other activities. The program also has the capacity to utilize satellite imagery where appropriate.

BUDGET PROCESS

FHM is one program with the budgets being distributed from two sources, USDA FS Research and FPM/FHP. The USDA Forest Service Research funding is coordinated and distributed to support the major activities associated with installation and collection of samples and data on the detection plots. This negotiation is between the appropriate state agency and the respective USDA FS Experiment Station.

The planning and funding for the off-detection plot effect/pest surveys is through the USDA FS FPM/FHP unit to the appropriate state agency. This funding is above the current funding level under the Cooperative Forest Health Program (formerly CFPAP) and is designed to supplement additional activities required through FHM. (See Appendix for an example of a Cooperative Forest Health Agreement Narrative). Currently, the submission process for the CFHP and the additional activities for FHM are separate, but in the future the funding may be consolidated into one program. The additional FHM funding through FPM/FHP is structured on a "sliding" scale depending on the number of years participating in FHM and is outlined below:

Period	FPM/FHP %	State %
Year 1	100	0
Year 2	80	20
Year 3	75	25
Year 4+	50	50

Funding for evaluation monitoring is the primary responsibility of USDA FS through the appropriate FPM/FHP unit(s). The funding structure will vary depending on the focus of the various evaluation monitoring projects.

FPM/FHP RESPONSIBILITIES

Detection Monitoring, On-Plot Activities

The role of FPM/FHP involves the application of tree crown and vigor procedures conducted on the detection plot network. This includes the development of the procedures for the field guide, the training of field crews, and the follow-up on site visit with field crews while they are collecting information (relating to the above procedures). This also includes the area of bio-indicators plants for general air pollution characterization. These activities should account for 15% to 30% of FPM/FHP's effort in the FHM Program. In Region 8, FPM will coordinate and train the state crews on how to conduct spring plot visits.

Detection Monitoring, Off-Plot Activities

The need still exists to determine standards for data collection. In many cases, annual or periodic surveys are already conducted for many effects/pests and data is collected on fire incidence and severity. Thus, the principal obstacle for a effect/pest/fire conditions database is survey method standardization, coordination, and development of GIS management. This should be our primary function in detection monitoring, encompassing 50% to 60% of our effort in FHM. This will require the establishement of a base line and to determine changes in forest conditions/health requires the maintenance of information on forest pests, fire, and other events that occur yearly which affect the forest resource.

To better assess forest effect/pest/fire conditions and establish data on trends, spatial mapping or GIS information is necessary. Thus, the intent of an effect condition database is to collect, store, assess, and manage information on damage needed for FHM. Much of the data will be acquired from annual, routine surveys combined with periodic special pest surveys conducted by FPM/FHP and/or state cooperators. Examples include insect and disease aerial detection surveys; hazard rating for various insect and disease pests, surveys to delineate the occurrence or range of a pests such as hemlock wooly adelgid and dogwood anthracnose; or data collected during specific pest evaluations such as for gypsy moth, eastern spruce budworm, and southern pine beetle. In some cases, this will require looking at the same area periodically. This same data base could also be utilized in other pest management and fire management activities. Information on forest pests would be collected, stored, and managed by FPM/FHP and state cooperators. Information compiled through the FHM program will be particularly useful in providing technical support for developing management recommendations. As a minimum, all states have agreed to try and meet the level of detection noted in Table 1 (page 16).

Evaluation Monitoring

This second level of FHM involves designing and implementing intensive surveys to evaluate a detected or unexplained problem. FPM/FHP has been active in evaluation monitoring and will continue to provide leadership and technical assistance in this area. This area should involve 10% to 35% of our effort in FHM. When reports from detection monitoring identify areas or problems of concern, FPM/FHP and the National FHM Program Managers will assess the situation and, as appropriate, convene multi-disciplinary teams to determine specific evaluation needs. These could include additional surveys, site- or area-specific evaluations, more detailed monitoring, and specific research studies. Criteria for evaluation monitoring project design and selection are to be developed by FPM/FHP in cooperation with the National FHM Deputy Program Manager.

Reporting and Interpretation of Results

The goal of monitoring is to detect and report problems requiring management response. The success of reporting depends on clear monitoring objectives and organized plans to produce timely information. Various levels of reports/summaries will be developed for the public, scientists, and decision makers. The information reported will also have relevance and meet the needs for various data users groups such as state cooperators.

FPM/FHP responsibilities for reporting include the interpretation of specific information on the detection plot network (i.e., crown ratings, damage signs and symptoms, and spring visit information in Region 8 only). The off-detection plot information will be the major aspect of FPM/FHP activity. This includes the development of regional effect/pest information which will be collected and organized into a data base for GIS applications. Both of these information sets and activities will be combined into annual regional and national reports on FHM which are being organized by USDA Forest Service Research and US-EPA EMAP.

In addition, the off-detection plot information along with other sources of data on forest conditions and stressors will be used in the development of annual state forest health reports. These reports will be developed by the cooperating state agencies with assistance from FPM/FHP.

Evaluation monitoring reports will be developed as needed and will vary depending on the focus of the evaluation monitoring project. Some of this information may be used to support observations and conclusions contained in the annual detection monitoring reports discussed earlier.

OBJECTIVES

The emphasis of the eastern FHM Program for FPM/FHP is on detecting unexpected deviations from established forest base line conditions or trends, conduct evaluations of these observed deviations, coordinate the activities with research, and report changes in forest damage. The FPM/FHP objectives discussed in this plan emphasize the adaptation of FPM/FHP assessment activities to the National FHM Program.

The objectives of the FHP/FPM activities are as follows:

1. To develop an eastwide approach (including standardized data collection and reporting) to detection of major types of forest effects, including adverse weather and air pollution.

    a. Annually produce data bases, reports, and maps of areas where forest effects are exerting stress that might cause forest decline and tree mortality. Special emphasis will be placed on new problems.

    b. Provide impact estimates for forest trees severely damaged by insects, diseases, and fire.

2. To determine probable causal agents for reduced tree vigor and mortality on the detection monitoring plots and to assist in the assessment of cause-effect relationships of forest declines and tree mortality in FHM.

3. To assist in the implementation of tree vigor rating methods and air pollution injury as a way to measure annual trends of forest health. To provide training to the field crews in proper use of the methods.

4. To assist the appropriate groups in the development of annual State and National forest health reports.

5. To help formulate Integrated Pest Management (IPM) guidelines applicable to a variety of problems or potential problems.

FPM/FHP PERMANENT FHM PLOT SUPPORT

The permanent forest health network of plots is designed to detect possible changes in forest conditions from man caused events on a regional level. FIA has the primary responsibility for the permanent plot network. FPM/FHP has the responsibility to provide support for the plots, as needed. To date, this support has been in the area of developing and implementing procedures which assess the vigor of the trees and detect changes in forest health. Procedures have been developed and training provided for crown evaluations and tree damage. Procedures for assessing sample (on annular plot) trees will not be used in 1992 but will be implemented in future years. The details of the measurements are contained in the Eastern FHM Measurements Field Guide. Each of these procedures is designed to assess a specific part of the plant or ecosystem as it relates to plant or forest health. The measures are also designed to be sensitive to changes over time so that change can be detected.

Crown Evaluations, trees 1.0" in dbh and larger

1. Crown Class - This measure describes the tree vigor in relation to sunlight received and a trees' position in relation to the neighboring trees.

2. Crown Diameter - This procedure measures the diameter of tree crown. It helps assess the growing space of a tree and can be used with other measures to estimate crown biomass. [Note: only on trees 5.0" in dbh and larger].

3. Crown Ratio - This is a measure of the ratio of tree crown length to total tree length. It can be used to estimate crown and foliar biomass.

4. Crown Density - This measurement estimates the amount of foliage, branches, and fruiting structures that block light transmission through the crown. This measure has been shown to be correlated with basal area of increment growth. [Note: only on trees 5.0" in dbh and larger].

Damage Assessment, trees 5.0" in dbh and larger

1. Crown Dieback - This procedure measures the amount of recent dieback in the crown. The system estimates the percent of dieback in the crown as a percent of the total crown. Dieback is often related to tree vigor.

2. Foliage Transparency - This is an estimate of defoliation. The crown transparency is measured as the percent of light visible through the foliated portion of the crown. This measure may reflect short term defoliation or longer term effects that are expressed as reduced foliage in the crown.

3. Tree Damage - This procedure identifies damage to the tree that may result in growth loss or mortality. Up to three damages can be recorded per tree. For each damage, the location on the tree and possible cause are recorded.

Crown Evaluation (Seedlings/Saplings)

The crown evaluation procedure for seedlings and saplings is designed as a rapid method to place the seedlings/saplings into good, medium, or poor vigor classes. This is done by assessing the amount of normal foliage and dieback in the crown.

Air Pollution Bio-indicator Plots

This procedure is designed to assess visible damage to bio-indicators by ozone. The methods are being tested and have been implemented for 1992.

Sample Tree (Located in the annular plot of the detection plots)

There are a number of measurements planned for sample trees such as root sampling and in-hand branch examination. There are no plans to implement any of these measurements in 1992.

Spring Visits to the Detection Plots (Region 8 only)

Since the forest health plots will be visited in the summer by FHM field crews, it is desirable to monitor pest activity on the plots in the spring for defoliators. These spring tree damages can result in growth losses but cannot be detected later in the summer. To monitor this potential damage, the state cooperators in Region 8 will visit each detection plot in the spring using the following method:

1. Scope and purpose: Spring plot visits will help to insure that certain spring foliar conditions (e.g., frost, selected insects and diseases, air pollution incidence confined to spring episodes) are not overlooked. Such conditions might be significant as FHM variables, but might have disappeared by the time crews visit the plots later in the year. All plots in the cooperating states will be visited in the spring.

2. Procedures:

   a. Sample Collection and Preparation: In cases where field diagnosis is not possible or is suspect, crews will supply specimens to the state FPM specialist for analysis. Specimens will be collected so as to preserve the condition for diagnosis, and crews will be trained/equipped for specimen collection and forwarding. FPM will assist state agencies in diagnostic work upon request.

   b. Examination: Trees from the detection plot tree species list will be examined within the plot area. Trees with 15 percent or more leaves affected will be reported for each species on the detection plot list. Crews will use crown rating cards to calibrate the 15 percent threshold. Trees will not be evaluated on an individual basis, but by species.

   c. Training:

   Indoor: Crews will be trained using 35 mm projected slides on foliar conditions they will likely encounter. Special emphasis will be placed on conditions specific to their geographic area. Trainees will be tested with an examination slide series.

   Outdoor: Trees showing various foliar conditions will be flagged and the conditions discussed. Field crews will be tested on: 1) their ability to discriminate between

various conditions listed on the spring plot form, and 2) their ability to calibrate their perception of the 15 percent and above foliage affected threshold.

3. Quality Assurance/Quality Control (QA/QC): Crews will be tested immediately after initial training to insure that they perform satisfactorily. Additionally, audits will be made throughout the field season by qualified individuals to insure that performance is up to standards. Crews will be observed in action and plots will be re-evaluated after field crew analysis. In the event of unsatisfactory performance, individual crew members will receive additional instruction until performance is up to standards. Records of performance will be maintained and used as a basis for attaining improvement goals within tolerances yet to be determined.

Other Plot Measurements

All other plot measurements are under the control of FIA. In future years there will be procedure modifications and additions where FPM/FHP may play a major role.

Training

Effective and repeatable training is vital to the success of the program. To accomplish this task FPM/FHP will hold a pre-training session of all trainers to discuss procedures and standardize training procedures. The pre-training will include a QA/QC testing at the end to insure that all trainers are providing the same estimates for a given tree.

Training of the crews will be done using the methods agreed upon at the pre-training meeting, and in accordance with the FHM field guide. The training will include classroom and field segments. Crews will receive the proper field aids, and be trained on a representative number of trees and species. The crews will then be checked on a number of trees and will then given a final test. Crew members with an unacceptable error rate will be retrained and retested.

QA/QC

QA/QC must be considered in all aspects of FPM/FHP FHM support. The two major activities are training and crew evaluation.

Training – All measurements will have a specified level of precision. This precision will be used to determine if the crews have been properly trained. Each trainee will receive instruction and hands-on experience with all methods. The trainees will then participate in an open-discussion type of instruction where actual values on numerous trees are discussed with the trainers and trainees. The purpose of this activity is to calibrate field crew personnel with the various methods. This will then be followed with a QA/QC test. If the error rate does not meet the specified precision, the person will be retrained and retested.

Crew Evaluation – FPM/FHP trainers will meet with each of the crews during the course of plot establishment and/or measurement. The purpose of the visit will be to answer questions by the crews and to check on how close the crews are in relation to the trainer. If problems are found, on site training will be done and documented. Also, the field crews will be requested to provide feedback at the end of the field season to identify problems associated with data collection, including training. This information will be used to modify and improve next years program.

FPM/FHP OFF-DETECTION PLOT EFFECTS/PESTS SURVEYS

Monitoring of Specific Effects/Pests

There are two processes that are important in the integration of FPM/FHP activities into FHM. The first process is the standardization of surveys and survey methods for known pests and various types of effects. FHM requires that certain major effect types (Table 1) and certain pests (Table 2) be surveyed for in a standardized manner and reported in a standardized manner so that the information from these surveys is quantifiable and comparable. With this process we are determining that all groups will attempt to monitor certain pests or effects. (However, it is recognized that funding, staffing, and priorities may make it impossible to complete all of the major pest surveys. If this does occur, FPM/FHP and the states will work together to establish priorities.) A list of these major pests follows in Tables 1 and 2. The items in Table 1 are required when a state participates in FHM. The items in Table 2 are optional and will be negotiated between the state agency and the appropriate USDA FS FPM/FHP unit.

Two aspects are reported with each major pest effect type, total amount of acres or other unit affected for each category of effect or major pests and the total amount unaffected. This information is important to determine the severity of a problem within a state or region. It is important to note in this list that minimum thresholds for survey and reporting are given. That is, the agencies agree that they will not miss the effect above a certain threshold. The reason for these minimum thresholds is to set a filter for detection level reporting below which data is not required. Cooperators can set lower thresholds and reporting standards to meet their own requirements, but the levels in Tables 1 and 2 are required for FHM. For all of these specified effects/major pests, a map is required for use in the development of regional GIS data layers. A survey method will be provided for each of these effects/major pests.

Table 1. General Effects

Effect	Action Threshold
Defoliation	>30% foliage loss over 5000 concentrated acres
Discoloration	>30% of foliage affected over 5000 concentrated acres
Dieback/Decline	>30% of trees affected with 30% of crown affected over 5000 acres
Stem Damage (Defect)	>30% of trees affected per acre over 5000 acres
Mortality	>30% of trees/acre affected over 5000 acres
Breakage	>30% of trees affected over 5000 concentrated acres

Table 2. Specified Effects/Pests

Effects/Pests	Forest Type	Frequency	Threshold for Survey	Map Resolution
Gypsy Moth	Hardwoods	Annual	Defoliation 1/	Not specified
Pine Sawflies	Pines	Annual	Defoliation	Not specified
Budworm	Spruce and Jack Pine	Annual	Defoliation	Not specified
Thrips	N. Hdwds.	Annual	>30% of foliage of individual trees and >1000 affected on any definable area	Not specified
Hemlock Wooly Adelgid	E. Hemlock	Annual	Distribution map	Not specified
Forest Tent Caterpillar	Hardwoods	Annual	Defoliation	Not specified
Southern Pine Beetle	S. Pines	Annual	Average of 1 spot per 2000 acres of type per county	Not specified
Other conifer bark beetles	Conifers	Annual	Mortality	Not specified
Dogwood Anthracnose (*Discula*)	Dogwood	Annual	Distribution map (Lab confirmed)	Not specified
Fusiform Rust	S. Pines	Annual	>10% of living trees with galls on or within 12" of main stem	County
Annosus Root Disease	Conifers	5 years	Mortality	Not specified
Armillaria Root Disease	All types	Annual	Mortality	Not specified

Table 2. Cont.

Effects/Pests	Forest Type	Frequency	Threshold for Survey	Map Resolution
Littleleaf Disease	S. Pines	Annual	Mortality	Not specified
Butternut Canker	Butternut	Annual	Distribution map	County
Beech-Bark Disease	American Beech	Annual	Stem damage	Not specified
Diplodia	Pines	Annual	Dieback	Not specified
Spruce-Fir Mortality	High elev. spruce-fir	Annual	Mortality	Not specified
Dutch Elm Disease	Amer. Elm	Annual	Distribution map (Lab. confirmed)	County
Oak Decline/ Mortality	Oak	5 years	Dieback/decline	Not specified
Oak Wilt	Oak	Annual	Any occurrence	County
Dieback	All types	5 years	Dieback/decline	Not specified
Defoliators	All types	Annual	Defoliation	Not specified
Heartrot	All types	10 years	FIA Data	Not specified
Drought	All types	Annual	Proper effect, Table 1	Not specified
Storm Damage	All types	Annual	Breakage	Not specified
Ozone	Sensitive species	Annual	>30% sensitive species with >30% of foliage/tree affected on 1000 acres	Not specified
Frost/Cold Injury	All types	Annual	Discoloration	Not specified

Table 2. Cont.

Effects/Pests	Forest Type	Frequency	Threshold for Survey	Map Resolution
Animal-caused damage	All types	Annual	Proper effect, Table 1	Not specified
Ash decline	Ash	5 years	Dieback/decline	Not specified
Walnut canker	Black walnut	5 years	>30% of trees over 100 acres	Not specified
Pine tussock moth	Pine	Annual	Defoliation	Not specified
Saddled prominent	Hardwoods	Annual	Defoliation	Not specified
Walnut shoot borer	Walnut	5 years	>30% of trees on 100 acres	Not specified
Cankerworms	Hardwoods	Annual	Defoliation	Not specified
White pine weevil	White pine	5 years	Dieback/decline	Not specified
White pine blister rust	White pine	10 years	Stem damage	Not specified
Red pine shoot moth	Red pine	5 years	Stem damage	Not specified
Hardwood borers	Hardwoods	10 years	Stem damage	Not specified
Needle cast	Conifers	Annual	Discoloration	Not specified

1/ Refers to standard criteria in Table 1.

Minimum Reporting Standards for Effects/Pests Surveys

These values are set as the minimum reporting standard. Cooperators are encouraged to collect more detailed data, but as a minimum to collect these data. This could also serve as a threshold to decide when a particular effect/pest should be surveyed in more detail. New pests can be added as the need arises where practical and all of these data should be organized and reported in a GIS-compatible format (e.g., longitude and latitude). The state and federal cooperators will coordinate these activities to insure compatibility between surveys and agree upon what is practical in lieu of funding and personal limitations.

The minimum to be reported, regardless of effect/pest, is:

1. Latitude and longitude to the nearest degree, map, county name, or quad coordinates (depending on pest/effect)
2. Host species - using FHM codes
3. Forest type - using FHM codes
4. Number of acres by county
5. Symptoms observed
6. Survey method used (aerial sketch map, video, windshield survey, etc.)
7. Effect/Pest
8. Intensity levels - when appropriate

This process will also provide for the detection and reporting of unspecified pests or effects. The inherent value of FHM is in the detection of factors that may play a role in forest health BEFORE they become a problem. Therefore, the monitoring and reporting of unspecified effects/pests is also important in evaluation of trends or patterns. For this process a FPM/FHP Monitoring Database will be created in which all effects/pests data is entered. A standard data entry format is being developed. The value of this database is that it will allow effects/pests data to be stored in a standard format, retrievable for summary and analysis within and among states, and makes effects/pests data readily available for reporting purposes. Distribution maps are not required now, but location information is required.

Survey Field Guide

Considerable work has been done to develop survey methods for certain effects/pests. FPM/FHP in cooperation with the state will build upon the existing methods and produce a effect/pest FHM survey field guide. The field guide will be developed by selecting specialists to author the methods used for each of the effects/pests. Prior to selecting the specialists, a standard format will be developed. This booklet will be maintained as a separate guide and updated as needed. For 1992, procedures will be developed for those general effect types in Table 1. Specific pest methods will be developed later.

Standard Pest Codes

A list of standard pest codes for forest pests is available. All FHM activities can use their own coding system. All codes will be referenced to the national coding system for reporting.

DATA MANAGEMENT AND REPORTING

Regional FHM Reporting of Effects/Pests

Major specified effects/pests will be organized through the use of GIS. Maps provided for each effect/pest will be entered as a data layer to be used in conjunction with other layers such as FHM plot locations, forest type, weather patterns, etc by FPM/FHP. Tabular data for major specified effects/pests as well as unspecified effects/pests will be entered into FPM/FHP Monitoring databases. The purpose of these databases is to provide a capability for entering, storing, processing, summarizing, and retrieving forest effect/pest data for use in monitoring trends.

Each year, effect/pest data will be summarized for use in the development of an annual regional FHM report. This report is intended to summarize FHM plot data and make use of off-detection plot data. The maps and tabular effect/pest data represent one example of off-detection plot data that contributes to the annual FHM report. Weather and air quality data represent examples of other off-detection plot data to be used in reporting. FIA/USDA FS Research has the lead responsibility in summarizing plot data and producing the annual FHM report. FPM/FHP specialists have responsibility in providing off-detection plot effect/pest data so that it can be incorporated into the report. This is one reason why so much emphasis is being placed upon standardization of methods and reporting.

State Forest Health Reports

These reports will focus on the forest types and the factors that influence tree condition as opposed to traditional forest pest reports that focused on the individual pest. A matrix table may be helpful to relate forest pests to the various forest types. It is important to include a definition of "forest health" and "significant change in forest condition" as it relates to a particular state's needs.

The following is a suggested outline for the annual state forest health report:

1. Purpose - What is reported and what is included
2. Description of the forest resource
3. Description of the factors affecting the condition of the resource - including historical information
4. Description of changes/trends in forest condition and stressors
5. Description of survey methods
6. Discussion of protection/control activities
7. Description of monitoring activities and projects
8. Issues and recommendations

Additional ancillary data will also be included concerning climate/weather and urban community information, as available and/or appropriate.

At a minimum, the states are asked to report annually the following:

1. Summary
2. Agreed upon Effects/Pests*

	Region 8	Northeastern Area
Defoliation (Table 1)	X	X
Discoloration (Table 1)	X	X
Dieback/Decline (Table 1)	X	X
Stem Damage/Defect (Table 1)	X	X
Mortality (Table 1)	X	X
Breakage (Table 1)	X	X
Gypsy Moth (Table 2)	X	X
Major Storm Damage (Table 2)	X	X
Southern Pine Beetle (Table 2)	X	
Fusiform Rust (Table 2)	X	

* See minimum reporting standards for list of data needs (Tables 1 and 2)

3. Other Major Effects/Pests - to be determined individually by each state
4. Describe unusual events

EVALUATION MONITORING

Detection monitoring may identify growth declines or tree mortality for which obvious causes can not be established. In addition, situations arise where the forest managers, researchers, or the general public suspect a significant forest decline. Multi-year measurements are needed to confirm the degree and/or the extent of decline and to establish probable causes for the decline before plans may be developed to mitigate the losses or to develop in-depth research studies.

This level of FHM involves designing and implementing intensive surveys to evaluate a detected or unexplained problem. FPM/FHP has been active in evaluation monitoring and will continue to provide leadership and technical assistance in this area. When reports from detection monitoring identify areas or problems of concern, FPM/FHP and the National FHM Program Managers will assess the situation and, as appropriate, convene multi-disciplinary teams to determine specific evaluation needs. These could include additional surveys, site- or area-specific evaluations, more detailed monitoring, and specific research studies.

Past Activities

North American Sugar Maple Decline Project (NAMP) was initiated as a result of a joint assessment by about 40 scientists and pest management specialists from Canada and the United States. The Canada-US project was planned jointly with federal, state, and provincial participation. Eventually, it was formalized with a Memorandum of Understanding. More than 170 plot-cluster are established and about 15,000 trees are monitored annually with standard assessment methods to determine the rate of tree decline and possible association with air pollution. Data are reported annually to the cooperators and to the respective federal governments. NAMP is acclaimed to be the first international project that was jointly planned, used the exact the same methods, and was jointly administered, and provided annual results with uniform analyses.

Cooperative survey to determine decline and mortality of red spruce and balsam fir was initiated in 1984. First phase included photographic color infrared sampling survey to establish that mortality was occurring. Consequently, as phase 2, plot-clusters were established in New England, New York and in West Virginia, to monitor the rate of tree decline. The field measurements continued from 1985 through 1989. The photo survey was repeated in 1990 to determine if the extent of mortality areas have changed.

A cooperative dogwood anthracnose project was initiated in 1988. These funds were used to conduct pilot tests on control techniques, determine the disease distribution and assess disease severity. The pilot testing has produced a set of control procedures for urban trees and the impact assessment, using 210 permanent plots, has documented the spread of the disease in the south from 0.5 million acres in 1988 to 9.5 million acres in 1992.

Components of Evaluation Projects

The following components need to be included in an evaluation monitoring project work plan. Also all participants in the project should be included in the organization and planning aspects if the project is expected to succeed.

1. Problem statement - Clearly identify the problem(s) that need to be answered as identified by FHM detection monitoring.

2. Objectives - The objectives should clearly state the products and the user(s) of the product. A statement concerning the procedures to modify and/or terminate the project should also be included.

3. Methods - The methods should be clearly stated and if possible be similar to methods for detection monitoring, when applicable. Data management procedures should also be developed.

4. QA/QC - The precision and if possible the accuracy of the methodology should be stated and meet the objectives of the project and products. Data precision estimation procedures should be clearly stated. Other training and standardization techniques should be addressed and developed.

5. Reports - Establishment, annual progress, and final reports should be planned for in the work plan in as much detail as possible. Consideration should be given to technical and general public reports.

6. Budgets - The entire budget for the project and divided into annual increments. If cooperative funding is involved, shares should be clearly stated. All of the funding groups should make long-term commitments with the understanding that funds are available annually and amounts can change.

APPENDIX

Example of a Cooperative Forest Health Agreement Narrative

Cooperative FHP (or FPM) Program for FY 199x

Forest Health Monitoring

(State)

The (Agency) will undertake the following activities for FY 199x:

1) The (Agency) will adopt the minimum standards for effect/pest surveys and use the standard FHM methodology (if different, procedure must be justified and documented) as described in Eastwide FPM/FHP Working Plan for the following effects/pests (from Table 1 or 2 in the Eastwide Working Plan):

   List appropriate effects/pests

2) The (Agency) will conduct spring visits (Region 8 only) to all detection plots or visit the detection plots throughout the year as needed and/or install supplemental effect/pest plots to document any potentially active pests. The (Agency) will agree to participate in the necessary training session to accomplish the additional visits to the detection plots.

3) The (Agency) agrees to conduct the following special surveys in support of the FHM program:

   List applicable surveys

4) The (Agency) will report the information collected under 1) and 2) to the USDA Forest Service FHP (or FPM) by January 1, 199x+1.

5) The (Agency) will develop and submit a forest health report by April 1, 199x+1 to the USDA Forest Service FHP (or FPM).

6) The (Agency) will (purchase, contract, conduct, other) (equipment, services, information management, training sessions, other) in support of FHM activities in the state.

   List all

The USDA Forest Service FHP (or FPM) will provide the following support to the (Agency) in FY 199x:

7) The USDA Forest Service FHP (or FPM) will provide training, including supporting documentation, to the (Agency) to support activities identified in items 1), 2), and 3).

8) The USDA Forest Service FHP (or FPM) will provide the necessary (technical support, raw or summarized data, summarized maps or tables, other), in an appropriate format, to accomplish items 4) and 5) by February 1, 199x+1 to (Agency).

The above items were developed in conjunction with the appropriate USDA Forest Service FHP (or FPM) personnel and agreed to by both groups. Items 4), 5), and 8) will be completed in the FY after the the field activities [items 1), 2), 3), and 7)] have been completed. Both the USDA Forest Service FHP (or FPM) and the (Agency) agree to implement the principles of quality assurance to accomplish the above activities. This agreement does not cover the main FHM detection plot effort (except specific items under 2)). Those activities will be covered in a separate agreement with USDA Forest Service Research.

The costs for each of the above activities is itemized below:

Activity	Cost
1) Effect/Pest Surveys	
Effect x	xxxx
Effect y	yyyy
Effect z	zzzz
Pest x	xxxx
Pest y	yyyy
2) Additional Plot Visits	
xxx plots will be done, average cost per plot - $xxxx	xxxx
3) Forest Health Report	xxxx
4) Effect/Pest Reporting from item 1)	xxxx
5) Special Surveys	
Survey x	xxxx
Survey y	yyyy
6) Other	xxxx
Total	XXXX
Less xx% State share	YYYY
Federal share	ZZZZ

Appendix C. Field Logistics

16. Field Logistics

R. Kucera and R. L. Tidwell

16.1 Eastern Field Logistics Plan

16.1.1 Introduction

A field crew will be comprised of a core of 5 individuals; two foresters, one soil scientist, one botanist, and one tree climber

During a day of sampling, there are a number of activities or operations that occur which are the responsibility of certain individuals. The following table lists the field operation and the person responsible for the activity.

Operation	Responsibility
Sampling schedule	Field crew leader
Crew assembly	Field crew leader
Transport to site	Field crew leader
Site location	Forester 1 & Forester 2
Plot establishment	Forester 1 & Forester 2
Sampling	Field crew
Sample maintenance	Tree Climber
Sample transfer/shipping	Tree Climber
Equipment maintenance	Field Crew
Data transfer	Field crew leader
Daily communication	Field crew leader

These operations will be discussed under the heading of the person or persons responsible for this activity. The following table lists the crew members and the agency that is responsible for providing the crew person.

Position	Agency
Forester 1	Forest Health Monitoring
Forester 2	Forest Health Monitoring
Botanist	Forest Health Monitoring
Soil Scientist	Forest Health Monitoring
Tree Climber	Forest Health Monitoring

16.1.2 Field Crew Leader

The field crew will be supervised by a designated crew leader. The crew leader will supervise all field operations and, if necessary, resolve all discrepancies or issues at the site. The field crew leader has the responsibility of:

- Maintaining sampling schedule.
- Assembly of field crew.
- Transportation to the sampling site.
- Ensuring adherence to sampling protocol.
- Ensuring proper use of field equipment.
- Maintaining site and sample integrity.
- Data transfer.
- Daily communication.

16.1.2.1 Sampling Schedule

The field crew leader will be responsible for sampling a certain number of plots within an index period. The crew leader will have the responsibility to meet this sampling quota while maintaining the quality of the measurements and samples, and following standard protocol. The field crew leader must be attentive in assessing field crew morale and creating a sampling schedule to maintain an adequate level of morale.

16.1.2.2 Assembly of Field Crew

The field crew leader is responsible for assembling the field crew each morning at an appropriate time. The field crew leader will also determine rendezvous points to assemble crews after scheduled time-off (after weekends, holidays, etc.).

16.1.2.3 Transportation to the Sampling Site

The field crew leader will be responsible for providing and maintaining adequate transportation to the site. Crews must make efficient use of vehicles.

16.1.2.4 Ensuring Adherence to Sampling Protocol

The field crew leader is expected to have a basic knowledge of all sampling procedures and be able to determine whether field crew members are adhering to sampling protocols. If protocols appear to be inconsistent or are being misinterpreted, the field crew leader should address the inconsistency during the daily communications update. Problems should be rectified by the next day.

16.1.2.5 Ensuring Proper Use of Field Equipment

Some field equipment will require special care (PDRs, laptops, bar code readers etc.) and proper use. The field crew leader should observe the use of equipment and if necessary instruct crew members in the proper use. Field crew members will inform the crew leader of equipment that is destroyed or in need of repair. The field crew leader is responsible for addressing the equipment problems in the note section of the daily communication update (see section 17.12 of the PDR instructions).

16.1.2.6 Maintaining Site and Sample Integrity

During sampling, flagging will be placed around the site to mark various sampling points (soil holes, vertical vegetation and PAR measurement points). Soil holes will be dug and branches will be sampled. The field crew leader will be responsible for maintaining plot integrity and anonymity when sampling is completed. The field crew leader will direct all of the crew members to assist in these activities.

A number of samples will be collected at the sampling site. These samples will be prepared and analyzed and incur quite a cost from collection through analysis and interpretation. It is imperative that the integrity of these samples are maintained. Some samples require cooling and transportation to laboratory facilities as soon as possible. The field crew leader is responsible to ensure adherence to sample maintenance protocol.

16.1.2.7 Data Transfer

Data from PDRs and ceptometers must be uploaded to laptop computers and transferred to the EPA VAX. The field crew leader will be responsible for this data transfer. Instructions for this operation are presented in section 17.12 of the PDR instructions.

16.1.2.8 Daily Communication

For this study, communication will take place electronically through the laptop computers or phone system. An "update" screen will appear which the field crew leader is requested to fill in. It will include the following information:

- Field Crew ID.
- Hexagon sampled that day.
- Hexagon expected to be sampled following day.
- Additional personnel with field crew (auditor, EPA personnel etc.).
- Field crew location (hotel name, address, Phone #).
- Expected location of next day.
- Comments/Problems.

The field crew leader or the logistical aide is expected to fill in the update and send it out electronically, **each day, whether or not data are being transmitted**. This update will be electronically sent to the EPA VAX which will then be used to update DG and E-MAIL accounts of appropriate individuals in the program. Instructions for this operation are presented in section 17.12 of the PDR instructions.

Some hotels "hardwire" phonelines, prohibiting the connection of the laptop to the phone system. In this instance, an 800 number will be available for updates (800-288-3171). Either an individual will record the information or a recorder will store this information. A LESC individual will enter this update information and electronically send it to the appropriate individuals.

16.1.3 Forester 1 & Forester 2

Forester 1 and forester 2 will be responsible for locating the sampling site, establishing the plot, and the data collection activities involved with the growth, visual crown rating, branch evaluation, bioindicator plants, increment cores, and root samples.

16.1.3.1 Sampling Site Location

In most cases, FIA photopoints will be used for the sampling plots. Information pertaining to the sites will be available at the training session. Foresters will follow standard FIA protocol in locating sampling sites. Procedures for this activity are detailed in Section 2.

16.1.3.2 Plot Establishment

Forester 1 and forester 2 will be responsible for establishing the plot. Details of this procedure are provided in Section 2. However, Section 2 only details establishment of the plot for growth and visual crown rating measurements. Soil sample holes and vegetation structure plots must also be established. It is very important that the plot establishment be accomplished in a sequence that 1) maintains plot integrity for other measurements (i.e., regeneration measurements before vegetation structure measurements), and 2) allows all field crew members to start data collection activities as soon as possible in order to finish sampling within a reasonable timeframe. To accomplish this, a plot layout procedure should be developed.

16.1.4 Field Crew

The field crew, as a whole, will be responsible for sampling activities. The field crew will share responsibility for equipment maintenance and equipment inventory. The tree climber will aide the crew with resupply requests, sample shipment and other administrative duties. These administrative duties may include calling in and reporting labor hours, sending or receiving messages and moving gear to the next hotel location.

16.1.4.1 Sampling

Individuals on the 5-person crew will be responsible for the following sampling activities:

- 2 Foresters
  - Forester 1 & Forester 2 - Plot set-up, Mensuration, Regeneration, Visual Crown Rating, Damage and Mortality, Increment Cores, Root Samples, Bioindicator Plants, In-hand Branch Evaluation
- Botanist - Vegetation Structure
- Soil scientist - Soils - Physical (characterization/sampling).
- Tree climber - Branch Sample Collection, Assist with excavation of soil holes, Sample Shipments

Forester 1 and forester 2 will be working together for the majority of the day. The tasks of plot layout, mensuration and regeneration, visual crown rating, damage and mortality measurements, root samples, and branch evaluation are expected to take a full day. The soil scientist will be working independently, with the exception of assistance in excavating soil holes during the morning. The botanist will be responsible for vegetation structure. Therefore, an efficient sampling schedule should be developed. The tree climber will obtain branches and provide them to the forester for in-hand evaluation. The tree climber will package the foliar samples and assist with sample handling for root, soil, lichen, and increment core samples. The tree climber will be responsible for sample shipments.

Sampling Schedule--

In order for the field crew to collect data in an efficient manner, a list of sample activities has been developed (Figure 16.1). Figure 16.1 attempts to identify which sampling activities will be accomplished. Field crew members must work on measurements together and certain measurements or operations must take place in sequence. This figure should be used as an example and should be modified during sampling if a more efficient schedule is developed.

Measurement	Sub-plots	Samples	FOR	FOR	SOIL SCI	BOT	CLIMB
Lichens, Wildlife, Veg. habitat	4	7 points each				6.5	
Dieback	4	all trees > 5" dbh	2	2			
Crown ratio	4						
Density	4						
Diameter	4						
Transparency	4						
Tree damage	4						
Soil Productivity	3 pits	yes	.5	.5	6.5		2*
Foliar chemistry	2	2trees/ subplot x2 subplots					3.5*
Branch evaluation	2	4trees 1/tree	.5				.5*
Root samples	2	4trees 1/tree		1			.5*
Increment cores	2	4trees 2/tree		1			.5*
Plot establish	all		1	1			
Mensuration	4	all/sub plot	1	1			
Pollution indicator plants	1 off plot	one plot off plot	1				

Figure 16.1 List of measurements in Eastern Demonstration. * denotes sample handling activity.

16.1.4.2 Equipment Maintenance

During training each field crew member will be provided equipment and an inventory list of the equipment they will receive. If equipment is damaged during field activities, the item should be identified on the inventory list and the service or repair that may be required should be specified. The field crew member will inform the field crew leader of the damaged equipment. The field crew leader is responsible for communicating this information through the daily crew update. If available, the field crew member will use replacement equipment. If supplies run low or an item of equipment is needed, contact the following personnel for resupply of equipment and consumables:

Bob Kucera
ManTech Environmental Technology, Inc.
2 Triangle Drive
Research Triangle Park, NC 27709
Work Phone: (919) 541-7589
Home Phone: (919) 490-5289

Inventory Procedure --

At the end of the field season, the field crew will return all equipment to the logistics lead. The logistics lead and each field crew member will check off each item on the inventory list that is provided at the beginning of the field season to each field crew member. All items must be accounted. Items will be inspected for damage and their condition recorded.

16.1.5 Tree Climber

The tree climber will be responsible for the following activities:

- Obtaining branch samples.
- Sample maintenance.
- Sample transfer and tracking.
- Sample shipping.

Six types of samples will be collected from the sample plots; 1) soil samples, 2) bulk density samples, 3) lichen samples, 4) increment cores, 5) foliar chemistry samples, and 6) root samples. The number of samples expected from each plot are identified in the appropriate methods section.

16.1.5.1 Sample Maintenance

This SOP is intended to describe the procedures necessary to maintain samples collected in the field.

All samples and film will be packaged by the field crew in a manner that will maintain integrity. Of the samples mentioned in the overview, only the soil samples must be maintained at approximately 4° C. Root samples must be stored at a temperature between 13° C and 0° C. **Lichen samples must not be placed in coolers due to the possibility of fungal growth.** Photographs of the soil pedon and plot will be taken. This film should also be maintained in a cool atmosphere. Cooling of samples and film can be accomplished in the field with the use of the frozen gel-packs and coolers. The tree climber is expected to provide and maintain coolers and frozen gel-packs for the field crews. The field crew is expected to maintain samples until received by the tree climber. The tree climber is expected to maintain sample integrity from time of receipt until sample shipment.

Equipment and Supplies --

- Cooler (hard plastic/polyfoam).
- Gel-packs.

Calibration and Standardization --

There are no calibration and standardization steps in this procedure.

Quality Control --

Coolers and gel-packs should be inspected for damage on a daily basis. Polyfoam shipping coolers should be contained in their cardboard packing cases at all times to avoid breakage. Avoid wetting the packing case around the shipping coolers because it will reduce the containers strength, which is intended to protect the cooler within. Leaking gel-packs should be discarded. Sample material should not be left outside of coolers or in direct sunlight for considerable lengths of time (>15 minutes).

Procedure --

1. The crew will be provided hard coolers and frozen gel-packs.

2. As samples are brought out of the field, they are placed into hard coolers. Place a layer of frozen gel-packs on the bottom of the cooler. Place a layer of plastic bags over the gel-packs to prevent samples from coming into direct contact with gel-packs.

3. Place soil samples into coolers.

4. Coolers containing sample material should be placed in cool areas (hotel rooms, refrigerators, etc.) until shipped.

5. Once the tree climber has received samples, this individual is expected to maintain samples at the appropriate temperature by either the use of gel-packs or storage in available cooling facilities until shipment to preparation or laboratory facilities.

6. Other samples (bulk density, roots, and lichens) must be stored in a manner that will protect their integrity. Bulk density samples can be stored in coolers for their protection until they can be shipped.

16.1.5.2 Sample Transfer and Tracking

As samples are transferred from the field crew to the tree climber, the number, and type of samples must be recorded in a manner that will allow for the tracking of these samples. This will assure that all the samples collected in the field have been transferred to the tree climber and it will allow tracking of samples throughout the preparation, sample analysis and archive phases of the program. Two types of techniques will be used for recording and tracking samples: 1) bar code scanning for soil samples and 2) hardcopy recording for the remaining samples.

Equipment and Supplies --

- Bar code reader.
- Bar codes.
- Laptop.
- Interface cables.
- Coolers.
- Frozen gel-packs.
- Large plastic bags.
- Clear adhesive tape.
- Sample tracking form.

Calibration and Standardization --

There are no calibration and standardization steps in this procedure.

Procedure --

Soil Samples

1. Through the electronic data information system, the samples ready for sample transfer by each crew will be available on the field crew laptop. The hexes and bar code sample numbers of outstanding samples will be updated on the computer.

2. When samples are ready to be shipped, set up the laser bar code reading device and initiate the " Pack Samples in Cooler" program on the laptop computer (see Section 17.12of PDR instructions).

4. If samples are in shipping boxes, remove samples from each box. Place gel-packs in the bottom of the box as stated in the sample maintenance procedure. If samples are in hard coolers, they should be removed and placed into shipping coolers. Hard coolers should remain with field crews and must be returned to the crews as soon as possible.

5. Place a bar code on the shipping cooler and tape over this bar code with clear adhesive tape. Scan this bar code. This will set up the computer for scanning samples to be placed in this cooler.

6. Enter the header information that is required for the " Pack Samples in Cooler" program.

7. Scan each bar coded sample and place the sample into the shipping cooler that was bar coded in procedure 5. This will record what samples are in each box and will be used later for sample transfer. Once the shipping cooler is full it can be taped shut if the sample material will be shipped that day.

8. Repeat procedure 5 and 6 for each shipping cooler to be filled.

9. After all samples are packaged, press the appropriate commands on the laptop (Section 17.12 of the PDR instructions). This will cross-check the samples transferred with the samples collected in the field. Any discrepancies will be identified. The tree climber will be expected to attempt to rectify discrepancies (i.e., if a sample for a hex has not been recorded, the tree climber should look through the samples to see if the sample is actually there and was not scanned, etc.).

10. Upon completion of sample transfer, the transfer file will be electronically sent to EPA-LV where the file will be reviewed and discrepancies forwarded to the field crew for rectification.

Bulk Density, Root, and Lichen Samples

1. Bulk density, root, and lichen samples will not be scanned with bar code readers. Therefore, upon transfer of samples, the hexagons, and number of samples of each type (root, tree cores, etc.) will be recorded on a packing slip.

2. Upon completion of sample transfer, place a copy of the packing slip into a plastic bag and place it into the shipping container.

(Note: Bulk density, root, and lichen samples may be accumulated from a number of plots before shipping to the laboratory (one sample plot should not fill up a sample container). Keep a running tally of samples on the packing slip until samples are ready to be shipped.)

16.1.5.3 Sample Shipping

All samples, except root and lichen samples, will be shipped to the preparation laboratory:

Rob Tidwell
Lockheed-ESC Warehouse
4675 S. Valley View Drive
Las Vegas, Nv 89103
(702) 795-8937 or 8938

Root samples will be shipped to:

Moss Baldwin
Forest Pathology Laboratory
VPI & SU
Glade Road Research Center
Blacksburg, VA 24061
(703) 231-5030

Lichen samples will be mailed to separate laboratory facilities.

Shipments can occur daily or when appropriate for the tree climber. EPA will provide pre-labeled federal express shipping forms for use in shipping samples. Use the express mailing forms in order and return all unused forms.

(Note: A packing slip (discussed in sample transfer section) <u>must</u> accompany each shipment. In the case of soil samples, the packing slip will record the number of boxes sent; for bulk density samples and lichens, the packing slip will contain the hexagons and the number of samples.)

Equipment and supplies --

- Bar code reader.
- Bar codes.
- Laptop.
- Interface cables.
- Coolers.
- Frozen gel-packs.
- Large plastic bags.
- Clear adhesive tape.

Calibration and Standardization --

There are no calibration and standardization steps in this procedure.

Procedure --

Soil Samples and Film

1. If samples have been transferred from field crews and are being shipped the same day, the gel-packs in the coolers do not have to be replaced. If transfer and shipping occur on different days, gel-packs must be replaced and samples repacked. Care must be taken not to place samples in different boxes during this procedure.

2. Fill out two packing slips identifying the number of coolers in the shipment, the actual numbers of bulk density samples and rolls of film. Keep one copy and place the remaining copy into one of the coolers heading to a specific destination. More than one cooler can be sent on a single packing slip. Therefore, label the other coolers as to their destination. Tape coolers shut.

3. Set up the laser bar code reading device and initiate the "SHIP COOLERS TO EMSL-LV" program from the "SAMPLE AND SHIPMENT TRACKING SERVICES" menu on the laptop computer. See Section 17.12 of the PDR instructions for the details of this program.

Lichen Samples

1. Fill out two packing slips identifying the samples in the shipment. Keep one copy and place the remaining copy into one of the coolers heading to a specific destination. More than one cooler can be sent on a single packing slip. Therefore, label the other coolers as to their destination. Tape coolers shut.

2. Proceed to the express mail facility for shipping. Lichen samples will be sent to:

   Dr. Bruce McCune
   Oregon State University
   Dept. of General Sciences
   Weniger Hall 355
   Corvallis, Oregon 97331-6505

16.2 Western Field Logistics Plan

(NOTE: This section is not included in the Southeast or SAMAB Demonstration field guides.)

Appendix D. Off-Frame Indicator Development

C.G. Shaw, III, K.W. Stolte, and C.J. Palmer

A rigorous program of constant testing and evaluation of parameters to measure on Detection Monitoring Plots needs to be maintained to ensure that all indicators used in the Forest Health Monitoring (FHM) program meet the desired criteria. These criteria include:

- Early observable responses to perturbation events.
- Unambiguous interpretability (known inferences can be drawn from changes over time).
- Simple quantification.
- Regional responsiveness.
- Index period stability and capability of regular remeasurement.
- High signal-to-noise ratio and a high precision (low variation) for measurement recording.
- Low environmental impact.
- Relatively inexpensive to implement.

To be considered a "core" indicator, all of these criteria should be met and documented.

This is the reason FHM will be testing several indicators this field season off-frame , and in some cases, in on-frame, pilot studies. Although the actual indicators to be tested this year are not yet determined, the following are possible candidates:

- Photosynthetically active radiation (PAR).
- Soil and root microbes and arthropods.
- Soil chemistry.
- Various foliage and crown assessments and foliage sampling techniques.
- Lichen communities and elemental analysis.
- Expanded vertical vegetation profiles to include dead and fallen material.
- Various indicators that can use remotely-sensed data.
- Pest organisms as indicators of forest health.

Terry Shaw, Ken Stolte, and Craig Palmer will meet in early May to evaluate the indicator development needs for this year. Indicator leads will be contacted to determine their priority research needs and reviews will be made of past work to determine which indicators need further development. From this, we will select the indicators to be evaluated off-frame this summer, based on priority needs and available funding.

In addition, we will initiate a process to guide future off-frame indicator development. We envision this process to consist of evaluation panels rating proposals for off-frame, developmental research on high-priority indicator needs. The process will be in place for use during FY93. We consider that having an operating system in place to direct off-frame indicator development a critical, but currently lacking component of the FHM program. When the process for off-frame indicator development is in place, it should receive the recognition that off-frame indicator development deserves as a critical, driving component of the FHM program.

Appendix E. California FHM State Plan, May 1, 1992

CALIFORNIA FHM STATE PLAN

May 1, 1992

Vernon J. LaBau
Anchorage Forestry Sciences Laboratory
Pacific Northwest Research Station
Detection Monitoring

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INTRODUCTION

In accordance with the master plan for implementing the Forest Health Monitoring Program in the United States, the State of California is scheduled for implementation of the Forest Health Monitoring field plot grid during the summer of 1992. This plan is intended to serve as the basic guide for the Detection Monitoring phase of the Forest Service's Forest Health Monitoring Program in California. The intended audience for this document are the planners, implementors, users, and cooperators associated with the Forest Health Monitoring program in California and the rest of the US. It is intended that this Plan be consistent with and integratable with other NFHM efforts throughout the United States. Major sections from the Forest Pest Management (FPM) Plan have been borrowed and used in this plan to assure later integratability of these plans into one major National FHM/FPM Plan.

BACKGROUND

Legislative Mandates and Directives

The Forest Health Monitoring (FHM) Program in California is being implemented in response to several national legislative mandates (i.e. Public Law 100-521), which have directed the Forest Service, USDA and the Environmental Protection Agency to, among other things, "increase the frequency of forest inventories in matters that relate to atmospheric pollution, and conduct such surveys as are necessary to monitor long-term trends in the health and productivity of forest ecosystems--." The Forest Service's Forest Inventory and Analysis (FIA) program which has been establishing and periodically re-measuring forest inventory and evaluation field plots throughout the United States for as much as 50 years, has a nationwide data base that will be used as a baseline data set in this endeavor.

Amendments to the Cooperative Forestry Assistance Act of 1978 (P.L. 95-313) by the Food, Agriculture, Conservation and Trade Act of 1990 (P.L. 101-624) authorize FPM involvement in forest health monitoring. Section 5 of P.L. 95-313, Insect and Disease Control, is redesignated Section 8, Forest Health Protection. Section 8(b)(1) directs the following: "Conduct surveys to detect and appraise insect infestations and disease conditions and man-made stresses affecting trees and establish a monitoring system throughout the forests of the United States to determine detrimental changes or improvements that occur over time, and report annually concerning such surveys and monitoring."

The Environmental Protection Agency (EPA), also received similar legislative directives, which resulted in their Environmental Monitoring and Assessment Program (EMAP), which was much better funded than the Forest Service Programs. EPA was directed to monitor all the major terrestrial and inland and coastal water ecosystems of the United States, and the Forest Ecosystem was one of the components EMAP began planning to monitor.

In addition to these federal legislative mandates and directives, the California Department of Forestry had a Forest Health Monitoring Coordinator position approved with State Legislature funding in the 1991 legislature. This, in effect, gave the California Department of Forestry impetus to proceed with FHM.

The federal agency planning for the California Forest Health Monitoring effort evolved out of the afore named legislative impetus. That national plan, developed in EPA and the Forest Service called for the establishment of a set of field plots to be established in California, beginning in 1992. The purpose of these plots was basically to look for early signs of degradation in the health of the forest ecosystems in California. These plots, therefore, were to be called Detection Monitoring sites.

The Problem Statement

The health of the Nation's forests is increasingly in the news. The public is concerned about management activities, deforestation and habitat loss, air pollution, global climate change, and damage from a variety of forest insect and disease problems. The USDA Forest Service (FS), U.S. Environmental Protection Agency (EPA), and other Federal and State agencies are increasingly required to provide information which responds adequately to these concerns. Unfortunately, much of the resource data now collected by the FS, other public agencies, and private organizations can not be compiled, integrated, analyzed, and interpreted to evaluate forest health.

The Mission Statement and Objectives for Research's Detection Monitoring

The Mission of the Detection Monitoring phase of FHM for the Pacific Northwest Forest Research Station is to develop and improve science and techniques for monitoring forest health of the forest and rangeland ecosystems of the Pacific Coast States at several levels of spatial and temporal resolution. The main objective associated with that goal is to conduct long-term periodic measurements or observations of selected physical and biological parameters for the purpose of initially establishing a baseline for detecting change, with the ultimate objective of detecting and quantifying deviation over time from that baseline due to changes in health of the forest ecosystem. Forest Inventory and Analysis (FIA) have the lead responsibility for NFHM and have a lead responsibility in the Detection Monitoring Phase of this effort.

The Goal and Objectives for Forest Pest Management

The goal of FPM in this endeavor is to discover if there are large-scale episodes of forest pest and other stressor effects that are not related to background cycles of forest growth, decline and stressor activity. This includes effects from (1) known agents; (2) changed activity of known agents; (3) new agents; and (4) unknown agents.

The objectives for the FPM Program is (1) document status and change in large-scale effects on forests of forest pests and other stress agents. This includes temporal and spatial change in extent, severity, duration, frequency,

host, and cause; and (2) conduct forest stressor effects surveys, provide training, and provide technical assistance in support of the NFHM plot network.

THE PROGRAM DESIGN

Although Forest Service (FS) Research, through the National Forest Health Monitoring (NFHM) Program Manager, has the overall lead for NFHM design, implementation, and reporting, Forest Service Forest Pest Management (FS FPM) has direct responsibility for designing and implementing the FPM components of NFHM.

The NFHM Program is a three-tiered, long-term process to provide regional (multi-state) and national information on forest health status and trends. Each successive tier requires progressively more detailed information. The tiers are:

Detection Monitoring -- to detect deviation of key monitoring elements from established baseline conditions or trends. This is the first and most extensive level. FPM and Research share responsibility for this tier which consists of (1) a plot component (Research) -- a geographically-based network of permanent plots distributed throughout the nation's forested areas, and (2) a survey component (FPM) -- forest damage surveys and reports of forest pest effects. Detection Monitoring will discover and describe changes in forest health conditions.

Evaluation Monitoring -- to attempt to identify causal relationships and management responses. This is the second level, is FPM's responsibility to initiate, and is activated by Detection Monitoring results. Evaluation Monitoring is the process for determining causes for changes in forest health status.

Intensive-Site, Ecosystem Monitoring -- to define basic relationships sufficient to predict consequences. This is the third level and provides the most detailed, long-term data for ecosystem research to determine causal relationships, predict rates of change in forest conditions, and identify management responses. FPM has little or no responsibility for Intensive-Site, Ecosystem Monitoring.

PROGRAM COOPERATION AND COORDINATION

Forest Service, EPA, and States are responding to forest health concerns by initiating a National Forest Health Monitoring Program (NFHM) designed to describe regional and national forest conditions and to detect changes, determine causal relationships, and predict consequences. NFHM success depends on participation by FS, EPA, and States. It incorporates recommendations from the Forest Response Research Program (part of the National Acid Precipitation Assessment Program), the Forest Health Strategic Plan, and the EPA Environmental Monitoring and Assessment Program. A number of FS Staffs will become involved both in NFHM and in related aspects of EPA's Environmental Monitoring and Assessment Program (EMAP).

Coordination within the Forest Service

National Forest Health Monitoring is designed to build on existing FS programs. The FS Staff units most involved have been Forest Fire and Atmospheric Sciences Research; Forest Inventory, Economics, and Recreation Research; Forest Pest Management; Timber Management; and Watershed and Air Management.

FS Research, through the NFHM Program Manager, has the lead for NFHM design, implementation, and reporting. FPM has direct responsibility for providing pest and forest conditions information in Detection Monitoring and for initiating Evaluation Monitoring activities. Both Detection and Evaluation Monitoring activities conducted by FPM will be coordinated with the NFHM Program. Forest Health Monitoring program and budget planning are coordinated among participating FS staff units.

As technical staff to National Forest System (NFS) resource managers, Regional and Area FPM staff will have an important role in planning Regional execution of the NFHM Program. Regional and Area FPM staff also have the responsibility for implementing the Regional FPM component of NFHM on NFS and other Federal lands.

Coordination with States

State cooperators will be fully involved with all phases of NFHM Program planning and execution. Regional and Area FPM staff will work with the Stations and the NFHM Program Manager to establish appropriate mechanisms for the State involvement essential for NFHM Program success. In California, the Department of Forestry and Fire Protection have a clear directive to be involved in forest health monitoring.

FHM/State Responsibility

Forest Pest Management and States are responsible for providing Regional and State forest pest/stressor effects information and for addressing how forest health may be affected. Data must be adequate to evaluate and interpret the relationship between forest pest and stressor effects and forest health changes.

THE DETECTION PLAN

A great deal of planning and general conceptualizing of aspects of the national FHM/EMAP went into establishing a national sampling scheme that would meet the mandated directives and intentions of the US Congress. A very comprehensive national plan was developed for selecting and installing monitoring sites and instilling and maintaining quality control in data acquisition through very structured training and through imposing quite strict QA/QC criteria. These stringent criteria were imposed on the process all the way through the data reduction, analysis, and reporting of results.

In addition, a very structured approach was developed to select a suite of indicators that would efficiently and effectively detect the "flags of change,"

with sufficient precision to make develop meaningful scientific results regarding changes in health of the nation's ecosystems. EMAP took the lead in this indicator development.

The planning phase in California began with an Information Needs Assessment (INA) meeting in Sacramento in May of 1991. The purpose of this meeting was to define needs to be addressed, evaluate the amount and level of expertise and technology required to speak to the need, and defining a strategy, politically, financially and practically, as to how the need should and/or could be met. A second part of the INA involved determining what the various federal, state, and other agencies and groups were doing in California in terms of monitoring ecosystem health. A third aspect of this INA was to provide information on the national FHM/EMAP program, and what that might entail when implemented in California.

THE SAMPLING DESIGN

The national EMAP sample design that was adopted to the FHM program was developed by a team of statisticians with provision for considerable flexibility in implementation of the design. It is based on a grid of 160,000 acre hexagons laid over the contiguous US, with plots systematically offset from the hexagon centroids and are about 27 kilometers apart. It requires about 12,500 of these hexagons to cover the contiguous US. It is estimated that about 4000 of those will occur on forest ecosystems. California has about 680 hexagon sites within its boundaries (Figure 1), with and estimated 280 forested sites. It is planned that about 75-80 of the plots will be visited each year for 4 years (Black dots in Figure 1).

At each of the centroid offset plots, a 40 square kilometer mini-hexagon is evaluated, wherein landscape characterization is performed using remote sensing media (thematic mapping classification). Within that hexagon, type maps are compiled on vegetation type and on land use.

Finally near the centroid of all the hexagons that are classified as forest ecosystem, a ground plot is established over a 1-hectare area. Four sample sub-points are placed equidistantly apart over the 1 hectare area (see Figure 2), and at these sub-points, a suite of forest health indicators is measured to look for signs of degradation of the ecosystem.

BASIC PREPARATIONS

As with any program of this magnitude, very thorough planning and very close coordination with cooperators are key criteria in conducting a successful Program. It was and is necessary for the U.S. Forest Service to work in close concert with other Federal agencies, especially EPA, and with the California Department of Forestry and Fire Protection.

Basic considerations including funding, staffing, the sampling design, preparation of operational plans and methods manuals, quality control and similar aspects. Much coordination and cooperation is needed to integrate these basic considerations in a mutually compatible manner. A great deal of

CALIFORNIA
FOREST HEALTH MONITORING SITES

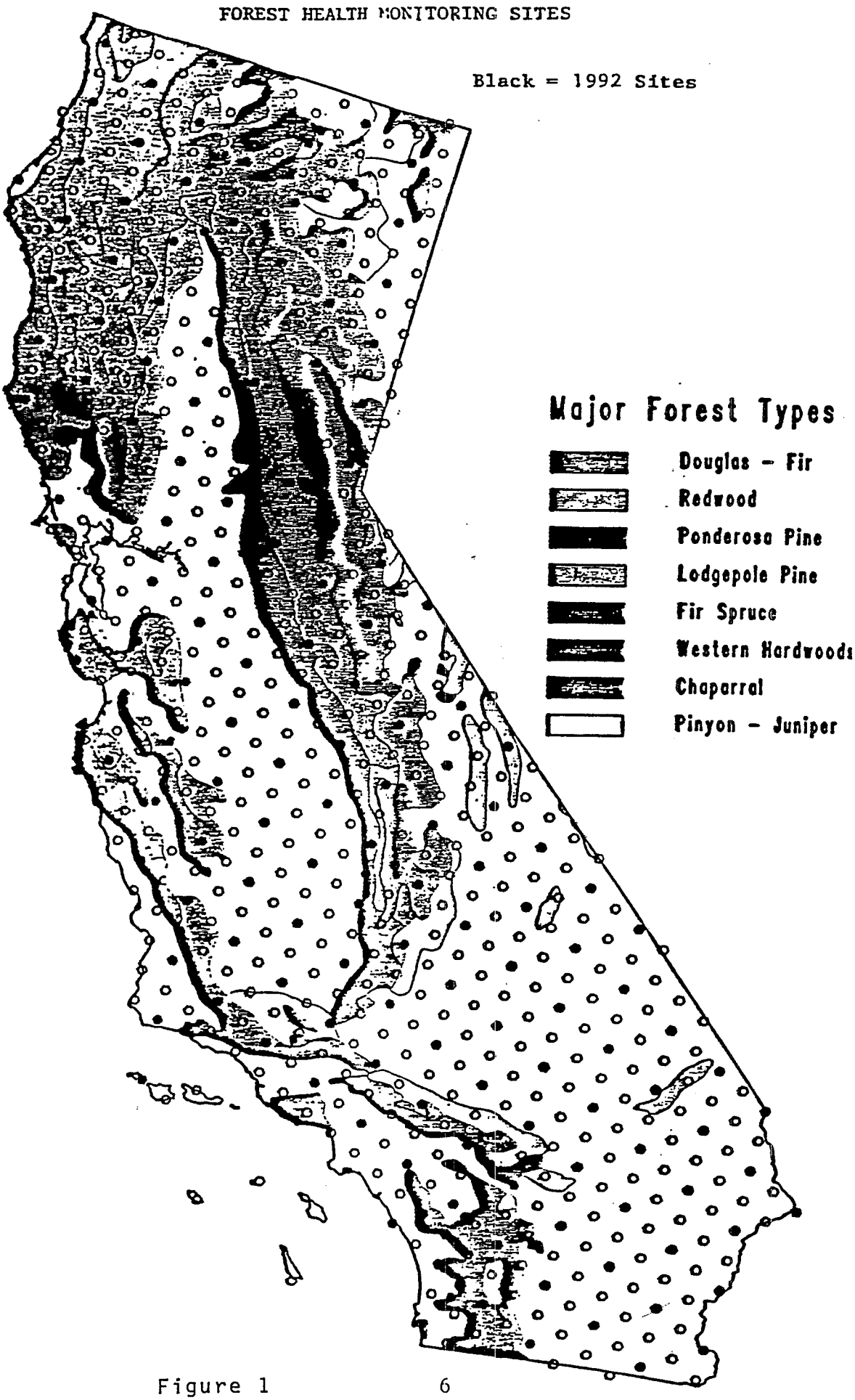
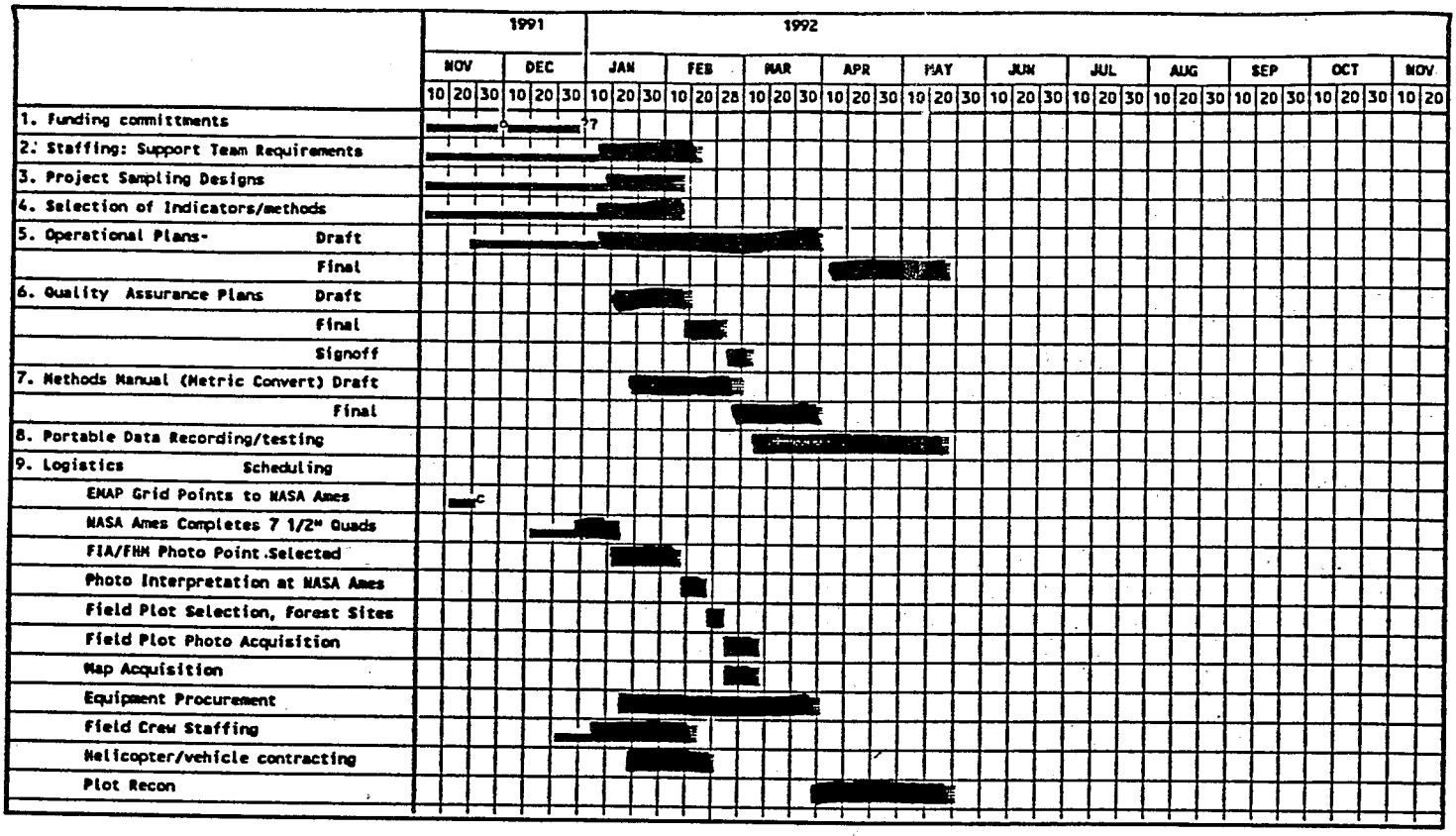


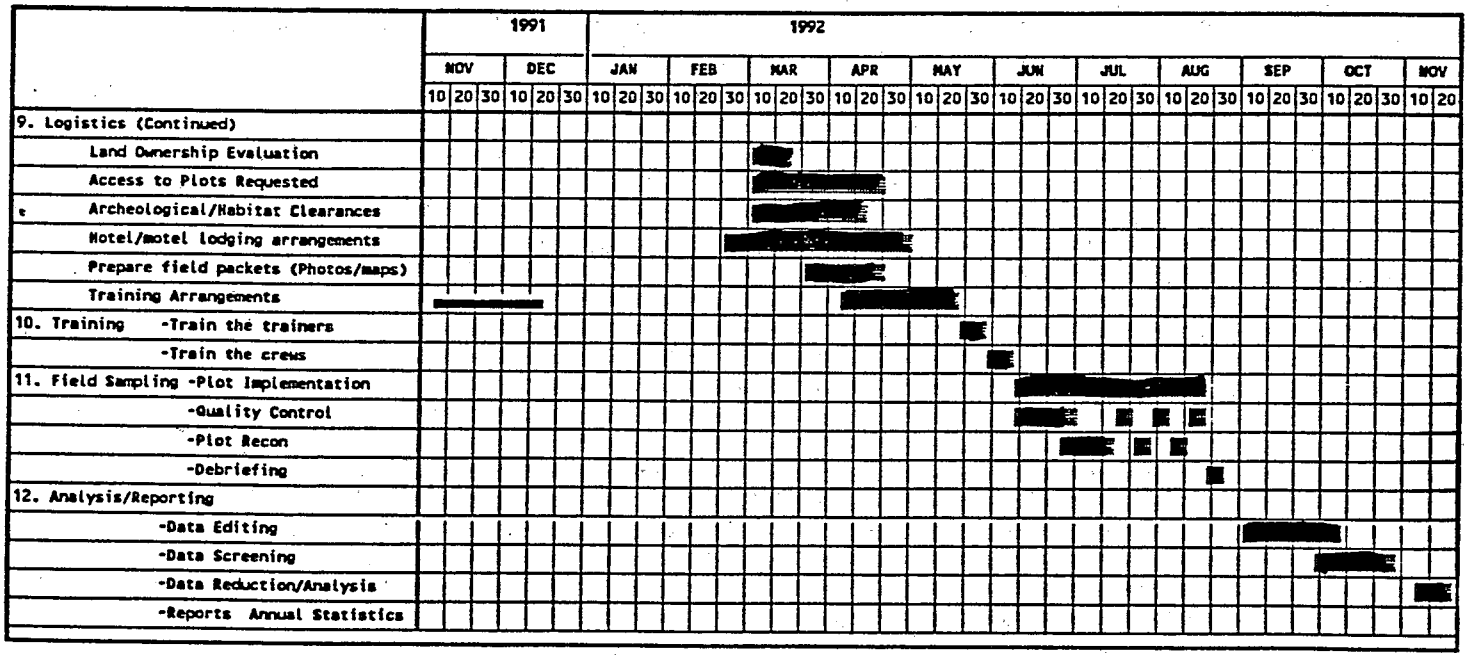
Figure 1

California Forest Health Monitoring

SUPERVISOR: Dan Osmaloi

DATE PREPARED: 1/6/92 STATUS AS OF: 1/6/92





LEGEND: scheduled % completed (of scheduled)
extended/resched % completed (of ext/resched)
o milestone not completed C milestone completed

TASK	MILESTONES	FY 1990 DATE	STATUS

Figure 2

strength in supporting these basic needs comes from approaching a plan of this magnitude from a position of multiple strengths.

An overview of how these basic preparation are planned for can be seen in the Gant Chart, Appendix A.

LOGISTICAL PREPARATIONS

The logistics consideration require careful and fairly precise planning so that each logistical hurdle is cleared in a timely manner, and does not "bottleneck" the process and cause missed deadlines at critical points. Again, the Gant Chart, Appendix A gives an idea of the critical flow patterns that must be followed in such an effort. Some of the important items include:

- Establishment of the sample grid to maps and aerial photos
- Acquisition of aerial photos and maps for the potential monitoring sites (flying 1:8,000 photography over sites).
- Interpretation of plot sites from aerial photos
- Selection of the set of forested field sites to visit on the ground
- Equipment procurement
- Contracting for transportation (jeeps, helicopters, pack animals)
- Determining land ownership
- Obtaining access permission on private or restricted lands.
- Obtaining Archeological permits, permits to traverse critical habitat, observe endangered plant and animal restrictions.
- Hire field crews
- Arrange for field crew lodging and meals.
- Arrange for training sites and instructors
- Coordinate with Government Resource Managers (District Rangers, Forest Supervisors, Resource Offices, Park Rangers, etc.) to access sites under their management.
- Recon in the plot centers for as many sites as possible so the 5 person crew does not waste time waiting on a photo interpreter-- they can walk into the site via a flagged route.

Based on initial indications, cooperators will play a major role in supporting these logistical operations. For instance, the California Department of Forestry has indicated a desire to assist and advise in the implementation of several of the logistical phases.

QUALITY CONTROL/QUALITY ASSURANCE

The Quality Control/Quality Assurance discipline developed by EPA for their EMAP effort has basically been adopted for the FHM/EMAP implementation in California. It has served the process well in the Eastern US, and will continue to stand us in good stead in the West. In addition, excellent quality control of data acquisition is assured through a very through set of data editing algorithms in the Portable Data Recorders. All data collected on all aspects of the FHM program are entered through the Portable Data Recorders (PDR), and have to pass through edit algorithms that screen for illogical or otherwise erroneous entries. The PDRs also prevent the recorder from closing out a plot without completing all data items.

In addition, all data are transferred via electronic mail to a data center each evening via dial-up modems. Also, all samples taken in the field are handled in such a manner to guarantee a minimum amount of contamination to samples as they are collected. There are stringent processed for getting the samples (soil, foliar, lichens, tree cores, etc.) to the labs at EPA in a timely manner. A computerized bar-coding process is used to assure proper coding of all samples.

Finally, there is a disciplined schedule and format for "hot-checking" and "cold-checking" the work of the field crews. Two people spend about half the summer in this type of Quality Control.

THE FIELD METHODS GUIDES

The field methods guides section is very extensive, and has been converted to metric and rewritten in that mode for California. It is included as an attachment to this document.

One important aspect of the field data collection process is the identification of damage and pathogens, etc. that contribute to forest health decline. At least one Forest Pest Management specialist will be hired as part of each field crew to help identify these situations. Hopefully, these specialists will be able to strengthen forest mortality estimates, which are an important component of the tables listed in Appendix B.

ANALYSIS

Most analysis will be done by Forest Service or EPA scientists. FIA analysis will likely be primarily restricted to presentation of tabular summaries and graphics and the analyses thereof. Scientific analyses will likely be deferred to more specialized analysts. If cooperators are used for special studies, or have special expertise in certain areas of data reduction and analysis they may be availed of for the analysis. Many analyses will be aimed at completing a core set of report tables, which is consistent across the whole U. S. In addition, some State specific tables will be produced, depending on the desires of the users. The eastern core set of table labels is shown in Appendix B, along with some Mortality and Lichen analysis tables added specifically for California. The mortality tables will be very general in nature, recognizing the difficulty of making specific calls of "cause of mortality" in the field. The presence of trained FPM people on the crews improves the possibility of making usable general tables on mortality.

All cooperators in this endeavor will be provided with an opportunity to review any narrative reports, conclusions and recommendations that result from the California Forest Health Monitoring effort. Cooperators will also have access to the data base for their own analyses, and it is expected that they will sometimes perform independent analyses from that of their colleagues.

The Forest Service Role in Analysis

The Forest Service has the responsibility of conducting all data reduction associated with forest mensurational aspects of FHM. Analyses of these forest mensurational and forest damage data will be done by Forest Service scientists using appropriate statistical analysis and reporting methods.

The EPA's Role in Analysis

The EPA has the responsibility for analyzing all soils data, tree foliar data, and similar chemical analyses. Likewise, analyses of these data samples will be done by EPA scientists using appropriate statistical analysis and reporting methods. Where collaboration of analyses are necessary, prior to report writing, this will be done in a timely manner to minimize delay in the reporting of results.

INFORMATION MANAGEMENT

Information Management, is herein assumed to be the following activities:

- The conduct of Information Needs Assessments to obtain guidance and suggestions from Forest Health Monitoring and related field scientists, as well as cooperators and potential users.
- The planning of data to be collected, based on desired results.
- The development of data recorder programs to record and field edit the data.
- The transfer of these data from field location to a central data repository site.
- The editing and screening of data in preparation for processing.
- The compilation of data into a form where it becomes information.
- The distribution of the information through reports, technical papers and other release media.
- The management of the data and information central repository files so the data can be easily accessed and evaluated by scientists cooperators, and other potential users.

All cooperators will be given an opportunity to participate in various aspects of Information Management. The Environmental Protection Agency will play a major role in most of the Information Management activities, being most evident in the Planning, Data Collection, and Data Analyses phases. State and local cooperators will also have major roles to play in these phases.

REPORTING RESULTS

Data analysis and interpretation will be performed at various centers of expertise, depending on the discipline being evaluated for change. The goal is to have data processed and preliminary reports of results ready within 9 months after the data are collected. More detailed reports, and additional studies will be forthcoming for a period of years following the initial data evaluation. Prior to final publication of the monitoring results, reports will be reviewed by both Forest Service and EPA scientists. Other cooperators will be given the opportunity to review results if they are asked or request to be included in the review process.

It is anticipated that some preliminary reports will be published within one year of the completion of the field work, however, results from these data will necessarily be limited since only one-quarter of the field sites will be measured in the first year. The California Forest Pest Council and the California Department of Forestry will have a major role in reviewing reports.

The Pacific Northwest Station's Inventory and Economics RD&A Program will have the lead role in preparing these reports. Analysts will endeavor to identify any differences between Forest Health Monitoring statistics and previous Forest Inventory and Analysis reports. These differences will be explained if possible.

IMPLEMENTATION SCHEDULE

It is estimated that, given the indicator and measurement requirements and pilot study work loads for the crews in the summer of 1992, up to 3 plots can be taken in a 5 day work-week by each crew. At that rate, over the 6 pay periods of summer training and work, about 50 plots will be completed by the end of August. Early results indicate that about 80 plots represent about one-quarter of all of the forested EMAP grid plots in California.

The current schedule of implementation calls for installing one-quarter of the total California EMAP grid each year for four years. It is the intention of the NFHM Program to begin re-visiting at least some of the first year's established sites in the second year, and again in the third year, while adding sites from the second year's implementation. By the fourth year, all of the grid of plots will be installed, and a large percentage of those that were installed in the first three years will have been revisited, some on every occasion.

Decision on the frequency of re-visitation will be made before beginning the second year of implementation. This will, of course be dependent on future budgets. It is recognized that such a revisitation system has to have solid standing in approved statistical methods, and such will be provided by the EPA/FS Consulting Statisticians.

PERSONNEL NEEDS

For the initial year of implementation, given the need to measure one-quarter of the forest sites, estimated to be about 75 sites, three five-person crews will be required. However funding levels restrict the program to hiring only two crews. Four of the five-person crew will be field staff. Plans are to hire a GS-11 Soil Scientist, a GS 7 Forest Pest Management person, a GS 5 Forest Mensurationist, and a GS 5 Biologist/Botanist. Mid-level skills are required for the GS-11 and GS-7 positions, which are quite specialized. Less specialized skills are needed for the two GS 5 positions, except that the Biologist must have good plant identification/classification skills, and the Forester must have some experience in forest measurements.

In addition, there will be a GS-9 Technician assisting with Recon and Quality Assurance. This person will be stationed in Portland, and will have the responsibility for getting the sampling grid put in place, and most logistics handled each year.

There will be a GS 4 assisting the GS-9, as well as GS 4s available to handle crew needs while they are in the field, such as mail, vehicle and equipment repair and maintenance, mailing collected samples to Las Vegas, interfacing with Las Vegas daily by phone or electronic mail, and doing data transfer, etc.

A GS-11 Forester will serve as Party Chief, making daily plot assignments, and seeing to it that the schedules are adhered to as much as possible. This person will be stationed in Sacramento.

There are also costs associated with Headquarters overhead, such as Team Leader and Time Card Clerks, etc. After the first field season, it will be necessary to add at least one Analyst to the staff.

Costs associated with these positions and their per-diem, etc can be found in Appendix C.

FUNDING NEEDS

The funding needs for the first year of implementation are estimated at about $517,000 to install 50 plots using three four-person field crews. About $133,000 of that is for field crew and field supervisor salary. About $84,000 is required for per diem for the crews. About $34,000 is for jeeps, helicopters and other transportation. About $149,000 is to cover Headquarters salary, per diem, and clerical support. About $55,000 is needed for field equipment purchase.

A detailed breakdown of all anticipated budget items for the 1992 field effort in California is presented in Appendix C

Most of the funding is provided by EPA and the Forest Service. However, the State of California is playing a significant role in providing funding and in-kind support. Additional in-kind support is forthcoming from other Federal agencies, such as NASA and the U. S. Park Service.

SELECTION OF THE INDICATOR SUITE

A suite of indicators was selected for testing in the Eastern US FHM/EMAP implementation and Pilot studies during the summers of 1990 and 1991. A great deal of concern existed with the suggestion that these be tested in the western US for applicability to FHM there. It was therefore decided that a Pilot study should be done to evaluate the logistics of using the Eastern Indicator set. In a meeting in Redding, California in May, 1991, a set of additional indicators was selected for testing in the west. The suite of indicators tested, along with a total list of variables measures or observed is summarized in Appendix D.

The suite of indicators generally encompasses the following general criteria:

- Forest Mensuration Indicators.
  - Tree Growth, Mortality, Age, etc.
  - Crown Evaluation (density, dieback, foliar transparency)
  - Foliar Evaluation (chemistry, needle density, needle age, etc.)
  - Dendrochronological Data (tree cores).
- Forest Ecosystem Damage
  - Tree damage --Signs and Symptoms (Insect, Disease, Other)
  - Damage to Indicator Plants
- Biodiversity Indicators
  - Vegetation Structure
  - Wildlife Habitat
- Soils Characteristics
  - Physical
  - Chemical
  - Fertility/Productivity

There were several additional data items collected, such as the standard plot/site descriptors (elevation, slope, aspect, terrain, etc.), as well as the new variables being tested under the Pilot study, such as Photosynthetic Active Radiation (PAR), root disease presence, tree height measurements, lichen characterization, and others. Many indicators listed above will not be fully implemented until they have passed through a very structures Pilot Study process.

In addition those listed above, numerous data are anticipated from ancillary sources, such as climatology, history of the ecosystem, remote sensing data, and etc.

LIST OF APPENDICES:

APPENDIX A GANT CHART OF ACTIVITIES

APPENDIX B LISTING OF ANALYSIS TABLE TITLES

APPENDIX C SUMMARY OF ANTICIPATED EXPENSES

APPENDIX D SUMMARY OF WESTERN U.S. INDICATORS AND DATA ITEMS

APPENDIX A

GANT CHART OF ACTIVITIES

For those receiving this via electronic mail, the Gant Chart is not transferrable to the DG. Activities are plotted on a weekly basis, as to time-lines for the following:

	Start	End	
Funding Planning Targets	10/1/91	11/30/91	@@
Staffing: Support Team Requirements	11/1/91	4/05/92	@@
Project Sampling Design Planning	10/1/91	2/10/92	*
Selection of Indicators Time-line	10/1/92	11/30/92	*
Operational Plan (This Plan)			
Draft	11/1/91	3/30/92	*
Final	4/1/92	5/15/92	*
Quality Assurance Plan			
Draft	1/15/92	2/10/92	@
Final	2/10/92	4/1/92	@
Methods Manual (Metric)			
Draft	1/25/92	3/1/92	@
Final	3/1/92	3/30/92	*
Portable Data Recording Testing			
Logistics Schedules:			
EMAP Grid points to NASA Ames	11/15/91	11/20/91	*
NASA Ames completes 7 1/2 minute quad overlays	12/15/91	2/1/92	@@
FIA/FHM Point Selection	1/15/92	4/1/92	@@
Photo interpretation	2/20/92	4/1/92	@@
Field Plot Selection--Forest Sites	2/25/92	4/1/92	@@
Field Photo Acquisition	2/25/92	4/15/92	@
Map Acquisition	3/5/92	4/1/92	#
Equipment Procurement	3/20/92	3/30/92	*
Field Crew Staffing	1/1/92	4/15/92	@&
Helicopter/vehicle contracting	4/1/92	4/20/92	@@
Site Recon	4/10/92	7/15/92	*
Land Ownership Evaluation	3/5/92	3/25/92	*
Access Permission Letters to Owners	3/25/92	4/15/92	?
Archeological/Habitat Clearances	3/25/92	4/15/92	?
Hotel/Motel Lodging Arrangements	3/25/92	4/30/92	?
Preparation of Field Work Packets	4/15/92	4/30/92	?
Make Training Arrangements	11/10/91	5/25/92	&
Training			
Train the Trainers	3/30/92	5/29/92	
Train the Crews	6/1/92	6/12/92	
Field Sampling			
Plot Implementation	6/14/92	8/26/92	
Quality Control	3/14/92	8/30/92	
Debriefing Session	8/27/92	8/28/92	
Analysis and Reporting			
Data Editing/Screening	6/30/92	10/25/92	
Data Reduction/Analysis	10/1/92	12/1/92	
Reports/Annual Statistics	11/15/92	ongoing	

&= Ahead *= On-target @= Slightly behind @@= Deadline problem.

APPENDIX B
LISTING OF
ANALYSIS TABLE TITLES
California Forest Health Monitoring

Table 1	Total area sampled by land use class and state
Table 2	Area of forest land sampled by forest type group and state.
Table 3	Area of forest land sampled by forest type group and stand size class.
Table 4a	Relative percentages of live trees sampled by detailed species and tree size, all forest type groups.
Table 4b	Relative percentages of live trees sampled by detailed species and tree size, by forest type group.
Table 5a	Percentages of live trees 10 cm and larger by major species and crown class, all forest type groups.
Table 5b	Percentages of live trees 10 cm and larger by major species and crown class, by forest type group.
Table 6a	Percentages of overstory trees 10 cm and larger by major species and crown die-back class, all forest type groups.
Table 6b	Percentages of overstory trees 10 cm and larger by major species and crown die-back class, by forest type group.
Table 7	Percentages of understory trees 10 cm and larger by major species and crown die-back class, all forest type groups.
Table 8a	Percentages of overstory trees 10 cm and larger by major species and foliar transparency class, all forest type groups.
Table 8b	Percentages of overstory trees 10 cm and larger by major species and foliar transparency class, by forest type group
Table 9a	Percentages of understory trees 10 cm and larger by major species and foliar transparency class, all forest type groups.
Table 9b	Percentages of understory trees 10 cm and larger by major species and foliar transparency class, by forest type group.

Table 10a Percentages of overstory trees 10 cm and larger by major species and crown ratio, all forest type groups.

Table 10b Percentages of overstory trees 10 cm and larger by major species and crown ratio, by forest type group.

Table 11a Percentages of understory trees 10 cm and larger by major species and crown ratio, all forest type groups.

Table 11b Percentages of understory trees 10 cm and larger by major species and crown ratio, by forest type group.

Table 12a Percentages of overstory trees 10 cm and larger by major species and crown density class, all forest type groups.

Table 12b Percentages of overstory trees 10 cm and larger by major species and crown density class, by forest type group.

Table 13 Percentages of understory trees 10 cm and larger by major species and crown density class, by forest type group.

Table 14 Percentage distribution of mortality trees, 10 cm and larger, by cause of death within major species, all forest type groups.

Table 15 Percentage distribution of mortality trees, 9.9 cm and smaller, by cause of death within major species, all forest type groups.

Table 16 Percentage distribution of damage signs and symptoms within major species, live trees, 10 cm and larger, all forest type groups.

Table 17 Percentage distribution of species impacted by damage signs and symptoms, live trees, 10 cm and larger, by forest type groups.

Table 18 Percentage of seedlings and saplings by major species and crown vigor class, all forest type groups.

Table 19 Percentage distribution of pollutants by in foliage by tree species by forest type groups.

Table 20 Percentage distribution of pollutants by lichen species by forest type groups.

Table 21 Percentage occurrence of soil pollutants by forest type group and soils taxonomic class.

APPENDIX C

SUMMARY OF ANTICIPATED EXPENSES

The following is a listing of costs that have been prepared using an extensive spread sheet analysis (available on request).

COSTS TO SUPPORT THREE FIELD CREWS

Salaries, associated with field work	$167,000
Office salary and overhead	149,000
Per diem, associated with field work	104,000
Equipment	69,000
Vehicle/pack train/helicopter support	34,000
Travel costs	24,000
Supplies, such as photos and maps	10,000
Other miscellaneous expenses*	55,000
Total	$612,000

*Other miscellaneous--such as training site, 5% contingency, etc.

==========

COSTS TO SUPPORT TWO FIELD CREWS

Salaries, associated with field work	$133,000
Office salary and overhead	149,000
Per diem, associated with field work	84,000
Equipment	55,000
Vehicle/pack train/helicopter support	34,000
Travel costs	24,000
Supplies, such as photos and maps	10,000
Other miscellaneous expenses*	28,000
Total	$517,000

*Other miscellaneous--such as training site, 5% contingency, etc.

Approximate Funding Shares: FS 57%; EPA 28%; Calif. 15%

APPENDIX D

SUMMARY OF WESTERN U.S. INDICATORS
AND DATA ITEMS
FOR
FOREST HEALTH MONITORING

September, 1991

SITE DESCRIPTIONS

- Plot identification
  - State (administration unit)
  - County (administration unit)
  - Plot number (identifier)
  - Map Identification Code
  - Universal Transverse Mercator Coordinates
  - Photo Identification Code
  - Photo year (year aerial photo was flown)
  - Elevation
  - Terrain position (i.e. floodplain, side slope, ridge-top)
  - Date of visit (mm/dd/yy)

- Plot description
  - Land condition class
  - Forest type (ecosystem)
  - California ecosystem code
  - Greenness Index (NDVI) for AVHRR Satellite imagery
  - Origin of stand/vegetation
  - Size of stand/vegetation
  - Past disturbance history
  - Disturbance period
  - Age of stand/vegetation (optional)
  - Forest site data-(tree species, height, age)

- Point description (subplot)
  - History
  - Slope
  - Aspect
  - Micro-relief
  - Subplot center condition
  - Slope correction (used in measuring from previous subplot)

  - Site and Risk Classification Indices (ie Keen/Dunning).

TREE MENSURATION (list may be reduced for seedling and sapling trees)

- Tree diameter
- Radial growth (from coring or remeasurement)
- Age (from coring)
- Core element analysis
- Damage (presence of pathogens or insects, etc.)
- Tree mortality
- Condition class (describes veg./use condition in which tree exists)
- Regeneration
- Seed/cone production and viability
- History (history of tree establishment)
- Height growth (?? --in pilot test)
- Root disease evaluations (?? --in pilot test)
- Mycorrhizae root sampling (?? -in pilot test)

- Tree crown evaluation
  - Ratio (percent of the tree in crown)
  - Class (dominance of tree in stand)
  - Density
  - Dieback
  - Foliar transparency
  - Needle retention
  - Shape (optional--used for vegetation profile changes)
  - Diameter (optional--used for vegetation profile changes)
  - Foliar sampling (from tree climbers or shotgun extraction)
    - Chemistry (including nutrients and nutrient cycling)
    - Needle age
    - Needle position in growth flushes
    - Branch order (relative to physiological activity)
    - Branch vertical position in crown

GENERAL MENSURATION

- Micro-plot vegetation characterization and description
- Air pollution bioindicators (visual symptoms on trees and plants)
  - Ozone damage
  - Sulfur dioxide damage
  - Hydrogen fluoride damage
- Photosynthetic active radiation-PAR (?? under pilot test)
- Vegetation habitat structure (vegetation profile)
- Lichen occurrence and chemistry (?? under pilot test).

SOILS

General processes:

Characterization and evaluation of:

- Physical properties
- Chemical properties, including toxins
- Fertility/nutrient attributes
- Productivity, in general

Soil analytic parameters evaluated:

- Air-dry moisture
- Total sand
- Total silt
- Total clay
- Electrical conductivity
- Ph
- Exchangeable calcium, magnesium, potassium, and sodium
- Cation exchange capacity
- Total exchangeable acidity
- Effective exchangeable acidity and exchangeable aluminum
- Mineralizable nitrogen
- Extractable phosphorus
- Exchangeable sulfate
- Total carbon and nitrogen
- Total sulfur
- Total phosphorus, calcium, magnesium, potassium, sodium, iron, manganese, copper, zinc, boron, aluminum, lead, chromium, nickel, cadmium, vanadium, arsenic, and mercury.

General list of soil variables observed or measured

- Taxonomy
  - series
  - order
  - suborder
  - great group
  - subgroup
  - particle size class
  - mineralogy class
  - reaction class
  - temperature regime
  - moisture regime
  - other class
- Major land resource area
- Slope
  - percent
  - shape
  - geomorphic position
  - hill-slope position
  - aspect
- Physiography
  - regional and local
- Water table
  - depth
  - days
  - kind
- Land use class
- Surface Stoniness class
- Hydraulic conductivity class
- Drainage class
- Elevation
- Parent material
  - bedrock inclination
  - mode of deposition
  - origin
  - bedrock fracture
- Hydrologic group
- Water erosion class
- Water run-off class
- Flooding frequency
- Ponding frequency
- Particle size control section
- Diagnostic feature
  - depths
  - kinds
- Horizon
  - depths
  - discontinuity
  - master and suffix designations

Moist color
- location
- percent
- hue
- value
- chroma

Boundary
- distinctness
- topography

Texture
- class
- modifier

Structure
- grade
- size
- shape

Mottles
- quality
- size
- contrast
- hue
- value
- chroma

Field property
- quality
- kind

Roots
- quantity
- size
- location

Pores
- quality
- size
- continuity
- shape

Concentration
- quality
- size
- shape
- kind

Rock fragments
- volume percent
- roundness
- kind
- size

Appendix F. Operations Plan, Colorado, Forest Health Monitoring

OPERATIONS PLAN, COLORADO

FOREST HEALTH MONITORING

INTRODUCTION

Western Forest Health Monitoring data collection activities will be initiated in 1992 in California and Colorado. Field crews will collect Implementation phase and Pilot phase Detection Monitoring data on systematic grids of ground plots covering the two States.

Data files will be transmitted to the Northeast Research Station for compilation, analysis, and reporting.

FHM Program

The Forest Service's Forest Health Monitoring (FHM) Program is a cooperative venture with the Environmental Protection Agency (EPA); State Forestry departments; USDA Forest Service Forest Inventory and Analysis (FIA), Forest Pest Management (FPM), Research Stations, and National Forests; and a broad spectrum of government, research, and private interests.

The objective of FHM is to develop a National baseline on the health and condition of forests. This baseline will be used to monitor forest health, detect deviations, and direct research to explain the deviations.

The FHM program comprises three levels of monitoring:

Detection Monitoring - a geographically based network of permanent plots coupled with off-plot damage/pest surveys distributed across the United States to describe the status of all forests. This type of monitoring is designed to detect health problems with the Nation's forests that are worthy of special evaluation.

Evaluation Monitoring - a more intensive assessment of forest health problems directed by the detection network, insect and disease surveys, or problems already known to exist. For specific forest health problems identified, multi-disciplinary teams will design specific activities.

Ecosystem Monitoring - the monitoring aspects of ecosystem research on causal relationships, rate change in forest condition, change mechanisms in forest ecosystems, and techniques research to improve detection monitoring methods. Several permanent sites across the country will be identified as ecological monitoring research sites.

Detection Monitoring - the level of monitoring being conducted in the West in 1992 comprises three levels of data collection activities (studies):

Pilot Study - an on-frame (data are collected on the plots of the sampling grid) or off-frame field study, usually limited in the number of locations where activity occurs. Its scope and purpose are to evaluate research indicators with respect to design, logistics, spatial and temporal variability, and/or comparability and effectiveness of measurement technique.

Demonstration Study - an evaluation of developmental indicators, Testing occurs regionally, on-frame, and for the purpose of determining if implementation criteria are met.

Implementation Study - the initiation or continuation of data collection at specified field locations on the EMAP grid. This is the onset of detection monitoring, and the variables measured are those that meet the criteria of being appropriate, ready, and interpretable for reporting.

Authority and Origins

The 1988 Forest Ecosystems and Atmospheric Pollution Research Act authorized the Forest Service to undertake monitoring to track long-term trends in the health and productivity of United States forest ecosystems. The amended Clean Air Act (1990) directed the Forest Service and EPA to research the short-term and long-term effects of air pollution on forests. The Forest Service began initial forest health monitoring work in the mid-1980's and initiated FHM as an outgrowth of its Global Change Research Program and its Forest Response Program.

Background

Data were collected on forest health monitoring plots in the New England States in 1990 and States in the South and Southeast in 1991.

Forest Health Monitoring moved West in the form of a pilot study conducted in California and Colorado in July and August 1991. This effort, the Western Pilot, tested the logistics and feasibility of establishing four 1/24th-acre subplots on the EMAP grid and collecting data and laboratory samples on trees, soils, vegetation, and solar radiation. The procedures being piloted, demonstrated and implemented in the East were tested on approximately seven sites in each of the two western States. The same crew collected the data in both States. The crew comprised foresters from the Pacific Northwest FIA unit and the Intermountain FIA unit, and soil scientists from the SCS and the Forest Service. The crew trained at Blodgett Forest near Georgetown, California. Trainers were from the EPA's EMAP-Forest program and various Forest Service associated with FHM. A representative of the Colorado State Forest Service was also in attendance. The pilot plots in California were scattered about the State; those in Colorado were concentrated near Durango, Colorado.

A debriefing session was held in Durango on August 29. Participants comprised field crew members, indicator leads, and other interested scientists. Problems were reported, discussed, and a written report was prepared by the EMAP-Forest field operations coordinator for FHM.

On December 5-6, 1991, a meeting was held in Ogden, Utah, to establish what Forest Health Monitoring activities would be conducted in the West in 1992. This plan reflects the conclusions reached at that meeting, with some minor and some major revisions.

PROCEDURES

General

Forest Health Monitoring plots will be established and measured in California and Colorado in 1992.

Grid

The 1/4 interpenetrating EMAP grid of hexagons will be established in Colorado, and either the 1/4 or a less intense interpenetrating EMAP grid sample will be established in California. The FIA sampling grid point nearest the center of the EMAP hexagon will be selected for the field plot. Field plots will be established at those FIA grid points determined to occupy forest land. This determination is made by viewing the prospective plot locations on aerial photographs.

In Colorado, the FIA sampling grid is the intersections of the 1,000 meter UTM lines oriented north/south with those oriented east/west.

Field Plot

The FHM plot consists of four circular subplots, each 1/24th-acre in size, and each ringed by an annular plot (collar) .208 acres in size (1/4 x 5/6 acre). The four subplots total 1/6-acre in size. The four subplots plus the annular plots total 1 acre in size.

Tree and understory vegetation tally and measurements, as well as photosynthetically active radiation measurements, are conducted on the 1/24th-acre subplots. The annular plots are used for data collection on soils, indicator plants, tree branches and roots; and for collecting tree foliage, tree core, tree root, and soil samples for laboratory analysis.

Field Plot Establishment

A plot will be established and measured in the field if forest land occupies any part of any subplot. Plots will not be established for those grid points that fall where all four subplots are nonforest.

Forty-two plots in Colorado have been identified from aerial photo inspection as requiring field visits. Some of these may be found to be nonforest upon field inspection.

Plot Variables

The Colorado and California data collection efforts for 1992 encompass both implementation and pilot studies. Pilot variables are divided into on-plot and off-plot variables; some variables are measured both on-and off-plot.

The following lists the variables, grouped by category:

Implementation Variables

1. Plot-level variables

   a. Plot Identification Variables

      1. State
      2. County
      3. Plot Number
      4. Photo Year
      5. Elevation
      6. Terrain Position
      7. Date
      8. Crew Member

   b. Condition Classification

      1. Condition
      2. Land Use Class
      3. Forest Type
      4. Stand Origin
      5. Stand Size
      6. Pest Disturbance
      7. Disturbance Period

2. Point-Level Variables

   a. Point Description Variables

      1. Slope Connection
      2. Point History
      3. Percent Slope
      4. Aspect
      5. Microrelief
      6. Subplot Center Condition
      7. Old Point History

   b. Boundary Delineation Variables

      1. Plot Type
      2. Condition
      3. Left Azimuth
      4. Corner Azimuth
      5. Corner Distance
      6. Right Azimuth

3. Point-Level Microplot Variables

   a. Understory Vegetation

      1. Microplot Center Condition
      2. Percent Moss
      3. Percent Ferns
      4. Percent Herbs
      5. Percent Shrubs
      6. Percent Seedlings

   b. Seedlings

      1. Species
      2. DBH/DRC
      3. Condition
      4. Number of Seedlings

   c. Saplings

      1. Tree Number
      2. Species
      3. DBH/DRC
      4. DBH Check
      5. Number of Stems
      6. Diameter of Largest Stem
      7. Slope Distance
      8. Azimuth
      9. Tree History
      10. Condition

4. Point Level Subplot

   a. Tree Variables

      1. Tree Number
      2. Species
      3. DBH/DRC
      4. DBH Check
      5. Number of Stems
      6. Diameter of Largest Stem
      7. Slope Distance
      8. Azimuth
      9. Tree History
      10. Condition

On-Plot Pilot Variables

Soils
Tree Crown Assessment
Tree Damage - Insect, Disease, and Other
Indicator Plants
PAR
Understory Vegetation
Tree Mortality

Off-Plot Pilot Variables

Tree Root Inspection and Sampling
Understory Vegetation Sampling
Soil Microbiology
PAR
Tree Height
Tree Core
Branch Extraction
Foliage Sample
Soils

Off-Plot FPM Activities

Forest Pest Management, R-2, and the Colorado State Forest Service will conduct additional detection phase data gathering activities in the vicinity of the FHM plots. This data will be collected simultaneously with FHM data collection.

ORGANIZATION

National organization of Forest Health Monitoring:

Joe Barnard - National Forest Health Monitoring Program Director
Sam Alexander - EMAP-Forests Technical Director
Ken Stolte - Deputy Program Director for Research
Bob Loomis - Deputy Program Director for Applications
Craig Palmer - National Indicator Lead for pilot studies
Rob Tidwell - Field Operations Coordinator, EMAP-Forests
Jerry Byers - Quality Control, EMAP-Forests

Forest Health Monitoring (West) Organization:

Terry Shaw - Western Lead for pilot studies
Dave Johnson - Region 2 Indicator Lead for Damage
Mike Schomaker - Colorado Co-Lead for Damage
Bill McLain - Colorado Field Operations Lead
Jim LaBau - California Field Operation Lead
John Hazard - Sampling Design Lead
Dave Cassel - Sampling Design

Field Crews

Two FHM crews will measure the 42 plots in Colorado. Each crew will be structured as follows:

Forester 1	Crew Leader
Forester 2	Insect, disease, and damage specialist
Plant Identification Specialist	Schooled and/or experienced or specialist skilled in plan identification.
Soils Scientist	Collects soils data
Entomologist/ Pathologist	Collects off-plot FPM data
Entomologist/ Pathologist	Collects off-plot insect, disease, and damage data for Colorado State Forest Service
Logistics Specialist	Transmits field data from PDR's to disc, packages and mails laboratory samples, maintains trucks and field equipment; utility field crew member.

Assignments

Operations Plan (Colorado) - Bill McLain
Field Operations (Colorado) - Bill McLain
Operations Plan (California) - Jim LaBau
Field Operations (California) - Jim LaBau

Procedures Development

1. Plot Establishment and implementation tree tally variables - Bill McLain, Jim LaBau, Bill Bechtold

2. Pilot Variables (On-Plot) - Craig Palmer
   - Soils - Rick Van Remortel
   - Crown Assessment - Ken Stolte, Terry Shaw, Mike Schomaker
   - Tree Damage (insects, disease, other) - Dave Johnson, Mike Schomaker
   - Indicator Plants - Ken Stolte
   - PAR - Judd Isembrands, Sarah Steele
   - Understory Vegetation - Steve Cline, Renee O'Brien

3. Pilot Variables (Off-Plot)
   - Root Wedging or Coring
   - Vegetation Habitat
   - PAR
   - Soil Microbiology - Craig Palmer
   - Tree Heights - Ken Stolte
   - Tree Cores - Terry Shaw
   - Branch Extraction
   - Foliage Sample
   - Needle Retention
   - Soils

Personnel Recruitment

FIA, INT Station, United States Forest Service, Ogden, Utah, will hire:

Crew Leader (Forester 1) - 2 each

FPM, State and Private Forestry, R-2, U.S. Forest Service will hire:

Forester 2 (I&D and Damage Specialist) - 2 each
Entomologist/Pathologist - 2 each

EMAP-Forest, Environmental Monitoring Systems Laboratory, U.S. Environmental Protection Agency, Las Vegas, will hire:

Soils Scientists - 2 each
Logistics Specialist - 2 each
Through the Bureau of Land Management

Region 2, U.S. Forest Service will hire:

Plant Identification Specialist - 2 each

The Colorado State Forest Service will hire:

Entomologist/Pathologist - 2 each

Equipment

Trucks - FPM, R-2 will supply four trucks (two for each field crew) for field work.

EMAP-Forest (Craig Palmer) will supply two trucks (one per crew) for logistics functions.

Forest Mensuration Equipment

FIA, INT Station is supplying the basic forest mensuration tools:

Angle Guage	4
Back Scribe	4
Clinometer	4
Compass	4
Cruisers Vest	4
D-Tape	4
First Aid Kit	4
Hand Lens	4
Hand Axe	4
Hard Hat	14
Increment Borer	4
Loggers Tape	4
Photo Scale Protractors	enough for training
Pocket Calculator	4
Quart Canteen	14
Stereoscope	2
Tatum	2
100 ft. Tape	4
Six Inch Rule	4
Flagging	
Photo Bags	
Witness Tree Tags	
Stakes	
Duffel Bag	4
Tents	2

Pilot Indicator Equipment

EMAP-Forest, Rob Tidwell, will provide all necessary Pilot indicator equipment.

PDR

EMAP-Forest, Chuck Liff, will provide PDR's.

Field Manuals

EMAP-Forest, Barbara Conkling, will provide field manuals.

Training

Plot layout and mensuration	- Bill McLain
	- Jim LaBau
Soils	- Rick Van Remortel
Crown Assessment	- Mike Schomaker
Crown Forms	- Jim LaBau
Indicator Plants	- Ken Stolte
PAR	- Sarah Steele
Understory Vegetation/Habitat	- Steve Cline
	- Renee O'Brien
Other Pilot Indicators	- Craig Palmer
	- Ken Stolte
	- Terry Shaw
Insect, Disease, and Damage	- Dave Johnson
PDR	- Mark Rubey

QUALITY CONTROL

Test plots will be measured by trainers and then remeasured by the field crews. This will be done immediately after the completion of training and again towards the end of the field season.

Hot checks will be conducted during the season; indicator leads will accompany the field crews to new plots and observe that portion of the data collection for which the lead has quality responsibility and authority.

SCHEDULE

March 30-April 3

Test PDR and field procedures in Durham, North Carolina.

May 18-22

Visual crown rating procedures training of VCR trainers in Ashville, North Carolina.

May 26-29

Training of all western trainers in Ogden, Utah.

June 1-5

Training of California and Colorado field crews in Logan, Utah.

June 8-12

Training of Colorado crew in Colorado.

June 15-August 21.

Field data collection in Colorado.

REPORTING

Data will be compiled at the USDA Forest Service Northeast Research Station.

The following lists the tables of data to be produced.

Table

1. Total area sampled by land use category.

2. Area of forest land sampled by forest type.

3. Area of forest land sampled by forest type group and stand-size class.

4. Relative percent of live trees tallied by species and diameter class.

5. Percent of tallied live trees 5.0-inches d.b.h. and larger by species and crown class.

5a. Percent of tallied live trees 5.0-inches d.b.h. and larger by species and crown class and forest type group.

6. Percent of tallied overstory trees 5.0-inches d.b.h. and larger by species and crown-dieback class.

6a. Percent of tallied overstory trees 5.0-inches d.b.h. and larger by species and crown-dieback class and forest type group.

7. Percent of tallied understory trees 5.0-inches d.b.h. and larger by species and crown-dieback class.

8. Percent of tallied overstory trees by species and foliage-transparency class.

8a. Percent of tallied overstory trees by species and foliage-transparency class and forest type group.

9. Percent of tallied understory trees 5.0-inches d.b.h. and larger by species and foliage-transparency class.

10. Percent of tallied overstory trees 5.0-inches d.b.h. and larger by species and crown ratio class.

10a. Percent of tallied overstory trees 5.0-inches d.b.h. and larger by species and crown ratio class and forest type groups.

11. Percent of tallied understory trees 5.0-inches d.b.h. and larger by species and crown ratio class.

12. Percent of tallied overstory trees 5.0-inches d.b.h. and larger by species and crown density class.

12a. Percent of tallied overstory trees 5.0-inches d.b.h. and larger by species and crown density class and forest type group.

13. Percent of tallied understory trees 5.0-inches d.b.h. and larger by species and crown density class.

14. Percent of overstory conifers 5.0-inches d.b.h. and larger by species and needle retention period.

15. Percent of understory conifers 5.0-inches d.b.h. and larger by species and needle retention period.

16. Percent distribution of damage signs and symptoms by species, live tally trees 5.0-inches d.b.h. and larger.

17. Percent distribution of species impacted by damage signs and symptoms, live tally trees 5.0-inches d.b.h. and larger.

18. Percent of seedlings and saplings by major species and crown vigor class.

BUDGET

Distribution of the proposed FY 1992 FHM funding for Colorado implementation field data collection.

Item	No.	PP	Salary	Per Diem	INT	R-2 FPM
Crew Leader	2	15	16,500	5,544	44,088	
Entomologist/Pathologist	2	6	5,430	5,544		21,948
Botanist	2	6	3,978	5,544	19,044	
Soils Specialist	2	6	6,600	5,544	24,288	
Logistics Specialist	2	6	4,386	5,544	19,860	
Truck	2	6		1,920	3,840	
Administration						
McLain .75 GM-13					43,500	
Rubey .50 GS-12					19,000	
Ogden Office and Compilation Support				20,880		
Supplies					4,000	
Travel for Planning, Training, Quality Control			24,000			
Station Overhead					27,500	
Totals					250,000	
21,948						

EPA will supply the soils scientists (2), logistics specialists (2), and trucks (2).

Appendix G. Southern Appalachian Man And Biosphere (SAMAB) Demonstration Plan

E.R. Smith

SAMAB Plan

The Southern Appalachian Man and Biosphere (SAMAB) Cooperative consists of eight federal agencies and a non-profit foundation whose members include a number a universities and private organizations. The eight federal agencies are: the United States Forest Service (USFS); the United States Fish and Wildlife Service (USFWS); the Department of Energy- Oak Ridge National Laboratory (DOE-ORNL); (EDA); the Tennessee Valley Authority (TVA); the National Park Service (NPS); the US Environmental Protection Agency (EPA); and the United States Geological Survey (USGS). At the February meeting of the SAMAB executive committee, it was decided that SAMAB would support a demonstration of the Forest Health Monitoring (FHM) program in the SAMAB Zone of Cooperation, and that a committee be formed of representatives from member organizations to: 1) serve as an interface between SAMAB and FHM, and 2) identify resources from member organizations that could be contributed to the demonstration effort.

The TVA will have lead responsibility for all SAMAB region activities:

- Coordinating field personnel.
- Analyzing data.
- Publishing a report.

The field crew will consist of two foresters - both provided by TVA, a botanist - provided by TVA and the NPS, one soil scientist - provided by TVA, SCS, and FHM, and one tree climber - provided by the FS. We have estimated 25 forested plots will be established using the Environmental Monitoring and Assessment Program (EMAP) 1/4 interpenetrating design. Map identification of plot locations will be done on a Geographic Information System (GIS) at TVA using a standard offset from the EMAP grid center (coordinates or an algorithm will be provided by EMAP). Forest Health Monitoring has agreed to take responsibility for training and all quality assurance/ quality control (QA/QC) work including audits. Training will be done in conjunction with training for the Southeastern Demonstration project, June 8, at Bent Creek Experimental Forest, near Asheville, NC. Field work will then commence the next week, June 15. We estimate it will require 12 weeks to complete the 25 plots.

Plot location and data collection will be consistent with FHM methodologies. More detailed information about the logistics can be found in Appendix 5. Plot field location and measurement will take place at the same time. Plot locations will be identified using a portable Global Positioning System (GPS) unit. Plot measurements will consist of those done on a standard FHM plot by the foresters: site condition, growth and regeneration data, visual symptoms data, plus collection of increment cores and a sample of lichens. The PAR measurements will be collected using the methods outlined for the Western Pilot for this indicator. Storage of samples will follow FHM protocol, as will transfer of data collected on the PDRs.

Collected data will be turned in daily to FHM and edited using standard FHM procedures. Once edited, the "clean" data will be made available to SAMAB participants. Analysis of data will be done in coordination with FHM and a report for the SAMAB Demonstration will be published by TVA.

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FHM Field Methods Guide for 1992

Appendix C

Handbook of Laboratory Methods for FHM

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