

STATUS OF ECOLOGICAL MONITORING DATA IN VERMONT

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Prepared by:

Timothy Scherbatskoy, Ph.D.
School of Natural Resources
University of Vermont
Burlington, VT 05405-0088 USA

VMC RESEARCH REPORT # 3

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I. EXECUTIVE SUMMARY

Concerns about the future long-term health of Vermont's forests and projected local, regional and global changes in climate and pollutant exposures have led to the formation of the Vermont Monitoring Cooperative, a long-term, integrated, ecological monitoring program. The VMC is a cooperative effort among the University of Vermont (UVM), the Vermont Agency of Natural Resources (VT ANR), other state agencies, and the US Forest Service (USFS). Its purpose is to coordinate long-term environmental and biological monitoring in forested ecosystems in Vermont, and to facilitate long-term research on the response of these ecosystems to the changing physical and chemical climate.

Preliminary research was conducted to: (1) identify the important questions and objectives to be addressed by a long-term ecological monitoring program in Vermont, and (2) identify and evaluate monitoring programs in Vermont concerned with the environment and/or forested ecosystems. An earlier report ("Planning for the Vermont Monitoring Cooperative," August, 1990) summarized planning discussions and workshops held to develop the objectives of the VMC and recommended specific monitoring priorities. The second objective, addressed here, summarizes and evaluates existing and historical Vermont monitoring resources as a basis for planning a long-term integrated monitoring network in Vermont. The primary focus of this work is in the area of Mt. Mansfield, Vermont (the "Mansfield site"), the location of the first intensive monitoring site in Vermont planned under the VMC. The Mansfield site includes the UVM Proctor Maple Research Center in Underhill, adjacent lands on Mt. Mansfield, and the UVM Jericho Research Forest. In addition, information about monitoring projects throughout Vermont is also being gathered to support planning for expansion of VMC activities to a second intensive site and a network of extensive sites in Vermont.

Information about monitoring and related research activities which met certain inclusion criteria were incorporated into computerized databases using dBASE III PLUS operating in an IBM-PC-compatible environment. This provides a convenient and expandable central repository for this information. At this time, these databases are reasonably comprehensive, but information about projects continues to be uncovered, and new information will be added in the future. One of the continuing responsibilities of the VMC should be to continue to develop, update, and distribute these databases.

Past and current monitoring activities at the Mansfield site were summarized and evaluated for their utility to a long-term ecological monitoring program. At present, there are 53 projects catalogued in the database for this site. The evaluation process for these projects used a ranking system based on ten criteria related to the objectives,

location, longevity, data quality, etc., of each project. This resulted in nine projects being ranked as unacceptable due to inadequate methods and QAQC reliability. The remaining projects were ranked in order of their overall value relative to the ranking criteria.

The distribution of high-quality monitoring projects in the various environmental media favored air quality and precipitation monitoring, followed by forest ecosystem measurements. Surface waters studies are currently poorly represented at this site, and wildlife studies are absent.

What emerges from this evaluation is a picture of a strong air quality/precipitation chemistry database extending back to 1981. This can be built on and extended into the future. Current monitoring at the Mansfield site in these media are reasonably comprehensive and methodologically current. Forest condition monitoring at the site includes a number of interesting, potentially-useful projects, but no long-term forest biomonitoring projects extend back before 1985. In the last few years several projects in this area have started which will have long-term monitoring significance. Finally, there are a number of supportive databases which apply to the site, although they may not be located exactly there. These include the long-term meteorology records of the National Weather service and UV-B monitoring at the Burlington airport, and several GIS and photo-survey databases.

The strengths and weaknesses of the collected assemblage of monitoring programs were discussed, and recommendations were made for improvements in the overall package of monitoring activities at this site. Also discussed were possible relationships between the VMC and other regional and national monitoring programs currently under development.

In concluding, currently active monitoring projects and selected historical projects were summarized to provide a description of possible projects which could comprise the new VMC monitoring program. The VMC Technical Committee is currently engaged in developing a monitoring workplan for the Mansfield site, and this listing provides useful information to assist in this process.

II. BACKGROUND

In the decades ahead, Vermont will probably experience significant changes in its chemical and physical climate. These changes and their associated impacts on the productivity and health of our forests are of major importance and concern to local and national resource managers. If we are to respond wisely to these changes, we must develop systems for measuring and evaluating them.

Long-term monitoring is required to evaluate deviations from baseline conditions and to identify subtle shifts and perturbations (Class 2 of Smith, 1981) in ecosystem conditions and processes. Comprehensive ecosystem monitoring systems can also permit rapid identification of higher-level pollution impacts (Class 3 of Smith, 1981) and ecosystem responses to other environmental changes. Long-term monitoring also provides excellent opportunities for basic and applied field research by providing local biological and environmental monitoring data, and by providing sites for experimental field manipulations.

The Vermont Monitoring Cooperative (VMC) was formed to address these concerns and issues in Vermont. Growing out of discussions between scientists, land managers, and planners in early 1989, a conceptual plan developed for a long-term, integrated environmental and biological monitoring program - the Vermont Monitoring Cooperative. This program was formed as a cooperative effort among the University of Vermont (UVM), the Vermont Agency of Natural Resources (VT ANR), other state agencies, and the USDA Forest Service Northeastern Forest Experiment Station (USFS). In the autumn of 1989 Congress appropriated \$250,000 for the establishment of a long-term integrated monitoring program in Vermont, these funds to be administered by the USFS.

Considerable effort has been put into planning the VMC. A planning document was prepared during the summer of 1990 ("Planning for the Vermont Monitoring Cooperative"), which identified science and management priorities for this program. Additional background information about the goals and structure of the VMC can be found in that first planning document. A VMC Technical Committee was established to evaluate existing state and federal monitoring programs in light of these planning recommendations, and to prepare a Monitoring Workplan by January 1991.

A second part of the initial planning process was to conduct background research on the status of environmental and biological monitoring programs and data in Vermont. The results of this research are discussed here. The purpose of this work was to identify monitoring strengths and weaknesses in Vermont in preparation for developing a long-term monitoring program in the state which will be compatible with existing and developing national and international monitoring networks.

III. SCOPE

The focus of this evaluation was on what will be referred to as the "Mansfield site," the area chosen for establishment of the first intensive monitoring site under the VMC. The Mansfield site is defined to include the Proctor Maple Research Center and nearby lands, Mt. Mansfield State Forest, Mt. Mansfield summit area, the UVM Jericho

Research Forest, Mill Brook, Browns River, Stevensville Brook, and Clay Brook. Towns included in this definition are Underhill, Stowe, Cambridge, and Jericho. The types of projects evaluated included monitoring programs, occasional surveys, and research projects with the potential to provide spatial or temporal trends in ecosystem components. The media considered included all the major components of forested ecosystems: air, water, forests, and wildlife. The time domain covered current, recent, and historical projects.

Also included in this evaluation were a limited number of supportive databases which apply to the site, although they may not be located exactly there. These include the long-term meteorology records of the National Weather service and UV-B monitoring at the Burlington airport, and several GIS and photo-survey databases.

A similar evaluation of monitoring resources throughout Vermont and in the Vermont border regions has also been initiated. Here the spatial domain covered all of Vermont and projects within approximately 50 km of Vermont's borders. This information will be useful in identifying a possible second intensive monitoring site in the state, and in providing a comprehensive overview of monitoring resources in and around Vermont. Evaluation of these projects will be the subject of a subsequent report.

IV. OBJECTIVES OF THE EVALUATION PROCESS

In preparation for establishing a coordinated, long-term ecological monitoring system in Vermont, it was necessary to evaluate the current status of monitoring information in the state. Thus, the primary objective of this work was to catalog and evaluate available information about current and historical monitoring projects. Specific objectives include:

1. Identify potential sources of monitoring information (e.g., Federal and State agencies, scientists, land managers, computer databases such as EDEX, RSIS.
2. Collect preliminary information about monitoring programs, research projects, and surveys in the Mansfield area.
3. Develop criteria for including projects in a monitoring database.
4. Develop a searchable computer database to catalog projects.
5. Develop a system for ranking the data quality of projects and the utility of each project to a sustained long-term monitoring program.

6. Identify projects which are valuable to planned and potential monitoring activities.
7. Identify significant gaps in the existing monitoring infrastructure, and make recommendations for adding projects in these areas.

Environmental and biological monitoring are needed to describe system conditions, variability, and trends in forested ecosystems, and to distinguish natural variation from changes due to external influences. This kind of monitoring also provides data for modeling ecosystem processes and predicting responses to changing environmental conditions. Data quality must be very high to accomplish these objectives, however, because we are generally dealing with low-level ecosystem perturbations which are difficult to distinguish from natural system variation. Thus, assessment of the data quality of monitoring projects is very important, and considerable effort has been made to rigorously evaluate this component of the projects.

V. PROCEDURES

A. Data Collection:

Data on monitoring and research activities at the Mansfield site and in other parts of Vermont were collected by contacting project managers, reviewing historical databases and reports, identifying logical sources of environmental data, and through my own knowledge of monitoring and research activities in Vermont.

Numerous agencies and individuals involved in environmental, ecological, and forestry activities in Vermont were contacted. These included agents of the Vermont Agency of Natural Resources, U.S. Forest Service, U.S. Geological Survey, lay monitoring groups, environmental organizations, and university researchers from within and outside Vermont. Each contact generally led to additional potential sources for information, so that a rich network of contacts has developed. Many older monitoring and related projects exist today only as computer databases, old reports, or notebooks. As these were identified, they were located and evaluated.

As anticipated, the scope of projects, their duration, and data quality varied widely. Criteria were developed to evaluate the utility of these projects to the VMC. In general, continuous monitoring projects or occasional research or survey projects are valuable to the VMC if they are reliable, repeatable, and concerned with environmental, ecological, or biological interactions between the environment and forest ecosystems. Specific criteria for project inclusion are discussed further below.

B. Database Development:

Two databases were developed to keep track of past and contemporary monitoring projects in Vermont. These contain projects meeting minimum inclusion criteria (see below) at the Mansfield site (filename MANS.DBF) and for all of Vermont (filename VT.DBF). These were built with the database management software dBASE III PLUS operating in an IBM-PC-compatible environment. Methods for using these databases are given in APPENDIX I.

These databases were designed to be similar in format and operation to the BORDER database, "An inventory of current environmental monitoring projects in the U.S.-Canadian Transboundary Region," (Glantz *et al.*, 1986). This facilitates regional integration of data about environmental monitoring projects in the Vermont-Canadian transboundary area, and provides additional user support for the databases.

C. Inclusion criteria:

For inclusion in the Mansfield database, projects must be located within the site as defined above and must meet the following criteria.

1. a continuous monitoring project, or
2. a periodic survey which could be accurately replicated, or
3. a one-time survey or research project which could be accurately replicated, and
4. the location where the data were/are collected is precisely known, and
5. the time when the data were/are collected is precisely known, and
6. the original data are available, and
7. the methods and quality control procedures are available, and
8. these methods and QC procedures are known to be reliable and accurate, and
9. the data describe some attributes of an ecosystem.

To evaluate and rank monitoring projects which met these inclusion criteria, a system of weighting factors was developed for these and additional criteria. This is described in more detail below under part VI C, Monitoring Projects Assessment.

These databases are not completed products; rather they are ongoing projects. At the time of this report, MANS.DBF includes all the significant monitoring projects that are ongoing in the Mansfield area, and most of the past projects meeting the inclusion criteria. Inevitably, some past projects will be unearthed and will be added to the database, as will new monitoring projects as they are implemented. The VT.DBF database, due to its larger scope, is farther from being comprehensive at this time.

Current plans call for completing this database and a related summary by December, 1990.

One of the major roles of the VMC is to facilitate coordination and integration of regional monitoring projects and the data from these projects. Maintaining, updating, and distributing these databases will be a continuing effort of the VMC.

VI. MONITORING PROJECTS

At this time, 53 projects have been catalogued in the Mansfield database. Monitoring projects are summarized in sections A (Past Projects) and B (Current Projects), below. A ranking evaluation of the projects and discussion of the procedure used to rate project quality is presented in section C (Assessment), below.

A. Past Projects:

Past surveys, monitoring projects, and research projects with monitoring potential are summarized below by category, dates, and project name (with abbreviation in parentheses). This list provides a convenient overview of past projects at the site. Most of these projects are located on the property of the PMRC; projects which are not located at the PMRC proper (i.e., are located on Mt. Mansfield, Jericho Research Forest, or Burlington Airport) are marked with an asterisk; those located at the PMRC with additional sites elsewhere in Vermont are marked with a double asterisk.

Air Quality:

1982 - 1986. U. Rhode Island/VT Air Poll. Control Aerosol Studies (URI/VT).

1988 - 1989. U. Rhode Island/VT Air Poll. Control Aerosol Studies (URI/VT).

1988 - 1990. EPA Acid Modes (ME-35) Network (Acid Modes Air).

1988 - 1990. EPRI Operational Evaluation Network (OEN Air).

Forest processes:

1963 - 1986. Maple sugar concentration and diameter relationships (PMRC Sap I).

1977 - 1987. Maple sugar concentration in sap (PMRC Sap II).

1977 and 1985. Vermont sugarbush health survey 1977-85 (VT Sugarbush). **

1978 - 1983. Maple tapping rate study (PMRC Taps).

1979 - 1985. Dept. of Energy biomass study (PMRC Biomass).

1975 - 1986. Maple sugar production in relation to sap volume, number of taps and sap sugar concentration (PMRC Crop).

- 1981. Rain and throughfall chemistry in a sugar maple plantation (PMRC Thrufall).
- 1982. Forest responses to anthropogenic stress (FORAST). *
- 1985. Maple decline survey (PMRC Decline).
- 1987. Regional analysis of growth trends in red spruce (Johnson). *

Precipitation chemistry:

- 1981 - 1987. Utility Acid Precipitation Study Program (UAPSP).
- 1982. High-elevation rain and cloud water chemistry (Mansfield Cloud). *
- 1988 - 1989. U. Rhode Island/VT Air Poll. Control Aerosol Studies (URI/VT).
- 1988 - 1990. EPRI Operational Evaluation Network (EPRI OEN Air).
- 1988 - 1990. EPA Acid Modes (ME-35) Network (Acid Modes Precip).

Soils:

- 1974. SCS soil survey mapping of Chittenden County. (SCS). **

Surface waters:

- 1982 - 1987. Long-term lakes monitoring program (WQ Lakes). *
- 1983. Rain and stream pH and volume relationships (Roy). *

Weather:

- 1977 - 1980. Wind measurements at the PMRC (PMRC Wind).
- 1978 - 1983. Air and soil temperature monitoring project (PMRC Temps).

B. Current Projects:

Current surveys, monitoring projects, research projects with monitoring potential, and databases are listed below by category, dates, and project name (with abbreviation in parentheses). All of these projects are currently in progress; some have been underway for many years, such as the National Weather Service programs. Furthermore, some of these are the projects which will be able to provide continuing monitoring for the VMC, such as the NADP/NTN or NAMS O3 projects. It is noteworthy that a relatively new category of project - Databases - appears here; these provide important new sources of information about the region and monitoring data existing for the region. Projects which are not located at the PMRC proper are marked with an asterisk; those located at the PMRC with additional sites elsewhere in Vermont are marked with a double asterisk.

Air quality:

- 1988 - present. Northeast States for Coordinated Air Use Management Regional Particle Monitoring Network (NESCAUM).
- 1988 - present. VT State and Local Air Monitoring Stations (NAMS PM10). **

1988 - present. VT State and Local Air Monitoring Stations (NAMS O3). **
1988 - present. EPA National Particulate Network (NPN).

Databases:

1932 - present. Remote Sensing Information System (RSIS). **
Current. Lamoille County Regional Planning Office GIS (Lamoille GIS). *
Current. Town of Underhill GIS (Underhill GIS). **
Current. University of Vermont GIS (UVM GIS). **
Current. Vermont Office of GIS. (VT GIS). **

Forest Insects:

1982 - present. Annual Forest Insect and Disease Conditions in Vermont Survey (VT Insects). **
1988 - present. Vermont Pear Thrips Survey Program (VT Thrips). **

Forest processes:

1948 - present. Forest Inventory and Analysis (FIA). -- see comments under VIII A.
1972 - present. VT Forestry Division annual aerial detection survey (VT Photo). **
1985 - present. Vermont Hardwood Health Survey (VT Hardwoods). **
1987 - present. Dynamics of stand establishment and development in the northern hardwood forests (Hannah). *
1988 - present. North American Sugar Maple Decline Project (NAMP). **
1989 - present. Nutrition and vigor of declining sugar maples before and after fertilization (Wilmot). **

Surface waters:

1988 - present. Mount Mansfield River Watch (MMRW). *

Solar radiation:

1985 - present. Robertson-Berger UV-B monitoring network (RB UV-B). *

Precipitation chemistry:

1980 - present. Vermont Acid Precipitation Monitoring Program. (VAPMP PMRC). **
1980 - present. Vermont Acid Precipitation Monitoring Program. (VAPMP Mans). *
1984 - present. National Atmospheric Deposition Program - National Trends Network (NADP/NTN). **

Weather:

1955 - present. National Weather Service cooperative network for climatological data (NWS Coops). *
1943 - present. National Weather Service Local Climatological Data (NWS LCD). *

C. Assessment:

Monitoring projects were numerically ranked by evaluating 10 criteria for each project (Table 1). Greater weight was given to the reliability of the project's methods and QAQC procedures than to the other criteria, emphasizing the importance of high quality, reliable data. Higher values identified projects of relatively greater value to the VMC. In the absence of additional criteria, these projects should have a higher priority for use or continuation. With the development of specific monitoring priorities by the VMC Technical Committee, however, new weighting factors could be added, modifying these rankings.

Ranking criteria used for monitoring projects at the Mansfield site. The numeric value used in ranking was equal to the sum of all ten criteria values multiplied by the tenth (reliable methods and QAQC).

Project type:	0 = research, 1 = survey, 2 = monitoring
Location well known:	0 = no, 1 = approximately, 2 = precisely
Closeness to PMRC:	0 = > 5 km, 1 = < 5 km, 2 = at PMRC proper
Dates well known:	0 = no, 1 = approximately, 2 = precisely
Project duration:	0 = 1 yr, 1 = 2-4 yrs, 2 = 5+ yrs
Frequency of collections:	0 = once, 1 = occasional, 2 = regularly
Project started/covers:	0 = since 1990, 1 = since 1985, 2 = since 1950, 3 = earlier
Original data available:	0 = no, 1 = yes
Methods, QAQC known:	0 = no, 1 = yes
Methods, QAQC reliable:	0 = no, 1 = moderately, 2 = very

The ranking procedure resulted in the following ordering of all projects in the Mansfield database. Of the 53 total projects, 10 were ranked zero due to unacceptable methods and QAQC reliability. Two are currently unranked (marked with an asterisk) pending additional information. The other projects are arranged below in descending order of relative value. A "perfect score" under the ranking system used was 38. The higher ranked projects are good candidates for possible continuation, providing a foundation for new studies, or replication at some time in the future.

<u>Rank</u>	<u>Abbreviation</u>	<u>Project name</u>	<u>Project type</u>
36	NADP/NTN PMRC	National Atmospheric Deposition Program - National Trends Network	Precipitation
36	UAPSP	Utility Acid Precipitation Study Program	Precipitation
34	NAMS O3	VT State and Local Air Monitoring Stations	Air quality
34	NAMS PM10	VT State and Local Air Monitoring Stations	Air quality
34	NESCAUM	Northeast States for Coordinated Air Use Management Regional Particle Monitoring Network	Air quality
32	Acid Modes Air	EPA Acid Modes (ME-35) Network	Air quality
32	OEN Air	EPRI Operational Evaluation Network	Air quality
32	URI/VT Air I	U Rhode Island/VT Air Poll Control Cooperative Aerosol Study	Air quality
32	URI/VT Air II	U Rhode Island/VT Air Poll Control Cooperative Aerosol Study	Air quality
32	URI/VT Precip	U Rhode Island/VT Air Poll Control Cooperative Aerosol Study	Precipitation
32	Acid Modes Precip	EPA Acid Modes (ME-35) Network	Precipitation
32	OEN Precip	EPRI Operational Evaluation Network	Precipitation
30	VT Hardwoods	Vermont Hardwood Health Survey	Forest vegetation
28	WQ Lakes	Long-term lakes monitoring program	Surface waters
17	VAPMP PMRC	Vermont Acid Precipitation Monitoring Program	Precipitation

<u>Rank</u>	<u>Abbreviation</u>	<u>Project name</u>	<u>Project type</u>
17	PMRC Temps	Air and soil temperature monitoring project	Weather
16	NAMP PMRC	North American Sugar Maple Decline 1977-1985	Forest vegetation
16	VAPMP Mans	Vermont Acid Precipitation Monitoring Program	Precipitation
16	NWS Coops	National Weather Service cooperative network for climatological data	Weather
16	NWS LCD	National Weather Service Local Climatological Data	Weather
15	RB UV-B	Robertson-Berger UV-B monitoring network	Solar radiation
14	VT Thrips	Vermont Pear Thrips Survey Program	Forest insects
14	VT Photo	VT Forestry Division annual aerial Project	Forest vegetation
14	VT Sugarbush	Vermont sugarbush health survey detection survey	Forest vegetation
14	MMRW	Mount Mansfield River Watch	Surface water
13	RSIS	Remote Sensing Information System	Database
13	VT Insects	Forest Insect and Disease Conditions in Vermont Annual Survey	Forest Insects
13	Wilmot	Nutrition and vigor of declining sugar maples.... fertilization	Forest vegetation
13	FIA	Forest Inventory and Analysis	Forest vegetation
12	Chittenden GIS	Chittenden County Geographic Information System	Database

<u>Rank</u>	<u>Abbreviation</u>	<u>Project name</u>	<u>Project type</u>
12	Lamoille GIS	Lamoille County Regional Planning Commission Geographic Information System	Database
12	UVM GIS	University of Vermont Geographic Information System	Database
12	VT OGIS	Vermont State Office of Geographic Information Systems	Database
12	SCS	SCS soil survey mapping of Chittenden County	Soils
11	PMRC Decline	Maple decline survey	Forest vegetation
10	FORAST	Forest responses to anthropogenic stress	Forest vegetation
10	Johnson	Regional analysis of growth trends in red spruce	Forest vegetation
8	Fitzgerald	Intra-event concentrations of trace metals in precipitation.	Precipitation
8	Hannah	Dynamics of stand establishment and development in the northern hardwood forests	Forest vegetation
6	Roy	Rain and stream pH and volume	Surface waters
*	McGill	Sulfur oxidation states in precipitation.	Precipitation
*	Norton	Concentrations of trace metals in New England mountain soils	Soils
0	NPN	National Particulate Network	Air quality
0	Mansfield Cloud	High-elevation rain and cloud water chemistry studies	Precipitation

<u>Rank</u>	<u>Abbreviation</u>	<u>Project name</u>	<u>Project type</u>
0	PMRC Thrufall	Rain and throughfall chemistry in a sugar maple plantation	Forest vegetation
0	PMRC Biomass	Dept. of Energy biomass study	Forest vegetation
0	PMRC Crop	Maple sugar production in relation to sap volume, number of taps and sap sugar concentration	Forest vegetation
0	PMRC Sap I	Maple sugar concentration and diameter relationships	Forest vegetation
0	PMRC Sap II	Maple sugar concentration in sap	Forest vegetation
0	PMRC Taps	Maple tapping rate study	Forest vegetation
0	PMRC Rain	Rain and snow measurements at the PMRC	Weather
0	PMRC Wind	Wind measurements at the PMRC	Weather

VII. MONITORING EQUIPMENT

A. Inventory:

A core inventory of sophisticated precipitation and air quality equipment now exists at the PMRC. Recent negotiations with EPRI (the Electric Power Research Institute) resulted in UVM being given all of the air quality monitoring equipment EPRI maintained there during the recent Operational Evaluation Network (OEN) studies. One of the factors leading to this was the development of the VMC, which could actively use the equipment. Conservatively, this represents about \$50,000 worth of equipment. All of this equipment can be used by the Vermont Monitoring Cooperative. The equipment acquired includes:

- climate-controlled instrument shelter
- meteorological tower
- meteorological equipment (temp, pressure, dewpoint, wind, etc.)

- DSM 3260 data logger
- transition flow reactor (TFR) filterpack modules
- meteorological tower, pumps, and filters for TFR
- AeroChem Metrics wet/dry precipitation sampler
- Belfort rain gauge
- pH meter
- conductivity meter
- analytic balance
- Toshiba laptop computer
- Dasibi ozone monitor

In addition, through other programs at UVM and VT ANR, additional monitoring equipment is potentially available for use by the VMC at the site, including:

- AeroChem Metrics wet/dry precipitation sampler
- two MCCP active cloud water samplers
- climate controlled monitoring shelter
- three hi-vol samplers
- meteorological tower
- meteorological equipment (temp, pressure, dewpoint, wind, etc.)

B. Use and Maintenance:

At present, precipitation monitoring (quantity and chemistry) is being continued at the site by PMRC personnel under the NADP/NTN, through a contract where the USGS supports the cost of routine sampling and all maintenance. In addition, hourly average meteorological measurements are also being collected by the data logger and downloaded weekly to a computer database.

Other programs for air quality and precipitation monitoring at the PMRC (NAMS O3, NAMS PM10, NESCAUM, VAMP) are also continuing using equipment and procedures maintained by the respective agency. Several forestry studies are currently active at the PMRC, including periodic vegetation/health/insect/disease surveys conducted by the VT Forestry Division, as well as research projects conducted by UVM and VT ANR personnel. Additional measurements are being continued at other locations within the Mansfield Site, such as precipitation and weather monitoring at the summit, weather and UV-B monitoring at the Burlington airport, and river monitoring in nearby streams by the Mt. Mansfield River Watch. These and other current monitoring activities are included in the summary in section IX Conclusions, below.

Costs for continuing the meteorology measurements are principally maintaining electric service and telephone (for electronic data transfer). These services currently cost \$75 per month. They are currently being billed to and paid by the UVM School of Natural Resources. In the future, it may be appropriate to consider these costs being assumed by the VMC.

There are currently no provisions for maintenance of equipment at the site. Routine maintenance of the site itself (mowing, plowing, etc.) are provided by the staff of the PMRC.

VIII. RECOMMENDATIONS

A. Current Strengths and Weaknesses:

The greatest assets of the Mansfield integrated monitoring site are its:

- air quality and precipitation chemistry data,
- past and current forest biology monitoring programs,
- geographic location, and
- potential for integration of on-site measurements in several disciplines.

The most prominent shortfalls in the monitoring activities at the Mansfield site are:

- the "spottiness" of some of the air quality data,
- the absence of forest-receptor dry deposition measurements, and
- the lack of long-term permanent-plot quantitative forest condition data.

Few sites in the region have such detailed data on aerosol chemistry in conjunction with standard air quality measurements. The URI/VT aerosol analysis, for example, is a unique data set describing concentrations of over 30 elements in daily air samples at a rural location. This project overlapped with high-quality daily precipitation chemistry measurements, and was followed by the establishment two years later of a long-term aerosol chemistry study (NESCAUM) also providing data for over 30 elements. In addition, for just over one year the URI/VT study made these measurements in both aerosol and precipitation samples. During this period, these data are complemented by two similar, high-quality atmospheric chemistry studies (EPRI OEN and EPA Acid Modes). The URI/VT study is a good candidate for periodic repetition every four years as a continued long-term monitoring program.

Because the PMRC has been a forest biology research station since its formation in 1943, there have been many forest monitoring studies conducted there. By today's standards,

many of these lack the accuracy, precision, or permanence needed to justify continued support. We are not alone in this, however; sites with continuable long-term forest measurements are the exception, not the rule. We do have some useful historical data on forest microclimatology, however, which will be valuable as we plan new measurements of this kind. In the future, questions may arise that will cause us to revisit some of the data from older studies for which good data records exist. In the last few years, the PMRC has moved aggressively to establish permanent plots and contemporary methods for continued study of forest vegetation dynamics and stress response (e.g., VT Thrips, NAMP, VT Hardwoods, and the Wilmot research). Discussions have also started to add plots at the Mansfield site under the USFS New England Forest Health Monitoring Program.

Some of the best long-term forest condition data, the Forest Inventory and Analysis (FIA), dating from 1948, are not at this time available to us. In fact, we do not yet know where the FIA plots are because their location is proprietary USFS information. We are currently working with the USFS to gain access to these data.

Because these various studies have been conducted at one site, there is high spatial concordance among them, enhancing our ability to develop integrated measures of multidisciplinary data. In addition, within the spatial context of the Mansfield site there is additional rich potential for multidisciplinary programs and data integration.

One additional strength of the developing VMC monitoring program is the existence of this report evaluating monitoring resources and the monitoring projects database. Detailed knowledge of our past and current monitoring resources is a valuable asset for the development of a sustainable, long-term, integrated monitoring effort.

B. Needed Improvements:

Although there are significant strengths in the monitoring resources we possess at the Mansfield site, there are also a number of obvious improvements in the infrastructure which are called for. Keep in mind, however, that the VMC Technical Committee is in the process of assessing monitoring priorities and developing a monitoring workplan. When this is done, we will have a clearer picture of specific program needs. Nonetheless, the following steps will probably need to be addressed in order to develop a comprehensive monitoring program.

Maintenance of monitoring equipment. We now have a large amount of sophisticated hardware which inevitably will require repair and maintenance. Additional equipment will be acquired. With the exception of the NADP/NTN precipitation monitoring station, there is currently no mechanism to support equipment maintenance or field maintenance personnel. A formal budget should be established for this purpose.

Data management. At the present time, monitoring data from the various projects discussed above are stored in a variety of places, with no coordinated mechanism for obtaining or using them. We know where these data are and how to obtain them, but there is no one to do the work of bringing the data together, nor to conduct interpretive analysis of them. A data manager should be hired immediately to begin this work and help guide further planning for monitoring and data acquisition methods.

Coordination of statewide weather data. It has been widely stressed that climate and weather data are some of the more important and cost-effective monitoring resources. Some basic climatic data monitoring is currently conducted at the PMRC and more will probably be recommended in the VMC Workplan. In addition, there is a rich database from the National Weather Service primary and cooperating stations. Because of the spatial and temporal density of weather data, it will require a major effort to coordinate them and integrate them with other studies. This should be undertaken, perhaps through the activities of the data manager.

Maintenance of the monitoring databases. The central catalogue of Mansfield and Vermont monitoring and research programs has already proven to be valuable and of considerable interest to a number of groups. In addition to the obvious role of providing an inventory of our monitoring data, this information aids strategic planning and methods development by planners, resource managers, and scientists. Efforts should be made to continue to update, enlarge, and use these databases.

Special studies. There are a number of new monitoring techniques which should be developed in order to position the VMC at the forefront of integrated monitoring science. Two critical areas needing development are data integration and deposition processing analysis. New approaches to data integration will be necessary, including development of new data management tools (GIS, hypertext, data visualization, expert systems, etc.). This will enhance our ability to evaluate these large interdisciplinary data sets, and improve our ability to work closely with other regional and national monitoring programs. Secondly, continued concern about characterizing atmospheric deposition to the land and effects within forested ecosystems (including toxics and dry deposition) will require evaluation of the pathways and mechanisms of substances passing through and interacting with ecosystem components. In both these areas, special studies should be conducted to investigate and develop new techniques. This work will also help ensure that the VMC continues to have a significant supportive role in regional and national monitoring efforts by the USFS and EPA.

Development of computer data transfer and communication networks. Most monitoring data and related information now reside in computer databases ranging from single diskettes to national databases such as EPA's AIRS or the USFS's EDEX; these are generally directly accessible. Electronic communications are also an efficient way of quickly sharing data in real-time. In order to efficiently acquire data from and distribute data to users of the VMC,

we will need to electronically access computer databases and electronic bulletin boards. The need for and utility of this approach will grow rapidly in the years ahead. Establishment of electronic communications networks - which we currently do not have - should be a high priority.

C. Relation to Other Programs:

There are a number of regional monitoring programs with which the VMC could effectively interact. These interactions will require program, methods, and data compatibility. Fortunately, many of the highly-ranked Mansfield monitoring projects already use equipment and methods which are state-of-the-art, and compatible with other modern monitoring efforts being initiated. This is most true within the realm of air quality and precipitation monitoring; biological monitoring is somewhat less standardized and therefore will be more difficult to coordinate with other programs.

The Mansfield site is well-connected to national precipitation and air quality monitoring programs through the continuing NADP/NTN and NAMS programs there. At the regional level, the Mansfield site is important in the NESCAUM program for ongoing air quality and aerosol trace metal monitoring. These connections alone provide good opportunities for coordination with ongoing efforts in other neighboring states and provinces. Within Vermont, the Mansfield site also supports other long-term efforts for precipitation pH (VAPMP), and several forest biology studies (VT Thrips, VT Hardwoods, NAMP, FORAST, and possibly FIA).

There are important potential connections on the horizon, as well. Chief among these is the possibility of formal placement of New England Forest Health Monitoring Program (NEFHMP) plots at the Mansfield site. This would provide integration and cross-validation between the NEFHMP and other programs such as NAMP, VT Hardwoods, etc. Because of the comprehensive monitoring at the site, detailed methods analysis and ancillary research could also be conducted in new NEFHMP plots there.

As the EPA Environmental Monitoring and Assessment Program (EMAP) gets under way, opportunities for coordination between this program and the VMC at this site will undoubtedly arise.

Current planning underway within the USFS Global Change Program calls for establishment of a network of integrated air/forest monitoring sites throughout the North-eastern and North-central regions. The VMC Mansfield site could play an important role in this network, providing appropriate regional spatial resolution, secure lands, elevational gradients, and, most importantly, a well-established and characterized baseline monitoring program.

US-Canadian transboundary pollution issues may be assisted by past and future monitoring activities at the Mansfield site. One example of this is seen in current discussions between Vermont and Environment Canada to cooperate on air trajectory analysis studies, using data from the Mansfield site. Another possible relationship may come from the International Joint Commission Air Quality Advisory Board (IJC AQAB), which is conducting an evaluation of pollution/effects monitoring needs and programs in the transboundary region.

Decisions to continue, resurrect, or initiate new projects at the Mansfield site should consider these possible connections and seek to build on the VMC's existing strengths and maximize program coordination with these other programs.

IX. CONCLUSIONS:

The data and programs at the Mansfield site provide a solid base for continued long-term monitoring efforts, and many rich opportunities for developing new monitoring activities based on past programs. Even a more critical evaluation of past and present monitoring than conducted here would reveal a group of programs well distributed in air, surface water, and forests media, providing an adequate basis for a core monitoring effort. In fact, some of the less-highly ranked programs also provide opportunities for future evaluation of historical and spatial trends in ecosystem processes, such as the FORAST, VT Insects, or VT Photo programs.

In looking to the future of the VMC, we can consider a monitoring program constructed of some of the currently active monitoring programs at the Mansfield site and certain past projects that might be replicated periodically. The following list consists of programs that fit these categories. This list is not a description of a comprehensive monitoring program for the VMC; it merely contains possible candidates from the existing monitoring programs at the Mansfield site.

CATEGORY

Abbreviation Program name / Objective.
Status / Temporal characteristics.

PRECIPITATION

NADP/NTN National Atmospheric Deposition Program.
National/regional precipitation chemistry.
Current. Weekly.

VAPMP PMRC Vermont Acid Precipitation: PMRC.
State-wide precipitation pH.
Current. Weekly.

VAPMP Mans Vermont Acid Precipitation: Mt. Mansfield.
State-wide precipitation pH.
Current. Weekly.

AIR QUALITY

NAMS O3 National/State/Local Air Monitoring Stations.
National/regional ozone air quality.
Current. Hourly.

NAMS PM10 National/State/Local Air Monitoring Stations.
National/regional particulate air quality.
Current. Every sixth day.

NESCAUM Northeast States for Coordinated Air Use Management Regional
Particle Monitoring Network.
Regional fine particulate chemistry.
Current. Three times per week.

URI/VT U. Rhode Island/VT Air Poll. Control Aerosol Study
Regional/local aerosol and precipitation trace metals.
Restart. Continuous for year every 4 years.

SOLAR RADIATION

RB UV-B Robertson-Berger UV-B monitoring network.
Regional UV-B.
Current. Hourly.

CATEGORY

Abbreviation Program name / Objective.
Status / Temporal characteristics.

WEATHER

PMRC Temps Air and soil temperature monitoring.
Local forest physical environment.
Restart. Continuous.

NWS Coops National Weather Service Cooperative Network for Climatological
Data: Mt. Mansfield.
Regional/local climate and weather.
Current. Daily.

NWS LCD National Weather Service Local Climatological Data: Burlington.
National/regional/local climate and weather.
Current. Hourly.

FOREST VEGETATION

VT Hardwoods Vermont Hardwood Health Survey.
State-wide hardwood forest conditions.
Current. Every five years.

NAMP PMRC North American Sugar Maple Decline Monitoring Program.
Regional maple forest conditions.
Current. Annual.

VT Thrips Vermont Pear Thrips Survey Program.
State-wide hardwood forest and Thrips relationships.
Current. Annual.

Wilmot Nutrition and vigor of declining sugar maples before and after
fertilization.
Local maple forest conditions and response to fertilization.
Current. Annual.

VT Photo VT Forestry Division annual aerial survey.
State-wide forest conditions.
Current. Annual.

CATEGORY

<u>Abbreviation</u>	<u>Program name / Objective. Status / Temporal characteristics.</u>
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VT Insect	VT forest insect and disease conditions annual survey. State-wide forest conditions. Current. Annual.
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FIA	Forest Inventory and Analysis. Regional forest conditions. Current. Every 10 years.
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Hannah	Dynamics of stand establishment and development in northern hardwood forests. Local hardwood forest conditions. Current. Annual.
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SURFACE WATERS

MMRW	Mount Mansfield River Watch. Local surface water conditions. Current. Monthly.
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DATABASES

UVM GIS	University of Vermont Geographic Information System. Regional/local GIS/mapping. Current.
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RSIS	Remote Sensing Information System. State-wide/local mapping. Current.
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Many of the above programs are currently supported at certain time resolutions by existing state or federal programs, and may continue to be. It is beyond the scope of this report to recommend particular funding strategies for particular programs; it would be safe to say, however, that the VMC could play an important role in continuing, restarting, or increasing the temporal or spatial resolution of some of these programs.

In the next months, the VMC Technical Committee will be developing a workplan for the monitoring program based on its view of priorities and budgetary constraints. This process will determine the final form of the VMC monitoring program. Hopefully, the information in this report will be useful in assessing current strengths and gaps in our monitoring resources at the Mansfield site.

X. REFERENCES

Ballinger, M.Y., J. Defferding, E.G. Chapman, M.D. Bettinson, and C.S. Glantz. 1987. User's guide to a data base of current environmental monitoring projects in the U.S.-Canadian transboundary region. Report PNL-UC-11. Pacific Northwest Laboratory, Richland, WA, 99352.

Glantz, C.S., M.Y. Ballinger, and E.G. Chapman. 1986. An inventory of current environmental monitoring projects in the U.S.-Canadian transboundary region. PNL-5880. Pacific Northwest Laboratory, Richland, WA, 99352.

Smith, W. Air pollution and forests. Interactions between air contaminants and forest ecosystems. Springer-Verlag, New York. 379 pp.

APPENDIX I

Instructions for using the Vermont Monitoring Databases

This Appendix describes methods for using the two databases of ecological monitoring programs at the Mansfield site (MANS.DBF) and throughout Vermont (VT.DBF). These databases contain descriptions of 53 projects in MANS.DBF and, at present, 30 additional projects in VT.DBF, with detailed information on project name, location, time period, methods, data storage, publications, names and addresses of principal contacts, etc. The database structure of each of these is given below. These databases were created and intended for use on IBM-PC compatible computers using the database management system dBASE III Plus.

There are two ways to use the Vermont Monitoring Databases. Users familiar with dBASE III Plus can access the databases directly through dBASE commands. Others can use a menu-driven system contained on the data distribution disks which will perform most needed operations on the database, such as read, print, edit, and search. Brief guidance is given here for using these systems. For more detail, users are referred to the dBASE III Plus User's Manual (Ashton-Tate, 1986), and the BORDER database user's guide (Ballinger, *et al.*, 1987).

FILES USED IN dBASE AND MENU ACCESS TO DATABASES

dBASE:

MANS.* - Associated files (*.DBF, *.DBT, etc.) for main Mansfield database

MANVAL.* - Associated files for evaluating Mansfield database.

MANSORT.* - Associated files for value-ranked Mansfield database.

MENU:

VMENU.PRG - Main menu

VMMENU.PRG - Mansfield sub-menu

VVMENU.PRG - VT sub-menu

STRUCTURE OF FILES MANS.DBF and VT.DBF:

MANS.DBF

Field	Field Name	Type	Width
1	TYPE	Character	35
2	ABREV	Character	14
3	NAME	Character	135
4	OBJECT	Character	135
5	SCOPE	Character	67
6	WHERE	Character	135
7	DATE	Character	67
8	FREQ	Character	67
9	VAR	Character	135
10	METHOD	Character	203
11	EQUIP	Character	135
12	QAQC	Character	135
13	DATA	Character	135
14	VALUE	Numeric	2
15	CONT	Character	67
16	ADDR	Character	135
17	PHONE	Character	40
18	REF	Character	203
19	COMM	Memo Field	Memo
Total.....			1856

The file VT.DBF has the same structure, but with two additional fields:

VT.DBF

Field	Field Name	Type	Width
1	TYPE	Character	35
2	ABREV	Character	14
3	NAME	Character	135
4	OBJECT	Character	135
5	SCOPE	Character	67
6	TOWN	Character	20
7	STATE	Character	15

8	WHERE	Character	135	
9	DATE	Character		67
10	FREQ	Character		67
11	VAR	Character	135	
12	METHOD	Character	203	
13	EQUIP	Character	135	
14	QAQC	Character	135	
15	DATA	Character	135	
16	VALUE	Numeric		2
17	CONT	Character		67
18	ADDR	Character	135	
19	PHONE	Character	40	
20	REF	Character	203	
21	COMM	Memo Field		Memo
Total			1907	

REFERENCES

Ashton-Tate. 1986. Learning and using dBASE III Plus.

Ballinger, M.Y., J. Defferding, E.G. Chapman, M.D. Bettinson, and C.S. Glantz. 1987. User's guide to a data base of current environmental monitoring projects in the U.S.-Canadian transboundary region. Report PNL-UC-11. Pacific Northwest Laboratory, Richland, WA, 99352.

APPENDIX II
Complete Listing of MANS.DBF Data Records as of 25 February, 1992

Listed below are the current complete records for the Mansfield site database. These records are sorted alphabetically by the field ABREV (Project Abbreviation).