

Shenandoah National Park Long-Term Ecological Monitoring System User Manuals

Section I: Overview

Section II: Forest Component User Manual

Section III: Aquatic Component User Manual

Section IV: Gypsy Moth Component User Manual

Section V: Database Management System Component User Manual

NPS/NRSHEN/NRTR-90/02



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**SHENANDOAH NATIONAL PARK
LONG-TERM ECOLOGICAL MONITORING SYSTEM**

SECTION I

OVERVIEW

**NPS/NRSHEN/NRTR-90/02
1st Edition: September 1990**

by

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This manual series is the result of the intensive efforts of many people. During the six year development and implementation period, the degree of cooperation and dedication to the task was exceptional and is deserving the extra attention given here.

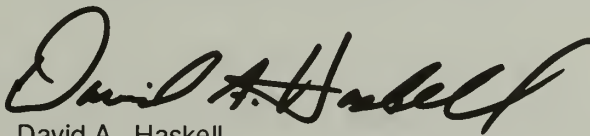
The Shenandoah National Park Inventory and Monitoring (I&M) program began with a vision; a vision born of the creative minds of several of our most respected National Park Service (NPS) scientists and managers. In this case, the vision was the realization of the critical importance of I&M to the future management and protection of the natural resources within the National Park System. There were undoubtedly others that contributed to this vision, however, those most active during recent years include: Dave Parsons, Dave Graber, Gary Davis, Ray Herrmann, Robert Stottlemyer, and Boyd Evison. The basic principles of I&M supported by these people and others can be found throughout this manual series. Their contribution to this effort is a real one and cannot be overlooked. Thank you all.

It is quantum leap from vision to action. The person that made this all possible was Mid-Atlantic Regional Chief Scientist John Karish. He recognized the urgent need for an I&M program at Shenandoah National Park (SNP) and provided financial support and program direction. He was determined to get this project started and to see it through; and he did.

One of the most unusual aspects of this project was the dedication of the I&M work group at Virginia Polytechnic Institute & State University. Their names can be found on the cover sheets of each manual section in which they were involved. These people showed a remarkable sense of responsibility for the quality of these manuals and can be rightly proud of their accomplishments.

The Park staff were the work horses of the project. Supervisory Natural Resource Specialist Rick Potts and Geographic Information Specialist Specialist Alison Teetor, were involved from the beginning, others entered the program as it grew, assuming key roles during the implementation period. Rick, more than any other, was responsible for the quality and reliability of field protocols selected for inclusion in the manuals. His uncompromising quest for quality is evident in all of his work. Superintendent Bill Wade and Assistant Superintendent Paul Anderson are avid supporters of the Park's I&M program. Their tenacious dedication to quality natural resource protection and management is well known.

These people made up the team. I am proud to have the opportunity to work with them on this project.



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RELATIONSHIP OF MONITORING, RESEARCH, AND MANAGEMENT

The subject of this series of documents is a Long-Term Ecological Monitoring System (LTEMs) that is to be used for managing the natural resources of the Shenandoah National Park. It is important to have a thorough understanding of some of the underlying concepts, especially that of monitoring. The terms monitoring and research are often used interchangeably, but their meanings are really quite different. Monitoring in the context of ecology is the systematic sampling and measurement over time of variables that describe the distribution and abundance of biological resources, the distribution and concentrations of physical, geological, and chemical properties, or the location and rates of important processes (O'Connor and Flemer 1987). It can be thought of as a descriptive status report on an integral of time and space. The purpose of monitoring is to obtain time series data sets that will detect significant changes in the environment and to provide timely warning and other important advice to managers (Segar et al. 1987).

Research can be defined as the systematic collection of data that produces new knowledge (O'Connor and Flemer 1987). The key word that distinguishes research from monitoring is "knowledge," which implies a greater understanding than can be obtained only by monitoring. The purpose of research in the context of ecology is to interpret facts, such as those obtained by monitoring, so that changes in the environment can be explained and the eventual consequences of those changes predicted. Research involves the experimental approach, in which the probable cause of an observation is determined by formulating an hypothesis and testing it in situations with and without the suspected cause. Research can be thought of simply as the use of the classical scientific method.

Unfortunately, a "scientific snobbery" has developed in ecology that dismisses "mere monitoring" as though it were unscientific (Taylor 1989). Ecological studies that are not conducted by means of specific questions, hypotheses, and the experimental approach are often regarded as "pedantic or pedestrian" (Likens 1983). A good example of this can be found in a review of the National Science Foundation's Long Term Ecological Research (LTER) program (Callahan 1984). He explains how the LTER program was developed through a series of workshops from 1977 to 1979 involving nearly 100 experts. During this time the title of the program wound up being "research," with "monitoring," "measurement," and "observation and study" having been considered and rejected. The evolution of this title

documented the rejection by the participants of "collecting data for the sake of collecting data." It reflected the insistence of the workshop participants that the only way to expand ecological theory and to solve problems of environmental resource management is to organize research projects around ecological questions and hypotheses.

While no one should argue that experimentation has an important place in ecology (and that the LTER program is making valuable contributions to ecology), the importance of monitoring has been greatly underestimated (Likens 1983, Taylor 1989). Many of the environmental concerns that we have today, such as acid deposition, ozone depletion, toxic waste disposal, and changes in global climate, were unheard of 30 to 50 years ago when some of the effective monitoring programs were being established. While monitoring programs may not be directed at specific questions originally, the long-term records from monitoring programs eventually provide the opportunity to formulate hypotheses and to use the experimental approach for determining cause and effect by using previous time series data sets as a comparison (Likens 1983). Taylor (1989) has taken this argument a step further and has suggested that the experimental approach often may not be appropriate for establishing ecological knowledge, particularly at the community and ecosystem levels. The philosophy of science, with its emphasis on hypothesis testing, had its origins in the physical sciences. There, scientists can presume that change is not likely to be occurring, so experiments can produce scientific knowledge by proceeding from hypotheses to theories to laws within a reasonably short period of time (certainly within the span of a professional career). Perhaps it is unreasonable to think that ecological knowledge can be established by the classical scientific method, because biological evolution and landscape geomorphology are ongoing processes. The complexity of interactions in communities and ecosystems also makes the design of effective experiments exceedingly difficult. Therefore, in ecology, observations and descriptions over long periods (monitoring) are necessary to formulate meaningful, testable hypotheses.

The Organic Act of 1916 established the National Park Service and gave it the challenging mandate to conserve scenery, natural and historic objects, and wildlife in national parks and to leave them unimpaired for future generations, while simultaneously providing for public enjoyment of the national parks (Keiter 1988). Although the term natural resource management did not appear in the original mandate, today this is the term that best describes the practice used by the Park Service to accomplish its fundamental purpose. Giles (1978) gave an excellent explanation of wildlife resource management, which is also applicable

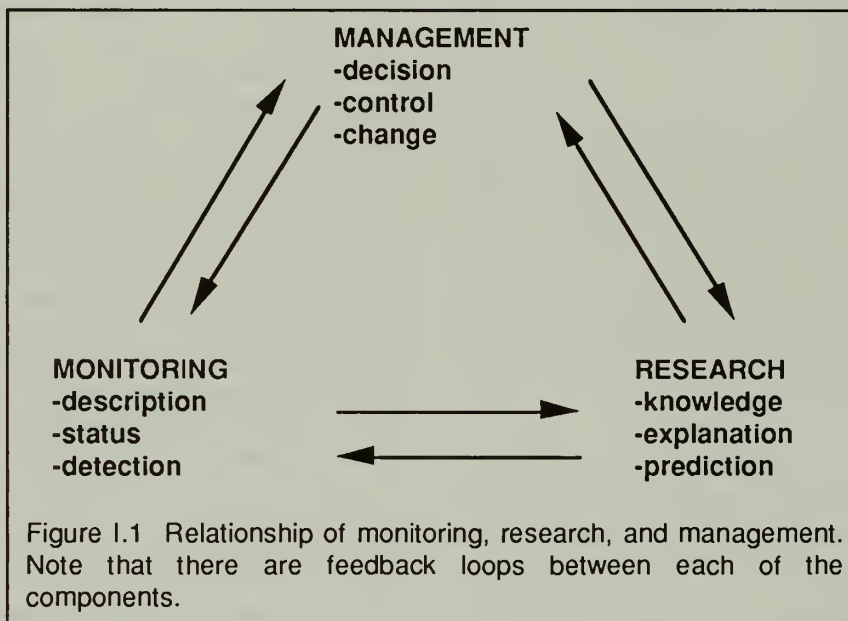
to the broader concept of natural resource management. A resource supplies specific benefits to people, and it is people who decide what is a resource. Natural aspects of the landscape, such as forests, mountains, streams, and wildlife, exist with or without people, but they only become natural resources because of human endeavors. These human endeavors do not have to be consumptive; simply enjoying the aesthetic qualities of a landscape unit can qualify it as a natural resource. If people disappeared or stopped utilizing forests, mountains, streams, and wildlife, these things would no longer be resources. Natural resource management is the science and art of making decisions and taking actions to manipulate the structure, dynamics, and relations of populations, habitats, and people to achieve specific human objectives by means of the natural resources. Because, by definition, a

natural resource is used to supply benefits to people, it would be impossible to maintain the availability of natural resources without their management. Management is a decision science. The object of this decision making is control. Unless change results that is significantly different from that which would occur without the presence of the manager, no management has occurred. There are two kinds of management: active and passive. Active management involves taking positive measures such as increasing, stabilizing, or decreasing. Passive management is achieved by preventing certain actions from taking place or letting natural developments take their course.

There are feedback loops between monitoring, research, and management (Fig. 1.1), and it will not be possible for the NPS to accomplish its mandate without careful attention to all three components. The LTEMs that is the subject of this series of documents can be used as an example of the relationships between the components. A major concern in the SNP at the present is infestation by the gypsy moth. As the name LTEMs implies, the continuing emphasis is on acquiring time series data sets that can be used to detect environmental changes. As part of the LTEMs, data are being acquired on gypsy moth populations, components of stream ecosystems, and components of forest ecosystems

throughout the SNP. By reviewing the descriptive status reports generated from the monitoring program, resource managers might detect changes in the macroinvertebrate communities of some streams that they suspect are being caused by gypsy moths defoliating the forest canopy over the streams. If the changes were suspected to be a significant detriment to the streams and the important brook trout populations that reside in them, resource managers could immediately make the decision to take control of the situation and change the

outcome by closing the affected streams to fishing. A more likely scenario would be for the monitoring program to generate a research program that would provide sufficient knowledge to explain the cause and effect and to predict the eventual outcome of gypsy moth infestation on stream ecosystems. The experimental ap-



proach could be used to answer questions such as: how does defoliation of the riparian forest cause a change in macroinvertebrate community structure and how will the changes in food and habitat affect brook trout populations? An hypothesis for the former question could be that the macroinvertebrate community will consist of fewer shredders because of less leaf input to the streams and more grazers because of the greater abundance of periphyton brought about by more sunlight reaching the stream. An hypothesis for the latter question could be that populations of brook trout will be reduced because of less macroinvertebrate food and increased water temperature. If this knowledge was acquired as a result of the research program, resource managers might decide to take firmer control of the situation and make more aggressive changes such as implementing integrated pest management to reduce gypsy moth populations.

Note that in Figure 1.1, the arrows go in both directions between each of the components. If a management decision is made, either to take action or not to take action, the outcome of that decision must be monitored to determine if the decision was correct. If a stream is closed to fishing to improve the success of brook trout, those populations should continue to be monitored to see if they do increase. Because of the

complexity of communities and ecosystems and their dynamic nature, it is difficult to determine if ecological research results are accurate; therefore, monitoring is necessary for validation. If research results suggest that macroinvertebrate shredders are reduced by gypsy moths defoliating the forest canopy, the macroinvertebrates should continue to be monitored to determine if natural population cycles might have been the cause. If an active management option is pursued, such as the use of pesticides to reduce gypsy moth populations, then additional research should be implemented to determine the ecological effects of that decision.

OVERVIEW OF LONG-TERM STUDIES

There are numerous examples that document the importance of long-term studies (monitoring and research) in ecology (see Likens 1983, Callahan 1984, Franklin 1989, Taylor 1989 for reviews and discussion). The explanation that is common to all long-term studies is that natural systems are complex, so it takes longer in ecology than other disciplines to build up enough useful background information for developing meaningful hypotheses (Likens 1983). Franklin (1989) specified four classes of ecological phenomena for which long-term studies are essential: slow processes, rare events or episodic phenomena, processes with high annual variability, and complex phenomena. Forest succession, population dynamics of long-lived organisms, soil development, and wood decay are examples of important slow ecological processes. Any ecological phenomena that require more than a few years to occur fall into the category of rare or episodic. Many long-lived species are episodic reproducers. Disturbances, such as fires, floods, and extreme weather conditions, are important because they reset ecosystems, but they occur occasionally and irregularly. Biological phenomena linked to highly variable physical phenomena will also be highly variable (e.g., plant productivity and precipitation). Patterns of complex phenomena, such as nutrient dynamics, are often difficult to distinguish from "noise" in ecosystems.

There are too many "success stories" in long-term studies to mention all of them here, but a few selected examples are included. The longest study has been the Park Grass Study at Rothamsted in England, which was begun in 1856 and continues today (Taylor 1989). The Park Grass Study was begun as an agricultural experiment to determine the combination of fertilizer treatments that would produce the best hay yield. Over the years it has evolved to be a study of ecological principles, including all flora and fauna. The Park Grass Study has shown that 100 years is not long enough to determine with certainty the full effects of even such a simple ecological treatment as fertilization. The most valuable plot in the study is the control.

The longest continuous environmental study on any landscape in North America is that at the Coweeta Hydrologic Laboratory in the mountains of North Carolina (see Swank and Crossley 1988 for a review). The Coweeta studies were begun in 1934 to test theories in forest hydrology. It was necessary to establish an extensive database describing the hydrologic cycle in watersheds, which has been accomplished by changing the vegetation cover and uses (e.g., grazing) of individual watershed units within Coweeta. In 1968, nutrient cycling studies were added as a logical extension of the hydrology studies. Both types of studies have been conducted according to the ecosystem concept. The Coweeta studies have made important contributions to understanding the nature of ecosystems and the best ways to manage natural resources. Specific hypotheses that have been tested have involved: mechanisms of resistance to disturbance and resilience following disturbance, closing of nutrient cycles, important shifts in successional species accompanying changes in substrate quality, alterations of nitrogen cycles, shifts in herbivory, and changes in stream communities.

Studies have been conducted at the Hubbard Brook Experimental Forest in New Hampshire since 1964, including terrestrial, aquatic, and atmospheric environments (see specific reviews by Bormann and Likens 1979, Likens 1985, Strayer et al. 1986, and frequent mention throughout Likens 1989). One of the most significant contributions of the long-term studies at Hubbard Brook was the documentation of acid deposition (Likens et al. 1979). Valuable insights into the effects of air pollution on forest productivity, forest harvesting practices, and forest developmental cycles have also been obtained.

The Long-Term Ecological Research (LTER) program of the National Science Foundation is a more recent effort, but probably has the broadest scope of any long-term study (see Callahan 1984 for an overview). It was developed from 1977 to 1979, and funding began in 1980. Fifteen sites have been established out of a planned total of 20 (Franklin 1989). These represent a diverse sample of ecosystems in the United States: coniferous forest, oak savannah, deciduous forest, salt marsh/estuary, desert, tall-grass prairie, short-grass prairie, large rivers, alpine tundra/lakes, lakes, and swamp. Comparability of data among sites is a high priority. At most sites, previous data were available. The LTER program is strongly oriented toward the experimental approach. The five core areas, which all funded programs are required to address, are: pattern and control of primary production, spatial and temporal distribution of populations selected to represent trophic structure, pattern and control of organic matter accumulation, patterns of inorganic input and

movements, and patterns and frequency of disturbance.

Although the above information represents just a small sample of the long-term studies that have been conducted, some important criteria for success are readily apparent (Likens 1983, Franklin 1989):

- 1) Continuous records must be maintained and constantly updated, scrutinized for errors, and rigorously analyzed. It is important to standardize methods and procedures. Careful attention must be given to what is the best frequency for samples in a time series.
- 2) Plots and other study sites should be permanently identified and marked, with records kept in more than one place.
- 3) There must be an appropriate administrative structure to guarantee stability and continuity. Dedication to a study should be rewarded appropriately so that the same talented persons will remain at work for as long as possible. Because of the duration of long-term studies, it is inevitable that there will be changes in personnel, so there should be plans for making smooth transitions. Provisions should be made for long-term storage of some samples, which could be useful for analyses that were overlooked initially or for which new techniques might become available. Voucher specimens of the biota should be placed in museums where they will be guaranteed to receive permanent curatorial care.
- 4) Funding must be sustained and reliable. Responsible agencies and institutions must be willing and able to make long-term commitments.

HISTORY OF MONITORING BY THE NATIONAL PARK SERVICE

The National Park Service has never had a sustained, comprehensive monitoring program. The monitoring that has been done largely reflects the changing priorities and philosophies for managing natural resources in national parks. The following review is based upon publications by Commission on Research and Resource Management Policy in the National Park System (1989), Stottlemeyer (1987), Franklin (1989), and Sellars (1989).

Scenic preservation was the major factor behind the establishment of the system of national parks that began with Yellowstone in 1872. The aspects of the scenery that appealed to the public were spectacular topography and conspicuous biological components

such as trees, wildflowers, large mammals, and attractive birds. The Organic Act of 1916 established the National Park Service and gave it dual responsibilities of preserving natural resources and providing for public enjoyment in national parks. During the first 20 years of its existence, the Park Service placed top priority on the latter responsibility. Most activities were aimed at promoting and developing the parks to accommodate visitors. Any preservation activities were primarily for protecting scenery. Forest fires were suppressed, predators of large mammals were eradicated, and forests were sprayed to prevent defoliation by insects.

There were no monitoring programs during this period. Because the accepted practice of protecting scenery, which has been termed facade management, had no foundation in science there was no need for ecological information. It was believed that as long as development activities did not change the scenery, the parks were being preserved. In fairness to the NPS, ecological science was not well understood at that time and was not capable of contributing information that would have been useful for managing natural resources.

In the 1930s, the NPS first began to give consideration to scientific information for managing natural resources. Ecology and other natural sciences had advanced to the point where it was possible to understand that the natural resources in parks were interrelated components of ecosystems. The leader of this effort was George Wright, an independently wealthy NPS biologist who personally funded the first biological survey of parks in the early 1930s. Wright believed that science based management was essential to the success of the National Park Service. The first monitoring programs were begun in this period. He and his colleagues began inventories and prepared management strategies based on their findings (Wright et al. 1933, Wright and Thompson 1935). Unfortunately, the scientific movement within the NPS was set back with Wright's death in an automobile accident in 1936. Money and manpower for science in the parks were greatly reduced during World War II and the years immediately after the war.

In the postwar years and continuing through the 1950s, NPS philosophy reverted to the original emphasis on development. Tourism increased dramatically during this period, and the Service responded with "Mission 66," a billion dollar program for construction of new facilities. Science was not given high priority during this period.

In the 1960s, scientists inside and outside the Service renewed George Wright's efforts to establish science based management in national parks. Two reports released in 1963 were particularly influential.

The National Academy of Science's Robbins' Report (prepared by a committee chaired by Dr. William J. Robbins) reiterated that parks were part of ecosystems in which the components were interrelated and that management should be based upon intensive scientific research to ensure preservation of natural resources. The Leopold Report (prepared by a special advisory board chaired by Dr. A. Starker Leopold) has been the foundation for natural resource management in the parks for the past 25 years. The Leopold Report also indicated that credible scientific information should be the basis for natural resource management but went a step further and described the biotic associations that should be maintained. It put forward the idea that national parks should be managed as "vignettes of primitive America," meaning that the biotic assemblages should be what existed, or would have evolved, without the discovery of America by Columbus and subsequent European settlement. Although the "vignettes" concept may have been unrealistic (Johnson and Agee 1988), the Leopold Report has been a significant positive influence on natural resource management because of its emphasis on maintaining overall biological integrity.

In spite of acceptance of natural resource management based on principles of ecology, the NPS did not establish a comprehensive long-term monitoring program in the years following the Leopold Report. Serious scientific endeavors have been undertaken, but most of these have been short-term studies directed toward solving immediate problems. There have been a few examples of long-term monitoring programs in national parks such as the unique marine resource program at Channel Islands National Park and the wolf-moose studies at Isle Royale National Park. Several parks (e.g., Olympic, Sequoia, and Rocky Mountain) have used their participation in the National Acid Precipitation Assessment Program to initiate long-term studies.

In the past several years there has been the most serious interest in the history of the NPS for establishing long-term monitoring programs. Draft I&M guidelines (NPS-75) were prepared in 1989. This document includes the Inventorying and Monitoring Policy Statement, which was put forward in the Natural Resources Inventory and Monitoring Initiative of May 1987 (revised July 1987):

"It is the policy of the National Park Service to assemble baseline inventory data describing the natural resources under its stewardship, and to monitor those resources forever - to detect or predict changes that may require intervention, and to provide reference points to which comparisons with other more altered parts of the home of mankind may be made."

Important definitions are given for:

natural resource inventorying - "the process of acquiring, managing, and analyzing information on Park resources, including the presence, distribution, condition of plants, animals, soils, water, air, natural features, biotic communities, and natural processes"

and

long-term monitoring - "the systematic collection and analysis of those resource data at regular intervals, in perpetuity, to predict or detect natural and human-induced changes, and to provide the basis for appropriate management response."

JUSTIFICATION FOR LONG-TERM MONITORING BY THE NATIONAL PARK SERVICE

It would have been ideal if the scientific programs begun by George Wright had been adopted as standard policy and continued to the present. More than 50 years of ecological data from national parks would now be available! Even though there has been a 50-year delay in recognizing the significance of ecological monitoring for managing the natural resources of national parks, the need has never been more critical than at the present.

Elfring (1986) has described the national parks as being at a cross-roads. He summarized the significant problems that were listed in a 1980 report by the Park Service titled *State of the Parks: A Report to Congress*. Seventy-three types of threats to the parks were listed. The sources of more than 50% of the problems were outside of the parks. Industrial and commercial development on adjacent lands, air pollution, urban encroachment, and roads were the most frequently cited external threats. Scenic resources were reported as threatened in more than 60% of parks, air quality in more than 45%, and animal, plant, and freshwater resources in more than 40%. A clear indication of the need for long-term monitoring programs is that 75% of the perceived problems were reported as being inadequately documented and in need of research. It is doubtful that any of the threats have lessened since the *State of the Park Report*, yet most park databases are still considered to be inadequate to document such environmental impact (Stottlemeyer 1987).

Quantification of ecological changes brought about by anthropogenic causes is difficult because ecosystems are continually changing, and these changes are not always predictable (Johnson and Agee 1988, Brubaker 1988). It is now recognized that a variety of natural disturbances play an integral role in

the long-term maintenance of virtually all ecosystems (Christensen 1988). The only hope for distinguishing natural and unnatural changes is to have a reliable database of ecological information.

Recommendations have been made that national parks, because of their reasonably natural conditions and the diversity of ecosystems represented, can be used to develop scientific knowledge and to help solve environmental problems beyond their boundaries. As protected areas dedicated to the preservation of natural ecosystems, national parks present many advantages as sites for conducting long-term ecological studies (Parsons 1989). The large national parks may be particularly important to the ecological health of the planet by serving as reservoirs of genetic diversity (Sellars 1989). With appropriate long-term monitoring programs, national parks can provide benchmarks for measuring local or global environmental changes (Commission on Research and Resource Management Policy in the National Park System 1989).

The concept of ecosystem management has been suggested recently as the most effective means for appropriate stewardship of national parks (Johnson and Agee 1988, Agee and Johnson 1988). They explain this strategy as follows:

“Ecosystem management involves regulating internal ecosystem structure and function, plus inputs and outputs, to achieve desirable conditions. It includes, within a chosen and not always geographic setting, the usual array of planning and management activities but conceptualized in a systems framework: identification of issues through research, public involvement, and political analysis; goal setting; plan development; use allocation; activity development (resources management, interpretation); monitoring; and evaluation.” With regard to monitoring, one of the principles of ecosystem management that they emphasize is that high quality information is necessary to identify trends and respond to them.

In 1988, the National Parks and Conservation Association, with funding from the Andrew Mellon Foundation, established an independent 17-member Commission on Research and Resource Management Policy in the National Park System, chaired by Dr. John C. Gordon.

The commission was charged to review the Leopold Report and to prepare its successor. In its report (Commission on Research and Resource Management Policy in the National Park System 1989), the commission was generally complimentary to the Leopold Report and did not suggest that it be discarded;

however, the commission did suggest some modifications. Included was a recommendation for the NPS to change its natural resource management policy to the holistic approach of ecosystem management. A specific recommendation was for “establishing an integrated inventory and monitoring program.”

INTRODUCTION TO SHENANDOAH NATIONAL PARK'S INVENTORY AND MONITORING PROGRAM

The decision was made in 1984 to develop a comprehensive I&M program for Shenandoah National Park (SNP). Realizing that this program would take several years to establish, it was divided into segments or phases. The first phase of this effort was to design and implement a core program. This program, later named the Long-Term Ecological Monitoring System (LTEMs), was designed to monitor a basic set of ecological parameters that would characterize the broad types and rates of changes likely to take place in the Park. The monitoring of specific populations or discrete ecosystem parameters would be added later during phase two. Of particular concern was the future impacts of the alien gypsy moth (*Lymantria dispar* L.) on forest systems. Therefore, much of the monitoring design was focused on those ecosystem components most likely to be affected by widespread defoliation, such as forest composition and aquatic systems. Other likely perturbations such as wildfire, acid deposition, air pollution impacts, and visitor use impacts were also considered when determining the monitoring design and protocols. By considering these other types of disturbances, the basic monitoring design would capture a range of change wider than those caused solely by gypsy moth.

The first three years were focused on the establishment of Park's I&M objectives, program design, selection of monitoring protocols, and the field testing of data collection methods. Two key factors considered at this time were what to monitor and how to do it. This might seem simple on the surface, but in reality it turned out to be the most difficult issue to settle. It quickly became obvious that we could not monitor everything. What was needed was a method to prioritize the “laundry list” of possibilities. The factors that were eventually selected to determine what would be monitored in the Park's I&M program included the following, in order of priority:

1. Resources specifically mentioned in the Park's enabling legislation, listed as threatened or endangered, or otherwise given special status by law;

2. Key ecosystem processes that can be well defined and accurately accessed. (High priority to those likely to be impacted by gypsy moth);
3. Species or processes that may impact on public health or safety or are locally controversial (gypsy moth threat to safety from tree mortality in developed areas);
4. Events such as fire, flood, erosion, weather patterns, etc.;
5. Resources being threatened by visitor use;
6. Baseline monitoring of species, populations or compositions that enhance our understanding of particular phenomena, relationships or population dynamics;
7. Species or populations that are of interest but of no particular management or ecological concern.

An evaluation of these priorities lead to a conceptual model of the total I&M program. We then had to focus on broad resource categories that were most likely to be impacted by gypsy moth defoliation. This process lead to a specific set of priorities.

From this set of priorities a list of species or processes that we wanted to monitor was established. The next step was to determine if the technology existed to accurately monitor them. As an example, stream macroinvertebrate community structure was high priority on the list of species populations to monitor. It was finally determined that the technology did exist to make the measurements and that it was feasible for us to do it. This process was continued for each priority on the list. Numerous meetings and brainstorming sessions with subject matter experts from nearby academic institutions, cooperating federal and state agencies, and the private sector were held to assist with this process. A literature review was also conducted for many of the more critical resources to be monitored. During this time period a cooperative agreement was established with Virginia Polytechnic Institute and State University (VPI & SU), to assist the Park in developing the LTEMs and in the writing of the user manual series. From this time on, most of the work was accomplished jointly between the principle investigators at VPI & SU and the staff of the Division of Natural Resources and Science, SNP.

It was discovered that it would not be practical to monitor some of the things that we wanted to. Following a rather lengthy period of study and analysis, we finally arrived at a set of parameters that were both a high priority and were technically feasible within our

projected budget and staffing constraints. The broad parameters that were most likely to detect changes brought about by gypsy moth defoliation and other major disturbances were included in Phase 1. Others were set aside for inclusion in the program during later phases. Pilot measurement protocols for the selected parameters were then designed and field tested. Numerous adjustments were made to perfect techniques. A great deal of care was taken to ensure that all measurements would be both accurate and repeatable. Quality assurance and quality control (QAQC) factors were developed along with the protocols. The Mid-Atlantic Regional Chief Scientist was consulted on numerous occasions for input on critical issues and to arrange for peer review of draft protocols.

An extremely important portion of the overall program development was the structure and design of the database management system. It was recognized from the onset that a custom designed database program would be needed to store, analyze, and process the large amounts of data that would be collected and to prepare data summary reports. The database was designed during the same time period as the protocols were developed so that as changes were made to collection protocols corresponding changes would be made to the database system.

The goal of the second three year LTEMs period was to establish the core forest and aquatic plot system. Since test plots were already worked out during previous years, little further modification was necessary. Baseline data were acquired during this period and some valuable inventory information was collected in the process. All of the aquatic plots were established in the first year. One third of the forest plots were established each year so that the remeasurement cycle of once every five years could be established. (The fourth year is to visit each plot to re-establish any lost corners and accomplish any other needed maintenance.)

An I&M program of this or similar magnitude requires a considerable amount of dedicated staffing to maintain and operate. A suggested minimum staffing would include:

Program Manager: Full time to one half time depending on program.

Database Manager: Full time.

GIS Support: Full time to one half time.

Field Technicians: two WY temporary biological technicians at SNP.

The three LTEMs resource components: gypsy moth, forest, and aquatic (physical, chemical, biological) were developed as the core of the I&M program. Other components that are currently being monitored but formal manuals have not yet been written include: mammals (bear, deer), air quality, meteorology and weather, fish, and watershed acidification. Monitoring components that need to be developed include: mammals (other than megafauna), amphibians and reptiles, insects, and bio-geochemical cycling.

In conclusion: It is recognized that this set of monitoring manuals will only directly apply to those areas that have a natural resource base similar to that of Shenandoah National Park. The specific techniques selected to monitor change in forest and aquatic systems will have to be designed to meet specific needs of each NPS area. However, the process that was used to establish priorities and select protocols should be applicable to nearly every situation and could be of some assistance to anyone planning a more formal and comprehensive I&M program.

RATIONALE FOR DESIGN

General Considerations

The 300 square mile Shenandoah National Park (SNP) was authorized by Congress in 1926 and dedicated by Franklin D. Roosevelt in 1936. Since its establishment, the Park has reverted from overused farmland to natural Appalachian forest. It has been the responsibility of the National Park Service to manage the SNP and maintain it as a natural area. In recent years Park managers have encouraged scientists from various colleges and universities to conduct research that would provide information essential for the proper management of the Park. Throughout this research many ecological and environmental characteristics have been inventoried and studied. Data describing these characteristics have been collected at various times and locations, with regard to management concerns and the unique objectives of research projects. Although this approach has led to a solution or understanding of many time and site-specific ecological phenomena and problems, the data collection efforts have not been coordinated park-wide, thus an understanding of long-term and large-scale environmental changes and ecological processes has not occurred. Also, it has been difficult to determine exactly what methods were used to collect data associated with the studies. Comparisons between studies and areas is therefore difficult and an integrated database to describe ecological and environmental characteristics over a variety of locations has not been possible.

Many threats and disturbances, now and in the future, will affect the National Parks. Global warming, toxic waste, acid precipitation, and introductions of "undesirable" exotic species have come to the forefront. The impact of some of these threats will not be known for many years while for others the impact is immediate. No matter what time frame is pertinent to experiencing the impacts of ecological perturbations it is clear that a large-scale, long-term ecological monitoring system (LTEMs) is necessary to determine the extent and intensity of perturbations and assist in managing problems, where appropriate.

While virtually any perturbation can be monitored not all ecological perturbations lend themselves to easily developing a LTEMs. For example, global warming is a well documented phenomenon but the extent of ecological impacts and the time-frame over which the impacts will occur is uncertain. Acid precipitation may affect ecosystems in the short-term but, as with global warming, the full extent of ecological impacts may occur gradually or for some ecosystems be limited in scope and intensity. Defoliation by the gypsy moth in the Shenandoah National Park is a perturbation that can be used as a model to develop a LTEMs.

Forest Component

The forest component of the Long-Term Ecological Monitoring System (LTEMs) is a permanent plot system to provide data for evaluating changes in the forest vegetation of the (SNP). The objectives of permanent plots are to evaluate changes in forest composition, structure, regeneration, and growth as they may be influenced by numerous natural and anthropogenic factors over time. The periodic measurement of permanent sample plots is statistically superior to independent inventories for evaluating changes in forest conditions (Avery and Burkhart 1983). These plots will be systematically established to cover a range of ecological land units (ELU) throughout the SNP. Data collected by measuring these plots at periodic intervals will provide information needed to identify changes that occur within the various ELUs as a result of natural succession or perturbations (gypsy moth, ice storms, fire, atmospheric deposition, etc.). The LTEMs will provide a general framework and baseline data to enable future researchers to utilize the plots for various study purposes.

The LTEMs is not intended to provide an inventory of the SNP's forest resources. Furthermore the objective of monitoring ecological changes precludes the LTEMs from being useful as a sampling system for inventorying the SNP. An inventory would be obtained with a more extensive system that could include hundreds of sampling sites, allocated to the

various forest cover types in proportion to the extent to which those cover types existed in the SNP. By contrast, the LTEMs system is established to monitor ecological changes in each of eight designated forest cover types identified within the SNP. To accomplish this goal, an equal number of sites must be identified in each cover type whenever possible. An additional forest cover type category has been identified in order to allow monitoring of unique vegetation cover types under the LTEMs program.

Criteria for Site Selection

Locations for LTEMs sites must be selected to encompass all representative combinations of forest cover type, elevation, aspect, and management districts of the SNP. The major categories of site (forest cover type, elevation, and aspect) and location (district) are as follows:

Forest Cover Type

- Chestnut Oak
- Northern Red Oak
- Cove Hardwoods
- Yellow-Poplar
- Black Locust
- Pitch Pine
- Virginia Pine
- Eastern Hemlock
- Special (unique cover types)

Elevation

- Low: 381-533 meters
(1250 - 1750 feet)
- Mid: 686-838 meters
(2250 - 2750 feet)
- High: 991-1143 meters
(3250 - 3750 feet)

Aspect

- Moist: 350 - 100 degrees azimuth
- Dry: 170 - 280 degrees azimuth

Administrative District

- North
- Central
- South

Each forest cover type represents a separate association of plant species that occurs within the SNP in response to a combination of site factors, natural succession, and disturbances, both natural and man-caused.

Forest cover and panoramic views associated with the significant topographic relief of the Blue Ridge and adjoining secondary ridges are the primary ameni-

ties of the SNP. Forest types are therefore the basic ecological variable used in the complex management of the park's aesthetic, wildlife, recreation, forest and water-based resources for the long-term benefits of our society.

Elevation and aspect are the two most important site factors that directly and indirectly affect forest cover. Both of site factors affect temperature and water on a site-specific basis. As elevation increases, temperature decreases and precipitation increases. Both of temperature and precipitation affect site quality by increasing available soil moisture. Site factors such as rock weathering and soil formation are affected by changes in vegetation type, soil micro-flora and -fauna, and soil leaching rates. In addition, there is recent evidence that suggests that certain air pollutants increase with increasing elevation.

Aspect affects forest cover primarily as a result of changes in site quality directly related to temperature-induced available soil moisture changes. As the aspect shifts from cool, moist north and northeast exposures to warm, dry south and southwest exposures, evapotranspiration rates increase significantly as a result of high afternoon air and soil temperatures, reduced relative humidity, and direct solar radiation. The end result is that each cover type may experience varying levels of environmental stress under differing combinations of elevation and aspect.

The 8 forest cover types encompass the complete range of forest cover conditions that occur in SNP. The 3 elevation levels and 2 aspects represent a workable array of site conditions that are representative of site conditions found within the 3 management districts of SNP. The combination of 8 cover types, 3 elevational categories, and 2 aspects produces 48 separate ELUs. To provide the necessary statistical replication for evaluating influences of cover type, elevation, or aspect, each ELU will be replicated by randomly locating a site for each ELU within each of the 3 management districts of the SNP, thus producing a theoretical total of 144 sites. The "special" forest cover type is not intended to be replicated and is therefore not included in the site totals.

Two difficulties will occur when trying to locate all the sites according to the above plan. First, some combinations of cover type and aspect are mutually exclusive. For example, it may be difficult to locate yellow-poplar on SW aspects or pines on NE aspects. The moist, cool, and fertile site conditions required for the establishment, growth, and development of yellow-poplar do not occur on most southwest aspects, and the rapid growth and competitive nature of most hardwoods normally preclude the germination and growth of pitch,

Table Mountain, and Virginia pine on northeastern aspects. Combinations which cannot be located can be disregarded without compromising the LTEMs objectives. Secondly, elevational differences throughout the SNP will make it difficult to find all ELUs in each District. The 3500 ft elevation classes may be especially difficult to locate in each District. While it is important that each ELU be represented by three sites within the SNP, it is not imperative that they be evenly divided among the three Districts. In these cases it is acceptable to select a second (or third) site within a single District.

Site Selection

The SNP has instituted a geographic information system that is linked to the LTEMs databases and provides immediate access to geographically referenced data to aid in making resource management decisions. The geographic information system/database provides the information used in the initial phase of LTEMs site selection. The term *site* in this case refers to the specific ELU location where the replicated research plots will be installed. Forest cover type, elevation, aspect, and administrative district are all data variables available from the SNP geographic information system database. The LTEMs site selection process is composed of two phases or levels. The first phase is based on the geographic information system/database and associated aerial imagery, and is accomplished in the office. The second phase is field verification in which the designated field party leader, using the geographic information system, travels to the specific site location to verify that the forest cover type, elevation, and aspect all meet the specified characteristics for an LTEMs site. The field party leader, after on-site verification, monuments the site location for the first plot, or rejects the site as not meeting the LTEMs requirements. In the case of site rejection, the field team leader would move to the next LTEMs site that was randomly selected as meeting the specific characteristics. This selection and verification process would continue until the required number of valid sites are found, or until it is determined that they do not exist within the boundaries of the SNP.

Permanent plot locations must be determined so that 1) they are representative of the forest conditions for which inferences will be made, 2) they can be relocated easily for remeasurement, and 3) their physical integrity can be maintained for the duration of the LTEMs program.

Aquatic Component

Site Selection

In order to select the best design for the aquatic component of the LTEMs, an extensive reconnaissance of SNP streams was conducted from January to April 1986. Thirty-three locations on thirty streams were visited. The reconnaissance consisted of making cursory examinations of the physical environment and macroinvertebrates at each location. Written notes and tape recordings of the investigators' observations were made for later review. In addition, information on geology (Gathright 1976), water chemistry (Dise 1984), and fishes (unpublished reports) were reviewed. From this information, the streams were classified in the following hierarchical system, and then representative study sites were selected from the different classifications. The rationale behind this design was to have all of the naturally occurring environmental conditions included in the LTEMs and to have sites spread throughout the area of the SNP. For the aquatic component, the term site refers to a designated length of stream along with the riparian area.

Administrative District

- North
- Central
- South

Geological Formation/Alkalinity

- Catoctin (100-200 ueq/L)
- Pedlar or Old Rag (20-100 ueq/L)
- Hampton or Erwin (<20 ueq/L)

Elevation

- Upper (>548.6 m [1800 ft])
- Lower (<548.6 m [1800 ft])

Other Factors

- Accessibility
- SNP trout monitoring sites
- Current research interests

Using the three administrative districts as the first level of classification was a convenient means of distributing the stream sites throughout the Park. In most cases, it will be impossible to predict where an adverse impact might occur. Therefore, spreading the sites throughout the Park increases the probability of having data from where they might be needed.

Geological formations were selected as the second level of classification because the SNP has a uniquely diverse geology and resulting water chemistry, particularly alkalinity. There are great differences among watersheds, and often between adjacent watersheds. Alkalinity and related water chemistry are probably significant factors affecting the distribution of the aquatic biota. Information on geological formations and alkalinity can be obtained from Gathright (1976) and Dise (1984), respectively. Streams in the SNP seldom have their watersheds entirely within a single geological formation; therefore, stream sites were established in watersheds that have at least 75% of their area within one of the geological formation categories.

Elevation affects the distribution of aquatic biota indirectly because of factors such as stream width, depth, current velocity, valley shading, and temperature. The SNP is located entirely within the northern section of the Blue Ridge physiographic province, which is the narrow (about 8 km) mountainous area between the low-lying Piedmont province to the east and the Ridge and Valley province to the west (Hoffman 1969, Gathright 1976). Drainage basins in Blue Ridge province typically have a steep gradient. On the west slope basins follow a trellis pattern, in which the small streams flowing down the mountains are parallel and join the main stream in the valley (Shenandoah River) at right angles (Reid and Wood 1976). Those on the east slope follow a dendritic pattern, so-called because of the resemblance to tree roots (Reid and Wood 1976). The criterion of 548.6 m (1800 ft) for distinguishing upper and lower sites was selected because field observations indicated that streams in the SNP tended to become very narrow and shallow (several m wide and less than knee deep) approximately above that elevation. This delimitation was somewhat arbitrary and was varied within reason when it was desirable to have both an upper and lower site on the same stream. Elevation was determined from the Potomac Appalachian Trail Club maps (scale 1:62,500). The USGS 7.5 min topographic maps were not as useful because they are not as accurate regarding trails, fire roads, and stream permanency.

Accessibility was given serious consideration when choosing sites. If a site cannot be reached with reasonable effort at the desired time, then the data are likely to be sporadic and would not be useful for monitoring. Trout populations in the SNP have been monitored for some time; therefore, it was logical to establish LTEMs sites at many of the same locations so that there would be ecological data to explain the results of fish sampling. Gypsy moth infestation and acid deposition are environmental concerns at the present time in the SNP. Preference was given to stream sites that are likely to be affected by either of these two perturbations

or sites that are being studied as part of other research projects.

One of the most important criteria that was used for designing the LTEMs was feasibility. For the purposes of monitoring, data that are not obtained consistently are of no value. Therefore, it was essential to design a system that would not be overly ambitious for the financial resources of the SNP. It was decided that it would be feasible to monitor about one-half of the sites that had been visited during the reconnaissance. Seventeen stream sites were selected for the aquatic LTEMs. These are listed below, according to the hierarchical classification system. Additional information on the sites is provided in Section III of this series (Aquatic Component User Manual).

South District

- Hampton or Erwin
 - Paine Run (Upper)
 - Paine Run (Lower)
 - Twomile Run (Upper)
 - Twomile Run (Lower)

Central District

- Pedlar or Old Rag
 - Hazel River (Upper)
 - Hazel River (Lower)
 - Staunton River (Upper)
 - Staunton River (Lower)
 - North Fork Dry Run (Upper)

Catoctin

- White Oak Canyon Run (Upper)
- White Oak Canyon Run (Lower)
- Hog Camp Branch (Upper)
- Rose River (Lower)

North District

- Catoctin and Pedlar
 - Piney River (Upper)
 - Piney River (Lower)
- Catoctin, Hampton, and Weverton
 - Jeremys Run (Upper)
- Pedlar
 - Lands Run (Upper)

The streams sites are 100-m longitudinal reaches, which are marked inconspicuously with PVC pipes at the upstream and downstream boundaries. The 100-m sections were selected so that they included riffles and pools and as many microhabitats as possible (different sizes of rocks, logs, different current velocities, etc.). The rationale was that a well chosen 100-m reach of a stream would be large enough for all of the biota to be represented, including the fishes.

Parameters

Scientific defensibility was a second criterion that was given equal consideration along with feasibility in designing the aquatic component of the LTEMs. It was important to choose parameters that would be likely to show measurable changes in response to perturbations and to have information that could be used to explain any observed changes. Benthic macroinvertebrates were chosen to be the focus of the biological monitoring. Voshell et al. (1989) explained several reasons why benthic macroinvertebrates are commonly used for ecological monitoring. They are abundant in almost all freshwater environments. Sedentary habits and comparatively large size, in combination with abundance, make them relatively easy to collect. Most can now be identified reliably to genus with comprehensive taxonomic works that have become available (e.g., Pennak 1978, Brigham et al. 1982, Merritt and Cummins 1984). The benthic macroinvertebrates that exist in a given area are indicative of the environmental conditions that have occurred for at least several months previously because their life cycles last from several months to a year or more. Taken as a group, benthic macroinvertebrates have diverse habitat and food preferences, but many individual taxa have narrowly defined niches. Therefore, it is likely that some taxa will demonstrate a change in response to any perturbation that might take place. Activities of benthic macroinvertebrates affect major ecological processes of freshwater ecosystems. These significant activities include grazing on primary producers, decomposing organic matter, preying on smaller invertebrates, temporarily storing materials (spiralling), and providing food for fish.

Fish, especially brook trout, are one of the most important natural resources in the SNP. Protection of fish is one of the main reasons for conducting long-term aquatic monitoring in the SNP. Fish were not included as a parameter in the LTEMs that was developed by VPI & SU because fish populations were already being monitored by a joint effort between the SNP and the Virginia Commission of Game and Inland Fisheries. Whenever possible, the existing sites for fish sampling were also used as LTEMs sites.

Although the LTEMs emphasized biological monitoring of benthic macroinvertebrates and assumed that fish would also be monitored, it was also necessary to include a variety of physical and chemical parameters that could be used to explain any changes that might occur in the biota. The parameters that were chosen are listed below, according to broad categories of water quality and habitat. The rationale for choosing these parameters was that they could be measured

reliably and that they were related to the success of the biota. Detailed explanations of these parameters can be found in Section III of this series (Aquatic Component User Manual).

Water Quality

- Discharge
- Temperature
- Dissolved oxygen
- pH
- Alkalinity
- Conductivity
- Sulfate
- Nitrate
- Chloride
- Calcium
- Magnesium
- Potassium and sodium
- Silica
- Seston
- Bacteria

Habitat

- Depth
- Width
- Substratum
- Riparian vegetation cover
- Riparian vegetation type
- Debris retention
- Fish cover
- Pool-riffle ratio

Sampling Frequency

The feasibility criterion was given serious consideration in the decision about how often to collect samples. Because the emphasis of the LTEMs was on biological monitoring of benthic macroinvertebrates, which are comparatively long lived (about 1 yr), it was decided that sampling in the spring and summer quarters would be sufficient. The spring fauna is the most abundant and diverse in mountain streams such as those in the SNP, because many species are "cool adapted" and go into various resting stages during the warm months. Highest flows usually occur in spring, thereby increasing concentrations of suspended matter for food and the amount of usable habitat. The low flows of summer offer the greatest likelihood of degraded water quality, especially lower concentrations of dissolved oxygen caused by higher water temperatures. Lower flows during summer can also cause significant reductions in the amount of habitat that is usable by the biota. Therefore, it was thought that spring and summer sampling would reflect "best case" and "worst case" conditions, respectively.

Gypsy Moth Component

During the early 1980s, male gypsy moths were found in ever increasing numbers in Shenandoah National Park and egg masses were discovered in the Park in the winter of 1983/84. At that time light infestations were found in the Mathew's Arm/Piney River developed area, near Gravel Springs, and in the Compton Gap area. These populations represented the advancing front of the general gypsy moth infestation and with the abundance of preferred tree species and favorable physical geography, the establishment and spread of gypsy moth through the Park seemed certain. Indeed, the gypsy moth has successfully invaded the Shenandoah National Park defoliating 16,000 acres in 1988 and 43,000 in 1989. These events will alter "natural" ecosystem components and processes to various degrees over time. Implementation of monitoring, research, and management actions are needed to measure, understand, and mitigate unacceptable levels of ecosystem change as dictated by the gypsy moth.

In order to accommodate both the monitoring and management aspects of the gypsy moth problem, the Gypsy Moth component of the LTEMs has two parts, one part is designed to directly interface with the Forest and Aquatic components and has the objective of quantifying ecological change as a result of gypsy moth feeding. The second part of the Gypsy Moth component provides resource managers with information to make decisions on controlling gypsy moth populations.

No single monitoring system will provide all of the information required to monitor and manage the gypsy moth under different population phases (i.e., endemic, increasing, outbreak, and collapse) or monitoring and management objectives. Several methods must be combined to achieve the desired results. The Gypsy Moth component of LTEMs addresses the above problems by describing:

- the sequence of monitoring and management activities that coincide with different infestation phases,
- how gypsy moth defoliation can be quantified within the context of the Shenandoah National Park's Long-term Ecological Monitoring System, and
- how treatment decisions can be supported through the use of population estimates, landscape characteristics, and program characteristics.

Because the gypsy moth is still new to most national parks, detection and eradication of new infestations are major concerns. These first detections often result in eradication programs conducted through the cooperative efforts of state and federal agencies.

Detection and Eradication

Detection and eradication activities include the use of "delta-type" pheromone-baited traps placed at regular intervals over large areas. For example, traps have been placed over one-third to one-half of the state of Virginia at 3 km intervals for several years. Upon detecting one or more male moths a "delimitation survey" would be initiated to determine: if moths can be detected at the same location during a second year, the spatial extent of male moths, and through intensive searches of the area(s) of interest, if eggs, larvae, pupae, or female adults are present. If any of these situations occurs then eradication efforts may be implemented throughout the area and another delimitation survey deployed to determine the success or failure of the program. If no moths or other life-stages are found then the extensive 3 km detection survey is once again used. If eradication efforts are not successful then a decision must be made concerning continuing eradication efforts or the need to develop long-term monitoring and management plans for gypsy moth infested areas. Shenandoah National Park has moved from the detection/eradication mode to a monitoring/management plan which was developed by SNP resource management specialists and updated yearly.

Monitoring and Management Programs

Once the decision is made to monitor and manage gypsy moth populations developing plans and implementing programs is the responsibility of the national park. Essentially, the decision has been made to consider the gypsy moth as a natural part of the many ecosystems that make up the SNP or any other large land area. Decisions must then be made concerning what areas will:

- be monitored to provide information about the gypsy moth and its impacts on other components of the ecosystem (i.e., for use in the LTEMs),
- be considered as management areas, and
- not be monitored at all.

Population estimates for following the dynamics of the gypsy moth populations and their impact on ecosystems can be measured from egg mass densities and defoliation. Similarly, the basis for control deci-

sions in gypsy moth management programs is the relationship between egg mass density and defoliation.

However, monitoring systems for determining impact and management are not the same. *When monitoring populations for ecological impact, emphasis must be placed not only on the gypsy moth but on the many ecological variables that can be affected by the defoliation process (i.e., those measured by the Forest and Aquatic components of LTEMs). When management is the primary consideration, emphasis must be placed on projecting the level and spatial extent of defoliation that will occur in the subsequent growing season.* Once this has been accomplished, plans can be made to prevent unacceptable levels of defoliation in visitor areas, parkways, and campgrounds. Gypsy moth monitoring systems must be designed to be compatible with the objectives of different land areas and the LTEMs in place in the SNP.

Designing a monitoring system for gypsy moth populations and their impact on a national park's natural resources is dependent on the objectives of the program and available resources. Tree defoliation is the direct impact of gypsy moth feeding. Thus, measuring the spatial extent and levels of defoliation are the main variables of interest within the context of long-term ecological monitoring. Defoliation is a function of larval populations and the amount of foliage available for larvae to feed upon at a given location. Through larval feeding, frass is produced and uneaten bits of leaf material fall to the ground. This results in changes in the availability of nutrients to the various components of ecosystems (Mattson and Addy 1975). Gypsy moth population dynamics is also important from the standpoint of demonstrating the relationship between the insect and the forest. Tree defoliation and mortality, changes in tree species composition, species changes in understory trees and herbs, changes in water chemistry in streams, and the distribution and abundance of birds and other wildlife are all possible results of gypsy moth population changes through time.

To obtain estimates of defoliation and gypsy moth population size the Gypsy Moth component of LTEMs is composed of 4 parts:

- aerial-based park-wide defoliation data,
- ground-based defoliation estimates associated with each LTEMs site,
- gypsy moth egg mass population estimates also associated with each LTEMs site, and
- pheromone traps used to determine when to begin taking defoliation and egg mass samples.

When used together the parts can provide both an intensive and extensive picture of gypsy moth populations and their impact on SNP natural resources. Over several years, they can also provide information concerning the dynamics of the gypsy moth in the SNP. All three monitoring system components should be implemented; however, they can also be used individually in the event that resources or priorities change.

Database Management System

A user friendly database management system is an essential part of any large-scale monitoring activity. Without a database management system the millions, if not billions of bytes of data that will be collected in the future will be useless because resource managers would not be able to access them. While database systems have been described as "nothing more than computer-based recordkeeping systems" (Date 1981) this grossly understates their complex nature, the level of knowledge, and user interaction required to design systems which:

- shield users from low-level computer system commands,
- maintain the integrity of the database through error-checking, and
- allow users to relate the logic of long-term ecological data collection to data input and information output.

The SNP LTEMs database management system was developed in conjunction with the specific field sampling plans for Forest, Aquatic, and Gypsy moth data collection. All data entry screens and data fields are tailored to handle the data forms which were designed for this project. With minor modifications the programs could be implemented for use in other ecological monitoring systems.

The LTEMs Database Management System User Manual is designed to aid data entry personnel and also to answer more technical questions about the installation and maintenance of the software. The first five chapters address data entry of the five classes of data: sites, forest, aquatic, gypsy moth, and dictionary support files. Each chapter contains its own chapter contents list and may be reproduced by itself to function as a data entry manual for that particular data type. The technical notes chapter will assist in installation and day-to-day operation of the database from a technical point of view. The programmer reference chapter gives more details about the computer code, the data files, and the relationships of the database files and indexes.

All LTEMs programs were developed using dBASE IV® and then compiled for execution using CLIPPER®. Hardware requirements are an IBM compatible, preferably a 386 or 286 type machine, with a minimum of a 70 megabyte hard disk and a printer. With the rapid development of computer systems and databases this system configuration should be viewed as an initial configuration. With time, databases will become extremely large and may require more disk space, a tape backup system, or other mass storage devices should be considered as necessary additions to the system. Faster processors and computer clocks other than a 386, 33 mhz configuration will also become available and users may wish to also consider upgrading the computer for speed and convenience.

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**SHENANDOAH NATIONAL PARK
LONG-TERM ECOLOGICAL MONITORING SYSTEM**

SECTION II

FOREST COMPONENT USER MANUAL

**NPS/NRSHEN/NRTR-90/02
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by

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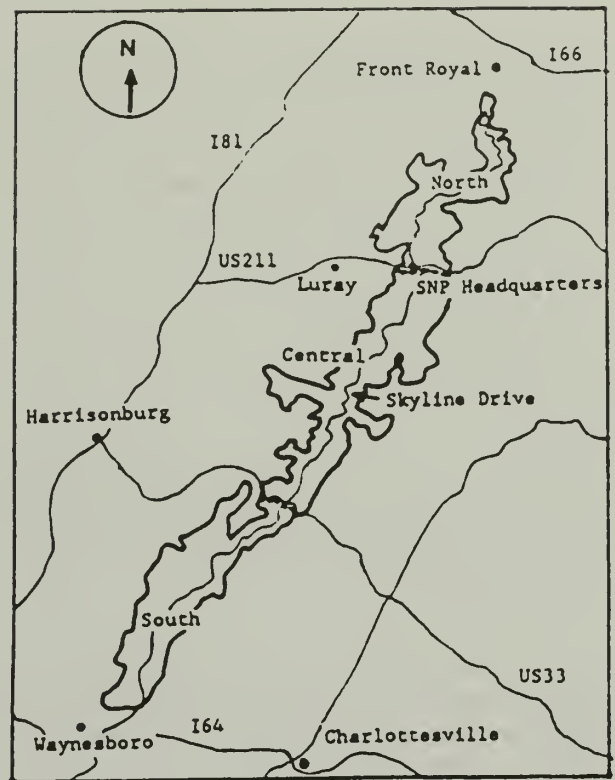
INTRODUCTION

The forest component of the Long-Term Ecological Monitoring System (LTEMs) is a permanent plot system to provide data for evaluating changes in the forest vegetation of the Shenandoah National Park (SNP). The objectives of permanent plots are to evaluate changes in forest composition, structure, regeneration, and growth as they may be influenced by numerous natural and anthropogenic factors over time. The periodic measurement of permanent sample plots is statistically superior to independent inventories for evaluating changes in forest conditions (Avery and Burkhart 1983). These plots will be systematically established to cover a range of ecological land units (ELU) throughout the SNP. Data collected by measuring these plots at periodic intervals will provide information needed to identify changes that occur within the various ELUs as a result of natural succession or perturbations (gypsy moth, ice storms, fire, atmospheric deposition, etc.). The LTEMs will provide a general framework and baseline data to enable future researchers to utilize the plots for various study purposes. This manual contains rationale for the general design of the LTEMs, methodology for locating sites, a guide for establishing and monumenting plots, and detailed instructions for collecting data.

The LTEMs is not intended to provide an inventory of the SNP's forest resources. Furthermore the objective of monitoring ecological changes precludes the LTEMs from being useful as a sampling system for inventorying the SNP. An inventory would be obtained with a more extensive system that could include hundreds of sampling sites, allocated to the various forest cover types in proportion to the extent to which those cover types existed in the SNP. By contrast, the LTEMs system is established to monitor ecological changes in each of eight designated forest cover types identified within the SNP. To accomplish this goal, an equal number of sites must be identified in each cover type whenever possible. An additional forest cover type category has been identified in order to allow monitoring of unique vegetation cover types under the LTEMs program.

CRITERIA FOR SITE SELECTION

Locations for LTEMs sites must be selected to encompass all representative combinations of **forest cover type, elevation, aspect, and**



— SHENANDOAH NP BORDER
- - - - SHENANDOAH NP DISTRICT BOUNDARY

Figure II.1. Location of the three administrative districts (North, Central, and South) in the Shenandoah National Park of Virginia.

administrative district (Fig. II.1) in the SNP. The major categories of site (forest cover type, elevation, and aspect) and location (district) are as follows:

Forest Cover Type

- Chestnut Oak
- Northern Red Oak
- Cove Hardwoods
- Yellow-Poplar
- Black Locust
- Pitch Pine
- Virginia Pine
- Eastern Hemlock
- Special (unique cover types)

Elevation

Low: 381-533 meters
(1250 - 1750 feet)

Mid: 686-838 meters
(2250 - 2750 feet)

High: 991-1143 meters
(3250 - 3750 feet)

Aspect

Moist: 350 - 100 degrees azimuth

Dry: 170 - 280 degrees azimuth

Administrative District

North

Central

South

Each forest cover type represents a separate association of plant species that occurs within the SNP in response to a combination of site factors, natural succession, and disturbances, both natural and man-caused.

Forest cover and panoramic views associated with the significant topographic relief of the Blue Ridge and adjoining secondary ridges are the primary amenities of the SNP. Forest types are therefore the basic ecological variable used in the complex management of the park's aesthetic, wildlife, recreation, forest, and water-based resources for the long-term benefits of our society. Background information and detailed descriptions of the forest cover types (eight identified types and one special category) are contained in Appendix II-A.

Elevation and aspect are the two most important site factors that directly and indirectly affect forest cover. Both of these site factors affect temperature and water on a site-specific basis. As elevation increases, temperature decreases and precipitation increases, both of which will affect site quality by increasing available soil moisture and such site factors as rock weathering and soil formation. Both of these are affected by changes in vegetation type, soil micro-flora and -fauna, and soil leaching rates. In addition, there is recent evidence that suggests that certain air pollutants increase with increasing elevation.

Aspect affects forest cover primarily as a result of changes in site quality directly related to temperature-induced available soil moisture changes. As the aspect shifts from cool, moist north and northeast exposures to warm, dry south and southwest exposures, evapotranspiration rates increase significantly as a result of high afternoon air and soil temperatures, reduced relative humidity, and direct solar radiation. The end result is that each cover type may experience varying levels of environmental stress under

differing combinations of elevation and aspect.

The eight forest cover types encompass the complete range of major forest cover conditions that occur in SNP. The three administrative levels and two aspects represent a workable array of site conditions that are representative of site conditions found within the three management districts of SNP. The combination of eight cover types, three elevational categories, and two aspects produces 48 separate ELUs. To provide the necessary statistical replication for evaluating influences of cover type, elevation, or aspect, each ELU will be replicated by randomly locating a site for each ELU within each of the three administrative districts of the SNP, thus producing a theoretical total of 144 sites. The **special** forest cover type is not intended to be replicated and is therefore not included in the site totals.

Two difficulties will occur when trying to locate all the sites according to the above plan. First, some combinations of cover type and aspect are mutually exclusive. For example, it may be difficult to locate yellow-poplar on SW aspects or pines on NE aspects. The moist, cool, and fertile site conditions required for the establishment, growth, and development of yellow-poplar do not occur on most southwest aspects, and the rapid growth and competitive nature of most hardwoods normally preclude the germination and growth of pitch, Table Mountain, and Virginia pine on northeastern aspects. Combinations which cannot be located can be disregarded without compromising the LTEMs objectives. Secondly, elevational differences throughout the SNP will make it difficult to find all ELUs in each district. The 3500 ft elevation classes may be especially difficult to locate in each district. While it is important that each ELU be represented by three sites within the SNP, it is not imperative that they be evenly divided among the three districts. In these cases it is acceptable to select a second (or third) site within a single district.

SITE SELECTION

The SNP has instituted a geographic information system (GIS) that provides immediate access to geographically referenced information to aid in making resource management decisions. The GIS database provides the information used in the initial phase of LTEMs site selection. The term **site** in this case refers to the specific ELU location where the replicated research **plots** will be installed. Forest cover type, elevation, aspect, and administrative district are all data variables

available from the SNP GIS database. The LTEMs site selection process is composed of two phases or levels. The first phase is based on the GIS database and associated aerial imagery, and is accomplished in the office. The second phase is field verification in which the designated field party leader, using the GIS data, travels to the specific site location to verify that the forest cover type, elevation, and aspect all meet the specified characteristics for an LTEMs site. The field party leader, after on-site verification, monuments the site location for the first plot, or rejects the site as not meeting the LTEMs requirements. In the case of site rejection, the field party leader would move to the next LTEMs site that was randomly selected as meeting the specific characteristics. This selection and verification process would continue until the required number of valid sites are found, or until it is determined that they do not exist within the boundaries of the SNP.

Permanent plot locations must be determined so that 1) they are representative of the forest conditions for which inferences will be made, 2) they can be relocated easily for remeasurement, and 3) their physical integrity can be maintained for the duration of the LTEMs program.

In the first phase of the site selection process the SNP's GIS is used to overlay forest cover type and elevation site variables in each administrative district.

The GIS system utilizes the standard Universal Transverse Mercator (UTM) rectangular coordinate grid system for the location of specific geographic information. The UTM coordinate grid appears on all U.S. Geological Survey (USGS) and U.S. Coast and Geodetic Survey (USC & GS) 7.5-minute series topographic maps. The 7.5-minute designation refers to the 7.5 minutes of Latitude (7.5 nautical miles) covered by each topographic map at a scale of 1:24000. Each topographic map has tick marks at 1000-meter intervals on both the North/South (N/S) and East/West (E/W) axes. The SNP's GIS system is designed to extract geographic information at any location within the SNP boundaries using the UTM grid system.

For the site selection process a geographical point has been located every 500 meters on both the N/S and E/W axes. These points are referred to as UTM grid nodes. Based on a 500-meter grid node spacing, there are about 3100 separate point locations available from which to randomly select the 144 potential site locations. Each 500-meter node represents 25 hectares of land area.

The UTM grid overlay is used to provide a random means by which actual site locations are determined. A list (by grid coordinates) of all grid nodes which fall within each forest cover type/elevation class is generated with the GIS. Then for each forest type/elevation combination, a node is randomly selected for each district that satisfies the moist and the dry aspect requirements. Aspect is determined directly from the USGS 7.5-minute topographic maps. Randomly selected nodes will be eliminated from consideration for an LTEMs site if the aspect class is not available at a site or the slope exceeds 50% (SNP policy). An alternate site will be randomly selected and used in case the aspect and slope criteria are not met or if it is found during the field verification that the site does not meet the site requirements. Each randomly selected site will be carefully located on the topographic map and associated aerial photograph to aid field personnel in determining the best way to gain access to the site area. When a site meets all of the criteria required for LTEMs based on the office information, the site will be assigned a discrete six-character identification code as follows:

$$\frac{L}{(1) \quad (2) \quad (3) \quad (4) \quad (5) \quad (6) \quad (7) \quad (8) \quad (9)}$$

Where:

- (1) = SNP administrative district
 - 1. North District
 - 2. Central District
 - 3. South District

- (2) = Indicates a long-term monitoring LTEMs plot and will be constant for all sites

- (3) = Forest cover type at time of plot establishment
 - 1. chestnut oak
 - 2. northern red oak
 - 3. cove hardwoods
 - 4. yellow-poplar
 - 5. black locust
 - 6. pitch pine
 - 7. Virginia pine
 - 8. eastern hemlock
 - 9. special

- (4) = Elevation
 - 1. low
 - 2. medium
 - 3. high

- (5) = Aspect
1. moist
 2. dry

- (6) = Will identify additional sites that are duplicates in an administrative district. May be a result of a need for additional replication or part of a new but closely related study
1. The first duplicate site
 2. to 0. Allows for 9 additional duplicate sites

An additional three characters will be added as appropriate.

- (7) = Site measurement sequence
1. the initial measurement when the plot was installed
 2. the first remeasurement
 3. the second remeasurement
 4. to 0. Additional remeasurement times

- (8) = Main Plot number in sequence of establishment at each site: 1, 2 or 3

- (9) = Forest cover type of the specified plot if different than original cover type indicated in (3). Use cover type designation as in (3). If there is no change enter a "9"

The first five characters will be assigned prior to field verification.

In the event that the 500-meter grid node network is too coarse and certain forest cover types are not represented in sufficient numbers, the grid node interval can be reduced to 250 meters or even 100 meters if necessary to increase the probability that a grid node will fall in a specific forest cover type. This lack of representation of such types as eastern hemlock and black locust is likely to happen because of the sparse nature of their occurrence.

An alternative method for selecting sites when the forest cover type is very sparse and erratic in distribution is to base the selection on actual field knowledge of the locations of a specific forest cover type. All specific cover type locations observed in the field would be carefully located on enlarged topographic maps of a scale of 1:4800. All cover maps would then be overlain with a grid (grid node interval of 25 or 50 meters). Each grid node that falls in the specific cover type would be numbered sequentially, and then the location of an

LTEMS site would be randomly selected from the numbered grid nodes. An attempt will be made to fill all 144 ELU cells; however, certain ELU combinations are mutually exclusive and must be passed over. An example of a cell that may not be filled due to the silvical characteristics of the tree species involved would be yellow-poplar at the low elevation on the dry aspect.

The second phase of site selection encompasses the procedures for locating a specified LTEMS site on the ground.

To ensure the accuracy and efficiency of field operations, the location of all LTEMS sites should be accurately located on USGS 7.5-minute topographic maps and aerial photographs. From this site location display, access to sites and travel between sites can be carefully and efficiently planned. For each site all known landmarks, such as benchmarks, roads, road intersections, unique topographic features, utility structures and buildings, should be carefully noted. Compass bearings and taped distances from appropriate features to each LTEMS site must be recorded to aid in the relocation process. In addition, an altimeter will be very useful for accurate verification of site locations and in the proper location of sample plots at each site.

When the field party leader has arrived at the designated site the leader will verify that the location fulfills the requirements for the specified forest cover type, elevation, and aspect. It is then necessary to determine the areal extent of the specified site conditions to ensure that there is sufficient area to properly locate three sample plots. The procedures are as follows.

1. On an expanded-scale topographic map (i.e., 1:4800 or similar scale) mark the elevation limits for the specified site within a radius of 200 meters. **Example:** For a mid-elevation site the elevation limits are 686-838 meters (2250-2750 feet). The 200-meter radius is flexible, but is considered realistic in terms of field efficiency. A radius in excess of 250 meters would not be appropriate because it would result in a location address outside the 500 meter UTM grid node selected by the GIS procedure.
2. Cross hatch within the elevation and radius limits all aspects that meet the specified aspect criteria. **Example:** For a moist site the aspect would include all areas with an azimuth from 350^o to 100^o (measured

clockwise).

3. Based on a field reconnaissance of the area included in 1 and 2 above, the field party leader will record all areas that meet the specified forest cover type criteria (App. II-A).

At this point, all of the area that is potentially available for sample plots at a specific site is known. The first plot at the site can be located at the UTM grid node location for the site provided that the forest cover type, elevation, and aspect meet the site requirements. The second and third sample plots can be randomly located as follows:

1. Overlay the topographic field map that displays the elevation, cover type, and aspect for the specified site with a 50m x 50m rectangular grid (grid lines oriented N/S and E/W). The northwest corner of a 50m x 50m cell is the address for the cell. This cell size should allow for the required minimum 10 meter buffer between plots.
2. Number all grid line intersections that fall within the elevation x cover type x aspect overlay area.
3. Randomly select two of the numbers and designate the grid nodes as the approximate starting corners for the second and third plots.

PLOT DESIGN

Three square main plots will be located at each of 144 hypothetical sites. There are two reasons for establishing three plots (rather than two or one) at each site: 1) a better estimate of stand conditions can be achieved by getting the average of three plots, and 2) three plots are needed to measure stand variability, which is necessary to statistically compare two sites. The ability to compare two sites may become important in the future if one of the sites is affected by some disturbance. An example of a need to compare two sites within a single ELU is as follows.

Example: Suppose site A and site B are both chestnut oak, at mid-elevation, with a moist aspect. Site A is in the North District and B is in the Central District. Initial measurements collected in 1989 may show that they both had the same type of forest regeneration, primarily oak. Suppose the area encompassing site A was heavily defoliated by the gypsy moth in 1990 and

1991. Remeasurement of these plots in 1994 may indicate more maple regeneration in site A than site B. The presence of three plots at each site will allow researchers to statistically compare these sites and determine whether there was a significant increase in maple regeneration in site A compared to site B. A similar comparison between sites could not be made without replicate plots. Due to the inherent variation in biological systems, a minimum of three replicate plots is required. Two plots would not provide the necessary sensitivity to detect many changes.

Each main plot is 24m x 24m (576m²) in size (Fig. II.2). This main plot will be referred to as the **tree plot** because all woody plants equal to or greater than 5m tall will be measured within the plot. Nested within each tree plot are sixteen 6m x 6m (36m²) quadrates. (Q1 to Q16 in Fig. II.2). Three of the 16 quadrate plots (Q1, Q4, and Q16) have been selected as **shrub plots**. All woody plants equal to or greater than 1m tall but less than 5m tall will be measured in the **shrub plots**. Finally, nested within each of the three shrub plots are two 1m x 1m (1m²) sub-subplots referred to as **regeneration plots**. The two regeneration plots (designated as R1 and R2 in Fig. II.2) will be located in the diagonal corners, away from the corner stakes of each of the three shrub plots being measured. Woody plant regeneration and herbaceous vegetation less than 1m tall and various cover variables will be measured in each regeneration plot.

In summary, there are three tree plots per site, three shrub plots per tree plot (nine per site), and two regeneration plots per shrub plot (six per tree plot and 18 per site). The plot center will be the center and focal point for photographic documentation of the plot.

PLOT INSTALLATION

With the approximate location of the three tree plots at each site already established, it is necessary to accurately establish and monument each plot. The final location of the plot should be such that variation in slope, aspect, and slope position is kept to a minimum within the plot. A buffer of at least 10 meters outside of the plot should be maintained in the exact same condition as the permanent plot. A buffer of at least 30 meters is needed from any disturbance that would affect the main canopy. It is important that all disturbance within the plot and in the buffer areas be kept at an absolute minimum. Whenever possible, access to the plots should be from the

downslope position to reduce the possibility of soil disturbance-caused erosion from flowing into or through the plot. All activities involved with boundary and corner establishment and plot measurement (data recorders) should be done from outside the plot whenever possible. All movement inside the plot boundaries should be well planned, kept to an absolute minimum, and accomplished with the utmost care.

Installing the main (24m x 24m) plot will require three to four persons and the following equipment:

- 1 staff compass and Jacob's staff,
- 1 range pole,
- 1 clinometer or Abney level,
- 4 fiberglass tapes (2-30m and 2-100m),
- 1 hand compass,
- 1 3 lb. maul,
- 9 3/8in OD x 18in reinforcing bar,
- 34 1/2in ID thick-walled PVC pipe,
- 1 roll pink or orange flagging,
- 10 consecutively numbered heavy gauge aluminum tags with 14 gauge or greater copper attaching wire for marking corners),
- 8 3/4in x 18in temporary wooden stakes (painted orange),
- 1 set of 10 chaining pins,
- 1 ball of white polyester store string (heavy duty),
- 1 cold chisel,
- 150 aluminum gutter nails (17.8cm long),
- 100 8d aluminum nails (6.0cm long),
- 250 heavy gauge aluminium tags (consecutively numbered with .556cm (7/32in) diameter holes for attachment).
- 1 35mm camera and film

The plot installation procedures are as follows (Fig. II.2). Note: Because all plot measurements are based on horizontal-plane measurements, all slope distances where the slope exceeds 3% must be corrected (Table II.1).

1. Establish Corner #1. Corner #1 is the control corner and will be the upper left hand corner of the plot when looking at the plot from downslope (see Fig. II.2). The line from corner #1 to corner #3 will be established first and will be perpendicular to the contour. The line from corner #1 to corner #2 should be along the contour and will be the second corner to be established.

- a. With the hand compass determine the approximate aspect bearings. This will be the boundary bearing from corner #1 to corner #3. Subtract 90° from the aspect and determine the approximate location of corner #2. If both of the lines have clear lines-of-sight, pound a temporary wooden stake at corner #1. If there is a major obstruction (i.e., tree greater than 6in DBH along either line-of-sight to corners #2 or #3), randomly move corner #1 upslope or downslope, or right or left along the contour at one-half meter intervals until the lines-of-sight are clear. Shrubs and saplings are not considered as major obstructions and should be carefully held aside with cotton string when establishing boundaries. Be careful not to damage vegetation when moving vegetation from the line-of-sight. Remove the string when the boundary line has been established. When major obstacles along the remaining two boundaries are encountered, 90° offsets around the obstructions are to be made.

- b. Set up the staff compass (be sure the proper declination is set and verified by the crew leader) directly over the temporary stake at corner #1 (use a plumb bob). Then determine and record the bearing/azimuth of the downslope direction perpendicular to the contour. This will be the left side plot boundary and the aspect of the plot unless the right side of the plot has an aspect that differs by between 3° and 10° . If more than 10° , the plot is not suitable for measurement. If between 3° and 10° , the aspect of the plot will be the mean of the left and right downhill slopes (This is the aspect of the plot and must be recorded on the data sheet).

2. Establish Corner #3. With a 100m tape securely anchored at corner #1 run the tape 24 horizontal meters along the boundary bearing and pound in a temporary stake at corner #3. Continue the tape around corner #3 at a 90° angle and run 24 horizontal meters toward corner #4.

3. Establish Corner #2. Subtract 90° from the left side boundary bearing and sight the staff compass along that bearing to establish the boundary from corner #1 to corner #2. Run the 0-end of 100-meter tape 24 horizontal meters along the bearing and set a temporary stake at corner #2. Securely fasten the tape at corner #2. Continue the 100-meter tape from corner #2 around corner #1 and down the diagonal 33.94 horizontal meters to corner #4. Place a temporary stake at 16.97m along the diagonal. This should be the center of the plot. This will be used as a focal point for plot photographs. The center will be verified when the shrub plot boundaries are installed.

4. Establish Corner #4. Corner #4 will be located by the intersection of the arcs scribed by three measurement tapes (a triangulation method). Securely fasten the 0-end of a 30-meter tape at corner #2 and run the tape 24 horizontal meters downslope. You now have a tape on the same bearing as from corner #1 to corner #3 (use a hand compass to determine the appropriate location of the line) to corner #4.

There are now three tapes intersecting at corner #4: Tape one going from corner #1 along the left boundary to corner #3 and then along the lower boundary to corner #4; tape two going from corner #2 along the upper boundary to corner #1 and then along the diagonal to corner #4; and tape three going from corner #2 along the right boundary to corner #4. The intersection of the three tapes will be the location of corner #4. Pound a temporary stake at corner #4. If the intersection of the three tapes varies by more than 0.5m there is a significant measurement error and all boundary measurements must be remeasured until the error is found and the error of closure is less than 0.5m. In order to isolate a measurement error use the diagonal measurement from corners #2 to corner #3 as a check. The horizontal distance should be 33.94m.

5. Alternate method for Locating Corner #4. An alternate method for locating corner #4 is to set up the staff compass at corner #2 and measure 24 horizontal meters along the boundary bearing and set a temporary stake at corner #4, and then check the location by setting up the staff compass at corner #3 and measure 24 horizontal meters along the lower boundary bearing and setting a temporary stake. The two stakes should be at the same point and would be satisfactory if less than 0.5m apart. If this alternate method were used, the permanent corner #4 stake would be located between the two temporary stakes.

This alternate method, where additional compass set-ups are used, is generally less desirable than the single compass set-up because of the known local magnetic field variations that occur in the SNP due to the high iron content of the parent rock.

TABLE II.1. Slope correction factors. To determine the slope distance multiply the horizontal distance by the correction factor for the measured slope % of the line in question. Slopes exceeding 50% cannot be included in LTEMs.

Slope %	Correction Factor	Slope %	Correction Factor
1	1.000	26	1.033
2	1.000	27	1.036
3	1.000	28	1.039
4	1.001	29	1.041
5	1.001	30	1.044
6	1.002	31	1.047
7	1.002	32	1.050
8	1.003	33	1.053
9	1.004	34	1.056
10	1.004	35	1.059
11	1.006	36	1.063
12	1.007	37	1.066
13	1.008	38	1.070
14	1.010	39	1.073
15	1.011	40	1.077
16	1.013	41	1.081
17	1.014	42	1.085
18	1.016	43	1.088
19	1.018	44	1.092
20	1.020	45	1.096
21	1.022	46	1.101
22	1.024	47	1.105
23	1.026	48	1.109
24	1.028	49	1.114
25	1.031	50	1.118

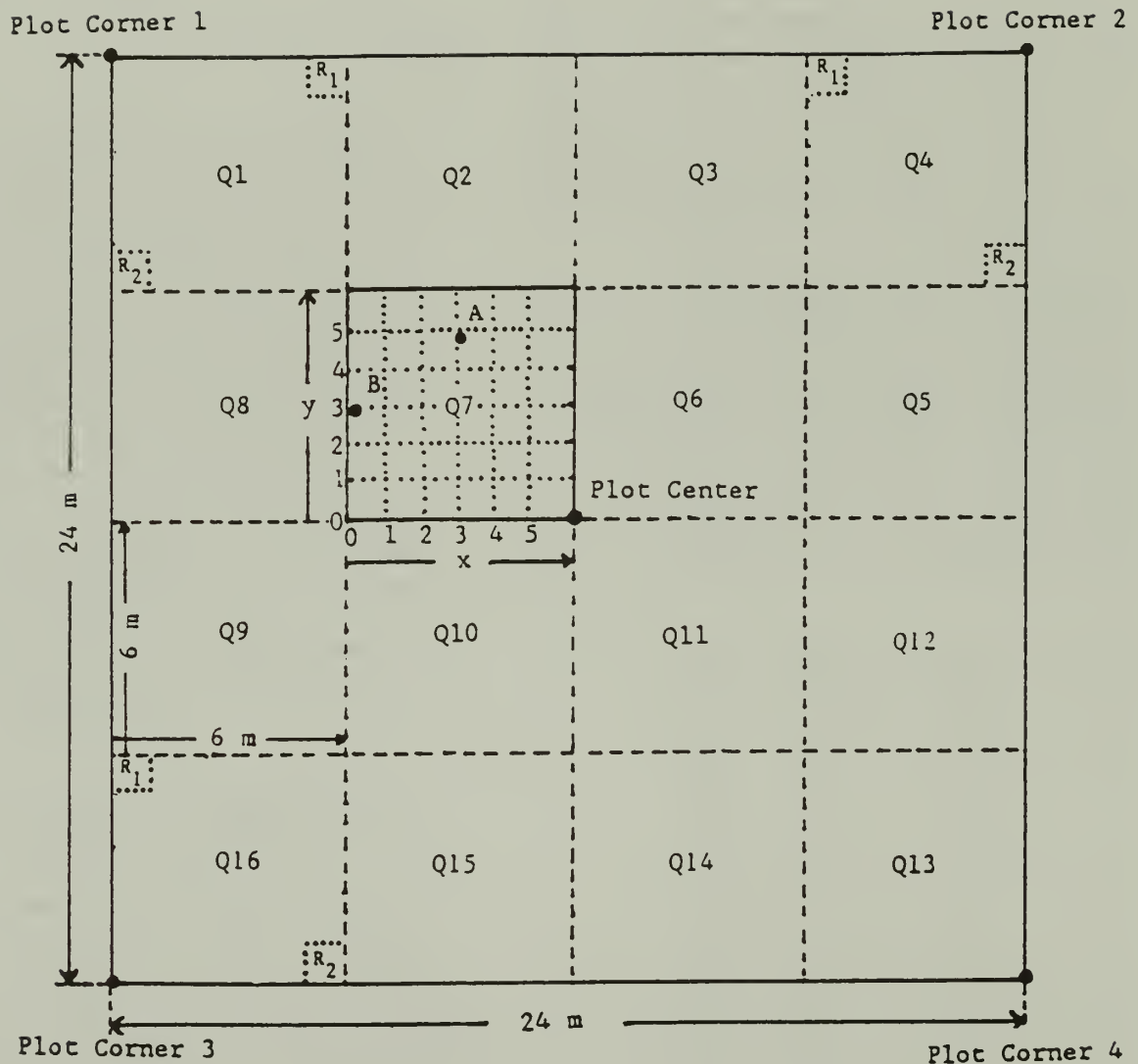


Figure II.2. Plot layout for LTEMs sites in Shenandoah National Park of Virginia. Tree plots are 24m x 24m and bounded by Plot Corners 1, 2, 3, and 4. Shrub plots are 6m x 6m and designated by Q1, Q2 . . . Q16. Three shrub plots, Q1, Q4 and Q16 have been selected for measurement during the initial measurement phase of LTEMs. Regeneration plots are 1m x 1m and designated by R1 and R2. Two regeneration plots will be measured in each of the 3 measured shrub plots as indicated. Quadrat Q7 contains an example of an x,y coordinate grid that will be used to locate trees within the quadrat to the nearest 1m. The location of any point within the quadrat would be identified by starting at 0,0 in the lower left corner, moving right along the x axis and then up along the y axis. Example: The position of point A within Q7 would be 3 (x), 5 (y), i.e., 3m to the right of "0" and 5m up from "0" or 3,5. The position of point B would be 0 (x), 3 (y) or 0,3.

6. Permanent Corner Installation. With all four corners properly located, carefully replace the temporary corner stakes with reinforcing bars (rebars) that will serve as permanent corners. Be sure to leave all tapes in place. The rebar should be driven into the ground so that no more than 15cm is protruding from the ground. In the case where the actual corner is on a rock then the permanent corner marker should be driven into the ground such that a vertical line from the top of the rebar should mark the exact location of the corner. (Fig. II.4) In some cases because of solid rock it will not be possible to place a corner stake at all. This should be clearly noted on the site description form. Etch the corner point on the rock (use cold chisel), if possible, and so note on the appropriate data sheet.

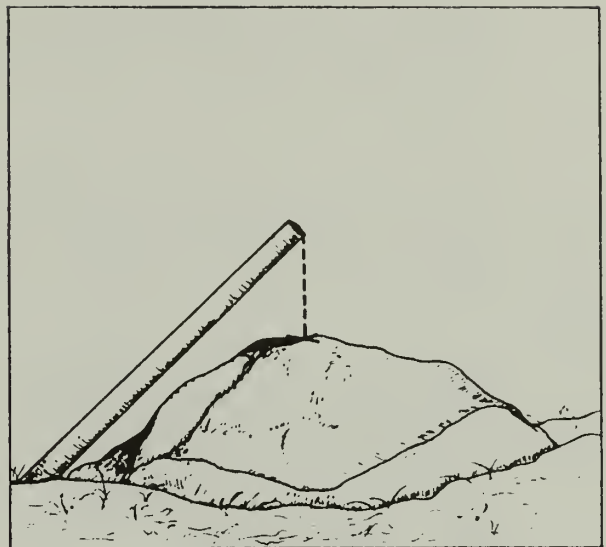


Figure II.4. A stake marking a corner over a rock. A vertical line from the end of the stake should indicate the corner. The location (x) of the corner should also be etched on the rock.

- a. Drive PCV pipe over the top of the rebar such that the PVC pipe extends at least 30cm above the ground line.
- b. Securely attach a uniquely numbered aluminium tag to each of the four corner PVC markers. Record these numbers on appropriate data sheets.

7. Establish Exterior Quadrate plot (6m x 6m) and Regeneration plot (1m x 1m) corners. There are tapes already in place along all boundaries of the plot. Remember to correct all slope distances if the slope is

greater than 3%. Refer to Figures II.2 and II.3 for locations of Quadrate and Regeneration Plot corners.

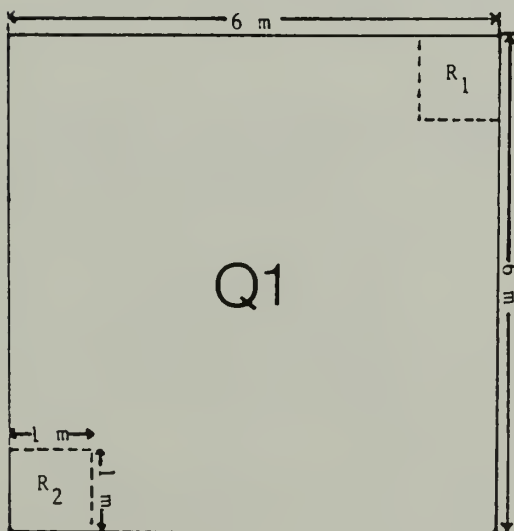


Figure II.3. The layout of one of the 16 quadrates in each tree plot showing the location of the 1m x 1m regeneration plots (R1 and R2) within the quadrate. In this case quadrate Q1 is one of the three 6m x 6m shrub measurement plots located in each tree plot.

- a. Upper boundary. Starting at corner #2 and going to corner #1, install PVC pipe corners at 5m (upper right corner of regeneration plot) and at 6m, 12m, and 18m (quadrate corners), and 19m (upper left corner of regeneration plot).
- b. Right boundary. Starting at corner #2 and going downslope to corner #4, install PVC pipe corners at 5m (upper right corner of regeneration plot, at 6m, 12m, and 18m (quadrate corners).
- c. Left boundary. Starting at corner #1 and going downslope to corner #3, install PVC pipe corners at 5m (upper left corner of regeneration plot), 6m, 12m, and 18m (quadrate corners), and at 19m (lower left corner of regeneration plot).
- d. Lower boundary. Starting at corner #3 and going along the lower boundary to corner #4, install PVC pipe corners at 5m (lower left corner of regeneration plot), at 6m, 12m, and 18m (quadrate corners).
- e. Rewind all tapes.

8. Establish Interior Quadrangle Plot and Regeneration Plot Corners. Refer to Figures II.2 and II.3 for location of quadrates and regeneration plot corners.

- a. Run tapes along the contour from the left to the right side of the main plots at 6m, 12m, and 18m intervals. (PVC pipes previously installed at these locations).
- b. Install PVC pipe corner at appropriate intervals to monument interior quadrangle and regeneration plot corners. Refer to Figures II.2 and II.3 to ensure proper placement of regeneration plot corners R2 in Q1, R2 in Q4, and R1 in Q16.
- c. Verify the proper location of quadrangle corner locations by running a tape at 6m, 12m, and 18m (correct for slope) intervals up and down the slope. (parallel to left and right boundaries). At the same time establish the regeneration plot corners R1 in Q1, R1 in Q4, and R2 in Q16.
- d. Only three of the four regeneration plot corners will be permanently marked. The fourth corner will be temporarily staked when the plot is measured.
- e. Verify the center of the plot location and install a reinforcing bar/PVC pipe and securely attach numbered aluminum tag. Record the tag number on the appropriate data sheet.

The relocation of plots is critically important to the success of the LTEMs project. Every effort must be made to ensure that the monumentation of each plot is properly accomplished. Extreme care must be taken in measuring and recording complete descriptions for the access to, and location of, each plot. Upon installation of a plot, at least two witness trees outside the plot will be clearly identified and marked. Witness trees should be located along the route that is normally used to access the plot and be within 30 meters of a plot corner. The witness trees will be tagged at DBH on the side of the tree facing the plot corner. The tags should be heavy gauge aluminum and embossed with an appropriate identification number. The tags should be attached with aluminum gutter nails so that at least 10cm of nail is exposed to allow for radial growth. Witness trees should be selected from species that are

long-lived and should be healthy and free from major defects that could reduce longevity. Ideally the expected life expectancy of a witness tree should be 30 or more years. The species and diameter (DBH), and the bearing and distance to the nearest plot corner, should be carefully recorded for each witness tree. Ideally, witness trees should be blazed with bright colored paint where it is permissible by the SNP. Additional witness trees should be used when they will assist in the relocation of plots.

DATA COLLECTION

There are five types of data forms that must be filled out at each LTEMs site. The forms are:

1. Site Description - one form per site
2. Stand (Tree Plot) Description - one form per plot = three forms per site
3. Tree Plot Data - one form per plot = three forms per site
4. Shrub Plot Data - three forms per tree plot = nine forms per site
5. Regeneration Plot Data - two forms per shrub plot = 18 forms per site

The following subsections contain a brief description of each form followed by a detailed description of how each item on the form is to be filled out.

Site Description Form

The Site Description form provides the detailed information necessary to relocate the site for future measurements. It also contains subjective observations about the site and immediate vicinity, including any evidence that could be related to the past history. Such things as fire scars and logging damage on trees, skid roads, species composition that suggest disturbance, exotic species, and cultural artifacts (foundations, home sites, machinery, dumps, etc.) should be included. Figure II.5 is a sample of the Site Description form, and the following numbered variables and associated explanation have corresponding numbers on the form.

1. Site #: A five character code that is unique for each site.

First character: Refers to one of three administrative districts in the SNP

- 1 = North District
- 2 = Central District

3 = South District

Second character: Refers to a long term monitoring plot. All LTEMs plots will have an "L".

Third to Fifth Character: A three-digit number assigned by the SNP.

2. UTM North and UTM East: The UTM coordinate grid location of the site (to corner #1 of plot #1) to the nearest 10m. 1000m UTM grid tick marks are found on all USGS 7.5-minute series topographic maps. UTM grid numbers become larger as you move North and as you move East. A seven digit UTM grid number is recorded for the N-S direction and a six digit UTM grid number is recorded for the E-W direction. **Example:** a UTM North number for the SNP would be 4274800. The first four digits are found directly on the 7.5-minute map. The last three digits must be interpolated from the scale on the map. The N-S distance between UTM 4274000 and 4275000 is 1000m. The distance between 4274100 and 4274200 is 100m. A UTM East number for the SNP would be 732900. The distance between 732000 and 733000 is 1000m. Since the location of a site will be to the nearest 10m, the last digit for both UTM coordinates will be 0.
3. Location - Drainage name: The name of the drainage in which the site is located taken from the USGS 7.5-minute map.
4. Geological Formation: The geological formation as indicated on the geological maps of SNP. There are five possible geological formations.

Hampton or Erwin (H)
Pedlar or Old Rag (P)
Catoctin (C)
Catoctin and Pedlar (CP)
Catoctin or Hampton (CH)

(The one or two letters following the formation names are the codes that will be used for data output).

5. Elevation: The elevation of the site expressed in feet and estimated to the nearest 10ft based on the topographic map and a portable altimeter.

6. Site Type (Aq. Fr). The site type is either an aquatic site (Aq.) or a forested site (Fr). All forested sites will be designated as (Fr).
7. Elevation Class: Used for aquatic plots only.
8. Vegetative Cover Type. This will be the composite forest cover type for the three plots at each site. For the initial measurement all plots will have the same cover type by design. However, over time the individual plot cover type can change. The dominant cover type for the three plots will be recorded using the following four digit codes (If each plot is different, then all three codes will be recorded).

<u>Forest Cover Type</u>	<u>Code</u>
Chestnut Oak	4400
Northern Red Oak	5500
Cove Hardwoods	2001
Yellow Poplar	5700
Black Locust	5000
Pitch Pine	2101
Virginia Pine	2102
Eastern Hemlock	2300
Special	9999

9. Quad: The USGS 7.5-minute series topographic quadrangle map name and the identification code. See Appendix II.B for quadrangle map name and code cross-reference list.
10. Aspect Class (Moist, Dry): Aspect class is determined by the aspect in degrees azimuth. All three plots at each site will have the same aspect class. A **moist** site will have an azimuth of 350° to 100° (clockwise) and a **dry** site will have an azimuth of 170° to 280° (clockwise).
11. Date: The month (two digits) followed by a dash (-) followed by the day (two digits) followed by a dash (-) followed by the year (two digits). **Example:** February 5, 1990 would be recorded as 02-05-90.
12. Crew: Record the last names of crew members that accomplished the field measurements at the site. The name of the party leader should be given first.
13. Past History, Comments: Write down subjective observations about the site and

SHENANDOAH NATIONAL PARK LTEMs

SITE DESCRIPTION (1/site)

① SITE #: _____

② UTM North _____
UTM East _____

③ LOCATION - Drainage name: _____

④ GEOLOGICAL FORMATION: _____

⑤ ELEVATION (ft): _____

⑥ SITE TYPE (AQ/FR): _____

⑦ ELEVATION CLASS (U/L)(AQ sites only): _____

⑧ VEGETATIVE COVER TYPE: _____

⑨ QUAD: _____

⑩ ASPECT CLASS (Moist, Dry): _____

⑪ DATE: _____

⑫ CREW: _____

⑬ PAST HISTORY, COMMENTS: _____

⑭ DIRECTIONS TO SITE: _____

⑮ ID CODE _____

Figure II.5. A sample of the Site Description Form to be filled out at each LTEMs site. An explanation of each circled number is contained in the text of this manual.

immediate vicinity that would aid in determining past history and in explaining the present conditions of the vegetation at the site. Observations to include are fire scars, logging damage, skid road, disturbance-related species, (i.e., eastern red cedar, tree-of-heaven, Norway spruce, or fruit trees), presence of damage to trees as a result of wind, snow, or ice, evidence of grazing (either domestic or wild animals), and cultural artifacts such as foundations, fences, rock fence rows, old machinery, or dumps.

14. Directions: The directions to the site, specifically to a corner of the first tree plot, must be absolutely clear and accurate. The directions will include compass bearings (hand compass corrected for declination and recorded to the nearest degree of azimuth) and taped distances (in m to the nearest meter) from a known geographical point. The starting point will be clearly documented on a master USGS 7.5-minute series topographic map maintained in the SNP office. A copy of that portion of the 7.5-minute map showing the known geographical point and the specific site (plot 1) will be attached to the Site Description form. The access route should traverse along established numbered or named roads, trails, and paths whenever possible. The names and numbers of the routes should be accurately recorded in this section. The directions should be accompanied by a detailed map showing the bearings and distances, as well as prominent features such as ridges, drainages, cliffs, rock out-crops, utility rights-of-way, structures, benchmarks, or other topographic and cultural features that would aid in relocating the site. This section should include the specific witness tree data for the first plot and the exact locations (bearings and distances) of plots 2 and 3. The plot corner and witness tree tag numbers for all three plots will be recorded on this form. Use the reverse side of the Site Description form as needed; however, be sure to indicate in the lower right corner that the information is **continued** on the reverse side.

15. ID Code: The first six characters of the ID Code will be recorded in accordance with the instructions in the Site Selection section of this manual.

Stand (Tree Plot) Description Form

A Stand (Tree Plot) Description form will be filled out for each of the three plots at a terrestrial site. One form will be filled out for each prism point on the streamside portions of an aquatic plot. The

form contains specific topographic and landform information and a detailed plot sketch for specific plot. Figure II.6 is a sample of the Stand (Tree Plot) Description form, and the following numbered variables and associated explanations have a corresponding number on the form.

1. Site #: Same as (1) on Site Description form (Fig. II.5).
2. Plot #: There are three plots at each site. The plots will be numbered in the order they are established as #1, #2, or #3.
3. Date: Same as (11) on Site Description form (Fig. II.5).
4. Basal Area Factor (prism point only): This variable will only be used for the streamside positions of an aquatic plot. Record the basal area factor (BAF) of the prism used for the point samples.
5. Slope %. The arithmetic mean of the slope % from corner #1 to corner #3, and from corner #2 to corner #4.
6. Aspect (degrees): The aspect of the plot is the azimuth of the line running perpendicular to the contour at corner #1 and extending to the intersection of the plot boundaries at corner #3 if this azimuth is less than 3° different from the azimuth from corner #2 to corner #4 (Fig. II.2). If the difference between these two azimuths is greater than 3° , use the arithmetic mean as the aspect of the plot. The azimuth will be recorded as three digits. **Examples:** An East aspect would be recorded as 090° , a West aspect would be recorded as 270° , and a North aspect as 000° .
7. Slope Pos: The slope position of the plot as derived from the diagram in Figure II.7 and expressed as one of the seven two-letter codes and Slope Position listed in the lower left hand corner of the form.
8. Slope Shape: A microrelief measure that describes the slope shape perpendicular to

the contour within each plot. The slope shape can be one of four shapes: concave, convex, planar, or undulating. A one-letter character is used to describe the shape and is given in the lower center of the form. The slope shape can be quantified by holding a tape tightly across the plot, perpendicular to the contour, at its center and at an equal height at each end (Fig. II.8). The vertical distance at plot center (plot center is considered to be anywhere within 2m either side of the actual plot center), between the ground surface and the horizontal tape (center height), determines the microrelief of the plot. If the center height is within 0.6m of the height at the ends, it is planar; and if the center height is more than 0.6m greater than the height at the ends, it is concave; if the height at the ends is more than 0.6m greater than the center height, or if the tape touches the ground between the two ends, and thus cannot be held straight, it is convex. If there is a series of three or more concave/convex shapes anywhere along the line, the slope shape would be classed as undulating.

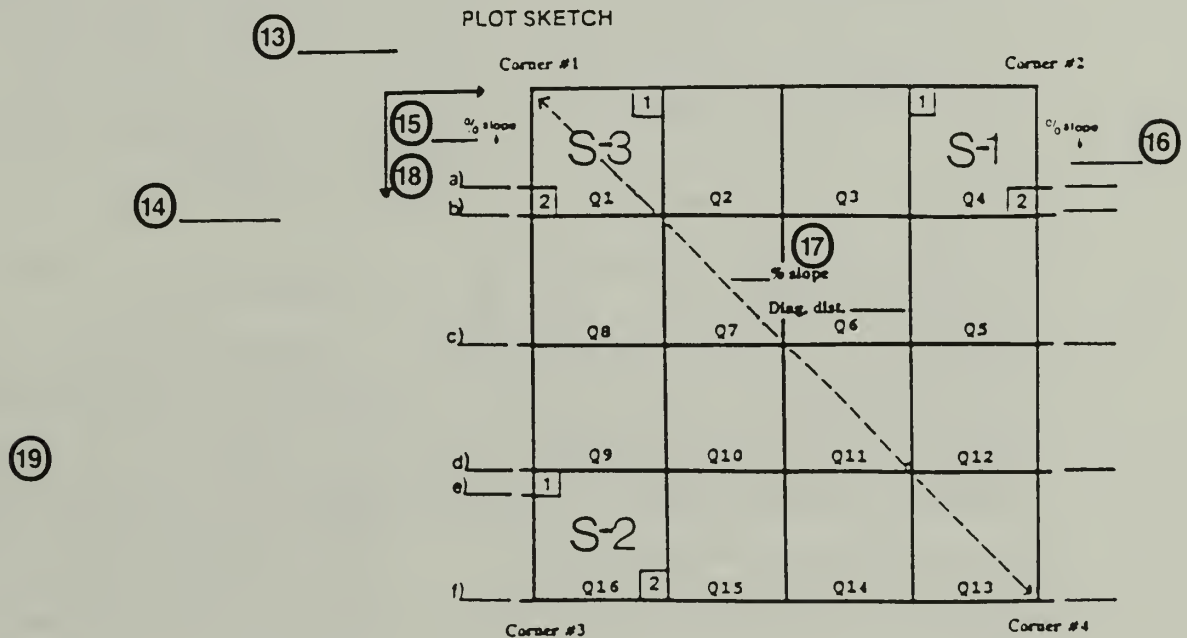
9. Cover Type: The cover type on the plot designated by one of the nine cover types and associated codes found under (8) on the Site Description form.
10. Stand Structure: The distribution of trees in the plot as described by vertical stratification. In this case, age is assumed to be positively correlated with tree diameter and crown size. Stand structure is recorded as one of the five single character codes found in the lower right hand corner of the form. A description of the five stand structure classes are contained in Appendix II-A.
11. Landform: One of seven terms used to characterize the form of a particular part of a landscape (Fig. II.9). A landform is associated with specific topographic features, and a particular landform type is generally composed of a land area of from one to several hectares. A **ridgetop** refers to the main or primary ridge of a named mountain as designated on a USGS 7.5-minute topographic map. A **spurridge** is a secondary or lower order lateral ridge emanating from the primary ridge. A **noseslope** is a slope with a diverging

drainage pattern, a **headslope** has a converging drainage pattern, and **sideslopes** are characterized by parallel drainage patterns. A **cove** is a deep, narrow, drainage depression in a slope, with one open end bounded by steep sideslopes and a steep headslope opposite the open end. The sideslopes of a cove are high enough above the cove floor to significantly affect the microclimate in the cove, and cause a more mesic vegetation type to occur than that which is found on the landforms adjacent to the cove. A **draw** is a depression in a landscape similar to a cove in shape, but usually much smaller in size. The sideslopes of a draw are not high enough to significantly affect the microclimate or vegetation type within the draw. The two letter codes associated with the seven landform types are found in the lower right hand corner of the data sheet (Fig. II.6).

12. Comments: This section should contain subjective comments about the biology, topography, and general environment within the plot and immediate vicinity (within 10m of the plot boundaries) that would aid in locating the plot or would add to the understanding, interpretation or evaluation of the vegetation within the plot.
13. Record azimuth of the boundary from corner #1 to corner #2. A three-digit number in degrees azimuth (to nearest degree) corrected for declination.
14. Record azimuth of the boundary from corner #1 to corner #3. A three-digit number in degrees azimuth (to nearest degree) corrected for declination.
15. Record the slope in percent, to the nearest percent measured from corner #1 to corner #3 along the left boundary.
16. Record the slope in percent, to the nearest percent measured from corner #2 to corner #4 along the right boundary.
17. Record the slope in percent, to the nearest percent, of the diagonal measured from corner #1 to corner #4, and record the slope distance, to the nearest cm, from corner #1 to corner #4.
18. Record the slope distances, to the nearest

SHENANDOAH NATIONAL PARK LTEMs
STAND (TREE PLOT) DESCRIPTION (3/site)

- ① SITE #: _____ ② PLOT #: _____ ③ DATE: _____
- ④ BASAL AREA FACTOR (prism point only): _____
- ⑤ SLOPE % _____ ⑥ ASPECT (degrees) _____ ⑦ SLOPE POS: _____
- ⑧ SLOPE SHAPE _____ ⑨ COVER TYPE _____ ⑩ STAND STRUCTURE _____
- ⑪ LANDFORM _____
- ⑫ COMMENTS: _____



SLOPE POSITION		SLOPE SHAPE		STAND STRUCTURE		LANDFORM	
SU	summit, ridge	V	concave	E	even-aged	RT	ridgetop
SH	shoulder, upper slope	X	convex	T	two-aged	SR	spurridge
BS	back slope, mid slope	P	planar	U	uneven-aged	NS	noeslope
FS	foot slope, lower slope	U	undulating	R	regular uneven-aged	HS	headslope
TS	toe slope, bottom slope			I	irregular uneven-aged	SS	sideslope
TE	terrace, bench or flat					CV	cove
FP	flood plain, stream bottom					DW	draw

⑳ ID CODE _____

Figure II.6. A sample of the Stand (Tree Plot) Description form to be filled out for each LTEMs plot. An example of each circled number is contained in the text of this manual.

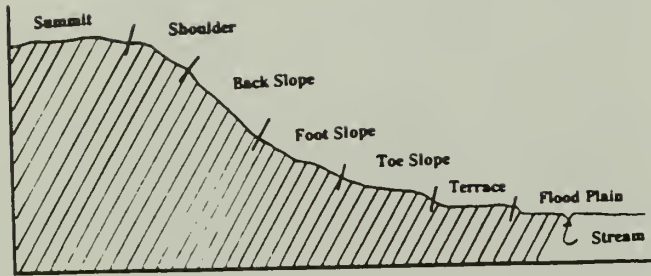


Figure II.7. Diagram of a landscape cross-section showing the seven slope positions.

cm, from corner #1 along the left boundary toward corner #3 at the following intermediate corners:

- a. Upper left corner of regeneration plot R2 in quadrat Q1.
- b. Lower left corner of quadrat Q1 (also lower left corner of R2).
- c. Lower left corner of quadrat Q8.
- d. Lower left corner of quadrat Q9 (also upper left corner of R1 in Q16).
- e. Lower left corner of regeneration plot R1 in quadrat Q16.
- f. Corner at #3. The total taped distance of the left boundary of the plot.

The same distance would be recorded for the right boundary of the plot if the right boundary slope is different than the left boundary.

19. Any other measurement information that relates to the plot should be accurately recorded in this portion of the data sheet. Such things as bearings and distances to the witness trees, witness tree descriptions, and any interior or exterior corner offsets must be recorded.
20. ID Code: The nine-character ID code will be recorded in accordance with the instructions in the Site Selection section of this manual.

Tree Plot Data Form

The Tree Plot Data form is a two-part form, with the second page (and additional pages as needed) being used when there are more than 30 woody plants in the plot. The form is used to record data on all trees in the plot that are equal to or greater than 5m tall. Data will be recorded by quadrat so

it will be necessary to cross-hatch the plot with string using the PVC pipe corner markers as guides. The Tree Plots will not be measured until the Shrub Plot and Regeneration Plot measurements have been completed. Measurement will start with quadrat Q1 and continue consecutively through quadrat Q16 (Fig. II.2). The location of each tree within a quadrat will be recorded to the nearest 1m using an x,y coordinate grid. To accomplish this it will be necessary to attach the 0-ends of two 30m tapes at the lower left hand corner of the quadrat being measured. One tape will run along the lower boundary (x axis) from left to right, and the other tape will run along the left boundary (y axis) from lower left corner to upper left corner. Figures II.10 and II.11 are samples of the two-part Tree Plot Data form, and the following numbered variables and associated explanation have a corresponding number on the example form.

1. Site #: Same as (1) on the Site Description form (Fig. II.5).
2. Tree Plot #: Same as (2) on the Stand (Tree Plot) Description form (Fig. II.6).
3. Page Sequence: If there are more than 30 trees in a plot, an additional data sheet (or sheets) will be required. Record the total number of Tree Plot Data sheets used for the plot. If only one sheet is used you would record a 1 in the space provided.
4. Date: Record the date that the data was collected using the same format as (1) on Site Description form (Fig. II.5).
5. Crew: Same as (12) on Site Description form (Fig. II.5).
6. Tree #: Each tree equal to or greater than 5m tall will be measured in the plot. The trees will be recorded consecutively and located by quadrat number and to the nearest 1m within the specified quadrat. If there are more than 30 trees in the plot continue on the second and third data sheets as necessary. Each tree will be identified by a discrete three- or four-digit

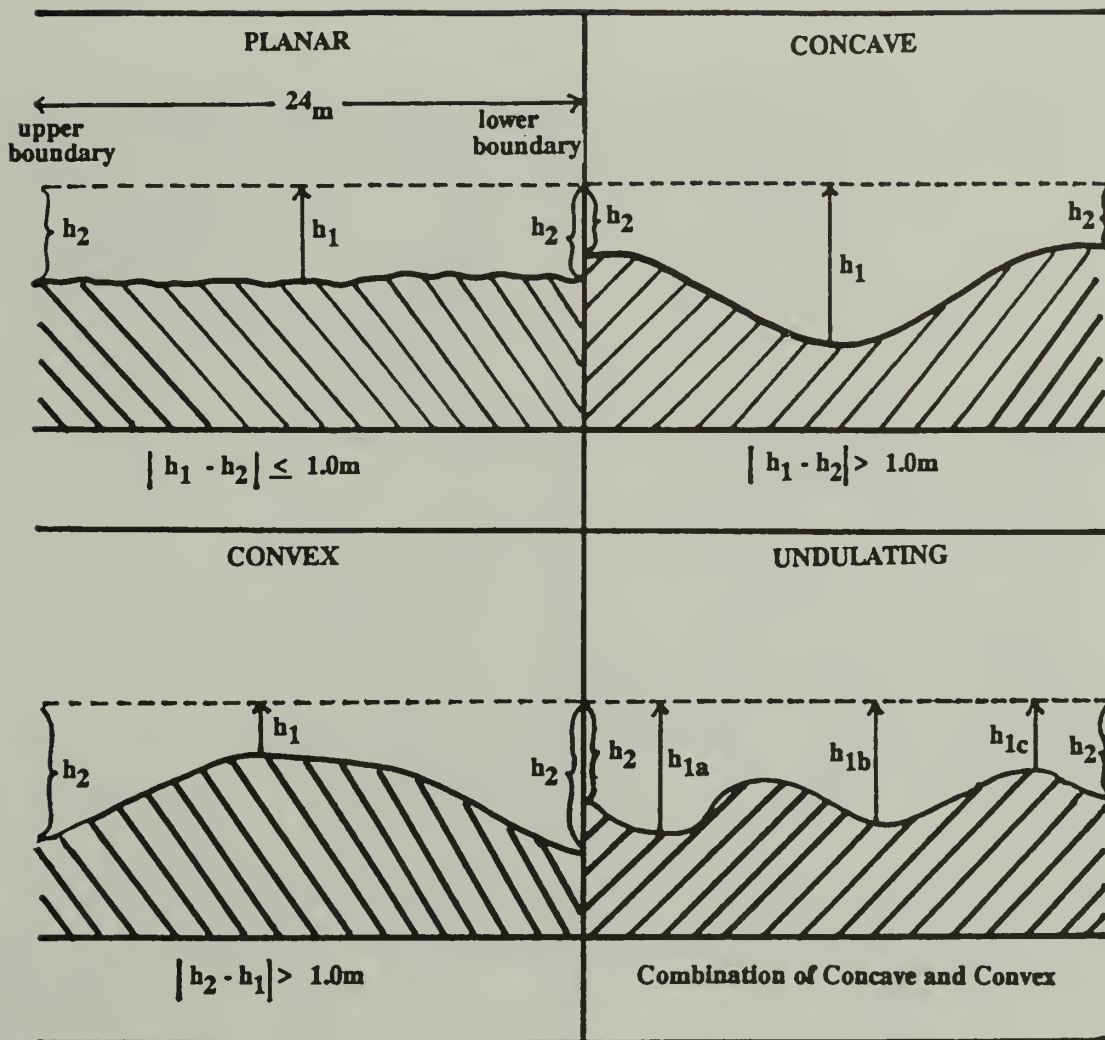


Figure II.8. Diagram showing slope shape. Slope shape is a microrelief measure that describes the slope shape perpendicular to the contour. The slope shape can be one of four shapes; planar, concave, convex, or undulating. The slope shape can be quantified by holding a tape or undulating. The slope shape can be quantified by holding a tape tightly across the plot perpendicular to the contour at its center and at an equal height (h_2) at each side of the plot (upper and lower). The distance at plot center (h_1) (plot center is considered anywhere within 2m either side of actual center) between the ground surface and tape center (center height h_1) determines the microrelief. If the center height is within 0.6m of the height at the ends, the slope shape is planar; if the center height is more than 0.6m greater than the height at the ends, it is concave; if the height at the ends is more than 0.6m greater than the center height or if the tape touches the ground between the two ends, and this cannot be held straight straight, it is convex. If there is a series of 3 or more concave/convex shapes anywhere along the line, the slope shape would be classed as undulating.

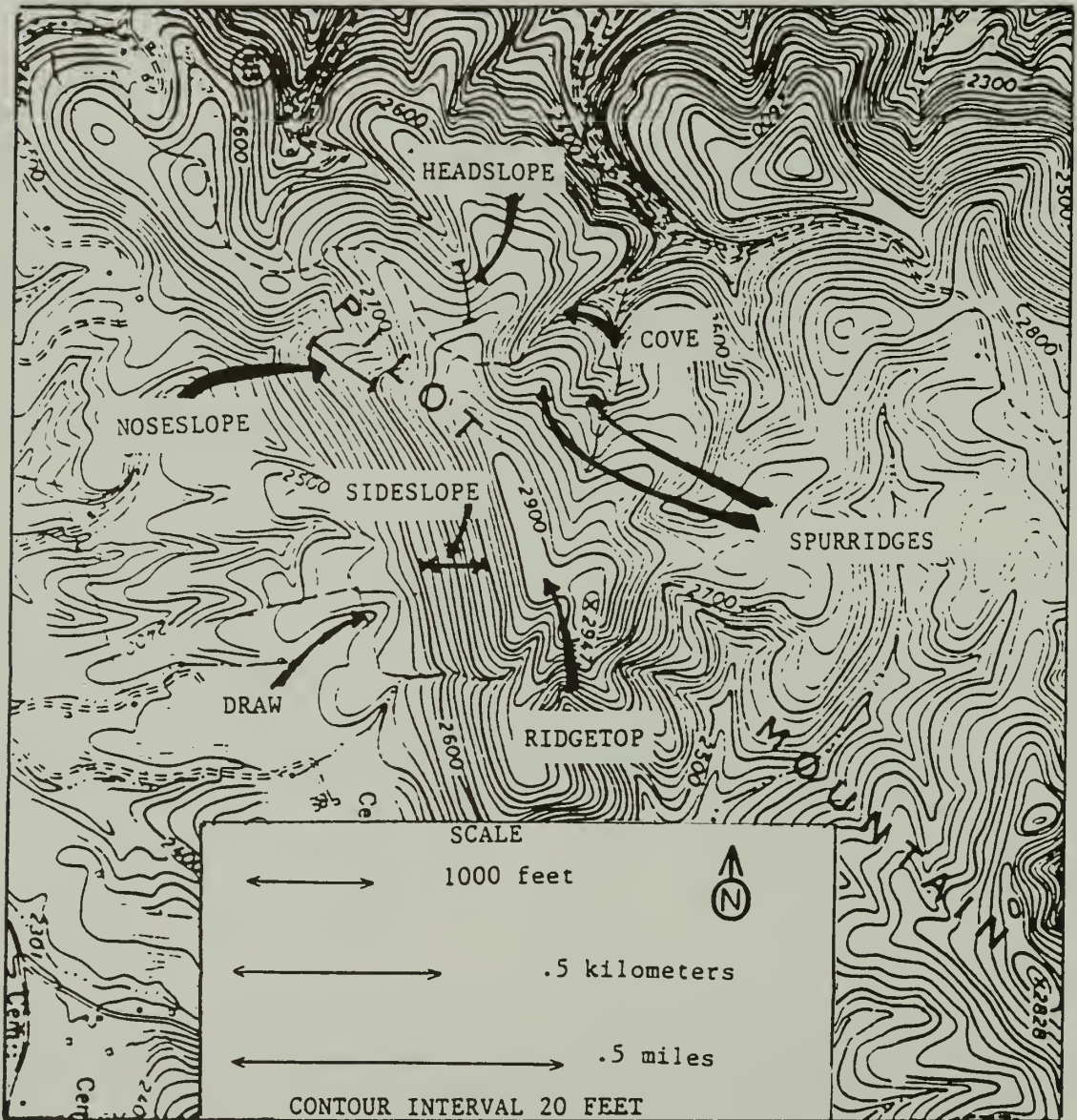


Figure II.9. The seven landform types as they are identified on an enlargement of a USGS 7.5-minute topographic map.

number embossed on a heavy gauge aluminum tag. The tags will be attached to the base of the tree with either an aluminum gutter nail (17.8cm long x .556cm in diameter), or 8d aluminum nails (6.0cm long). The 8d aluminum nails will be used for all dead trees and trees that are 10cm or less at DBH. The nails will be pounded into the base of the tree so that the head is located 15cm above the ground on the uphill side of the tree. The diameter of the tree will be measured 1.22m above the head of the nail (1.37m above the ground). See Figure II.17 for the correct location for making the diameter measurement. The aluminium gutter nails should be driven into the tree base at least 4cm but no more than 6cm. This will allow for a maximum amount of tree growth before the nail and tag are covered over by wood and bark. The 8d aluminum nails should be pounded into the tree base at least 2cm or until the nail is firmly imbedded.

7. **Quadrat:** Record the quadrat in which the tree to be measured is located as Q plus the quadrat number, i.e., Q1, Q5. There are 16 quadrats (Fig. II.2) in each plot. Tree measurements will begin in Q1 and proceed in numerical order to quadrat Q16.
8. **Coordinates, X,Y:** The location of the numbered tree within the specified quadrat to the nearest 1m using the x,y coordinate system as displayed in Figure II.2. Quadrat Q7 of Figure II.2 contains two examples of the x,y coordinate grid used to locate trees within the quadrat to the nearest 1m. The location of any point (tree) within the quadrat would be identified by starting at 0,0 (x,y) in the lower left corner, moving right along the x axis and then up along the y axis. **Examples:** The position of point A (Fig. II.2) within Q7 would be 3(x), 5(y), i.e., 3m to the right of "0" and 5m up from and recorded as 3, 5. The position of point B (Fig. II.2) would be 0(x), 3(y) and recorded as 0, 3.
9. **Species:** The species of a numbered tree using a three-letter code. The first letter is the first letter of the Genus, the second letter is the first letter of the species. The third letter is a unique letter taken from the species name. Appendix II-C contains the three-letter code for the genus, and species (and common names) for woody plants

found in the SNP. If a species is found that has not been previously identified, the field party leader will derive the appropriate three-letter code and ensure that it is added to the Appendix II-C master list maintained by the SNP Resource Manager.

10. **DBH:** The diameter at breast height (1.37m above the ground or 1.22m above the head of the tree tag nail) DBH measured in cm to the nearest 0.1cm using a diameter tape. Refer to the Individual Tree Measurement section of Appendix II-D for the standard procedures for diameter measurement.
11. **Live/Dead:** Indicate whether the tree is alive or dead by entering "L" for live and "D" for dead.
12. **Crown Health:** This variable allows the health of a crown to be placed into one of three **live** categories or one of two **dead** categories. When assessing the crown health of a tree it must be done in relation to crowns of the same species located in a similar vertical position within the canopy. The three live classes refer to the estimated amount of the foliage that is intact, expressed as a percent. The **recently dead** class would be assigned for a tree with no foliage but with fine twigs present and no bark sloughing. The **dead** class would be assigned for all other standing dead trees. The crown health variable must be assessed between the time when leaves are fully developed (about May 15, depending on elevation) and when normal leaf senescence is likely to occur (about August 15 depending on elevation, aspect, and seasonal weather). The crown health and associated single number code are found in the lower center of the second page of the two-part Tree Plot Data form (Fig. II.11).
13. **Crown Class:** The crown class of all live trees will be recorded with a one-letter code that represents the four crown classes described in Appendix II-A (Fig.II.A-1). The crown classes and associated single letter codes are found in the lower left corner of the second page of the two-part Tree Plot Data form (Fig. II.11).
14. **Codes/Notes:** Tree condition codes that can be used to describe the tree condition. Eight condition codes are available. The tree condition and associated numeric code

is found in the lower right hand corner of the second page of the two-part Tree Plot Data form (Fig. II.11). A maximum of three tree condition attributes can be recorded per tree.

15. Tree #: Tree height and age will be determined from three dominant or codominant trees within the plot that are representative of the plot and are common species associated with the specified forest cover type. See Appendix II-A for species associated with the various forest cover types. The selected tree numbers, taken from the measured trees on the plot, will be recorded.
16. Age: The age of the tree will be determined from an increment core taken from the tree in accordance with the instructions provided in Appendix II-D. The procedures for numbering and preserving the core will be strictly adhered to.
17. Distance to tree: Record the **horizontal** distance, in ft, from the tree to be measured to the point where the tree height is measured. This will normally be 50, 100, or 150ft depending on the height of the tree. Refer to Appendix II-D for procedures used to properly measure tree heights.
18. Measured Slope %, Base/Top: Record the measured slope % as observed with the height-finding instrument (either a clinometer or an Abney level) at the base of the tree and at the top of the tree. If the base of the tree is below the 0% level, record the reading as a negative (-) number. If the base of the tree is above the 0% level, record the reading as a positive number (+). The (-) and (+) signs should precede the slope % values on the data sheet, i.e., -18 or +35.
19. Calculate Height: The height of the tree is determined by combining the **Base** and **Top** values as recorded in (18) and dividing by the appropriate distance-from-the-tree constant. If the **Base** value recorded in (18) is a negative number add the **Base** value to the **Top** value to obtain the uncorrected height value. If the **Base** value is a positive number subtract the **Base** value from the **Top** value to obtain the uncorrected height value. If the distance from the base of tree to the point where the tree was measured in

(17) is 100ft, then the height of the tree is equal to the uncorrected height value expressed in ft. If the distance in (17) is 50ft then the height of the tree, in ft, is equal to the uncorrected height value divided by 2. If the distance in (17) is 150ft, then the height of the tree, in ft, is equal to the uncorrected height value divided by 0.67. The height of the tree is recorded in feet to the nearest .5ft.

20. ID Code: Same as (20) on the Stand (Tree Plot) Description form (Fig. II.6).
21. Page ___ of ___: The first blank is for the page number of the present page in sequence. If the page is the second page of Tree Plot Data enter a 2. The second blank is the total number of Tree Plot Data forms used and must be entered on all Tree Plot Data forms.
22. Tree #: The next consecutive number following the last recorded number on the previous Tree Plot Data form for the specific plot will be recorded on the form. Each additional tree measured will be numbered consecutively.

Shrub Plot Data Form

The Shrub Plot Data form is used to record data on all woody plants equal to or greater than 1m tall and less than 5m tall in three of the quadrates within each plot. The designated quadrates for measurement are Q1, Q4, and Q16 and the designated shrub plot numbers are S3, S1, and S2 respectively (Fig. II.6). The boundaries of the quadrates to be measured should be clearly marked with string using the PVC pipe installed at the corners when the plot was installed, as guides. The Shrub Plots will be measured after measurement of the Regeneration Plots has been completed. Figure II.12 is an example of the Shrub Plot Data form and the following numbered variables and associated explanation have a corresponding number on the example form.

1. Site #: Same as (1) on the Site Description form (Fig. II.5).
2. Tree Plot#: Same as (2) on the Stand (Tree Plot) Description form (Fig. II.6).
3. Shrub Plot#: The shrub plot number, either S1, S2, or S3 as shown in the plot sketch (Fig. II.6).

SHENANDOAH NATIONAL PARK LTEMs

TREE PLOT DATA (3/site)

① SITE #: _____ ② TREE PLOT #: _____ ③ Page 1 of _____

④ DATE: _____ ⑤ CREW: _____

⑥ Tree #	⑦ Quadrate	⑧ Coordinates		⑨ Species	⑩ DBH	⑪ Live/ Dead	⑫ Crown Health	⑬ Crown Class	⑭ Codes/Notes		
		X	Y						1	2	3
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____	_____

TREE HEIGHT (ft) / AGE DATA (3 trees)

⑮ Tree #	⑯ Age	⑰ Distance to tree (ft)	⑱ Measured Slope %:		⑲ Calculate Height		
			Base	Top	Base	+ Top	= Height (ft)
_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____	_____

⑳ ID CODE _____ | _____

Figure II.10. A sample of the first page of the two-part Tree Plot Data form to be filled out at each of the LTEMs plots. A explanation of each circled number is contained in the text of this manual.

SHENANDOAH NATIONAL PARK LTEMs

TREE PLOT DATA (3/site)

SITE #: _____ TREE PLOT #: _____ (21) Page ____ of ____

DATE: _____ CREW: _____

(22)

Tree #	Quadrat	Coordinates		Species	DBH	Live/Dead	Crown Health	Crown Class	Codes/Notes		
		X	Y						1	2	3

Crown Class	Crown Health	Condition Codes
D Dominant	1 90-100%	1 Top Missing
C Codominant	2 50-89%	2 Insect Damage
I Intermediate	3 1-49%	3 Animal Damage
S Supressed	4 Recently dead	4 Stem Disease
	5 Dead	5 Lean > 45%
Live/Dead		6 Lightning Damage
D Dead		7 Ice Damage
L or blank Live		8 Other _____

(20) ID CODE _____

Figure II.11 A sample of the second page of the two-part Tree Plot Data form to be filled out at each of the LTEMs plots. An explanation of each circled number is contained in the text of this manual. Numbers are a continuation of Figure II.10.

4. Date: Record the date that the data was collected using the same format as (1) on the Site Description form (Fig. II.5).
5. Crew: Same as (12) on the Site Description form (Fig. II.5).
6. Species: The genus and species of each woody stem that is equal to or greater than 1m tall and less than 5m tall will be identified. The three-letter codes for all of the species found in the shrub plot will be entered in the boxes along the row to the right of **Species**. Appendix II-C is a woody plant dictionary that provides the correct three-letter code for each species.
7. Dot Tally: Each stem of the species found within the plot will be recorded. A **dot-line in a square** system of tally will be used. A completed square will represent 10 individual stems. A stem will be considered to be separate if it forks at 10cm or less above the ground line (root collar). If the stem forks above 10cm from the ground it will be considered as one stem. Sprout stems originating from the base of a stump or tree (root stock) will be treated as individual stems. A sprout stem is defined as any individual stem originating from the root collar or base, up to a height of 30cm from the ground, of a living or dead tree. In addition to the dot tally count, the root stocks with sprout stems will be numbered consecutively and the number of stems originating from a root stock that are greater than 1m and less than 5m tall, and the total number of sprout stems originating from the root stock will be recorded. The format for recording will be as follows: 3-7/16, where 3 is root stock number, 7 is the number of sprout stems that are within the 1-5m height class, and 16 is the total number of sprout stems originating from the root stock. This root-stock/sprout-stem data will be recorded in the lower part of the dot tally box for the specific species. For the dot tally, a stem is counted as in the plot if one-half or more of the cross-sectional, area of the stem at the ground line (root collar), is inside the plot boundary. For the root stock sprout stem tally a sprout stem is considered in the plot, if more than one-half of the root stock cross-section at a height of 10cm from the ground is in the plot. A vine that is found within the 1-5m measurement range for a shrub plot will not be tallied unless the stem originates in the plot. A comment about vines in a plot should be made in **comment** section of the data form.
8. Total: The numerical total of the dot tally (individual stems). The **total** does not include the additional root stock sprout stem information.
9. Comments: Use this space to describe specific characteristics of the shrub composition within the plot. If there is sprouting from stumps, as may be the case when fire, wind, ice, or animal browse damage has occurred, this fact should be described in detail in this section. Evidence of animal browsing or damage from other animal (or human) activity should also be noted. The occurrence of vines in the plot, but not originating in the plot, should be noted.
10. ID CODE: Same as (20) on Stand (Tree Plot) Description form (Fig. II.6).

Regeneration Plot Data Form

There are two Regeneration Plots in each of the three Shrub Plots within a Tree plot. Within the 1m x 1m regeneration plot all woody plants less than 1m tall will be recorded by species. In addition, ground cover will be estimated and the five most common herbaceous species will be recorded. The regeneration plots will be the first plots to measure following the establishment of the tree plot, to ensure that a minimum amount of disturbance occurs prior to measurement. Three of the four corners of each regeneration plot were established when the tree plot was installed. The fourth corner can be determined from the information contained on the Plot Sketch contained on the Stand (Tree Plot) Description form (Fig. II.6). Figure II.6 contains the slope distances to be used in setting the temporary stake that marks the fourth corner of the regeneration plot. Figure II.13 is a sample of the Regeneration Plot Data form and the following numbered variables and associated explanation have a corresponding number on the example form.

1. Site #: Same as (1) on the Site Description form (Fig. II.5).
2. Tree Plot#: Same as (2) on the Stand (Tree Plot) Description form (Fig. II.6).

SHENANDOAH NATIONAL PARK LTEMs

SHRUB PLOT DATA (3/tree plot)

① SITE #: _____ ② TREE PLOT #: _____ ③ SHRUB PLOT #: _____
 ④ DATE: _____ ⑤ CREW: _____

SHRUB PLOT DATA

⑥ Species												
⑦ dot tally												
⑧ Total												

Species												
dot tally												
Total												

⑨ Comments

⑩ ID CODE _____

Figure II.12. A sample of the Shrub Plot Data form to be filled out at each of three shrub plots within an LTEMs plot. A explanation of each circled number is contained in the text of this LTEMs plot. A explanation of each circled number is contained in the text of this manual.

3. Shrub Plot #. The shrub plot number, either S_1 , S_2 , or S_3 depending on the location of the specific regeneration plots.
4. Date: Record the date that the data was collected using the same format as (1) on the Site Description form (Fig. II.5).
5. Crew: Same as (12) on the Site Description form (Fig. II.5).
6. Regeneration Plot #1. The form contains the tally sheet for both of the regeneration plots for the specified shrub plot. This portion of the tally sheet is to be used for Regeneration Plot #1.
7. Species: The genus and species of each woody stem that is less than 1m tall will be identified. The three-letter codes for all the species found in the regeneration plot will be entered in the boxes along the row to the right of **Species**. Appendix II-C is a woody plant dictionary that provides the correct three-letter code for each species. If there are no woody stems less than 1m in height, record **NONE** to the right of **Species**.
8. Tally: Each stem of the species found within the plot will be recorded. A **dot-line in a square** system of tally will be used. A completed square will represent 10 individual stems. A stem will be considered to be separate if it forks at or below 10cm from the ground line (root collar). Sprouts from the base of a tree or stump will be treated as individual stems. A stem is counted in the plot if one-half or more of the cross-sectional area of the stem, at the ground line, is inside the plot boundary.
9. Total: The numerical total of the dot tally.
10. Ground Cover Percentage: The ground cover is broken into five major categories; rock, organic litter, woody debris, mineral soil, and herbaceous cover. Herbaceous cover is further subdivided into four components; forbs (F), grasses (G), sedges (S), and squawroot (SR). The ground cover percentage will be expressed as one of six cover classes as represented by the diagram shown in Figure II.14. Each category will be determined by the vertical projection of the specific cover type onto the ground surface and expressed as one of the six numerical cover class codes provided at the bottom of the tally sheet and in Figure II.14. A description of the five categories are as follows.
 - a. Rock: Any single stone equal to or greater than 5cm in diameter is classed as rock.
 - b. Organic Litter: All non-living organic material; leaves, twigs less than 2.5cm in diameter and 10cm long, bark with a one-side surface area of less than 25 sq cm, nuts, seeds, and other fallen or dead organic material.
 - c. Woody Debris: Non living organic plant material that has a one-side surface area of 25 sq cm or more, or has a diameter equal to or greater than 2.5cm and length 10cm.
 - d. Mineral Soil: Bare, exposed mineral soil with particle sizes less than 5cm in diameter.
 - e. Herbaceous: Living herbaceous material expressed as one of the four types of herbaceous material. All herbaceous ground cover estimates should be made between May 15 and August 15 to ensure that the ground cover is intact. If there are indications that the ground cover is losing leaves, then the ground cover measurement should not be made and so noted on the tally sheet.
11. Five Most Common Herbaceous Spp. Properly identify and list in descending order of abundance, the five most prevalent herbaceous species in the regeneration plot. The three-letter code for genus and species from Appendix II-E will be entered under **Species** on the tally sheet. Then estimate and record the relative percent cover of each species compared to the total plot using one of the six cover code classes given at the bottom of the tally sheet and as displayed in Figure II.14. **Example:** Suppose the total herbaceous cover is estimated as 40% of the plot and fern is 20% of the plot, the ground cover code (Rel. % cover class) for the total herbaceous cover is 3 (26-50%) and the ground cover code for fern is 2 (8-25%) (Fig. II.14).

SHENANDOAH NATIONAL PARK LTEMs
 REGENERATION PLOT DATA (2/shrub plot)

① SITE #: _____ ② TREE PLOT #: _____ ③ SHRUB PLOT #: _____
 ④ DATE: _____ ⑤ CREW: _____

⑥ REGENERATION PLOT # 1

Woody Stem Count

⑦	Species													
⑧	Tally													
⑨	Total													

⑩ Ground Cover Percentages

⑪ 5 Most Common Herb Spp.

		Organic	Woody	Mineral	Herbaceous					
	Rock	Litter	Debris	Soil	F	G	S	SR	Species	Rel. % cover class*
Cover Class	_____	_____	_____	_____	_____	_____	_____	_____	1) _____	_____
									2) _____	_____
									3) _____	_____
									4) _____	_____
									5) _____	_____

Herbaceous Codes: F = forbs G = grasses SR = squawroot
 S = sedges

⑫ REGENERATION PLOT # 2

Woody Stem Count

	Species													
	Tally													
	Total													

Ground Cover Percentages

5 Most Common Herb Spp.

		Organic	Woody	Mineral	Herbaceous					
	Rock	Litter	Debris	Soil	F	G	S	SR	Species	Rel. % cover class*
Cover Class	_____	_____	_____	_____	_____	_____	_____	_____	1) _____	_____
									2) _____	_____
									3) _____	_____
									4) _____	_____
									5) _____	_____

Herbaceous Codes: F = forbs G = grasses SR = squawroot
 S = sedges

Cover class codes: 1 = 0-7% 2 = 7-25% 3 = 25-50% 4 = 50-75% 5 = 75-93% 6 = 93-100%

* Rel.% cover is the amount of cover for each spp relative to the plot. This is coded 1-6 using the cover class codes.

⑬ ID CODE _____|_____

Figure II.13. A sample of the Regeneration Plot Data form to be filled out at each of the two regeneration plots located in each of the three shrub plots within an LTEMs plot. An explanation of each circled number is contained in the text of this manual.

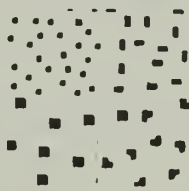
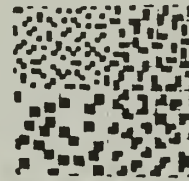
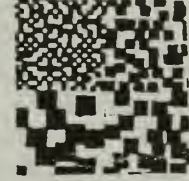

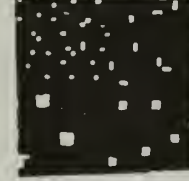
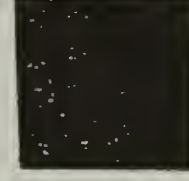
<u>Ground Cover Class</u>	<u>Range</u>	<u>Example</u>
1	0 - 7%	 7%
2	8 - 25%	 25%
3	26 - 50%	 50%
4	51 - 75%	 75%
5	76 - 93%	 93%
6	94 - 100%	 100%

Figure II.14. Ground cover classes for estimating the percent of a regeneration plot occupied by the give classes of ground cover, and relative percent cover class of the five most common herbaceous species.

Proper identification of all plants is extremely important. Appendix II.F contains some ideas and procedures that will aid in ensuring that woody and herbaceous plant identification is done correctly.

12. Regeneration Plot #2: The tally sheet to be used for the second regeneration plot of the designated shrub plot.
13. ID Code: Same as (20) on the Stand (Tree Plot) Description form (Fig. II.6).

Photographic Documentation

Ground level photographic documentation can provide excellent qualitative information that can be helpful in analyzing and interpreting vegetation changes that occur over time.

To aid in interpretation and analysis of LTEMs information, photographs will be taken at each of the three plots at an LTEMs site. Photographs will be taken when the plots are installed and then at five year intervals. Two sets of photographs will be taken at each plot. One during the growing season (April 15 to September 1) when the leaves are present, and a second during the dormant season (December 1 to March 1) when leaves are off.

Two picture points will be established at each plot. The first point will be two meters upslope from corner #1 along the extension of the diagonal from corner #1 to corner #4. The second will be at a similar point upslope from corner #2 along the extension of the diagonal from corner #2 to corner #3 (Fig. II.6).

The line-of-sight will be along the diagonal. The focal point will be on a standard red and white surveyors range pole placed vertically at the center of the plot. The pictures will be taken at a height 1.5m, focused on the center point (range pole) with a line-of-sight parallel to the slope of the diagonal (center of the photograph) at the 1.5m mark on the range pole. Three exposures using a standard 50mm lens will be made at each point. The first exposure will be taken at an f/stop of f8, followed by two higher "f" stops. The objective is to get the maximum depth-of-field possible given the light conditions under the forest canopy. A Kodachrome or equivalent film type should be used. Record in the **comments** section (line 12) of the Stand (Tree Plot) Description form (Fig. II.6) the following information for each exposure.

1. Location: LTEMs site number, plot number and diagonal, i.e., corner #1 to corner #4, corner #2 to corner #3.
2. Film type and film speed (ASA or ISO).
3. Shutter speed.
4. Lens opening: The "f" stops in the sequence the pictures were taken.
5. Date the pictures were taken.
6. Name of person taking the pictures.
7. Name and model of camera used.
8. Lens type and size.

When the photographs have been developed all of the above information must be carefully documented on the photographs. The photographs will then be appropriately cataloged and stored for future reference.

FOREST COMPONENT OF AQUATIC PLOTS

It was not possible to establish standard, permanently marked LTEMs forest vegetation plots along stream sites due to the extremely variable, rugged topography bordering most streams in the SNP. In addition, since vegetation along streams does not generally fit directly into any of the forest cover types currently in use, it is desirable to refer to the vegetation present along stream sites as **stream vegetation** and treat this as a distinct class. The interface between the forested landscape and a stream may be thought of as a continually **disturbed** area, and vegetational patterns are not affected by competition for scarce resources such as soil moisture to the same degree as on upland sites. Resources tend to be sufficiently available so that most species are capable of becoming established along stream banks when there is a suitable regeneration opening.

Forest vegetation sampling at stream sites should be considered as follows. Please refer to Figure II.15 as necessary, and a similar drawing should be produced for every stream site where vegetation data is recorded.

1. Locate white (or black) orange-capped PVC aquatic site markers. From one of these markers follow a bearing (azimuth) in a

- direction perpendicular to the streambed and record the azimuth and distance from the marker to a point 2m from the edge of the stream. This point is to be the first sampling point. A stand (Tree Plot) Description form (Fig. II.6) must be filled out for each of the 10 prism points.
- Take a 10-factor prism point and record all trees by species, DBH, crown class, and comments, similar to Forest LTEMs sites. Fill out the first page of the two part Tree Plot Data form (Fig. II.10) at each of the 10 prism points. Tally woody stems equal to or greater than 1m and less than 5m in height located within a 3.4m radius of plot center. Use appropriate portion of the Shrub Plot Data form (Fig. II.12). This plot radius covers the same horizontal area as the 6m x 6m square Forest plots. Record all woody stems equal to or greater than 1m tall, and herbaceous vegetation within 0.3m radius of plot center. Use the appropriate portion of a Regeneration Plot form (Fig. II.13).
 - Proceed along the stream 25m to the next point, staying within the aquatic site. Record bearing and distance on the drawing. Run the transect as nearly as possible parallel with the streambed. Continue the sampling procedure as above. Sample five sites per plot on each side of the stream. Be sure to record azimuth and distances between all points, mark stream flow direction on the drawing, indicate direction of the transect with arrows on the drawing, and reference the transect to both aquatic site markers.
 - Measure the total tree height and determine the age for one dominant or codominant tree at each of the 10 prism points. Record this information on the Tree Plot Data form (Fig. II.10).

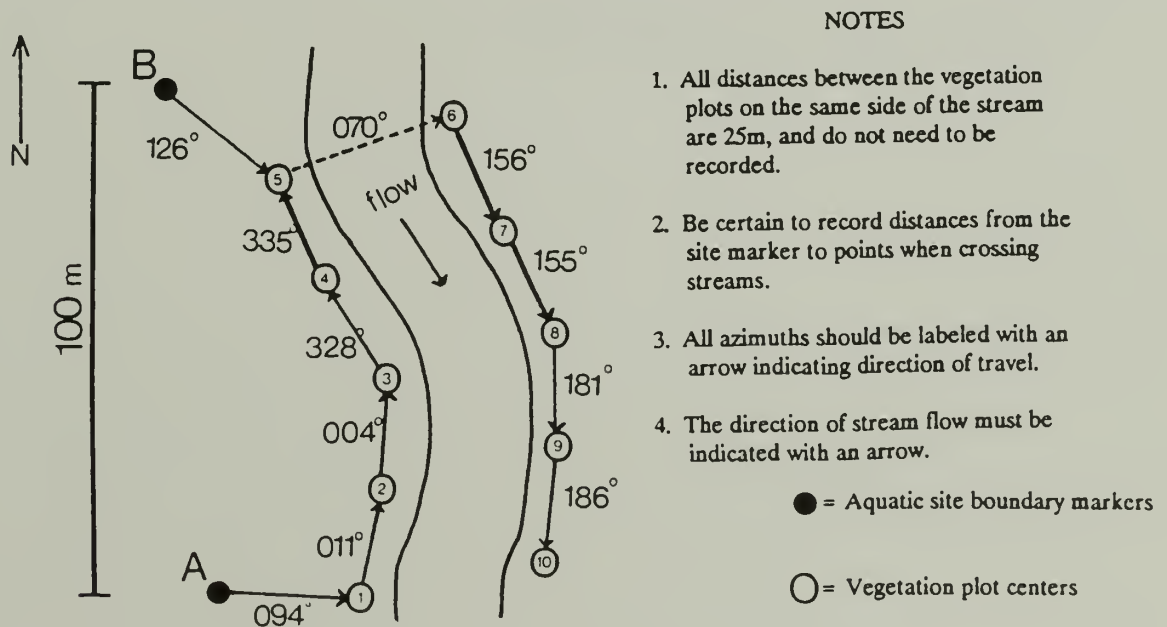


Figure II.15. Layout of transect for sampling forest component of aquatic plots.

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APPENDIX II-A

FOREST COVER TYPES

APPENDIX II-A

FOREST COVER TYPES

INTRODUCTION AND BACKGROUND

The major forest cover types identified for the Long-Term Ecological Monitoring Systems (LTEMS) for the Shenandoah National Park (SNP) are based on the Forest Cover Types of the United States and Canada (Eyre 1980). However, some modifications and additions have been made to the standard types in order to meet the needs of the project. In order to better understand and interpret the interactions between forest vegetation and the environment in which it exists, some background into the rationale for forest cover typing and a discussion of forest stand structure, shade tolerance, and crown classification is appropriate.

Forests in the SNP, like most natural forests, vary in species composition, growth rates, and physical structure along environmental gradients related to constantly changing topographic, microclimatic, and edaphic conditions across the landscape, and due to the stages of ecological succession of the stand at a particular point in time. As a result of this inherent variability, the broad forest cover type classifications described in this appendix contain highly heterogeneous combinations of species and relative abundances of those species. For the most part the forest cover types are closely related to site quality, with the presence of various species and species combinations being related to their ability to compete for required resources under a given combination of environmental conditions. The notable exception to this is the black locust type which is found across a wide range of site qualities. Its presence is closely related to the early stages of secondary succession resulting from severe disturbance rather than to site quality. The Virginia pine component of the pine forest cover type shares a broad range of site qualities similar to black locust.

The forest cover types are named after the predominant species in the main canopy of the stand. Normally dominance is determined by basal area (cross-sectional area of tree boles at breast height); however, during the initial inspections of a potential plot, ocular estimates of percent crown cover by species would be satisfactory. A quick check of the basal area, by species for most second growth stands in the

park, can be made with a prism or angle gauge with a basal area factor (BAF) of 10 square feet per acre. For light density stands composed of pole-sized trees, a BAF of 5 would be appropriate; and for large, old growth trees a BAF of 20 would be used. For more detailed information on the point sampling technique and the use of a prism, the reader is referred to the Forestry Handbook (Wenger 1984) pages 396-405. The forest cover type name is normally composed of from one to not more than three species. The species are listed in descending order of abundance within the main canopy. In order for an area to be designated a forest and be assigned a forest cover type, at least 25% of the area must be in tree crowns (based on vertical projections of crown area to the ground surface). In order for a specific species to be included in the forest cover type name, it must comprise at least 20% of the total basal area.

Stand structure often complicates the identification and designation of forest cover types. Stand structure refers to the distribution of trees in a stand by age, size, or crown classes and is described by vertical stratification of crowns by species. In the SNP pine species except for eastern white pine the average life expectancy is about 60 to 80 years. For white pine, eastern hemlock, and most hardwoods except for white oak and sugar maple, the average life expectancy is from 80 to 150 years. For sugar maple and white oak the average life expectancy would be 150 to 300 years. Common terms used to describe structure are:

Even-aged - A stand of trees having a narrow range of ages, usually considered as not exceeding 20% of the average life expectancy of the major trees that make up the main canopy of the forest.

Uneven-aged - A stand with trees of three or more age classes distributed across the rotation. All-aged is often used in place of uneven-aged and is defined as a stand in which trees of all or almost all ages classes from seedling to mature trees are represented. Two common subclasses of uneven-aged stands are regular uneven-aged and irregular uneven-aged.

Regular uneven-aged - A stand in which three or more distinct age classes occupy approximately equal areas and provide a balanced distribution of age classes.

Irregular uneven-aged - Stands that have three or more distinct age classes which do not occupy approximately equal areas. The distribution of age classes is unbalanced.

Two-aged - A stand containing two distinct age classes which differ by more than 20% of the rotation length.

All of the above stand structure types potentially occur in the SNP and knowledge of these structural forms will aid in the interpretation of stand and plot data. Probably the two most common stand structure types found in SNP are irregular uneven-aged and two-aged. These structure types are generally in a transition stage and are a result of relatively severe disturbance in the past. The loss of American chestnut during the first half of the century, and abusive tree harvesting practices prior to government ownership are probably the two most common causes; however, wildfire and ice damage have also been important. When large isolated trees or small groups of trees die or are removed over time, the tendency is for a stand of irregular uneven-aged structure to develop. When selective cutting, or **high-grading** (cut the best and leave the rest) occurred, stands with a distinct two-aged structure resulted. When cutting was relatively heavy or damage severe, the present-day stands are often composed of a few large holdover trees that carry a significant part of the basal area, and small trees that provide most of the crown cover. Under these canopy cover conditions the small trees would be the basis for naming the forest cover type. As a general statement, uneven-aged stands will normally be composed of the more shade tolerant species, with the abundance of shade tolerant trees increasing over time in the absence of major disturbance. Even-aged structures are generally formed following significant disturbances, are more common in early stages of secondary succession, and develop with the fastest growing, most competitive, and usually shade intolerant species forming the new forest community.

In the previous discussion of stand structure, reference was made to age and the distribution of age classes within a stand. An estimate of tree age is often erroneously made by assuming that tree size (diameter, height, or crown area) is correlated with tree age. Tree size is related to site quality

(trees grow faster and larger on better sites), tree shade tolerance, and crown position in the forest canopy. For shade tolerant species, age and size are more likely to be correlated than for shade intolerant species, especially when a tree is located in a subcanopy position.

The differentiation of tree crowns based on their relative positions in a crown canopy is helpful in describing the physical characteristics of the stand, interpreting present stand conditions, and predicting future stand development. The crown classification (Fig. II.A.1) most commonly used in describing relative crown positions is based on four classes as follows:

Dominant - Trees with crowns extending above the general level of the main canopy of adjacent trees, and receiving full light from above and partly from the sides.

Codominant - Trees with crowns forming the general level of the main canopy of adjacent trees, and receiving full light from above and comparatively little from the sides.

Intermediate - Trees with crowns extending into the lower portion of the main canopy of adjacent trees, but shorter in height than the codominants. They receive little direct light from above and none from the sides. Usually intermediate crown-classed trees have small crowns that are crowded on the sides.

Overtopped/Suppressed - Trees with crowns entirely below the general level of the canopy of adjacent trees, and receiving no direct light from above or from the sides.

Individual tree silvical characteristics, especially shade tolerance, are important in understanding stand structural attributes, and in predicting future stand development. Tolerance, in the context of this discussion, is related to the ability of a forest tree to survive and develop under a forest canopy, and is primarily a function of light. However, it must be understood that moisture, nutrition, and such factors as disease, insects, and browsing must also be considered. There are normally considered to be five levels of shade tolerance with very tolerant species being able to become established, grow, and develop under a full canopy, while a very intolerant species requires full sunlight of exposed sites in order to become established and flourish. Table II.A.1 provides the relative shade tolerance of the common tree species found in SNP.



Figure II.A.1. The relative positions of trees using four classes for crown classification. D = Dominant; C = Codominant; I = Intermediate; and O = Overtopped.

FOREST COVER TYPE DESCRIPTIONS

The eight named forest cover types and the unspecified special type are described in detail. Each description will include the general site characteristics, current extent, and conditions under which the cover type is likely to occur. Reference will be made to the Society of American Foresters (SAF) designated types (Eyre 1980) where appropriate, and the range of site qualities on which the type normally occurs will be expressed in terms of site index in meters. Site index is defined as an indirect measure of site quality for a given species, or closely related group of species, expressed as the height of dominant trees at a specified base age. In this manual the base age is 50 years, and the reference species is white oak. As an example, if we determine the site index to be 20, then we are saying that if white oak were growing at the specified location then its height would be 20m (65.6 ft) at 50 years of age. For a point of reference the average site index, base age 50, for white oak on the SNP would be about 18m (59 ft) with a range of 14 - 28m (46 - 92 ft). The ranges of site index given for each type is meant to provide a relative idea of where the particular forest cover type fits into the site quality scheme rather than as a definitive measure of site quality.

Chestnut Oak

SAF Code: 44 Extent: 49% of SNP area
Site Index₅₀ Range: 15.2 - 19.8 m (50 - 65 ft)

The chestnut oak type and associated subtypes generally occur on the dryer and poorer sites in the SNP. The most common sites have shallow soils where rock outcrops are common, and are associated with steep slopes, ridge tops, and spur ridges with southern or western aspects. Available soil moisture is the limiting factor for growth and production on most of the sites occupied by chestnut oak and associated species. Common associated species include scarlet oak, hickory species, black oak, northern red oak, red maple, black locust, pitch pine, and Virginia pine. On the better quality sites within the type, basswood, white ash, and eastern white pine are often found. Historically, the chestnut oak have been subjected to periodic wildfire and have been logged on one or more occasions. In general the stands range from 40-150 years old and are even-aged or two-aged; however, in some cases stands with an irregular uneven-aged structure occur.

Common understory species include red maple, mountain laurel, bear oak, striped maple, sassafras, *Vitis spp.*, and *Vaccinium spp.* Flowering dogwood is a very common understory species, especially on the better sites within the type.

Most of the species associated with the chestnut oak types are prolific sprouters, and many of the stems have developed from clumps of stump sprouts following a disturbance. In openings where sprout competition is minimal, individuals of seed origin readily develop. The chestnut oak type is often a physiographic climax due to its competitive ability on sites of limited productivity.

Associated subtypes include:

- chestnut oak - northern red oak
- hickory - mixed oaks
- chestnut oak - pitch pine
- chestnut oak - white oak
- chestnut oak - eastern white pine - northern red oak
- chestnut oak - black oak - scarlet oak
- chestnut oak - yellow-poplar
- hickory
- bear oak - pitch pine - chestnut oak
- scarlet oak - pitch pine
- black oak - northern red oak
- bear oak

TABLE II-A-1. Relative shade tolerance of tree and woody shrub species found in the Shenandoah National Park of Virginia.¹

VERY TOLERANT			
American beech Fraser fir	American holly red spruce	eastern hemlock striped maple	flowering dogwood sugar maple
TOLERANT			
American basswood downy serviceberry red maple	American hornbeam eastern hophornbeam red mulberry	boxelder eastern redbud sourwood	common persimmon mountain maple yellow buckeye
INTERMEDIATE			
American chestnut eastern white pine mountain laurel shagbark hickory yellow birch	black birch elms northern red oak spice bush	black oak green ash pignut hickory white ash	chestnut oak hackberry sassafras white oak
INTOLERANT			
American sycamore black locust hawthorns pitch pine shortleaf pine tree-of-heaven	bear oak black walnut mockernut hickory post oak sweet cherry viburnums	black cherry butternut mountain ash royal paulownia sweetgum witch hazel	blackgum cucumbertree northern catalpa scarlet oak Table Mountain pine yellow-poplar
VERY INTOLERANT			
bigtooth aspen sumacs	eastern cottonwood Virginia pine	hazel alder	pin cherry

¹Based on a synthesis of information from Fowells (1965), Preston (1961), Elias (1980), Spurr and Barnes (1980), and the authors field observations in Virginia

Northern Red Oak

SAF Code: 55 Extent: 10% of SNP area
 Site Index₅₀ Range: 18.2 - 22.8m (60 - 75 ft)

The sites dominated by the northern red oak type and associated subtypes are generally cool, with good moisture conditions throughout most of the growing season, and are considered to be of medium site quality. On southern and western aspects the northern red oak type occurs on the gently sloping, lower slope positions, while on northern and eastern aspects the type occurs on moderate to steep slopes of mid- and upper-slope positions. The northern red oak type is closely related to the cove hardwood type in terms of the micro-climatic conditions that prevail. Common associated main canopy species include white oak, black oak, hickory, white ash, chestnut oak, yellow-poplar, and black birch. Understory species include witch hazel, red maple, flowering dogwood, mountain laurel, striped maple, *Azalea spp.*, *Rubus spp.*, *Vaccinium spp.*, and *Viburnum spp.* Seedlings of overstory species are also found. The stands in SNP range in age from less than 40 to not much over 100 years. The most common disturbance has been related to the loss of American chestnut and periodic logging prior to government ownership. Wildfires do occur; however, the severity of fire is relatively low compared to that which occurs in the chestnut oak and pine types. In general, an even-aged stand structure would be the most prevalent; however, two-aged and irregular uneven-aged stands are common.

Because of the similarity in successional development of eastern white pine and the northern red oak type, white pine is included in the northern red oak type. The abundance of white pine in the SNP is minor; however, it may be appropriate to include LTEMs plots on sites where white pine is the dominant species and include the data under the **special** forest cover type class.

The northern red oak type is most likely subclimax, with the climax type tending toward red maple and perhaps eventually to a domination by American beech, eastern hemlock, and sugar maple. The SNP is on the eastern edge of the sugar maple's natural range and therefore the extent of sugar maple dominance is in question. The occurrence of scattered sugar maple in the coves suggest that in time it would be a part of the climax forest type.

Associated subtypes include:

northern red oak - white oak
 white oak
 white oak - black oak - chestnut oak
 black oak
 white oak - black oak - northern red oak
 white oak - black oak
 black oak - northern red oak
 white pine - mixed oak
 white pine
 white pine - yellow-poplar
 white pine - chestnut oak

Cove Hardwoods

SAF Code: None Extent: 15% of SNP area
 Site Index₅₀ Range: 19.8 - 24.4m (65 - 80 ft)

The cove hardwood type, composed mainly of northern red oak, white ash, and basswood, is similar to the northern red oak type in terms of species, but has a slightly higher site quality range. The type is differentiated on the basis of the cove being a unique landform. While the species may overlap with other types, the rate of vegetation change is likely to be more rapid and the reasons for change are probably different from those found on ridges and associated side slopes. Because of the protected nature of a cove, the damage from wind, ice, and wildfire would be significantly less than that found on adjacent broad sideslopes. The higher site quality, coupled with the sheltered cove effect, has probably been a major factor in explaining the increased number of species being present on the cove sites when compared to the northern red oak type. The higher number of species and the more diverse silvical characteristics of these species are likely to result in a more rapid rate and different direction of successional change when compared to closely related types. Because of the more valuable species and more abundant high quality stems on cove hardwood sites, logging disturbance prior to government ownership was probably more severe and the amount of wood removed was relatively high. As a result of the more intense logging and generally more shade tolerant species being present, the stand structure of cove hardwoods tends to be irregular uneven-aged. At present the stands are sub-climax and it is expected that American beech and sugar maple will be significant components of future climax stands. Common associated species include yellow-poplar on the better sites; red maple, black birch, hickory spp, and eastern hemlock on average sites; chestnut oak on the poorest sites; and black locust on severely disturbed sites. Dominant understory

species include striped maple, witch hazel, spicebush, flowering dogwood, *Vitis spp*, *Rubus spp*, and black cherry.

Most of the cove hardwood stands range from 40 to 100 years old with only a few less than 40 years and some more than 100 years old.

Subtypes found on cove sites that include a white pine component of more than 50% should not be considered as an LTEMs plot under the cove hardwood type.

Associated subtypes include:

- white ash
- white pine - northern red oak - red maple
- red maple
- red maple - mixed oak
- sugar maple
- white pine - eastern hemlock - mixed oak
- white pine - eastern hemlock - mixed hardwoods
- sugar maple - basswood
- black birch
- sugar maple - black birch - yellow birch
- basswood
- American beech - sugar maple

Yellow-Poplar

SAF Code: 57 **Extent:** 16% of SNP area
Site Index₅₀ Range: 22.8 - 28.0m (75 - 92 ft)

The yellow-poplar type is a highly productive combination of hardwood species dominated by yellow-poplar, with northern red oak, sugar maple, American beech, basswood, black locust, black birch, white oak, white ash, red maple, eastern hemlock, and eastern white pine being common associates. The sites dominated by the yellow-poplar and associated subtypes represent the best sites in the SNP. The sites are generally cool, moist, with good moisture conditions throughout the growing season, and are situated on moderate to deep, fertile and well-drained soils. The type occurs to a limited degree on gently sloping, lower slope positions, and protected coves of southern and western aspects. On northern and eastern aspects it occurs extensively on moderate to steep slopes of lower - and mid-slope positions and in coves.

In general, yellow-poplar-dominated stands are in an early subclimax successional stage. Yellow-poplar is a shade intolerant species and therefore most often exhibits an even-aged or

two-aged stand structure. As the species composition shifts to the more tolerant species, such as northern red oak, basswood, sugar maple, and white ash, the stands will tend toward an uneven-aged structure. In the absence of disturbance the climax type will include a significant component of sugar maple, American beech, and perhaps eastern hemlock. Most stands in the SNP are estimated to be under 100 years old; however, individual stems on many sites are well over 100 years of age.

Yellow-poplar is a unique species in that it responds vigorously to increasing site quality. For example, at a site index₅₀ of 24.4m (80 ft) for white oak, yellow-poplar on the same site would have a site index₅₀ of 30.5m (100 ft) (Doolittle 1958). This means that on a comparable site yellow-poplar would be 6.1m (20 ft) taller than a white oak on the same site. However, at a location with a site index₅₀ of 16.8 m (55 ft) for white oak, the site index₅₀ for yellow-poplar is predicted to be the same as that for white oak.

Common understory species include flowering dogwood, spicebush, red maple, striped maple, witch hazel, downy serviceberry, sassafras, and *Vitis spp*. On many sites, as a result of dense overstory canopy and high basal areas, the understory is often sparse and composed of only the more shade tolerant species.

Associated subtypes include:

- yellow-poplar - mixed oak
- yellow-poplar - white ash
- yellow-poplar - black birch
- yellow-poplar - white oak - sugar maple
- yellow-poplar - Virginia pine
- yellow-poplar - white oak - northern red oak
- yellow-poplar - eastern hemlock

Black Locust

SAF Code: 50 **Extent:** 4% of SNP area
Site Index₅₀ Range: 16.8 - 24.4m (55 - 80 ft)

The black locust type develops on a wide range of sites following abandonment of fields and pastures and following wildfires or other severe disturbances. Black locust is a pioneer species and usually develops as nearly pure even-aged stands during the earliest stages of a secondary succession. Invasion by other hardwoods takes only a few years. Normally the type is short lived, perhaps 40 - 60 years, and succession to associated hardwood types occurs relatively

rapidly. Because of the wide range of sites on which the type occurs, associated species could include almost any species native to the SNP. The most common associated species include red maple, yellow-poplar, hickory, black cherry, white ash, and various oak species. On the very best sites, scattered individual trees will be found in the main canopy of more shade tolerant species. Understory species are quite variable; however, the most common include flowering dogwood, red maple, spice bush, black cherry, *Rubus spp.*, *Malus spp.*, and *Vitis spp.*

In the SNP the black locust type is not relegated to any particular topographic or specific site condition. Its presence is associated with those areas previously classified as open land or grassland and areas that have been subjected to severe disturbances. Most of the area cleared prior to government ownership was at upper elevations, where slopes were gradual and could be used for pasture and grazing.

Once black locust starts to lose dominance in the stand as a result of competition from more shade tolerant species, the transition to a more advanced stage of secondary succession will occur rapidly. Therefore, if a stand does not have 40% or more black locust with dominant or co-dominant crowns in the main canopy, the site should not be included for a LTEMs plot under the black locust type. Since these relatively old, rapidly changing black locust stands are of ecological importance, it would be appropriate to include them in the LTEMs program by installing plots and including the data under the special forest cover type class.

Associated subtypes include:

- black locust - black cherry - red maple
- black locust - black cherry
- black locust - black cherry - mixed oak

Pitch Pine

SAF Code: 45 **Extent:** 3% of SNP Area
Site Index₅₀ Range: 13.7 - 19.8m (45 - 65 ft)

The pitch pine type occurs most often on dry, poor quality sites, characterized by shallow, sandy, and shaley soils associated with ridges and steep side slopes on southern and western aspects. Table Mountain pine is a common associate, and when the two species occur together, they are usually located on the poorest quality sites in the SNP. On the poorest sites the pitch pine - Table

Mountain pine type may be a physiographic or fire climax. On the better sites the pitch pine type is subclimax, giving way to more tolerant hardwoods. The common associated overstory species on the average sites include chestnut oak, scarlet oak, black locust, white oak, blackgum, and Virginia pine. Common understory species include mountain laurel, bear oak, sassafras, *Vaccinium spp.*, and the red maple on the better sites. The origin of the type is probably most often associated with wildfire or other severe disturbance. The pitch pine type is usually found at higher elevations than the closely associated Virginia pine type. When the pitch pine type is composed of mostly pine species the stands will tend to be even-aged; however, when pine-hardwood mixes occur the stands will tend to be more irregular uneven-aged. The pine species seldom exceed 70 - 100 years of age, with the pine starting to drop out of the stands between 50 and 70 years, depending on site quality.

Associated subtypes include:

- pitch pine - Table Mountain pine
- pitch pine - chestnut oak
- pitch pine - scarlet oak
- Table Mountain pine
- pitch pine - black oak
- pitch pine - Virginia pine
- pitch pine - white pine

Virginia Pine

SAF Code: 79 **Extent:** 3% of SNP Area
Site Index₅₀ Range: 16.8 - 22.8m (55 - 75 ft)

The Virginia pine type is closely related to the pitch pine type; however, there are some subtle differences. The Virginia pine type would be more likely to occur on the better sites, within the range of the pine type. The origin of the Virginia pine type is not as closely tied to wildfire as is the pitch pine type. Intensive forest harvesting, and the abandonment of fields and pastures are common sites for Virginia pine invasion. The Virginia pine type would be more likely to occur at lower elevations within the SNP than would pitch pine. Virginia pine is an early secondary succession species and would seldom, if ever, be a subclimax type.

Common overstory associates in the Virginia pine type include chestnut oak, white oak, black oak, northern red oak, scarlet oak, red maple, black locust, eastern red cedar, sourwood, and pitch pine. Understory species include mountain laurel, flowering dogwood, red maple, bear oak,

Vaccinium spp., sassafras, blackgum, sourwood, and *Vitis spp.* When Virginia pine dominates in a stand, the structure will be even-aged; and, as the pine component starts to decline, an irregular uneven-aged structure would be common. Virginia pine will generally start to decline and mortality becomes high when the stands reach 60 - 75 years of age.

Associated subtypes:

- Virginia pine - mixed oak
- Virginia pine - pitch pine
- eastern redcedar - Virginia pine - mixed oak
- Virginia pine - mixed hardwoods

Eastern Hemlock

SAF Code: 23 **Extent:** less than 1% of SNP area
Site Index₅₀ Range: 19.8 - 24.4m (65 - 80 ft)

Eastern hemlock is the smallest type within the SNP in terms of the area it occupies. However, it is very important ecologically.

Historically, the abundance and distribution of eastern hemlock has been controlled to a large degree by the periodic occurrence of wildfire. Hemlock is thin-barked and shallow-rooted; therefore, seedlings and saplings are very susceptible to damage and death from fire. Older (50 years and older) hemlock occurs mostly in protected cove sites on moist, cool northern, and eastern aspects. With the control of wildfire as a primary management objective since the establishment of the SNP, eastern hemlock is migrating out of the coves and onto adjacent mid-and lower-slope sites of favorable site quality. At present, hemlock found outside of the coves is relegated to the subcanopy; however, because it is long-lived and very shade tolerant, hemlock will likely move to a main canopy position over time, and become a significant component of the climax type.

The eastern hemlock type occurs on sites similar to those occupied by the northern red oak type and the cove hardwood type. Common associated species include northern red oak, basswood, yellow birch, yellow-poplar, eastern white pine, sugar maple, and American beech. Due to the dense main canopy, hemlock understory is often sparse, containing only the most shade tolerant species. Common understory species include hemlock seedlings and saplings, witch hazel, striped maple, mountain maple, sugar maple, blackgum, and *Viburnum spp.* Most

hemlock stands in the SNP are 40 years or older. Stand structure is variable, but uneven-aged stands are probably the most common.

Associated subtypes include:

- hemlock - yellow birch
- hemlock - eastern white pine
- hemlock - yellow-poplar
- hemlock - northern red oak

Special

The **special** type classification was established to accommodate ecologically important vegetation conditions that are unique and restricted to a relatively narrow range of sites or locations within the park. It is not necessary that the vegetation types included under the special type classification be replicated in each district or that they fit into the specified elevation and aspect categories. If the distribution of the vegetation type allows for replication and it is deemed important, then the sites should be replicated. It is necessary that, if physically possible, three plots be established and measured at each site.

Initially, two cover types have been identified for inclusion in the special category, the eastern white pine type and the black locust type that contains less than 40% dominant and codominant black locust stems and where the locust is in a rapid state of decline. Other candidate **special** types could include unique streamside vegetation; open land sites that presently do not qualify as a forest type, but are likely to develop as such; recently burned areas where post-wildfire vegetation development is of significant interest; other sites of localized major disturbances; and sites impacted by insects such as the gypsy moth, and disease.

APPENDIX II-B

**USGS 7.5 MINUTE QUADRANGLE MAP
NAME AND CODE CROSS-REFERENCE**

APPENDIX II-B

**USGS 7.5-MINUTE QUADRANGLE MAP
NAME AND CODE CROSS-REFERENCE**

USGS 7.5-minute Quadrangle Map Name and Code Cross-reference. The left two columns provide the Code for each Quadrangle used in the SNP LTEMs in numerical order followed by the Quadrangle name. The right two columns provide the Quadrangle name in alphabetical order followed by the Code.

CODE by NAME CROSS-REFERENCE

<u>CODE</u>	<u>QUADRANGLE NAME</u>	<u>QUADRANGLE NAME</u>	<u>CODE</u>
M40	GREENFIELD	BENTONVILLE	U44
N39	WAYNESBORO WEST	BIG MEADOWS	S43
N40	WAYNESBORO EAST	BRIGHTWOOD	R45
N41	CROZET	BROWN'S COVE	P41
P39	FORT DEFIANCE	CHESTER GAP	U45
P40	CRIMORA	CRIMORA	P40
P41	BROWN'S COVE	CROZET	N41
P42	FREE UNION	ELKTON EAST	R42
Q40	GROTTOES	ELKTON WEST	R41
Q41	MCGAHEYSVILLE	FLETCHER	R43
Q42	SWIFT RUN GAP	FLINT HILL	U46
Q43	STANARDSVILLE	FORT DEFIANCE	P39
Q44	ROCHELLE	FREE UNION	P42
R41	ELKTON WEST	FRONT ROYAL	V45
R42	ELKTON EAST	GREENFIELD	M40
R43	FLETCHER	GROTTOES	Q40
R44	MADISON	LURAY	T43
R45	BRIGHTWOOD	MADISON	R44
S42	STANLEY	MASSIE'S CORNER	T46
S43	BIG MEADOWS	MCGAHEYSVILLE	Q41
S44	OLD RAG MTN	OLD RAG MTN	S44
S45	WOODVILLE	RILEYVILLE	U43
T43	LURAY	ROCHELLE	Q44
T44	THORNTON GAP	STANARDSVILLE	Q43
T45	WASHINGTON	STANLEY	S42
T46	MASSIE'S CORNER	STRASBURG	V44
U43	RILEYVILLE	SWIFT RUN GAP	Q42
U44	BENTONVILLE	THORNTON GAP	T44
U45	CHESTER GAP	WASHINGTON	T45
U46	FLINT HILL	WAYNESBORO EAST	N40
V44	STRASBURG	WAYNESBORO WEST	N39
V45	FRONT ROYAL	WOODVILLE	S45

APPENDIX II-C

WOODY PLANT DICTIONARY

APPENDIX II-C

WOODY PLANT DICTIONARY

A woody plant dictionary containing field code, common name, genus, and species of trees and shrubs commonly found in the Shenandoah National Park of Virginia.

Code	Common Name	Genus	Species
AFR	Fraser Fir	Abies	fraseri
ANG	Boxelder	Acer	negundo
APN	Striped Maple	Acer	pennsylvanicum
APL	Norway Maple	Acer	platanoides
ARB	Red Maple	Acer	rubrum
ASC	Sugar Maple	Acer	saccharum
ASP	Mountain Maple	Acer	spicatum
ACE	Maple	Acer	spp
AHP	Horse Chestnut	Aesculus	hippocastanum
AOC	Yellow Buckeye	Aesculus	octandra
AAL	Tree-of-Heaven	Ailanthus	altissima
ARG	Speckled Alder	Alnus	rugosa
ASR	Hazel Alder	Alnus	serrulata
ALN	Alder	Alnus	spp
ATL	Pawpaw	Asimina	triloba
AAR	Downy Serviceberry	Amelanchier	arborea
AME	Serviceberry	Amelanchier	spp
AZA	Azalea	Azalea	spp
BAL	Yellow Birch	Betula	alleghaniensis
BLN	Black Birch	Betula	lenta
BPP	Paper Birch	Betula	papyrifera
BPL	Gray Birch	Betula	populifolia
BPR	Paper Mulberry	Broussonetia	papyrifera
BSM	Boxwood	Buxus	sempervirens
CRP	Am. Hornbeam (Musclewood)	Carpinus	caroliniana
CCR	Bitternut Hickory	Carya	cordiformis
CGL	Pignut Hickory	Carya	glabra
CLC	Shellbark Hickory	Carya	laciniosa
COV	Shagbark Hickory	Carya	ovata
CTM	Mockernut Hickory	Carya	tomentosa
CAY	Hickory	Carya	spp
CDN	American Chestnut	Castanea	dentata
CPM	Allegheny Chinkapin	Castanea	pumila
CSP	Northern Catalpa	Catalpa	speciosa
COC	Hackberry	Celtis	occidentalis
CCN	Eastern redbud	Cercis	canadensis
COB	Quince	Cydonia	oblonga
CLE	Clematis	Clematis	spp
CAT	Alternate Leaved Dogwood	Cornus	alternifolia
CFL	Flowering Dogwood	Cornus	florida
CAM	American Hazelnut	Corylus	americanus
CCT	Beaked Hazelnut	Corylus	cornuta
CRG	Hawthorn	Crataegus	spp
DYR	Common Persimmon	Diospyros	virginiana
FGR	American Beech	Fagus	grandifolia

Code	Common Name	Genus	Species
FAM	White Ash	Fraxinus	americana
FNG	Black Ash	Fraxinus	nigra
FPN	Green Ash	Fraxinus	pennsylvanica
GTR	Honey Locust	Gleditsia	triacanthos
GDC	Kentucky Coffee Tree	Gymnocladus	dioica
HVR	Witch Hazel	Hamamelis	virginiana
HAR	Wild Hydrangea	Hydrangea	arborescens
IMN	Largeleaf Holly	Ilex	montana
IOP	American Holly	Ilex	opaca
JCN	Butternut	Juglans	cinerea
JNG	Black Walnut	Juglans	nigra
JVR	Eastern Red Cedar	Juniperus	virginiana
KLT	Mountain Laurel	Kalmia	latifolia
LBN	Spicebush	Lindera	benzoin
LTL	Yellow Poplar	Liriodendron	tulipifera
LST	Sweetgum	Liquidambar	styraciflua
LJP	Japanese Honeysuckle	Lonicera	japonica
MPM	Osage Orange	Maclura	pomifera
MAC	Cucumbertree	Magnolia	acuminata
MAG	Magnolia	Magnolia	spp
MAL	Apple	Malus	spp
MRB	Red Mullberry	Morus	rubra
NSL	Blackgum	Nyssa	sylvatica
OVR	E. Hophornbeam (Ironwood)	Ostrya	virginiana
OAR	Sourwood	Oxydendrum	arborescens
PQN	Virginia Creeper	Parthenocissus	quinquefolia
PTM	Royal Paulownia	Paulownia	tomentosa
PRB	Red Spruce	Picea	rubens
PEC	Shortleaf Pine	Pinus	echinata
PPN	Table Mountain Pine	Pinus	pungens
PRG	Pitch Pine	Pinus	rigida
PST	Eastern White Pine	Pinus	strobus
PSY	Scotch Pine	Pinus	sylvestris
PVR	Virginia Pine	Pinus	virginiana
POC	American Sycamore	Platanus	occidentalis
PDL	Eastern Cottonwood	Populus	deltoides
PGR	Bigtooth Aspen	Populus	grandidentata
PTR	Quaking Aspen	Populus	tremuloides
PAV	Sweet Cherry	Prunus	avium
PPS	Pin Cherry	Prunus	pennsylvanica
PPR	Peach	Prunus	persica
PSR	Black Cherry	Prunus	serotina
PRU	Cherry/Plum/Peach	Prunus	spp
PVG	Choke Cherry	Prunus	virginiana
PTF	Hop Tree	Ptelea	trifoliata
QAL	White Oak	Quercus	alba
QBC	Swamp White Oak	Quercus	bicolor
QCC	Scarlet Oak	Quercus	coccinea
QIL	Bear Oak	Quercus	ilicifolia
QIM	Shingle Oak	Quercus	imbricaria
QMR	Blackjack Oak	Quercus	marilandica
QPR	Chestnut Oak	Quercus	prinus

Code	Common Name	Genus	Species
QRB	Northern red oak	Quercus	rubra
QST	Post Oak	Quercus	stellata
QUE	Oak	Quercus	spp
QVL	Black Oak	Quercus	velutina
RMA	Great Rhododendron	Rhododendron	maximum
RCP	Winged Sumac	Rhus	copallina
RGL	Smooth Sumac	Rhus	glabra
RTP	Staghorn Sumac	Rhus	typhina
RIB	Gooseberry, etc.	Ribes	spp
RPS	Black Locust	Robina	pseudoacacia
ROS	Wild Rose	Rosa	spp
ROD	Raspberry Flowering	Rubus	odarus
RUB	Blackberry, etc.	Rubus	spp
SAI	Willow	Salix	spp
SAL	Sassafras	Sassafras	albidum
SCN	Common Elderberry	Sambucus	canadensis
SPB	Red Elderberry	Sambucus	pubens
SAB	Elderberry	Sambucus	spp
SHR	Carrion Flower	Smilax	herbacea
SMI	Greenbriar	Smilax	spp
SRT	Common Greenbriar	Smilax	rotundifolia
STM	Bristly Greenbriar	Smilax	tamnoides
SAM	Mountain-Ash	Sorbus	americana
SOR	Coralberry	Symphoricarpos	orbiculatus
TCD	Native Yew	Taxus	canadensis
TCS	Japanese Yew	Taxus	cuspidata
TAM	Basswood	Tilia	americana
TRD	Poison-Ivy	Toxicodendron	radicans
TTX	Poison-Oak	Toxicodendron	toxicodendron
TCN	Eastern Hemlock	Tsuga	canadensis
URB	Slippery Elm	Ulmus	rubra
UAM	American Elm	Ulmus	americana
UTH	Rock Elm	Ulmus	thomasii
VAC	Blueberry, Huckleberry etc.	Vaccinium	spp
VAR	Maple Leaved Viburnum	Viburnum	acerifolium
VPR	Smooth Blackhaw	Viburnum	prunifolium
VIB	Viburnum	Viburnum	spp
VIT	Grapevine	Vitis	spp

APPENDIX II-D

STANDARD MEASUREMENT PROCEDURES

APPENDIX II-D

STANDARD MEASUREMENT PROCEDURES AND QUALITY ASSURANCE ¹

INTRODUCTION

Appropriate standardization of research methods within a project and among projects which contribute data to a centralized database is critical for valid integration, synthesis, interpretation, and assessment of results. The ability to implement standardized measurement procedures for data collection greatly enhances the assurance of quality data and directly influences the level of confidence placed on assessment and management decisions that are based on the results obtained from data analysis. For studies such as LTEMs, where the primary objective is to determine changes in the SNP ecosystems that occur over time, the use of standardized methods and procedures is an absolute necessity. Without standardized methods and consistent procedures for taking measurements across time, it will be impossible to determine if there are real differences in the attributes used to characterize and quantify a particular forest community, or if the differences are due solely or in part to the methods and procedures used to measure the attributes chosen to quantify the forest community.

The purpose of this Appendix is to provide standardized methods and procedures so that data quality for the LTEMs is documented and can be assessed, and that future measurements will result in valid comparisons.

INDIVIDUAL TREE LEVEL MEASUREMENTS

Individual trees in a forest stand respond to a multitude of abiotic and biotic influences. The primary determinants of vigor and growth are the amount of site resources (e.g., water, nutrients, and light) available and the physiological age of the trees. The availability of resources is determined by the external conditions of the climate and site and also by conditions within the

forest stand. The position of an individual tree relative to its neighbors, and density, basal area, and species composition of the forest stand all influence the amount of water, light, and nutrients available for any one tree. These tree-stand interactions make it necessary to collect stand-level data as well as individual tree data.

The observations on individual trees are designed to determine the size, age, growth, and vigor of individuals within the forest population. The primary size variable to be used is the diameter at breast height (DBH). A random sample of trees within the permanent plots will be measured for a secondary size variable, tree height. The sample of trees may be stratified by size, species, condition, etc., as needed for specific objectives. These same trees may also be cored to determine tree age. Tree growth will be determined as the difference between the size attribute measured from one sampling interval to the next.

The standard operating procedures (SOPs) for individual tree measurements are contained in this section. The documentation of a standard or recommend operating procedure for increment coring, measuring DBH, and tree height. Use of these SOPs should reduce inter- and intra-site variability, reduce documentation requirements for the individual researchers, and provide management team with information of defined and documented quality.

PROCEDURE FOR MEASUREMENT OF DIAMETER AT BREAST HEIGHT

Diameter measurements are the most commonly collected variable in forest inventory work. Diameters can be used in predicating basal area, density, volumes, and product potential of trees inventoried, and can be used for inventories to establish change over time.

¹ The information presented in this Appendix was obtained from the following document: Zedaker, S.M. and N.S. Nicholas. November 1989. *Quality Assurance Methods Manual For Forest Site Classification and Field Measurements*. School of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University. Blacksburg, VA 24061. The authors of this Appendix used only those procedures and associated discussions from the Zedaker and Nicholas (1989) manual that directly apply to the SNP LTEMs project.

Diameter measurements can be made with diameter tapes or with calipers. Metal diameter tapes will be used for all DBH measurements. Additional measurements with calipers may be done if asymmetry data are needed. Tapes vary in the maximum diameter of tree that can be measured from 64 to 320cm. One side of the tape is graduated in centimeters and millimeters so that the diameter can be read directly from the tape, and the other side is normally in linear meters graduated in centimeters and millimeters. The tapes are equipped with a claw hook on the end of the tape and a hand crank rewind. Diameter tapes are available either in left-hand or right-hand tapes. Calipers are also available in a range of sizes. Dial calipers measure diameter to 150mm with accuracy to 0.3mm, while tree calipers can measure up to 125cm.

DBH measurements are made outside of the bark (d.o.b.) at a height of 1.37m above the ground. When on a slope, trees are measured on the uphill side of the tree. Record the DBH to the nearest mm for each tree tallied.

In the cases of irregularities at DBH, such as swellings, bumps, depressions, and branches, diameters are measured immediately above the irregularity at the place where it ceases to affect the normal stem form (Fig. II.D.1). Fenceline trees containing, or suspected of containing, wire are measured for diameter at the normal 1.37m height. Swell-butted trees should be measured at a point 0.46m above the end of the pronounced swell or bottleneck if the bottleneck is more than 0.91m high. If it is doubtful as to whether a tree is swell-butted, measure at 1.37m above the ground. If the stem forks immediately above DBH, the diameter is measured below the swell at the place where the fork ceases to affect the normal stem form. When the stem forks below DBH, and above 0.30m, consider the tree as two or more trees and measure diameter at a point 1.07m above the point where the piths intersect. A tree which forks below 0.30m is measured as two trees with the diameter taken at 1.37m on each stem. A tree is not measured as forked if the piths intersect above 1.37m. Figure II.D.1 illustrates procedures for DBH measurements in a variety of situations.

All trees (stems at least 1.37m tall and having a DBH of 5cm or greater) on any permanent plot are tagged with hard aluminum numbered tree tags or otherwise permanently marked at a consistent height. The mark must be at or below 1.17m to avoid swelling that impacts the DBH region. Tags are nailed on the uphill side of the tree 15cm from

the ground (the length of a gutter spike). If a stem is dead or if the DBH is less than 10.0cm, then use an 8d aluminum nail to tag the tree. If the stem is alive and has a DBH of greater than or equal to 10.0cm, then use an aluminum gutter spike to tag the tree. Both spikes and nails should be perpendicular to the tree bole axis. Gutter spikes should be pounded in at least 4cm but no more than 6cm, and the 8d nails at least 2cm or until the nail is firmly imbedded.

A measuring rod should be balanced on top of the spike or nail or held at the mark. DBH will be measured at a consistent height of 1.37m. A diameter tape or caliper should be placed at a right angle to the stem at the point where the measurement is taken. The tape should be pulled taut, allowing no sag in the tape before reading the measurement.

The hook on the end of the tape is used to facilitate placing the tape around large trees. When measuring with calipers, caliper arms should be securely pressed to the sides of the tree. Two caliper readings at right angles should be taken: one north/south and one east/west. Care must be taken to ensure no abnormalities, such as lumps, swells, limbs, and vines, occur at the point of measurement.

Most diameter tapes come in a vinyl-covered steel case, and the flexible tape is enameled or chrome-clad steel so that very little maintenance is required. The tape should be wiped dry after use in wet or muddy conditions and a light coat of oil applied. Since only metal tapes are used, stretching will not occur, but tapes with visible kinks should be replaced.

Tree calipers are usually made of aluminum and need little maintenance. Occasionally, screws holding the caliper pieces together will need to be tightened.

Periodically, all calipers are to be checked by measuring three objects of known width. Point of measurement must be obvious so that any variation of measurements is certain to be instrument-related and not sampler-related. Calipers must be adjusted until all measure ± 1 mm of the known widths.

No calibrations are needed for diameter tapes.

When a caliper is used, DBH is an average of the two measurements:

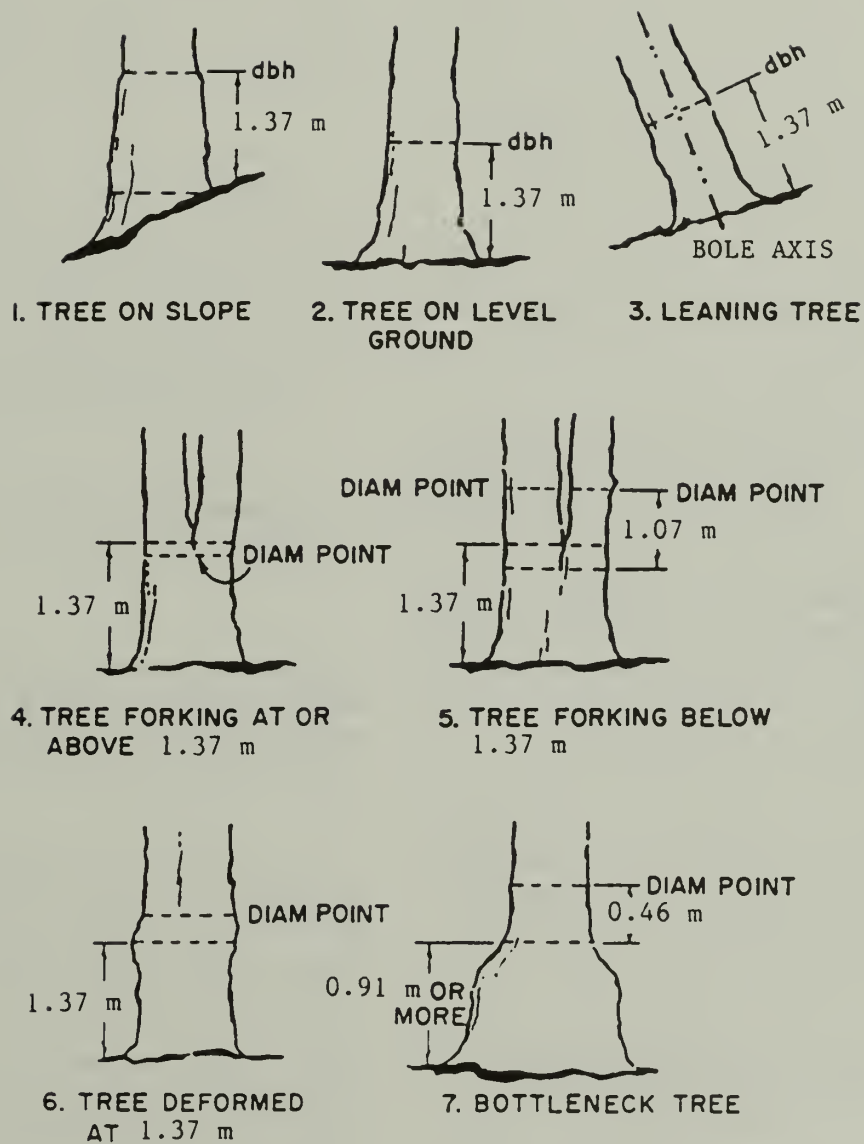


FIGURE II.D.1. Locations of diameter breast height (DBH) measurements for a variety of bole form situations. DBH measurements will always be taken perpendicular to the bole axis as illustrated in drawing #3 (modified from USDA Forest Service 1985).

$$DBH = \frac{(\text{north/south DBH} + \text{east/west DBH})}{2}$$

DBH is measured in the field to the nearest millimeter.

Sources of error during diameter measurements include tape or caliper arm not fitted tightly, abnormalities on the stem at the point of measurement, the tape or caliper not placed at a right angle to the stem at the point of measurement, and an incorrect point of measurement for fork trees. An additional source of error is the degree of asymmetry of the stem.

Extreme care should be taken when removing vines from trees in order not to remove bark with vines before the measurement is taken. Removal of bark could result in distortion of diameter measurements.

Field technicians will be tested monthly for precision and accuracy in DBH measurements. Precision is determined by repeated measure; accuracy by comparison to its **known** diameter. Data quality assurance technicians, who provide the measurement **standard** for the crew, will carefully determine the diameter of 20 selected trees. Technicians failing to measure these trees within the acceptable measurement accuracy tolerance will receive additional training.

DATA QUALITY ESTIMATE

Variable	Repeated Measurement Error at		Measurement Accuracy Tolerance
	Lower Limit	Upper Limit	
DBH	± 0.2 cm	± 0.4cm	0.2 cm

PROCEDURE FOR MEASUREMENT OF TREE HEIGHT

Tree height is used to establish site index, calculate volume, determine height growth over time, and determine live crown ratio. Tree height is an ambiguous term unless it is clearly defined. Tree height is the vertical distance between the ground and some point on the tree, which may vary by the objectives of individual projects. Total live height is that distance between the ground and the top of the live crown. Other tree height variables (e.g., height to the live crown, merchantable height) must be clearly defined by

the individual investigator.

Equipment to be used includes a clinometer (degree and percent scale), and a logger's tape. Height poles may also be used in place of a tape where appropriate.

When using a clinometer and a logger's tape, a technician sticks the end of the tape into the side of the tree at estimated eye level and walks the tape out in any direction for as clear a view as possible of the entire tree. For most accurate results:

- 1) trees should not lean more than 5° from the vertical;
- 2) leaning trees should be measured at right angles to the direction of lean;
- 3) the tape should be walked out along the topographic contour whenever possible (Avery and Burkhart 1983); and
- 4) whenever the slope to the top of the tree exceeds 100%, extend the distance from the base of the tree enough to reduce the slope to 100% or less.

If the height poles are used to directly measure height, one technician raises the height pole directly below the tree within 1m of the bole while another walks to a point where the top of the tree is visible and can be aligned with the appropriate mark on the height pole.

When collecting data for total tree height and live crown ratio, the technician reports the distance to the nearest 0.1m (0.5ft) and the slope percent for the 1) top of the tree, 2) top of the live crown, 3) bottom of the continuous live crown (defined as lowermost live branch whose length is equal to or greater than the average live branch length), and 4) base of the tree. The top of a tree is defined for a conifer as the top of the tallest leader (if more than one), and for a hardwood as the top of the uppermost branch.

In rough terrain it may be preferred to measure tree height without a tape. Technician A places a height pole at the base of the measured tree. The length of the pole should not be less than one-fifth of the tree height and preferably about one-fourth. Technician B reports the slope percent for the 1) top of the tree, 2) top of the live crown, 3) bottom of the live crown, 4) top of the height pole, and 5) base of the tree. The length of the height pole is

also recorded (Curtis and Bruce 1968). Slope percent readings of greater than 100% should be avoided (by moving to another location to make that measurement) due to the reduced accuracy of the clinometer scale. A second technician may be needed in dense stands to shake the tree and point at the base.

Instruments should be kept dry if possible. Excessive humidity may cause condensation on the clinometer lens, rendering the instrument temporarily useless. Clinometers should be stored in areas where temperatures do not drop below freezing.

At the beginning of each field season all clinometers should be checked. Clinometers should be placed on a known level surface (determined using a high-quality carpenter's level), and checked to see if the horizontal sighting line lines up on the zero point of the scale. Clinometers that are off line should be sent to the supplier or manufacturer for adjustment.

Checks should be made on the clinometer on a weekly basis and recorded. These checks are performed in a short time and eliminate error created by using equipment that is out of adjustment.

For all calculations using the clinometer and logger's tape, distance may have to be converted from feet to meters, and slope percent must be converted to slope angle.

Tree height is then calculated:

Distance from tree x (\tan angle b + \tan angle a)

where: angle a = angle at tree base, and angle b = angle at top of tree.

Adding or subtracting the two angles depends on the terrain. If both angles are positive or both are negative, then subtract them. Otherwise add them (Avery and Burkhart 1983). Tree height should be reported ± 0.1 m (0.5ft).

For all calculations when using the clinometer and height pole, pole length is reported in meters and measured to nearest decimeter.

Tree height is then calculated:

Pole length x
 $\frac{(\text{slope to tree top} - \text{slope to tree base})}{(\text{slope to pole top} - \text{slope to tree base})}$

Live crown ratio is calculated:

$\frac{\text{Length of live crown}}{\text{tree height}} \times 100$

where: length of live crown using a tape and clinometer = distance from tree x (\tan angle d - \tan angle c) and angle c = angle at bottom of live crown, and angle d = angle at top of live crown.

Length of live crown is calculated:

Pole length x
 $\frac{(\text{slope to tree top} - \text{slope to live crown base})}{(\text{slope to pole top} - \text{slope to tree base})}$

or

$\frac{(\text{slope to live crown base} - \text{slope to tree base})}{(\text{slope to pole top} - \text{slope to tree base})}$

Equipment out of adjustment, elliptical stem at merchantable height d.o.b., broken tops, and dense crown cover are sources of error during height measurements.

Technicians should go through monthly checks using the clinometer by comparing a measured value against a known height. For example, place a target on a telescoping pole and raise the target to a height of 9.1m (30ft). Then have an operator stand at a distance of 30.5m (100ft) away from the pole on level ground and sight on the target. Assuming that the operator is 1.8m (6 ft) tall, the clinometer should read +24%. Next, the operator sights on the base of the pole. The clinometer should now read -6%. Because the readings are of opposite signs, they should be added, with signs ignored. Adding the two readings produces a sum of 30%. Multiplying the baseline distance of 30.5m (100ft) by 30% produces a value of 9.1m (30ft) -- the height of the target from the ground. Technicians failing to meet the required measurement accuracy tolerance will receive additional training.

DATA QUALITY ESTIMATE

Variable	Repeated Measurement Error at		Measurement Accuracy Tolerance
	Lower Limit	Upper Limit	
Height	± 0.4 m	$\pm 0.4\%$	0.4m

PROCEDURES FOR FIELD INCREMENT CORING FOR TREE AGE, SITE INDEX, AND DENDROCHRONOLOGY

Increment cores can be used to determine age and growth dynamics, to access factors affecting growth, or to establish and analyze climatological patterns. The sampling, evaluation, and ultimate use of the ring-width data can vary, depending on the problem under investigation. The collection techniques described here are used in the determination of age and site index. Some of the cores also may be used for chemical analysis.

Cores are collected with increment borers and are stored for transportation in holding tubes or drinking straws. The borer is composed of three parts: bit, handle, and extractor. The bit and extractor are stored in the handle for transportation. The bit has a collar at the back of the threads. The collar compresses the tissue surrounding the bit to a diameter approximately equal to that of the outside of the bit threads. This makes it possible to twist the bit in as far as desired, and to remove the core and the bit before the tissue applies full pressure to the bit shank (Phipps 1985).

Varying bit lengths and bit diameters are available. Generally, the greater the borer diameter and the greater the length, the more strength is required to operate the borer. Here 305-mm (12-in) and 346-mm (14-in) cutting bits are recommended for use. A 406-mm or longer (16-in) bit may be needed for trees of larger girth. Although various bit diameters are available, at least 5mm (0.2in) is required to produce a suitable cross-sectional width, allowing for sanding or planning.

Increment borers are made of tempered steel. They are available with or without a Teflon coated bit. Because Teflon is inert, it does not interfere with chemical analysis of the core. The Teflon coating should enable the bit to slip through the wood more easily and should make the core more readily extractable from the borer. However, there is some question about the durability of the Teflon coating. Researchers collecting cores will have to test both types, if necessary, to see which will make sampling most efficient.

Eccentricities of stem form and eccentricities of pith location are two major sources of error which can be reduced when several cores per tree are taken. Research results support this, citing variance in increment growth on silver fir and Norway spruce of $\pm 15.8\%$ when only one core

per stem is measured (Siostrozonek 1958). The sources of error listed above represent only two of the more major ones in a long list of uncertainties involved in sampling tree cores. Often only one core per tree is obtained. This occurs for a variety of reasons, including the effort required in sampling major regional areas and the purpose of the research being conducted with the core data.

Before sampling, the tree should be carefully examined for damage or irregularities (e.g., swelling at DBH from insect, fungal or other pathogenic damage, or abiotic damage from wind, snow, ice, or lightning) which might have interrupted or interfered with regular growth. If any such irregularities are noted, a replacement tree should be sampled. Before the core is taken, information on the site, stand, and tree being sampled are recorded.

Before starting, beeswax may be applied to the bit to reduce friction which can cause metal fatigue and lead to bit breakage. Coring is then done perpendicular to the stem bole 15cm (6in) below breast height (1.37m). If the tree being sampled is on a slope, the core should be taken on a treeside parallel to the slope to reduce, as much as possible, growth distortions caused by tension or compression wood. Similarly, if a tree is leaning, the core should be taken 90° from the lean to reduce sampling of irregular growth rings.

If possible, the center ring should be sampled, as it will be used to determine the age of the tree when it reached DBH. This may be difficult since it is rare that the geometric center of the tree is also where the pith is located. Phipps (1985) describes a good method for sampling the pith once an initial sample has been taken. Before extracting the first core, turn the handle 360° . This loosens the core for removal but leaves it in the same position as it was when attached to the tree. When the core is removed, the arcs of the rings near the center indicate whether the pith center is to the right or the left of the first core hole, and how far to the right core hole, and how far to the right or left the center is. Remove the core from the extractor and place it back in the hole from which it came, leaving several centimeters of core sticking out of the tree. For the second attempt, orient the borer parallel to the first core, and the estimated distance to the right or left. If the estimated distance is quite short, it is also a good idea to bore either up or down a few centimeters to make sure there is good solid wood into which the borer bit can dig.

Cores should be labeled with a unique identification number recorded on the holding tube or straw. This identification number is recorded along with: name of collector, date collected, tree identification number, and the location (relevant plot or point).

After recording this information, cores should be carefully packaged for transport back to the lab. Broken cores must be stored in proper sequence. Both ends of the holding tube or straw should be carefully taped (masking tape) closed. The straws should be placed in a container where they cannot be bent or broken. Lightweight plastic carrying tubes available at art supply stores are excellent for this purpose. Cores should be refrigerated as soon as possible to avoid molding.

Personnel taking the cores and collecting the field data should be experienced. Otherwise, much time is lost in collecting cores which have been sampled incorrectly or in replacing equipment which has been handled carelessly. Training should be conducted on a regular basis. Sampling checks can be done easily by the person responsible for recording the data, who can ensure that cores are being taken parallel to the ground and perpendicular to the stem.

When the core is removed from the tree, it is necessary to examine it to see whether it is suitable for further laboratory analysis or needs to be recorded. Ocular examination reveals whether the sample has been taken too close to an adventitious bud or a branch trace, resulting in distorted year rings. Other things such as fungal infection or insect infestation might be revealed. It is better to discover an unsuitable core in the field than in the laboratory (Phipps 1985).

One person should be designated to be in charge of sample custody until the cores have been delivered to the laboratory. It is most expedient that the person recording the data be responsible for the cores reaching the laboratory in good condition and with no mix-up. The designated person should also be recorded on the field tally sheet. Upon receipt of the cores at the laboratory, a person is appointed to be responsible for sample custody. This is recorded in the laboratory notebook.

Rust provides a surface on which debris can accumulate. Thus, a bit that has accumulated debris almost certainly has some rust and corrosion, often impairing core removal from the bit. The cutting edge may also be damaged by

corrosion. If damage is not advanced enough to have seriously dulled the cutting edge, the bit can be cleaned and put back into use.

A cleaning kit for .22 caliber rifles works very well for cleaning increment borer bits. The powder solvent usually contained in the cleaning kits works very well to remove the stains caused by the interaction of tannins with the steel of the bit. It is always desirable to remove enough residue to leave a smooth, rust-free tube surface and, therefore, legible cores. It is necessary to remove all stains and contamination for certain uses, such as trace chemical analyses. When sampling cores from some pine species, repeated cleaning procedures may be necessary because of the build-up of resin on the borer.

Always insert the cleaning rod from the butt end of the bit (never from the cutting-edge end). A cleaning swatch should not fit tightly when inserted into the bit. Because the bit tube narrows near the cutting-edge end, a swatch inserted in the butt end will fit tighter as it is pushed toward the cutting-edge end.

If the cutting edge has been dulled by corrosion, it is possible to touch up the edge with sharpening stones. Forestry supply houses carry bit-sharpening kits that include wedge-shaped and cone-shaped sharpening stones useful for this purpose. Sharpening is a tedious, time-consuming task which should not be performed in the field. If the cutting edge has been nicked or chipped by mishandling, sharpening stones are of little use. In such cases, the bits must either be discarded or returned to a forestry supply house to be machine-sharpened.

When a bit is sharpened by machine, a certain amount of the end of the bit is removed. This in turn changes the position of the cutting edge in relation to the threads and the inter-thread surface. No matter how carefully a new edge is machined, the bit is not the same as the original. If properly cared for, a bit may never need to be sharpened.

Considerable friction develops between the tree tissues and the increment borer bit, particularly in the thread section. No matter what measures are used to reduce friction, it cannot be totally avoided. Friction causes heat that eventually takes its toll in metal fatigue. Commonly, the first visible signs of metal fatigue are cracks at the cutting edge. Eventually, as cracks lengthen during bit use, a chunk of the bit between adjacent cracks will break out. Stop

using the bit when cracks develop.

No matter how carefully increment borers are used, bit occasionally breaks. If the bit is relatively new and has been properly used, breakage may be due to a fault in its manufacture. A common fault is that the hole in the bit is not exactly in the center of the bit throughout its length. A break resulting from this fault will occur nearly equidistant from each end of the bit, and the hole at the break will be obviously off-center. Often, faulty bits will be replaced by forestry supply houses when returned to them.

If bits are properly cared for to avoid rust, corrosion, resin buildup, and excess heat buildup, the bit will likely succumb to metal fatigue before the cutting edge becomes dull. Breakdown of a bit by metal fatigue will likely not occur until well over a thousand cores have been taken.

Errors can be introduced during core collection or during measurements. Sources of error during core collection include unrepresentative sampling methodologies (e.g., inadequate sample size or cores taken from trees with eccentricities of stem form or pith location), poor coring techniques (e.g., core not taken perpendicular to the vertical axis of the stem), and incorrect marking techniques for the cores after collection or during storage.

Sources of error during core measurement include instrumental errors (e.g., incorrectly calibrated micrometer), measurement inaccuracies (e.g., failure to adjust for missing, false or discontinuous year rings, as well as incorrect measurement of annual increments), and changes in cores resulting from shrinking and swelling affected by storage temperature and humidity (Abetz 1960; Fritts 1976).

Errors in measurement can occur when personnel are not trained sufficiently in using the machines or when cores are not prepared correctly for measurement. It is important to keep these sources of error in mind and in check as much as possible. The data collected from increment cores are measurements which will be average and transformed to facilitate the study and analysis of regional forest growth trends. The inclusion of systematic or unsystematic errors threatens the integrity of the information which can be extrapolated from the core samples.

Before core collection is especially important to train field crews in sampling techniques to ensure

that the cores sampled are of high quality. Also of importance during sampling is the accurate recording of complete field notes and information about the sampled trees. Samples must be carefully and clearly labeled. Equally important to ensure data reliability is to provide an adequate sample size. Sample size must be justified in the project plans of the individual researchers by describing sampling methodology. Sufficient quantities of materials should be obtained to allow for data loss when certain samples are found to be anomalous or to yield questionable data. Also, as previously noted, the sample should be examined for flaws immediately after collection in the field, before it is labeled and packed for transportation (Fritts 1976).

DATA QUALITY ESTIMATE

Variable	Repeated Measurement Error at		Measurement Accuracy
	Lower Limit	Upper Limit	Tolerance
Age	± 2 yr	± 2 yr	± 2 yr

APPENDIX II-E

HERBACEOUS PLANT DICTONARY

APPENDIX II-E

HERBACEOUS PLANT DICTIONARY

An herbaceous plant dictionary containing field code, common name, genus, and species of herbaceous plants commonly found in the Shenandoah National Park of Virginia.

Code	Common Name	Genus	Species
AML	Yarrow	Achillea	millefolium
APC	Baneberry	Actaea	pachypoda
APD	Maidenhair Fern	Adiantum	pedatum
AAS	White Snake Root formerly Eupatorium rugosum	Ageratina	altissima
AGR	Agrimony	Agrimonia	spp
APT	Garlic Mustard formerly Alliaria officinalis	Alliaria	petiolata
ALL	Onion	Allium	spp
AAT	Ragweed	Ambrosia	artemisiifolia
AMS	Fly Poison	Amianthium	muscaetoxicum
ABR	Hog Peanut	Amphicarpa	bracteata
ANE	Angelica	Angelica	spp
ANT	Pussytoes	Antennaria	spp
API	Parsley Family	Apiaceae Family	
AND	Wild Sarsparilla	Aralia	nudicaulis
APO	Dogbane	Apocynum	spp
ACD	Columbine	Aquilegia	canadensis
ARA	Sarsparilla	Aralia	spp
ATR	Jack in the Pulpit	Arisaema	triphylllum
AMN	Common Burdock	Artium	minus
ACN	Wild Ginger	Asarum	canadense
AEX	Poke Milkweed	Asclepias	exaltata
ASL	Milkweed	Asclepias	spp
APL	Ebony Spleenwort	Asplenium	platyneuron
ADV	White Wood Aster	Aster	divaricatus
AST	Asters	Asteraceae family	
BBP	Spanish Needle	Bidens	bipinnata
BRA	Mustards	Brassicaceae family	
BOT	Grape Fern	Botrychium	spp
BVR	Rattlesnake Fern	Botrychium	virginianum
CAR	Tall Bellflower	Campanula	americana
CDV	Southern Harebell	Campanula	divaricata
CTH	Blue Cohosh	Caulophyllum	thalictroides
CAL	Lamb's Quarters	Chenopodium	album
CMC	Striped Pipsissewa or Spotted Wintergreen	Chimaphila	maculata
CLC	Ox Eye Daisy	Chrysanthemum	leucanthemum
CRC	Black Cohosh	Cimicifuga	racemosa
CAP	Dwarf Enchanters Nightshade	Circaea	alpina
CQD	Enchanters Nightshade	Circaea	quadrisulcata
CIR	Enchanters Nightshade	Circaea	spp
CLE	Clematis	Clematis	spp
CVR	Virgin's Bower	Clematis	virginiana
CCD	Horse Balm	Collinsonia	canadensis

Code	Common Name	Genus	Species
CCM	Asiatic Dayflower	Commelina	communis
COM	Dayflower	Commelina	spp
CAC	Squawroot	Conopholis	americana
CON	Bindweed	Convolvulus	spp
CFV	Yellow Corydalis	Corydalis	flavula
COR	Fumewort	Corydalis	spp
CCS	Honewort	Cryptotaenia	canadensis
DCR	Queen Anne's Lace	Daucus	carota
DPN	Hay Scented Fern	Dennstaedtia	punctilobula
DES	Trefoil (see Lotus)	Desmodium	spp
DIO	Wild Yam	Dioscorea	spp
DMR	Marginal Wood Fern	Dryopteris	marginalis
EAN	Daisy Fleabane	Erigeron	annuus
EUP	Joe Pye Weed formerly Eupatroium	Eupatoriadelphis	spp
FAB	Pea Family	Fabaceae family	
FVR	Wild Strawberry	Fragaria	virginiana
FRA	Strawberry	Fragaria	spp
GAP	Cleavers	Gallium	aparine
GLN	Lance Leaved Licorice	Galium	lanceolatum
GTF	Fragrant Bedstraw	Gallium	triflorum
GPR	Teaberry	Gaultheria	procumbens
GAL	Bedstraw	Galium	spp
GMC	Wild Geranium	Geranium	maculatum
GRB	Herb-Robert	Geranium	robertianum
GER	Geranium	Geranium	spp
GCN	White Avens	Geum	canadense
GVR	Rough Avens	Geum	virginianum
GEU	Avens	Geum	spp
GHR	Heal All	Glechoma	herbacea
GOO	Rattlesnake Plantain	Goodyera	spp
HPL	American Pennyroyal	Hedeoma	pulegioides
HDV	Woodland Sunflower	Helianthus	divaricatus
HAM	Liverleaf	Hepatica	americana
HEP	Hepatica	Hepatica	spp
HLT	Cow Parsnip formerly Heracleum maximum	Heracleum	lantanum
HVN	Rattlesnake Weed	Hieracium	venosum
HCR	Bluets	Houstonia	caerulea
HLN	Long Leaved Bluets	Houstonia	longifolia
HTN	Narrow Leaved Bluets	Houstonia	tenuifolia
HOU	Bluets	Houstonia	spp
HVG	Virginia Waterleaf	Hydrophyllum	virginianum
HMT	Dwarf St. Johnswort	Hypericum	mutilum
ICP	Spotted Jewelweed	Impatiens	capensis
IPL	Pale Jewelweed	Impatiens	pallida
IMP	Jewelweed	Impatiens	spp
IPR	Morning Glory	Ipomea	purpurea
IRI	Iris Family	Iridaceae family	
LAM	Mint Family	Lamiaceae family	
LCL	Fringed Loosestrife	Lysimachia	ciliata
LHR	Wild Lettuce	Lactuca	hirsuta

Code	Common Name	Genus	Species
LCN	Wood Nettle	Laportea	canadensis
LIL	Lilies	Liliaceae family	
LIN	Indian Tobacco	Lobelia	inflata
LOT	Trefoil (see Desmodium)	Lotus	spp
LQD	Whorled Loosestrife	Lysimachia	quadrifolia
LYT	Loosestrifes	Lythraceae family	
MCN	Canada Mayflower	Maianthemum	canadense
MVR	Indian Cucumberroot	Medeola	virginiana
MLN	Cowwheat	Melampyrum	lineare
MCD	Moonseed	Menispermum	canadense
MPP	Peppermint	Mentha	piperita
MSP	Spearmint	Mentha	spicata
MFS	Wild Bergamot	Monarda	fistulosa
MUN	Indian Pipe	Monotropa	uniflora
NCT	Catnip	Nepeta	cataria
OUN	Cancer Root	Orobanche	uniflora
OCL	Sweet Cicily (see OLN)	Osmorhiza	claytoni
OLN	Sweet Cicily (see OCL)	Osmorhiza	longistylis
OSM	Sweet Cicily	Osmorhiza	spp
OXA	Wood Sorrel	Oxalis	spp
PQQ	Ginseng	Panax	quinquefolius
PST	Wild Parsnip	Pastinaca	sativa
PCN	Wood Betony or Lousewort	Pedicularis	canadensis
PPL	Wild Kidney Bean	Phaseolus	polystachios
PLP	Lopseed	Phyrma	leptostachya
PAM	Pokeweed	Phytolacca	americana
PPM	Clearweed	Pilea	pumila
PMJ	Common Plantain	Plantago	major
POA	Grass (don't assume genus)	Poa	spp
PVN	Jacob's Ladder	Polemonium	van-bruntiae
POL	Buckwheats	Polygonaceae family	
POG	Soloman's Seal	Polygonatum	spp
PST	Arrow-leaved Tearthumb	Polygonum	sagittatum
PSC	Climbing False Buckwheat	Polygonum	scandens
PVM	Jumpseed	Polygonum	virginianum
POY	Knotweed	Polygonum	spp
PCD	Small Flowered Leaf Cup	Polymnia	canadensis
PAC	Christmas Fern	Polysticum	acrostichoides
POR	Haircap Moss genus	Polytrichum	spp
POT	Cinquefoil	Potentilla	spp
PAL	White Lettuce	Prenanthes	alba
PSP	Lions' Foot	Prenanthes	serpentaria
PRE	Lettuce	Prenanthes	spp
RRP	Creeping Buttercup	Ranunculus	repens
RAB	Kidney-leaved Buttercup	Ranunculus	abortivus
RAN	Buttercup	Ranunculus	spp
ROA	Herbaceous spp	Rosaceae family	
SCD	Bloodroot	Sanguinaria	canadensis
SCS	Black Snakeroot	Sanicula	canadensis
SOV	Heartleaf	Scutellaria	ovata
SAR	Golden Ragwort	Senecio	aureus
SST	Starry Campion	Silene	stellata

Code	Common Name	Genus	Species
SVL	Bladder Campion formerly <i>Silene cucubalus</i>	<i>Silene</i>	<i>vulgaris</i>
SRC	False Solomon's Seal	<i>Smilacina</i>	<i>racemosa</i>
STF	Three-leaved	<i>Smilacina</i>	<i>trifolia</i> Soloman's Seal
SCR	Horse Nettle	<i>Solanum</i>	<i>carolinense</i>
SOL	Goldenrod	<i>Solidago</i>	<i>spp</i>
SMD	Common Chickweed	<i>Stellaria</i>	<i>media</i>
STR	Twisted Stalk	<i>Streptopus</i>	<i>spp</i>
TOF	Common Dandelion	<i>Taraxacum</i>	<i>officinale</i>
TDC	Early Meadow Rue	<i>Thalictrum</i>	<i>dioicum</i>
TPB	Tall Meadow Rue formerly <i>Thalictrum polygamum</i>	<i>Thalictrum</i>	<i>pubescens</i>
THA	Meadow Rue	<i>Thalictrum</i>	<i>spp</i>
TRI	Trillium	<i>Trillium</i>	<i>spp</i>
UDC	Stinging Nettle	<i>Urtica</i>	<i>dioica</i>
UPR	Perfoliate Bellwort	<i>Uvularia</i>	<i>perfoliata</i>
UPD	Mountain Bellwort	<i>Uvularia</i>	<i>pudica</i>
USS	Sessile Bellwort	<i>Uvularia</i>	<i>sessilifolia</i>
VAL	Wingstem formerly <i>Actinomeris alternifolia</i>	<i>Verbesina</i>	<i>alternifolia</i>
VER	Veronica	<i>Veronica</i>	<i>spp</i>
VCR	Cow Vetch	<i>Vicia</i>	<i>cracca</i>
VKT	Field Pansy	<i>Viola</i>	<i>kitaibelliana</i>
VPD	Birdfoot Violet	<i>Viola</i>	<i>pedata</i>
VSG	Arrow Leaved Violet	<i>Viola</i>	<i>sagittata</i>
VIO	Violets	<i>Viola</i>	<i>spp</i>
XAS	Turkeybeard	<i>Xerophyllum</i>	<i>asphodeloides</i>
XFE	UNKNOWN Fern		
XGR	UNKNOWN Grass		
XLI	UNKNOWN Lichen		
XMO	UNKNOWN Moss		
XXX	UNKNOWN Miscellaneous		
ZAR	Golden Alexander	<i>Zizia</i>	<i>aurea</i>

APPENDIX II-F

WOODY AND HERBACEOUS PLANT IDENTIFICATION

APPENDIX II-F

WOODY AND HERBACEOUS PLANT IDENTIFICATION

Accurate plant identification is essential for all members of field teams who install plots and collect data for LTEMs. Errors in plant identification from one sampling period to the next could cause serious errors in the conclusions drawn concerning plant community shifts that have occurred in the interval between sampling. At least one member of the LTEMs field team must have a sound background and experience in plant taxonomy and dendrology. The remaining team members should have a general botany background and be capable of and have an interest in learning plant identification in the field. Without a doubt, woody, and herbaceous plant identification in the field requires careful and continuous observation, a keen sense for subtle shifts in environmental conditions, and a great deal of patience.

A detailed woody plant dictionary and an herbaceous plant dictionary has already been developed for the SNP and can be found in Appendix II-C and Appendix II-E respectively. While these dictionaries may not be absolutely complete they do contain the vast majority of plant species found in the SNP and serve as an excellent guide when trying to identify an unknown plant species in the field.

A comprehensive training program is recommended for field teams prior to going into the field for data collection. In addition refresher sessions need to be conducted at periodic intervals (4-6 weeks) during the field season and when the team is about to commence sampling in a different geographic area or in a different forest cover type. The following types of education and training sessions.

1. Color 35mm slide sets of the major plant species. The slides should show the species in its native habitat and ideally each species be shown when in flowering and with no flowers (two parts of the season represented). Along with the slides, specific information about the environmental conditions under which the species is most likely to be found, associated plant species and the importance of the species should be presented and discussed.
2. Mounted voucher specimens of each species should be available for careful study by the

field team when learning the species and for identifying unknown samples that have been brought in from the field. The specimens should be mounted on heavy paperboard and covered with clean contact paper to help preserve the specimen. An identification tag containing the following information should be permanently attached in the lower right-hand corner of the mounting sheet.

- a. Agency making the collection in case it would be National Park Service, Shenandoah National Park - LTEMs
 - b. General Area the flora represents. Include the region of the state and the state
 - c. Scientific Name
 - d. Common Name/s
 - e. Location. Give the location where the specimen was found based on a named feature on a USGS 7.5 minute topographic map
 - f. Name. Give the name of person or field team that made the collection
 - g. Date. Give the day, month, and year the sample was collected
3. A field notebook containing 4in x 6in color photographs mounted in 8.5in x 11in clear plastic loose-leaf sheets. Four photographs (two on each side) can be displayed per sheet. Fresh specimens are briefly pressed (to insure that all important parts of the sample are in focus) placed on light colored background matboard, and photograph taken using an appropriate lighted copy stand. A mounting tag with the common name of the specimen is appropriately placed on the matboard. As an example; a balanced set of incandescent photo-lamps and a Tunglar film produce high quality color photographs.

This photographic plant inventory can also be implemented to illustrate insect, disease, and environmental stress effects on various plant species.

Samples of unknown plant species found in the field must be documented as to the exact location that it was found and recorded in the comment section of the appropriate field data sheet, and carefully pressed and taken to the office for identification. If the specimen turns out to be a previously unidentified species the information must be added to the appropriate SNP plant dictionary, the necessary herbarium mounts prepared and photographs made.

**SHENANDOAH NATIONAL PARK
LONG-TERM ECOLOGICAL MONITORING SYSTEM**

SECTION III

AQUATIC COMPONENT USER MANUAL

**NPS/NRSHEN/NRTR-90/02
1st Edition: September 1990**

by

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The purpose of this manual is to describe the field and laboratory techniques that should be used to acquire data for the aquatic component of the Long-Term Ecological Monitoring System (LTEMs) that has been developed for the Shenandoah National Park (SNP or park). The major aquatic resources in the SNP are the numerous small streams. The primary tasks that the manual addresses are: choosing and establishing stream sites, finding existing sites, taking measurements and samples in the field, analyzing samples in the laboratory, calculating final results, and keeping records of data prior to entry in the database management system. The user manual is intended to provide sufficient information for persons with some background in field biology (e.g., fisheries, wildlife, entomology, ecology, forestry, natural resource management, recreation). The most likely users will be National Park Service employees, but the manual will also enable other researchers in the various aquatic sciences to contribute to the LTEMs.

DESIGN

Site Selection

In order for the aquatic LTEMs to be successful, the stream sites must be representative of all the different environments in the SNP. For the aquatic component, the term site refers to a designated length of stream along with the riparian area. The stream sites are classified in the following hierarchical system:

Administrative District

- South
- Central
- North

Geological Formation/Alkalinity

- Catoctin (100-200 $\mu\text{eq/L}$)
- Pedlar or Old Rag (20-100 $\mu\text{eq/L}$)
- Hampton or Erwin (<20 $\mu\text{eq/L}$)

Elevation

- Upper (>548.6 m [1800 ft])
- Lower (<548.6 m [1800 ft])

Other Factors

- Accessibility
- SNP trout monitoring sites
- Current research interests

Using the three administrative districts as the first level of classification is a convenient means of distributing the stream sites throughout the park. In most cases, it is impossible to predict where an adverse impact might occur. Therefore, spreading the sites throughout the park increases the probability of having data from where they might be needed.

Geological formations were selected as the second level of classification because the SNP has a uniquely diverse geology and resulting water chemistry, particularly alkalinity. There are great differences among watersheds, and often between adjacent watersheds. Alkalinity and related water chemistry are probably significant factors affecting the distribution of the aquatic biota. Information on geological formations and alkalinity can be obtained from Gathright (1976) and Dise (1984), respectively. Streams in the SNP seldom have their watersheds entirely within a single geological formation. An effort should be made to establish stream sites in watersheds which have at least 75% of their area within one of the geological formation categories.

Elevation affects the distribution of aquatic biota indirectly because of factors such as stream width, depth, current velocity, valley shading, and temperature. The SNP is located entirely within the northern section of the Blue Ridge physiographic province, which is the narrow (about 8 km) mountainous area between the low-lying Piedmont province to the east and the Ridge and Valley province to the west (Hoffman 1969, Gathright 1976). Drainage basins in the Blue Ridge province typically have a steep gradient. Drainage basins on the west slope follow a trellis pattern, in which the small streams flowing down the mountains are parallel and join the main stream in the valley (Shenandoah River) at right angles (Reid and Wood 1976). Those on the east slope follow a dendritic pattern, so-called because of the resemblance to tree roots (Reid and Wood 1976). The criterion of 548.6 m (1800 ft) for distinguishing upper and lower sites was selected because field observations indicated that streams in the SNP tended to become very narrow and shallow (several m wide and less than knee deep) approximately above that elevation. This delimitation is somewhat arbitrary and can be varied within reason when it is desirable to have both an upper and lower site on the same stream. Elevation is best determined from the Potomac Appalachian Trail Club maps (scale 1:62,500). The USGS 7.5 min topographic maps are not as useful because they are not as accurate regarding trails, fire roads, and stream permanency.

Accessibility should be given serious consideration when choosing sites. If a site cannot be reached with reasonable effort at the desired time, then the data

are likely to be sporadic and would not be useful for monitoring. Trout populations in the SNP have been monitored for some time; therefore, it is logical to establish stream plots at many of the same sites so that there will be ecological data to explain the results of fish sampling. Gypsy moth infestation and acid deposition are environmental concerns at the present time in the SNP. Some preference should be given to stream plots that are likely to be affected or are being studied as part of other research projects.

Site Locations

Based upon the hierarchical classification system described above, 17 stream sites were selected for the aquatic LTEMs. These are listed below, with exceptions to the classification system marked with an asterisk and explained in the following paragraph. Detailed descriptions of the site locations, including maps and travel directions, are given in Appendix III.A.

South District

- Hampton or Erwin
 - Paine Run (Upper)
 - Paine Run (Lower)
 - Twomile Run (Upper)*
 - Twomile Run (Lower)

Central District

- Pedlar or Old Rag
 - Hazel River (Upper)
 - Hazel River (Lower)
 - Staunton River (Upper)
 - Staunton River (Lower)
 - North Fork Dry Run (Upper)*

Catoctin

- White Oak Canyon Run (Upper)
- White Oak Canyon Run (Lower)
- Hog Camp Branch (Upper)
- Rose River (Lower)

North District

- Catoctin and Pedlar*
 - Piney River (Upper)*
 - Piney River (Lower)
- Catoctin, Hampton, and Weverton*
 - Jeremys Run (Upper)*
- Pedlar
 - Lands Run (Upper)*

The "upper" sites on Twomile Run, North Fork Dry Run, and Lands Run lie at an elevation below 548.6 m (1800 ft), but their physical characteristics more resemble the other upper elevation sites. North Fork Dry Run was selected for a stream site because of the comprehensive studies on acid deposition being conducted in this watershed. The upper reaches of Piney River, Jeremys Run, and Lands Run do not have 75% of their watershed contained within a single geological formation category. Upper elevation sites were established on these three streams because of the likelihood of gypsy moth defoliation.

Site Layout

The stream sites consist of 100-m longitudinal reaches, which are marked by 91-cm (36-inch) lengths of 5-cm (2-inch) (i.d.) PVC pipe, either painted entirely black or with black end caps. The PVC pipe is secured by driving a 102-cm (40-inch) length of sharpened 2-cm (3/4-inch) steel rebar into the ground, attaching a chain link to the rebar with a hose clamp, and then passing a 1 x 9-cm (1/4 x 3 1/2-inch) hexhead bolt through the pipe and chain link (Appendix III.B.1). A 1-cm (5/16-inch) hole is drilled 30 cm (12-inches) from the bottom of the PVC pipe prior to going into the field for placement. There are two markers for each site, one at the upstream boundary and one at the downstream boundary. Both markers are on the same side of the stream, with the side and distance from the stream varying among sites in order to provide the most protection from floods. Specific locations of the markers at each of the sites are included with the detailed descriptions of the site locations in Appendix III.A.

Parameters

This section lists all of the parameters that are included in the LTEMs. Also included are brief explanations of the parameters and their utility for ecological monitoring in streams.

Water Quality

Discharge. Discharge (or streamflow) is the volume of water, including dissolved and mixed sediments or solids, moving past a cross section of stream per unit time (Buchanan and Somers 1969). Discharge and the associated stream morphology affect the distribution of both fish and macroinvertebrates. Fish and macroinvertebrates, because of their diverse modes of existence and food habits, prefer a variety of habitats with different streamflows. During extreme conditions of flood and drought, discharge can change the stream habitat and drastically alter the entire stream morphology. Streamflow also affects water quality by diluting or

concentrating certain parameters. Extensive loss of vegetation in a watershed, such as might be caused by fire or insect damage, will lead to changes in discharge.

Temperature. Temperature is the degree of hotness or coldness. Temperature can be both a controlling and limiting factor in the aquatic environment (Warren 1971). The growth and life cycles of fish and invertebrates are significantly affected by temperature because they are poikilothermic (body temperature follows closely the temperature of the water). Many of the water quality parameters are also affected by temperature, especially dissolved oxygen. In small mountain streams, the temperature is usually below 20 °C, except perhaps for brief periods in summer. Like discharge, water temperature can be affected by watershed disturbances. Defoliation of the canopy over a stream by gypsy moths could affect the water temperature by allowing more sunlight to reach the stream.

Dissolved Oxygen. The amount of oxygen dissolved in water, which is supplied by the atmosphere and photosynthetic plants, is one of the most fundamental parameters of the aquatic environment because oxygen is essential for all aerobic aquatic organisms. Oxygen levels are affected by temperature; as the water temperature increases, the solubility of oxygen decreases. Cool mountain streams with abundant riffles usually have oxygen concentrations at saturation throughout the year (9 - 14 mg/L). Other influences on dissolved oxygen are altitude and aerobic bacteria of decay (Cole 1979).

Hydrogen Ion Activity. Hydrogen ion activity is the concentration of hydrogen ions and is expressed as pH (potentia hydrogenii), with a range of 1-14 (Cole 1979). At pH 7 the molar concentration of hydrogen is neutral. An increase in hydrogen results in a lowered pH; a decrease in hydrogen indicates an alkaline reaction and an increase in pH. Hydrogen ion activity is dependent on alkalinity, the capacity of the aquatic environment to neutralize acid (Feldman and Conner 1985). The composition and abundance of most stream biota are influenced by pH.

Alkalinity. Alkalinity, or buffering capacity, is an index of the ability of a solution to neutralize acid. Underlying geological formations and their degree of weathering influence alkalinity (Cole 1979). Alkalinity is responsible for much of the overall chemical environment because it is a major variable controlling the form and concentration of many ions as well as the hydrogen ion activity (Feldman and Connor 1985). The community structure of macroinvertebrates and fish are influenced by alkalinity, with the usual trend being greater abundance and diversity in streams with high alkalinity. The

water quality criterion for alkalinity is 20 mg/L or more for the protection of freshwater aquatic life, except where natural concentrations are less (U. S. Environmental Protection Agency 1976).

Conductivity. This parameter is a measure of the resistance of a solution to electrical flow (Wetzel 1983). Conductivity is indicative of the total ions in solution; therefore, it is sometimes considered a shortcut for analyzing total dissolved solids. Conductivity is a good indicator of a variety of impacts on the aquatic environment.

Sulfate. Sulfate is the predominant form of sulfur in water and is apparently necessary for plant growth. Sulfur is important in protein metabolism but is supplied to organisms originally as sulfate. The mean composition of sulfate in North American inland waters is 15.31% of total ions, with concentrations ranging from 1 to > 6000 mg/L (Reid and Wood 1976).

Nitrate. This oxide of nitrogen occurs in fresh waters through the sources of precipitation, surface and groundwater drainage, and fixation in both water and soil (Wetzel 1983). It is the most available form of nitrogen and is therefore very important for plant growth (Hynes 1970). Pollution from sewage and agricultural fertilizers can lead to high concentrations of nitrogen compounds that disrupt the balance of aquatic ecosystems. Nitrate averages 1.77% of the total ions found in North American inland waters; concentrations range from near zero to 9 mg/L (Reid and Wood 1976).

Chloride. Chloride is the major halide of chlorine stored in most freshwater algal cells (Cole 1979). The atmosphere and geological formations are the natural sources of chloride. Elevated levels usually indicate a source of pollution such as sewage. On the average, chloride accounts for 7.44% of total ions in North American inland waters, with concentrations ranging from near zero to > 5400 mg/L (Reid and Wood 1976).

Calcium. Implicated in numerous ways in the growth and population dynamics of freshwater flora and fauna, calcium is considered a micronutrient and varies with temperature, pH, and substrate composition (Wetzel 1983, Reid and Wood 1976). Limestone streams normally have high concentrations of calcium, which usually mean well buffered systems with abundant and diverse fauna. In soft water streams, which exist on igneous rock, calcium levels are low and the fauna is usually much sparser. The mean composition of calcium in North American inland waters is 19.36% of total ions, with concentrations ranging from near zero to 80 mg/L (Reid and Wood 1976).

Magnesium. Magnesium and calcium react similarly in streams although magnesium is normally found at lower concentrations (Reid and Wood 1976). Its source is the mineral crust of the earth, and the metabolic demand for magnesium is generally minor compared to its availability in freshwater (Wetzel 1983); however, it is still considered an important cation to the freshwater flora and fauna. Magnesium averages 4.87% of total ions in North American inland waters; concentrations range from near zero to 10 mg/L (Reid and Wood 1976).

Potassium and Sodium. These two closely related cations occur from the weathering of rock (Cole 1979). Any alteration of their concentrations in natural waters is not common (Wetzel 1983). Both potassium and sodium are important in algal metabolism. The mean compositions of sodium and potassium in North American inland waters are 7.46% and 1.77% of total ions, respectively; their combined concentrations range from near zero to 13,000 mg/L (Reid and Wood 1976).

Silica. Silica is one of the major forms of silicon that occurs in freshwater. It occurs from the weathering of rocks and is an essential nutrient for diatoms, which use it in construction of their frustules (Cole 1979). The mean composition of silica in North American inland waters is 8.60% of total ions (Reid and Wood 1976).

Seston. Seston is the particulate matter that is suspended in water, including both the organic and inorganic material. Organic seston is utilized for food by many macroinvertebrates. Collector-filterers, or suspension feeders, filter seston from the water column, while seston that has settled to the substrate is utilized by the collector-gatherers (Merritt and Cummins 1984). Although seston has a positive influence as food, excessive levels can be detrimental because the material settles on the firm substrates making them unsuitable for attachment by many macroinvertebrates. Seston is affected by discharge, stream morphology, type and amount of riparian vegetation, and debris retention structures. A review of studies in small streams indicated that the annual mean for organic seston is about 3 mg/L; however, during the year concentrations of organic seston may range from 0.04 to 15.0 mg/L (Webster et al. 1979).

Bacteria. Fecal streptococcus, total coliform, and fecal coliform are indications of the levels of animal intestinal organisms present in the water, but also include nonenteric (soil born) organisms as well. Ratios of these bacteria are used to indicate and distinguish between human and animal pollution (American Public Health Association et al. 1981).

Habitat

Depth. Stream depth is an important factor in determining the amount of usable habitat for macroinvertebrates and fish. It is defined as the height of the water column from the existing surface level to the channel bottom (Platts et al. 1983).

Width. The different communities of macroinvertebrates and fish that occur within watersheds appear to be related to stream width. The relationship is probably an indirect one, with wider streams having a greater diversity of microhabitats and warmer temperature regimes. Width is defined as the horizontal distance along a transect line from shore to shore at the existing water level, including only the distance that is covered with water (Platts et al. 1983).

Substratum. The substratum can be any organic or inorganic materials that are sufficiently stable for organisms to live on or in. In SNP streams the substratum consists almost entirely of mineral particles, with size of the particles being the most important ecological factor. Benthic macroinvertebrates are dependent upon a suitable substratum for attachment sites, hiding places, and in some cases food (periphyton). Coarse substrate (boulders, cobbles, pebbles) that lies loosely on the stream bottom provides the best habitat for macroinvertebrates because of the diversity of currents and pore spaces created. Gravel is important for the spawning of some stream fish.

Riparian Vegetation Cover. This parameter refers to the amount of shading provided by the tree canopy (overstory) and also the amount of litterfall that can be expected to be deposited in the stream. Small mountain streams typically have a dense canopy that shades the channel for much of the year. The light and temperature conditions that result from the shading are major factors in determining the communities of periphyton, macroinvertebrates, and fish, and the leaf input during autumn is the major source of energy for the ecosystem.

Riparian Vegetation Type. This parameter reflects the type of vegetation that would be expected to be predominant in the litterfall as well as the amount. Macroinvertebrate communities in small mountain streams are adapted for an energy input from leaves, rather than grasses and forbs. Trees contribute more usable litterfall than shrubs, which contribute more than grasses and forbs. The riparian vegetation type also indicates the stability of the banks. The heavy root systems of trees stabilize banks more than the lighter root systems of shrubs or grasses and forbs. Having no riparian vegetation along small streams would be indicative of perturbation.

Debris Retention. This parameter is an indication of a stream's capacity to retain litterfall and prevent its downstream transport. Debris retention structures include rock outcrops, boulders, trees rooted in the channel, and fallen logs. Higher productivity of macroinvertebrates and fish would be expected with more debris retention structures. In addition, debris retention structures are usually associated with fish cover and amount of pools (see below).

Fish Cover. Fish cover is considered to be the places where 15 to 20-cm (6 to 8-inch) brook trout could hide without being visible from above. Structures that provide cover are large rocks, logs, undercut banks, and terrestrial vegetation that bends over into the water. Cover is an important factor in evaluating the quality of habitat for fish, with greater survival and growth being positively correlated with more cover.

Pool-Riffle. This parameter indicates the relative amount of pool habitat (deep, still water) in comparison to the amount of riffle habitat (shallow, flowing water). In order to be considered a pool, the depth should be sufficient for 15 to 20-cm (6 to 8-inch) brook trout to reside there. Pool-riffle is another assessment of the quality of the habitat for fish, because some important species (e.g., brook trout) are more productive when there are ample pool areas. However, benthic macroinvertebrates, which are a major source of food, are more productive in riffles, and brook trout require riffle areas for spawning. The optimum pool-riffle ratio may be 1 to 1 (50% pool), or slightly higher.

Biological

Periphyton. The community of algae that lives attached to rocks and other firm substrates accounts for almost all of the primary production in small mountain streams. Periphyton comprises an important portion of the diet of many grazing macroinvertebrates. Periphyton may also provide detritus for collector macroinvertebrates when it dies. The amount of chlorophyll *a* in the periphyton is indicative of the biomass of live algae. The autotrophic index can be used to determine the relative amounts of live algae as compared to nonliving detritus attached to firm substrates. Any perturbation that changes the amount of light reaching the stream (e.g., gypsy moth defoliation) would cause a corresponding change in periphyton biomass.

Macroinvertebrates. The prefix "macro" has no exact definition. Macroinvertebrates are generally considered to be those worms, molluscs, and arthropods that are large enough to be seen with the unaided eye. It should be kept in mind that this delimitation refers to the mature stages of those organisms; the early stages

of some macroinvertebrates can only be seen with the aid of a stereomicroscope or magnifier. The term "benthic" refers to organisms living on the bottom of aquatic environments or on firm substrates protruding above the bottom. The benthic community contains a variety of organisms; however, in small streams like those in the SNP, most of the community members are the immature stages (nymphs and larvae) of insects. All of the so-called "aquatic" insects actually leave the water for a terrestrial adult stage, during which reproduction takes place.

Benthic macroinvertebrates are commonly used for ecological monitoring for several reasons (Voshell et al. 1989). They are abundant in almost all freshwater environments. Sedentary habits and comparatively large size, in combination with abundance, make them relatively easy to collect. Most can now be identified reliably to genus with comprehensive taxonomic works that have become available (e.g., Pennak 1978, Brigham et al. 1982, Merritt and Cummins 1984). The benthic macroinvertebrates that exist in a given area are indicative of the environmental conditions that have occurred for at least several months previously because their life cycles last from several months to a year or more. Taken as a group, benthic macroinvertebrates have diverse habitat and food preferences, but many individual taxa have narrowly defined niches. Therefore, it is likely that some taxa will demonstrate a change in response to any perturbation that might take place. Activities of benthic macroinvertebrates affect major ecological processes of freshwater ecosystems. These significant activities include grazing on primary producers, decomposing organic matter, preying on smaller invertebrates, temporarily storing materials (spiralling), and providing food for fish.

Three types of macroinvertebrate samples are taken at each stream site: quantitative benthic, qualitative benthic, and aerial. The quantitative benthic samples are the mainstay of the macroinvertebrate monitoring program. The data from those samples can be used to make statistical comparisons among streams and over time. Benthic macroinvertebrates are microhabitat specialists, and quantitative sampling devices cannot be placed in some of the microhabitats that occur in streams. Therefore, qualitative benthic samples are also taken to determine at least the presence or absence of taxa in those locations so that the taxa lists for each stream site will be comprehensive. The aerial samples, which are also qualitative, are taken to capture the adult stages of the insects that are aquatic as immatures. Aerial sampling of adults is done for two reasons: (1) adult specimens can usually be identified to the species level, whereas immature specimens can be identified usually only to genus; and (2) the taxa lists

for the sites will be more comprehensive because the immature aquatic stages might be missed or be absent as a result of a recent emergence.

Sampling Frequency

The LTEMs was designed to store and analyze data according to quarters of years, defined as spring (April, May, June), summer (July, August, September), fall (October, November, December), and winter (January, February, March). Because of the effort required, it is likely that it will be possible only to sample in one or two quarters consistently. If this is the case then the spring and summer quarters should be emphasized, in that order. The spring fauna is the most abundant and diverse in mountain streams such as those in the SNP, and this is the time of year when most taxa can be collected in both immature and adult stages to facilitate taxonomic identifications. Early stages of some of the summer fauna are also present in the spring. Highest flows usually occur in spring, diluting dissolved substances and increasing concentrations of suspended matter. The low flows of summer offer the greatest likelihood of degraded water quality, especially lower concentrations of dissolved oxygen caused by higher water temperatures. Lower flows during summer can also cause significant reductions in the amount of habitat that is usable by the biota. Therefore, summer sampling will probably reflect "worst case" conditions.

Within any quarter, all stream sites should be sampled as close in time as possible in order to reduce variability caused by the rapidly changing life cycles of the aquatic insect fauna. It would be ideal if all sites could be sampled within 2 wk, but the time for sampling all sites should not exceed 4 wk. Sampling for the spring and summer quarters should be concentrated in May and August, respectively.

FIELD SAMPLES AND MEASUREMENTS

General Information

Effort

This section describes the methods for the parameters that can be measured in the field and for taking samples of those parameters that require final analysis in the laboratory. It takes two persons approximately 4 hr to complete these procedures at each stream site, excluding hiking time.

Preliminary Tasks

Before leaving the vehicle the stream site code, date, and names of the persons doing the field work

should be entered on the Field Records, Discharge Measurement, and Habitat Measurements sheets (Appendices III.C.1, III.C.2, and III.C.3, respectively). The sample bottles for water quality, bacteria, and periphyton should be numbered or otherwise labeled externally and entered on the Field Records sheet. The labels for all macroinvertebrate samples should be made ready to drop in the containers immediately after collection. The composition of these labels and the writing upon them should be sufficient to withstand the effects of the preservatives in which they will be placed (alcohol or formaldehyde). A particularly effective labeling technique is to use one of the devices that embosses self-sticking plastic tape, and then drop the strips of plastic tape into the samples without exposing the adhesive backing. Using bright colors of plastic tape makes the labels easier to find in the samples. A less effective alternative is to use paper with at least 50% rag content and to write with #2 pencil or India ink. If electronic instruments (pH, conductivity, dissolved oxygen) are going to be used later at the vehicle rather than *in situ*, those instruments should be prepared for use when the samples are returned. Two backpacks (one bare frame and one with bag) are required to transport the apparatus to the stream. A checklist of the equipment that must be carried is found in Appendix III.C.16.

Sampling Sequence

Upon reaching the stream sites, it is important to follow a protocol designed so that the disturbance caused by some activities does not affect any samples or measurements that follow. All bottles for water quality and bacteria samples should be filled and instrument readings taken before any disturbance of the stream bottom. The temperature reading should be taken at this time also. The 100-m tape for marking transects at 10-m intervals can be placed along the center of the stream channel at any time after the water quality and bacteria samples are taken, but care should still be taken not to disturb the bottom any more than necessary while traversing the length of the site. Next, the discharge is measured below the site, then the periphyton and macroinvertebrates are sampled, always moving progressively upstream. The discharge measurement and the quantitative benthic macroinvertebrate samples require two people, but an effective division of labor after that is for one person to take the periphyton and qualitative benthic macroinvertebrates samples while the other person takes the aerial samples of adult insects. The final measurements involve the habitat parameters, and these require both persons. Habitat measurements can be made by proceeding in either direction in the stream, and there is no concern about disturbing the bottom because there is no further sampling at the site.

Upon return to the vehicle, water quality and periphyton samples that require later analysis in the laboratory should be packed on ice, water quality measurements with electronic instruments should be completed (pH, conductivity, dissolved oxygen) if they were not done at the stream, and macroinvertebrate samples should be preserved.

Equipment

A list of all equipment needed for the field and laboratory procedures is provided in Appendix III.B.2.

Water Quality

Physical/Chemical and Bacteria

Samples should be collected before disturbing the stream in any manner. Try to fill bottles without entering the stream. Collect samples in moving water where there is no accumulation of debris on the surface and no indication of stagnation, but do not sample in an area where the current is so swift that splashing occurs. If it is necessary to enter the stream to find a suitable area, then stand still and reach as far upstream as possible when filling the bottles. Special care should be taken when collecting the water samples to be used for measurements of bacteria. When filling the bottle, it is necessary to avoid contamination from the person taking the sample. This is best accomplished by holding the bottle near its bottom and slanting it slightly in the upstream direction when filling. When measuring temperature, avoid standing water and sunny spots because these might be atypical areas with slightly elevated temperatures. These guidelines also apply to the use of electronic instruments, which may be used for *in situ* measurements of temperature, pH, conductivity, or dissolved oxygen. After all bottles have been filled, leave them in shallow water in a shaded area of the stream while the remaining samples and measurements are being taken.

A summary of how measurements should be made or samples collected is given below. There are many alternatives for water sample containers. Because the SNP will be contracting some of the water quality analyses, other laboratories may have individual preferences that would also be acceptable.

Temperature, pH, conductivity, dissolved oxygen	Electronic instruments or kits
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Alkalinity, pH, conductivity, nitrate, sulfate, calcium, magnesium, chloride, sodium, potassium, silica	1-L dark plastic bottle
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Seston	1-L dark plastic bottle
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Bacteria	1-L plastic bottle, autoclaved
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Temperature (Optional)	Long-stem thermometer
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When taking field measurements with electronic instruments or kits, it is sometimes difficult to know if the equipment is functioning properly. Therefore, it may be useful to be familiar with the ranges that have been recorded in the SNP for the water quality parameters that will be measured in the field:

Temperature (°C)	0.0 - 22.0
pH	4.95 - 7.39
Conductivity (µmhos)	10 - 93
Dissolved oxygen (mg/L)	5.6 - 10.9

Immediately upon returning to the vehicle, all of the water quality samples should be packed on ice in a cooler.

Discharge

Discharge should be measured by the six-tenths-depth method as recommended by the U. S. Geological Survey (Buchanan and Somers 1969) and the U. S. Forest Service (Platts et al. 1983). Methods are described in detail in the preceding publications. The principle is that depth and current velocity are measured at frequent intervals along a transect, the discharge is calculated for each individual section along the transect, then the total discharge of the stream is calculated by summing the discharges from all of the individual sections. Discharge should be measured below the site at the closest suitable location. Either a mechanical or electronic current meter (e.g., Scientific Instruments Model 1205 or Marsh-McBirney Model 201, respectively) can be used to make the velocity measurements (see equipment list in Appendix III.B.2). A separate data sheet is used to record the measurements in the field and to facilitate the discharge calculations (Appendix III.C.2). After selecting a suitable location, consisting of a stable, flat streambed with the threads of velocity parallel to each other, the transect is established by stretching a tag line across the stream at right angles to the direction of flow. "Tag line" is the term used by hydrologists for a small-diameter cord marked

with appropriate intervals to indicate distances when measuring discharge. The tag line can be secured by small metal rods or surveyor's pins driven into the streambank. Because discharge is measured outside of the stream site, rocks or debris can be moved to improve flow and streambed profile.

Using the tag line, determine the stream width to the nearest 0.1 m and record on the data sheet. The depth and current velocity must now be measured at frequent intervals along the transect that is demarcated by the tag line. This can be done from either side of the stream. The initial reference point for distance along the transect is where the tag line is secured to the pin. Beginning at one edge of the stream and proceeding at intervals of 0.1 - 0.3 m, measure and record the distance from the initial point (nearest 0.1 m), depth (nearest 0.01 m), and current velocity (direct reading from an electronic instrument or revolutions and seconds from a mechanical instrument). At both stream edges the depth and velocity will normally be zero. The number of recordings across the tag line varies with stream morphology, but as a general rule the narrower the stream (typically the upper sites) the smaller the recording intervals (0.1 m), and the wider the stream (typically the lower sites) the larger the intervals (0.3 m). When the bottom and current are irregular, recordings should not necessarily be made at regular intervals. Where current is visibly different over a short distance, recordings should deliberately be taken in the fastest and slowest water. Where rocks protrude sharply from the channel bottom, recordings should be made at the apex and close to the base. According to the six-tenths-depth method, the meter should be placed at six-tenths of the depth below the surface or four-tenths of the depth above the stream bottom.

SNP personnel use a Marsh-McBirney Model 201 electronic flow meter with a top-setting wading rod for measuring velocity. The following instructions apply to the use of that particular instrument. Attach the sensor to the wading rod, being careful not to overtighten the thumbscrew. Immerse the sensor in the water and turn the selector switch to "CAL" to check for electronic failure or low batteries. The readout should fall between 9.8 and 10.2 if everything is functioning properly. To set the sensor at six-tenths depth, the sliding decimeter scale should be lined up with the centimeter scale on the top-setting wading rod. For example, if the measured depth was 52 cm, line up the 5 on the sliding scale with the 2 on the centimeter scale. This will set the sensor at six-tenths depth. To get a velocity reading, set the selector switch on "M/sec." To help stabilize the readings, use the time constant switch. A time delay amounting to the switch setting multiplied by 5 sec occurs before the first full scale reading is reached. For example, if the time constant is set on 6, the first reading is reached at

30 sec. It is recommended by the manufacturer that readings be attempted at the smallest time constant first. If the readings do not stabilize adequately after the required time delay, then turn the time constant to the next highest number and try again.

Biological

Periphyton

A quantitative measurement can be made by scraping the periphyton from a known area of substrate. Four samples should be taken from each stream site by a stratified random design. (See the next section, Macroinvertebrates - Quantitative Benthic, for an explanation of stratified random design.) One sample should be taken from each of four cobble-size rocks selected from different segments of the site. The rocks must be of suitable shape and texture for attaching the bar-clamp sampler (Appendix III.B.3). The thickness of the rock cannot exceed the maximum opening of the bar-clamp sampler (11 cm), and the surface must be reasonably flat and smooth in order for the rubber gasket to seal properly. Also, do not choose rocks that are covered with obvious sedimentary materials; this can usually be avoided by selecting rocks from shallow riffle areas.

Attach the bar-clamp sampler securely to the rock, making sure of the seal by visual examination. Clean the entire area of the rock contained within the sampler with an acid etching brush. Move the brush firmly but slowly in all directions, being careful not to let any material "spring" off the brush. Rinse the inside of the sampler and the brush with distilled water from a squeeze bottle, making sure that no water leaves the sampler. The rinse water containing the periphyton in the sampler is then removed with an eye dropper and placed in a 60-ml dark plastic bottle. Repeat the procedure as necessary. The rock surface should appear clean (different color) when the periphyton has been satisfactorily removed.

Keep the periphyton sample cool at the stream by placing the bottle in shallow water at a shady spot, and pack the sample on ice in a cooler upon returning to the vehicle.

An alternative to sampling periphyton on natural substrates such as rocks is to use artificial substrates, which are usually standard 25 x 75-mm glass microscope slides. A floating rack constructed of clear vinyl plastic and styrofoam is commonly used to hold the slides (American Public Health Association et al. 1981). The periphyton from measured areas of each of several slides is scraped into dark plastic bottles. A major disadvantage of using this method is that it requires two

visits: one to place the samplers and one to retrieve them several weeks later. In addition, the glass slides do not collect the same community of algae as the rock substratum. Sampling natural substrates may be preferable for the LTEMs because the primary interest is how much periphyton biomass, either alive or as detritus, is available to consumers.

Macroinvertebrates

The LTEMs includes three types of macroinvertebrate sampling: quantitative benthic, qualitative benthic, and aerial. It is essential to collect both types of benthic samples consistently. Aerial sampling of adult aquatic insects is optional. The main purpose of collecting adult specimens is to obtain species level identifications, but the identifications can be done only by specialists in systematics.

Quantitative Benthic. The sampling devices that are recommended for the LTEMs are the Portable Invertebrate Box Sampler (PIBS) or the Surber Sampler (Appendix III.B.4). Although there are many different types of quantitative samplers, the PIBS is the best device for macroinvertebrates in rocky-bottomed streams (Voshell et al. 1989). The foam-lined bottom establishes a thorough seal by taking the shape of the bottom; therefore, the PIBS is effective on irregular cobble substratum as well as pebbles and gravels. In addition, the PIBS is completely enclosed, with wire mesh on the front side and solid side walls, so organisms cannot escape while sampling is in progress. The square shape and the edges at the bottom make it easy to attach to a backpack frame for transporting to remote areas. If the PIBS is attached to the backpack frame so that the catch net is up, the net can be inverted toward the wire mesh and used to carry gear. The Surber Sampler is not as effective at preventing organisms from escaping during sampling because it is not completely enclosed and does not fit closely to irregular substratum. The Surber Sampler should only be used when the water is not deep enough to use the PIBS. Do not use two different devices at a stream site on the same occasion. Both sampling devices should be outfitted with 350- μ m mesh catch nets. This mesh size has been shown to be fine enough to retain most organisms, yet not so fine that stream currents will cause a backwash out of the net. Coarser mesh nets (> 500 μ m) do not retain many of the small macroinvertebrates, most notably the abundant Chironomidae (Insecta: Diptera) (Voshell et al. 1989).

Quantitative benthic sampling cannot be completely random in rocky-bottom streams, such as those in the SNP. The physical placement of the sampling device is restricted by factors such as size and shape of the substratum, current velocity, depth of water, and in

some cases, even the width of the channels containing water. For these reasons, sampling in rocky-bottomed streams is usually designed as "stratified random," meaning that samples are always taken in the same habitat or "stratum." For the LTEMs the sampling stratum should be shallow riffles where the substratum consists predominantly of cobble and pebble/gravel. The sampler should be placed in areas where the depth and current are sufficient to wash dislodged organisms into the catch net but not so deep that the sampler is completely submersed. The substratum where the sampler is placed should not be so irregular that the sampler will not seal against the stream bottom. The area of stream bottom enclosed by the sampler should contain a mixture of substrate, consisting mostly of cobbles, some pebble/gravel, and a little underlying sand. (See the section on Habitat and Appendix III.C.7 for an explanation of substratum categories.) Homogeneous areas of small gravel and sand should be avoided because the diversity and abundance of macroinvertebrates will be very low.

Three quantitative samples should be taken at each stream site. Take the samples in different segments of the site, always beginning downstream and walking upstream to find the next suitable sampling area. Benthic macroinvertebrates are motile, and measurements of their abundance will be affected by walking through areas to be sampled. Spread the samples out as much as possible within the site, but when suitable benthic habitats are scarce take the samples wherever depth, flow, and substratum are optimum. After placing the sampler on the bottom, check to make sure that there is a good seal. The best position for the person taking the sample is to kneel behind the sampler with the catch net passing between the legs and the knees on the edges of the device; alternatively, the person can sit on the box (Appendix III.B.4). With either position the weight of the person taking the sample pushes the PIBS tightly against the substratum. If it is difficult to establish a good seal, the second person can assist by standing on the PIBS at the appropriate place. The instruments that will be needed for sampling are a vegetable brush, a small hand rake, and forceps. Brush each individual rock on all sides, so that the organisms will be dislodged and swept into the catch net. This is best done by holding the rocks underwater to make sure that no organisms are thrown out of the sampler. Each rock should also be visually examined at close range, because many aquatic insects have special means of attaching themselves very tightly to rock surfaces. Use forceps to remove any organisms found clinging after brushing. It is more efficient if a second person examines the individual rocks and removes the firmly attached organisms. After all of the larger rocks have been brushed, examined, and removed, rake the remaining fine substrate to stir up the sediment inhabiting organisms. Try

to rake down to a depth of about 10 cm. After raking, remove the catch net from the PIBS, or pick up the sampler in the case of the Surber. The catch net should be washed several times to concentrate the contents into the end. This is best accomplished by taking the net to a nearby pool area. The mouth of the net is briefly submersed and then raised rapidly. The contents of the sample are placed into a storage container by inverting the net, pushing an arm into the net, and gently tapping the apex from the inside. It is usually necessary to reverse and rewash the net several times to get all of the contents into the container. The appropriate label should be placed in the container immediately. Completely invert the catch net and backwash it before proceeding to take the next sample.

Any container that is a practical size and leakproof will suffice for storing benthic macroinvertebrate samples. Wide-mouth plastic jars are good because they do not break, but glass canning jars are also commonly used. A technique that has been used successfully in the Aquatic Entomology Program at VPI&SU for over a decade is to place the samples in small plastic trash bags that measure 23 x 20 x 46 cm (9 x 8 x 18 inches) and hold a volume of 15 L (4 gal). These bags are available in grocery stores. They can be doubled if there is concern about the contents of a sample making punctures (e.g., sticks). When the samples are first collected the plastic bags are tied loosely to contain the material, then upon returning to the vehicle, they are reopened, preservative is added, and the bags tied tightly. All of the bags containing separate samples from one stream site are placed in a 2.5-L plastic bucket with a snap-top lid (such as the ones used for cottage cheese). The appropriate labeling code should be written on the outside of the plastic bucket with a wax pencil.

There are several choices of fluids that can be used to preserve macroinvertebrates; formaldehyde, ethanol, and isopropanol are most commonly used. Benthic samples, which contain much bacteria-laden detritus and bottom sediment, are more difficult to preserve than separate organisms. Formaldehyde is the most effective preservative for benthic samples, but it must be used with caution because of human-health risks. If formaldehyde is used, the concentration should be 5% of the standard stock solution that is called formalin. Formalin contains 37% formaldehyde, so the concentration of formaldehyde in the preservative is a little less than 2%. The material in the sample only needs to be covered with the 5% formalin solution; it is not necessary to fill the sample container. Both ethanol and isopropanol are adequate substitutes for formaldehyde, and there is little difference between the two alcohols. Macroinvertebrates are best preserved with

a 70% solution of alcohol. More concentrated solutions make the specimens brittle and difficult to identify, while lower concentrations will not adequately retard decomposition by bacteria in the detritus and bottom sediment. Because benthic samples will retain some water and the live organisms contained in the sample have a great deal of water in their bodies, special attention must be given to dilution when preserving with alcohol. A 70% effective concentration can be approximated in the field by generously covering the material in samples with undiluted alcohol.

Qualitative Benthic. These samples are taken with a D-frame dip (or kick) net. The major objective is to obtain specimens from the many microhabitats that cannot be sampled with the quantitative device. Examples of these other microhabitats include leaf packs, surfaces of large rocks or logs, underneath large rocks or logs, exposed roots at the margins, and vegetation (either aquatic or terrestrial) hanging into the water (Appendix III.B.5). The investigators should use their powers of observation (and imagination) to find as many places as possible where macroinvertebrates might reside. It is usually best to dislodge the organisms with the hands and let them wash into the net. It is sometimes necessary to move objects with the feet, but this should be avoided usually because the specimens are often damaged. The net should be emptied at frequent intervals (at least after each microhabitat), combining all material into a single container. It is not necessary to retain all material in the net since this is a qualitative sample. It is difficult to state how much qualitative sampling is "enough" to achieve the goal of obtaining a complete taxa list. Try to sample each noticeable microhabitat, and try to expend equal effort among stream sites. The qualitative benthic samples are preserved in the same manner as the quantitative ones.

Aerial. The qualitative sample of emergent adult insects is obtained with an aerial net (Appendix III.B.6). One investigator should walk the entire site one time in one direction, while alternately sweeping both banks of the stream. Sweep the riparian vegetation with the net and periodically examine the contents. Sample different types of vegetation and different distances above the ground. The most effective use of the net is to sweep the tips of the vegetation or to bring the net up under branches and tap them. Sometimes flying insects will be observed and can be captured in flight. Captured insects can be retained while the investigator is walking by looping the net sideways over the rim. Periodically the contents of the net should be examined and the insects removed individually with forceps. The specimens are placed in a small jar (2 oz is convenient) containing 70% alcohol, along with the appropriate

label. It is desirable to retain only the aquatic insects, but this requires some entomological experience. The alternative is for the investigator to retain all specimens.

Habitat

Habitat measurements are made at 10-m intervals along each 100-m stream site. The 100-m measuring tape should be extended longitudinally between the upper and lower boundaries of the site. The tape should be placed along the middle of the stream, following the general shape of the channel as much as possible. Surveyor's pins or other type of stakes can be used to secure the ends of the tape, or a large rock can simply be placed on the tape. All habitat measurements are recorded on a separate field sheet (Appendix III.C.3). Measurements can be made by proceeding either upstream or downstream, but this should be recorded by circling the appropriate arrow for flow on the field sheet. The tag line used in the discharge procedures is also used to mark each transect in succession for the habitat measurements. The tag line can be secured on the streambanks with surveyor's pins. The overall scheme for habitat measurements is illustrated for a representative stream site in Appendix III.C.4. Note that transects T0 through T10 demarcate segments S1 through S10, respectively. Width, depth, riparian vegetation, and substratum are measured at each transect. Debris retention, fish cover, and pool-riffle ratio are measured throughout each segment.

Depth

Three depth measurements should be made along each transect, at distances of one-fourth, one-half, and three-fourths of the transect width. Depth is best measured with a wading rod, which is sturdy enough to withstand the current and the flat base will not slip into crevices. Other alternatives are a folding rule or meter stick. Depth measurements should be recorded to the nearest cm.

Width

Measure the width of the stream at each transect to the nearest 0.1 m. Measure the width between the two edges of water, not the banks of the channel. Islands, which are defined as rock or land structures greater than 30 cm (1 ft) high and 30 cm (1 ft) wide, are excluded from the measurement of stream width.

Riparian Vegetation Cover

This measurement should only be made when the leaves of deciduous trees would be expected to be present. At each transect, look directly up and rank the amount of cover over the stream channel into one of

three categories: 3 = 67-100% covered; 2 = 34-66% covered; 1 = 0-33% covered. This qualitative estimate is recorded on the habitat field sheet in the column "r. cover." Photographs of conditions representing each category are provided in Appendix III.C.5. In Category 1 the stream is exposed to the sun almost the entire day. Category 1 is not likely to occur in the SNP unless there has been extensive perturbation of the surrounding forest. Category 1 is the situation that would normally be expected for a small stream located in a forest during the early stages of succession, or for a river which is too large for the trees to shade. Most of the streams in the SNP, particularly the smaller ones at higher elevations, are likely to have riparian cover that fits Category 3. This is the condition when the limbs of most of the trees on both banks meet over the stream channel, thereby shading most of the water. In Category 2 the limbs of the trees do not meet over the water, but the trees are tall enough and the stream narrow enough that the water is shaded except during the middle of the day.

Riparian Vegetation Type

At each transect examine the vegetation on both banks that would fall or blow into the stream and decide whether the majority of the material would come from trees, shrubs, or grasses and forbs. Be sure to include the overstory that arises from the streambanks when making this qualitative evaluation. The categorization is recorded on the habitat field sheet in the column "r. type," as either T = trees, S = shrubs, or GF = grasses and forbs. No riparian vegetation is recorded as N. Photographs of flora representing each category are provided in Appendix III.C.6.

Substratum

The composition of the stream bottom is visually analyzed at 0.3-m intervals along the width of each transect. The tag line from the discharge measurements is useful for this purpose because it has convenient markings. In SNP streams the substratum consists almost entirely of mineral particles. Look directly under each 0.3-m segment of the tag line, and categorize the dominant substrate material according to the following sizes and terms:

Large, immovable	Bedrock (BR)
>25 cm, movable	Boulder (B)
6-25 cm	Cobble (C)
.2-6 cm	Pebble/Gravel (PG)
<.2 cm	Sand (S)

Photographs of each substrate category are provided in Appendix III.C.7 for reference. A length of PVC pipe with the substrate sizes delineated ("cobblestick") is very useful for making rapid and accurate decisions.

Record the abbreviation of the dominant type for each 0.3 m in the spaces on the habitat field sheet under "Predominant Substrate."

Debris Retention

Examine each segment between adjacent transects and categorize them according to the abundance of retention structures: 3 = abundant; 2 = intermediate; and 1 = none. Debris retention structures include rock outcrops, boulders, trees rooted in the channel, and fallen logs. The amount of debris accumulated on the structures does not enter into the decision. These qualitative estimates should be recorded on the habitat field sheet in the column "d. reten." Photographs of conditions representing each category are provided in Appendix III.C.8 for reference.

Fish Cover

Examine each segment between two adjacent transects and categorize them according to the abundance of fish cover: 3 = abundant (more than 50% of segment has cover); 2 = intermediate (25-50% of segment has cover); and 1 = exposed (less than 25% of segment has cover). Fish cover is considered to be places where 15 to 20-cm (6 to 8-inch) brook trout could hide without being visible from above. Structures that provide cover are large rocks, logs, undercut banks, and terrestrial vegetation that bends over into the water. In order to be usable cover, the water should be at least 15 cm deep and the current should be less than 15 cm/s. Depths and velocities must be estimated visually when categorizing fish cover. Photographs of conditions representing each category are provided in Appendix III.C.9 for reference. These qualitative estimates should be made according to the existing water level. Estimates are recorded on the habitat field sheet in the column "f. cover."

Pool-Riffle

Examine each segment between two adjacent transects and estimate the length of the segment that is pool (deep, still water) and the length that is riffle (shallow, flowing water). In order to be considered a pool, the depth and current should be appropriate for 15 to 20-cm (6 to 8-inch) brook trout to reside there (at least 15 cm deep with current less than 15 cm/s). Pocket water in the channel during low flow can be considered as a pool; glides and runs (smooth, slow-flowing water) are considered to be riffles. The 100-m tape that is stretched longitudinally along the channel is helpful, but pool-riffle is still largely a qualitative estimate. Depth

and current must be estimated visually. It should be kept in mind that pool-riffle refers only to major differences along the length of a segment and that minor differences across the width of a segment are disregarded. Photographs in Appendix III.C.10 provide some examples of pool-riffle estimates. The estimates are recorded on the habitat field sheet in the column "P:R", to the nearest 1 m and totaling 10 m.

LABORATORY ANALYSES AND CALCULATIONS

This section explains how the samples that have been collected in the field are analyzed to produce the final results. In addition, some measurements that were taken in the field require further calculations to reach appropriate units for reporting. Many of these analyses and calculations are standard methods that are described in readily available books and bulletins, which will be referenced without repeating the details. Several summary and worksheets are provided so that the laboratory analyses and calculations can be performed efficiently and accurately (Appendices III.C.11 - 15). On all of these sheets, the site code, date that the site was sampled, and name of the person who is compiling the data should be entered. Upon completing the procedures described in this section, all data are ready for entry into the database management system.

Water Quality

Discharge

Buchanan and Somers (1969) provide a thorough description of how to calculate discharge from the measurements that were taken. The Discharge Measurement sheet that was used in the field (Appendix III.C.2) has spaces to complete the calculations. The final result should be entered in the appropriate space on the Water Quality Summary sheet (Appendix III.C.11).

Chemical Parameters

Upon returning from field sampling, refrigerate all samples until they are analyzed. All chemical parameters should be analyzed according to methods recommended by either the American Public Health Association et al. (APHA, 1981, or later editions) or U.S. Environmental Protection Agency (USEPA, 1983). The following are specific recommendations within these two references for some of the parameters. Record all final results, including those measurements taken in the field (temperature, conductivity, pH, dissolved oxygen), on the Water Quality Summary sheet (Appendix III.C.11).

Alkalinity: double endpoint titration; APHA et al. (1981), method 403.

Sulfate: turbidimetric; USEPA (1983), method 375.4.

Nitrate: spectrophotometric, cadmium reduction; USEPA (1983), method 353.3.

Chloride: colorimetric, automated ferricyanide AAI or AAll; USEPA (1983), methods 325.1 or 325.2.

Calcium: atomic absorption spectrophotometric; APHA et al. (1981), method 303 A.

Magnesium: atomic absorption spectrophotometric; APHA et al. (1981), method 303 A.

Potassium: atomic absorption spectrophotometric; APHA et al. (1981), method 303 A.

Sodium: atomic absorption spectrophotometric; APHA et al. (1981), method 303 A.

Silica: colorimetric; USEPA (1983) method 370.1.

Seston

The methods for seston analysis are almost the same as those that APHA et al. (1981) suggest for residue analysis (Section 209). Use the Seston Worksheet (Appendix III.C.12) to record the sample weights (pans and filters) at each step. Use the Water Quality Summary sheet (Appendix III.C.11) to record the final calculations (sample weights minus tare weights of clean filters and pans divided by volume of water filtered). Weights should be reported in mg and final concentrations in mg/L. Other references that may be useful are Gurtz et al. (1980) and Voshell and Parker (1985).

Total seston, or suspended particulate matter, is synonymous with total nonfiltrable residue and can be measured by a slight modification of Method 209 D. Because of the low concentration of seston in SNP streams, at least 1 L of water should be filtered. The sample should be dried at 60 °C for 24 hr, instead of 103-105 °C for 1 hr, to make sure that no organic matter is volatilized. This weight is recorded on the worksheet in the column labelled "Dry Wt." The concentration of total seston is calculated by subtracting the tare weight from the dry weight of the sample and dividing by the volume of water filtered. The concentration should be recorded on the water quality summary sheet in the space labeled "Total".

Inorganic seston is synonymous with the ash of nonfiltrable residue and can be measured by a slight

modification of Method 209 G. The sample should be ignited at 500 °C for 1 hr, instead of 550 °C for 15 min. After cooling, a few drops of distilled water should be placed on the filter to restore the water of hydration. Then the sample should be dried at 60 °C for 24 hr, weighed, and recorded on the worksheet in the column labeled "Ash Wt." The concentration of inorganic seston is calculated by subtracting the tare weight from the sample ash weight and dividing by the amount of water filtered. Record the concentration on the Water Quality Summary sheet in the space labeled "Inorganic."

Organic seston is synonymous with volatile nonfiltrable residue and can also be measured by the same modification of Method 209 G. The amount of organic seston in sample is the difference between the dry weight of the sample containing total seston and the weight after ignition, wetting, and redrying. Record this sample weight on the worksheet in the column labeled "AFDW" (ash-free dry weight). Calculate the concentration of organic seston by subtracting the tare weight from the ash-free dry weight and dividing by the amount of water filtered. Record the concentration on the Water Quality Summary sheet in the space labeled "Organic." The organic seston/inorganic seston ratio should be calculated by division, rounded to the nearest 0.01, and entered in the space labeled "O/I."

Bacteria

Total Coliform: standard MPN test; APHA et al. (1981), Method 908 A.

Fecal Coliform: MPN procedure; APHA et al. (1981), Method 908 C.

Fecal Streptococcus: multiple-tube technic; APHA et al. (1981), Method 910 A.

Record all results on the Bacteria and Seston Worksheet (Appendix III.C.14). Results should be expressed as MPN (Most Probable Number)/100 ml.

Habitat

The Habitat Measurements sheet that was used in the field (Appendix III.C.3) should be used as a worksheet to make the calculations described below. Final results should be recorded on the summary sheet for habitat measurements (Appendix III.C.13).

Depth

Calculate the mean depth at each transect by adding the three measured depths and dividing by four to account for zero depths at the shore (Platts et al. 1983). The overall mean depth at the site is calculated

by averaging the 11 transect mean depths. Round to the nearest cm.

Width

The mean width of the site is calculated by averaging the 11 transect widths. Round to the nearest 0.1 m.

Riparian Vegetation Cover

Average the 11 rankings taken at each transect. Round to the nearest 0.1. Results can be interpreted as follows: 2.6 - 3 is mostly shaded; 1.6 - 2.5 is mostly intermediate conditions of shading; 1 - 1.5 is mostly exposed to sunlight.

Riparian Vegetation Type

Add the number of entries for each of the four vegetation types at the 11 transects. Calculate the proportions of each type for the entire site. Round to the nearest 1%.

Substratum

Add the number of entries for each of the five substrate types at all 11 transects. Calculate the proportions of each type for the entire site. Round to the nearest 1%.

Debris Retention

Average the rankings for the 10 segments. Round to the nearest 0.1. Results can be interpreted as follows: 2.6 - 3 is mostly abundant retention capacity; 1.6 - 2.5 is mostly intermediate retention capacity; 1 - 1.5 is mostly without the capacity to retain debris.

Fish Cover

Average the rankings for the 10 segments. Round to the nearest 0.1. Results can be interpreted as follows: 2.6 - 3 is mostly abundant cover; 1.6 - 2.5 is mostly intermediate cover; 1 - 1.5 is mostly exposed.

Pool-Riffle

Average the pool values for the 10 segments, then average the riffle values. Round both the pool and riffle averages to the nearest whole number. An important rule to remember when rounding off is that if the digit to be rounded is followed by a 5 standing alone or followed only by zeros, the digit is not changed if it is even but is increased by one if the digit is odd (e.g., 2.5 rounds to 2, 7.5 rounds to 8) (Sokal and Rohlf 1981). The two

averages should total 10. Report the average results as the pool:riffle ratio. This ratio can also be interpreted as the proportion of pool and riffle at the site (e.g., 2:8 ratio means that 20% of the site is pool and 80% is riffle).

Biological

Periphyton

Biomass. Spectrophotometric determination of chlorophyll *a* is used to estimate the biomass of live periphyton, according to Method 1002 G.3 in APHA et al. (1981). Three of the periphyton samples should be analyzed separately and averaged. This method includes a correction factor for the presence of pheophytin *a*, a common degradation product of chlorophyll *a* that interferes with determination of chlorophyll *a*. Use the Bacteria and Periphyton Worksheet (Appendix III.C.14) to record the various steps of this procedure. The final results should be expressed as $\mu\text{g}/\text{cm}^2$. Method 1002 G.3 is actually written for phytoplankton samples, which are reported according to volume. To report periphyton in terms of surface area, the area of the sampler in cm^2 should be substituted for V_2 in the equations. In addition the final result should be converted from mg to μg .

Autotrophic Index (AI). The AI is calculated by dividing the total biomass of periphyton by the amount of chlorophyll *a*, in accordance with APHA et al. (1981) Method 1002 G except that the units are $\mu\text{g}/\text{cm}^2$. Use the Bacteria and Periphyton Worksheet (Appendix III.C.14) to make the calculations. The amount of chlorophyll *a* is obtained from the procedures described above. The total biomass of periphyton, including both living and dead material, is measured by filtering the fourth periphyton sample and analyzing it by the same method as organic seston (Method 209 G, ash-free dry weight).

Macroinvertebrates

Quantitative and Qualitative Benthic. The analysis of each benthic sample is done in a series of steps that may take place over a period of several days; therefore, it is essential to establish a log that traces the analysis of each sample from its return to the laboratory to the final identification and enumeration of specimens. The log should have a separate entry for each benthic sample that was taken, including the code, location, type, replicate, and date collected. The steps that should be recorded in the log are: return to the laboratory, washing, sorting, and identification along with enumeration. The date that each step was completed and the initials of the person completing the step should be recorded. The log should be kept in a sturdy, permanently bound notebook, which cannot have pages removed.

The first step in analyzing benthic macroinvertebrate samples is to remove any remaining fine detritus and the original preservative, which will have become darkly stained from leaf leachate. This is accomplished by placing each sample in a 355- μ m brass soil sieve (U. S. Series No. 45) and washing thoroughly with tap water. A sieve of this particular mesh size is used in order to correspond with the mesh size of the nets on the samplers that were used to collect the samples. The sample should be gently stirred and shaken while it is being washed. The purpose of this procedure is to make the sample clean enough for the organisms to be seen and removed. Therefore, it is important to wash samples thoroughly; however, care should be taken not to damage the specimens because accurate identifications depend on having all external structures intact. All material should be removed from the sieve and placed in a suitable container for temporary storage. Round glass bowls, measuring 11.5 cm in diameter and 5.5 cm high, work very well for this purpose. The original coded label that was placed in the sample during field collection should be kept with the sample throughout all steps of analysis. If the sample is to be sorted immediately, water can be added to the container; if there will be a delay before sorting (e.g., overnight) then 70% ethanol should be added. Special efforts are required to make sure that all material is removed from the sieve. The material can be concentrated at the bottom of the sieve by holding the sieve at an angle under a faucet. A flexible hose attached to the faucet is particularly effective for this task. The sample is best transferred to the container by gently washing it out of the sieve with a squeeze bottle containing either water or alcohol. The bottom area of the sieve should be backwashed with the squeeze bottle to complete the removal of the sample.

The next step is to remove the organisms from the debris in the sample. This procedure can be referred to as "sorting," but it is commonly called "bug picking." The importance of this step cannot be over-emphasized. If all of the organisms are not consistently removed from the samples, significant variability will be introduced into the monitoring program, perhaps even making the careful field work for naught. Therefore, it is essential that a rigid protocol be established and followed. The sample should be placed in a shallow white enamel pan, covered with approximately 1 cm of water, and all organisms taken out with forceps. An efficient size of enamel pan is 19.5 cm wide x 31 cm long x 5.5 cm high. If the sample contains a great deal of debris, only a small portion should be placed in the sorting pan at one time. The pan should be examined in a systematic fashion, proceeding along imaginary rows and columns. The debris should be gently stirred with the forceps. There should be adequate lighting immediately above the pan, such as a desk lamp with a flexible arm. An

illuminated magnifier is helpful, but not essential for the size of organisms that will be retained by a 355- μ m mesh. An efficient approach is to carefully examine the entire pan with the unaided eye, then scan the entire contents a second time with the illuminated magnifier. As the organisms are removed they can be placed into a single container or they can be separated into taxonomic groupings, depending upon the expertise of the persons doing the sorting. A 59-ml (2-oz) bottle is a handy size for holding all organisms collectively; 7-g (4-dram) vials are best for holding individual taxonomic groups. After the second scan of the pan, dispose of the material and continue sorting portions of the sample until finished. Make sure that the containers are filled with 70% ethanol and are tightly sealed. Each jar or vial should contain a copy of the site code, and the original field label should be in one of the containers.

The last step involves identifying the specimens to the lowest possible taxonomic level and counting the number in each taxon. Each specimen must be carefully examined with a reasonably good quality stereomicroscope having magnification up to at least 40X. Identification is accomplished by using taxonomic publications that contain descriptions and keys. Brigham et al. (1982) and Merritt and Cummins (1984) are two excellent works that cover all of the aquatic insects that will be found in Virginia. Some more specialized publications that cover the most common individual orders of insects in more detail are: Edmunds et al. (1976), Ephemeroptera; Wiggins (1977), Trichoptera; and Stewart and Stark (1989), Plecoptera. Macroinvertebrates other than insects can be identified with Pennak (1978) or an older work that is still quite useful, Ward and Whipple (1959). Occasionally immature stages of terrestrial insects are found in aquatic samples because of accidental dislodgement into the water. These can be particularly troublesome because they may not key out with the references for aquatic fauna. A recent book (Stehr 1987), which covers the immature stages of all insects, contains a key to orders that can be used to resolve this problem. Benthic macroinvertebrates should be identified to at least the following taxonomic levels:

- Insecta - genus (except Diptera, family)
- Crustacea - genus
- Mollusca - family
- Oligochaeta - class
- Turbellaria - class

Sometimes it may not be possible to identify early stages to these levels. It should be kept in mind that good taxonomic references by themselves do not guarantee accurate identifications. Formal training in a course, such as aquatic entomology or invertebrate zoology, or experience obtained under the supervision

of a specialist is necessary. It is always a good idea to have representatives of each taxon verified by specialists at universities or museums.

As specimens are identified they should be sorted for separate storage. A series of vials lined up on the bench is handy for this purpose; special trays are available, or can be constructed, to keep the vials from tipping over. Watch glasses and porcelain spot test plates are also handy for temporarily holding individual taxa while a sample is being identified. Specimens should always be kept immersed in 70% alcohol. For the quantitative benthic samples all specimens should be enumerated. Individuals can either be tallied as they are identified or counted at one time after the entire sample is finished. It is probably more efficient to continuously tally the abundant taxa and count the sparse taxa at the end. Tally meters are useful for both continuous and final counting. For the qualitative benthic samples the taxa are only recorded as being present; there is no need to count the specimens. All data should be recorded on the Benthic Macroinvertebrate Worksheets (Appendix III.C.15). It is very important to fill in all of the information at the top of each worksheet (site code, date, sample type and replicate, person making the identifications). The column for comments should be used to record any special circumstances, such as questionable identifications that need more attention or specimens having been sent to a specialist for verification. Macroinvertebrate data are entered into the database management system by taxonomic codes, rather than scientific names. After the samples are identified and enumerated, the taxonomic codes should be written on the worksheets in the column labeled

"Taxa Codes" to make data entry faster and more accurate. The taxonomic codes can be found in the dictionary for the aquatic component of the database management system.

When a sample is completely identified and counted, all specimens should be stored individually in 4-dram vials containing 70% alcohol. Make sure the vials are filled and tightly sealed. Either patent-lip vials with neoprene stoppers or screw-cap vials with conical plastic liners will prevent evaporation of the alcohol for extended periods of time (several yrs). Each vial should contain a label bearing the site code, site name, date, taxonomic name, and name of the person making the identification. Vials should be stored in collective lots corresponding to site, date, sample type, and replicate. The original field label should be kept with the corresponding lot. Cardboard unit trays, which are available commercially, are efficient for storing samples in this manner. All samples should be kept at least until the data are entered into the database management system and successfully analyzed. Inevitably questions will arise, and certain taxa in some samples will have to be reexamined. Eventually storage space and costs of new vials will make it necessary to dispose of old samples. The SNP should decide how long samples will be kept; a minimum of 1 yr after entry into the database management system is recommended. It is imperative to keep several vials of each taxon collected each year as a voucher collection. The voucher collection serves as a tool for training employees or consultants, educating the public, and resolving any taxonomic questions that might arise in the future.

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APPENDIX III.A

LOCATIONS OF STREAM SITES

Stream Site 3L300: Paine Run - Upper (Top Arrow)



Directions (PATC Map, Southern District):

Take the Paine Run Trail off the Skyline Drive; at the second switchback, take path on right side of trail to Blackrock Springs; at the springs, hike downhill to the stream then 100 m upstream.

Location of Markers:

On left descending bank; top marker 15 m from stream edge near 28-cm white oak; bottom marker 8 m from stream edge near 20-cm white oak.

Elevation: 560.8 m (1840 ft)

UTM: 696700E, 4331200N

Stream Site 3L301: Paine Run - Lower (Bottom Arrow)



Directions (PATC Map, Southern District):

Take Rt. 661 at Grottoes off Rt. 340; drive to end of road; hike down old road (with gate at top) to stream; also SNP Trout Section #123.

Location of Markers:

On right descending bank; top marker 20 m from stream edge, across trail, near 30-cm pine; bottom marker 20 m from stream edge, across trail, up steep slope, in line with upstream edge of road/stream crossing.

Elevation: 426.7 m (1400 ft)

UTM: 693200E, 4229950N

Stream Site 3L302: Twomile Run - Upper (Right Arrow)



Directions (PATC Map, Southern District):

Take Onemile Run Trail off the Skyline Drive; at the point on the trail where it starts down towards Onemile Run (approx. 640.1 m [2100 ft]), "bushwhack" in an easterly direction down a ravine towards Twomile Run; at the run, go downstream until you reach a tributary entering from the east; it is helpful to have 3 persons for carrying equipment over steep terrain.

Location of Markers:

On left descending bank; top marker 20 m from stream edge near double trunk red oak, in line with tributary entering from the east; bottom marker 10 m from stream edge near 25-cm white oak.

Elevation: 512.1 m (1680 ft)

UTM: 705500E, 4242750N

Stream Site 3L303: Twomile Run - Lower (Left Arrow)



Directions (PATC Map, Southern District):

Take Rt. 649 off Rt. 340; Rt. 649 becomes a dirt road after crossing Rt. 754; follow road to left after you can no longer go straight because of private gate; park at area at end of road; hike down trail to boundary; also SNP Trout Section #103.

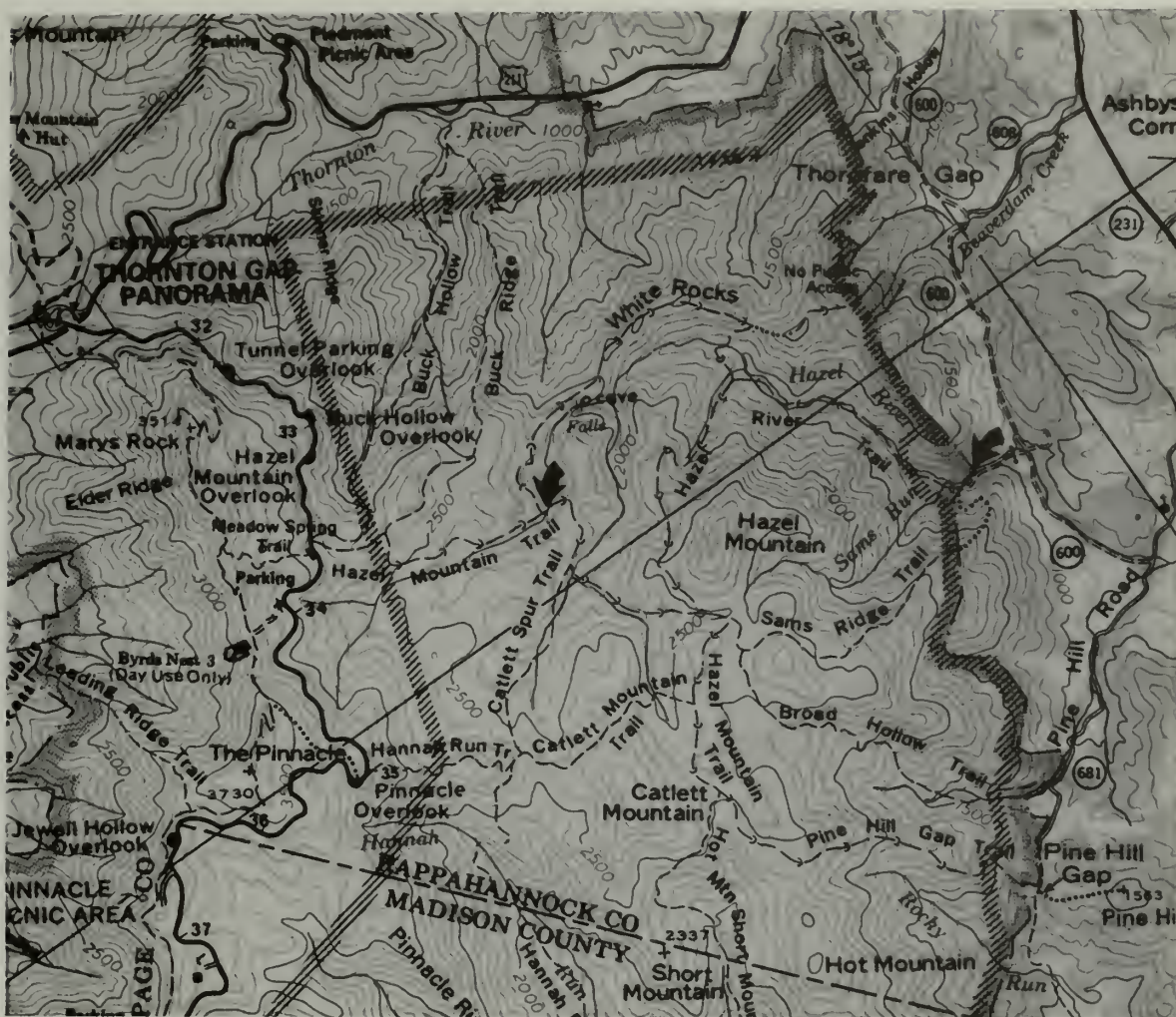
Location of Markers:

On left descending bank; top marker 20 m from stream edge up moderate slope; bottom marker 20 m from stream edge near 30-cm red oak on boundary.

Elevation: 408.4 m (1340 ft)

UTM: 703500E, 4245200N

Stream Site 2L302: Hazel River - Upper (Left Arrow)



Directions (PATC Map, Central District):

Drive down fire road at parking area on Skyline Drive for Hazel Mountain Trail, then follow Hazel Mountain Trail to the first stream crossing; also SNP Trout Section #90.

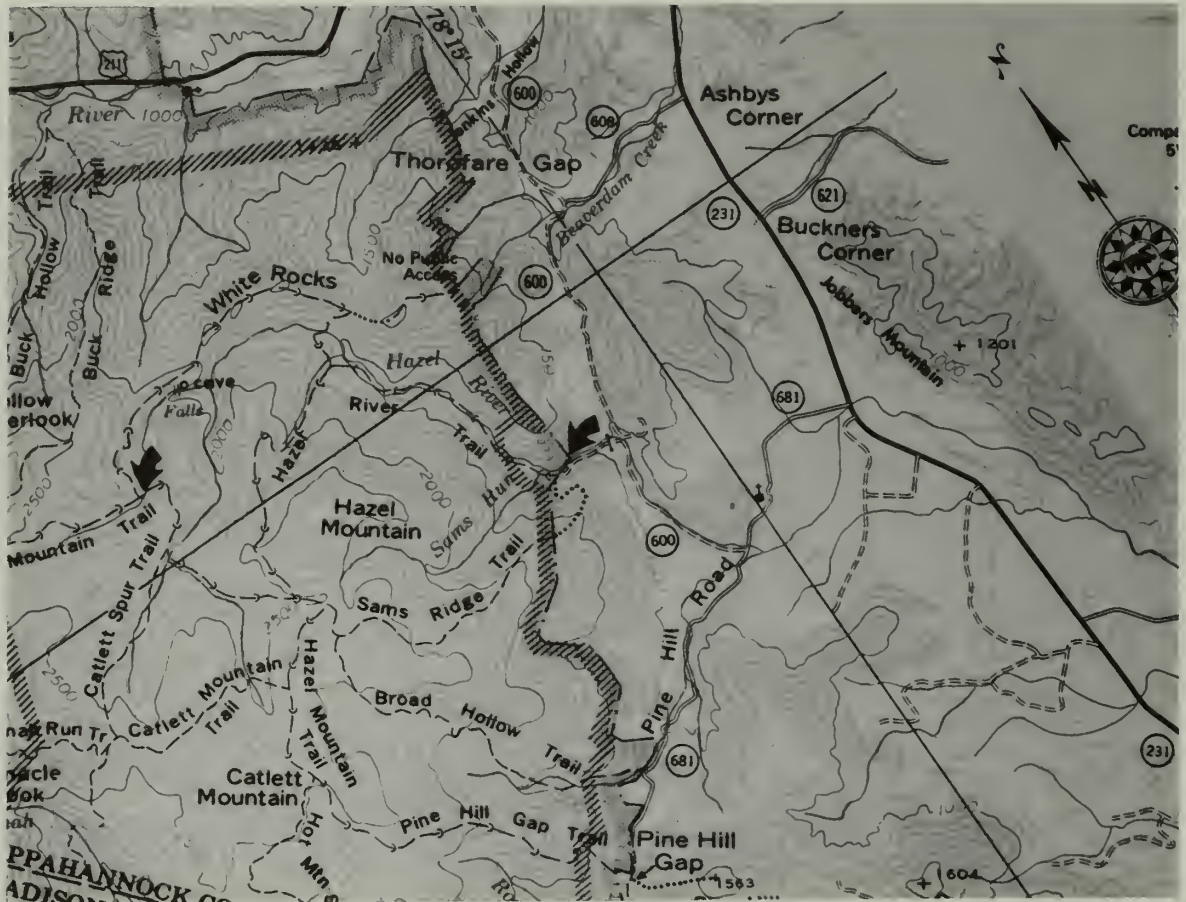
Location of Markers:

On left descending bank; top marker 10 m from stream edge near 20-cm hemlock; bottom marker 11 m from stream edge near 36-cm hemlock, in line with downstream edge of trail/stream crossing.

Elevation: 670.6 m (2200 ft)

UTM: 735450E, 4279000N

Stream Site 2L303: Hazel River - Lower (Right Arrow)



Directions (PATC Map, Central District):

Take Rt. 600 off Rt. 681; drive up private road to boundary; bottom marker is just above ford; also SNP Trout Section #71.

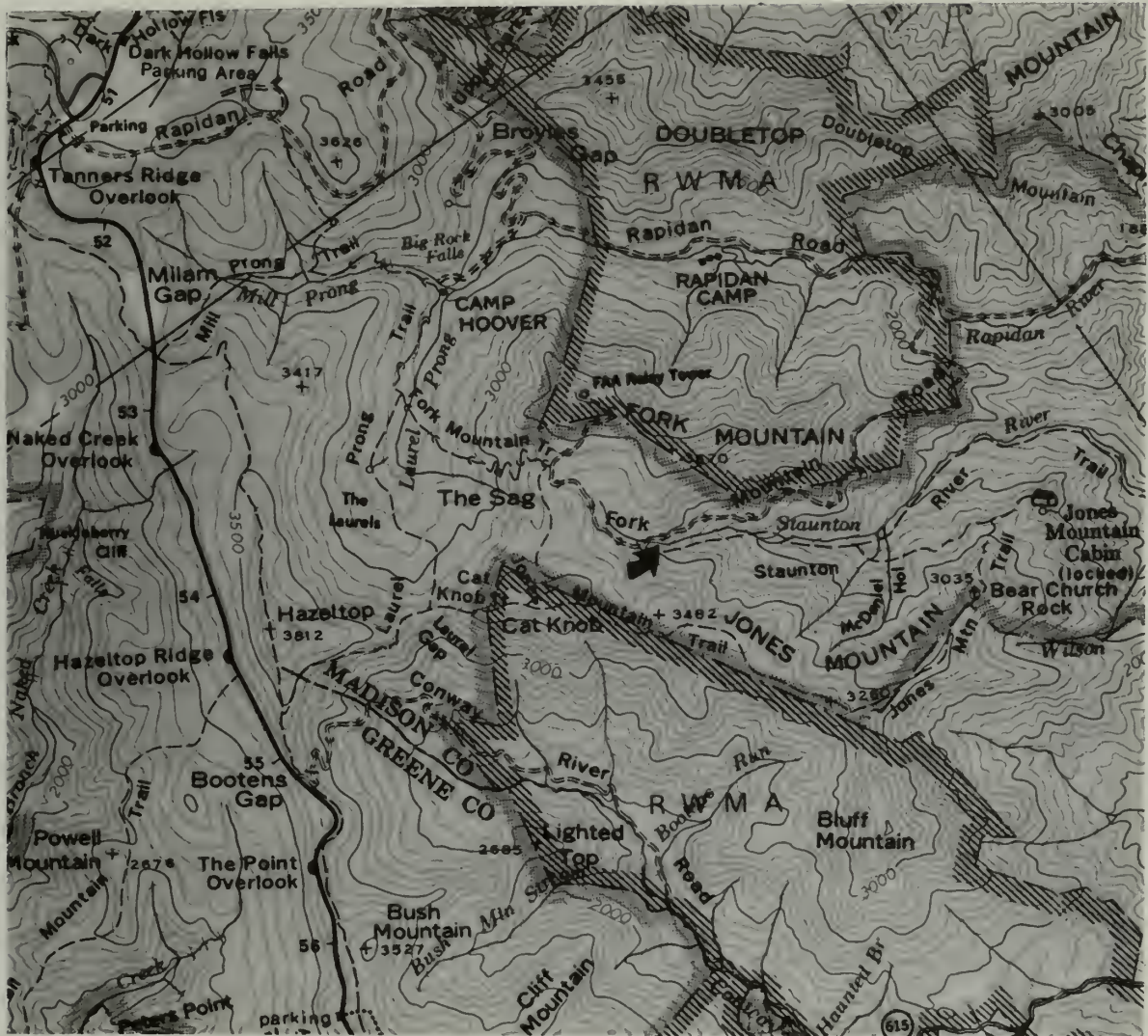
Location of Markers:

On right descending bank; top marker 17 m from stream edge, across trail, near 61-cm poplar; bottom marker 13 m from stream edge on boundary.

Elevation: 347.5 m (1140 ft)

UTM: 738350E,4277450N

Stream Site 2L306: Staunton River - Upper



Directions (PATC Map, Central District):

Take the Rapidan Road off Skyline Drive; then Fork Mountain Road to road/stream crossing.

Location of Markers:

On left descending bank; top marker 15 m from stream edge near 23-cm locust, approximately 50 m downstream of crossing; bottom marker 15 m from stream edge near double trunk hemlock, in line with top of 1.8-m falls.

Elevation: 902.2 m (2960 ft)

UTM: 725250E, 4260600N

Stream Site 2L307: Staunton River - Lower (Right Arrow)



Directions (PATC Map, Central District):

Take Rt. 662 off Rt. 230; park at PATC cabin parking area; go straight to stream from parking area; can come from above, via Rapidan Road, depending on road conditions; also SNP Trout Section #72.

Location of Markers:

On left descending bank; top marker 15 m from stream edge, up a moderate slope, near a 76-cm red oak; bottom marker 12 m from stream edge, up a steep slope, near a 38-cm maple.

Elevation: 347.5 m (1140 ft)

UTM: 729250E, 4258250N

Stream Site 2L308: North Fork Dry Run - Upper



Directions (PATC Map, Central District):

Take dirt road to Lambert's property off Rt. 669; park near the Lambert house; hike to the boundary; also SNP Trout Section #131.

Location of Markers:

On right descending bank; top marker 10 m from stream edge, near several red oaks; bottom marker 9 m from stream edge, near 20-cm red oak on boundary.

Elevation: 499.9 m (1640 ft)

UTM: 729900E, 4279900N

Stream Site 2L300: White Oak Canyon Run - Upper (Left Arrow)



Directions (PATC Map, Central District):

Take the White Oak Canyon Road off the Skyline Drive; park and hike to stream.

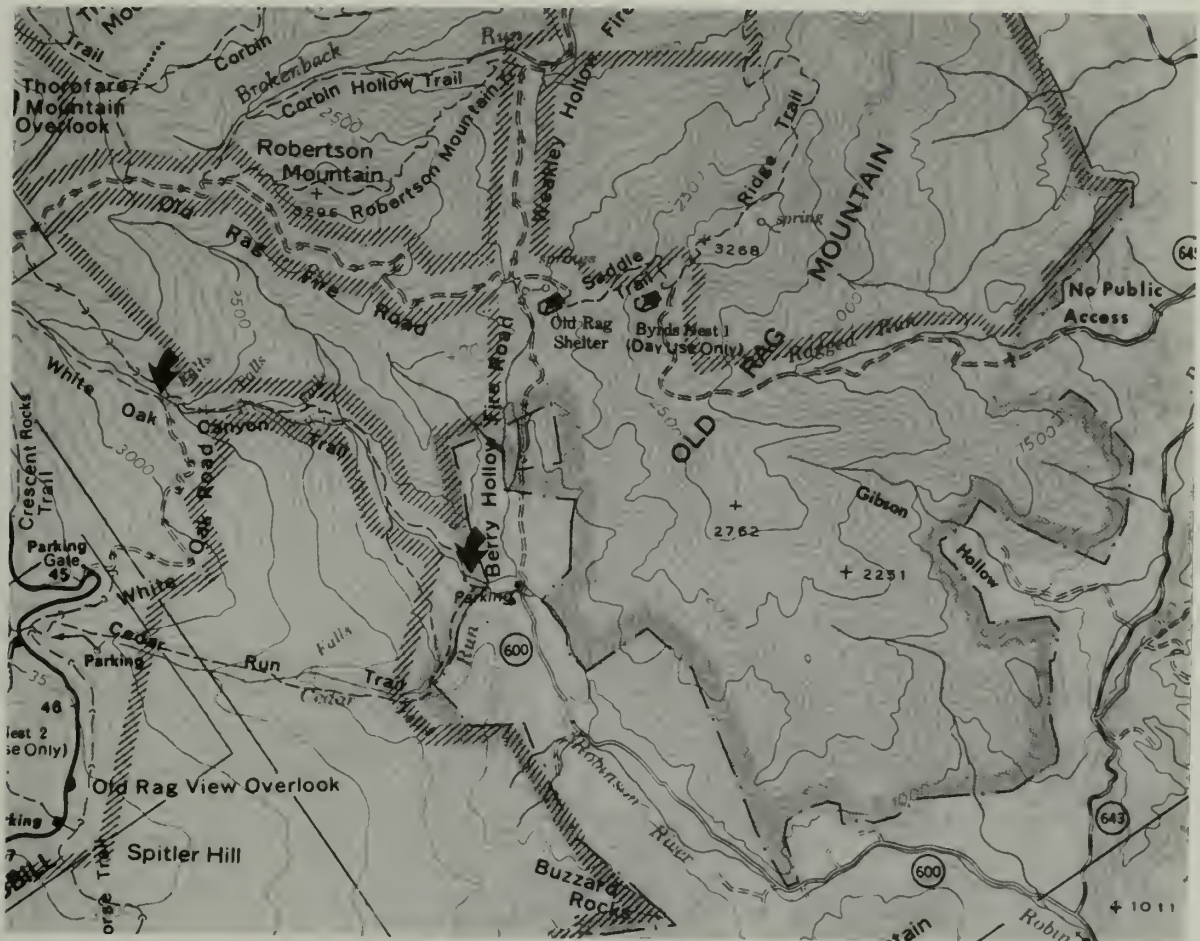
Location of Markers:

On right descending bank; top marker 10 m from stream edge, across trail, near a 30-cm maple; bottom marker 12 m from stream edge, across trail, near 41-cm maple, approximately 50 m upstream of trail/stream crossing.

Elevation: 792.5 m (2600 ft)

UTM: 729550E, 4271600N

Stream Site 2L301: White Oak Canyon Run - Lower (Right Arrow)



Directions (PATC Map, Central District):

Take Rt. 600 off Rt. 643; park at SNP parking area; take White Oak trail to steel bridge; also SNP Trout Section #9.

Location of Markers:

On left descending bank; top marker 15 m from stream edge, near 61-cm hemlock, approximately 20 m downstream of bridge; bottom marker 8 m from stream edge, near 61-cm white oak, up a steep slope.

Elevation: 341.4 m (1120 ft)

UTM: 730950E, 4268900N

Stream Site 2L304: Hogcamp Branch - Upper



Directions (PATC Map, Central District):

Take the Rose River Road off the Skyline Drive to bridge; also SNP Trout Section #55.

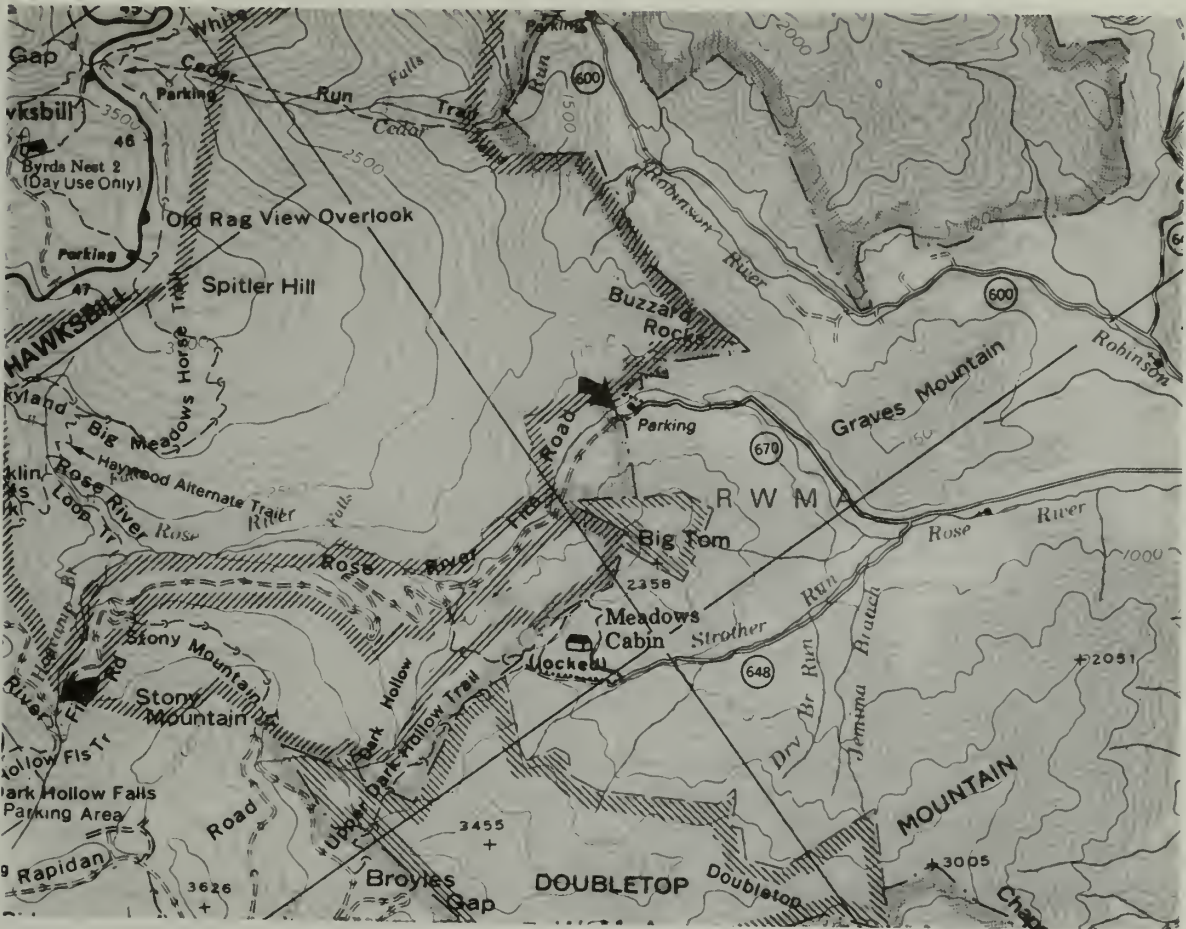
Location of Markers:

On left descending bank; top marker 15 m from stream edge, near 23-cm poplar, approximately 10 m downstream of bridge; bottom marker 9 m from stream edge, near 20-cm forked birch.

Elevation: 853.4 m (2800 ft)

UTM: 724700E, 4266500N

Stream Site 2L305: Rose River - Lower (Right Arrow)



Directions (PATC Map, Central District):

Take Rt. 670 off Rt. 231; park at boundary; an unmarked trail, which intersects with the road just before the yellow gate, leads directly to the site; also SNP Trout Section #15.

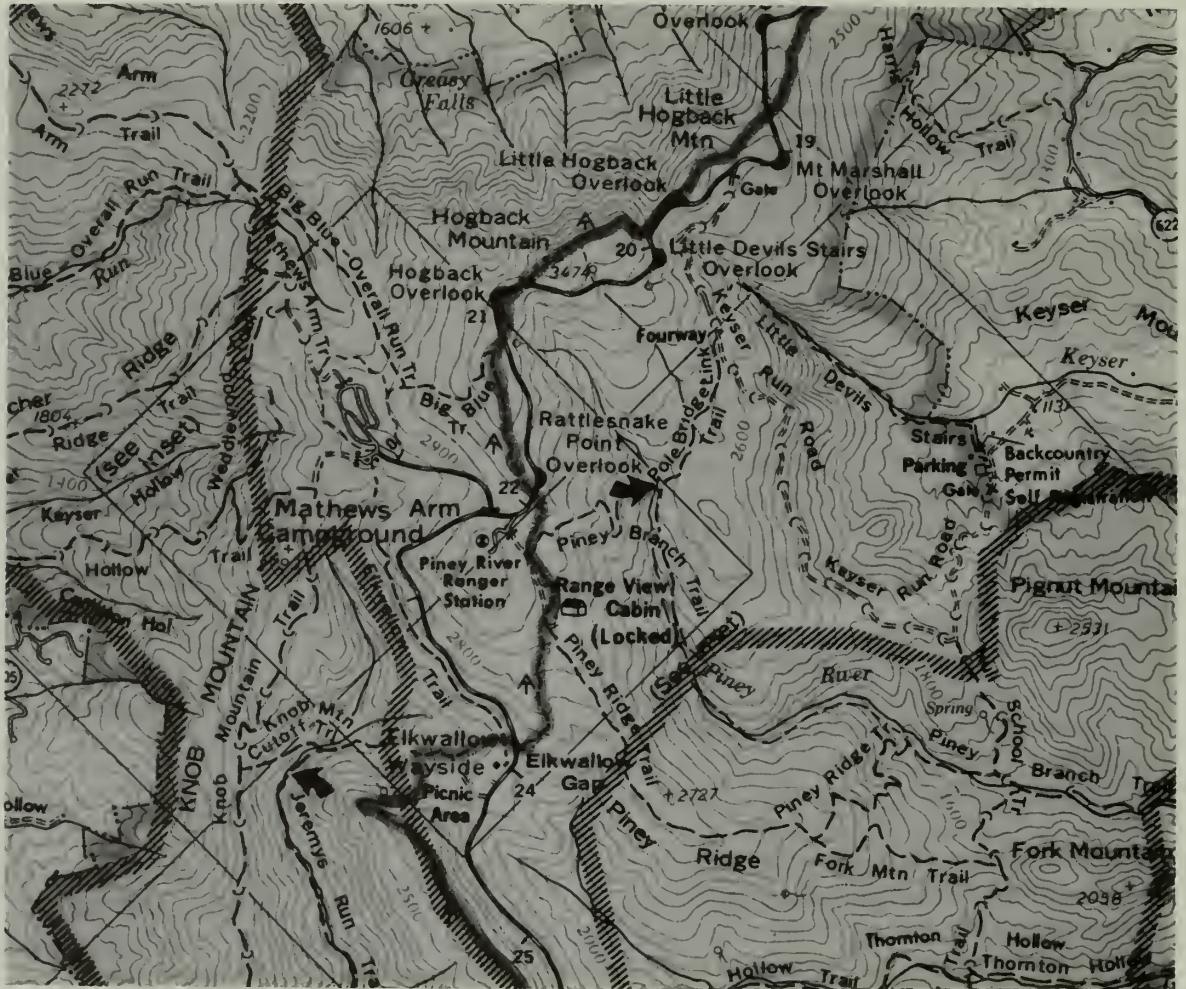
Location of Markers:

On left descending bank; top marker 15 m from stream edge, near 61-cm white oak; bottom marker 15 m from stream edge, across a small gully, approximately 50 m upstream of boundary.

Elevation: 341.4 m (1120 ft)

UTM: 729550E, 4266050N

Stream Site 1L308: Piney River - Upper (Top Arrow)



Directions (PATC Map, Northern District):

Take Keyser Run Road to Pole Bridge Link Trail; hike to "old" Piney Branch trail/stream crossing; it is helpful to have 3 persons for carrying equipment.

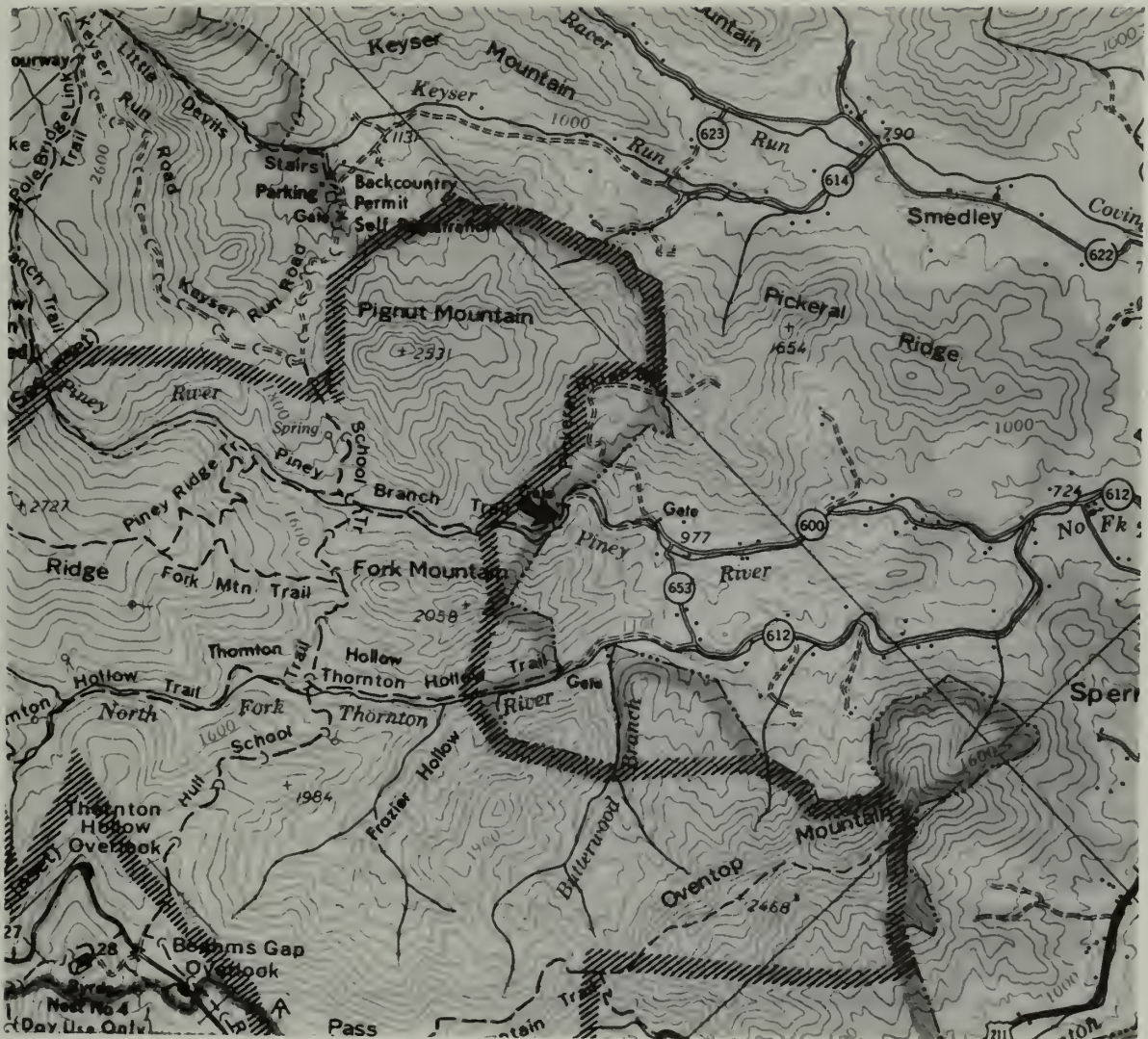
Location of Markers:

On right descending bank; top marker 5 m from stream edge, near 76-cm white oak, at the "old" crossing; bottom marker 12 m from stream edge, near 15-cm red oak, in line with top of falls.

Elevation: 768.1 m (2520 ft)

UTM: 736250E, 4291800N

Stream Site 1L309: Piney River - Lower



Directions (PATC Map, Northern District):

Take Rt. 600 off Rt. 211; park at washed out bridge or along Rt. 653; hike to boundary; also SNP Trout Section #3.

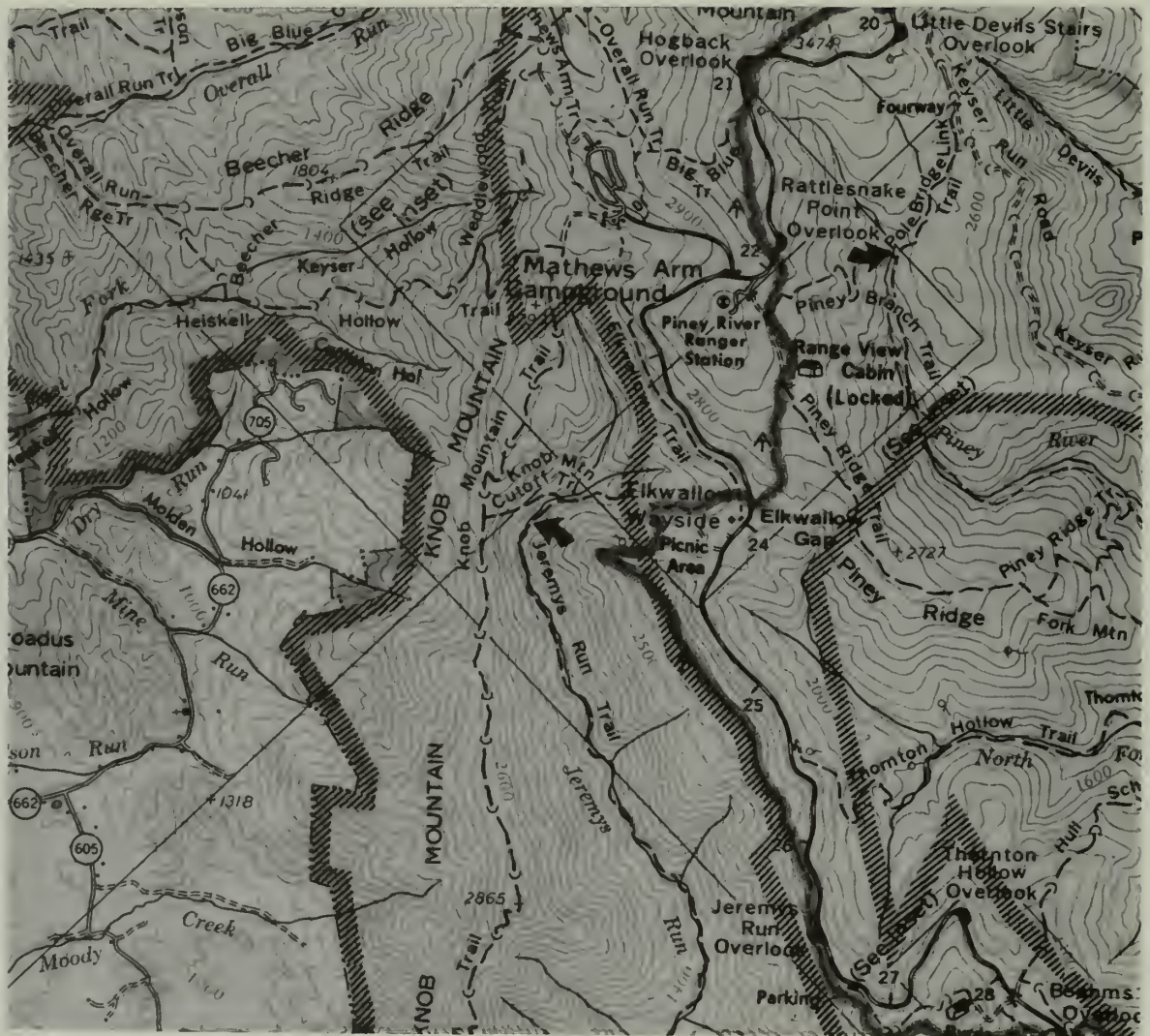
Location of Markers:

On left descending bank; top marker 20 m from stream edge, across trail, near 20-cm ash; bottom marker 20 m from stream edge, across trail and old rock wall, in line with upstream edge of trail/stream crossing.

Elevation: 353.6 m (1160 ft)

UTM: 737750E, 4286950N

Stream Site 1L313: Jeremys Run - Upper (Bottom Arrow)



Directions (PATC Map, Northern District):

Take Jeremys Run Trail off Skyline Drive at Elkwallow Picnic Area to first trail/stream crossing; also SNP Trout Section #2.

Location of Markers:

On left descending bank; top marker 10 m from stream edge, near 30-cm red oak; bottom marker 7 m from stream edge, in line with downstream edge of trail/stream crossing.

Elevation: 548.6 m (1800 ft)

UTM: 732550E, 4292100N

Stream Site 1L307: Lands Run - Upper



Directions (PATC Map, Northern District):

Take Lands Run Gap Road off Skyline Drive to road/stream crossing.

Location of Markers:

On right descending bank; top marker 10 m from stream edge, near 13-cm maple; bottom marker 10 m from stream edge, near 36-cm maple, approximately 5 m upstream of crossing.

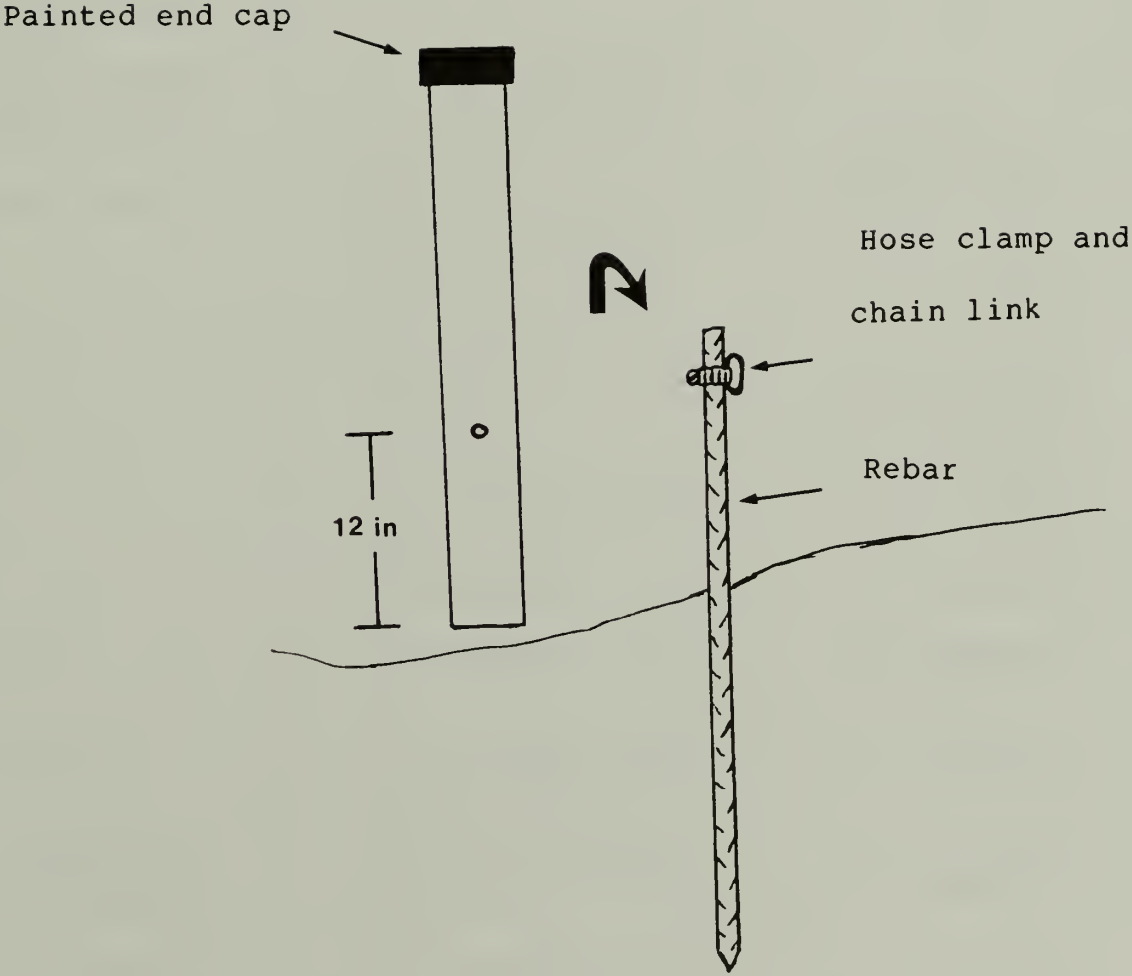
Elevation: 518.2 m (1700 ft)

UTM: 744050E, 4301200N

APPENDIX III.B

EQUIPMENT, BIOLOGICAL SAMPLING

Stream Site Marker



Equipment List

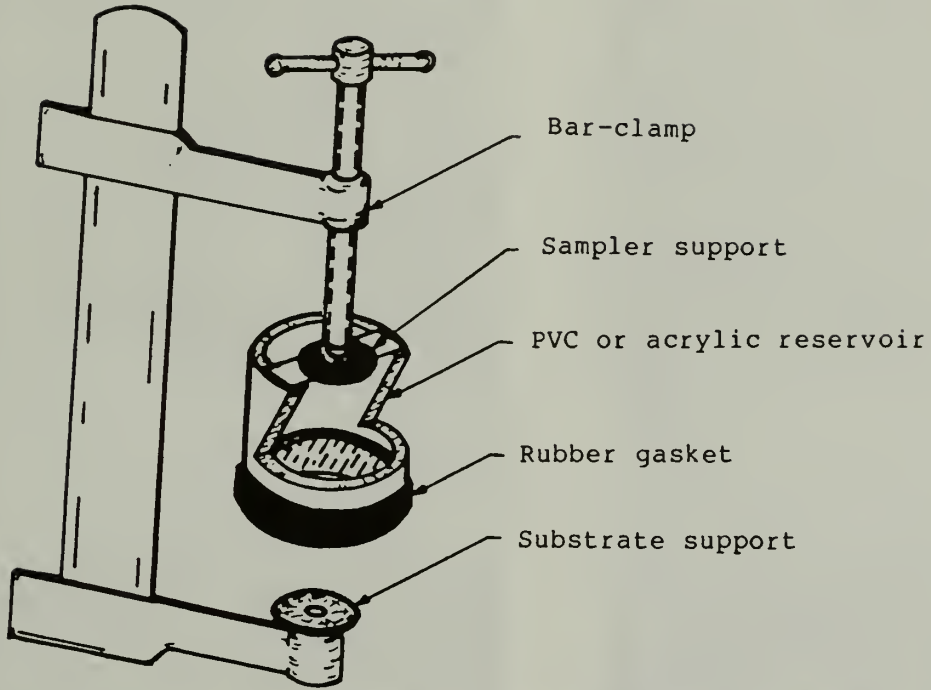
The following is a list of equipment needed for the field and some of the laboratory procedures in the aquatic component of the LTEMs. The list is reasonably complete except for the items needed to do the routine chemical analyses in the laboratory. Those common laboratory items are listed in accepted methods manuals (American Public Health Association et al. 1981, U.S. Environmental Protection Agency 1983). A source of supply is listed, but it should be noted that there are additional sources for most items.

PARAMETER	EQUIPMENT	VENDOR
Discharge	Mini-current meter (electronic or mechanical)	Marsh-McBirney Inc. 8595 Grovemont Circle Gaithersburg, MD 20877
		Scientific Instruments 518 West Cherry St. Milwaukee, WI 53212
Depth	Top setting metric wading rod, tag line, stopwatch	Forestry Suppliers 205 West Rankin St. Jackson, MS 39204
		Forestry suppliers
Width	Tag line, wading rod, 100-m tape	
Riparian vegetation cover, type	Tag line, 100-m tape	
Debris retention	Tag line, 100-m tape	
Fish cover	Tag line, 100-m tape	
Pool-Riffle	Tag line, 100-m tape	
Substratum	Tag line, cobblestick, 100-m tape	
Water temperature	YSI Model 33 meter, long-stem thermometer	American Scientific 8855 McGaw Rd. Columbia, MD 21045
Dissolved oxygen	YSI Model 58 meter,	Fisher Scientific, P.O. Box 40339 Raleigh, NC 27629
	Hach kit	Hach Company P.O. Box 389 Loveland, CO 80539

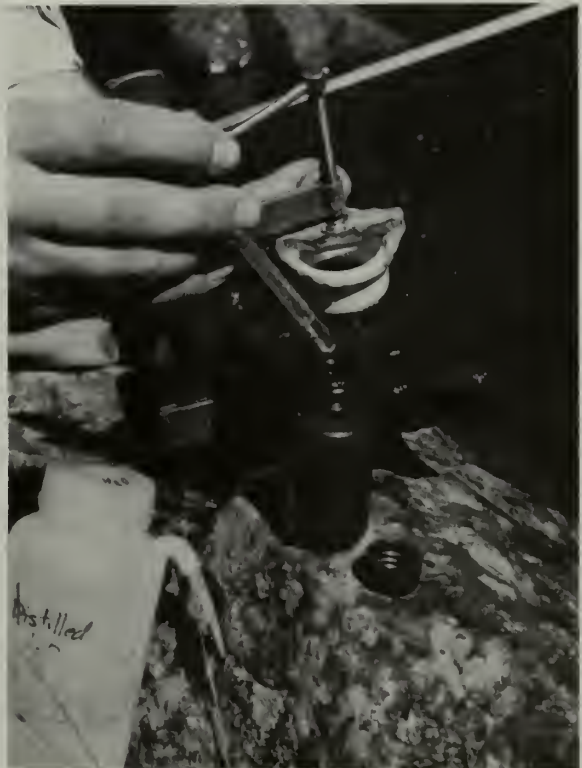
Conductivity	YSI model 33 meter	Fisher Scientific
pH	Fisher Accumet 640 meter with calomel reference electrode and universal electrode (or equivalent), electrode storage solution	Fisher Scientific
Alkalinity, conductivity, pH, nitrate, sulfate, calcium, magnesium, chloride, sodium, potassium, silica	1-L dark plastic collection bottle	Fisher Scientific
Seston	1-L collection bottle, vacuum pump, filter funnel (47mm), filter flask, vacuum hose, glass fiber filters (47mm), aluminum pans, filter forceps, filter flask (2 L), graduated cylinder (1 L), muffle/ashing furnace, convection drying oven, electronic analytical balance (0.00001g)	Fisher Scientific GELMAN filtering products
Bacteria	1-L autoclavable plastic bottles	Fisher Scientific
Periphyton (chlorophyll a)	Bar-clamp sampler (fabricated), acid etching brush, wash bottle, eye dropper, 60-ml dark plastic bottles, filtering equipment (see seston), hydrochloric acid, aqueous acetone, magnesium carbonate, whirl-pak bags, tissue grinder,	Hardware Store Fisher Scientific

	grinding chamber and bit, 12-ml graduated centrifuge tubes, centrifuge, pipets, cuvets, spectrophotometer	Perkin-Elmer 2000 York Rd. Oak Brook, IL 60521
Macro- invertebrates	D-frame kick net, aerial net	BioQuip 1320 E. Franklin Ave El Segundo, CA 90245
	Surber sampler (350 um net)	Wildco 301 Cass St Saginaw, MI 48602
	Portable invertebrate box sampler (PIBS) (350 um net)	Ellis-Rutter P.O. Box 401 Punta Gorda, FL 33950
	2.5-L plastic containers with lids	Genpak Corp. Box 727 Glens Falls, NY 12801
	4-dram vials, 2-oz jars, formaldehyde (opt.), ethanol, forceps	Fisher Scientific
	Vegetable brush Hand rake	Hardware store
	Dymo labeler	Office supply store
Miscellaneous	Hip waders, 2 backpacks	Outdoor recreation supplier

Periphyton Sampling
Bar-Clamp Sampler



Brushing



Removing

Quantitative Benthic Sampling



PIBS



PIBS



PIBS



PIBS



Surber



Surber

Qualitative Benthic Sampling



Leaf Pack



Rock Outcrop



Roots



Overhanging Vegetation

Aerial Sampling



APPENDIX III.C

RECORDS, MEASUREMENTS, ANALYSES, CALCULATIONS

FIELD RECORDS

SITE _____ DATE _____

TAKEN BY _____

H₂O TEMP. _____ °C pH _____

D.O. _____ mg/L (___ Meter or ___ Hach) COND. _____ μmhos

Bottle #'s _____

SESTON _____

CHEM. _____

BACT. _____

PERIPH. _____

MACROINVERTEBRATE (Samples Collected)

BENTHIC - Quan: _____ PIBS or _____ SURBER

BENTHIC - Qual: _____

AERIAL - Qual: _____

NOTES: _____

DISCHARGE MEASUREMENT

SITE _____ DATE _____

TAKEN BY _____

WIDTH _____ METHOD _____

Dist. from initial pt.	width	depth	rev.	sec.	vel.		Discharge
					m/s	f/s	
Total							

HABITAT MEASUREMENTS SITE _____ DATE _____

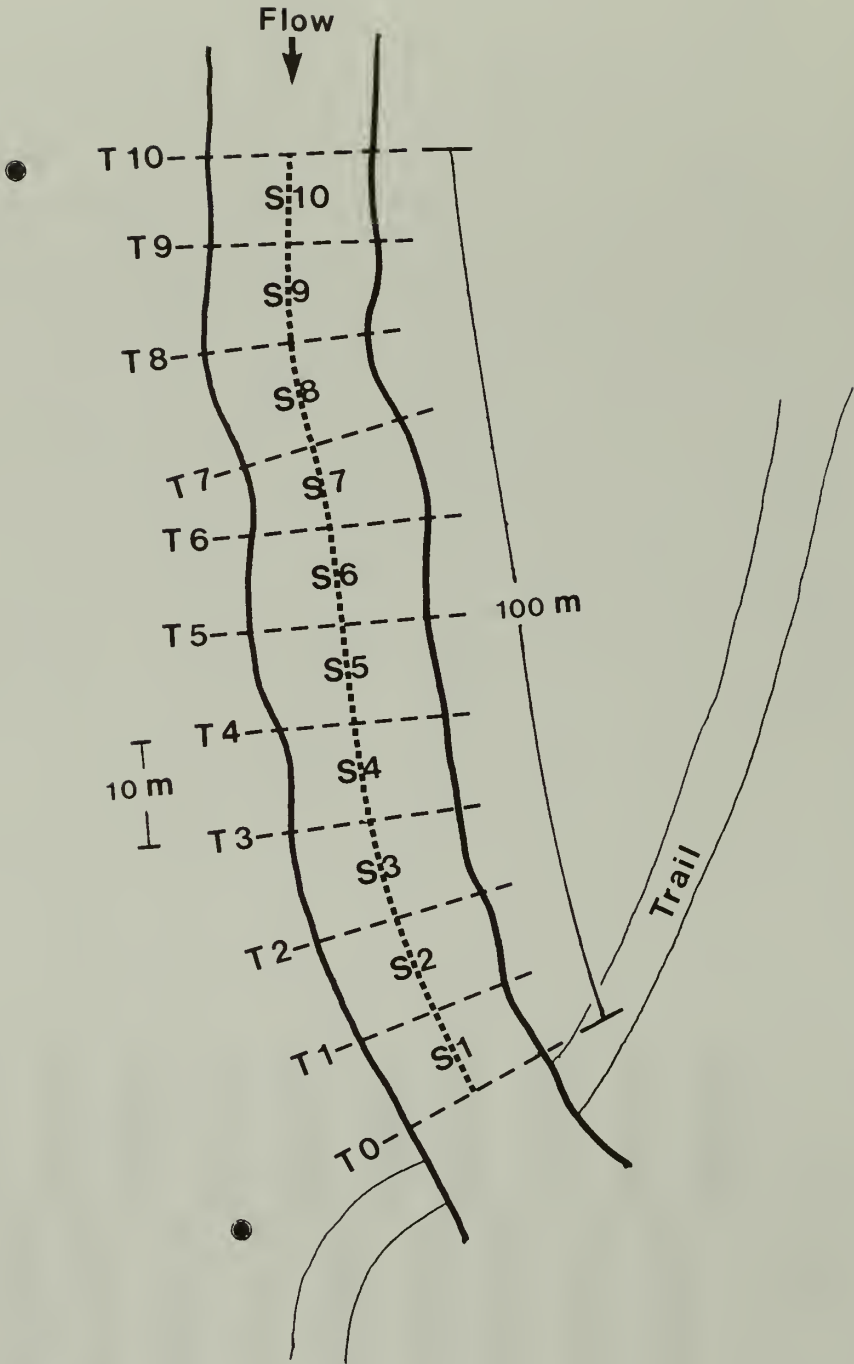
TAKEN BY _____

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
T0																												
S1																												
T1																												
S2																												
T2																												
S3																												
T3																												
S4																												
T4																												
S5																												
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S6																												
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S7																												
T7																												
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T9																												
S10																												
T10																												

Notes: _____

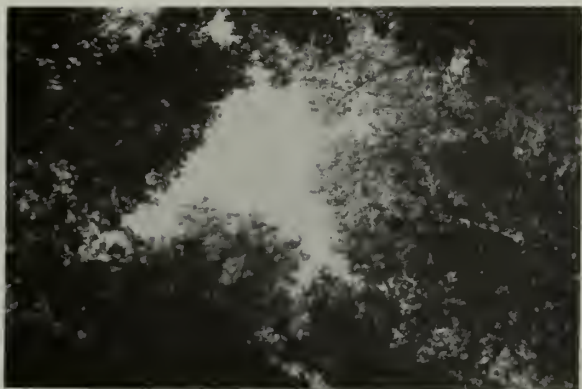
flow
 ↓ ↑

Representative Stream Site



Transects (T0 - T10) and segments (S1 - S10) are used for making habitat measurements.

Categories for Riparian Vegetation Cover



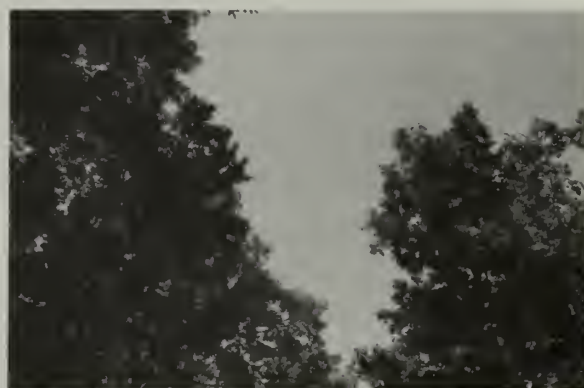
3 = 67-100% covered



3 = 67-100% covered



2 = 34-66% covered



2 = 34-66% covered

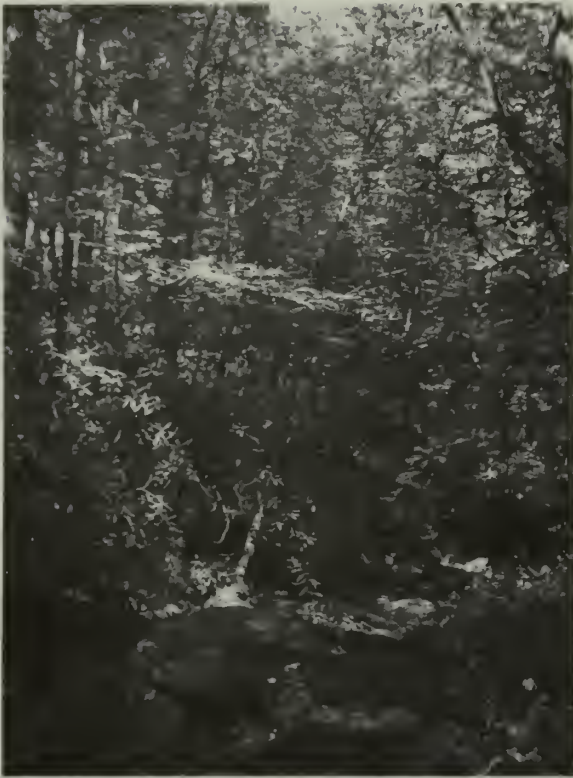


1 = 0-33% covered



1 = 0-33% covered

Categories for Riparian Vegetation Type



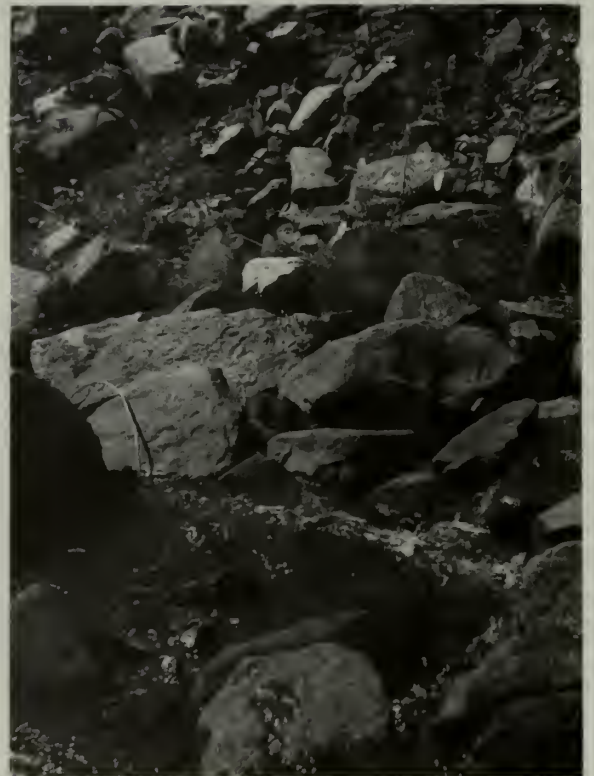
T = Trees



S = Shrubs



GF = Grasses and Forbs

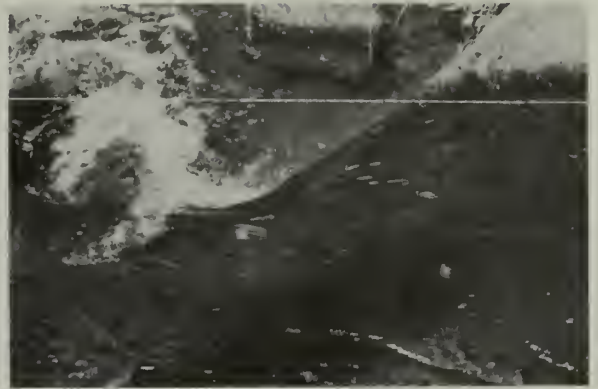


N = None

Categories for Substratum



BR = Bedrock



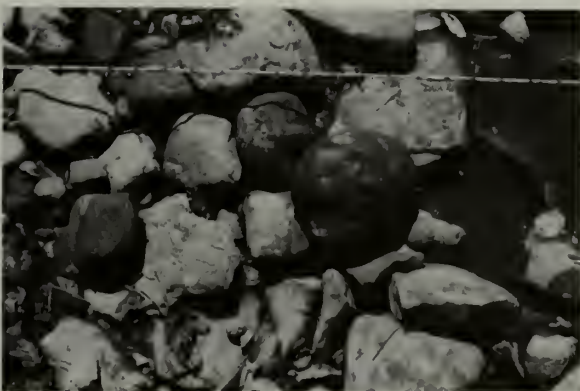
BR = Bedrock



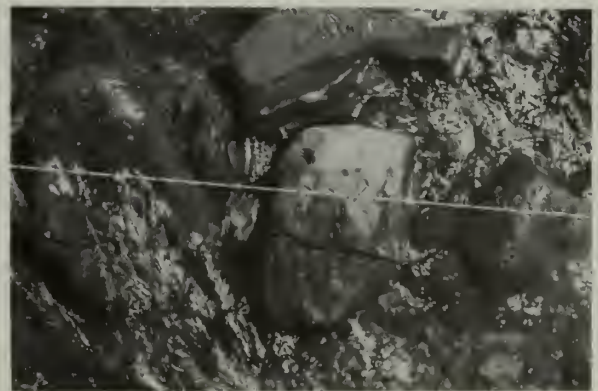
B = Boulder



B = Boulder



C = Cobble



C = Cobble



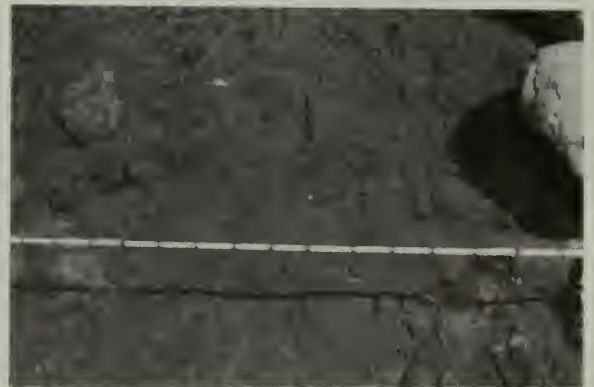
PG = Pebble/Gravel



PG = Pebble/Gravel



S = Sand



S = Sand

Categories for Debris Retention
(Persons or arrows delimit 10-m segments)



3 = Abundant



3 = Abundant



2 = Intermediate



2 = Intermediate



1 = None



1 = None

Categories for Fish Cover
(Arrows indicate structures providing cover)



3 = Abundant



3 = Abundant



2 = Intermediate



2 = Intermediate



1 = Exposed



1 = Exposed

Examples of Pool-Riffle Ratios
(Persons or arrows delimit 10-m segments)



0 : 10



2 : 8



5 : 5



6 : 4



9 : 1



10 : 0

WATER QUALITY SUMMARY

SITE _____

DATE _____

COMPILED BY _____

FIELD MEASUREMENTS:

H₂O Temp. _____ °C

pH _____

Conductivity _____ μmhos

D.O. _____ mg/L

DISCHARGE CALCULATION: _____ m³/s X 35.315 = _____ ft³/s

SESTON ANALYSES:

Filter#	Total mg/L	Organic mg/L	Inorganic mg/L	O/I
_____	_____	_____	_____	_____

CHEMICAL ANALYSES:

pH _____ Alk. _____ mg/L Alk. _____ μeq/L Cond. _____ μmhos

SO₄ _____ mg/L NO₃ _____ mg/L Cl _____ mg/L SiO₂ _____ mg/L

Ca _____ mg/L Mg _____ mg/L K _____ mg/L Na _____ mg/L

HABITAT MEASUREMENTS SUMMARY

SITE _____ DATE _____

CALCULATED BY _____

DEPTH _____ cm

WIDTH _____ m

RIPARIAN VEGETATION COVER _____

RIPARIAN VEGETATION TYPE:

T _____% S _____% GF _____% N _____%

DEBRIS RETENTION _____

FISH COVER _____

POOL - RIFFLE:

RATIO _____ : _____ (P:R)

SUBSTRATUM:

BR _____% B _____% C _____% PG _____% S _____%

BACTERIA AND PERIPHYTON WORKSHEET

SITE _____ DATE _____

ANALYZED BY _____

BACTERIA ANALYSES:

Fec. St. _____ MPN/100mL T. Coli. _____ MPN/100mL F. coli. _____ MPN/100mL

PERIPHYTON ANALYSES:

Chlorophyll a:

Correction Factors for Calibration 750nm _____ 663nm _____

Rep/tube #s	mL in extraction	750nm	663nm	750nm	665nm	$\mu\text{g}/\text{cm}^2$
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____
_____	_____	_____	_____	_____	_____	_____

Mean chl a _____ $\mu\text{g}/\text{cm}^2$

Total Biomass:

Filt. #	Area Sampled (cm^2)	Tare Wt. (μg)	Dry Wt. (μg)	Ash Wt. (μg)	AFDW (μg)
_____	_____	_____	_____	_____	_____

Autotrophic Index:

A.I. = _____ AFDW $\mu\text{g}/\text{cm}^2$ / _____ mean chl a $\mu\text{g}/\text{cm}^2$ = _____

FIELD EQUIPMENT CHECKLIST

- Data sheets/clipboard
- Pencils
- 100-m tape
- Hammer
- Stake (for securing 100-m tape)
- Surveyor's pins
- PIBS and/or Surber
- D-frame net
- Vegetable brush
- Hand rake
- Forceps
- Plastic bags (8 per site)
- Labels for benthic samples
- Ethyl alcohol
- Flow meter
- Top setting metric wading rod
- Dissolved oxygen meter
- Tag line
- Thermometer
- Hip boots
- Cobblestick
-
-
-
-
-

**SHENANDOAH NATIONAL PARK
LONG-TERM ECOLOGICAL MONITORING SYSTEM**

SECTION IV

GYPSY MOTH COMPONENT USER MANUAL

**NPS/NRSHEN/NRTR-90/02
1st Edition: September 1990**

by

F. William Ravlin, Shelby J. Fleischer, and Susan L. Rutherford

**Department of Entomology
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061**

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Appendices

Gypsy Moth Population Sampling Methods	A.1
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The purpose of this manual is to describe field techniques that can be used to acquire data for monitoring and managing the gypsy moth in a national park setting. Because the spatial and temporal dynamics of gypsy moth populations change with the different phases of a gypsy moth infestation, different management and monitoring approaches are required.

Several methods have been developed for sampling the different life-stages of the gypsy moth. Each method has its pros and cons and may or may not be appropriate for a particular management situation. For example, the use of pheromone-baited traps for monitoring male moths works well for detection of populations in newly infested areas and for delimiting egg mass surveys as populations begin their initial increase. However, once defoliation occurs over large areas, pheromone-baited traps are only useful for detecting population change over large areas. Conversely, egg mass surveys are effective for quantifying populations when they are at moderate to high levels but are not useful over large areas or when populations are at very low levels. Appendix IV.A. compares the different gypsy moth sampling tools on the basis of parameters that are of interest to natural resource managers.

No single sampling technique will provide all of the information required to monitor or manage the gypsy moth under different population phases or monitoring and management objectives. Several methods must be combined to achieve the desired results.

This manual addresses:

- the sequence of monitoring and management activities that coincide with different infestation phases.
- how gypsy moth populations can be quantified within the context of the Shenandoah National Park's Long-term Ecological Monitoring System (LTEMs), and
- how treatment decisions can be supported through the use of population estimates, landscape characteristics, and program characteristics.

FROM ERADICATION TO MONITORING AND MANAGEMENT

Detection/Eradication Programs

Because the gypsy moth is still new to most national parks, detection and eradication of new infestations are major concerns. As mentioned above,

pheromone-baited traps are useful in detecting and spatially delimiting new infestations. These first detections often result in eradication programs conducted through the cooperative efforts of state and federal agencies. The sequence of activities that is frequently followed is described in Figure IV.1.

Detection/eradication activities include the use of "delta-type" pheromone-baited traps placed at regular intervals over large areas. For example, traps have been placed over one-third to one-half of the state of Virginia at 3 km intervals for several years. Upon detecting one or more male moths, a "delimitation survey" is initiated to determine: if moths can be detected at the same location during a second year, the spatial extent of male moths, and through intensive searches of the area(s) of interest, if eggs, larvae, pupae, or female adults are present. If any of these situations occurs then eradication efforts may be implemented throughout the area and another delimitation survey deployed to determine the success or failure of the program. If no moths or other life-stages are found then the 3 km detection survey is once again used. If eradication efforts are not successful then a decision must be made concerning continuing eradication efforts or the need to develop long-term monitoring and management plans for gypsy moth infested areas. Shenandoah National Park (SNP) has moved from the detection/eradication mode to a monitoring/management plan which was developed by SNP resource management specialists and updated yearly.

Monitoring and Management Programs

Once the decision is made to monitor or manage gypsy moth populations, developing plans and implementing programs is the responsibility of the national park. Essentially, the decision has been made to consider the gypsy moth as a natural part of the many ecosystems that make up the SNP or any other large land area. Decisions must then be made concerning what areas will:

- be monitored to provide information about the gypsy moth and its impacts on other components of the ecosystem for use in the LTEMs,
- be considered as management areas, or
- not be monitored at all.

Population estimates for following the dynamics of gypsy moth populations and their impact on ecosystems can be measured from egg mass densities and defoliation. Similarly, the basis for control decisions in gypsy moth management programs is the

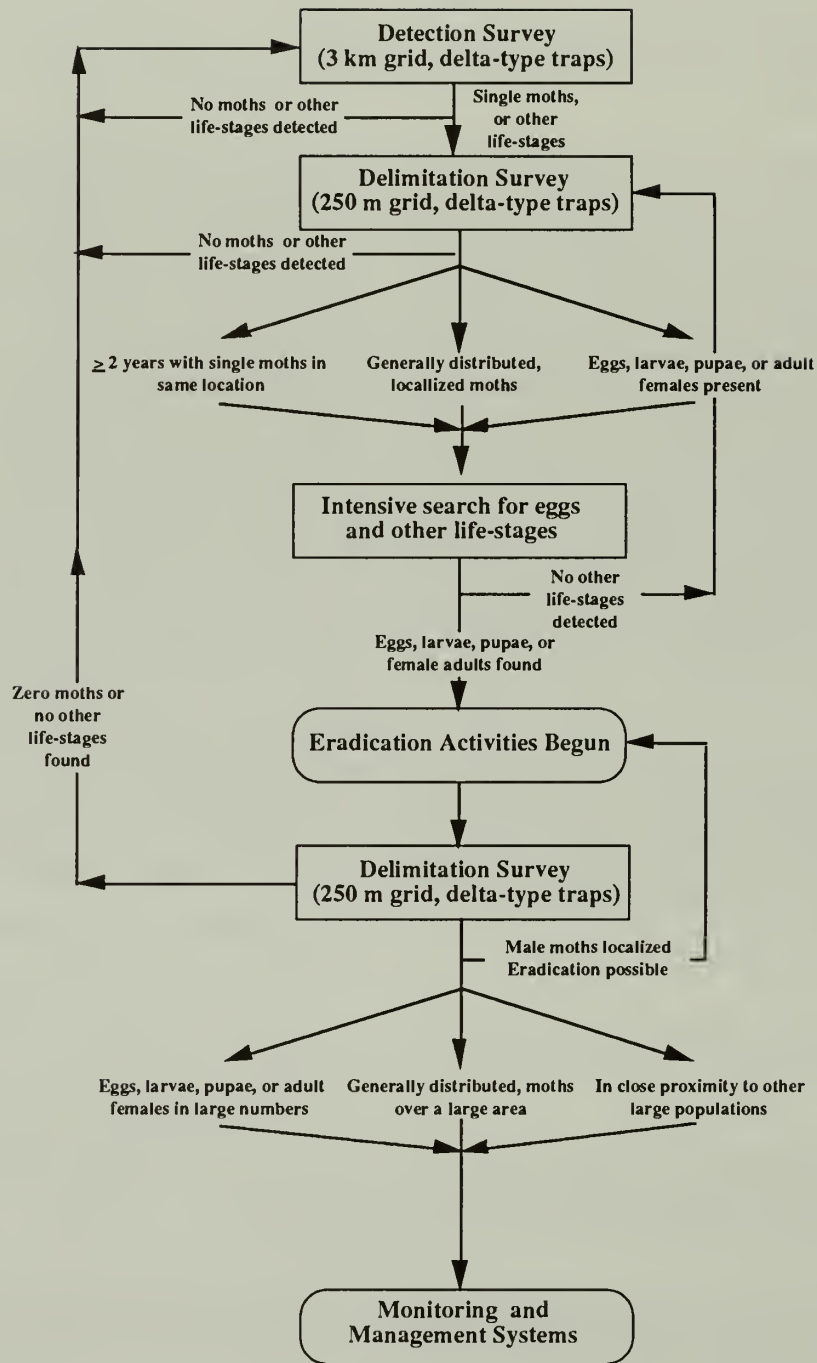


Figure IV.1. Sequence of activities and decisions in gypsy moth detection/eradication programs.

relationship between egg mass density and defoliation (Fig. IV.2).

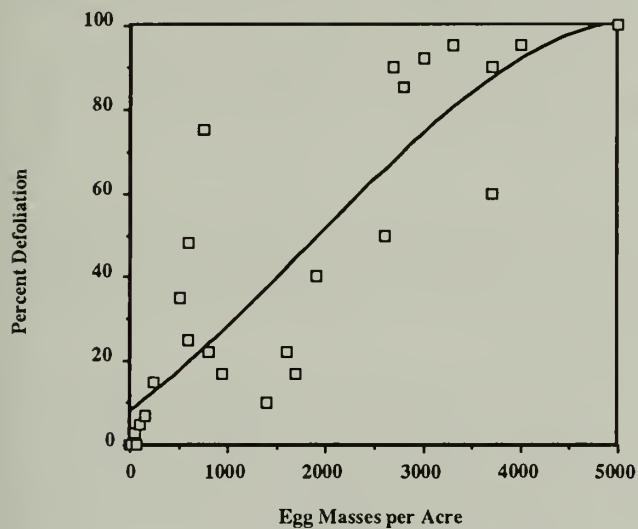


Figure IV.2. Egg mass/Defoliation relationship.

However, monitoring systems for determining impact and supporting management are not the same. When monitoring populations for ecological impact, emphasis should be placed not only on the gypsy moth but on the many system variables that are affected by defoliation (i.e., those measured by the Forest and Aquatic components of LTEMs). When management is the primary consideration, emphasis should be placed on projecting the level and spatial extent of defoliation that will occur in the subsequent growing season. Once this has been accomplished, plans can be made to prevent unacceptable levels of defoliation in visitor areas, parkways, and campgrounds. Gypsy moth monitoring systems must be designed to be compatible with the objectives of different land areas and the LTEMs in place in the SNP.

MONITORING THE GYPSY MOTH IN A LONG-TERM ECOLOGICAL MONITORING SYSTEM

Designing a monitoring system for gypsy moth populations and their impacts on the SNP's natural resources is dependent on the objectives of the program and available resources. Tree defoliation is the direct impact of gypsy moth feeding. Thus, measuring the spatial extent and levels of defoliation are the main variables of interest within the context of long-term ecological monitoring. Defoliation is a function of larval populations and the amount of foliage available for larvae to feed upon at a given location. Through larval feeding, frass is produced and uneaten bits of leaf material fall to the ground. This results in changes in the availability of nutrients to the various components of

ecosystems (Mattson and Addy 1975). Gypsy moth population dynamics is also important from the standpoint of demonstrating the relationship between the insect and the forest. Tree defoliation and mortality, changes in tree species composition, species changes in understory trees and herbs, and the distribution and abundance of birds and other wildlife are all possible results of gypsy moth population changes through time.

To obtain estimates of tree defoliation and gypsy moth population size the gypsy moth population monitoring system for LTEMs is composed of 4 components:

- aerial-based park-wide defoliation data,
- ground-based defoliation estimates associated with each LTEMs site,
- gypsy moth egg mass population density estimates also associated with each LTEMs site, and
- pheromone traps used to determine when to begin taking defoliation and egg mass samples.

When used together these components can provide both an intensive and extensive picture of gypsy moth populations and their impact on SNP natural resources. Over several years, they can also provide information concerning the dynamics of the gypsy moth in the SNP. All four monitoring system components should be implemented; however they can also be used individually in the event that resources or priorities change.

Defoliation Estimates

Aerial-based Park-wide Defoliation Data

The minimum level of gypsy moth monitoring includes determining the percent and spatial extent of tree defoliation over large areas using aerial photography, sketch mapping, or other methods of remote sensing. In areas where the gypsy moth is established, photographs or sketch maps are often taken as a standard part of national park resource management programs or state level gypsy moth suppression programs. Aerial photographs and sketch maps have the advantages of covering large areas, being relatively inexpensive and are able to capture the spatial extent of defoliation. Defoliation levels can also be grossly categorized (e.g., low, medium, high) and digitized to be compatible with computer programs to produce defoliation maps (e.g., Fig. IV.3). However, accuracy in determining the level and location of defoliation cannot

be guaranteed. Because LTEMs sites are small relative to defoliated areas, human error in sketching the extent of defoliation and interpreting the photographs or photograph resolution can include or exclude LTEMs sites.



Figure IV.3. Map showing the distribution of tree defoliation caused by gypsy moth feeding in the Northern District of the SNP in 1987.

Ground-based Defoliation Estimates

To obtain accurate estimates of the percent defoliation that LTEMs sites experience and have the ability to relate those estimates to LTEMs variables, ground-based defoliation estimates should be taken directly at LTEMs sites and used together with aerial-based estimates.

- Three ground-based defoliation estimates should be taken at each LTEMs site (one per plot).
- Estimates should be made at each plot center and consist of visual inspection of the overstory canopy soon after defoliation episodes.

It is critical that ground-based defoliation estimates be taken to coincide with peak defoliation. Peak defoliation can occur any time between June 15 and July 15 depending on weather patterns and elevation. Another factor that affects when defoliation estimates should be taken is refoliation. If trees are 60% or more

defoliated then there is a high probability that new leaves will be produced (refoliation) within the next two weeks. Defoliation estimates should be made within this two-week period. If trees are defoliated less than 60% refoliation may not occur and gypsy moth damage will be apparent for the remainder of the growing season.

Timing Defoliation Estimates. Burlap bands wrapped around tree boles can be used to time ground-based defoliation estimates. Three bands should be placed at locations associated with LTEMs sites such that they are:

- similar in elevation and anticipated population level as LTEMs sites scheduled for sampling,
- no closer than 500 meters to possible control activities (e.g., visitor areas),
- easily accessible by SNP personnel (e.g., near fire roads),
- placed on oaks with a diameter at breast height of at least 30 cm,
- in place by June 1, and
- inspected weekly after their initial placement.

Defoliation estimates should begin one week after the first appearance of pupae under the bands.

Defoliation Ratings and Plot Layout. Because it is difficult and time-consuming to measure exact percentages of defoliation, categories or ratings have been developed to be used for ground-based defoliation estimates. Defoliation ratings should be taken from each LTEMs plot center (Fig. IV.4). The entire plot should be visually scanned and defoliation estimates should be based on the criteria presented in Figure IV.4.

When estimating defoliation be sure to include the entire plot in the determination and pay careful attention to relative amount of pieces and whole leaves missing. Defoliation estimates together with Site, Plot, and Date data should then be recorded on data sheets (Fig. IV.6).

Combining Aerial- and Ground-based Defoliation Estimates with Other LTEMs Variables

Ultimately resource managers will want to combine aerial- and ground-based defoliation data with several variables collected in the LTEMs. This can be done by formatting the digitized aerial-based defoliation estimates to be compatible with the LTEMs database

<u>Rating</u>	<u>Percent Defoliation</u>	<u>Criteria</u>
1	0 - 25%	Defoliation not generally noticeable, if present <i>few holes in leaves</i> . <i>All leaves present</i> .
2	26 - 50%	<i>Many holes in leaves and large pieces of leaves missing</i> . Often some whole leaves missing.
3	51 - 75%	<i>Many leaves missing</i> . Remaining leaves with large holes and missing large pieces.
4	76 - 100%	<i>Majority to all leaves missing</i> . Remaining leaves with large pieces missing.

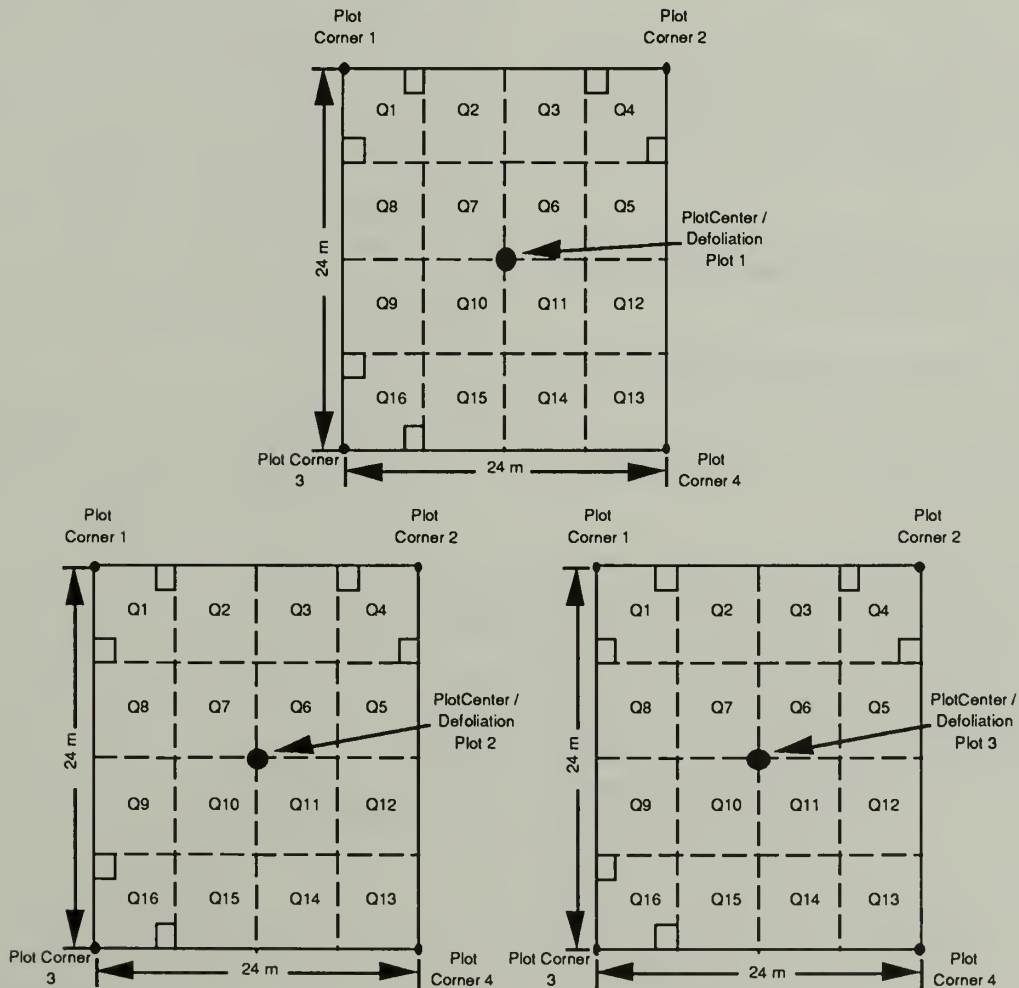


Figure IV.4. Defoliation plot layout within terrestrial LTEM plots. Q1 - Q16 are tree and shrub plots within the Terrestrial component of LTEM

and displaying the defoliated areas along with selected LTEMs variables using a geographic information system (GIS). A GIS is an integrated collection of computer programs designed to automate the collection, storage, retrieval, analysis, and presentation of geographically referenced data. Examples of GISs are Arc/Info®, GRASS, and MOSS®. Other analyses can also be performed once the data have been entered into the LTEMs data base. Percent defoliation can be related statistically to species composition or species-specific mortality rates for each plot, site, or groups of sites found at different elevations. It is these analyses that can provide quantitative support to statements concerning the impact of gypsy moth on the SNP's ecosystems and adjoining areas.

Sampling Egg Masses for the LTEMs

Plot Layout and Sample Method

Egg mass surveys give a quantitative assessment of gypsy moth populations for each LTEMs site and plot, can be used to track population densities through time, and project defoliation for the coming season (e.g., Fig. IV.2)

- Egg mass surveys can be done any time after leaf fall until mid-April when eggs have the potential to begin hatching.
- Each LTEMs plot should be sampled with three samples per plot or nine per site.
- Only quadrates Q7, Q11, and Q13 should be sampled (Fig. IV.5).

Quadrates Q7, Q11, and Q13 were chosen so that walking through regeneration plots will be avoided and egg mass sample plots (egg plot) can be easily located. All objects within each egg plot must be searched for egg masses. This includes trees, shrubs, logs, and rocks. Trees are considered to be within an egg plot if at least one half of the base of the tree lies within the plot boundary. Upper parts of trees should be searched with binoculars. Trees should be searched from three sides to ensure an accurate count. Logs and other debris on the ground should be turned over and examined closely for egg masses. A stout stick is often useful in this ground search to save wear and tear on your hands and back. The date, location, and number of new egg masses for each egg mass plot is then recorded on the Gypsy Moth Egg Mass data sheets (Fig. IV.7).

New Versus Old Egg Masses

Only new egg masses (those laid during the current year) should be counted. New egg masses are firm to the touch, while old egg masses (those laid during previous years) will readily collapse under pressure. Differentiating between old and new egg masses that are out of reach can be very subjective. Old egg masses may be lighter in color due to exposure to sunlight and rain and rougher in appearance or partially destroyed. Practicing differentiating old from new egg masses near ground level, where one's accuracy can be confirmed is recommended.

Use of Pheromone-baited Traps to Time LTEMs Samples

It will not always be necessary to monitor LTEMs sites for defoliation and egg masses although yearly monitoring of egg mass populations will produce the best long-term picture of gypsy moth population dynamics. Determining what years to monitor and what years not to monitor cannot be done without a continuous monitoring of populations in general. This monitoring can be accomplished through the use of pheromone-baited traps placed at LTEMs sites. Pheromone-baited traps will provide a measure of large-scale changes that gypsy moth populations are undergoing and a means to schedule defoliation and egg mass samples for the following field season.

- Defoliation and egg mass samples should begin the following season at sites where moth catches have increased for two consecutive years or when other indications such as visible defoliation are observed.

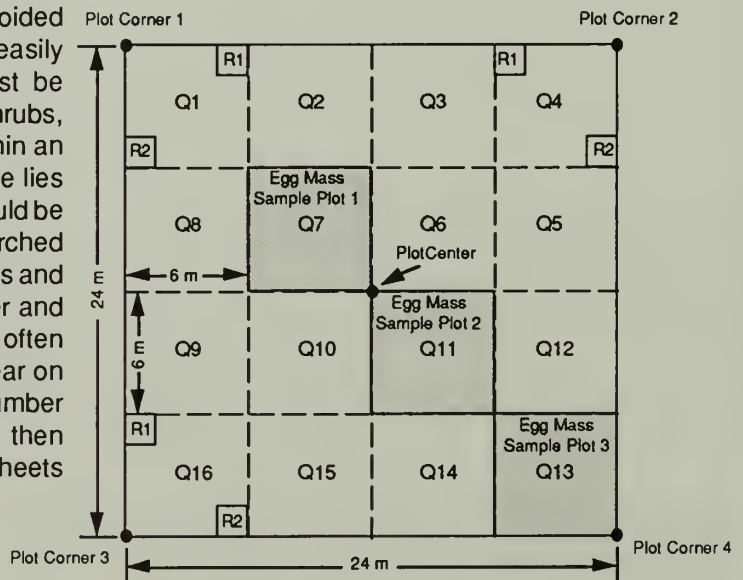


Figure IV.5. Egg mass sample plot layout.

Shenandoah National Park
Long-Term Ecological Monitoring System

Gypsy Moth Defoliation Data

SITE _____	DATE _____
PLOT _____	DEFOLIATION RATING _____
PLOT _____	DEFOLIATION RATING _____
PLOT _____	DEFOLIATION RATING _____
SITE _____	DATE _____
PLOT _____	DEFOLIATION RATING _____
PLOT _____	DEFOLIATION RATING _____
PLOT _____	DEFOLIATION RATING _____
SITE _____	DATE _____
PLOT _____	DEFOLIATION RATING _____
PLOT _____	DEFOLIATION RATING _____
PLOT _____	DEFOLIATION RATING _____
SITE _____	DATE _____
PLOT _____	DEFOLIATION RATING _____
PLOT _____	DEFOLIATION RATING _____
PLOT _____	DEFOLIATION RATING _____

Defoliation Ratings

1 = 0-25%, 2 = 26-50%, 3 = 51-75%, 4 = 76-100% Defoliation

Figure. IV.6. Gypsy moth defoliation data sheet.

**Shenandoah National Park
Long-Term Ecological Monitoring System**

Gypsy Moth Egg Mass Data

SITE _____	DATE _____	
PLOT _____		
EGGPLOT 1 _____	EGGPLOT 2 _____	EGGPLOT 3 _____
PLOT _____		
EGGPLOT 1 _____	EGGPLOT 2 _____	EGGPLOT 3 _____
PLOT _____		
EGGPLOT 1 _____	EGGPLOT 2 _____	EGGPLOT 3 _____
SITE _____	DATE _____	
PLOT _____		
EGGPLOT 1 _____	EGGPLOT 2 _____	EGGPLOT 3 _____
PLOT _____		
EGGPLOT 1 _____	EGGPLOT 2 _____	EGGPLOT 3 _____
PLOT _____		
EGGPLOT 1 _____	EGGPLOT 2 _____	EGGPLOT 3 _____
SITE _____	DATE _____	
PLOT _____		
EGGPLOT 1 _____	EGGPLOT 2 _____	EGGPLOT 3 _____
PLOT _____		
EGGPLOT 1 _____	EGGPLOT 2 _____	EGGPLOT 3 _____
PLOT _____		
EGGPLOT 1 _____	EGGPLOT 2 _____	EGGPLOT 3 _____

Figure. IV.7. Gypsy moth egg mass data sheet.

Pheromone-baited traps will be necessary only if they are not used in a gypsy moth management program as described in this manual. *NOTE:* Pheromone-baited traps will not be useful to measure large-scale changes in gypsy moth populations during the early phases of an infestation because moths will not be universally prevalent. In these situations a continuous grid of traps over large areas will provide data on the location and relative density of gypsy moth populations and can be used to monitor changes in populations on a small spatial scale (e.g., within a 1 km²).

Trapping Protocol

Pheromone-baited traps are designed to attract and capture male moths using a synthetic pheromone that mimics the sex attractant of female gypsy moths. Field personnel must take care in handling, assembling, installing, and servicing traps if the data are to be meaningful. The assembly of traps is discussed and diagrammed in Appendix IV.D.

When you reach an LTEMs site, install the trap onto any tree. Hang the trap 4 to 5 feet off the ground. Use the north side of the tree. Use flagging to mark your way to the trap site.

To install the trap, first install a hanger made from a wire clothes hanger to the tree. See Appendix IV.B for instructions on making the hanger.

To install the trap onto the hanger, slide the hole in the spout of the milk carton trap onto the loop. The trap should be suspended by the hanger, with the hood of the trap approximately 1 to 2 inches away from the tree (the distance from the trap to the tree can affect the trap catch). Make sure the hanger is firmly stapled to the tree, using 6 or more staples (don't be shy). If it is not, the hanger will rotate, and the trap can become damaged by banging against the tree.

Trap Service

Pheromone traps must be installed prior to the time adults moths start to fly.

- Traps should be installed by June 15.

If possible, traps should be serviced twice during each field season. However, it is only the final moth count that will be used in making LTEMs monitoring decisions.

- The first service should be at midseason (approximately the middle of July). This service visit insures that traps are still in place, allows personnel to be sure that trap locations can be found, and

allows personnel to replace damaged traps.

- The second service visit should be at the end of the moth flight season (about late August to early September).

Count the number of moths captured at each service visit. Repeatedly emptying of the trap will affect the total catch at the end of the season. You should not empty the trap more than once during the season, and once at the end of the moth flight season (i.e., twice for the whole season).

After counting the moths they should be transferred to a plastic bag, carried away from the site, and disposed of. The dead moths should not be dumped near the site of the trap, as they may affect the subsequent catch of the trap. Field personnel may wish to count the moths at the site as they transfer them to a plastic bag or, if the quantity is high, count them later. All plastic bags containing moths must be labelled with the site number using indelible magic marker prior to leaving the site. The supervisor has the right to ask for the bags with the moths. If the supervisor does not want the moths, dispose of them in an appropriate trash container (any trash can that can handle organic wastes will work).

Sentinel Traps

Sentinel traps are pheromone traps that are serviced weekly towards the end of the male moth flight season (after July 24). Data from sentinel traps can be used to estimate the time that moths stop flying in a given geographical area.

Placement. Distribute sentinel traps so that they are placed in habitats and elevations that are similar to the established LTEMs sites. Since these traps will need to be serviced more frequently, sentinel traps should be in a location that is convenient to access. Sentinel traps do not have to be part of the LTEMs site samples. They can be additional traps located more conveniently as long as they are at least 500 meters from potential control activities. Remember that the end of moth flight in these sentinel traps will be used to estimate the end of moth flight in the LTEMs traps throughout the entire quad.

Determining the End of the Flight Season. There are two protocols for using the sentinel traps to determine when the moth flight season has ended. The first protocol is designed to directly measure the end of moth flight. The second protocol is designed to indicate when approximately 99% of the moth catch has already occurred, but allows for traps to be closed out even though a small proportion of moths are still flying. If this

second protocol is used, the sentinel traps must have been in place for the entire trapping season, and the cumulative catch should be recorded on the side of the trap.

- When sentinel traps for an area indicate two consecutive weeks of no moth capture, final service visits can begin for that area or
- When sentinel trap catch for a one-week trapping interval is less than 1% of the cumulative catch, and this occurs in two consecutive weeks, final service visits can begin for that area.

Final Service Visit

The final service visit is the last one to occur and the trap is removed at that time.

- The final service visit occurs after the sentinel traps indicate no capture, or less than 1% capture, of moths for two consecutive weeks (see the Sentinel Trap Protocols, above). There is also a third alternative. If the midseason trap check results in more than 1000 moths captured, then you may use that midseason service visit as the final service visit.



Shenandoah National Park
Long-Term Ecological Monitoring System

Gypsy Moth Pheromone Trap Data

TRAP PLACEMENT

TRAP CHECK (circle one)

DATE: _____

TRAP TYPE: _____

.....

SITE

MOTHS

_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
_____	_____
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_____	_____

Figure IV.8. Gypsy moth pheromone trap data sheet.

GYPSY MOTH MANAGEMENT PROGRAMS FOR NATIONAL PARKS

System Design and Monitoring System Considerations

Management programs must address the question of whether or not a given level of defoliation will occur as a result of an egg mass density and the subsequent larval population. It is necessary to specify whether or not to control a population based on a threshold egg mass density. The earliest treatment thresholds were published in "The Comprehensive Gypsy Moth Management System" study where Etter discussed 250, and 1,000 egg masses per acre as possible action thresholds (Appendix K-9, Nat'l Gypsy Moth Management Board 1979). These thresholds continue to be used by many gypsy moth management programs throughout the United States today (Ravlin et al. 1987). Thus, treatment decisions are based on egg mass densities and egg mass densities are determined through field sampling programs.

Egg mass sampling is expensive and for most national parks it will be possible to sample and treat only a fraction of the entire park. A system for prioritizing areas to receive egg mass samples and eventually control tactics must be put in place to support control decisions while working within budgetary constraints. There are no generally accepted methods for prioritizing areas and research conducted during the last five years has sought to address this problem through the use of pheromone-baited traps for male gypsy moths. Pheromone-baited traps have been universally used in gypsy moth detection, eradication, and management programs in the United States (Ravlin et al. 1987). However, decision-makers have not had models that relate pheromone trap results (moths per trap) with the density of other gypsy moth life-stages, particularly egg masses. Thus, management programs have been forced to expend more of their resources on expensive egg mass sampling without the benefit of using pheromone trap results to assist in the process of prioritizing areas to receive egg mass samples.

For gypsy moth management programs it would be useful if the number of pheromone trap-captured moths could be used to estimate one or more of the following parameters: egg mass density, egg density, the probability of occurrence of an unacceptably high population (i.e., exceeding a treatment threshold), or be

used to trigger and target egg mass sampling for more precise population estimates. Regression techniques for determining if a relationship exists between moths per trap and egg mass density have been described for the Douglas-fir tussock moth (Daterman 1978, Shepherd et al. 1985) and the spruce budworm (Allen et al. 1986). Regressions have been performed on gypsy moth data taken from the Maryland Integrated Pest Management Pilot project, plots distributed throughout Virginia, and several areas in the SNP. In all cases there are significant regressions between moths per trap and egg mass density. But, like the tussock moth and budworm, there were differences between locations and years with the proportion of variability explained ranging from 30 to 80%. While there is utility in these relationships, data from Massachusetts do not always support them (Elkinton, 1987). Reasons for this are not fully known. Many factors affect the dynamics of pheromone trap/moth interactions and the relationship between trap catch and egg mass density. Male moth dispersal and behavior are particularly important. More importantly, because male moths move away from the location from which they emerged it is not reasonable to assume that there will always be a good relationship between moths and egg masses when data are taken from a single location. Another approach to this problem is to stratify egg mass and moth data into density categories and determine the probability of exceeding different egg mass densities (Table 1). This approach has the advantage of providing managers with a measure of risk and alleviates the need to project egg mass densities given moth counts (Ravlin 1990).

Table IV.1. Probability of exceeding a given egg mass density based on the number of moths captured in a pheromone-baited trap.

Egg Masses/ Acre	Moths Captured per Trap		
	0 - 500	501 - 1000	>1000
0 - 250	0.88	0.40	0.10
251 - 500	0.00	0.20	0.05
501 - 1000	0.00	0.10	0.25
>1000	0.12	0.30	0.60

A PHEROMONE TRAP-BASED MONITORING SYSTEM

General Concepts

Figure IV.9 describes how pheromone trap results and egg mass sampling can be combined with other variables to determine areas requiring more intensive sampling. The basis for this system is an extensive survey using a grid of pheromone traps, the results of which serve as a trigger for initiating egg mass sampling at the local level. Using the results of male moth surveys to determine egg mass sample areas requires that point data from pheromone traps be converted to a continuous surface and lines of constant moth density (contours) determined using a GIS. At this point, a male moth threshold for egg mass sampling must be set by managers based on the probability of exceeding an egg mass treatment threshold (Table IV.1). During the initial stages of an infestation it is recommended that a threshold of between 200 and 500 moths be used and adjusted to increase or decrease the size of areas requiring egg mass sampling.

Following the selection of a male moth threshold and generation of moth contours, a 1 km grid is overlaid on areas to be managed and all 1 km grid cells that are intersected by a contour line greater than or equal to the moth threshold are candidates for egg mass sampling. Other factors that influence the selection of areas for egg mass sampling are last year's egg mass density, population trend (previous year's moths/current year's moths), susceptibility, accessibility of sites for sampling, and political and economic considerations. All of these factors can be combined using a GIS to produce a composite map (Fig. IV.10) used together with USGS topographic maps and other relevant information.

Figure IV.11 shows a gypsy moth population map. In this map only those 1 km cells that are intersected by the 500 moth contour are candidates to receive egg mass samples. The number of cells to receive egg mass samples can be further reduced by considering other variables such as the degree to which the population is increasing, last year's sample results, land use, and management objectives.

Once an area has been targeted for sampling, sequential egg mass sampling schemes can be gener-

ated based on treatment thresholds and sampling error selected by park managers. Use of sequential sampling will be discussed below. Following egg mass sampling, treatment blocks can then be delimited based on management objectives, egg mass density, and landscape features.

Implementation

Terminology

LTEMS uses Universal Transverse Mercator (UTM) coordinates and topographic maps for accurate identification of site and plot positions on the Earth. In this manual we describe the codes used in the LTEMS database when referring to locational data.

Quad Codes. The 7.5-minute topographic maps (1:24000 scale, published by the U.S. Department of Interior Geologic Survey) should be used by field personnel. Each 7.5-minute map is termed a "quadrangle", or more commonly a "quad". There are 32 quads, each covering approximately 58 square miles, in the SNP. Each quad has a name, but quad names can be duplicated across states, and knowing a quad name does not tell you where it is located. To organize the quads, a code has been associated with each quad.

The quad code can be determined from the Index to Topographic Maps (the "Index Map"), which is published by the U.S. Geologic Survey. An Index Map is a state map with the quads overlaid on it. *The quad code is a combination of a letter, which refers to a row on the Index Map, and a two digit number, which refers to a column on the Index Map.*

The letters start at the bottom of the state of Virginia, with the letter "A", and move northward one quad at a time. *The letter of the quad code identifies the position of the quad on the north-south axis.*

The number in the quad code identifies the position of the quad on an east-west axis. The numbers run consecutively from west to east, and start at the most western quad in Virginia.

The quad code can identify the location of a quad in the SNP. Cross-references for quad codes and quad names (quad name is the name printed on the map by the Geologic Survey) is provided in Table IV.2.

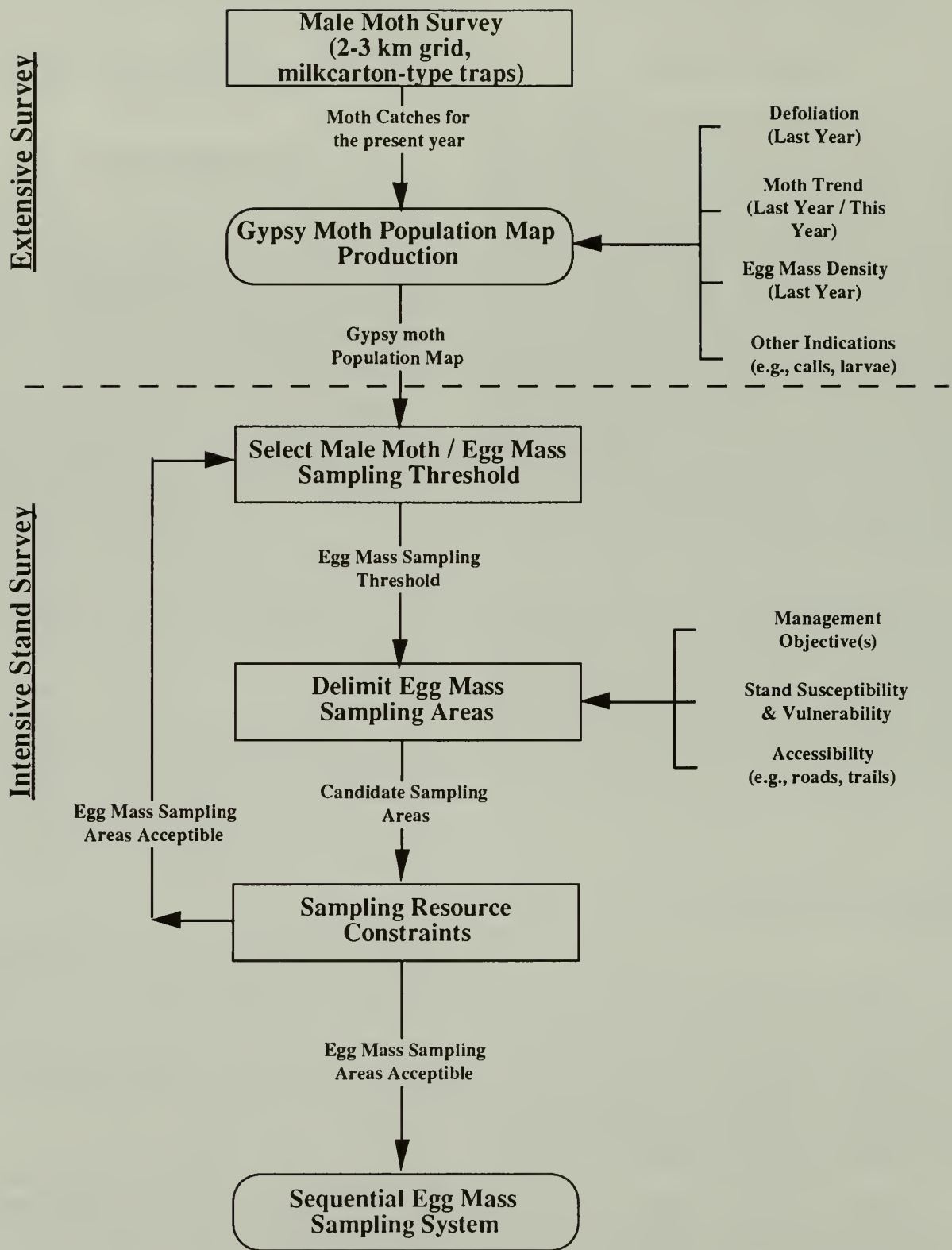


Figure IV.9. Sequence of activities and decisions for making treatment and monitoring decisions for management areas.

Pheromone trap data from field

LTEMS Gypsy Moth Database

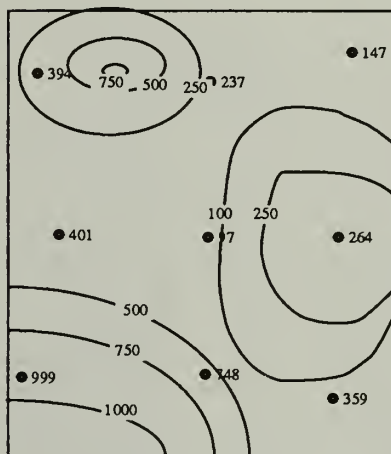
Database query

Data entered into geographic information system

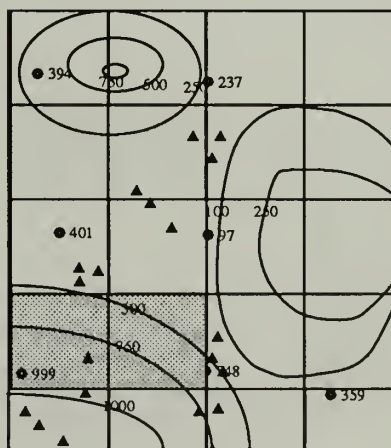
Point data map produced



Contour and point data map produced



Egg mass data from last year added to map as points and 1 km grid overlaid to produce a population map



0 fold change 10 fold increase 100 fold increase

Figure IV. 10. Sequence of maps for determining egg mass sample areas.

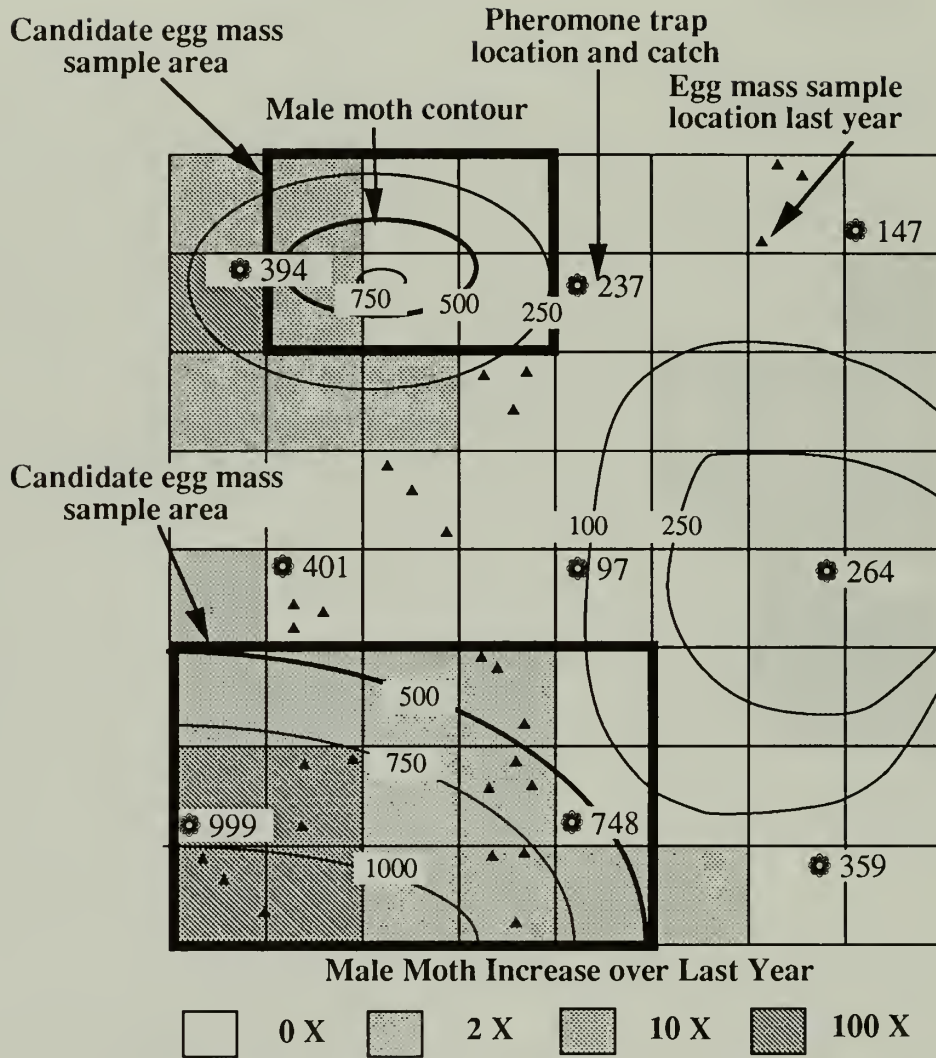


Figure IV.11. Gypsy moth population map showing pheromone trap catches, lines of constant moth catch (contours), the previous year's egg mass sample locations, and population changes in 1 km cells.

Table IV.2. Shenandoah National Park quad names and codes

Quad Code	Quad Name
U44	Bentonville
S43	Big Meadows
R45	Brightwood
P41	Brown's Cove
U45	Chester Gap
P40	Crimora
N41	Crozet
R42	Elkton East
R41	Elkton West
R43	Fletcher
U46	Flint Hill
P39	Fort Defiance
P42	Free Union
V45	Front Royal
M40	Greenfield
Q40	Grottoes
T43	Luray
R44	Madison
T46	Massie's Corner
Q41	McGaheysville
S44	Old Rag Mountain
U43	Rileyville
Q44	Rochelle
Q43	Standardsville
S42	Stanley
V44	Strasburg
Q42	Swift Run Gap
T44	Thornton Gap
T45	Washington
N40	Waynesboro East
N39	Waynesboro West
S45	Woodville

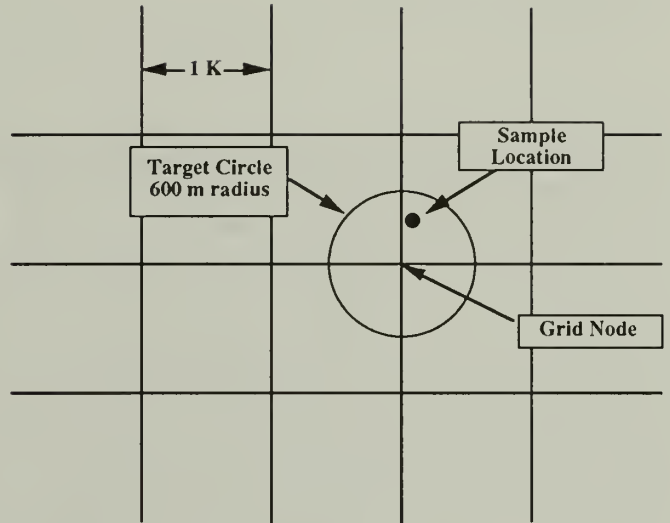


Figure IV.12. Schematic showing target circle, grid node, and sample location.

In practice, SNP personnel will attempt to set up a *sampling location* within the target area. When a location is established, the UTM coordinates that identify that location will be determined from a quad map and entered into the gypsy moth management database. *Sampling locations are real points in the field and are identified by UTM coordinates.* Sampling sites are only determined by field personnel when sites are established and the Gypsy moth management database does not know where a sampling site is until those data have been appropriately entered (on Form 1). *NOTE: A distinction is made between the LTEMs database that is used for measuring the impact of gypsy moth on the SNP and a gypsy moth management database which is designed to be used for assisting in making control decisions.*

Grid nodes and Sample Sites. The extensive survey for male moths is designed to be taken across the entire SNP. To ensure the area in the project is systematically surveyed a grid has been placed over the area. The grid nodes are defined by the intersection of UTM lines running in a north-south and an east-west direction. The intersection of these lines is called a *grid node*. Details of the grid are discussed below. *Each grid node and its associated target circle (also discussed in the next section) represents an area within which there will be an attempt to place a pheromone trap and take data.*

Grid node numbering system. A kilometer is 1,000 meters, or 3,281 feet, or 0.62 miles. In order to accommodate a variety of intertrap spacings a 1 km grid node system was overlaid over the entire project area.

Each grid node within each quad is assigned a number. There are approximately 130 to 210 1 km grid nodes in a quad. The numbering system starts in the northwest corner of the quad, with the number 1, and moves eastward, assigning the next number at one kilometer intervals, until it reaches the east end of the quad. It then drops south 1 kilometer, and then moves westward. *The grid node numbering system is an S-shaped pattern.* This process is repeated for each quad. The purpose of the S-shaped pattern is to have the number give an approximate location of each sample site in each quad. The S-shaped pattern is necessary because the number of rows and columns in the grid are

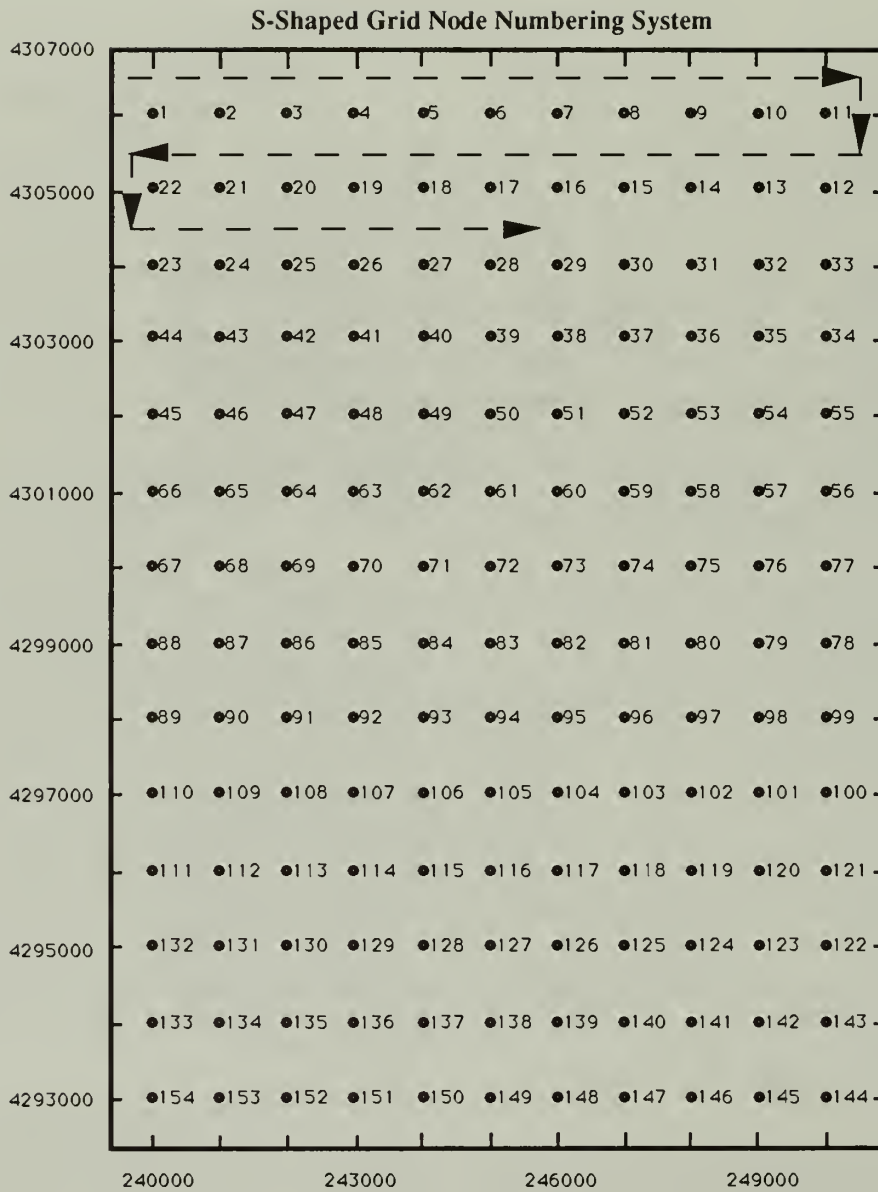


Figure IV.13. S-Shaped numbering system for pheromone trap grids.

different in different quads. If tighter grids are used, the resource manager will develop unique numbering systems and advise you what grid node system to use. For example, the thousands digit will generally indicate a 250-meter grid.

Summary. Locational data are based on the UTM coordinate system and 7.5-minute topographic maps (quads). Quads are assigned a code, where a letter refers to the position on a north-south direction and the number to a position on an east-west direction.

A grid exists over the SNP, and the grid node with the appropriate target circle is the area for placing sampling sites. A number is assigned to each grid node, and that same number will be used for the sampling site associated with that grid node. The grid node numbering system follows a S-shaped pattern, starting at the northwest corner of the quad. The numbering system is repeated for each quad.

Grid Nodes, Sampling Locations, Target Circles, and Omits

Setting up the grid. The spacing between grid nodes is a variable that is a function of

- infestation status,
- management objectives,
- budget constraints, and
- sample location accessibility.

Infestation status plays an important role in determining which areas should be included in a pheromone trap grid design. As discussed earlier, after populations have cycled through one or more defoliation episodes the amount of information that can be obtained from pheromone trap data diminishes. Pheromone traps can still be of benefit to resource managers by providing an early warning that populations are increasing and that control activities may have to begin in the following field season.

Management objectives determine whether or not areas will be considered for control activities. For example, if wilderness areas are a consideration then it is possible that control activities (e.g., insecticides) will never be conducted within these areas. Thus, from a management perspective there is little reason to monitor for making control decisions.

The effect that budget constraints have on system design is clear in that resource managers must strike a balance between obtaining enough data to

make control decisions on as small an area as possible and yet stay within the confines of the budget and other related sampling resources.

Sample location accessibility is also important for national parks. The amount of time available to service sample locations will affect the program in general and managers may wish to omit areas from the monitoring system that cannot be accessed in a reasonable period of time.

It is desirable to space pheromone traps as close together as possible up to an intertrap spacing of 500 m. As the intertrap spacing becomes larger (e.g., 2 or 3 km) the size of populations that will be identified as potentially causing significant impact will, on the average, be larger. A 2 km spacing should be considered as an initial grid, with the variables listed above (e.g., management objective) then considered in determining the final system design.

Due to the need to satisfy a variety of possible grid spacings a 1 km grid was developed for the entire SNP. On the topographic maps, a 1km grid results from connecting the blue tic marks at the edge of the map. Care must be taken to connect the appropriate marks. The blue tic marks follow the UTM coordinate system, whereas the boundaries of the quad map follow the latitude-longitude system. This results in the lines connecting blue tic marks not being directly perpendicular to the borders of the topographic map. The blue tic marks are spaced 1 km, or 1000 meters, apart. The intersections of lines (grid nodes) that result from connecting these 1 km blue tic marks is a 1 km grid. The numbers associated with these blue tic marks are the UTM coordinates.

Target Circles. The grid node represents the center of a target area in which to place a sample site. But the target area is much larger than the intersection of two lines. *The target area is a circle on a map, the center of that circle being the intersection of the two lines (the grid node), and the radius is 30% of the inter-grid-node distance.* Thus, the size of the circle depends upon the spacing between grid nodes. The size of the circle for a 2 and 3 km grid are as follows:

	<u>GRID</u>	
	<u>2K</u>	<u>3K</u>
circle radius		
on the earth (meters)	600	900
circle diameter		
on the earth (meters)	1200	1800
circle diameter on the map		
mm	50	75
inches	2	3
acres	266	600

Sample Locations. In practice, SNP personnel will attempt to set up a *sample location* within the target area. When the actual sample site is established, the UTM coordinates that identify that site are established. *Sample locations are real points on a map where data are collected. Sample locations are determined by field personnel when locations are established.* The gypsy moth management database does not know where a sampling location is until that data has been appropriately entered on a data Form 1: Site Identification. *By submitting a Form 1 to the database, locations become "known" to the database.*

Sample locations established in the first year of a gypsy moth extensive survey should be considered permanent sample locations. This will provide continuity of the data through time and throughout the SNP.

Site numbers will be assigned to each sample location. Numbers associated with the sample grid have been assigned using the S-shaped numbering system discussed previously. Additional sites may be established for grids of higher resolution within portions of the project area. These should be given unique numbers by the field supervisors.

Placement of Sample Locations Within Target Circles. To place a sample location within the target circle, the following priorities should be followed:

- The first priority is to be within the target circle.
- The second priority is to be within, or as near as possible to, gypsy moth habitat (see Appendix IV.D.)
- The third priority is to place the site at least 15 paces (about 30 to 40 feet) into the hardwood stand.
- If the first three priorities for site placement are met, then field personnel should place the site at the most accessible location.

For purposes of site placement, gypsy moth habitat is considered to be forested hardwoods. No distinction is made among hardwood species.

Placing sample locations 15 paces into stands is done to avoid placement on an edge of a stand. An edge is defined as a break in the forest canopy. By placing a trap away from the forest edge, standardization should be increased and less vandalism should occur. Resource managers may also want to consider edge areas as unique management units because of the tendency for egg mass populations to accumulate there and because edges often are associated with

parkways (e.g., Skyline drive) or visitor areas (Bellinger et al. 1989).

Omits. It is highly desirable that all targets are sampled. The spacing between grid nodes and the target circle sizes have been adjusted to help make this possible. However, there will be situations where it is not feasible to sample a target. The following is a protocol for determining which sites can be omitted.

Sites that are assigned to field personnel can be omitted if there exists a reasonable safety concern. Field personnel should visit the nearest access point of all sites that do not present an obvious safety hazard. If more than 60 minutes is estimated for one-way access to the target circle and all adjacent sites can be accessed, then the site can be omitted. *Every effort short of compromising one's own safety, including expending more than 60 minutes for one-way access, should be made to prevent sites next to each other from being omitted.*

If a site is omitted, a Form 1 should still be filled out. The space for "omit" in the trap type field should be filled in. The UTM coordinates for an omitted site are the UTM coordinates of the grid node for that target circle (the center of the target circle).

Placement of Grid and Target Circles on Maps. Experience has shown that fewer errors are made if the topographic maps are labeled in a well-defined manner. Protocols for drawing on the 7.5-minute topographic maps are as follows:

- The quad code should be written in the lower right hand corner with indelible dark blue or black fine tip markers.
- Independent cities, state, county, and federal boundaries should be highlighted in yellow.
- The grid of intersecting UTM lines and the target circles should be written in pencil.
- The sampling location, as established in the field, should be written in red pencil. Use a small "x" to show the sampling site on the map.
- Write the sample location number within the target circle in red pencil.

Be sure to read only the light blue tic marks on the outside of the map margin line when connecting the UTM measurement marks. *Also, be sure to connect the correct marks. The UTM marks lie at a slight angle relative to the rest of the map.* Use a good quality straight edge, such as a metal ruler with a cork backing, to

ensure straight lines (some wooden yardsticks have enough curve to distort UTM coordinates).

moth flight season (about late August to early September).

Pheromone Traps

Trapping Protocol

Pheromone-baited traps will be used to sample gypsy moth male adults at each sample site. These traps are designed to attract and capture male moths using a synthetic pheromone that mimics the sex attractant of female gypsy moths. Field personnel must take care in handling, assembling, installing and servicing traps if the data are to be meaningful. The assembly of traps is discussed and diagrammed in Appendix IV.B.

When you reach the sampling site, install the trap onto a tree if at all possible (as opposed to a telephone pole, etc.). Hang the trap 4 to 5 feet off the ground. Use the north side of the tree. Use flagging to mark your way to the trap site.

To install the trap, first install a hanger made from a wire clothes hanger to the tree. See Appendix IV.B. for instructions on making the hanger.

To install the trap onto the hanger, slide the hole in the spout of the milk carton trap onto the loop. The trap should be suspended by the hanger, with the hood of the trap approximately 1 to 2 inches away from the tree (the distance from the trap to the tree can affect the trap catch). Make sure the hanger is firmly stapled to the tree, using 6 or more staples. If it is not, the hanger will rotate, and the trap can become damaged by banging against the tree.

Trap Service

The traps must be installed prior to the time adults moths start to fly.

- This means they need to be installed by June 15.

Traps should be serviced twice during each field season.

- The first service should be at midseason (approximately the middle of July). This service visit ensures that traps are still in place, allows personnel to be sure that trap locations can be found, and allows personnel to replace damaged traps.
- The second service visit should be at the end of the

Count the number of moths captured at each service visit. However, repeatedly emptying of the trap will affect the total catch at the end of the season. You should not empty the trap more than once during the season, and once at the end of the moth flight season (i.e., twice for the whole season).

After counting the moths they should be transferred to a plastic bag, carried away from the site, and disposed of. The dead moths should not be dumped near the site of the trap, as they may affect the subsequent catch of the trap. Field personnel may wish to count the moths at the site as they transfer them to a plastic bag or, if the quantity is high, count them later. All plastic bags containing moths must be labelled with the site number using indelible magic marker prior to leaving the site. The supervisor has the right to ask for the bags with the moths. If the supervisor does not want the moths, dispose of them in an appropriate trash container (any trash can that can handle organic wastes will work).

Sentinel Traps

Sentinel traps are pheromone traps that are serviced weekly towards the end of the male moth flight season (after July 24). Data from sentinel traps can be used to estimate the time that moths stop flying in a given geographical area.

Placement. Distribute sentinel traps so that no two adjacent quads are without at least one sentinel trap and in habitats and elevations that are similar to the established pheromone trap sampling sites within the quad. Since these traps will need to be serviced more frequently, sentinel traps should be in a location that is convenient to access. Sentinel traps do not have to be part of the extensive trapping grid. They can be chosen from the extensive survey grid or they can be additional traps located more conveniently as long as they are *at least 500 meters* from an established sampling site. However, remember that the end of moth flight in these sentinel traps will be used to estimate the end of moth flight in the other traps throughout the entire quad.

Sentinel traps should be chosen from areas where *at least 25 moths* were captured by the midseason check. If no such areas exist, then the default date for beginning final service visit is August 15.

Determining the End of the Flight Season.

There are two protocols for using the sentinel traps to determine when the moth flight season has essentially ended. The first protocol is designed to directly measure the end of moth flight. The second protocol is designed to indicate when approximately 99% of the moth catch has already occurred, but allows for traps to be closed out even though a small proportion of the moth population is still flying. If this second protocol is used, the sentinel traps must have been in place for the entire trapping season, and the cumulative catch should be recorded on the side of the trap.

- When sentinel traps for an area indicate two consecutive weeks of no moth capture, final service visits can begin for that area or
- When sentinel trap catch for a one week trapping interval is less than 1% of the cumulative catch, and this occurs in two consecutive weeks, final service visits can begin for that area.

Final Service Visit

The final service visit is the last one to occur, and the trap is removed at that time.

The final service visit occurs after the sentinel traps indicate no capture, or less than 1% capture, of moths for two consecutive weeks (see the Sentinel Trap Protocols, above). There is also a third alternative. If the midseason trap check results in more than 1000 moths captured, then you may use that midseason service visit as the final service visit.

Processing of data, such as making maps, etc., cannot be started until the final service visit on a sufficient percentage of the traps in an area is completed.

There is a variable on the data form used to tell the database that the service visit is the final service visit.

You should tell the database which of the three possible criteria (either of the two sentinel trap rules, or the midseason catch of > 1000) you are using to allow the trap to be taken down.

Gypsy Moth Egg Mass Sampling

Gypsy Moth Egg Masses

Gypsy moths spend over half of the year as an egg. These eggs are laid in late summer in a single mass (called an "egg mass") per female, and are covered by the abdominal hairs of the female. It is the

hairy covering, which has a buff-colored, velvety appearance when newly deposited, that you can see. You can find the shiny round eggs by rubbing off the hairy covering. Gypsy moths overwinter within these eggs.

Location. Gypsy moth females often lay egg masses in sheltered locations such as the underside of tree limbs, bark crevices, or under rock overhangs. In developed areas, eaves of houses and other man-made objects (e.g., park benches) are used for egg mass deposition. But this just describes where egg masses are *generally* found. They can be laid in almost any location.

New Versus Old Egg Masses. Although first instar larvae hatch from egg masses in the spring, the egg masses themselves can persist into the following year. Thus, some egg masses may be remnants from the previous year and do not contain live eggs. In order to make control decisions managers must know how many newly laid egg masses are present. It is the newly laid egg masses that will contribute to the next spring's larval population.

If you have access to the egg masses you can distinguish newly laid masses from old masses by touching them and by rubbing the hairs off and looking closely at the eggs themselves. Newly laid masses are firmer to the touch. The eggs within newly laid masses are whole and are opaque to dark colored depending on the degree of development of the larvae inside. Eggs within last year's masses are translucent due to the lack of anything inside. It takes a few minutes of practice to be confident of your ability to distinguish newly laid egg masses from old ones.

Often it is not possible to reach egg masses and more subjective information must be relied upon to distinguish new from old egg masses. The buff-colored abdominal hairs that cover the egg mass will, to varying degrees, lose their color with age. The sun may bleach out the buff color or other aging factors may cause the color to fade. Also, in collapsing populations, new egg masses may be smaller. If you can reach a portion of the egg masses, you can "calibrate" your estimate of new versus old judged by color against the more accurate estimate judged by directly touching egg masses.

Make your estimate of the percent of old egg masses from a subset of 20 masses that are representative of the ones in 1/40th acre plots described below. They can be the same ones used for the 1/40th acre plot count, but they do not have to be. Ideally, egg masses that can be touched should be chosen, but if they are out of reach, estimates must be based on what can be seen. Many will have much fewer than 20 egg masses to choose from. In these situations make estimates using

what is available. Choose a number of egg masses that make the calculation easy, such as 5 or 10.

Egg Mass Size and Shape. On a smooth surface, egg masses are oblong to tear drop shaped. Females first lay eggs that are at the wide portion of the tear drop shaped and then moves towards the apex as she finishes laying eggs. But females will deposit egg masses in a shape that conforms to the surface upon which they are deposited. Thus, in a narrow bark crevice, egg masses will be more elongated.

The size of egg masses will depend on the number of eggs it contains. If healthy females lay eggs, the number of eggs can approach and even exceed a thousand. These egg masses are relatively large and are commonly found in low density populations. If females have been stressed during their larval growth, the number of eggs in a mass will be severely reduced to a few hundred or even less than one hundred and these egg masses will be relatively small. It is not uncommon to find most of the egg masses to be very small in populations that are severely infected by NPV or in populations that have depleted their food reserves by defoliating trees. NPV is an abbreviation for nucleopolyhedrosis virus. This disease affects gypsy moth larvae when population levels are high. As a result of starvation and NPV, gypsy moth populations can go from outbreak levels to becoming virtually nondetectable within a single growing season.

The size of egg masses can give managers a clue as to the number of eggs they contain and whether populations have been stressed and may be collapsing. A rough estimate of this is entered in variable 18, where you are asked to estimate the percent of egg masses that are smaller than a quarter. Use the wide portion of the mass for comparison. But use some judgment in the field. Elongate egg masses that are relatively long need to be judged as big egg masses, even if the width does not exceed the width of a quarter.

Sampling For Gypsy Moth Egg Masses

Managers will direct you to 1 kilometer (1 km) cells that need egg mass samples taken. These cells were partially defined by drawing contour lines from the pheromone trap data and selecting a egg mass sampling threshold (e.g., 500 moths). Cells that fall within the sampling threshold contour lines are candidates for egg mass samples. In addition to pheromone trap results, the trend in male moth catch from the previous to the current year, the location and density of egg mass counts from the previous year, the need to evaluate intervention tactics, time and cost constraints, and specific management objectives are used by managers to define cells that need egg mass samples (Fig. IV.11).

Most egg mass samples will come from 1/40th acre sample sites. These are circles with a radius of 5.67 m (18.6 ft). The entire area within the circle is searched for egg masses. If the center of the bole of a tree falls within the circle, the entire tree is included in the sample area. Use binoculars to search the higher portions of tree boles and crowns. Look at trees from three sides to ensure the entire surface is searched. The understory and ground area within the circle should also be searched. Turn over loose bark and rocks on the ground.

Within each 1 km cell, a minimum of four 1/40th acre samples should be taken. Try to spread the samples out within the 1 km cell to adequately represent the area. At a minimum, keep the samples 100 meters (about 300 feet) apart. Sample areas that are good gypsy moth habitat (see Appendix IV.D.) and place less emphasis on areas of poor habitat. While you are travelling through areas that have few egg masses, look at good egg deposition sites (e.g., undersides of tree limbs, etc.). If you see an egg mass, put a 1/40th acre site at that spot.

The minimum number of samples per 1 km cell is four, but the actual number of samples depends on what you find in the field. A sequential sample plan has been developed (see below) that allows you to stop sampling a 1 km cell quickly if you are well below or well above a threshold that is important to the management of that area. If you are close to that threshold, more samples, up to a maximum of ten per 1 km cell, will be required.

Sequential Sampling Plans

Theory. Sequential sampling is a technique that concentrates sampling resources in areas that are close to treatment thresholds. It was developed during World War II, when a need existed to perform quality control work quickly and with known accuracy levels in munitions plants. It has been applied to many insect pest problem since the 1950s.

You can understand sequential sampling plans by thinking about probabilities of drawing cards from a deck of cards. Imagine a large deck of cards, each with a number printed on it. If you took all the cards together, the average would be a known value. For this example, let's assume that the true average of all the cards is 10. Let's also assume that we know the percentage of cards that have the number 1, the number 2, etc., for each number that can exist on any card. For this example, assume it is a bell-shaped distribution, so that there are lots of cards with the number 10, slightly fewer with the numbers 11 and 9, fewer still with the numbers 12 and 8, and very few with the numbers 2 and 18. You draw

one card. There is a good chance it is the number 10, and a smaller chance it is the number 2. You draw a second card. Again, it is more likely that it is the number 10, or 9, or 11. It is unlikely that it is the number 2, and even more unlikely that you drew two 2s in a row. Thus, it is likely that your cumulative sum is close to 20, but unlikely that it is close to 4.

Sequential sampling plans take advantage of these probabilities. Let's say you need to find decks of cards in which the true average is 10. In one deck that you test you draw two cards and the cumulative sum is four. You can say within certain levels of confidence that this deck has a true average that is less than 10 and then you are finished sampling that deck of cards. In a second deck, the cumulative sum of two cards is 37. Again, you conclude that the true average is not 10, and you stop sampling. But in a third deck of cards, your first two samples add up to 18. You have to be concerned that the true average in this third deck is 10, so the sampling plan tells you to draw a third card. Your time sampling cards is concentrated in decks of cards that are close to your management concern.

In the SNP, treatment thresholds are average egg mass counts per 1 km cell that managers use to trigger further action. The sequential plans give you a way of saying if gypsy moth populations are close to treatment thresholds. The plan estimates the probability of sampling the cumulative sum that you have taken from field samples if the true average is a given treatment threshold. If that probability is low (the numbers are too low or too high), the plan concludes that you are probably not sampling a population that is close to a treatment threshold and you can move on to the next 1K cell. Otherwise, it recommends that you take another sample, and repeat the process of summing the field counts. Thus, when you are close to a treatment threshold, you will take the most samples and thus increase the accuracy of the average egg mass density estimate. When you are obtaining counts in the field that suggest that populations are far removed from treatment thresholds (very high or very low densities), you will take fewer samples.

Procedure. Different treatment thresholds may be used for different areas of the SNP. To accommodate the various thresholds, three sequential sampling plans have been developed for some commonly used thresholds, with a separate table provided for each plan. The sequential plans all work the same way, they just use different tables. Managers will determine the appropriate table for the area you are sampling.

Sequential Egg Mass Sampling Tables. To use a sequential sampling plan, first take four 1/40th acre egg mass samples. As stated earlier, within each

1 km cell, a minimum of four 1/40th acre samples should be taken. Try to spread the samples out within the 1 km cell to adequately represent the area. At a minimum, keep the samples 100 meters (about 300 feet) apart. Sample the area that is good gypsy moth habitat (see Appendix IV.D.), and place less emphasis on areas of poor habitat. While you are travelling through areas that have few egg masses, look at good egg deposition sites (undersides of tree limbs, etc.). If you see an egg mass, put a 1/40th acre site at that spot.

Sum the four counts. These are counts of new egg masses. Compare that sum to the range of values that are in the "sample 4" row of the table you are using. At the bottom of the table, the plan will recommend that you either stop or continue sampling. If the column suggests to stop, then you can move to the next 1 km cell that needs sampling. If it suggests that you continue, then there exists a reasonable probability that you are in a 1 km cell that will have an average egg mass density that is close to a treatment threshold. Take another sample, and add that to your previous sum. Compare that sum to the range of values in the "sample 5" row. Continue this process up to the tenth sample.

Note that the tables only show the ranges for the fourth through ninth samples. It is assumed you will take at least four samples. At the ninth sample, you may be requested to continue sampling, so take the tenth sample. But ten will generally be the last sample, regardless of the counts, so the row for the tenth sample was not printed.

Record each sample count on a separate form. *Record the actual count in the 1/40th acre plot, not the cumulative sum.* Calculate the cumulative sum for your own use of the sequential sampling plan in the field.

Validation. It is essential to keep track of how well the sequential plans are working on a continuing basis. A small percentage of the 1 km cells (e.g., 10%) should be used as validation data. Take 10 samples in the 1 km cells used for sequential sampling validation. As always, put each sample on a separate form and assign a new form number to each form. Check "yes" in variable box 15 on the op-scan form to tell the database that this is a validation 1 km cell. A conclusion of being above or below a given threshold will be determined from the 10 samples and will be compared to what would have been determined if the sequential plan had been used. These data will help in refining the sequential sampling plans for future years.

**FORM 1: SITE IDENTIFICATION
COMPLETED AT TRAP PLACEMENT**

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<input type="radio"/> OAK HARDWOOD (>50% OAK) <input type="radio"/> MIXED HARDWOOD (<50% OAK) <input type="radio"/> HARDWOOD (NO OAK) <input type="radio"/> CONIFER/HARDWOOD (>25% CONIFER AND >25% OAK) <input type="radio"/> CONIFER (>75% CONIFER) <input type="radio"/> ASPEN (>75% ASPEN) <input type="radio"/> FIELD (FEW TREES) <input type="radio"/> LONE TREE <input type="radio"/> ORNAMENTAL/ <input type="radio"/> STREET <input type="radio"/> OTHER* (*use comments)		COUNTY	FEDERAL	<table border="1" style="width:100%; height:100%; border-collapse: collapse;"> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> <tr><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td><td> </td></tr> </table>																																																																																																																																									

YEAR OF QUAD MAP REVISION _____

**FORM 2: PHEROMONE TRAP CATCH
COMPLETED AT TRAP INSPECTION**

1. QUAD CODE	2. SITE NO.	3. DATE		4. TRAP CONDITION	5. IS THIS A SENTINEL TRAP?	6. INITIALS			
		MO	DAY						
(A) 0 0	0 0 0 0	APR () 0 0	0 0	<input type="radio"/> GOOD	<input type="radio"/> YES <input type="radio"/> NO	(A) (A) (A)			
(B) 1 1	1 1 1 1	MAY () 1 1	1 1	<input type="radio"/> DAMAGED		(B) (B) (B)			
(C) 2 2	2 2 2 2	JUN () 2 2	2 2	<input type="radio"/> ON GROUND	<input type="radio"/> YES <input type="radio"/> NO	(C) (C) (C)			
(D) 3 3	3 3 3 3	JUL () 3 3	3 3	<input type="radio"/> MISSING		(D) (D) (D)			
(E) 4 4	4 4 4 4	AUG () 4	4	<input type="radio"/> INACCESSIBLE	<input type="radio"/> YES <input type="radio"/> NO	(E) (E) (E)			
(F) 5 5	5 5 5 5	SEP () 5	5	<input type="radio"/> FULL OF MOTHS		(F) (F) (F)			
(G) 6 6	6 6 6 6	OCT () 8	8		<input type="radio"/> YES <input type="radio"/> NO	(G) (G) (G)			
(H) 7 7	7 7 7 7	NOV () 7	7			(H) (H) (H)			
(I) 8 8	8 8 8 8		8		<input type="radio"/> YES <input type="radio"/> NO	(I) (I) (I)			
(J) 9 9	9 9 9 9		9			(J) (J) (J)			
(K) 7. DEPTH OF MOTHS(cm)	8. MOTH CATCH	9. EXTRA VARIABLES				10. IS THIS THE FINAL SERVICE VISIT?	(K) (K) (K)		
(L) () ()	() () () ()	A	B	C	D		E	F	(L) (L) (L)
(M) () ()	() () () ()	0	0	0	0	0	0	(M) (M) (M)	<input type="radio"/> YES <input type="radio"/> NO
(N) () ()	() () () ()	1	1	1	1	1	1	(N) (N) (N)	
(O) () ()	() () () ()	2	2	2	2	2	2	(O) (O) (O)	<input type="radio"/> YES <input type="radio"/> NO
(P) () ()	() () () ()	3	3	3	3	3	3	(P) (P) (P)	
(Q) () ()	() () () ()	4	4	4	4	4	4	(Q) (Q) (Q)	<input type="radio"/> YES <input type="radio"/> NO
(R) () ()	() () () ()	5	5	5	5	5	5	(R) (R) (R)	
(S) () ()	() () () ()	6	6	6	6	6	6	(S) (S) (S)	<input type="radio"/> YES <input type="radio"/> NO
(T) () ()	() () () ()	7	7	7	7	7	7	(T) (T) (T)	
(U) () ()	() () () ()	8	8	8	8	8	8	(U) (U) (U)	<input type="radio"/> YES <input type="radio"/> NO
(V) () ()	() () () ()	9	9	9	9	9	9	(V) (V) (V)	
(W) () ()	() () () ()							(W) (W) (W)	<input type="radio"/> YES <input type="radio"/> NO
(X) () ()	() () () ()							(X) (X) (X)	
(Y) () ()	() () () ()							(Y) (Y) (Y)	<input type="radio"/> YES <input type="radio"/> NO
(Z) () ()	() () () ()							(Z) (Z) (Z)	
11. NPV EVIDENT		12. COMMENTS							
<input type="radio"/> YES <input type="radio"/> NO <input type="radio"/> DO NOT KNOW									

FORM 4: EGG MASS DATA

1. QUAD CODE		2. 1K GRID NODE (SW)		3. FORM NUMBER		4. DATE		5. UNIVERSAL TRANSVERSE MERCATOR				6. COUNTY (FIPS CODE)		7. STATE	
						MO	DAY	EAST - WEST		NORTH - SOUTH					
A 0 0		0 0 0 0		0 0 0		AUG	0	O E 4		O N		0 0 0		<input type="radio"/> WV <input type="radio"/> VA 8. DOES THE EGG MASS SITE LIE IN AN ADJACENT QUAD? <input type="radio"/> YES <input type="radio"/> NO	
B 1 1		1 1 1 1		1 1 1		SEP	1 1	0 0 0 0 ●		0 0 0 0 0 ●		0 0 0			
C 2 2		2 2 2 2		2 2 2		OCT	2 2	1 1 1 1		1 1 1 1 1		1 1 1			
D 3 3		3 3 3 3		3 3 3		NOV	3 3	2 2 2 2 2		2 2 2 2 2		2 2 2			
E 4 4		4 4 4 4		4 4 4		DEC	4	3 3 3 3 3		3 3 3 3 3		3 3 3			
F 5 5		5 5 5 5		5 5 5		JAN	5	4 4 4 4 4 ●		4 4 4 4 4		4 4 4			
G 6 6		6 6 6 6		6 6 6		FEB	6	5 5 5 5 5		5 5 5 5 5		5 5 5			
H 7 7		7 7 7 7		7 7 7		MAR	7	6 6 6 6 6		6 6 6 6 6		6 6 6			
I 8 8		8 8 8 8		8 8 8		APR	8	7 7 7 7 7		7 7 7 7 7		7 7 7			
J 9 9		9 9 9 9		9 9 9			9	8 8 8 8 8		8 8 8 8 8		8 8 8			
K		L		M		N		O		P		Q		R	
9. POLITICAL / MGR JURISDICTION		10. MANAGERIAL DISTRICT CODE		11. HABITAT		12. SAMPLE METHOD		13. SAMPLE PLAN		14. EXTRA VARIABLES		A		B	
(WHERE SAMPLES TAKEN)		COUNTY		FEDERAL		<input type="radio"/> OAK HARDWOOD (>50% OAK) <input type="radio"/> MIXED HARDWOOD (<50% OAK) <input type="radio"/> HARDWOOD (NO OAK) <input type="radio"/> CONIFER / HARDWOOD (>25% CONIFER AND >25% OAK) <input type="radio"/> CONIFER (>75% CONIFER) <input type="radio"/> ASPEN (>75% ASPEN) <input type="radio"/> FIELD (FEW TREES) <input type="radio"/> LONE TREE <input type="radio"/> ORNAMENTAL / STREET <input type="radio"/> OTHER*		<input type="radio"/> FIXED (1/40 ACRE) <input type="radio"/> TIMED WALK <input type="radio"/> URBAN <input type="radio"/> OTHER 1 <input type="radio"/> OTHER 2		<input type="radio"/> SEQUENTIAL-1 <input type="radio"/> SEQUENTIAL-2 <input type="radio"/> SEQUENTIAL-3 <input type="radio"/> SEQUENTIAL-4 <input type="radio"/> SEQUENTIAL-5 <input type="radio"/> FOUR SITES PER 1K CELL <input type="radio"/> OTHER-1 <input type="radio"/> OTHER-2 <input type="radio"/> NONE		<input type="radio"/> YES <input type="radio"/> NO		<input type="radio"/> YES <input type="radio"/> NO	
<input type="radio"/> SNP <input type="radio"/> Blue Ridge Pkwy <input type="radio"/> Other Natl Park <input type="radio"/> GW Natl For <input type="radio"/> Jef Natl For <input type="radio"/> MON Natl For <input type="radio"/> Other Natl For <input type="radio"/> VDACS <input type="radio"/> WVDA <input type="radio"/> County <input type="radio"/> Other*		<input type="radio"/> 0 0 <input type="radio"/> 1 1 <input type="radio"/> 2 2 <input type="radio"/> 3 3 <input type="radio"/> 4 4 <input type="radio"/> 5 5 <input type="radio"/> 6 6 <input type="radio"/> 7 7 <input type="radio"/> 8 8 <input type="radio"/> 9 9		<input type="radio"/> 0 0 <input type="radio"/> 1 1 <input type="radio"/> 2 2 <input type="radio"/> 3 3 <input type="radio"/> 4 4 <input type="radio"/> 5 5 <input type="radio"/> 6 6 <input type="radio"/> 7 7 <input type="radio"/> 8 8 <input type="radio"/> 9 9		* (Use Comments)		* (Use Comments)				<input type="radio"/> 0 0 0 0 <input type="radio"/> 1 1 1 1 <input type="radio"/> 2 2 2 2 <input type="radio"/> 3 3 3 3 <input type="radio"/> 4 4 4 4 <input type="radio"/> 5 5 5 5 <input type="radio"/> 6 6 6 6 <input type="radio"/> 7 7 7 7 <input type="radio"/> 8 8 8 8 <input type="radio"/> 9 9 9 9			
TAKE UP TO TWO EGG MASS SAMPLES AT THIS UTM - LOCATION										20. TRAPPER INITIALS		21. COMMENTS			
SAMPLE 1		16. EGG MASS COUNT		17. DISTRIBUTION		18. PERCENT OLD EGG MASSES		19. PERCENT EGG MASSES SMALLER THAN A QUARTER		A A A					
		0 0 0 0		<input type="radio"/> GROUND		0 0 0		<input type="radio"/> 0-20		B B B					
		1 1 1 1		<input type="radio"/> SINGLE TREE		1 1 1		<input type="radio"/> 21-40		C C C					
		2 2 2 2		<input type="radio"/> MULTIPLE TREES		2 2		<input type="radio"/> 41-60		D D D					
		3 3 3 3		<input type="radio"/> MAN-MADE OBJECTS OR OTHER		3 3		<input type="radio"/> 61-80		E E E					
		4 4 4 4				4 4		<input type="radio"/> 81-100		F F F					
		5 5 5 5				5 5				G G G					
		6 6 6 6				6 6				H H H					
		7 7 7 7				7 7				I I I					
		8 8 8 8				8 8				J J J					
9 9 9 9				9 9				K K K							
SAMPLE 2		16. EGG MASS COUNT		17. DISTRIBUTION		18. PERCENT OLD EGG MASSES		19. PERCENT EGG MASSES SMALLER THAN A QUARTER		L L L					
		0 0 0 0		<input type="radio"/> GROUND		0 0 0		<input type="radio"/> 0-20		M M M					
		1 1 1 1		<input type="radio"/> SINGLE TREE		1 1 1		<input type="radio"/> 21-40		N N N					
		2 2 2 2		<input type="radio"/> MULTIPLE TREES		2 2		<input type="radio"/> 41-60		O O O					
		3 3 3 3		<input type="radio"/> MAN-MADE OBJECTS OR OTHER		3 3		<input type="radio"/> 61-80		P P P					
		4 4 4 4				4 4		<input type="radio"/> 81-100		Q Q Q					
		5 5 5 5				5 5				R R R					
		6 6 6 6				6 6				S S S					
		7 7 7 7				7 7				T T T					
		8 8 8 8				8 8				U U U					
9 9 9 9				9 9				V V V							
								W W W							
								X X X							
								Y Y Y							
								Z Z Z							

SEQUENTIAL PLAN 1 - SINGLE THRESHOLD (250)

Sample	Cumulative Egg Mass Count		
4	0-6	7-42	>42
5	0-12	13-48	>48
6	0-18	19-54	>54
7	0-24	25-60	>60
8	0-30	31-66	>66
9	0-36	37-73	>73
	STOP	CONTINUE SAMPLING	STOP

SEQUENTIAL PLAN 2 - SINGLE THRESHOLD (500)

Sample	Cumulative Egg Mass Count		
4	0-15	16-81	>81
5	0-27	28-94	>94
6	0-39	40-106	>106
7	0-52	53-118	>118
8	0-64	65-130	>130
9	0-76	77-143	>143
	STOP	CONTINUE SAMPLING	STOP

SEQUENTIAL PLAN 3 - SINGLE THRESHOLD (1000)

Sample	Cumulative Egg Mass Count		
4	0-18	19-178	>178
5	0-43	44-202	>202
6	0-67	68-227	>227
7	0-92	93-252	>252
8	0-116	117-276	>276
9	0-141	142-301	>301
	STOP	CONTINUE SAMPLING	STOP

Sequential egg mass sampling decision tables.

ACKNOWLEDGEMENTS

This manual would not have been possible without the support of the USDA, Forest Service. Research projects between the Forest Service and the Department of Entomology at VPI & SU have continued over the last seven years and have served as the basis for much of the system that is presented in this manual. Another major source of information has come from the Appalachian Gypsy Moth Integrated Pest Management Project. This Forest Pest Management demonstration project has provided funding to the Department of Entomology at VPI & SU for the development and implementation of database management and geographic information systems. Thanks go to Dr. Richard C. Reardon (USDA, Forest Service, Morgantown, WV) and Mr. Alan Bullard (USDA, Forest Service, Morgantown, WV). Many other individuals have contributed to the development of monitoring system technology for the gypsy moth. Special thanks go to Drs. Michael L. McManus (USDA, Forest Service, Hamden, CT), and Maxwell McFadden (USDA, Forest Service, Radnor, PA). Their ideas and support are reflected in this work. We, of course, wish to thank the Park Service for providing the opportunity and funding to carry out the project. Thanks go to David Karish and David Haskell. Their patience was appreciated.

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APPENDIX IV.A

GYPSY MOTH POPULATION SAMPLING METHODS

Comparison of Gypsy Moth Sampling Methods

<u>Method</u>	<u>Relative Accuracy</u>	<u>Spatial Coverage</u>	<u>Decision Value</u>	<u>Population Level</u>	<u>Cost</u>
Egg Mass Density					
Timed-walk (Eggen & Abrahamson 1983)	Low	Narrow	Low	Mod-High	Mod
Fixed- & Var.-radius (Wilson & Fontaine 1978)	High	Narrow	High	Mod-High	High
Fixed-radius	High	Narrow	High	Mod-High	High
Sequential (Fleischer et al., Kolodny-Hirsch 1986)	High	Narrow	High	Low-High	Mod
Larval/Pupal Density					
Burlap bands	Low	Narrow	Low	Low	High
Branch sampling	Low	Narrow	Low	Mod-High	High
Canopy sprays	High	Narrow	???	Low-High	Prohib
Frass funnel traps	High	Narrow	Mod	Mod-High	Prohib
Defoliation					
Subjective Eval.	Mod	Broad	Med	Mod-High	Low
Ground photographs	High	Narrow	Med	Low-High	High
Aerial photographs	Mod-High	Broad	Low	Mod-High	Low
Adult Males					
Pheromone traps	Mod	Broad	Mod	Low-High	Low
Phenology Sampling					
Frass funnel traps	High	Narrow	Mod	Mod-High	Prohib
Male sentinel traps	High	Broad	High	Low-High	Low

Eggen, D. A. and L. P. Abrahamson. 1983. Estimating gypsy moth egg mass densities. School of Forestry, Misc. Publ. No. 1 (ESF 83-002), Univ. of Syracuse, Syracuse, N.Y.

Fleischer, S. J., F. W. Ravlin, and R. C. Reardon. 1991. Implementation of sequential sampling plans for gypsy moth (Lepidoptera: Lymantriidae) egg mass in eastern hardwood forests. J. Econ. Entomol. (In review).

Kolodny-Hirsch, D. M. 1986. Evaluation of methods for sampling gypsy moth (Lepidoptera: Lymantriidae) egg mass populations of sequential sampling plans. Environ. Entomol. 15: 122-127.

Wilson, R. W. Jr. and G. A. Fontaine. 1978. Gypsy moth handbook: gypsy moth egg mass sampling with fixed- and variable-radius plots. USDA Agric. Handb. 523.

APPENDIX IV.B.

GYPSY MOTH PHEROMONE-BAITED TRAP ASSEMBLY

PHEROMONE TRAP ASSEMBLY

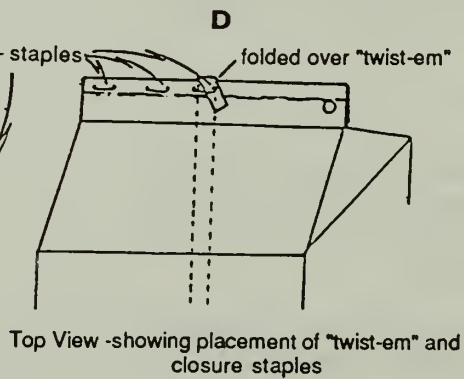
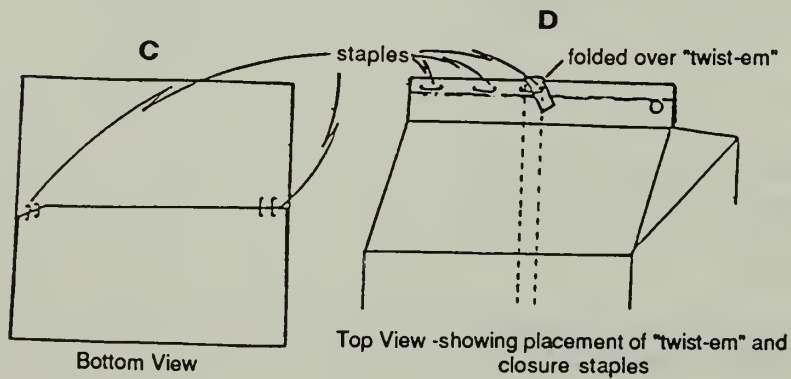
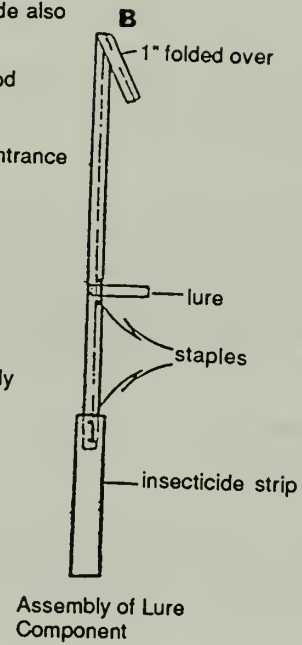
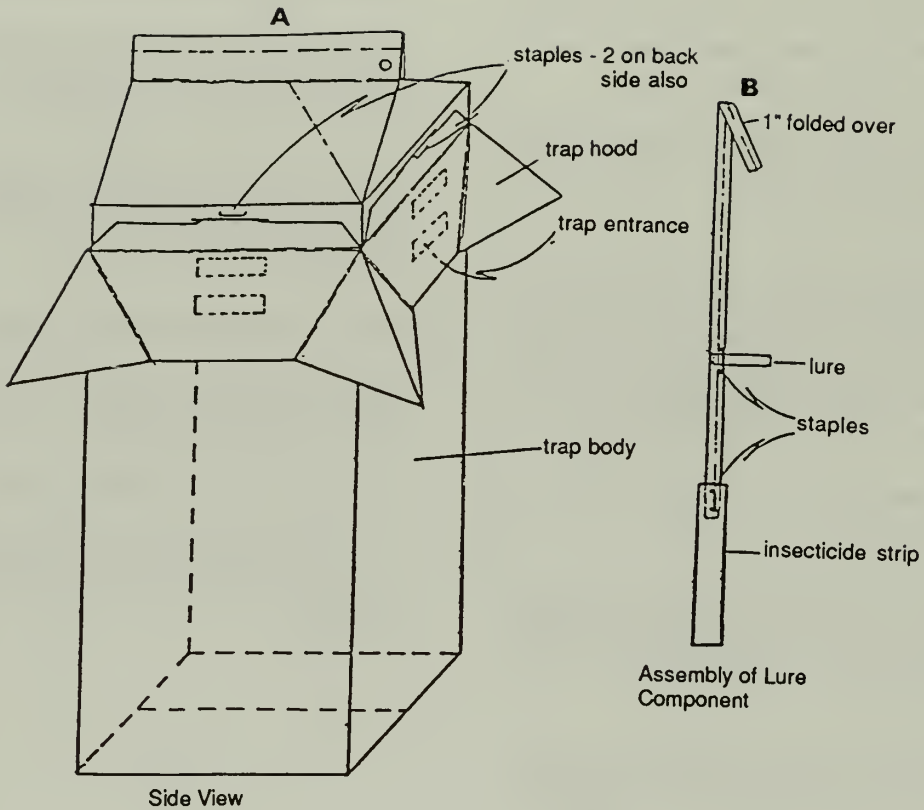
1. Take one trap and hood. Unfold, bend at the creases, and punch out all holes (the trap entrances for the moths, see figure A on next page). If the body seems likely to come apart at the seams, staple the seams together.
2. Close the bottom flaps of the trap body. Try to make the bottom flat. Fasten it on both sides with stapling pliers (Figure C).
3. Slide hood (shiny side up) over the body from the top until you go below the slits which are above the trap entrances. Slide the hood back upwards so that the semicircular tabs on the hood go into the slits. Staple the hood tabs to the body with stapling pliers (Figure A).
4. Assemble the chemical components onto a twist tie (Figure B):
 - A. Staple the insecticide strip (DDVP strip; also called Vapona strip) to one end of an 7 inch twist tie. Minimize handling of the insecticide strip.
 - B. Staple the pheromone lure on the twist tie so that it is perpendicular to the twist tie and about 2.5 inches above the insecticide strip.
 - C. Fold over the top 1/2-inch of the twist tie.
5. Insert the twist tie into the trap body, leaving to top 1/2-inch bent over the top. The twist tie should be near the center of the trap, and off center of the pour spout.
6. Staple the top shut. Make sure the twist tie is secure. Do not staple the pour spout shut.
7. Crease the hood (Figure A).
8. Hang the trap by sliding the hole in the pour spout over the hook in the clothes hanger, and bend the wire so that the pour spout stays closed.

TRAP HANGER ASSEMBLY

1. Bend one wire clothes hanger into a long oval with the hook at the top (Figures 1 and 2).
2. Bend the oval so that it makes a 90-degree turn. Make the bend so that the side with the hook is 5 inches long (Figures 2 and 3).
3. Firmly staple the side of the hanger that does not have the hook to the tree (Figure 3). Use 6 or more staples (don't be shy).

TO INSTALL THE TRAP ON THE HANGER:

1. Slide the hole in the pour spout of the milk carton trap onto the hook.
2. Bend the end of the hook so that it is closed.
3. The trap should be suspended by the hanger with the hood of the trap 1 to 2 inches away from the tree.



APPENDIX IV.C.

GYPSY MOTH SAMPLING EQUIPMENT

Equipment List

<u>Item</u>	<u>Vendor</u>	<u>Estimated Cost</u>
All Sampling		
Clipboard	Department store	2.00
Compass	Forestry suppliers	25.00
Data sheets	SNP	-
1:24,000 scale maps	USGS	2.50
Permanent marking pen	Department store	1.00
Pheromone Trapping		
Duct tape	Hardware store	4.00/roll
Pheromone traps & lures	USDA, APHIS	-
Staple gun	Hardware store	15.00
Staples	Hardware store	2.00/box
Clothes hangers	Hardware store	-
Egg Mass Survey		
Binoculars	Department store	25.00/roll
Tally meter	Forestry Suppliers	8.00

Forestry Suppliers, 205 W. Rankin St., P.O. Box 8397, Jackson, MS 39204,
1-800-647-5368

APPENDIX IV.D.

GYPSY MOTH HOST PLANT PREFERENCES

Gypsy Moth Host Plant Preferences

Class I: Species that support high rates of gypsy moth development and survival.

Overstory: apple, basswood, bigtooth aspen, quaking aspen, gray, paper, and river birch, boxelder, larch, American mountain-ash, all oak species, lombardy poplar, sweet gum, willow.

Understory: alder, hawthorn, hazelnut, eastern hophornbeam, serviceberry, all sumac species, witch-hazel.

Class II: Species that do not support high rates of survival of early larval instars, but do support development and survival of fourth instar and older.

Overstory: chestnut, eastern hemlock, all pine species, all spruce species.

Class III: Nonpreferred species fed upon by 4th instars and older.

Overstory: American beech, black and yellow birch, blackgum (tupelo), Ohio and yellow buckeye, butternut, sweet and black cherry, eastern cottonwood, cucumbertree, American and slippery elm, hackberry, all hickory species, Norway, red silver, and sugar maple, pear, silver poplar, sassafras, black walnut.

Understory: blueberries, pin and choke cherry, American hornbeam, paw paw, persimmon, redbud, sourwood, sweetfern.

Class IV: Nonpreferred species that are rarely fed upon.

Overstory: all ash species, baldcypress, *Catalpa*, eastern redcedar, balsam and fraser fir, American holly, horsechestnut, Kentucky coffee-tree, black and honey locust, mulberry, sycamore, tulip-tree (yellow poplar).

Understory: all *Azalea* species, dogwood, elderberry, grape, greenbrier, juniper, mountain and striped maple, *Rhododendron*, all *Rubus* species, sheep and mountain laurel, spicebush, sarsparilla, all *Viburnum* species.

**SHENANDOAH NATIONAL PARK
LONG-TERM ECOLOGICAL MONITORING SYSTEM**

SECTION V

DATABASE MANAGEMENT SYSTEM

**NPS/NRSHEN/NRTR-90/02
1st Edition: September 1990**

by

Susan L. Rutherford and F. William Ravlin

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INTRODUCTION

The Shenandoah National Park LTEMs database system was developed in conjunction with the specific field sampling plans for forest, aquatic, and gypsy moth data collection. All data entry screens and data fields are tailored to handle the data forms which were designed for this project. With minor modifications the programs could be implemented for use in other ecological monitoring systems.

All programs were developed using dBASE IV[®] and then compiled for execution using CLIPPER[®]. Hardware requirements are an IBM compatible, preferably a 386 or 286 type machine, with a minimum of a 70 megabyte hard disk and a printer. With the rapid evolution of databases and computer systems this system configuration should be viewed as an initial configuration. With time, databases will become extremely large and may require more disk space, a tape backup system, or other mass storage devices which may be considered necessary additions to the system. Faster processors and computer clocks will also become available and users may wish to consider upgrading the computer for speed and convenience.

This manual is designed to aid data entry personnel and also to answer more technical questions about the installation and maintenance of the software. The first five chapters address data entry of the five classes of data: sites, forest, aquatic, gypsy moth, and dictionary support files. Each chapter contains its own chapter contents list and may be reproduced by itself to function as a data entry manual for that particular data type. The technical notes chapter will assist in installation and day-to-day operation of the database from a technical point of view. The programmer reference chapter gives more details about the dBASE code, the data files, and the relationships of the database files and indexes.

SITE DATABASE

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SITE DATABASE

Several keys will be important to know about during your session with the computer. The RETURN key is the one on the right of the keyboard with a <_]. This key is used to skip from one entry area (lighted box) to the next on the screen. The cursor is a blinking underline character on the screen which shows you where the next letter will type. To move the cursor there are four cursor keys found on the right of the keyboard. These are the 2,4,6, and 8 keys which also have direction arrows on them. The left and right arrows (4 and 6) will move left and right within the box where the cursor resides. The up and down arrows (2 and 8) will move the cursor to the next or previous box on the screen. During data entry the cursor will automatically move to the next box whenever you fill the previous box. The HOME key will take you to the beginning of the lighted box where the cursor resides. The END key will take to the end of that box. The INS key will allow you to insert characters between ones already there. The DEL key will delete characters. PGUP and PGDN will submit the entire screen to the database without typing in data for all boxes on the screen. The F3 key is found on the left side of the keyboard. This one is used by the programs to quit from a screen. Please note: if you quit NO DATA from that screen will be saved.

GETTING THE MENU

Once you have an C> on the screen type **LTEMS** and press RETURN. The menu will display as shown in Figure V.1.1.

```
Shenandoah National Park
Long Term Ecological Monitoring System
Main Menu

Which Subsystem do you want to access? :1 :

1 - Site data
2 - Forest data
3 - Aquatic data
4 - Gypsy moth data
5 - Dictionary maintenance
Q - Quit
```

Figure V.1.1. LTEMs main menu.

Option 1 will give you access to the site portion of the LTEMs database. To quit from the menu and return to DOS press F3 or type option Q. Once you have selected option 1 for site data, you

must select which function you would like to use using the site function menu as shown in Figure V.1.2.

```
Shenandoah National Park
Long Term Ecological Monitoring System
Site Menu

Enter option number:

1 - Enter new site data
2 - Correct site data
3 - Add data to an old site
4 - Delete a site
Q - Quit
```

Figure V.1.2. Site menu.

Option 1 allows you to enter new data into the site file. Option 2 allows data correction. To add data to a site in the site file use option 3. To quit and return to the main menu press F3 or type Q.

DATA ENTRY

Selection of data entry (option 1) will generate a data entry screen which is shown in Figure V.1.3.

```
Site Data

SITE #: 1L300
UTM North: 4301900   UTM East: 744100
Stream Name: Lands Run 9HA
Geological Formation:
Elevation (ft): 2100
Site Type: FR
Elevation Class: U
Vegetative Type: 4400
Quad: U45
Aspect Class: M

Option ( 1=Quit 2=Save Data): 2
```

Figure V.1.3. Site data entry screen.

Data should be filled in as shown in Figure V.1.3. The site number is a five digit code. The first number is the region code; 1 for North, 2 for Central and 3 for South. The second column is L for long-term or S for short-term plots. The last 3 digits are a unique site number for this site. UTMs are locational data for the entire site given in the Universal Transverse Mercator coordinate system. UTMs are validated to be sure they lie within the area defined by the quad

reference file as the minimum and maximum points. The stream name is the stream or drainage name of the area in which the site is located. Geological formation is entered for aquatic sites. Codes are listed in Table V.1.1. Elevation is given in feet. Site type is either aquatic or forest (see Table V.1.1). Quad is the quad code for the topographic quad where the site is located (see Table V.1.2). Aspect is either moist or dry (see Table V.1.1). Elevation class is entered for aquatic sites only, as upper or lower (see Table V.1.1). This is used because the upper sites on some streams is at an actual elevation which is higher than the lower site but not above 1800 feet. Vegetative type is the cover type for the entire site. It is coded using the cover type codes as defined for stand data (see Table V.1.1).

Table V.1.1. Site Record Variable Codes

Data Element	Value	Code
Geological formation		
	Hampton or Erwin	H
	Pedlar or Old Rag	P
	Catoctin	C
	Catoctin or Pedlar	CP
	Catoctin or Hampton	CH
Site type		
	Aquatic	AQ
	Forest	FR
Aspect class		
	Dry	D
	Moist	M
Elevation class		
	Upper	U
	Lower	L
Vegetative type		
	Chestnut oak	4400
	Red oak	5500
	Red oak/ash/ basswood (cove)	2001
	Yellow poplar	5700
	Black locust	5000
	Pine	2100
	Pitch pine	2101
	Virginia pine	2102
	Eastern white pine	2103
	Hemlock	2300
	Special forest type	9999

Table V.1.2. Quad Codes for SNP

Code	Quad Name
U44	BENTONVILLE
S43	BIG MEADOWS
R45	BRIGHTWOOD
P41	BROWN'S COVE
U45	CHESTER GAP
P40	CRIMORA
N41	CROZET
R42	ELKTON EAST
R41	ELKTON WEST
R43	FLETCHER
U46	FLINT HILL
P39	FORT DEFIANCE
P42	FREE UNION
V45	FRONT ROYAL
M40	GREENFIELD
Q40	GROTTOES
T43	LURAY
R44	MADISON
T46	MASSIE'S CORNER
Q41	MCGAHEYSVILLE
S44	OLD RAG MTN
U43	RILEYVILLE
Q44	ROCHELLE
Q43	STANARDSVILLE
S42	STANLEY
V44	STRASBURG
Q42	SWIFT RUN GAP
T44	THORNTON GAP
T45	WASHINGTON
N40	WAYNESBORO EAST
N39	WAYNESBORO WEST
S45	WOODVILLE

When a box is filled the cursor automatically moves to the next box. If you do not fill the box you must press the RETURN key to get to the next box. The last box is preset to option 2 (save the data). To quit and not save any data for a given screen, press F3 with the cursor on the SITE# block or type a 1 in the option box (last one on the screen). Once all data is typed you may use the PGDN key from any point on the screen to save the data. The site number is checked to be sure that it has not been used previously. If it has, you will not be able to save it without changing the code to a unique one.

DATA CORRECTION

Selection of data correction (option 2) will generate the question:

Enter site number to be corrected or press F3 to quit

Entry of a site number which is not yet in the database will produce the message:

No entry found for site number requested
Press any key to continue...

Entry of a valid site number will produce a screen as shown in Figure V.1.3. Changes may be made to any lighted box on the screen. The site number cannot be changed if it has been used in any of the other data files. You must first use aquatic or forestry data correction to change the site number on the data records.

Entry of a valid site number will produce a screen as shown in Figure V.1.3. You will be asked to "Enter a Y to delete the record." If you type a Y the site record will be deleted. Any other response will keep the record in the database. If the site number has been used in any of the other data records you will not be able to remove the site record.

ADD DATA TO AN OLD SITE

Selection of the add data option (option 3) will ask the question:

Enter site number to be corrected or press F3 to quit

Entry of a site number which is not yet in the database will produce the message:

No entry found for site number requested
Press any key to continue...

Entry of a valid site number will produce a screen as shown in Figure V.1.3. Data may be added to the site record in any of the lighted boxes.

DELETION OF A SITE

Selection of the deletion option (option 4) will ask the question:

Enter site number to be deleted or press F3 to quit

Entry of a site number which is not yet in the database will produce the message:

No entry found for site number requested
Press any key to continue...

FOREST DATABASE

CHAPTER CONTENTS

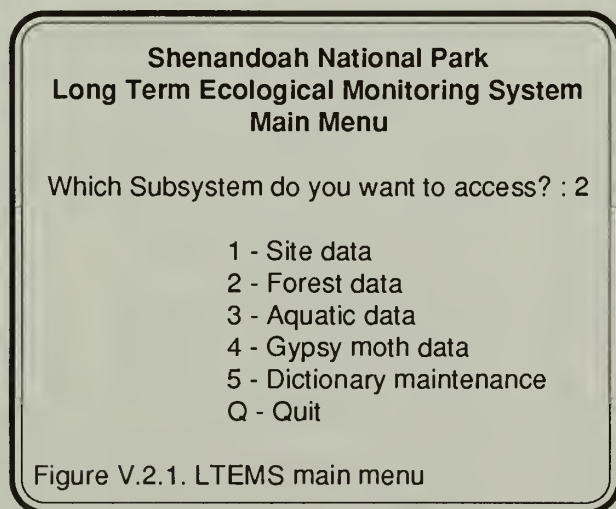
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FOREST DATABASE

Several keys will be important to know about during your session with the computer. The RETURN key is the one on the right of the keyboard with a <_]. This key is used to skip from one entry area (lighted box) to the next on the screen. The cursor is a blinking underline character on the screen which shows you where the next letter will type. To move the cursor there are four cursor keys found on the right of the keyboard. These are the 2,4,6, and 8 keys which also have direction arrows on them. The left and right arrows (4 and 6) will move left and right within the box where the cursor resides. The up and down arrows (2 and 8) will move the cursor to the next or previous box on the screen. During data entry the cursor will automatically move to the next box whenever you fill the previous box. The HOME key will take you to the beginning of the lighted box where the cursor resides. The END key will take to the end of that box. The INS key will allow you to insert characters between ones already there. The DEL key will delete characters. PGUP and PGDN will submit the entire screen to the database without typing in data for all boxes on the screen. The F3 key is found on the left side of the keyboard. This one is used by the programs to quit from a screen. Please note: if you quit NO DATA from that screen will be saved.

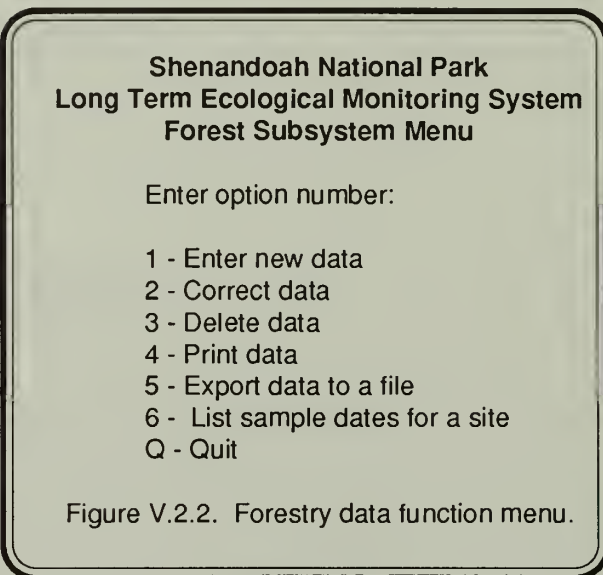
GETTING THE MENU

Once you have an **C>** on the screen type **LTEMS** and press RETURN. The menu will display as shown in Figure V.2.1.

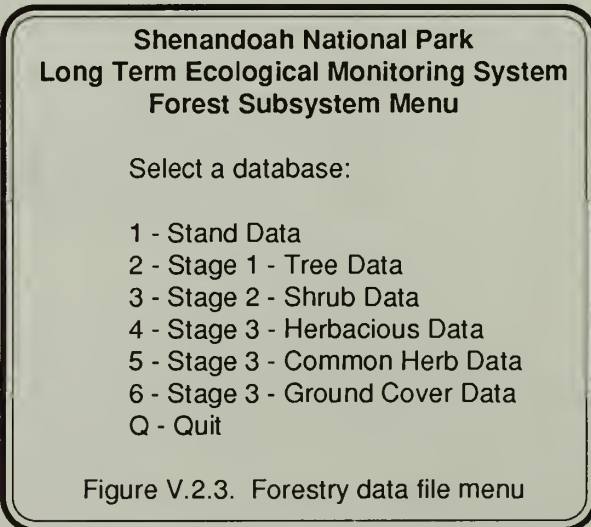


Option 2 will give you access to the forestry portion of the LTEMS database. To quit from the menu and return to DOS press F3 or type Option Q. Once you have selected Option 2 for forest data, you must select which function you would like to use using

the next menu as shown in Figure V.2.2. Please note: you must enter site data before you may enter any forest data for that site.



Option 1 allows you to enter new data into any of the forest data files. Option 2 allows data correction. To delete data from the forest data files use Option 3. Option 4 will allow you to print data for a site or subset of sites. Use option 5 to create an export data file. If you need to know what sample dates have been entered for a site use option 6. To quit and return to the main menu press F3 or type Q. After you have selected a function you will be given another menu (Fig. V.2.3) to select which data file you want to use.



On this screen you are given the choice of six different forest data types to use. Once you select the data type, you may perform the selected function numerous times on that data file. Once you quit from the data entry or correction screen, you will

be returned to the database selection menu. If you want to use the selected function (i.e enter data) you may select another database and continue working. If you need to select a new function, quit from the database selection and you will get the function selection menu (Fig. V.2.2).

DATA ENTRY

Stand Data Entry

Selection of the stand data type (Option 1) will generate a data entry screen which is shown in Figure V.2.4.

Stand Data

Site #: 1L001 Plot #: 1 Sample date:8/17/88
 Basal Area Factor: 10.0
 Slope(%): 45
 Aspect(AZ): 150
 Slope Position(SU,SH,TS,BS,FS,FP,TE): TE
 Slope Shape (V,X,P): V
 Cover Type: 8800
 Stand Structure (E,T,U): E
 Land Form: CV
 Comments: this is a space for comments
 Option (1=Quit 2=Save Data): 2

Figure V.2.4. Stand data entry screen

Data should be filled in as shown in Figure V.2.4. Units and valid ranges for each item are listed in Table V.2.1. Codes for items which have been assigned codes are listed in Table V.2.2. As each box is filled the cursor automatically moves to the next box. If you do not fill a box you must press the RETURN key to get to the next box. The last box in preset to Option 2 (save the data). To quit and not save any data for a given screen press F3 with the cursor on the site block or type a 1 in the option box (last one on the screen). Once the data is typed you may use the PGDN key from any point on the screen to save the data. All data is validated to be sure the value is in range or a valid code. The combination of the site number and sample date must be unique. If data has already been entered for this site and date you will be given an error message and told to use the correction option to change the data which has been typed. If you have made a typing mistake on the site or date retype them and try to save the data again. Any range or code errors will generate error messages on the screen. If there are any errors, the data will not be saved in the database.

After entry of a stand record the program will automatically cycle through tree, shrub, and herb screens to allow you to enter all the forest information for a given plot. To return to the stand data entry screen quit from the tree data entry screen by pressing F3. Be sure to enter the proper plot and subplot number on the tree, shrub, and regen screens when you are entering data.

Table V.2.1: Stand Data Units and Ranges

Data Element	Data Type	Unit	Range
Basal area	Numeric	factor	5.0 - 25.0
Slope	Numeric	%	0 - 200
Aspect	Numeric	azimuth	0 - 360
Slope position	2 Letters	code	Table V.2.2
Slope shape	1 Letter	code	Table V.2.2
Cover type	4 Numbers	code	Table V.2.2
Stand structure	1 Letter	code	Table V.2.2
Land form	2 Letters	code	Table V.2.2

Table V.2.2: Stand Data Variable Codes

Data element	Value	Code
Cover type		
	Chestnut oak	4400
	Red oak	5500
	Red oak/ash/ basswood (cove)	2001
	Yellow poplar	5700
	Black locust	5000
	Pine	2100
	Pitch pine	2101
	Virginia pine	2102
	Eastern white pine	2103
	Hemlock	2300
	Special forest type	9999
Slope Position		
	Summit	SU
	Shoulder	SH
	Back Slope	BS
	Toe Slope	TS
	Foot Slope	FS
	Flood Plain	FP
	Terrace	TE
Slope Shape		
	Concave	V
	Convex	X
	Planar	P

Table V.2.2(cont): Stand Data Variable Codes

Data element	Value	Code
Structure	Even aged	E
	Two aged	T
	Uneven aged	U
Land form	Ridge top	RT
	Spur ridge	SR
	No slope	NS
	Head slope	HS
	Side slope	SS
	Cove	CV
	Draw	DW

Stage 1 - Tree Data Entry

Selection of the Stage 1 - tree data entry (Option 2 of the data type selection menu shown in Figure V.2.3) will generate a data entry screen shown in Figure V.2.5.

Intensive Plots - Tree data

Site #: 1L001 Plot #: 1 Sample Date: 08/17/87

Quadrant	X	Y	Spe	DBH	D	Crwn	Crw	Notes	Age	Ht
3	2	3	QRB	25	D	2	15	2	15	10

Figure V.2.5. Tree data entry screen.

The first line of the screen will appear first. This should be filled in with the site number, sample date, and a plot number. The site number, date, and plot number together form a unique code for this sample of plants. If this combination has been entered before you will be asked if you want to add plants to a sample typed previously. If you answer yes(Y) or true(T), you may add plants. If you answer no(N) or false(F), you can change the site, date, or plot number and try again. The answer is preset to add more plants to the sample. You may quit entry at any time and resume entering trees at a later session. Be sure to mark your place on the data sheet when you stop. When adding more trees to a plot record, previously typed entries are not displayed on the screen. Please note: the plot number will range from 1 to 10 for forest data at aquatic sites and should be entered as 1 to 9 and 0 for 10. There is only 1 digit for the plot number.

After the top line has been entered, you will be able to enter multiple lines of plant data on the lower part of the screen. You must enter a species code in that block of each line. If this species code is left blank or you enter QUIT as the code, you will return to a blank data entry screen to enter a new site, date, plot number combination. You may also quit by pressing the F3 key for the species code.

Each plant line is validated as it is typed and saved. Units and valid ranges for stage 1 data are presented in Table V.2.3. Codes assigned to specific variables are listed in Table V.2.4. Species codes are validated against the plant dictionary. A species code may be added to the dictionary by accessing the dictionary data entry menu. A complete listing of species codes in the dictionary (as of Jan. 1990) is presented in Appendix V.A.1. The description for the species code is obtained from the dictionary and will display on the screen when the data is validated. Quadrate refers to the 16 blocks within each plot layout. X and Y are distances from the corner of the quadrat to the tree in meters. The D column refers to Live or Dead. A blank in this column is converted to live.

After each tree plot you will get the shrub data entry screen to enter all the shrub subplots and their regen plots. Enter the shrub plot number on the shrub screen heading to enter data or press F3 to quit.

Table V.2.3: Stage 1 Data Units and Ranges

Data Element	Data type	Unit	Range
Quadrat	Numeric		1-16
X	Numeric	meter	0-6
Y	Numeric	meter	0-6
Species	3 Letters	code	App. V.A.1
DBH	Numeric	cm	5-120
D(live/dead)	1 Letter	code	Table V.2.4
Crown health	1 Number	code	Table V.2.4
Crown class	1 Letter	code	Table V.2.4
Notes	1 Number	code	Table V.2.4
Age	Numeric	years	
Height	Numeric	feet	1-200

Table V.2.4: Stage 1 Variable Codes

Data Element	Value	Code
Crown Class	Dominant	D
	Codominant	C
	Intermediate	I
	Supressed	S
Live/Dead	Live	L or blank
	Dead	D
Crown health	90-100%	1
	89-50%	2
	1-49%	3
	Recently dead	4
	Dead	5
Notes	Top Missing	1
	Insect Damage	2
	Animal Damage	3
	Stem Disease	4
	Lean > 45%	5
	Lightning Damage	6
	Ice Damage	7
	Other	8

Stage 2 - Shrub Data Entry

Selection of the Stage 2 - shrub data entry (Option 3 of the data type selection menu shown in Figure V.2.3) will generate a data entry screen shown in Figure V.2.6.

Intensive Plots - Understory

Site #: 1L001 Tree Plot #: 1 Shrubplot #: 1
Sample date: 08/17/87

2nd Stage - Shrub data

Species Code: QRB ARB
Stems: 25 15

Figure V.2.6. Shrub data entry screen.

The first two lines of the screen will appear first. These should be filled in with the site number, sample date, a plot number, and the shrubplot within the plot. The site number, date, plot number, and shrubplot number together form a unique code for this

sample of plants. If this combination has been entered before you will be asked if you want to add plants to a sample typed previously. If you answer yes(Y) or true(T), you may add plants. If you answer no(N) or false(F), you can change the site, date, plot, or shrubplot number and try again. The answer is preset to add more plants to the sample. Please note the tree plot number will range from 1 to 10 for forest data at aquatic sites and should be entered as 1 to 9 and 0 for 10. There is only 1 digit for the plot number. Only 1 shrub plot is taken at each tree prism point and therefore the shrub plot number is always 1 on an aquatic site.

After the top two lines have been entered, you will be able to enter multiple columns of plant data on the lower part of the screen. You must enter a species code in the top block of each column. If this species code is left blank or you enter QUIT as the code, you will return to a blank data entry screen to enter a new site, date plot number combination. You may also quit by pressing the F3 key for the species code.

Each plant is validated as it is typed and saved. Species codes are validated against the plant dictionary. A species code may be added to the dictionary by accessing the dictionary data entry menu. A complete listing of species codes in the dictionary is presented in Appendix V.A.1. The stem count must be numeric. After the shrub data has been entered you will get a regen screen to enter herb data.

Stage 3 - Herb Data Entry

Selection of the Stage 3 - herb data entry or (Option 4 of the data type selection menu shown in Figure V.2.3) will generate a data entry screen shown in Figure V.2.7.

Intensive Plots - Understory

Site #: 1L001 Plot #: 1 Shrubplot #: 1
Sample date:08/17/87 Herbplot #: 1

3rd Stage - Regeneration plot 1

Species Code: ARB QRB
Stems: 25 15

Figure V.2.7: Herbacious data entry screen.

The first two lines of the screen will appear first. These should be filled in with the site number, sample date, a plot number, and the shrubplot within

the plot. The herb plot number is preset to start at 1 but may be changed by typing over it. The site number, date, plot number, shrubplot number and herb plot number together form a unique code for this sample of plants. If this combination has been entered before you will be asked if you want to add plants to a sample typed previously. If you answer yes(Y) or true(T), you may add plants. If you answer no(N) or false(F), you can change the site, date, plot, shrubplot, or herb plot number and try again. The answer is preset to add more plants to the sample.

After the top two lines have been entered, you will be able to enter multiple columns of plant data on the lower part of the screen. Each plant is validated as it is typed and saved. Species codes are validated against the plant dictionary. A species code may be added to the dictionary by accessing the dictionary data entry menu. A complete listing of species codes in the dictionary is presented in Appendix V.A.2. The stem count must be numeric.

You must enter a species code in the top block of each column. If this species code is left blank or you enter QUIT as the code, you will continue on to enter the ground cover percentages and the most common herb species. You may also continue to the ground cover by pressing the F3 key for the species code. If there are no species present for this herbplot you must enter NON (none) for the species in order to proceed to the ground cover screen.

Stage 3 - Common Herb Data Entry

Selection of the Stage 3 - common herb data entry (Option 5 of the data type selection menu shown in Figure V.2.3) will generate a data entry screen shown in Figure V.2.8. Up to five common herba-

Intensive Plots - Understory

Site #: 1L001 Plot #: 1 Shrubplot #: 1
 Sample date:08/17/87 Herbplot #: 1

3rd Stage - Regeneration plot 1

Species Code:	ARB	QRB
# Stems:	25	15

Ground Cover Percentages 5 Most Common Herbs
 Rock Org. Woody Mineral Herbaceous
 Litter Debris Soil F G S SR Spe. %Cover

4	1	2	1	2	1	1	2	QRB	3
---	---	---	---	---	---	---	---	-----	---

Figure V.2.8: Common herb / ground cover data entry screen.

ceous species may be entered on the right side of the screen using the species codes from Appendix V.A.2 and a cover class rating from Table V.2.5. Species codes will be validated using the plant dictionary.

Table V.2.5: Stage 3 Variable Codes

Data Element	Value	Code
Cover Class	0%	0
	1-7%	1
	8-25%	2
	26-50%	3
	51-75%	4
	75-93%	5
	94-100%	6
Herbaceous codes	Forbes	F
	Grasses	G
	Sedges	S
	Squawroot	SR

Stage 3 - Ground Cover Data Entry

Selection of the Stage 3 - ground cover data entry (Option 6 of the data type selection menu shown in Figure V.2.3) will generate a data entry screen shown in Figure V.2.8. The ground cover percentages are entered on the left half of the screen using the cover class ratings (0-6). Table V.2.5 presents cover class and herbacious codes.

Getting Out

Quitting from the data file selection menu with the F3 key or Q option will display the function selection menu shown in Figure V.2.2.

DATA CORRECTION

Selection of Option 2 (data correction) on the function menu will display the data file selection menu shown in Figure V.2.3.

Special Notes About Site, Plot, Date Changes

If changes are to be made to all records which have been entered for a given site, sample date, plot number combination some care must be used to utilize the proper options to make the change you need to. If all records for a plot and date combination in the stand, tree, shrub, and herb data sets are to have the plot, site, or date changed, use the stand

data correction and then use Option 1 of the correction options. If the stand record is to be left alone and the site, plot, or date is to be changed in the tree, shrub and herb data sets, use the tree data correction and then use Option 1 of the correction options. Both of these ways of making changes will change all the shrubplot and herbplot records associated with the requested plot.

If site, plot, date, or shrubplot changes are to be made to a given shrubplot in both the shrub and the herb records, use the shrub data correction and then use Option 1 of the correction options. Use of a ? for the shrubplot will change the site, date, or plot of all shrub and herb records for all shrubplots within the plot.

If site, plot, date, shrubplot, or herbplot changes are to be made to a given herbplot in the herb record, use the herb data correction and then use Option 1 of the correction options. Use of a ? for the herbplot will change the site, date, plot, or shrubplot of all herb records for all herbplots within the shrubplot.

Stand Data Correction

Selection of the stand data type (Option 1) will generate the question:

Enter site number and sample date and plot number to be corrected or press F3 to quit

Site #: Plot #: Sample date: / /

Entry of a site number, plot number, sample date combination that does not exist in the database will produce the message:

Site number, sample date, plot number combination does not exist in database
Press any key to continue...

Entry of a valid site date combination will produce the question:

What do you want to change?
Enter one of the following codes: 2

1 - Change site #, sample date, plot #, on all stand, tree, shrub, and herb records for this plot

2 - Change information on this stand record

Use Option 1 to change the plot number, sample date or site number on all records with the selected site, date, plot number combination in all six forestry data types. You will get a screen with the top part of form. You make the appropriate changes and save the data. The new combination will be checked to be sure it has not yet been used. If the new combination is already in the database you will be given the option to retype the plot number, sample date, or site number or QUIT. This option will change all records for this plot in the Stage 1, Stage 2, Stage 3, ground cover, and common herb databases as well as the stand record. All tree, shrub and herb lines which are changed will be displayed on the screen as they are changed.

Option 2 only changes the stand record and allows changes to all data items in the record. A screen like the data entry screen shown in Figure V.2.4 appears. Make any corrections in the lighted boxes of the screen. If the site, plot, or date is changed it will be checked to be sure the combination has not been used previously. All data validation described for data entry will be done for corrected data as well. If a data item is invalid the old value is retained in the database.

Stage 1 - Tree Data Correction

Selection of the Stage 1 - tree data type (Option 2) will generate the question:

Enter site number and sample date and plot number to be corrected or press F3 to quit

Site #: Plot #: Sample date: / /

Entry of a site number, sample date, plot number combination that does not exist in the database will produce the message:

Site number, sample date, plot number combination does not exist in database
Press any key to continue...

Entry of a valid site, date, plot number combination will produce the question:

What do you want to change?
Enter one of the following codes: 5

- 1 - Change site #, sample date, plot #, on all tree, shrub, and herb records for this plot
- 2 - Change site #, sample date, plot #, on all tree records for this plot
- 3 - Change site #, sample date, plot #, on certain tree lines of this plot
- 4 - Change tree data on a given tree line
- 5 - Display tree lines without making corrections
- Q - Quit

Use Option 1 to change the plot number, sample date, or site number on all records with the selected site, date, plot number combination in the Stage 1, Stage 2, and Stage 3 databases. You will get a screen with the top part of form. You make the appropriate changes and save the data. The new combination will be checked to be sure it has not yet been used. If the new combination is already in the database you will be given the option to add the plants from the old combination to this record. This option will change all records for this plot in all plant databases. All tree, shrub, and herb lines which are changed will be displayed on the screen as they are changed.

Option 2 behaves like Option 1 except that it only changes the records for this plot which are contained in the stage 1 database (tree records only).

Option 3 behaves similarly to Option 2 except that instead of changing all records it is selective. Once you have made changes as stated above you will get a screen showing all tree lines and their record numbers. You will then be asked to "Enter record number to be changed or Q to quit". This question will repeat until you quit, changing each record specified.

Option 4 allows you to change information on a specific tree line. You will get a screen like the data entry screen showing the tree sample lines and the record number for each line. You will then be asked "Enter record number to be changed or Q to quit". Enter the number shown on the line you need to correct. The entire line will appear at the bottom of the screen in lighted boxes. Make the changes and save them. Validation will be done as described for data entry. Any invalid data will revert to the original value and not be changed in the database. Changes you make will not reflect on the upper portion of the screen interactively. If you wish to view the changes you can quit and then use Option 5 of the correction question to view the plant data without making changes.

Option 5 displays the tree data but does not allow you to make any corrections until you use Option 1, 2, 3, or 4.

Stage 2 - Shrub Data Correction

Selection of the Stage 2 - shrub data type (Option 3) will generate the question:

Enter site number, sample date, plot #, and subplot # to be corrected or press F3 to quit

To change site#, date or plot# on all subplots enter ? for subplot

Site #:1L001 Plot #:4 ShrubPlot #:?
Sample date:08/17/87

Entry of a site number, sample date, plot, shrubplot number combination that does not exist in the database will produce the message:

Site number, sample date, plot, shrubplot number combination does not exist in database

Press any key to continue...

Entry of a valid site, date, plot, shrubplot number combination will produce the question:

What do you want to change?
Enter one of the following codes: 5

- 1 - Change site #, sample date, plot #, subplot # on all shrub, and herb records for this plot
- 2 - Change site #, sample date, plot #, subplot # on all shrub records for this plot
- 3 - Change site #, sample date, plot #, subplot # on certain shrub lines of this plot
- 4 - Change shrub data on a given shrub line
- 5 - Display shrub lines without making corrections
- Q - Quit

Use Option 1 to change the plot number, shrubplot number, sample date, or site number on all records with the selected site, date, plot, shrubplot number combination in the Stage 2 and Stage 3 databases. You will get a screen with the top part of form. You make the appropriate changes and save the data. The new combination will be checked to be sure it has not yet been used. If the new combination is already in the database you will be given the option

to add the plants from the old combination to this record. This option will change all records for this plot in the stage 2 and stage 3 databases. All shrub and herb lines which are changed will be displayed on the screen as they are changed.

Option 2 behaves like Option 1 except that it only changes the records for this plot which are contained in the stage 2 database (shrub records only).

Option 3 behaves similarly to Option 2 except that instead of changing all records it is selective. Once you have made changes as stated above you will get a screen showing all shrub lines and their record numbers. You will then be asked to "Enter record number to be changed or Q to quit". This question will repeat until you quit, changing each record specified.

Option 4 allows you to change information on a specific shrub line. You will get a screen like the data entry screen showing the shrub sample lines and the record number for each line. You will then be asked "Enter record number to be changed or Q to quit". Enter the number shown on the line you need to correct. The entire line will appear at the bottom of the screen in lighted boxes. Make the changes and save them. Validation will be done as described for data entry. Any invalid data will revert to the original value and not be changed in the database. Changes you make will not reflect on the upper portion of the screen interactively. If you wish to view the changes you can quit and then use Option 5 of the correction question to view the plant data without making changes.

Option 5 displays the shrub data but does not allow you to make any corrections until you use Option 1, 2, 3, or 4.

Stage 3 - Herb Data Correction

Selection of the Stage 3 - herb data type (Option 4) will generate the question:

Enter site number, sample date, plot #, shrubplot#, and herb to be corrected or press F3 to quit.

To change site#, date, plot# or shrubplot# on all herbplots enter ? for herbplot

Site#:1L001 Plot#:4 ShrubPlot#:1
HerbPlot#: ? Sample date:08/17/87

Entry of a site number, sample date, plot, shrubplot number combination that does not exist in the database will produce the message:

Site number, sample date, plot, shrubplot, herbplot number combination does not exist in database
Press any key to continue...

Entry of a valid site, date, plot, shrubplot, herbplot number combination will produce the question:

What do you want to change?
Enter one of the following codes: 5

- 1 - Change site #, sample date, plot #, sub-plot#, herbplot# on all herb records for this plot
- 3 - Change site #, sample date, plot #, sub-plot#, herbplot# on certain herb lines of this plot
- 4 - Change herb data on a given herb line
- 5 - Display herb lines without making corrections
- 6 - Change ground cover percentages on a given herb line
- 7 - Display ground cover data without making corrections
- 8 - Change common herb percentages on a given herb line
- 9 - Display common herb data without making corrections

Use Option 1 to change the plot number, shrubplot number, herbplot number, sample date or site number on all records with the selected site, date, plot, shrubplot, herbplot number combination in the Stage 3 databases. You will get a screen with the top part of form. You make the appropriate changes and save the data. The new combination will be checked to be sure it has not yet been used. If the new combination is already in the database you will be given the option to add the plants from the old combination to this record. This option will change all records for this plot in the stage 3 database (herb records, ground cover percentages, and common herb species).

Option 3 behaves similarly to Option 1 except that instead of changing all records it is selective. Once you have made changes as stated above you will get a screen showing only herb lines and their record numbers. You will then be asked to "Enter record number to be changed or Q to quit". This

question will repeat until you quit, changing each record specified.

Option 4 allows you to change information on a specific herb line. You will get a screen like the data entry screen showing the herb sample lines and the record number for each line. You will then be asked "Enter record number to be changed or Q to quit". Enter the number shown on the line you need to correct. The entire line will appear at the bottom of the screen in lighted boxes. Make the changes and save them. Validation will be done as described for data entry. Any invalid data will revert to the original value and not be changed in the database. Changes you make will not reflect on the upper portion of the screen interactively. If you wish to view the changes you can quit and then use Option 5 of the correction question to view the plant data without making changes.

Option 6 allows you to change information on the ground cover percentage line. You will get a screen like the data entry screen showing the ground cover percentage line. Make the changes and save them. Validation will be done as described for data entry. Any invalid data will revert to the original value and not be changed in the database. Changes you make will not reflect on the screen interactively. If you wish to view the changes you can quit and then use Option 7 of the correction question to view the ground cover data without making changes.

Option 8 allows you to change information on a specific common herb line. You will get a screen like the data entry screen showing the common herb sample lines and the record number for each line. You will then be asked "Enter record number to be changed or Q to quit". Enter the number shown on the line you need to correct. The entire line will appear at the bottom of the screen in lighted boxes. Make the changes and save them. Validation will be done as described for data entry. Any invalid data will revert to the original value and not be changed in the database. Changes you make will not reflect on the upper portion of the screen interactively. If you wish to view the changes you can quit and then use Option 9 of the correction question to view the common herb data without making changes.

Options 5, 7, and 9 display the herb data but do not allow you to make any corrections until you use Option 1, 3, 4, 6, or 8.

DELETION OF ENTRIES

Selection of Option 3 (delete data) on the function menu will display the data file selection menu shown in Figure V.2.3. Deletions of whole plots,

shrubplots, or herbplots are possible, as well as single data line deletion. The deletion process works exactly like the correction process. For a discussion of selection of the proper option selection within the delete menu refer to the section entitled Special Notes About Site Plot Date Changes in Data Correction.

Stand Data Deletion

Selection of the stand data option will ask the question:

Enter site number and sample date and plot number to be deleted or press F3 to quit

Site #: 1L001 Plot #: 1
Sample date: 08/17/87

Entry of a site plot date combination which is not yet in the database will produce the message:

Site number, sample date, plot number combination does not exist in database
Press any key to continue...

Entry of a valid combination will generate the question:

What do you want to delete?
Enter one of the following codes: 2

- 1 - Delete all stand, tree, shrub, and herb records for this plot
- 2 - Delete this stand record
- Q - Quit

Use Option 1 to delete the plot number, sample date or site number combination all six forestry data types. You will get a screen displaying the entire stand record and be asked:

Press Y to delete this stand record

If you enter Y the stand record will be removed and the screen will then display all lines of the tree data, shrub data, and herb data to be removed and again ask if these records should be removed. If you answer anything except Y you will quit from this stand record deletion and keep the record in the database.

This option will delete all records for this plot in the Stage 1, Stage 2, and Stage 3 databases as

well as the stand record. Option 2 only deletes the stand record.

Stage 1 - Tree Data Deletion

Selection of the tree data option will ask the question:

Enter site number and sample date and plot number to be deleted or press F3 to quit

Site #: 1L001 Plot #: 1
Sample date: 08/17/87

Entry of a site plot date combination which is not yet in the database will produce the message:

Site number, sample date, plot number combination does not exist in database
Press any key to continue...

Entry of a valid combination will generate the question:

What do you want to delete?
Enter one of the following codes: 4

- 1 - Delete all tree, shrub, and herb records for this plot
- 2 - Delete all tree records for this plot
- 3 - Delete certain tree lines of this plot
- 4 - Display tree lines without making corrections
- Q - Quit

Option 1 or 2 will display the tree lines on the screen. At the bottom you will be asked to "Press Y to delete all records for this sample". Any other key will keep the data and return to the menu. All tree shrub and herb data for the site, date, plot number combination will be deleted using Option 1. Only tree data will be deleted using Option 2.

Option 3 allows you to specify which tree sample line you need to delete. You will be shown the tree data with the record numbers. You will then be asked: "Enter record number to be deleted or Q to quit". The record you request will then be displayed at the bottom of the screen with the question: "Is this the record to delete? enter Y to delete". Enter a Y to delete that one tree entry. Any other key will save the record and ask for another record number to delete. You must quit from the record number question to return to the menu.

Option 4 allows to view all tree data for a given site, date, plot number without deleting the data.

Stage 2 - Shrub Data Deletion

Selection of the shrub data option will ask the question:

Enter site number, sample date, plot #, and subplot # to be deleted or press F3 to quit
To change site#, date or plot# on all subplots enter ? for subplot

Site #: 1L001 Plot #: 4 Shrub Plot #: ?
Sample date: 08/17/87

Entry of a site plot shrubplot date combination which is not yet in the database will produce the message:

Site number, sample date, plot, shrubplot number combination does not exist in database
Press any key to continue...

Entry of a valid combination will generate the question:

What do you want to delete?
Enter one of the following codes: 1

- 1 - Delete all shrub, and herb records for this plot
- 2 - Delete all shrub records for this plot
- 3 - Delete certain shrub lines of this plot
- 4 - Display shrub lines without making corrections
- Q - Quit

Option 1 or 2 will display the shrub lines on the screen. At the bottom you will be asked to "Press Y to delete all records for this sample". Any other key will keep the data and return to the menu. All shrub and herb data for the site, date, plot number combination will be deleted using Option 1. Only shrub data will be deleted using Option 2.

Option 3 allows you to specify which shrub sample line you need to delete. You will be shown the shrub data with the record numbers. You will then be asked: "Enter record number to be deleted or Q to quit". The record you request will then be displayed at the bottom of the screen with the question: "Is this

the record to delete? enter Y to delete". Enter a Y to delete that one shrub entry. Any other key will save the record and ask for another record number to delete. You must quit from the record number question to return to the menu.

Option 4 allows to view all shrub data for a given site, date, plot, shrubplot number without deleting the data.

Stage 3 - Herb Data Deletion

Selection of the herb data option will ask the question:

Enter site number, sample date, plot #, subplot#, and herb to be deleted or press F3 to quit.

To change site#, date, plot# or subplot# on all herbplots enter ? for herbplot

Site#: 1L001 Plot#: 4 Sub Plot#:1 Herb Plot#: 1
Sample date: 08/17/87

Entry of a site plot shrubplot herbplot date combination which is not yet in the database will produce the message:

Site number, sample date, plot, shrubplot number combination does not exist in database
Press any key to continue...

Entry of a valid combination will generate the question:

What do you want to delete?
Enter one of the following codes: 1

- 1 - Delete all herb records for this plot
- 3 - Delete certain herb lines of this plot
- 4 - Display herb lines without making corrections
- 5 - Delete ground cover percentages for plot
- 6 - Display ground cover percentages without making corrections
- 7 - Delete certain common herb lines of this plot
- 8 - Display common herb lines without making corrections
- Q - Quit

Option 1 will display the herb lines on the screen. At the bottom you will be asked to "Press Y

to delete all records for this sample". Any other key will keep the data and return to the menu. All herb data for the site, date, plot, shrubplot, herbplot number combination will be deleted using Option 1.

Option 3 allows you to specify which herb sample line you need to delete. You will be shown the herb data with the record numbers. You will then be asked: "Enter record number to be deleted or Q to quit". The record you request will then be displayed at the bottom of the screen with the question: "Is this the record to delete? enter Y to delete". Enter a Y to delete that one herb entry. Any other key will save the record and ask for another record number to delete. You must quit from the record number question to return to the menu.

Option 5 allows you to specify which ground cover percentage line you need to delete. You will be shown the ground cover data with the record numbers. You will then be asked: "Enter record number to be deleted or Q to quit". The record you request will then be displayed at the bottom of the screen with the question: "Is this the record to delete? enter Y to delete". Enter a Y to delete that one ground cover entry. Any other key will save the record and ask for another record number to delete. You must quit from the record number question to return to the menu.

Option 7 allows you to specify which common herb sample line you need to delete. You will be shown the common herb data with the record numbers. You will then be asked: "Enter record number to be deleted or Q to quit". The record you request will then be displayed at the bottom of the screen with the question: "Is this the record to delete? enter Y to delete". Enter a Y to delete that one common herb entry. Any other key will save the record and ask for another record number to delete. You must quit from the record number question to return to the menu.

Options 4, 6, and 8 allow to view all herb data for a given site, date, plot, shrubplot number without deleting the data.

PRINTING THE DATA

Selection of Option 4 of the function menu (Figure V.2.2) will allow you to print a detailed forest inventory on an individual site basis. First you will be asked whether you want to print the output to the screen (S), printer (P) or a file (F) or quit (Q). If you want to send the output to a file to be printed using a wordprocessor or other means you will be asked for the name of the output file. The output file will be written to the current directory of the hard disk unless you specify another path.

You are then given the option to print 1 Site and Date (1), a Range of sites (R), or Search the Database (S). If you select 1 you will be asked for the site number and sample date to be printed. If you ask for a Range of sites you will be asked:

Enter Beginning Site:
 Enter Ending Site:
 Enter Beginning Date: / /
 Enter Ending Date: / /

All forest data for sites in the site number range and date sampled range will be printed. If you request to search the database you will be given a screen to fill in the parameters describing the sites you wish to print as shown in Figure V.2.9.

Indicate which items are to be selected for below

Type ALL or leave items blank to include all values

District (N,C,S,ALL):
 Aspect Class(D,M,N,ALL):
 Cover type (code):
 Elevation Min: Max:
 Slope Class (1,2,3,ALL):
 Slope Pos (TS,SU,SH,BS,FS,FP,TE,ALL):
 Aquatic or Forest sites (AQ,FR):
 Beginning Date: / / Ending Date: / /

Figure V.2.9. Output parameter specification menu

All sites which satisfy all the selection criteria you supply on the screen will be printed. Each individual site is printed as shown in Appendix V.B. Each vegetation summary will be several pages of output.

The vegetation summary lists the site number and site classification variables followed by stand characteristics of plot 1. Tree data for that plot includes for each species: the number of live trees, the relative density (percent of total trees for the plot which is this species), average DBH (cm), basal area (m²/HA), and the relative dominance (percent of total basal area for the plot).

Shrub data shows the number of stems for each species and the percent of the total stems

(relative density). Regeneration data also shows number of stems and relative density per species. Ground cover percentages and the five most common herbaceous species print using the cover class codes entered in the database (see Table V.2.5).

EXPORTING TO A FILE

Option 5 of the data function menu (Figure V.2.2) will allow you to export a data file for use by another software package. You will be asked: Do you want to subset the data (S) or export the entire file (E)? If you want to subset the file you will be given the parameter specification screen as presented in Figure V.2.9. Once the parameters are stored you will be asked which database file you want to export (Fig. V.2.10). You may select more than one file for the same set of parameters. Each time you select a database it will ask you to name a file for the output file and then write records to that file. The output file will be written to the current directory of the hard disk unless you specify another path. The record format of the exported files for each database are shown in tables V.2.6 through V.2.12.

**Shenandoah National Park
 Long Term Ecological Monitoring System
 Export File Menu**

Enter database to export

- 1 - Site File
- 2 - Stand File
- 3 - Tree File
- 4 - Shrub File
- 5 - Herb File
- 6 - Ground Cover File
- 7 - Common Herb File
- Q - Quit

Figure V.2.10. LTEMs export file menu

Table V.2.6: Site Record Export File

Columns	Data description	Length
1-5	Site number	5
6-15	UTM North	10
16-25	UTM East	10
26-27	Geologic formation	2
28-31	Elevation	4
32-56	Stream name	25
57-58	Soil type	2
59-61	Quadrangle code	3
62-63	Aquatic or forest site (AQ,FR)	2
64-64	Aspect class	1
65-65	Elevation class (U,L)	1
66-70	Cover type for entire site	5

Table V.2.7: Stand Record Export File

Columns	Data description	Length
1-5	Site Number	5
6-13	Sample date (yyyymmdd)	8
14-18	Cover type for plot	5
19-20	Stand structure	2
21-21	Plot number	1
22-24	Aspect	3
25-27	Slope	3
28-29	Slope position	2
30-30	Slope shape	1
31-32	Land form	2
33-36	Basal area	4
37-40	Elevation	4
41-42	Geologic formation	2
43-47	Cover type for entire site	5
48-48	Aspect class	1

Table V.2.8: Stage 1 Record Export File

Columns	Data description	Length
1-5	Site number	5
6-13	Sample date (yyyymmdd)	8
14-14	Plot number	1
15-17	Species code	3
18-22	DBH	5
23-23	Crown class	1
24-24	Live/dead status	1
25-27	Tree age	3
28-30	Tree height	3
31-31	Note 1	1
32-32	Note 2	1
33-33	Note 3	1
34-34	Crown health	1
35-36	Land form	2
37-41	Cover type for plot	5
42-43	Stand structure	2
44-46	Aspect	3
47-49	Slope	3
50-51	Slope position	2
52-52	Slope shape	1
53-56	Basal area	4
57-60	Elevation	4
61-62	Geologic formation	2
63-67	Cover type for entire site	5
68-68	Aspect class	1

Table V.2.9: Stage 2 Record Export File

Columns	Data description	Length
1-5	Site number	5
6-13	Sample date (yyyymmdd)	8
14-14	Plot number	1
15-15	Shrub plot number	1
16-18	Species code	3
19-21	Stem count	3
22-23	Land form	2
24-28	Cover type for plot	5
29-30	Stand structure	2
31-33	Aspect	3
34-36	Slope	3
37-38	Slope position	2
39-39	Slope shape	1
40-43	Elevation	4
44-45	Geologic formation	2
46-50	Cover type for entire site	5
51-51	Aspect class	1

Table V.2.10: Stage 3 Record Export File

Columns	Data description	Length
1-5	Site number	5
6-13	Sample date	8
14-14	Plot number	1
15-15	Shrub plot number	1
16-16	Herb plot number	1
17-19	Species code	3
20-22	Stem count	3
23-24	Land form	2
25-29	Cover type for plot	5
30-31	Stand structure	2
32-34	Aspect	3
35-37	Slope	3
38-39	Slope position	2
40-40	Slope shape	1
41-44	Elevation	4
45-46	Geologic formation	2
47-51	Cover type for entire site	5
52-52	Aspect class	1

Table V.2.12: Stage 3 Common Herb Record Export File

Columns	Data description	Length
1-5	Site number	5
6-13	Sample date	8
14-14	Plot number	1
15-15	Shrub plot number	1
16-16	Herb plot number	1
17-19	Species code	3
20-20	Cover class	1
21-22	Land form	2
24-27	Cover type for plot	5
28-29	Stand structure	2
30-32	Aspect	3
33-35	Slope	3
36-37	Slope position	2
38-38	Slope shape	1
39-42	Elevation	4
43-44	Geologic formation	2
45-49	Cover type for entire site	5
50-50	Aspect class	1

Table V.2.11: Stage 3 Ground Cover Record Export File

Columns	Data description	Length
1-5	Site number	5
6-13	Sample date	8
14-14	Plot number	1
15-15	Shrub plot number	1
16-16	Herb plot number	1
17-17	Rock	1
18-18	Organic litter	1
19-19	Woody debris	1
20-20	Mineral soil	1
21-21	Forbes	1
22-22	Grass	1
23-23	Sedge	1
24-24	Squaw root	1
25-26	Land form	2
27-31	Cover type for plot	5
32-33	Stand structure	2
34-36	Aspect	3
37-39	Slope	3
40-41	Slope position	2
42-42	Slope shape	1
43-46	Elevation	4
47-48	Geologic formation	2
49-53	Cover type for entire site	5
54-54	Aspect class	1

LISTING SAMPLE DATES

Because all data correction depends on knowing the sample date, quarter, and sample number, it is necessary to be able to scan the data to determine what dates and samples have been entered. Selection of option 6 (list sample dates for a site) on the function menu (Fig. V.2.2) will ask the question:

Enter the site to list dates for:

After entering the site number you will receive the data file selection menu shown in Figure V.2.10. The program will search the selected database and type a list of sample dates and sample numbers which have been found for that site. You may scan more than one database for the same site by selecting each file in succession. Press F3 or type Q to return to the main menu.

AQUATIC DATABASE

CHAPTER CONTENTS

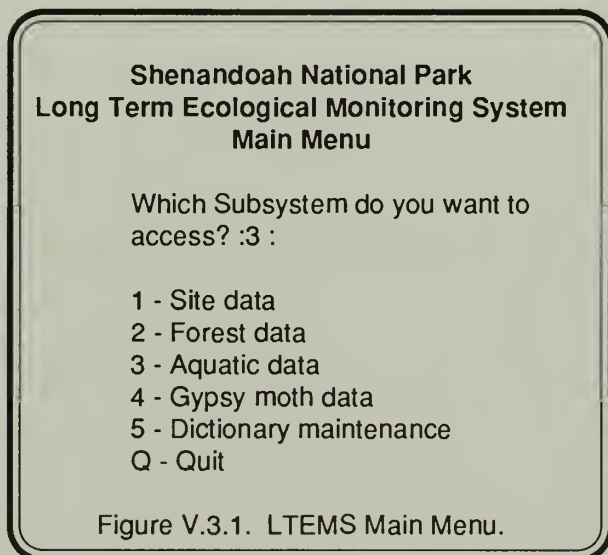
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AQUATIC DATABASE

Several keys will be important to know about during your session with the computer. The RETURN key is the one on the right of the keyboard with a <_|. This key is used to skip from one entry area (lighted box) to the next on the screen. The cursor is a blinking underline character on the screen which shows you where the next letter will type. To move the cursor there are four cursor keys found on the right of the keyboard. These are the 2,4,6, and 8 keys which also have direction arrows on them. The left and right arrows (4 and 6) will move left and right within the box where the cursor resides. The up and down arrows (2 and 8) will move the cursor to the next or previous box on the screen. During data entry the cursor will automatically move to the next box whenever you fill the previous box. The HOME key will take you to the beginning of the lighted box where the cursor resides. The END key will take to the end of that box. The INS key will allow you to insert characters between ones already there. The DEL key will delete characters. PGUP and PGDN will submit the entire screen to the database without typing in data for all boxes on the screen. The F3 key is found on the left side of the keyboard. This one is used by the programs to quit from a screen. Please note: if you quit NO DATA from that screen will be saved.

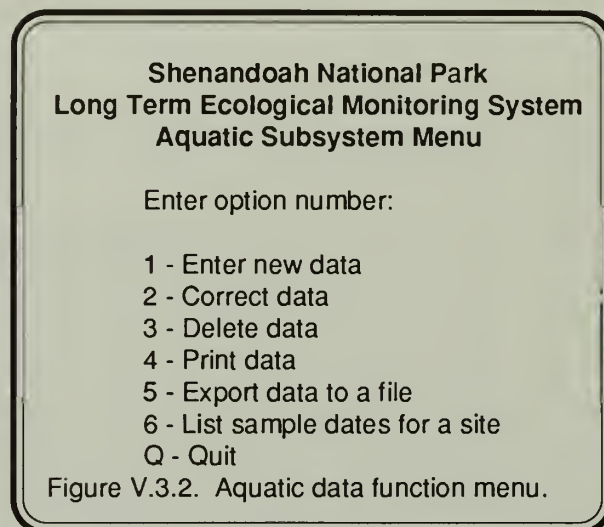
GETTING THE MENU

Once you have an **C>** on the screen type **LTEMS** and press RETURN. The menu will display as shown in Figure V.3.1.

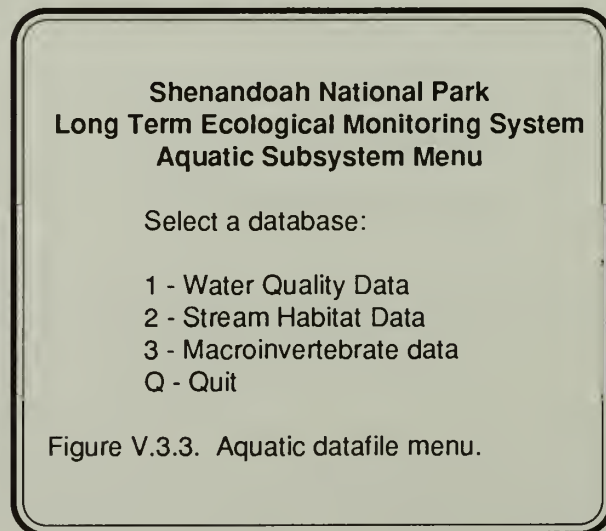


Option 3 will give you access to the aquatic portion of the LTEMs database. To quit from the menu and return to DOS press F3 or type Option Q.

Once you have selected Option 3 for aquatic data, you must select which function you would like to use using the next menu as shown in Figure V.3.2.



Option 1 allows you to enter new data into any of the aquatic data files. Option 2 allows data correction. To delete data from the aquatic data files use Option 3. Option 4 will allow you to print data for a site or a subset of sites. Use option 5 to create an export data file. If you need to know what sample dates have been entered for a site use option 6. To quit and return to the main menu press F3 or type Q. After you have selected a function you will be given another menu (Fig. V.3.3) to select which data file you want to use.



On this screen you are given the choice of three different aquatic data types to use. Once you select the data type you may perform the selected function numerous times on that data file. Once you quit from the data entry or correction screen, you will be returned to the database selection menu. If you

want to use the selected function (i.e., enter data) you may select another database and continue working. If you need to select a new function, quit from the database selection and you will get the function selection menu (Fig. V.3.2).

DATA ENTRY

Water Quality Data Entry

Selection of the water quality data type (Option 1) will generate a data entry screen which is shown in Figure V.3.4.

Water Quality Data

Site #: 1L001 Sample Date: 08/17/87
Quarter: 3

H2O Temp: 15. D.O.(X): 10.2
Discharge: 15.678
Seston: Total Organic Inorganic O/I
095.25 045.00 050.25 0.95

pH: 06.83 Alkalinity: 231 Conductivity: 115
SO4: 09.2 NO3: 0.60 Cl: 01.0 SiO2: 10.1
Ca: 060.53 Mg: 05.6 K: 075.2 Na: 050.54

Fec St: 04300 T. Coli: 05400 F. Coli: 04100
Chlorophyll #1: 0.4525 #2 0.5924 #3: 0.3045
Al: 1300

Option (1=Quit 2=Save Data): 2

Figure V.3.4: Water quality data entry screen

Data should be filled in as shown in Figure V.3.4. Units and valid ranges for each data item are listed in Table V.3.1. As each box is filled the cursor automatically moves to the next box. If you do not fill a box you must press the RETURN key to get to the next box. The last box is preset to option 2 (save the data). To quit and not save any data for a given screen press F3 with the cursor on the site block or type a 1 in the option box (last one on the screen). Once the data is typed you may use the PGDN key from any point on the screen to save the data. All data is validated to be sure the value is in range. The combination of the site number and sample date must be unique. If data has already been entered for this site and date you will be given an error message and told to use the correction option to change the data which has been typed previously. If you have made a typing mistake on the site or date retype them and try to save the data again. Any range errors will also

generate error messages on the screen. If there are any errors, the data will not be saved in the database.

Table V.3.1: Stream Data Units and Ranges

<u>Data element</u>	<u>Data type</u>	<u>Unit</u>	<u>Range</u>
H2O Temperature	Numeric	° C	0 - 25.0
pH	Numeric		0 - 14.00
Conductivity	Numeric	<i>u</i> mhos	0 - 200
Alkalinity	Numeric	<i>ueq</i> /L	0 - 600
Dissolved Oxygen	Numeric	mg/L	0 - 15.5
Total seston	Numeric	mg DW/L	0 - 100.0
Organic seston	Numeric	mg AFDW/L	0 - 100.0
Inorganic seston	Numeric	mg Ash/L	0 - 100.0
O/I	Numeric	Ratio	0 - 2.00
Autotrophic Index	Numeric		0 - 10000
Chlorophyll	Numeric	<i>ug</i> /cm ²	0 - 9.0000
Discharge	Numeric	cubic m./sec.	0 - 10.000
Sulfate (SO4)	Numeric	mg/L	0 - 10.0
Nitrate (NO3)	Numeric	mg/L	0 - 1.00
Chloride (Cl)	Numeric	mg/L	0 - 10.0
Calcium (Ca)	Numeric	mg/L	0 - 100.00
Magnesium (Mg)	Numeric	mg/L	0 - 10.0
Potassium (K)	Numeric	mg/L	0 - 100.00
Sodium (Na)	Numeric	mg/L	0 - 100.00
Silica (SiO4)	Numeric	mg/L	0 - 10.0
Fecal Streptococ.	Numeric	MPN/100ml	0 - 100000
Total Coliform	Numeric	MPN/100ml	0 - 100000
Fecal Coliform	Numeric	MPN/100ml	0 - 100000
Depth	Numeric	cm	0 - 200
Width	Numeric	m	0 - 20.0
Riparian Cover	Numeric	calculated	0 - 3.0
Riparian Type	2 Numbers	percent	0 - 100
	2 Letters	Code	see Table V.3.2
Debris Retention	Numeric	calculated	0 - 3.0
Fish Cover	Numeric	calculated	0 - 3.0
Pool:Riffle	Numeric	ratio	0 - 10.00
Substrate Comp.	2 Numbers	percent	0 - 100
	2 Letters	Code	see Table V.3.3

Stream Habitat Data Entry

Selection of the habitat data entry (Option 2 of the data type selection menu shown in Figure V.3.3) will generate a data entry screen shown in Figure V.3.5.

Data should be filled in as shown in Figure V.3.5. Units and valid ranges for each data item are listed in Table V.3.1. As each box is filled the cursor automatically moves to the next box. If you do not fill a box you must press the RETURN key to get to the next box. The last box is preset to Option 2 (save the data). To quit and not save any data for a given

screen press F3 with the cursor on the site block or type a 1 in the option box (last one on the screen).

Calculations must be made to get some of the aquatic habitat values. Refer to the aquatic component user manual for the methods used to calculate these values.

Aquatic Habitat Data

Site: 1L001 Sample Date: 08/17/87
 Quarter: 3

Mean Site Depth: 65
 Mean Site Width: 15
 Percent Riparian Cover: 1.2
 Riparian Type: 90T 10S
 Debris Retention: 1.6
 Fish Cover: 1.8
 Pool:Riffle: 6:0
 Site Bottom - Substrate 20BR
 Composition: 40C
 40S

Option (1=Quit 2=Save Data): 2

Figure V.3.5. Aquatic habitat data entry screen.

Riparian type is entered with up to four components. Codes for the components are listed in Table V.3.2. Enter a 2-digit percent for the component followed by the code. To enter 40% trees you would type 40T.

Table V.3.2. Riparian Type Codes

Type	Code
Trees	T
Shrubs	S
Grasses/Forbes	GF
None	N

Substrate composition is entered with up to five components. Codes for the components are listed in Table V.3.3. Enter a 2 digit percent for the component followed by the code. To enter a substrate of 45 % sand and 55% gravel you would enter 45S on the first line and 55PG on the second line. The percentages should add up to 100.

Table V.3.3. Substrate Component Codes

Component	Code
Bedrock	BR
Boulder	B
Cobble	C
Gravel	PG
Sand	S

Once the data are typed you may use the PGDN key from any point on the screen to save the data. All data is validated for range of value. The combination of the site number and sample date must be unique. If data has already been entered for this site and date you will be given an error message and told to use the correction option to change the data which has been typed previously. If you have made a typing mistake on the site or date retype them and try to save the data again. Any range errors will also generate error messages on the screen. If there are any errors, the data will not be saved in the database.

Macroinvertebrate Data Entry

Selection of the aquatic insect data entry (Option 3 of the data type selection menu shown in Figure V.3.3) will generate a data entry screen shown in Figure V.3.6.

Macroinvertebrate Data

Site: 1L001 Sample Date: 08/25/87 Qtr: 3
 Sample Number: 1 Sample Method: SUR

Taxa Description Code	Insect Count	Number /Meter	Stage	Weight	Reared (Y/N)
4 Insecta	15	3	I	2.55	F
4125	25	5.6	M	0.44	F

Figure V.3.6. Macroinvertebrate data entry

The first two lines of the screen will appear first. These should be filled in with the site number, sample date, quarter, a sample number for this date and site, and a sample type code. Use of a standard sample number for each sample method will assist in finding data for corrections. We suggest using 1-3 for PIBS and SUR, 4 for AER, 5 for QUD, and 6 for RED. The site number, date, and sample number together form a unique code for this sample of macroinverte-

brates. If this combination has been entered before you will be asked if you want to add insects to a sample typed previously. If you answer yes(Y) or true(T), you may add insects. If you answer no(N) or false(F), you can correct the site, date, or sample number and try again. The answer is preset to add more insects to the sample.

The sample method code is checked against the sample method code dictionary. If the code is not defined in the dictionary you will not be able to enter that code. You may add the code to the sample method dictionary by accessing dictionary data entry. A listing of codes for aquatic data collection (as of January 1990) is presented in Table V.3.4.

Table V.3.4. Aquatic Sample Method Codes

Code	Sample Method
PIB	PIBS
SUR	Surber
AER	Aerial
QUD	Qualitative D-Frame Kick net
RED	Reared

After the top two lines have been entered, you will be able to enter multiple lines of macroinvertebrate data on the lower part of the screen. You must enter a taxa code in the first block of each line. If this taxa code is left blank or you enter QUIT as the code, you will return to a blank data entry screen to enter a new site, date, sample number combination. You may also quit by pressing the F3 key for the taxa code. This method allows you to enter unlimited numbers of insect lines for a given sample.

Each macroinvertebrate line is validated as it is typed and saved. Taxa codes are validated against the taxa dictionary. A taxa code may be added to the dictionary by accessing the dictionary data entry menu. The description for the taxa code is obtained from the dictionary and will display on the screen when the data is validated. A complete listing of taxa codes in the dictionary may be printed using the dictionary print option. The numeric values for the insect count, number of insects per meter square and weight are checked to be sure they are numeric. Square meter insect counts are not used in LTEMs but have been put in the database to accommodate other data collection methods. The stage must be coded as listed in Table V.3.5. The reared column is preset to false(F) or no(N). You may change it to yes(Y) or true(T).

Table V.3.5. Aquatic Insect Stage Codes

Code	Description
M	Male adult
F	Female adult
S	Subimago
I	Nymph or larva (Imago)
P	Pupa

Getting Out

Quitting from the data file selection menu with the F3 key or Q option will display the function selection menu shown in Figure V.3.2.

DATA CORRECTION

Selection of Option 2 (data correction) on the function menu will display the data file selection menu shown in Figure V.3.3.

Water Quality or Habitat Data Correction

Selection of the water chemistry data type (Option 1) or stream habitat data type (Option 2) will generate the question:

Enter site number, year and quarter to be corrected or press F3 to quit

Entry of a site number, year and quarter combination that does not exist in the database will produce the message:

Site number, year and quarter combination does not exist in the database
Press any key to continue ...

Entry of a valid site number, year and quarter combination will produce a screen like the data entry screen shown in Figure V.3.4 or Figure V.3.5. Make any corrections in the lighted boxes of the screen. If the site quarter or date is changed it will be checked to be sure the combination has not been used previously. All data validation described for data entry will be done for corrected data as well. If a data item is invalid the old value is retained in the database.

Macroinvertebrate Data Correction

Selection of the macroinvertebrate data type (Option 3) will generate the question:

Enter site number, year, quarter and sample number to be corrected or press F3 to quit

Entry of a site number, year and quarter and sample number combination that does not exist in the database will produce the message:

Site number, year, quarter, sample number combination does not exist in database
Press any key to continue...

Entry of a valid site, year, quarter, sample number combination will produce the question:

What do you want to change?

Enter one of the following codes: 4

1 - Change sample method, sample date, sample #, site # on all records for this sample

2 - Change sample method, sample date, sample #, site # on certain macroinvertebrate lines of this sample

3 - Change macroinvertebrate data on a given macroinvertebrate line

4 - Display macroinvertebrate lines without making corrections

Q - Quit

Use Option 1 to change the sample method code, sample number, sample date, quarter or site number on all records with the selected site, year, quarter, sample number combination. You will get a screen with the top part of form. You make the appropriate changes and save the data. If you make changes to the site, date, quarter, or sample number, the new combination will be checked to be sure it has not yet been used. If the new combination is already in the database you will be given the option to add the insects from the old combination to this record. Sample method code will also be validated using the dictionary. This option will change all records for this sample.

Option 2 behaves similarly to Option 1 except that instead of changing all records it is selective. Once you have made changes as stated above you will get a screen showing all macroinvertebrate lines and their record numbers. You will then be asked to "Enter record number to be changed or Q to quit". This question will repeat until you quit, changing each record specified.

Option 3 allows you to change information on a specific macroinvertebrate line. You will get a

screen like the data entry screen showing the macroinvertebrate sample lines and the record number for each line. You will then be asked "Enter record number to be changed or Q to quit". Enter the number shown on the line you need to correct. The entire line will appear at the bottom of the screen in lighted boxes. Make the changes and save them. Validation will be done as described for data entry. Any invalid data will revert to the original value and not be changed in the database. Changes you make will not reflect on the upper portion of the screen interactively. If you wish to view the changes you can quit and then use Option 4 of the correction question to view the insect data without making changes.

Option 4 displays the macroinvertebrate data but does not allow you to make any corrections until you use Option 1, 2, or 3.

DELETION OF ENTRIES

Selection of Option 3 (delete data) on the function menu will display the data file selection menu shown in Figure V.3.3.

Water Quality or Habitat Data Deletion

Selection of the water chemistry or stream habitat data will ask the question:

Enter site number, year and quarter to be deleted or press F3 to quit

Entry of a site year quarter combination which is not yet in the database will produce the message:

Site number, year quarter combination does not exist in database
Press any key to continue...

Entry of a valid combination will display the entire stream record on the screen. You will be asked "Is this the record to delete?"

Enter a Y to delete the record shown on the screen. Any other key will keep the record in the database.

Macroinvertebrate Data Deletion

If you need to remove macroinvertebrate samples for this stream site you will need to select the macroinvertebrate option of the data file selection menu. You will be asked:

Enter site number, year, quarter and sample number to be deleted or press F3 to quit

Entry of a site, year, quarter, sample number combination which is not yet in the database will produce the message:

Site number, year, quarter, sample number combination does not exist in database

Entry of a valid combination will generate the question:

What do you want to delete?
Enter one of the following codes: 3

- 1 - Delete all records for this sample
- 2 - Delete certain macroinvertebrate lines of this sample
- 3 - Display macroinvertebrate lines without making corrections
- Q - Quit

Option 1 will display the macroinvertebrate lines on the screen. At the bottom you will be asked to "Press Y to delete all records for this sample". Any other key will keep the data and return to the menu. All macroinvertebrate data for the site, year, quarter, sample number combination will be deleted using Option 1.

Option 2 allows you to specify which macroinvertebrate sample line you need to delete. You will be shown the macroinvertebrate data with the record numbers. You will then be asked: "Enter record number to be deleted or Q to quit". The record you request will then be displayed at the bottom of the screen with the question: "Is this the record to delete? enter Y to delete". Enter a Y to delete that one insect entry. Any other key will save the record and ask for another record number to delete. You must quit from the record number question to return to the menu.

Option 3 allows to view all macroinvertebrate data for a given site, date, sample number without deleting the data.

PRINTING THE DATA

Selection of Option 4 of the function menu (Figure V.3.2) will result in the message:

Printing of aquatic data cannot be done from this menu. Exit from this program and use LTOUT to print data
Press any key to continue...

Because of the memory used to generate the macroinvertebrate summary it is necessary to use a separate program to print the reports. Use F3 to quit from each level of this system and return to DOS. Then type **LTOUT** and press RETURN. The menu will display as shown in Figure V.3.7. Printing of forest data will work in either LTEMMS or LTOUT.

Shenandoah National Park
Long Term Ecological Monitoring System
Main Menu

Which Subsystem do you want to access?

- 1 - Site data
- 2 - Forest data
- 3 - Aquatic data
- Q - Quit

Figure V.3.7. LTOUT main menu.

Option 1 accesses the site information, Option 2 the forest information and Option 3 the aquatic information. You must select whether to print a report or export flat files as shown in Figure V.3.8.

This menu only allows data output, if you need to change, add or remove data use the LTEMMS program

How would you like to output the data?

- 1 - Print report
- 2 - Export files
- Q - QUIT

Figure V.3.8. LTOUT function menu.

If you select to print site data you will get the message "You must print either forest or aquatic data, try again Press any key to continue...". Printing of forest files works exactly as described in the forest section of the manual. The print report option with the aquatic files will allow you to print a detailed macroinvertebrate inventory and stream characteristics on an individual site basis. First you will be asked whether you want to print the output to the screen (S), printer (P) or a file (F) or quit (Q). If you want to send the output to a file to be printed using a wordprocessor or other means you will be asked for the name of the output file. The output file will be written to the current directory of the hard disk unless you specify another path.

You are then given the option to print 1 Site and Date (1), a Range of sites (R), or Search the Database (S). If you select 1 you will be asked for the site number, quarter, and year to be printed. If you ask for a Range of sites you will be asked:

Enter Beginning Site:
Enter Ending Site:
Enter Beginning Quarter: and year:
Enter Ending Quarter: and year:

All aquatic data for sites in the site number range and quarter sampled range will be printed. If you request to search the database you will be given a screen to fill in the parameters describing the sites you wish to print as shown in Figure V.3.9.

Indicate which items are to be selected for below
Type ALL or leave items blank to include all
values

Press F3 or type Q for District to quit

District (N,C,S,ALL):
Cover type (code):
Elevation (U or L):
Geological Formation (H,P,C,CP,CH):
Beginning Quarter: and year:
Ending Quarter: and year:

Figure V.3.9. Output parameter specification screen

All sites which satisfy all the selection criteria you supply on the screen will be printed. For each site three reports will print as shown in Appendix V.C. If there is no data for the stream habitat record you must enter a blank record for that site, quarter and date. Without a stream record to accompany the macroinvertebrate record neither will print.

The water chemistry/stream habitat summary shows the recorded values for all those data. The only calculated value is mean chlorophyll which is the average of the three observed values.

The listing of taxa collected shows the four sample types across the top and all macroinvertebrates found down the side. An X is placed opposite any organism which was found using that sample type. Quantitative includes either the Surber or the PIBS.

The community structure of benthic invertebrate summary lists the actual numbers of each organism found in each quantitative sample. A mean of each organism is calculated based on the three sample counts. The number per square meter is calculated by multiplying the mean times 10 for the PIBS and 10.76 for the Surber. Density is the total number of organisms collected in each sample. The total number of different species found for each sample is listed. Diversity is calculated using the Shannon Index.

EXPORTING TO A FILE

Option 5 of the data function menu (Fig.V.3.2) or Option 2 of the LTOU function menu (Fig.V.3.8) will allow you to export a data file for use by another software package. You will be asked: Do you want to subset the data (S) or export the entire file (E)? If you want to subset the file you will be given the parameter specification screen as presented in Figure V.3.9. Once the parameters are stored you will be asked which database file you want to export (Fig. V.3.10). You may select more than one file for the same set of parameters. Each time you select a database it will ask you to name a file for the output file and then write records to that file. The output file will be written to the current directory of the hard disk unless you specify another path. The record format of the exported files for each database are shown in tables 3.6 through 3.8.

Shenandoah National Park Long Term Ecological Monitoring System Export File Menu

Enter database to export:

- 1 - Site File
- 2 - Stream File
- 3 - Invertebrate File
- Q - Quit

Figure V.3.10. LTEMs Export Menu

Table V.3.6: Stream Record Export File

Columns	Data description	Length
1-5	Site number	5
6-6	Quarter	1
7-14	Sample date (yyyymmdd)	8
15-18	Temperature	4
19-22	Dissolved oxygen	4
23-27	pH	5
28-30	Alkalinity	3
31-33	Conductivity	3
34-35	Hardness	2
36-41	Seston	6
42-47	Organic seston	6
48-53	Inorganic seston	6
54-57	Organic/Inorganic ratio	4
58-61	Total Phosphorus	4
62-65	Nitrate	4
66-69	Sulfate	4
70-75	Fecal Streptococcus	6
76-81	Total Coliform	6
82-87	Fecal Coliform	6
88-93	Chlorophyll 1	6
94-99	Chlorophyll 2	6
100-105	Chlorophyll 3	6
106-111	Discharge	6
112-114	Depth	3
115-116	Width	2
117-119	Riparian cover	3
120-139	Riparian type	20
140-142	Debris	3
143-145	Fish cover	3
146-150	Pool:riffle	5
151-170	Substrate	20
171-175	Autotrophic index	5
176-180	Aluminum	5
181-185	Dissolved organic carbon	5
186-191	Average chlorophyll	6
192-195	Chloride	4
196-201	Calcium	6
202-205	Magnesium	4
206-211	Potassium	6
212-217	Sodium	6
218-221	Silica	4
222-225	Elevation	4
226-227	Geologic formation	2
228-232	Cover type for entire site	5
233-233	Aspect class	1
234-234	Elevation class (U,L)	1

Table V.3.7: Macroinvertebrate Record Export File

Columns	Data description	Length
1-5	Site number	5
6-6	Quarter	1
7-14	Sample date (yyyymmdd)	8
15-15	Sample number	1
16-18	Sample method	3
19-25	Taxa code	7
26-29	Insect count	4
30-34	Count per meter	5
35-40	Weight	6
41-41	Stage	1
42-43	Functional group	2
44-44	Reared (T= true, F=false)	1
45-48	Elevation	5
49-50	Geologic formation	2
51-55	Cover type for entire site	5
56-56	Aspect class	1
57-57	Elevation class (U,L)	1

Table V.3.8: Site Record Export File

Columns	Data description	Length
1-5	Site number	5
6-15	UTM North	10
16-25	UTM East	10
26-27	Geologic formation	2
28-31	Elevation	4
32-56	Stream name	25
57-58	Soil type	2
59-61	Quadrangle code	3
62-63	Aquatic or forest site (AQ,FR)	2
64-64	Aspect class	1
65-65	Elevation class (U,L)	1
66-70	Cover type for entire site	5

LISTING SAMPLE DATES

Because all data correction depends on knowing the sample date, quarter, and sample number, it is necessary to be able to scan the data to determine what dates and samples have been entered. Selection of option 6 (list sample dates for a site) on the function menu (Fig. V.3.2) will ask the question:

Enter the site to list dates for:

After entering the site number you will receive the data file selection menu shown in Figure V.3.9. The program will search the selected database and type a list of sample dates and sample numbers which have been found for that site. You may scan more than one database for the same site by selecting each file in succession. Press F3 or type Q to return to the main menu.

GYPSY MOTH DATABASE

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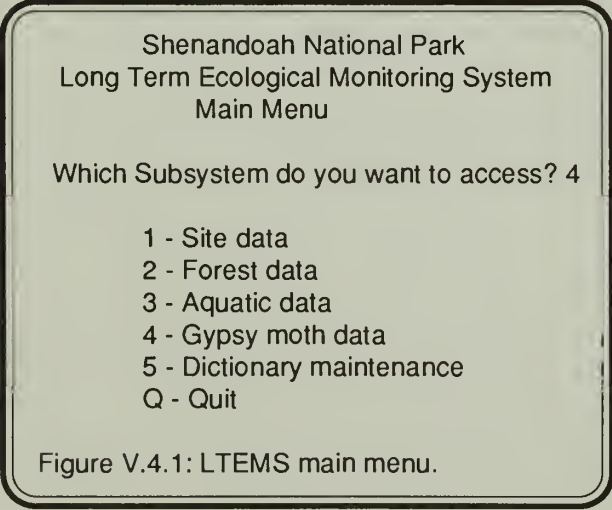
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GYPSY MOTH DATABASE

Several keys will be important to know about during your session with the computer. The RETURN key is the one on the right of the keyboard with a <_]. This key is used to skip from one entry area (lighted box) to the next on the screen. The cursor is a blinking underline character on the screen which shows you where the next letter will type. To move the cursor there are four cursor keys found on the right of the keyboard. These are the 2,4,6, and 8 keys which also have direction arrows on them. The left and right arrows (4 and 6) will move left and right within the box where the cursor resides. The up and down arrows (2 and 8) will move the cursor to the next or previous box on the screen. During data entry the cursor will automatically move to the next box whenever you fill the previous box. The HOME key will take you to the beginning of the lighted box where the cursor resides. The END key will take to the end of that box. The INS key will allow you to insert characters between ones already there. The DEL key will delete characters. PGUP and PGDN will submit the entire screen to the database without typing in data for all boxes on the screen. The F3 key is found on the left side of the keyboard. This one is used by the programs to quit from a screen. Please note: if you quit NO DATA from that screen will be saved.

GETTING THE MENU

Once you have an C> on the screen type LTEMS and press RETURN. The menu will display as shown in Figure V.4.1.



```
Shenandoah National Park
Long Term Ecological Monitoring System
Main Menu

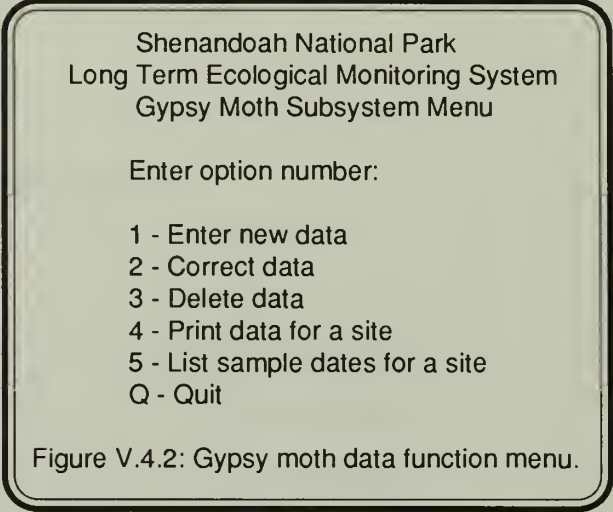
Which Subsystem do you want to access? 4

1 - Site data
2 - Forest data
3 - Aquatic data
4 - Gypsy moth data
5 - Dictionary maintenance
Q - Quit
```

Figure V.4.1: LTEMS main menu.

Option 4 will give you access to the gypsy moth portion of the LTEMS database. To quit from the menu and return to DOS press F3 or type option Q.

Once you have selected option 4 for gypsy moth data, you must select which function you would like to use using the next menu as shown in Figure V.4.2.



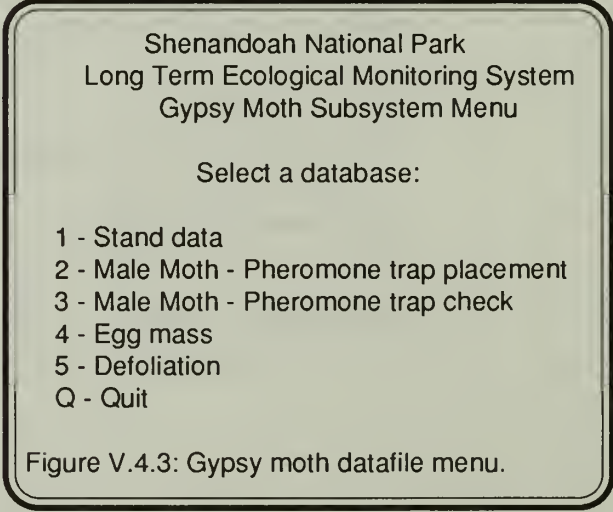
```
Shenandoah National Park
Long Term Ecological Monitoring System
Gypsy Moth Subsystem Menu

Enter option number:

1 - Enter new data
2 - Correct data
3 - Delete data
4 - Print data for a site
5 - List sample dates for a site
Q - Quit
```

Figure V.4.2: Gypsy moth data function menu.

Option 1 allows you to enter new data into any of the gypsy moth data files. Option 2 allows data correction. To delete data from the gypsy moth data files use option 3. Option 4 will allow you to print data for a site. If you need to know what sample dates have been entered for a site use option 5. To quit and return to the main menu press F3 or type Q. After you have selected a function you will be given another menu (Fig. V.4.3) to select which data file you want to use.



```
Shenandoah National Park
Long Term Ecological Monitoring System
Gypsy Moth Subsystem Menu

Select a database:

1 - Stand data
2 - Male Moth - Pheromone trap placement
3 - Male Moth - Pheromone trap check
4 - Egg mass
5 - Defoliation
Q - Quit
```

Figure V.4.3: Gypsy moth datafile menu.

On this screen you are given the choice of four different gypsy moth data types or the stand record. The stand record access is included because stand level data must be entered even if no forest data is taken at the site. If forest data has been taken and entered for the site you should not enter any stand data from this menu. Once you select the data type you may perform the selected function numerous times on that data file. Once you quit from the data

entry or correction screen, you will be returned to the database selection menu. If you want to use the selected function (i.e. enter data) you may select another database and continue working. If you need to select a new function, quit from the database selection and you will get the function selection menu (Fig. V.4.2).

DATA ENTRY

Stand Data Entry

Selection of the stand data type (option 1) will generate a data entry screen which is shown in Figure V.4.4.

Stand Data

Site #: 1L001 Plot #: 1 Sample date:8/17/88
 Basal Area Factor: 10.0
 Slope(%): 45
 Aspect(AZ): 150
 Slope Position(SU,SH,TS,BS,FS,FP,TE): TE
 Slope Shape (V,X,P): V
 Cover Type: 8800
 Stand Structure (E,T,U): E
 Land Form: CV
 Comments: this is a space for comments
 Option (1=Quit 2=Save Data): 2

Figure V.4.4. Stand data entry screen

Data should be filled in as shown in Figure V.4.4. Units and valid ranges for each item are listed in

Table V.4.1. Codes for items which have been assigned codes are listed in Table V.4.2. As each box is filled the cursor automatically moves to the next box. If you do not fill a box you must press the RETURN key to get to the next box. The last box in preset to Option 2 (save the data). To quit and not save any data for a given screen press F3 with the cursor on the site block or type a 1 in the option box (last one on the screen). Once the data is typed you may use the PGDN key from any point on the screen to save the data. All data is validated to be sure the value is in range or a valid code. The combination of the site number and sample date must be unique. If data has already been entered for this site and date you will be given an error message and told to use the correction option to change the data which has been typed. If you have made a typing mistake on the site or date retype them and try to save the data again. Any range or code errors will generate error messages on the screen. If there are any errors, the data will not be saved in the database.

After entry of a stand record the program will automatically cycle to the tree screen for this plot. To return to the stand data entry screen quit from the tree data entry screen by pressing F3. You should not use access to enter forest data.

Table V.4.1: Stand Data Units and Ranges

Data Element	Data Type	Unit	Range
Basal area	Numeric	factor	5.0 - 25.0
Slope	Numeric	%	0 - 200
Aspect	Numeric	azimuth	0 - 360
Slope position	2 Letters	code	Table V.4.2
Slope shape	1 Letter	code	Table V.4.2
Cover type	4 Numbers	code	Table V.4.2
Stand structure	1 Letter	code	Table V.4.2
Land form	2 Letters	code	Table V.4.2

Table V.4.2: Stand Data Variable Codes

Data element	Value	Code
Cover type	Chestnut oak	4400
	Red oak	5500
	Red oak/ash/ basswood (cove)	2001
	Yellow poplar	5700
	Black locust	5000
	Pine	2100
	Pitch pine	2101
	Virginia pine	2102
	Eastern white pine	2103
	Hemlock	2300
	Special forest type	9999
Slope Position	Summit	SU
	Shoulder	SH
	Back Slope	BS
	Toe Slope	TS
	Foot Slope	FS
	Flood Plain	FP
	Terrace	TE
Slope Shape	Concave	V
	Convex	X
	Planar	P

Table V.4.2(cont): Stand Data Variable Codes

Data element	Value	Code
Structure	Even aged	E
	Two aged	T
	Uneven aged	U
Land form	Ridge top	RT
	Spur ridge	SR
	No slope	NS
	Head slope	HS
	Side slope	SS
	Cove	CV
	Draw	DW

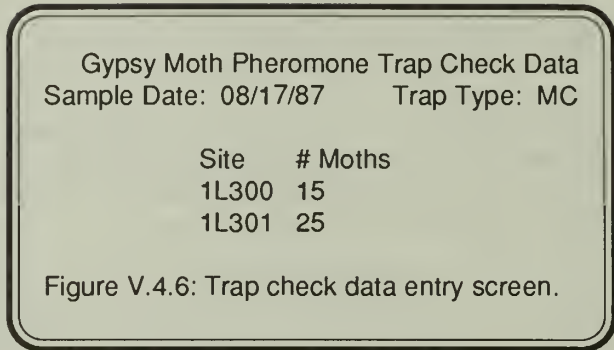


Figure V.4.6: Trap check data entry screen.

The first line of the screen will appear first. This should be filled in with the sample date. The site of the trap checked and the number of moths caught are entered on subsequent lines. The site number and date together form a unique code for this trap check. If this combination has been entered before you will get an error message. After the top line has been entered, you will be able to enter multiple columns of trap check data on the lower part of the screen. You must enter a site number in the first block of each row. If this site number is left blank or you enter 1Q as the site, you will get a new sample date line. You may also quit by pressing the F3 key for the site number. To return to data file selection menu (Fig. V.4.3) press the F3 key for the date.

Each pheomone trap check line is validated as it is typed and saved. The site year combination is checked to be sure a trap has been placed at that plot. The moth count must be numeric. If there are any errors the data will not be saved.

Pheromone Trap Placement Data Entry

Selection of the pheromone trap placement data entry (option 2 of the data type selection menu shown in Figure V.4.3) will generate a data entry screen shown in Figure V.4.5.

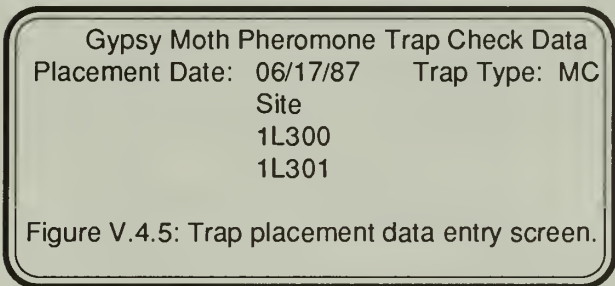


Figure V.4.5: Trap placement data entry screen.

The first line of the screen will appear first. This should be filled in with the placement date. On subsequent lines you enter the site number of the traps which were placed on that date. The site number and year together form a unique code for this trap placement record. If this combination has been entered before you will get an error message. If the site is left blank or you enter 1Q as the code, you will return to a blank data entry screen to enter a new placement date. You may also quit by pressing the F3 key for the site number. To return to the data file selection menu (Fig. V.4.3) press F3 for the date. Each trap placement line is validated as it is typed and saved. If there are any errors the data will not be saved.

Pheromone Trap Check Data Entry

Selection of the trap check data entry (option 3 of the data type selection menu shown in Figure V.4.3) will generate a data entry screen shown in Figure V.4.6.

Egg Mass Data Entry

Selection of the egg mass data entry (option 4 of the data type selection menu shown in Figure V.4.3) will generate a data entry screen shown in Figure V.4.7.

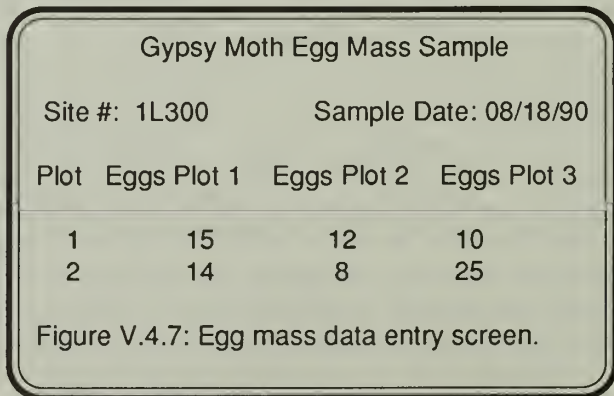


Figure V.4.7: Egg mass data entry screen.

The first line of the screen will appear first. This should be filled in with the sample date and site number. The plot number and number of egg masses in each of the three samples of that plot are entered

on subsequent lines. The site number, plot number and sample date form the unique identifier for a set of three egg mass samples for each plot. If both egg mass counts and plot number are left blank or you press F3 for the plot number, you will get a new site, sample date line. To return to the data selection menu (Fig. V.4.3) press F3 for the site.

Each egg mass line is validated as it is typed and saved. The site, plot, sample date combination is checked for uniqueness. The site is also checked to be sure site data has been entered. The egg mass count must be numeric. If there are any errors the data will not be saved.

Defoliation Data Entry

Selection of the defoliation data entry (option 5 of the data type selection menu shown in Figure V.4.3) will generate a data entry screen shown in Figure V.4.8.

Gypsy Moth Defoliation Data

Site: 1L300 Sample Date: 08/18/90

Plot #	Defoliation Code
1	3
2	4
3	1

Figure V.4.8: Defoliation data entry screen.

The first line of the screen will appear first. This should be filled in with the site number and sample date. The plot number and the defoliation rating are entered on subsequent lines. The site number, plot number and sample date form the unique identifier for each observation. If both defoliation rating and plot number are left blank or you press F3, you will get a new site, sample date line. To return to the data selection menu (Fig. V.4.3) press F3 for the site.

Each defoliation line is validated as it is typed and saved. The site, plot, and sample date combination is checked for uniqueness. The site is also checked to be sure site data has been entered. The defoliation rating must be between 1 and 4 as described in Table V.4.3. If there are any errors the data will not be saved.

Table V.4.3: Defoliation Rating Codes

Amount of defoliation	Code
0-25%	1
26-50%	2
51-75%	3
76-100%	4

Getting out

Quitting from the data file selection menu with the F3 key or Q option will display the function selection menu shown in Figure V.4.2.

DATA CORRECTION

Selection of option 2 (data correction) on the function menu will display the data file selection menu shown in Figure V.4.3.

Stand Data Correction

Selection of the stand data type (option 1) will generate the question:

Enter site number and sample date and plot number to be corrected or press F3 to quit

Site #: Plot #: Sample date: / /

Entry of a site number/sample date combination that does not exist in the database will produce the message:

Site number, sample date, plot number combination does not exist in database
Press any key to continue...

Entry of a valid site date combination will produce the question:

What do you want to change?
Enter one of the following codes: 2

1 - Change site #, sample date, plot #, on all stand, tree, shrub, and herb records for this plot
2 - Change information on this stand record
Q - Quit

Use option 1 to change the plot number, sample date or site number on all records with the

selected site, date, plot number combination in all six forest data types. You will get a screen with the top part of form. You make the appropriate changes and save the data. The new combination will be checked to be sure it has not yet been used. If the new combination is already in the database you will be given the option to retype the plot number, sample date, or site number or QUIT. This option will change all records for this plot in the stage1, stage2, and stage 3 databases as well as the stand record. All tree, shrub and herb lines which are changed will be displayed on the screen as they are changed. DO NOT use this option unless you are familiar with the status of the forest data for this site.

Option 2 only changes the stand record and allows changes to all data items in the record. A screen like the data entry screen shown in Figure V.4.4 appears. Make any corrections in the lighted boxes of the screen. If the site, plot, or date is changed it will be checked to be sure the combination has not been used previously. All data validation described for data entry will be done for corrected data as well. If a data item is invalid the old value is retained in the database.

Pheromone Trap Placement Data Correction

Selection of the trap placement data type (option 2) will generate the question:

Enter site number and year to be corrected or press F3 to quit
Site #: Year:

Entry of a site number year combination that does not exist in the database will produce the message:

Site number year combination does not exist in database
Press any key to continue...

Entry of a valid site year combination will produce the question:

What do you want to change?
Enter one of the following codes:
1 - Change site # on all trap catch and placement records for this plot
2 - Change information on this placement record
Q - Quit

Use option 1 to change the site number on all records with the selected site year combination in the trap placement and trap catch databases. You will

get a screen with the top part of form. You make the appropriate changes and save the data. The new site will be checked to be sure it has not yet been used. If the trap data for the new site is already in the database you will be given an error message. This option will change all records for this site in both databases. All trap catch lines which are changed will be displayed on the screen as they are changed.

Option 2 allows you to change information on the trap placement line. If there are any trap catch records for the site you will only be able to change the date using this option. If you need to change the site number you will have to use option 1 and change the catch records as well.

Pheromone Trap Catch Data Correction

Selection of the trap catch data type (option 3) will generate the question:

Enter site number and year to be corrected or press F3 to quit
Site #: Year:

Entry of a site number year combination that does not exist in the database will produce the message:

Site number year combination does not exist in database
Press any key to continue...

Entry of a valid site, year combination will produce the question:

What do you want to change?
Enter one of the following codes:

1 - Change site # on all trap catch and placement records for this plot
2 - Change information on a trap catch record
3 - Display trap catch data without making corrections
Q - Quit

Use option 1 to change the site number on all records with the selected site year combination in the trap placement and trap catch databases. You will get a screen with the top part of form. You make the appropriate changes and save the data. The new combination of site and year will be checked to be sure it has not yet been used for trap information. If the new combination is already in the database you will be given an error message. This option will change all records for this site in both databases. All

trap catch lines which are changed will be displayed on the screen as they are changed.

Option 2 allows you to change information on a specific trap catch line. The list of all trap catch records for the site will display on the screen. You will then be asked to "Enter record number to be changed or Q to quit". This question will repeat until you quit, changing each record specified. If you change the site, the existence of a trap placement record for that new site is verified.

Egg Mass Data Correction

Selection of the egg mass data type (option 4) will generate the question:

Enter site number, plot number and sample date to be corrected or press F3 to quit
Site #: 1L300 Plot #: 1 Sample date: 08/18/87

Entry of a site number, sample date, plot, subplot number combination that does not exist in the database will produce the message:

Site number, sample date, plot number combination does not exist in database
Press any key to continue...

Entry of a valid site, date, plot number combination will produce the question:

What do you want to change?
Enter one of the following codes: 4

- 1 - Change site #, sample date, plot #, on all egg mass records for this plot
- 2 - Change site #, sample date, plot #, on certain egg mass lines of this plot
- 3 - Change egg mass data on a given egg mass line
- 4 - Display egg mass lines without making corrections
- Q - Quit

Defoliation Data Correction

Selection of the defoliation data type (option 5) will generate the question:

Enter site number, plot number, and sample date to be corrected or press F3 to quit
Site #: 1L300 Plot #: 1 Sample date: 08/18/87

Entry of a site number, sample date, plot combination that does not exist in the database will produce the message:

Site number, sample date, plot number combination does not exist in database
Press any key to continue...

Entry of a valid site, date, plot number combination will produce a data correction screen showing the record to be changed. You make the appropriate changes and save the data. The new combination of site plot and sample date will be checked to be sure it has not yet been used. If the new combination is already in the database you will be given an error message.

DELETION OF ENTRIES

Selection of option 3 (delete data) on the function menu will display the data file selection menu shown in Figure V.4.3.

Stand Data Deletion

Selection of the stand data option will ask the question:

Enter site number and sample date and plot number to be deleted or press F3 to quit
Site #: 1L001 Plot #: 1 Sample date: 08/17/87

Entry of a site plot date combination which is not yet in the database will produce the message:

Site number, sample date, plot number combination does not exist in database
Press any key to continue...

Entry of a valid combination will generate the question:

What do you want to change?
Enter one of the following codes: 2

- 1 - Delete all stand, tree, shrub, and herb records for this plot
- 2 - Delete this stand record
- Q - Quit

Use option 1 to delete the plot number, sample date or site number combination all six forest data types. You will get a screen displaying the entire stand record and be asked:

Press Y to delete this stand record

If you enter Y the stand record will be removed and the screen will then display all lines of the tree data, shrub data, and herb data to be removed and again ask if these records should be removed. If you answer anything except Y you will quit from this stand record deletion and keep the record in the database. DO NOT delete forest data without knowledge of what the forest records contain.

This option will delete all records for this plot in the stage 1, stage 2, and stage 3 databases as well as the stand record. Option 2 only deletes the stand record.

Pheromone Trap Placement or Catch Data Deletion

Selection of the pheromone trap placement or the trap catch data option will ask the question:

Enter site number and year to be deleted or press F3 to quit
Site #: Year:

Entry of a site year combination which is not yet in the database will produce the message:

Site number year combination does not exist in database
Press any key to continue...

Entry of a valid combination will generate the question:

What do you want to delete?
Enter one of the following codes: 4

- 1 - Delete all trap catch and placement records for this site
- 2 - Delete information on a trap catch record
- 3 - Display trap catch data without making deletions
- Q - Quit

Option 1 will display the pheromone trap catch lines on the screen. At the bottom you will be asked to "Press Y to delete the placement and catch records for this site". Any other key will keep the data and return to the menu. All pheromone trap placement and catch data for the site year combination will be deleted using option 1.

Option 2 allows you to specify which pheromone trap catch sample line you need to delete. You will be shown the catch data with the record numbers.

You will then be asked: "Enter record number to be deleted or Q to quit". You will continue to be asked for record numbers until you quit. You will then be asked to "Press Y to delete trap catch record # X". Enter a Y to delete that one catch entry. Any other key will save the record and get the next catch record in the stack for deletions. Once all records requested have been deleted you will return to the menu.

Option 3 allows to view all catch data for a given site year without deleting the data.

Egg Mass Data Deletion

Selection of the egg mass data type (option 4) will generate the question:

Enter site number, plot number and sample date to be deleted or press F3 to quit
Site #: 1L001 Plot #: 1 Sample date: 08/17/87

Entry of a site number, sample date, plot number combination that does not exist in the database will produce the message:

Site number, sample date, plot number combination does not exist in database
Press any key to continue...

Entry of a valid site, date, plot number combination will produce the question:

What do you want to delete?
Enter one of the following codes: 3

- 1 - Delete all egg mass records for this plot
- 2 - Delete certain egg mass lines of this plot
- 3 - Display egg mass lines without making corrections
- Q - Quit

Option 1 will display the egg mass lines on the screen. At the bottom you will be asked to "Press Y to delete the egg mass records for this plot". Any other key will keep the data and return to the menu. All egg mass records for the site plot date combination will be deleted using option 1.

Option 2 allows you to specify which egg mass sample line you need to delete. You will be shown the egg mass data with the record numbers. You will then be asked: "Enter record number to be deleted or Q to quit". You will continue to be asked for record numbers until you quit. You will then be asked to "Press Y to delete egg mass record # X". Enter a Y to delete that one egg mass entry. Any other key will save the record and get the next record in the stack for

deletions. Once all records requested have been deleted you will return to the menu.

Option 3 allows to view all egg mass data for a given site plot and date without deleting the data.

Defoliation Data Deletion

Selection of the defoliation data type (option 5) will generate the question:

Enter site number,plot number and sample date to be deleted or press F3 to quit
Site #: 1L001 Plot #: 1 Sample date: 08/17/87

Entry of a site number, sample date, plot number combination that does not exist in the database will produce the message:

Site number, sample date, plot number combination does not exist in database
Press any key to continue...

Entry of a valid site, date, plot number combination will produce a data deletion screen showing the record to be deleted. You will then be asked to "Press Y to delete this record". Enter a Y to delete the record. Any other key will save the record and return you to the deletion screen.

LISTING SAMPLE DATES

Because all data correction depends on knowing the sample date, quarter, and sample number, it is necessary to be able to scan the data to determine what dates and samples have been entered. Selection of option 6 (list sample dates for a site) on the function menu (Fig. V.4.2) will ask the question:

Enter the site to list dates for:

After entering the site number you will receive the data file selection menu shown in Figure V.4.3. The program will search the selected database and type a list of sample dates and sample numbers which have been found for that site. You may scan more than one database for the same site by selecting each file in succession. Press F3 or type Q to return to the main menu.

DICTIONARY MAINTENANCE

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DICTIONARY MAINTENANCE

Several keys will be important to know about during your session with the computer. The RETURN key is the one on the right of the keyboard with a <_]. This key is used to skip from one entry area (lighted box) to the next on the screen. The cursor is a blinking underline character on the screen which shows you where the next letter will type. To move the cursor there are four cursor keys found on the right of the keyboard. These are the 2,4,6, and 8 keys which also have direction arrows on them. The left and right arrows (4 and 6) will move left and right within the box where the cursor resides. The up and down arrows (2 and 8) will move the cursor to the next or previous box on the screen. During data entry the cursor will automatically move to the next box whenever you fill the previous box. The HOME key will take you to the beginning of the lighted box where the cursor resides. The END key will take to the end of that box. The INS key will allow you to insert characters between ones already there. The DEL key will delete characters. PGUP and PGDN will submit the entire screen to the database without typing in data for all boxes on the screen. The F3 key is found on the left side of the keyboard. This one is used by the programs to quit from a screen. Please note: if you quit NO DATA from that screen will be saved.

GETTING THE MENU

Once you have an C> on the screen type LTEMS and press RETURN. The menu will display as shown in Figure V.5.1.

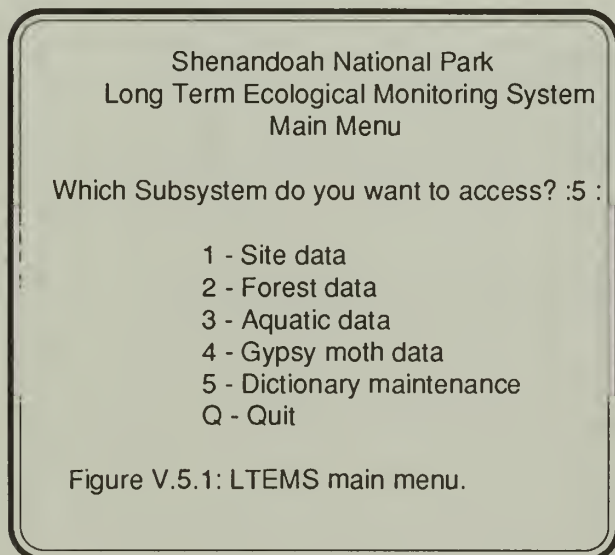


Figure V.5.1: LTEMS main menu.

Option 5 will give you access to the dictionary portion of the LTEMS database. To quit from the menu and return to DOS press F3 or type option Q.

Once you have selected option 5 for dictionary maintenance, you must select which function you would like to use using the next menu as shown in Figure V.5.2.

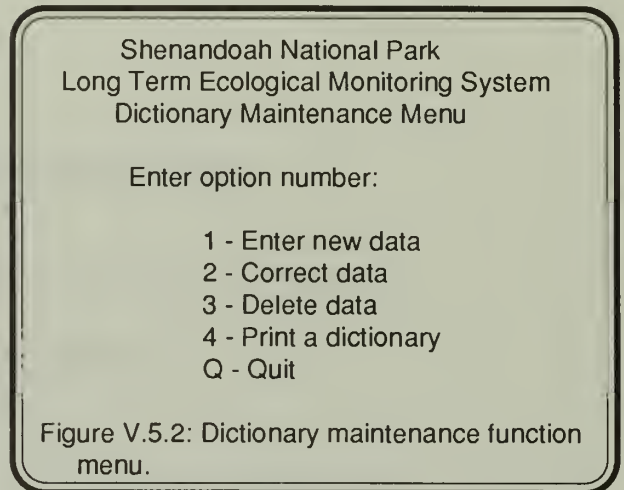


Figure V.5.2: Dictionary maintenance function menu.

Option 1 allows you to enter new data into any of the dictionary files. Option 2 allows data correction. To delete data from a dictionary use option 3. Option 4 will allow you to print a dictionary. To quit and return to the main menu press F3 or type Q. After you have selected a function you will be given another menu (Fig. V.5.3) to select which dictionary file you want to use.

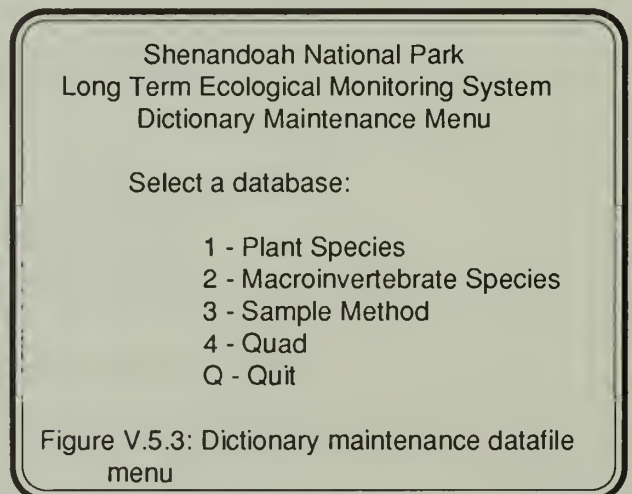


Figure V.5.3: Dictionary maintenance datafile menu

On this screen you are given the choice of four different dictionary files to use. Once you select a file you may perform the selected function numerous times on that dictionary file. Once you quit from the data entry or correction screen, you will be returned to the database selection menu. If you want to use the selected function (ie enter data, etc.) you may select another database and continue to work. If you need to select a new function quit from the database

selection and you will get the function selection menu (Fig. V.5.2).

DATA ENTRY

Plant Species Data Entry

Selection of the plant dictionary (option 1) will generate a data entry screen which is shown in Figure V.5.4.

Plant Dictionary

Plant Code: QRB
 Common Name: Red Oak
 Genus: Quercus
 Species: rubrum
 Subspecies:
 SAF Code:

Option (1=Quit 2=Save Data): 2

Figure V.5.4: Plant dictionary data entry screen.

Data should be filled in as shown in Figure V.5.4. Plant code is 3 letters - the first is the first letter of the Genus name and the next 2 are the first 2 consonants of the species name. The plant code is automatically capitalized when you type it. The first letter of the common name and the genus are automatically capitalized when they are typed. When a box is filled the cursor automatically moves to the next box. If you do not fill the box you must press the RETURN key to get to the next box. The last box is preset to option 2 (save the data). To quit and not save any data for a given screen, press F3 with the cursor on the CODE block or type a 1 in the option box (last one on the screen). Once all data is typed you may use the PGDN key from any point on the screen to save the data. The plant code is checked to be sure that it has not been used previously. If it has, you will not be able to save it without changing the code to a unique one.

Macroinvertebrate Taxa Data Entry

Selection of the macroinvertebrate dictionary (option 2) will generate a data entry screen which is shown in Figure V.5.5.

Taxa Dictionary

Taxa Code:
 Description:
 Tolerant:
 Mode of Existence:
 Trophic Level:
 Functional Group:
 Dominant Food:

Option (1=Quit 2=Save Data): 2

Figure V.5.5: Macroinvertebrate dictionary data entry screen.

Data should be filled in as shown in Figure V.5.5. The taxa code in a seven column code of letters and numbers. The first space is phylum, the second is class, the third is order, the fourth is family, the fifth is tribe or subfamily, the sixth is genus and the seventh is species. When a new taxa is encountered, the taxonomic hierarchy must be obtained from the literature. The position of this taxa in the dictionary can then be located and a new code can be assigned. Tolerance, mode of existence, trophic level, functional group, and dominant food can also be obtained from the literature. Codes for values of these items are listed in Table V.5.1.

Table V.5.1. Taxa Dictionary Variable Codes

Data Element	Value	Code
Tolerance	Intolerant	I
	Facultative	F
	Tolerant	T
Mode of Existence	Burrowers	B
	Clingers	CG
	Climbers	CL
	Planktonic	PT
	Skaters	SK
	Sprawlers	SP
Trophic Level	Swimmers	SW
	Carnivores	CR
	Detritivores	DT
	Herbivores	HB
Functional Group	Collector - gatherers	CG
	Collector - filterers	CF
	Piercers	PI
	Predators	PR
	Scrapers	SC
	Shredders	SH

Table V.5.1. Taxa Dictionary Variable Codes

Data Element	Value	Code
Dominant Food		
Animal tissue		AT
Coarse particulate organic matter		CP
Fine particulate organic matter		FP
Plant-animal tissue		PA
Periphyton		PP
Plant tissue		PT

The taxa code is automatically capitalized when you type it. The first letter of the common name and the genus are automatically capitalized when they are typed. When a box is filled the cursor automatically moves to the next box. If you do not fill the box you must press the RETURN key to get to the next box. The last box is preset to option 2 (save the data). To quit and not save any data for a given screen, press F3 with the cursor on the CODE block or type a 1 in the option box (last one on the screen). Once all data is typed you may use the PGDN key from any point on the screen to save the data. The taxa code is checked to be sure that it has not been used previously. If it has, you will not be able to save it without changing the code to a unique one.

Sample Method Code Data Entry

Selection of the sample method code dictionary (option 3 of the datafile selection menu shown in Figure V.5.3) will generate a data entry screen shown in Figure V.5.6.

Sample Method Dictionary

Sample Method Code: SUR

Description: Surber sampler

Option (1=Quit 2=Save Data): 2

Figure V.5.6: Sample method code data entry screen.

Data should be filled in as shown in Figure V.5.6. Sample method code is 3 letters. The sample method code is automatically capitalized when you type it. The first letter of the description is automatically capitalized when it is typed. When a box is filled the

cursor automatically moves to the next box. If you do not fill the box you must press the RETURN key to get to the next box. The last box is preset to option 2 (save the data). To quit and not save any data for a given screen, press F3 with the cursor on the CODE block or type a 1 in the option box (last one on the screen). Once all data is typed you may use the PGDN key from any point on the screen to save the data. The sample method code is checked to be sure that it has not been used previously. If it has, you will not be able to save it without changing the code to a unique one.

Quad Code Data Entry

Selection of the quad dictionary (option 4 of the datafile selection menu shown in Figure V.5.3) will generate a data entry screen shown in Figure V.5.7.

Quad Dictionary

Quad Code:

Quad Name:

UTM East: Minimum: 0 Maximum: 0

UTM North: Minimum: 0 Maximum: 0

Zone:

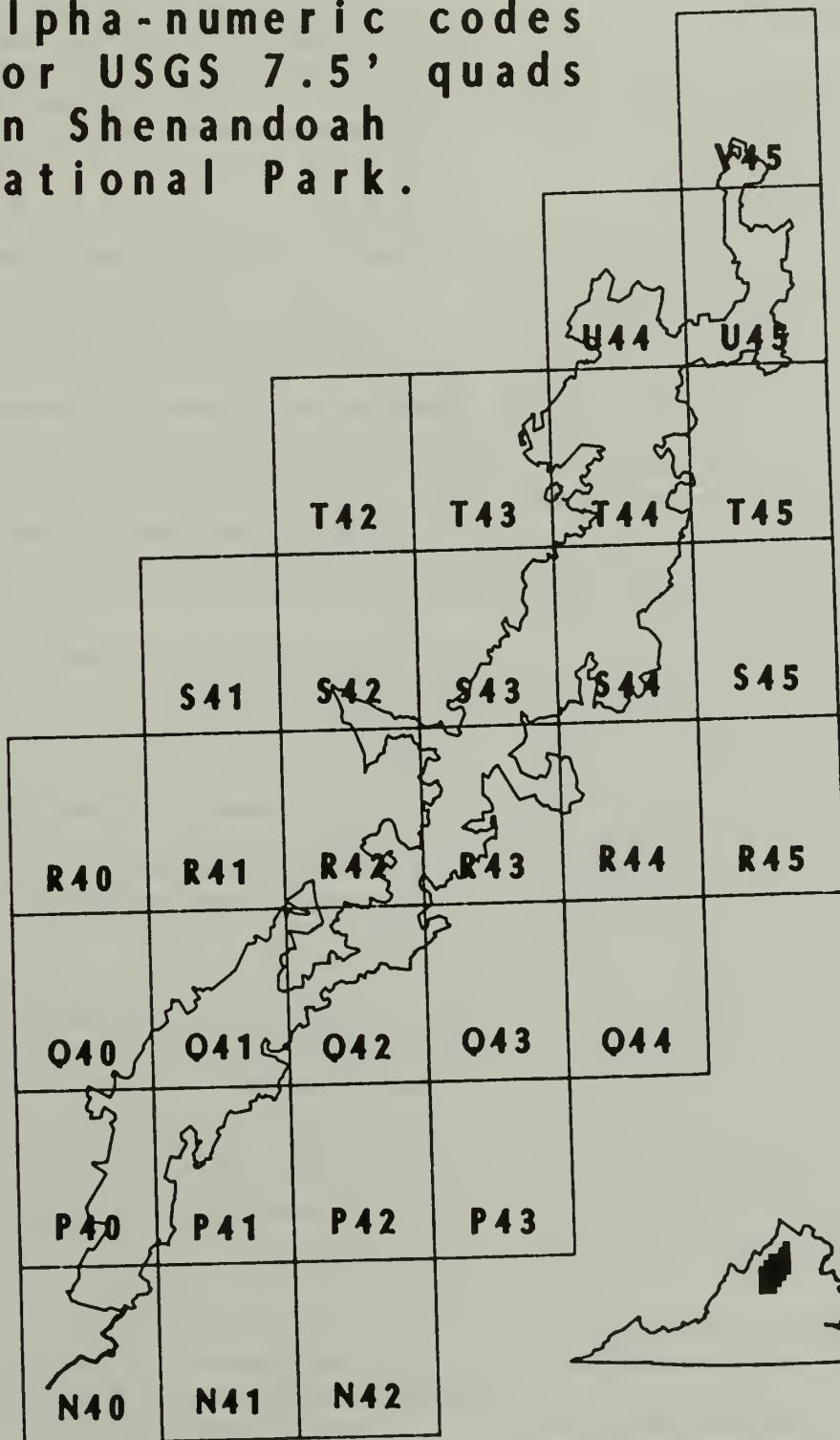
Option (1=Quit 2=Save Data): 2

Figure V.5.7: Quad code data entry screen.

Data should be filled in as shown in Figure V.5.7. The quad code is 1 letter and 2 numbers. For Virginia the index map of 7 1/2 minute topographic quadrangles is numbered 1 to 69 from West to East and lettered A to Z (excluding I and O) from South to North. Quad A01 is in the very SW corner of the state. Figure V.5.8 shows the quad numbering system for the Shenandoah Park. The quad code is automatically capitalized when you type it. The first letter of the quad name is automatically capitalized when it is typed. Minimum and maximum UTM's are to define the boundaries of the quad and used to validate the UTM locations of each site entered for that quad. The zone is the UTM grid system zone.

When a box is filled the cursor automatically moves to the next box. If you do not fill the box you must press the RETURN key to get to the next box. The last box is preset to option 2 (save the data). To quit and not save any data for a given screen, press F3 with the cursor on the CODE block or type a 1 in the option box (last one on the screen). Once all data is typed you may use the PGDN key from any point on the screen to save the data. The quad code is checked to be sure that it has not been used previously.

**Alpha-numeric codes
for USGS 7.5' quads
in Shenandoah
National Park.**



**Two-guys Mapping
Entomology, VPI & SU**

Figure V.5.8. Map showing quad codes for Shenandoah National Park

If it has, you will not be able to save it without changing the code to a unique one.

Getting Out

Quitting from the data file selection menu with the F3 key or Q option will display the function selection menu shown in Figure V.5.2.

DATA CORRECTION

Selection of option 2 (data correction) on the function menu will display the data file selection menu shown in Figure V.5.3.

Plant Species Correction

Selection of the plant dictionary file (option 1) will generate the question:

What plant code do you wish to change?
Enter code or use F3 to quit

Entry of a plant code which is not yet in the dictionary will produce the message:

No entry found for plant code requested
Press any key to continue...

Entry of a valid plant code will produce a screen as shown in Figure V.5.4. Changes may be made to any lighted box on the screen. If the plant code is changed it is checked to be sure that the new code has not been used previously. Assuming that the new code is a unique one, all data sets using plant code as data are then checked to see if the old plant code has been entered into any data records. Any occurrences of the old plant code are then changed to the new code.

Macroinvertebrate Taxa Correction

Selection of the macroinvertebrate dictionary file with the correction function will result in the following question:

What taxa code do you wish to change?
Enter taxa code or use F3 to quit

Entry of a taxa code which is not yet in the dictionary will produce the message:

No entry found for taxa code requested
Press any key to continue...

Entry of a valid plant code will produce a screen as shown in Figure V.5.5. Changes may be made to any lighted box on the screen. If the taxa code is changed it is checked to be sure that the new code has not been used previously. Assuming that the new code is a unique one, the macroinvertebrate database is then checked to see if the old taxa code has been entered into any data records. Any occurrences of the old taxa code are then changed to the new code.

Sample Method Code Correction

Selection of the sample method dictionary file with the correction function will result in the following question:

What sample method code do you wish to make changes to?
Enter sample method code or use F3 to quit

Entry of a sample method code which is not yet in the dictionary will produce the message:

No entry found for sample method code requested
Press any key to continue...

Entry of a valid sample method code will produce a screen as shown in Figure V.5.6. Changes may be made to any lighted box on the screen. If the sample method code is changed it is checked to be sure that the new code has not been used previously. Assuming that the new code is a unique one all data sets using sample method code as data are then checked to see if the old sample method code has been entered into any other data records. Any occurrences of the old sample method code are then changed to the new code.

Quad Code Correction

Selection of the quad dictionary file with the correction function will result in the following question:

What quad code do you wish to change?
Enter quad code or use F3 to quit

Entry of a quad code which is not yet in the dictionary will produce the message:

No entry found for quad code requested
Press any key to continue...

Entry of a valid quad code will produce a screen as shown in Figure V.5.7. Changes may be

made to any lighted box on the screen. If the quad code is changed it is checked to be sure that the new code has not been used previously. Assuming that the new code is a unique one all data sets using sample method code as data are then checked to see if the old sample method code has been entered into any other data records. Any occurrences of the old sample method code are then changed to the new code.

If you quit from the data file selection menu using the F3 key or option Q you will be returned to the function selection menu shown in Figure V.5.2.

DELETION OF ENTRIES

Selection of option 3 (delete data) on the function menu will display the data file selection menu shown in Figure V.5.3.

Plant Species Code Deletion

Selection of the plant dictionary (option 1) will ask the question:

What plant code do you wish to delete?
Enter code or use F3 to quit

Entry of a plant code which is not yet in the dictionary will produce the message:

No entry found for plant code requested
Press any key to continue...

Entry of a valid plant code will display the entire record on the screen. You will be asked "Is this the record to delete? enter Y to delete". Enter a Y to delete the record shown on the screen. Any other key will keep the record in the dictionary. All data files using the plant code as data are checked for that code. If the code has been used in the data you will not be able to delete the code. You may select the correction function and change the code in this case.

Macroinvertebrate Taxa Deletion

Selection of the macroinvertebrate dictionary (option 2) will ask the question:

What taxa code do you wish to delete?
Enter code or use F3 to quit

Entry of a taxa code which is not yet in the dictionary will produce the message:

No entry found for taxa code requested
Press any key to continue...

Entry of a valid taxa code will display the entire record on the screen. You will be asked "Is this the record to delete? enter Y to delete". Enter a Y to delete the record shown on the screen. Any other key will keep the record in the dictionary. All data files using the taxa code as data are checked for that code. If the code has been used in the data you will not be able to delete the code. You may select the correction function and change the code in this case.

Sample Method Code Deletion

Selection of the sample method dictionary (option 3) will ask the question:

What sample method code do you wish to delete?
Enter code or use F3 to quit

Entry of a sample method code which is not yet in the dictionary will produce the message:

No entry found for sample method code requested
Press any key to continue...

Entry of a valid sample method code will display the entire record on the screen. You will be asked "Is this the record to delete? enter Y to delete". Enter a Y to delete the record shown on the screen. Any other key will keep the record in the dictionary. All data files using the sample method code as data are checked for that code. If the code has been used in the data you will not be able to delete the code. You may select the correction function and change the code in this case.

Quad Code Deletion

Selection of the quad dictionary (option 4) will ask the question:

What quad code do you wish to delete?
Enter code or use F3 to quit

Entry of a quad code which is not yet in the dictionary will produce the message:

No entry found for quad code requested
Press any key to continue...

Entry of a valid quad code will display the entire record on the screen. You will be asked "Is this the record to delete? enter Y to delete". Enter a Y to delete the record shown on the screen. Any other key will keep the record in the dictionary. All data files using the quad code as data are checked for that code. If the code has been used in the data you will

not be able to delete the code. You may select the correction function and change the code in this case.

PRINTING THE DICTIONARIES

Selection of option 4 (print a dictionary) of the function menu will generate the data file selection menu (Fig. V.5.3). Selection of the plant dictionary results in the following question:

Do you want plants listed in genus species
or common name order? G or C

Answer G for genus species order and C for common name order. The other dictionaries are printed in code order only. All dictionary prints will automatically print on the printer connected to your PC.

TECHNICAL NOTES

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TECHNICAL NOTES

Installation of the System

To install the LTEMS database on the harddisk you must first create the directories needed to house the files. The programs contain a compiled set of file names and paths which must be used unless the programs are changed (see next section for details in changing the path). The currently compiled directories are to be created on drive **D**. These are D:\LTEM\LTEMS\PROG, D:\LTEM\LTEMS\DATA, and D:\LTEM\CLIPPER\. To create these type the following:

```
D:
CD\
MD\LTEM
MD\LTEM\LTEMS
MD\LTEM\CLIPPER
MD\LTEM\LTEMS\PROG
MD\LTEM\LTEMS\DATA
```

Alter the CONFIG.SYS file to have the lines:
BUFFERS = 40
FILES = 45

Install the CLIPPER software into the \LTEM\CLIPPER directory. Copy the CLT.BAT file from the LTEMS software into the \LTEM\CLIPPER directory. To do this insert the Clipper System Disk in drive A and type:

```
CD\LTEM\CLIPPER
A:
CLIPCOPY D:
```

You will be asked to insert several other diskettes to complete the clipper installation. When this is finished find the CLT.BAT diskette and put it in drive A. Type:

```
D:
COPY A:CLT.BAT D:
```

The ... \PROG directory will contain all files with a filetype of PRG or EXE except the BLDCLIND.PRG and BLDCLIND.EXE files. The BLDCLIND files are housed in the ... \DATA directory along with all files with filetype NDX, DBF, and FRM. To copy these files place the diskette with the PRG files in drive A and type:

```
CD\LTEM\LTEMS\PROG
COPY A:*.PRG D:
```

Place the EXE file diskette in drive A and type:

```
CD\LTEM\LTEMS\PROG
COPY A:*.EXE D:
```

Place the BLDCLIND file diskette in drive A and type:

```
CD\LTEM\LTEMS\DATA
COPY A:BLDCLIND.* D:
```

Place the DBF and FRM file diskette in drive A and type:

```
CD\LTEM\LTEMS\DATA
COPY A:*.DBF D:
COPY A:*.FRM D:
BLDCLIND
```

The BLDCLIND program will run which takes some computing time. This will build all the index (NDX) files for the data which is contained in the DBF files. One note of warning: if this is the initial installation the DBF files will not contain any data. However, if you are moving from one computer to another with data in the files BE SURE YOU HAVE THE CURRENT COPY OF THE DATA.

Once you have installed the files you should have 147 PRG files, 2 EXE files, 17 DBF files, 21 NDX files, 4 FRM files, and 2 BLDCLIND files in the two directories.

Changing the Drive or Directory Names

The path to the drive and directory are defined by a line of code in the LTEMS.PRG and the LTOUT.PRG files. If you need to change to a different drive or need to change the actual directory names containing the files these 2 PRG files must be changed. First install all the files as described above, changing the drive and/or directory names to suit. To change the LTEMS program edit the LTEMS.PRG file and change line 19 to list the correct drive letter and directory names. Similarly edit LTOUT.PRG and change line 17. Both programs must now be recompiled using CLIPPER to make the changes in the EXE files. To make the compile run automatically you must edit the CLT.BAT file and change the drive and/or directory names in 3 places. To compile the programs type:

```
CD\...\CLIPPER
CLT LTEMS
CLT LTOUT
```


This will write a new EXE file for each program and erase the old copy.

Recompiling Changes to PRG Files

Any changes which must be made to the PRG files to change the program operation must be compiled into the corresponding EXE file. If changes are made to the modules for printing reports or exporting data files then both LTEMs and LTOU must be recompiled. Any other changes only affect the LTEMs program. To recompile LTEMs type:

```
CD\LTEM\CLIPPER  
CLT LTEMs
```

To also recompile LTOU then type:

```
CLT LTOU
```

Entering Data on Multiple Machines

Running the LTEMs database on more than one host machine is not recommended. This practice can cause serious data integrity problems resulting in bad or lost data. If it is absolutely necessary for data entry to occur on more than one machine, each machine should be dedicated to a specific data type. All site data must be entered on the host machine before setting up the site file on the second machine. No sites may be added on the second machine and data cannot be entered for sites which have not yet been defined.

Aquatic Data

To set up a second machine to accept aquatic data you will need to make empty copies of the STREAM and AQINS DBF files and their indexes on a floppy. This is done in DBASE on the host machine by placing a floppy in drive A and typing:

```
DBASE  
ESC to dot prompt  
USE STREAM  
COPY STRUCTURE TO A:STREAM  
USE AQINS  
COPY STRUCTURE TO A:AQINS  
RUN A:  
USE AQINS  
INDEX ON UPPER(SMPMETH) TO AQSMPTH  
INDEX ON UPPER(SITE)+  
SUBSTR(DTOC(SMPDATE),7,2)+QUARTER  
+ASMPL TO AQSTQT  
INDEX ON UPPER(SITE)+  
SUBSTR(DTOC(SMPDATE),7,2)+QUARTER  
+UPPER(TAXA)+ASMPL TO AQTAXA
```

```
USE STREAM  
INDEX ON UPPER(SITE)+  
SUBSTR(DTOC(SMPDATE),7,2)+QUARTER  
TO STRMSTQT  
RUN D:  
QUIT
```

Now you must copy other files to a floppy to transfer them to the other machine. To do this place a diskette in the A drive of the host machine and type:

```
CD\LTEM\LTEMs\DATA  
COPY TAXADICT.DBF A:  
COPY TAXA.NDX A:  
COPY SITE.DBF A:  
COPY SITE.NDX A:  
COPY SMPMETH.DBF A:  
COPY SMPMETH.NDX A:  
CD\LTEM\LTEMs\PROG  
COPY LTEMs.EXE A:
```

Copy these files onto the appropriate directories on the other machine. You should now be able to enter aquatic data on the second machine.

Once data entry is complete you must append all the data records in the AQINS.DBF and STREAM.DBF files of the temporary machine to the host machine. You MAY NOT add any new taxa codes to the dictionary of the temporary machine without also adding them on the host machine as these additions will not transfer back.

To append the records from the second machine onto the host machine place an empty diskette in drive A and type the following:

```
CD\LTEM\LTEMs\DATA  
DBASE  
USE STREAM  
Make note of the number of records which are in the  
file. This is listed at the bottom of the screen  
as Record:23/200 which means 200.  
COPY FILE TO A:STRM.DAT SDF  
USE AQINS  
Make note of the number of records which are in the  
file.  
COPY FILE TO A:AQIN.DAT SDF  
QUIT
```

Take the diskette to the host machine and place in the A drive. Type the following:

```
CD\LTEM\LTEMs\DATA  
DBASE  
USE STREAM INDEX STRMSTQT
```

Make note of the number of records which are in the file.

```
APPEND FROM A:STRM.DAT SDF
```

Be sure the number of records is now equal to the old file plus the records being transferred.

```
USEAQINS INDEX AQSTQT,AQTAXA,AQSMPMTH
```

Make note of the number of records which are in the file.

```
APPEND FROM A:AQIN.DAT SDF
```

Be sure the number of records is now equal to the old file plus the records being transferred.

Once you check the total records to be sure all records are transferred, you should erase all files which you created on the second machine. If you need to continue adding records from the second machine then remove all the records from the DBF files so they are not transferred a second time when the next round of data entry is complete.

If there are any problems with use of the new files you should run the BLDCLIND program to rebuild all of the indexes. To do this type:

```
CD\LTEM\LTEMS\DATA
BLDCLIND
```

Forest Data

To set up a second machine to accept forestry data you will need to make empty copies of the STAND, STAGE1, STAGE2, STAGE3, STG3COM and STG3GC DBF files and their indexes on a floppy diskette. This is done in dBASE on the host machine by placing a diskette in drive A and typing:

```
DBASE
ESC to dot prompt
USE STAND
COPY STRUCTURE TO A:STAND
USE STAGE1
COPY STRUCTURE TO A:STAGE1
USE STAGE2
COPY STRUCTURE TO A:STAGE2
USE STAGE3
COPY STRUCTURE TO A:STAGE3
USE STG3COM
COPY STRUCTURE TO A:STG3COM
USE STG3GC
COPY STRUCTURE TO A:STG3GC
RUN A:
USE STAND
INDEX ON UPPER(SITE)+DTC(SMPDATE)+
      PLOTNO TO STNDDATE
```

```
USE STAGE1
INDEX ON UPPER(SITE)+DTC(SMPDATE)+
      PLOTNO+UPPER(SPECODE) TO
      STG1STDT
```

```
USE STAGE2
INDEX ON UPPER(SITE)+DTC(SMPDATE)+
      PLOTNO+SPLOTNO+
      UPPER(SPECODE) TO STG2STDT
```

```
USE STAGE3
INDEX ON UPPER(SITE)+DTC(SMPDATE)+
      PLOTNO+SPLOTNO+HPLTNO+
      UPPER(SPECODE) TO STG3STDT
```

```
USE STG3COM
INDEX ON UPPER(SITE)+DTC(SMPDATE)+
      PLOTNO+SPLOTNO+HPLTNO+
      UPPER(SPECODE) TO S3CMSTDT
```

```
USE STG3GC
INDEX ON UPPER(SITE)+DTC(SMPDATE)+
      PLOTNO+SPLOTNO+HPLTNO TO
      S3GCSTDT
```

```
RUN D:
QUIT
```

Now you must copy other files to a floppy to transfer them to the other machine. To do this place a diskette in the A drive of the host machine and type:

```
CD\LTEM\LTEMS\DATA
COPY PLNTDICT.DBF A:
COPY PLNTCODE.NDX A:
COPY SITE.DBF A:
COPY SITE.NDX A:
CD\LTEM\LTEMS\PROG
COPY LTEMS.EXE A:
```

Copy these files onto the appropriate directories on the other machine. You should now be able to enter forest data on the second machine.

Once data entry is complete you must append all the data records in the STAND, STAGE1, STAGE2, STAGE3, STG3COM and STG3GC DBF files of the temporary machine to the host machine. You MAY NOT add any new plant codes to the dictionary of the temporary machine without also adding them on the host machine as these additions will not transfer back.

To append the records from the second machine onto the host machine place an empty diskette in drive A and type the following:

```
CD\LTEM\LTEMS\DATA
DBASE
USE STAND
```

Make note of the number of records which are in the file. This is listed at the bottom of the screen as Record:23/200 which means 200.

```
COPY FILE TO A:STND.DAT SDF
USE STAGE1
```

Make note of the number of records which are in the file.

```
COPY FILE TO A:STG1.DAT SDF
USE STAGE2
```

Make note of the number of records which are in the file.

```
COPY FILE TO A:STG2.DAT SDF
USE STAGE3
```

Make note of the number of records which are in the file.

```
COPY FILE TO A:STG3.DAT SDF
USE STG3COM
```

Make note of the number of records which are in the file.

```
COPY FILE TO A:STG3C.DAT SDF
USE STG3GC
```

Make note of the number of records which are in the file.

```
COPY FILE TO A:STG3G.DAT SDF
QUIT
```

Take the diskette to the host machine and place in the A drive. Type the following:

```
CD\LTEM\LTEMS\DATA
DBASE
```

```
USE STAND INDEX STNDDATE
```

Make note of the number of records which are in the file.

```
APPEND FROM A:STND.DAT SDF
```

Be sure the number of records is now equal to the old file plus the records being transferred.

```
USE STAGE1 INDEX STG1STDT
```

Make note of the number of records which are in the file.

```
APPEND FROM A:STG1.DAT SDF
```

Check the new number of records.

```
USE STAGE2 INDEX STG2STDT
```

Make note of the number of records which are in the file.

```
APPEND FROM A:STG2.DAT SDF
```

Check the new number of records.

```
USE STAGE3 INDEX STG3STDT
```

Make note of the number of records which are in the file.

```
APPEND FROM A:STG3.DAT SDF
```

Check the new number of records.

```
USE STG3GC INDEX S3GCSTDT
```

Make note of the number of records which are in the file.

```
APPEND FROM A:STG3G.DAT SDF
```

Check the new number of records.

```
USE STG3COM INDEX S3CMSTDT
```

Make note of the number of records which are in the file.

```
APPEND FROM A:STG3C.DAT SDF
```

Check the new number of records.

Once you check the total records to be sure all records are transferred, you should erase all files which you created on the second machine. If you need to continue adding records from the second machine then remove all the records from the DBF files so they are not transferred a second time when the next round of data entry is complete.

If there are any problems with use of the new files you should run the BLDCLIND program to rebuild all of the indexes. To do this type:

```
CD\LTEM\LTEMS\DATA
BLDCLIND
```


PROGRAMMER GUIDE

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PROGRAMMER GUIDE

The LTEMs database is coded entirely in dBASE®. All programs are then compiled using the CLIPPER® compiler into machine readable code. The programs use too many files and indexes to run under dBASE III+® and the initial version of dBASE IV® has too many software problems to allow the LTEMs program to execute successfully. Therefore only the CLIPPER® compiled version is operational. Indexes are compatible with dBASE so it is possible to look at the data files from within dBASE. Because of the number of open files required, you must be running under DOS 3.2 or higher. You must also alter the config.sys file to have the lines: buffers = 40 and files = 45.

Data Record Descriptions

There are 17 data files (.dbf) and 21 index files (.ndx) associated with the LTEMs database system. Of the 17 data files, 1 defines the sites, 6 contain forest data, 2 contain aquatic data, 4 contain gypsy moth data, and 4 are data dictionaries for definition of various codes. The dictionaries allow for code validation and also link codes to given plant names or macroinvertebrate descriptions.

Tables V.7.1 thru V.7.17 describe each database record including field names, widths, and a description of the data contained in each field. The dbf file name is in parenthesis in the table title. For example, the site database file name is site.dbf.

Table V.7.1: Site (site) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
UTMN	Character	10	UTM North
UTME	Character	10	UTM East
GEOL	Character	2	Geological Formation
ELEV	Character	4	Elevation (feet)
STREAM	Character	25	Stream Name
SOIL	Character	2	Soil Type
QUAD	Character	3	Quad Code
SITETYP	Character	2	Site Type (AQ or FR)
ASPCTCLS	Character	1	Aspect Class
ELEVCLASS	Character	1	Elevation Class
VEGTYPE	Character	5	Site Level Cover Type
** Total **		71	

Table V.7.2: Stand (stand) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
SMPDATE	Date	8	Sample Date
COVER	Character	5	Stand Level Cover Type
STNDSTR	Character	2	Stand Structure
PLOTNO	Character	1	Plot Number
ASPECT	Character	3	Aspect
SLOPE	Character	3	Slope
SLOPOS	Character	2	Slope Position
SLOSHP	Character	1	Slope Shape
COMMENTS	Character	35	Comments about stand
LNDFRM	Character	2	Land form
BA	Character	4	Basal area prism factor
** Total **		72	

Table V.7.3: Stage 1 (stage1) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
SMPDATE	Date	8	Sample Date
PLOTNO	Character	1	Plot Number
SPECODE	Character	3	Tree Species Code
DBH	Character	5	Diameter Breast Height (cm)
CROWNCLS	Character	1	Crown Class
STATUS	Character	1	Live/Dead Status
AGE	Character	3	Age of Tree
HEIGHT	Character	3	Height of Tree (feet)
QUADRATE	Character	2	Quadrat Number
X	Character	1	Distance from corner (m)
Y	Character	1	Distance from corner (m)
NOTE1	Character	1	Note Code
NOTE2	Character	1	Note Code
NOTE3	Character	1	Note Code
CRWNHLTH	Character	1	Crown Health
** Total **		39	

Table V.7.4: Stage 2 (stage2) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
SMPDATE	Date	8	Sample Date
PLOTNO	Character	1	Plot Number
SPLOTNO	Character	1	Shrub Plot Number
SPECODE	Character	3	Shrub Species Code
SHCOUNT	Character	3	Stem Count for Species
** Total **		22	

Table V.7.5: Stage 3 (stage3) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
SMPDATE	Date	8	Sample Date
PLOTNO	Character	1	Plot Number
SPLOTNO	Character	1	Shrub Plot Number
HPLOTNO	Character	1	Herb Plot Number
SPECODE	Character	3	Herb Species Code
STEMCNT	Character	3	Stem Count for Species
COVERCLS	Character	1	Cover Class (1987 data only)
** Total **		24	

Table V.7.6: Stage 3 Ground Cover (stg3gc) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
SMPDATE	Date	8	Sample Date
PLOTNO	Character	1	Plot Number
SPLOTNO	Character	1	Shrub Plot Number
HPLOTNO	Character	1	Herb Plot Number
ROCK	Character	1	% Rock in Ground Cover (code)
ORGAN	Character	1	% Organic Matter in Ground Cover (code)
WOODY	Character	1	% Woody Debris in Ground Cover (code)
MINER	Character	1	% Mineral Soil in Ground Cover (code)
FORBES	Character	1	% Forbes in Ground Cover (code)
GRASS	Character	1	% Grass in Ground Cover (code)
SEDGE	Character	1	% Sedges in Ground Cover (code)
SQUAWRT	Character	1	% Squaw Root in Ground Cover (code)
** Total **		25	

Table V.7.7: Stage 3 Common Herb (stg3com) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
SMPDATE	Date	8	Sample date
PLOTNO	Character	1	Plot Number
SPLOTNO	Character	1	Shrub Plot Number
HPLOTNO	Character	1	Herb Plot Number
SPECODE	Character	3	Herb Species Code
COVERCLS	Character	1	% Cover (code)
** Total **		21	

Table V.7.8: Stream (stream) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
QUARTER	Character	1	Calendar Quarter
SMPDATE	Date	8	Sample Date
TEMP	Character	4	Water Temperature (C)
DO	Character	4	Dissolved Oxygen (mg/L)
PH	Character	5	pH of Water
ALKALIN	Character	3	Alkalinity (μ eq/L)
CONDUCT	Character	3	Conductivity (μ mhos)
HARDNESS	Character	2	Hardness (1987 data only)
SESTON	Character	6	Total Seston (mg DW/L)
ORGSESTON	Character	6	Organic Seston (mg AFDW/L)
INORSESTON	Character	6	Inorganic Seston (mg Ash/L)
OIRATIO	Character	4	Organic:Inorganic Ratio
TPHOS	Character	4	Total Phosphorus (1987 data only)
NITR	Character	4	Nitrate (mg/L)
SULF	Character	4	Sulfate (mg/L)
FECST	Character	6	Fecal Streptococcus (MPN/100ml)
TCOLI	Character	6	Total Coliform (MPN/100ml)
FCOLI	Character	6	Fecal Coliform (MPN/100ml)
CHL1	Character	6	Chlorophyll sample 1 (μ g/cm ²)
CHL2	Character	6	Chlorophyll sample 2 (μ g/cm ²)
CHL3	Character	6	Chlorophyll sample 3 (μ g/cm ²)
DISCHRG	Character	6	Discharge (m ³ /sec)
DEPTH	Character	3	Stream Depth (cm)
WIDTH	Character	2	Stream Width (m)
RIPCVR	Character	3	Riparian Cover Code
RIPTYPE	Character	20	Riparian Type Code
DEBRIS	Character	3	Debris Retention Code
FISHCVR	Character	3	Fish Cover Code
POOLRIFL	Character	5	Pool:Riffle Ratio
SUBSTRATE	Character	20	Substrate Composition Code
AI	Character	5	Autotrophic Index
ALUM	Character	5	Aluminum (mg/L)
DOC	Character	5	Dissolved Organic Carbon
AVGCHL	Numeric	6.4	Average Chlorophyll (μ g/cm ²)
CHLOR	Character	4	Chloride (mg/L)
CALC	Character	6	Calcium (mg/L)
MAGNES	Character	4	Magnesium (mg/L)
POTAS	Character	6	Potassium (mg/L)
SODIUM	Character	6	Sodium (mg/L)
SILICA	Character	4	Silica (mg/L)
** Total **		222	

Table V.7.9: Macroinvertebrate (aqins) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
QUARTER	Character	1	Calendar Quarter
SMPDATE	Date	8	Sample Date
ASMPL	Character	1	Sample Number
SMPMETH	Character	3	Sample Method
TAXA	Character	7	Taxa Code
INSCNT	Character	4	Insect Count for Taxa
METERCNT	Character	5	Insect Count per Meter for Taxa
WEIGHT	Character	6	Weight of Taxa
STAGE	Character	1	Life Stage
FUNCGRP	Character	2	Functional Group
REARED	Logical	1	Reared
** Total **		45	

Table V.7.10: Plant Dictionary (plntdict) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SPECODE	Character	3	Plant Species Code
COMMON	Character	25	Common Name
GENUS	Character	25	Genus
SPEC	Character	25	Species
SUBSPEC	Character	15	Subspecies
SAFCODE	Character	5	SAF Code
** Total **		99	

Table V.7.11: Taxa Dictionary (taxadict) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
DESC	Character	30	Taxa Description
TAXA	Character	7	Taxa Code
TOLERANT	Character	1	Tolerance
MODEEXIST	Character	2	Mode of Existence
TROPHIC	Character	2	Trophic Level
FUNCGRP	Character	2	Functional Group
DOMFOOD	Character	2	Dominant Food
** Total **		47	

Table V.7.12: Sample Method Dictionary (simplmeth) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SMPMETH	Character	3	Sample Method Code
DESC	Character	60	Sample Method Description
** Total **		64	

Table V.7.13: Quad Dictionary (quad) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
QUAD	Character	3	Quad Code
QUADNAME	Character	25	Quad Name
UTMEMIN	Numeric	6	Minimum UTM East
UTMEMAX	Numeric	6	Maximum UTM East
UTMNMIN	Numeric	7	Minimum UTM North
UTMNMAX	Numeric	7	Maximum UTM North
ZONE	Character	2	UTM Zone
** Total **		57	

Table V.7.14: Gypsy Moth Trap Placement (gytrap) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
PLOTNO	Character	1	Plot Number
PLACEDATE	Date	8	Trap Placement Date
TRAPTYPE	Character	2	Trap Type
** Total **		17	

Table V.7.15: Gypsy Moth Trap Catch (gymale) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
PLOTNO	Character	1	Plot Number
SMPDATE	Date	8	Sample Date
MOTHS	Character	4	Number of Moths Caught
** Total **		19	

Table V.7.16: Egg Mass (eggmass) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
PLOTNO	Character	1	Plot Number
ESMPL	Character	1	Egg Mass Sample Number
SMPDATE	Date	8	Sample Date
EGGMASSENT	Character	4	Egg Mass Count
EMACRE	Character	6	Egg Masses per Acre
** Total **		26	

Table V.7.17: Defoliation (defol) Record Layout

<u>Field Name</u>	<u>Type</u>	<u>Width</u>	<u>Description</u>
SITE	Character	5	Site Number
PLOTNO	Character	1	Plot Number
SMPDATE	Date	8	Sample Date
DEFRATE	Character	1	Defoliation Rating Code
** Total **		16	

Table V.7.18 shows each index file name and the items which are used to build the key. The database which is referenced by the index is listed in the first column with the key elements in the second column and the index name last.

Table V.7.18: Index Keys and Names

<u>Database</u>	<u>Index Key</u>	<u>Index name</u>
plntdict	upper(specode) upper(common) upper(genus) + ' ' + upper(spec)	plntcode plntname plntspec
stand	upper(site)+dtoc(smpdate)+upper(plotno)	stnddate
site	upper(site)	site
quad	upper(quad)	quad
stream	upper(site)+substr(dtoc(smpdate),7,2)+quarter	strmstqt
smpmeth	upper(smpmeth)	smpmeth
aqins	upper(smpmeth)	aqsmpmth
	upper(site) +substr(dtoc(smpdate),7,2)+quarter+upper(taxa)+asmpl	aqtaxa
	upper(site)+substr(dtoc(smpdate),7,2)+quarter+asmpl	aqstqt
stage1	upper(site)+dtoc(smpdate)+plotno+upper(specode)	stg1stdt
stage2	upper(site)+dtoc(smpdate)+plotno+splotno+upper(specode)	stg2stdt
stage3	upper(site)+dtoc(smpdate)+plotno+splotno+hplotno+upper(specode)	stg3stdt
stg3gc	upper(site)+dtoc(smpdate)+plotno+splotno+hplotno	s3gcstdt
stg3com	upper(site)+dtoc(smpdate)+plotno+splotno+hplotno+upper(specode)	s3cmstdt
taxadict	upper (taxa)	taxa
eggmass	site +dtoc(smpdate) +plotno	eggstdt
defol	site +dtoc(smpdate) +plotno	defstdt
gymale	site+plotno + substr(dtoc(smpdate),7,2) +dtoc(smpdate)	gymlstdt
gytrap	site+plotno + substr(dtoc(placedate),7,2)	gytrstdt

Figure V. 7.1 shows how the data and dictionary records are linked together. Data set names are in bold type and linked field names are in light face with the links indicated by lines. Table V.7.19 lists various relations which can be set to automatically link certain files. Other combination of linked files may be requested. Additional examples are available in the *vue.prg files found on the \prog directory of the installed database code.

Table V.7.19: Relations Between Datafiles

<u>View type</u>	<u>dBASE Commands</u>
STAND VIEW	SET EXACT OFF SELECT B USE STAND INDEX STNDDATE SELECT A USE SITE INDEX SITE SELECT STAND SET RELATION TO SITE INTO SITE
FOREST DATA VIEW	SET EXACT OFF SELECT C USE STAGE1 INDEX STG1STDT SELECT B USE STAND INDEX STNDDATE SELECT D USE STAGE2 INDEX STG2STDT SELECT E USE STAGE3 INDEX STG3STDT SELECT F USE PLNTDICT INDEX PLNTCODE SELECT A USE SITE INDEX SITE SET RELATION TO SITE INTO STAND SELECT STAND SET RELATION TO SITE +DTC(SMPDATE) +PLOTNO INTO STAGE1 SELECT STAGE1 SET RELATION TO SITE +DTC(SMPDATE) +PLOTNO INTO STAGE2 SELECT STAGE2 SET RELATION TO SITE +DTC(SMPDATE) +PLOTNO INTO STAGE3 SELECT SITE
AQUATIC DATA VIEW	SET EXACT OFF SELECT C USE STREAM INDEX STRMSTQT SELECT B USE STAND INDEX STNDDATE SELECT D USE AQINS INDEX AQTAXA SELECT E USE TAXADICT INDEX TAXA SELECT A USE SITE INDEX SITE SET RELATION TO SITE INTO STREAM SELECT STREAM SET RELATION TO SITE + SUBSTR(DTC(SMPDATE),7,2) + QUARTER INTO AQINS SELECT SITE

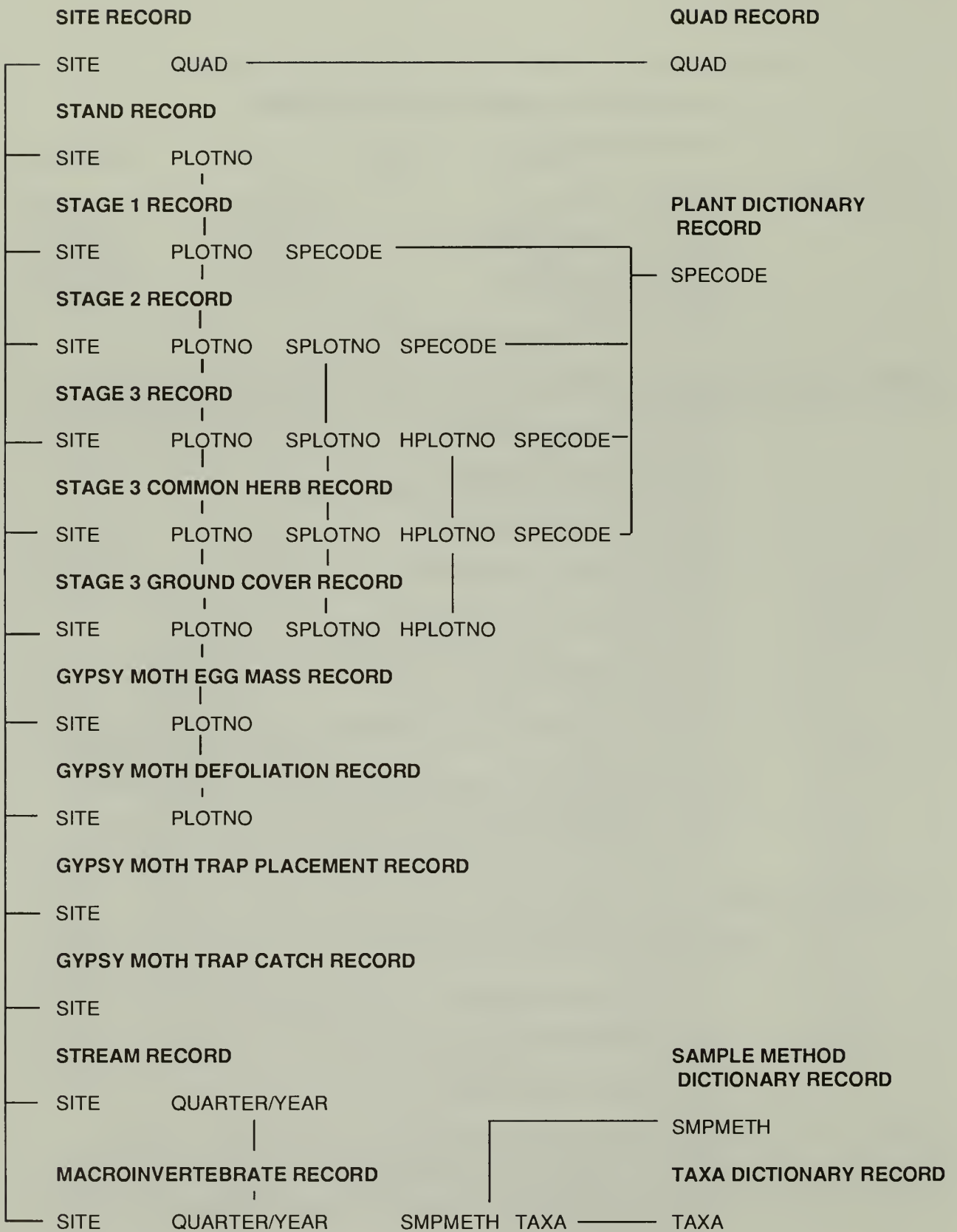


Figure V.7.1. File linkages.

Program Description

All programs are written using a structured programming approach. This means that each function is in a separate subroutine. The LTEMs system is started with the program named LTEMs. This module calls different subroutines for each of the functions on the menu. These subroutines may then call more subroutines. The nested structure of these routines is shown in Figures V.7.2 thru V.7.9. Because of the memory requirements of the aquatic output reporting, the print option must be called from another calling program. This program is named LTOU. The nested structure of LTOU is presented in Figure V.7.10.

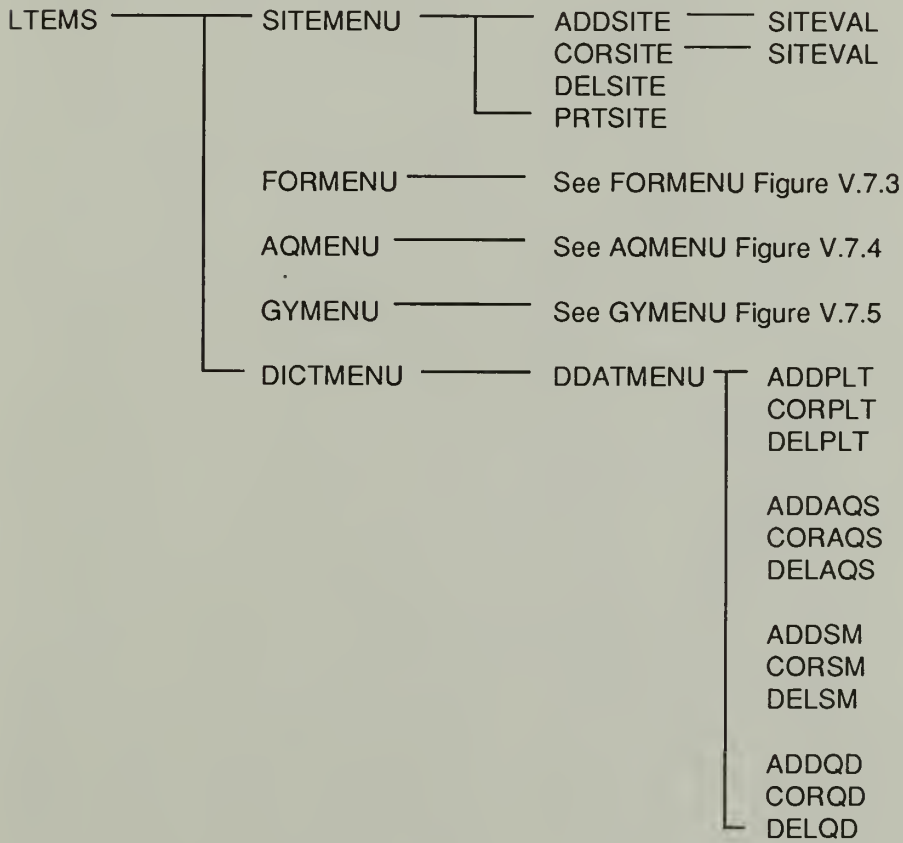


Figure V.7.2. LTEMs module map.

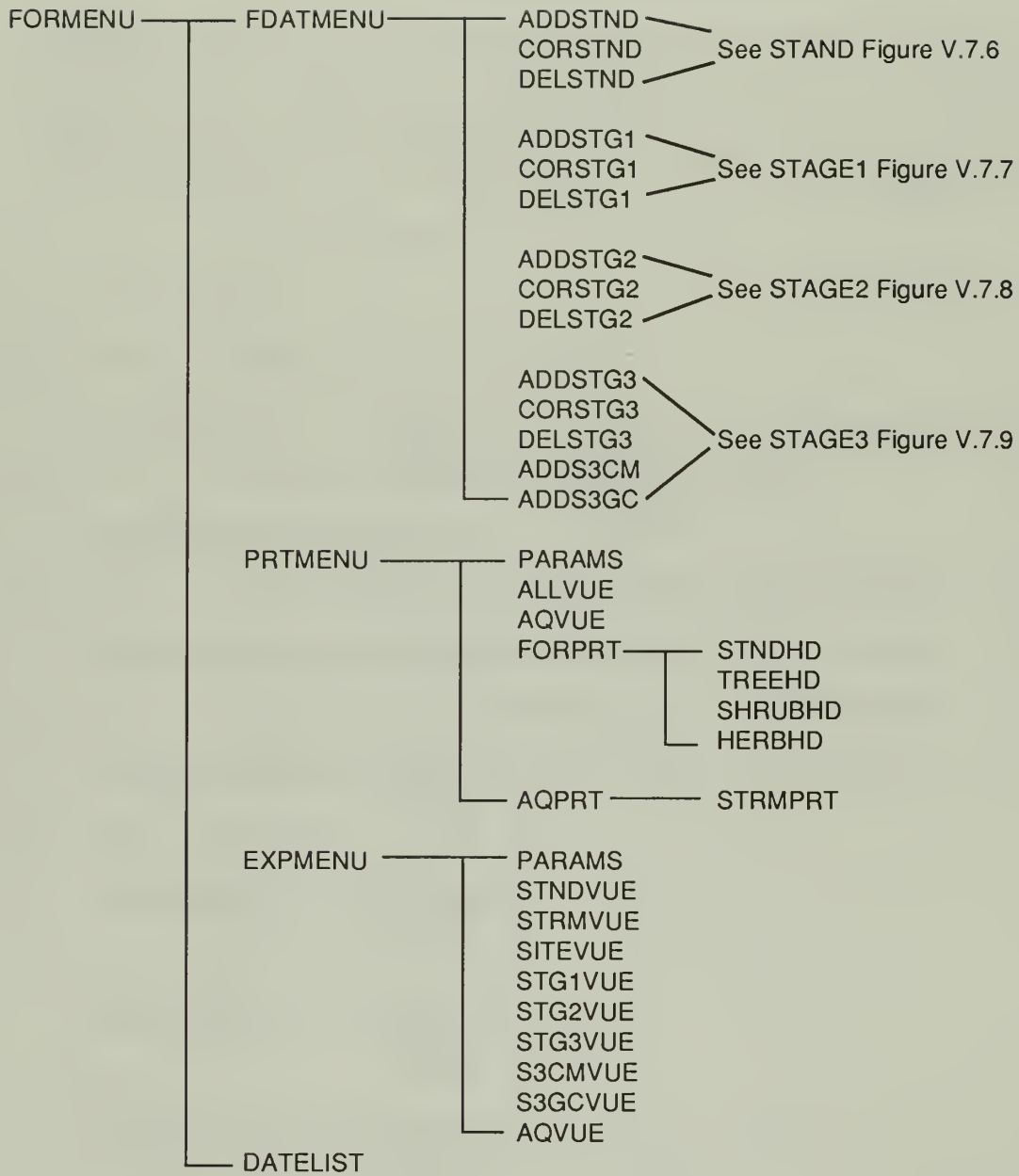


Figure V.7.3. FORMENU module map.

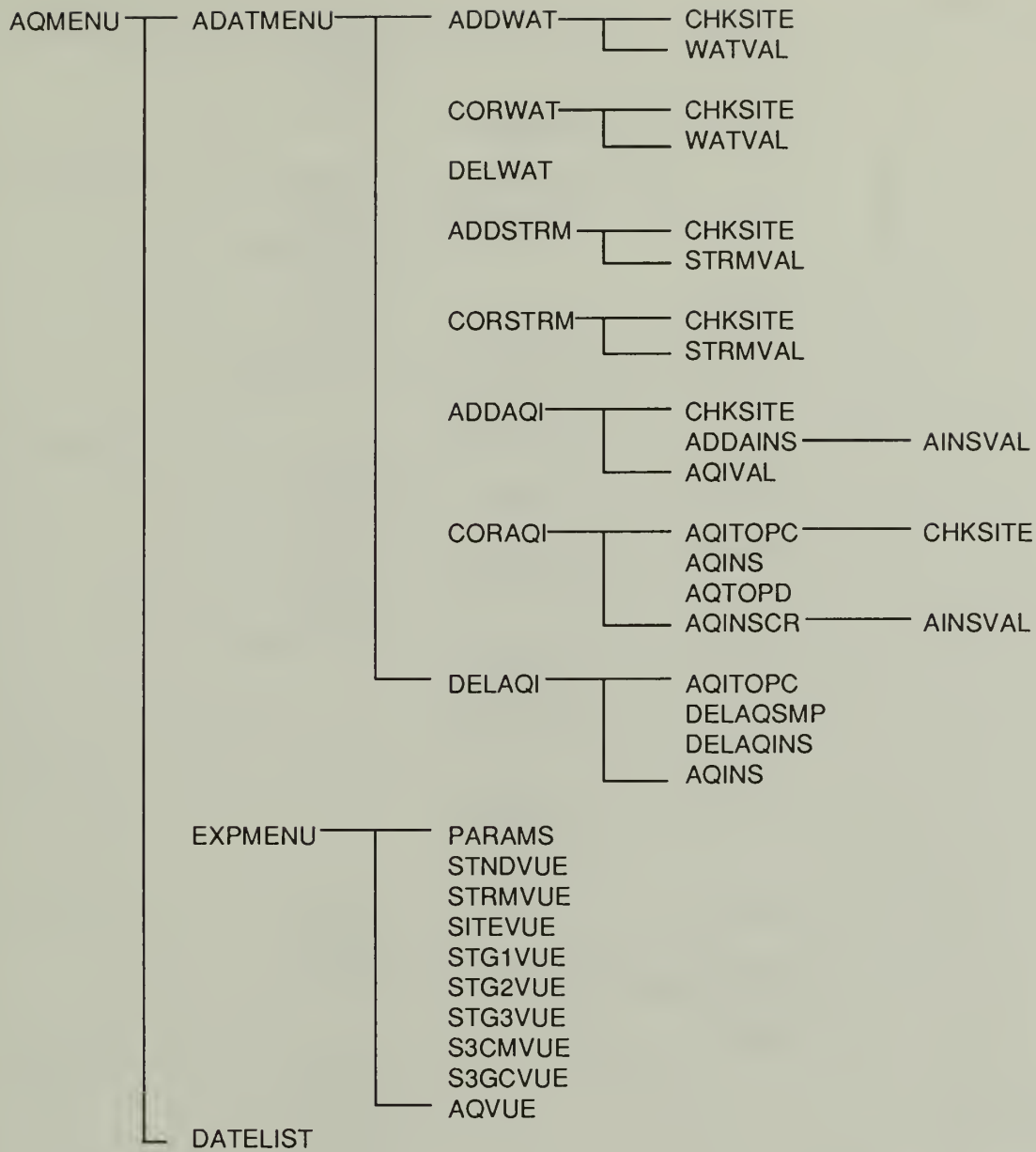


Figure V.7.4. AQMENU module map.

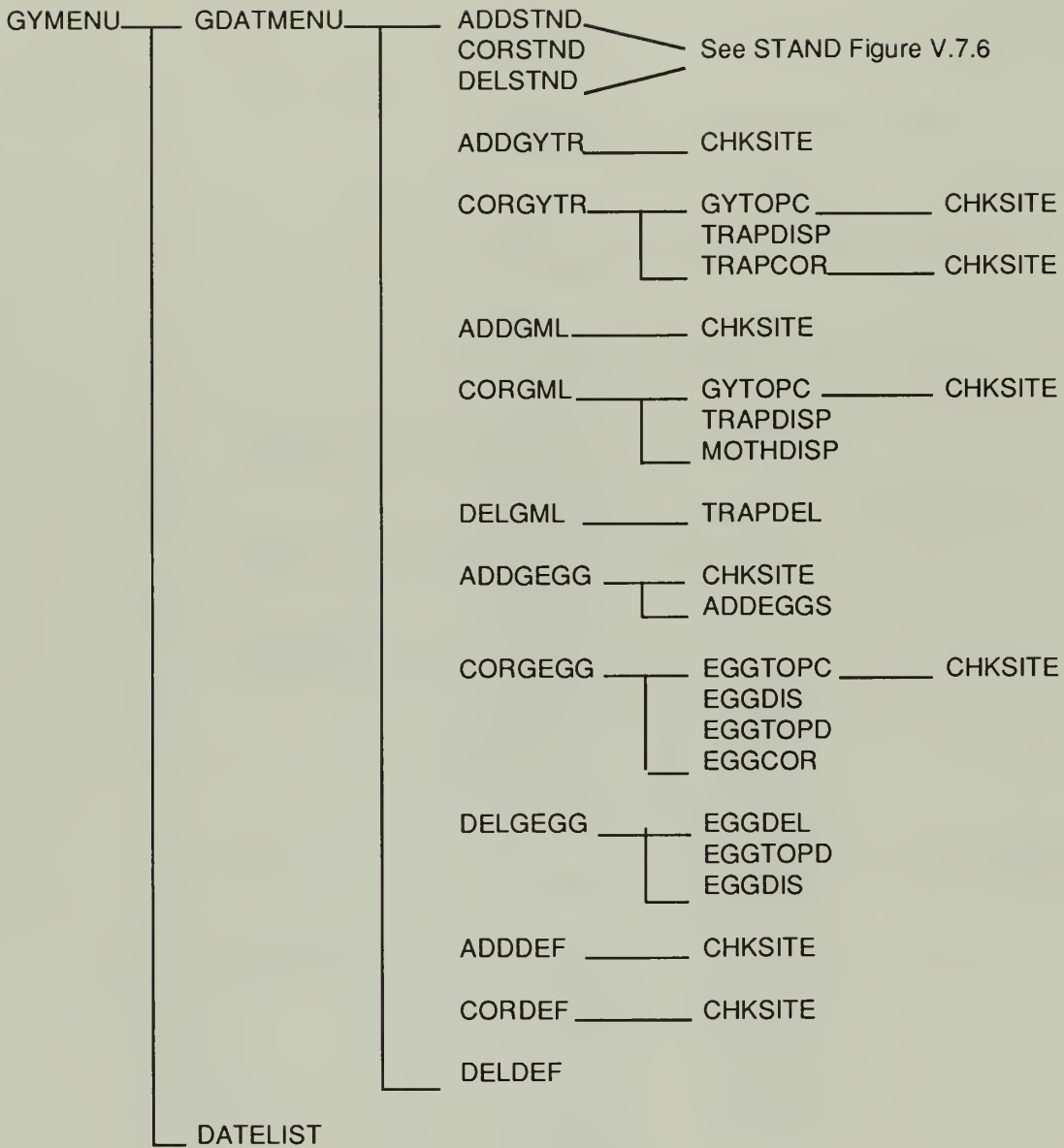


Figure V.7.5. GYMENU module map.

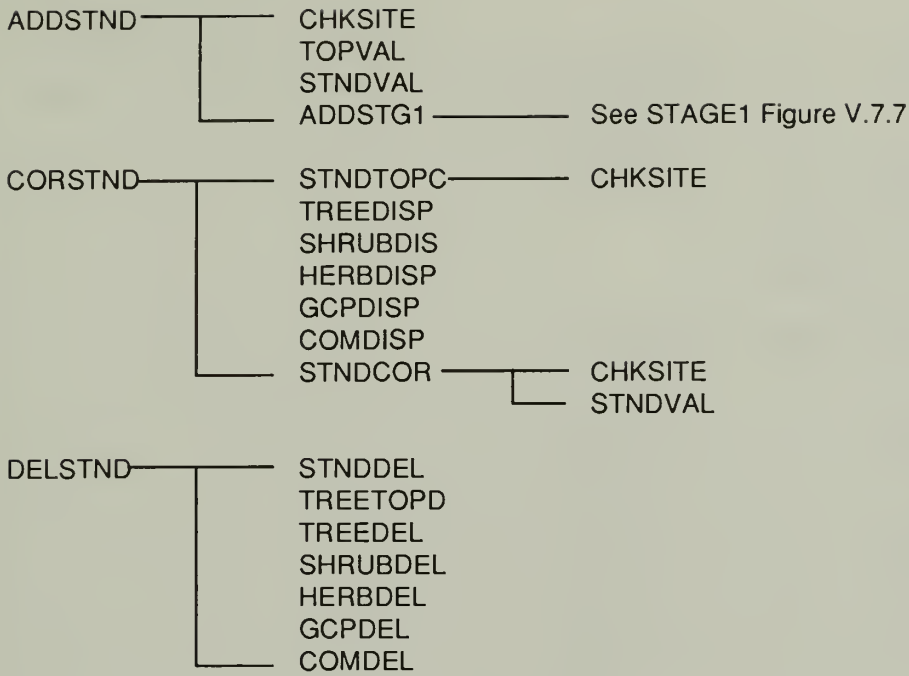


Figure V.7.6. STAND module map.

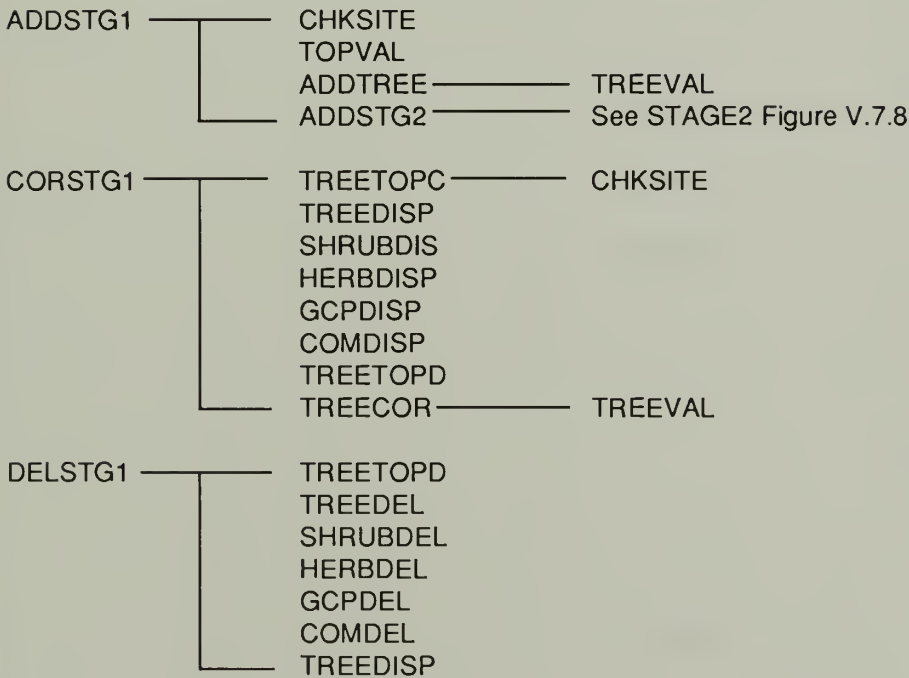


Figure V.7.7. STAGE1 module map.

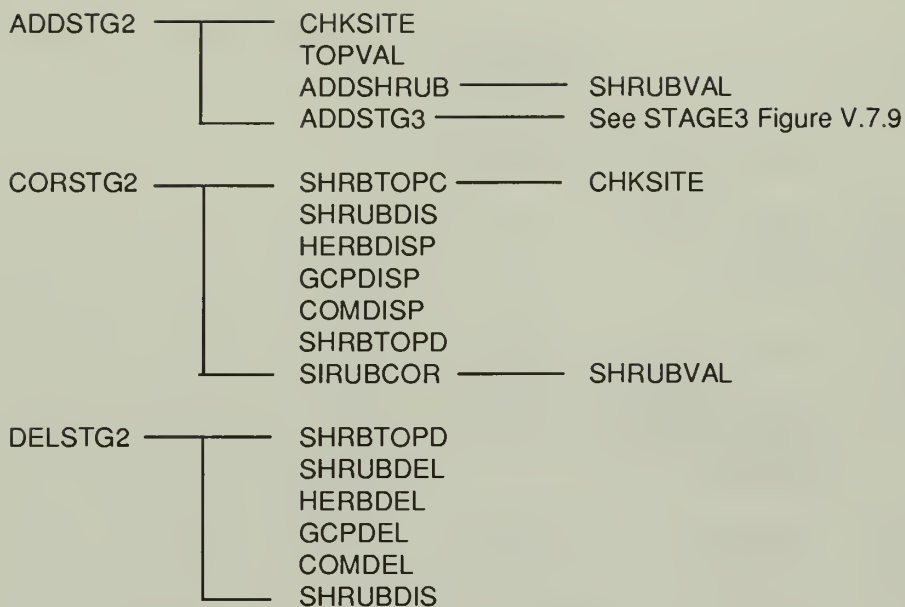


Figure V.7.8. STAGE2 module map.

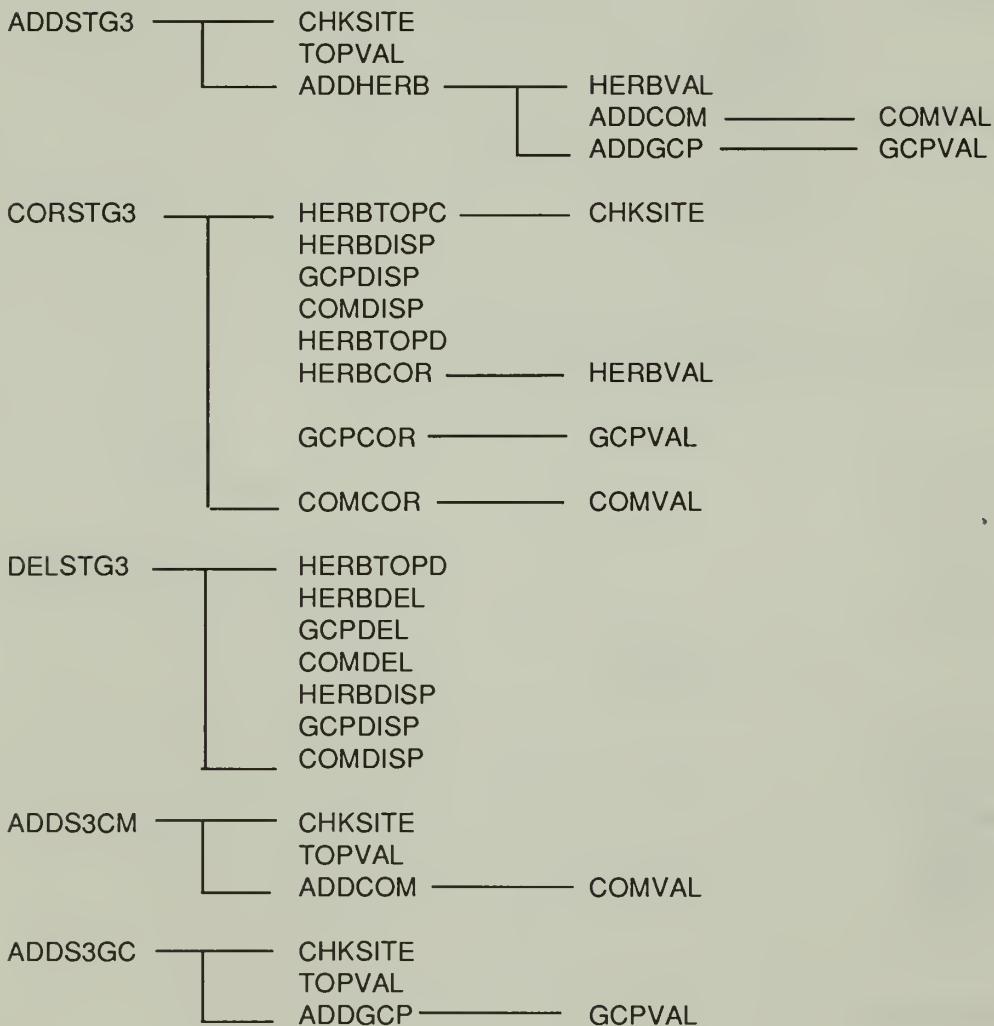


Figure V.7.9. STAGE3 module map.

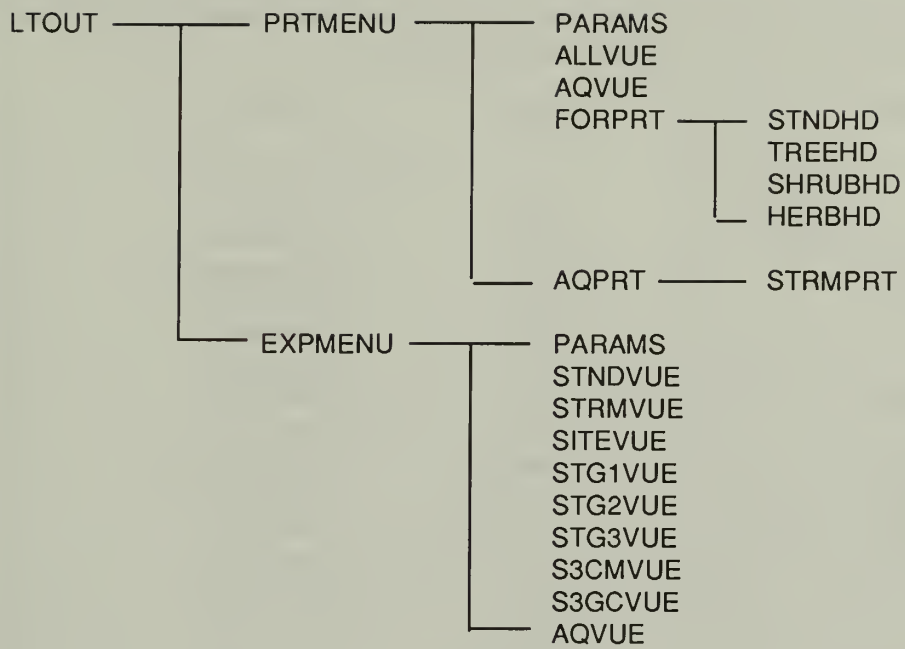


Figure V.7.10. LTOUT module map.

Appendix A.1. A woody plant dictionary containing field code, common name, genus, and species of trees and shrubs commonly found in the Shenandoah National Park of Virginia.

Code	Common Name	Genus	Species
AFR	Fraser Fir	Abies	fraseri
ANG	Boxelder	Acer	negundo
APN	Striped Maple	Acer	pennsylvanicum
APL	Norway Maple	Acer	platanoides
ARB	Red Maple	Acer	rubrum
ASC	Sugar Maple	Acer	saccharum
ASP	Mountain Maple	Acer	spicatum
ACE	Maple	Acer	spp
AHP	Horse Chestnut	Aesculus	hippocastanum
AOC	Yellow Buckeye	Aesculus	octandra
AAL	Tree-of-Heaven	Ailanthus	altissima
ARG	Speckled Alder	Alnus	rugosa
ASR	Hazel Alder	Alnus	serrulata
ALN	Alder	Alnus	spp
ATL	Pawpaw	Asimina	triloba
AAR	Downy Serviceberry	Amelanchier	arborea
AME	Serviceberry	Amelanchier	spp
AZA	Azalea	Azalea	spp
BAL	Yellow Birch	Betula	alleghaniensis
BLN	Black Birch	Betula	lenta
BPP	Paper Birch	Betula	papyrifera
BPL	Gray Birch	Betula	populifolia
BPR	Paper Mulberry	Broussonetia	papyrifera
BSM	Boxwood	Buxus	sempervirens
CRP	Am. Hornbeam (Musclewood)	Carpinus	caroliniana
CCR	Bitternut Hickory	Carya	cordiformis
CGL	Pignut Hickory	Carya	glabra
CLC	Shellbark Hickory	Carya	laciniosa
COV	Shagbark Hickory	Carya	ovata
CTM	Mockernut Hickory	Carya	tomentosa
CAY	Hickory	Carya	spp
CDN	American Chestnut	Castanea	dentata
CPM	Allegheny Chinkapin	Castanea	pumila
CSP	Northern Catalpa	Catalpa	speciosa
COC	Hackberry	Celtis	occidentalis
CCN	Eastern redbud	Cercis	canadensis
COB	Quince	Cydonia	oblonga
CLE	Clematis	Clematis	spp
CAT	Alternate Leaved Dogwood	Cornus	alternifolia
CFL	Flowering Dogwood	Cornus	florida
CAM	American Hazelnut	Corylus	americanus
CCT	Beaked Hazelnut	Corylus	cornuta
CRG	Hawthorn	Crataegus	spp
DYR	Common Persimmon	Diospyros	virginiana
FGR	American Beech	Fagus	grandifolia
FAM	White Ash	Fraxinus	americana
FNG	Black Ash	Fraxinus	nigra

Code	Common Name	Genus	Species
FPN	Green Ash	Fraxinus	pennsylvanica
GTR	Honey Locust	Gleditsia	triacanthos
GDC	Kentucky Coffee Tree	Gymnocladus	dioica
HVR	Witch Hazel	Hamamelis	virginiana
HAR	Wild Hydrangea	Hydrangea	arborescens
IMN	Largeleaf Holly	Ilex	montana
IOP	American Holly	Ilex	opaca
JCN	Butternut	Juglans	cinerea
JNG	Black Walnut	Juglans	nigra
JVR	Eastern Red Cedar	Juniperus	virginiana
KLT	Mountain Laurel	Kalmi	latifolia
LBN	Spicebush	Lindera	benzoin
LTL	Yellow Poplar	Liriodendron	tulipifera
LST	Sweetgum	Liquidambar	styraciflua
LJP	Japanese Honeysuckle	Lonicera	japonica
MPM	Osage Orange	Maclura	pomifera
MAC	Cucumbertree	Magnolia	acuminata
MAG	Magnolia	Magnolia	spp
MAL	Apple	Malus	spp
MRB	Red Mullberry	Morus	rubra
NSL	Blackgum	Nyssa	sylvatica
OVR	E. Hophornbeam (Ironwood)	Ostrya	virginiana
OAR	Sourwood	Oxydendrum	arborescens
PQN	Virginia Creeper	Parthenocissus	quinquefolia
PTM	Royal Paulownia	Paulownia	tomentosa
PRB	Red Spruce	Picea	rubens
PEC	Shortleaf Pine	Pinus	echinata
PPN	Table Mountain Pine	Pinus	pungens
PRG	Pitch Pine	Pinus	rigida
PST	Eastern White Pine	Pinus	strobus
PSY	Scotch Pine	Pinus	sylvestris
PVR	Virginia Pine	Pinus	virginiana
POC	American Sycamore	Platanus	nusoccidentalis
PDL	Eastern Cottonwood	Populus	deltoides
PGR	Bigtooth Aspen	Populus	grandidentata
PTR	Quaking Aspen	Populus	tremuloides
PAV	Sweet Cherry	Prunus	avium
PPS	Pin Cherry	Prunus	pennsylvanica
PPR	Peach	Prunus	persica
PSR	Black Cherry	Prunus	serotina
PRU	Cherry/Plum/Peach	Prunus	spp
PVG	Choke Cherry	Prunus	virginiana
PTF	Hop Tree	Ptelea	trifoliata
QAL	White Oak	Quercus	alba
QBC	Swamp White Oak	Quercus	biocolor
QCC	Scarlet Oak	Quercus	coccinea
QIL	Bear Oak	Quercus	ilicifolia
QIM	Shingle Oak	Quercus	imbricaria
QMR	Blackjack Oak	Quercus	marilandica
QPR	Chestnut Oak	Quercus	prinus

Code	Common Name	Genus	Species
QRB	Northern red oak	Quercus	rubra
QST	Post Oak	Quercus	stellata
QUE	Oak	Quercus	spp
QVL	Black Oak	Quercus	velutina
RMA	Great Rhododendron	Rhododendron	maximum
RCP	Winged Sumac	Rhus	copallina
RGL	Smooth Sumac	Rhus	glabra
RTP	Staghorn Sumac	Rhus	typhina
RIB	Gooseberry, etc.	Ribes	spp
RPS	Black Locust	Robina	pseudoacacia
ROS	Wild Rose	Rosa	spp
ROD	Raspberry Flowering	Rubus	odoratus
RUB	Blackberry, etc.	Rubus	spp
SAI	Willow	Salix	spp
SAL	Sassafras	Sassafras	albidum
SCN	Common Elderberry	Sambucus	canadensis
SPB	Red Elderberry	Sambucus	pubens
SAB	Elderberry	Sambucus	spp
SHR	Carrion Flower	Smilax	herbacea
SMI	Greenbriar	Smilax	spp
SRT	Common Greenbriar	Smilax	rotundifolia
STM	Bristly Greenbriar	Smilax	tamnoides
SAM	Mountain-Ash	Sorbus	americana
SOR	Coralberry	Symphoricarpos	orbiculatus
TCD	Native Yew	Taxus	canadensis
TCS	Japanese Yew	Taxus	cuspidata
TAM	Basswood	Tilia	americana
TRD	Poison-Ivy	Toxicodendron	radicans
TTX	Poison-Oak	Toxicodendron	toxicodendron
TCN	Eastern Hemlock	Tsuga	canadensis
URB	Slippery Elm	Ulmus	rubra
UAM	American Elm	Ulmus	americana
UTH	Rock Elm	Ulmus	thomasii
VAC	Blueberry, Huckleberry etc.	Vaccinium	spp
VAR	Maple Leaved Viburnum	Viburnum	acerifolium
VPR	Smooth Blackhaw	Viburnum	prunifolium
VIB	Viburnum	Viburnum	spp
VIT	Grapevine	Vitis	spp

Appendix A.2. An herbaceous plant dictionary containing field code, common name, genus, and species of herbaceous plants commonly found in the Shenandoah National Park of Virginia.

Code	Common Name	Genus	Species
AML	Yarrow	Achillea	millefolium
APC	Baneberry	Actaea	pachypoda
APD	Maidenhair Fern	Adiantum	pedatum
AAS	White Snake Root formerly Eupatorium rugosum	Ageratina	altissima
AGR	Agrimony	Agrimonia	spp
APT	Garlic Mustard formerly Alliaria officinalis	Alliariapetiolata	
ALL	Onion	Allium spp	
AAT	Ragweed	Ambrosia	artemisiifolia
AMS	Fly Poison	Amianthium	muscaetoxicum
ABR	Hog Peanut	Amphicarpa	bracteata
ANE	Angelica	Angelica	spp
ANT	Pussytoes	Antennaria	spp
API	Parsley Family	Apiaceae Family	
AND	Wild Sarsparilla	Aralia	nudicaulis
APO	Dogbane	Apocynum	spp
ACD	Columbine	Aquilegia	canadensis
ARA	Sarsparilla	Aralia	spp
ATR	Jack in the Pulpit	Arisaema	triphillum
AMN	Common Burdock	Artium	minus
ACN	Wild Ginger	Asarum	canadense
AEX	Poke Milkweed	Asclepia	sexaltata
ASL	Milkweed	Asclepias	spp
APL	Ebony Spleenwort	Asplenium	platyneuron
ADV	White Wood Aster	Aster	divaricatus
AST	Asters	Asteraceae family	
BBP	Spanish Needle	Bidens	bipinnata
BRA	Mustards	Brassicaceae family	
BOT	Grape Fern	Botrychium	spp
BVR	Rattlesnake Fern	Botrychium	virginianum
CAR	Tall Bellflower	Campanula	americana
CDV	Southern Harebell	Campanula	divaricata
CTH	Blue Cohosh	Caulophyllum	thalictroides
CAL	Lamb's Quarters	Chenopodium	album
CMC	Striped Pipsissewa or Spotted Wintergreen	Chimaphila	maculata
CLC	Ox Eye Daisy	Chrysanthemum	leucanthemum
CRC	Black Cohosh	Cimicifuga	racemosa
CAP	Dwarf Enchangers Nightshade	Circaea	alpina
CQD	Enchanters Nightshade	Circaea	quadrisulcata
CIR	Enchanters Nightshade	Circaea	spp
CLE	Clematis	Clematis	spp
CVR	Virgin's Bower	Clematis	virginiana
CCD	Horse Balm	Collinsonia	canadensis
CCM	Asiatic Dayflower	Commelina	communis
COM	Dayflower	Commelina	spp

Code	Common Name	Genus	Species
CAC	Squawroot	Conopholis	americana
CON	Bindweed	Convolvulus	spp
CFV	Yellow Corydalis	Corydalis	flavula
COR	Fumewort	Corydalis	spp
CCS	Honewort	Cryptotaenia	canadensis
DCR	Queen Anne's Lace	Daucus	carota
DPN	Hay Scented Fern	Dennstaedtia	punctilobula
DES	Trefoil (see Lotus)	Desmodium	spp
DIO	Wild Yam	Dioscorea	spp
DMR	Marginal Wood Fern	Dryopteris	marginalis
EAN	Daisy Fleabane	Erigeron	annuus
EUP	Joe Pye Weed formerly Eupatrouium	Eupatoriadelphis	spp
FAB	Pea Family	Fabaceae family	
FVR	Wild Strawberry	Fragaria	virginiana
FRA	Strawberry	Fragaria	spp
GAP	Cleavers	Gallium	aparine
GLN	Lance Leaved Licorice	Gallium	lanceolatum
GTF	Fragrant Bedstraw	Gallium	triflorum
GPR	Teaberry	Gaultheria	procumbens
GAL	Bedstraw	Galium	spp
GMC	Wild Geranium	Geranium	maculatum
GRB	Herb-Robert	Geranium	robertianum
GER	Geranium	Geranium	spp
GCN	White Avens	Geum	canadense
GVR	Rough Avens	Geum	virginianum
GEU	Avens	Geum	spp
GHR	Heal All	Glechoma	herbacea
GOO	Rattlesnake Plantain	Goodyera	spp
HPL	American Pennyroyal	Hedeoma	pulegioides
HDV	Woodland Sunflower	Helianthus	divaricatus
HAM	Liverleaf	Hepatica	americana
HEP	Hepatica	Hepatica	spp
HLT	Cow Parsnip formerly Heracleum maximum?	Heracleum	lantanum
HVN	Rattlesnake Weed	Hieracium	venosum
HCR	Bluets	Houstonia	caerulea
HLN	Long Leaved Bluets	Houstonia	longifolia
HTN	Narrow Leaved Bluets	Houstonia	tenuifolia
HOU	Bluets	Houstonia	spp
HVG	Virginia Waterleaf	Hydrophyllum	virginianum
HMT	Dwarf St. Johnswort	Hypericum	mutilus
ICP	Spotted Jewelweed	Impatiens	capensis
IPL	Pale Jewelweed	Impatiens	pallida
IMP	Jewelweed	Impatiens	spp
IPR	Morning Glory	Ipomea	purpurea
IRI	Iris Family	Iridaceae family	
LAM	Mint Family	Lamiaceae family	
LCL	Fringed Loosestrife	Lysimachia	ciliata
LHR	Wild Lettuce	Lactuca	hirsuta

Code	Common Name	Genus	Species
LCN	Wood Nettle	Laportea	canadensis
LIL	Lilies	Liliaceae family	
LIN	Indian Tobacco	Lobelia	inflata
LOT	Trefoil (see Desmodium)	Lotus	spp
LQD	Whorled Loosestrife	Lysimachia	quadrifolia
LYT	Loosestrifes	Lythraceae family	
MCN	Canada Mayflower	Maianthemum	canadense
MVR	Indian Cucumberroot	Medeola	virginiana
MLN	Cowwheat	Melampyrum	lineare
MCD	Moonseed	Menispermum	canadense
MPP	Peppermint	Mentha	piperita
MSP	Spearmint	Mentha	spicata
MFS	Wild Bergamot	Monarda	fistulosa
MUN	Indian Pipe	Monotropa	uniflora
NCT	Catnip	Nepeta	cataria
OUN	Cancer Root	Orobanche	uniflora
OCL	Sweet Cicily (see OLN)	Osmorhiza	claytoni
OLN	Sweet Cicily (see OCL)	Osmorhiza	longistylis
OSM	Sweet Cicily	Osmorhiza	spp
OXA	Wood Sorrel	Oxalis	spp
PQQ	Ginseng	Panax	quinquefolius
PST	Wild Parsnip	Pastinaca	sativa
PCN	Wood Betony or Lousewort	Pedicularis	canadensis
PPL	Wild Kidney Bean	Phaseolus	polystachios
PLP	Lopseed	Phyrma	leptostachya
PAM	Pokeweed	Phytolacca	americana
PPM	Clearweed	Pilea	pumila
PMJ	Common Plantain	Plantago	major
POA	Grass (don't assume genus)	Poa	spp
PVN	Jacob's Ladder	Polemonium	van-bruntiae
POL	Buckwheats	Polygonaceae family	
POG	Soloman's Seal	Polygonatum	spp
PST	Arrow-leaved Tearthumb	Polygonum	sagittatum
PSC	Climbing False Buckwheat	Polygonum	scandens
PVM	Jumpseed	Polygonum	virginianum
POY	Knotweed	Polygonum	spp
PCD	Small Flowered Leaf Cup	Polymnia	canadensis
PAC	Christmas Fern	Polysticum	acrostichoides
POR	Haircap Moss genus	Polytrichum	spp
POT	Cinquefoil	Potentilla	spp
PAL	White Lettuce	Prenanthes	alba
PSP	Lions' Foot	Prenanthes	serpentaria
PRE	Lettuce	Prenanthes	spp
RRP	Creeping Buttercup	Ranunculus	repens
RAB	Kidney-leaved Buttercup	Ranunculus	abortivus
RAN	Buttercup	Ranunculus	spp
ROA	Herbaceous spp	Rosaceae family	
SCD	Bloodroot	Sanguinaria	canadensis
SCS	Black Snakeroot	Sanicula	canadensis
SOV	Heartleaf	Scutellaria	ovata

Code	Common Name	Genus	Species
SAR	Golden Ragwort	Senecio	aureus
SST	Starry Campion	Silene	stellata
SVL	Bladder Campion formerly <i>Silene cucubalus</i>	Silene	vulgaris
SRC	False Solomon's Seal	Smilacina	racemosa
STF	Three-leaved	Smilacina	trifolia Soloman's Seal
SCR	Horse Nettle	Solanum	carolinense
SOL	Goldenrod	Solidago	spp
SMD	Common Chickweed	Stellaria	media
STR	Twisted Stalk	Streptopus	spp
TOF	Common Dandelion	Taraxacum	officinale
TDC	Early Meadow Rue	Thalictrum	dioicum
TPB	Tall Meadow Rue formerly <i>Thalictrum polygamum</i>	Thalictrum	pubescens
THA	Meadow Rue	Thalictrum	spp
TRI	Trillium	Trillium	spp
UDC	Stinging Nettle	Urtica	dioica
UPR	Perfoliate Bellwort	Uvularia	perfoliata
UPD	Mountain Bellwort	Uvularia	pudica
USS	Sessile Bellwort	Uvularia	sessilifolia
VAL	Wingstem formerly <i>Actinomeris alternifolia</i>	Verbesina	alternifolia
VER	Veronica	Veronica	spp
VCR	Cow Vetch	Vicia	cracca
VKT	Field Pansy	Viola	kitaibelliana
VP	DBirdfoot Violet	Viola	pedata
VSG	Arrow Leaved Violet	Viola	sagittata
VIO	Violets	Viola	spp
XAS	Turkeybeard	Xerophyllum	asphodeloides
XFE	UNKNOWN Fern		
XGR	UNKNOWN Grass		
XLI	UNKNOWN Lichen		
XMO	UNKNOWN Moss		
XXX	UNKNOWN Miscellaneous		
ZAR	Golden Alexander	Zizia	aurea

Regen Data - Tree Plot #: 1 Shrub Plot #: 1 Herb Plot #: 2

Species	Density # Stems	Relative Density
AILANTHUS ALTISSIMA	11	48

Regen Data - Tree Plot #: 1 Shrub Plot #: 1 Herb Plot #: 2

Species	Density # Stems	Relative Density
Acer rubrum	2	9
CORNUS FLORIDA	1	4
FRAXINUS AMERICANA	2	9
LIRIODENDRON TULIPIF	2	9
SASSAFRAS ALBIDUM	2	9
VITUS SPP.	3	13

Ground Cover Percentages

Org.	Min	Woody	Squaw	5 Most Common Herbs
Rock	Litter	Soil	Debris	Forbes
1	2	3	4	Grass
				Sedge
				Root
				Species
				% Cover
				QAL
				3
				QRB
				4

Shrub Data - Tree Plot #: 1 Shrub Plot #: 2

Species	Density # Stems	Relative Density
CORNUS FLORIDA	11	73
CARYA GLABRA	1	7
FRAXINUS AMERICANA	2	13
PRUNUS SEROTINA	1	7

Regen Data - Tree Plot #: 1 Shrub Plot #: 2 Herb Plot #: 1

Species	Density # Stems	Relative Density
Acer rubrum	2	18
FRAXINUS AMERICANA	1	9
LIRIODENDRON TULIPIF	6	55
ULMAS RUBRA	1	9
VITUS SPP.	1	9

Ground Cover Percentages

Org.	Min	Woody	Squaw	5 Most Common Herbs
Rock	Litter	Soil	Debris	Forbes
1	2	3	4	Grass
				Sedge
				Root
				Species
				% Cover

Regen Data - Tree Plot #: 1 Shrub Plot #: 2 Herb Plot #: 2

Species	Density # Stems	Relative Density
AILANTHUS ALTISSIMA	2	13
CORNUS FLORIDA	4	25
FRAXINUS AMERICANA	1	6
LIRIODENDRON TULIPIF	3	19
SASSAFRAS ALBIDUM	2	13
ULMAS RUBRA	1	6
VITUS SPP.	3	19

Ground Cover Percentages

Org.	Min	Woody	Squaw	5 Most Common Herbs					
Rock	Litter	Soil	Debris	Forbes	Grass	Sedge	Root	Species	% Cover
1	5	3		4				QAL	2
								QAL	3

Shrub Data - Tree

Plot #: 1 Shrub Plot #: 3

Species	Density # Stems	Relative Density
CORNUS FLORIDA	9	90
NYSSA SYLVATICA	1	10

Regen Data - Tree Plot #: 1 Shrub Plot #: 3 Herb Plot #: 1

Species	Density # Stems	Relative Density
AILANTHUS ALTISSIMA	1	6
CORNUS FLORIDA	3	19
FRAXINUS AMERICANA	9	56
LIRIODENDRON TULIPIF	1	6
SASSAFRAS ALBIDUM	1	6
ULMAS RUBRA	1	6

Ground Cover Percentages

Org.	Min	Woody	Squaw	5 Most Common Herbs					
Rock	Litter	Soil	Debris	Forbes	Grass	Sedge	Root	Species	% Cover

Regen Data - Tree Plot #: 1 Shrub Plot #: 3 Herb Plot #: 2

Species	Density # Stems	Relative Density
AILANTHUS ALTISSIMA	13	48
Acer rubrum	3	11
FRAXINUS AMERICANA	4	15
LIRIODENDRON TULIPIF	3	11
SASSAFRAS ALBIDUM	2	7
ULMAS RUBRA	2	7

Ground Cover Percentages

Org.	Min	Woody	Squaw	5 Most Common Herbs
Rock	Litter	Soil	Debris	Forbes
		Grass	Sedge	Root
				Species
				% Cover

Plot #: 2 Cover type: 4400 Stand Structure: T
 Slope: 018 Slope pos: BS Date Sampled: 07/23/87 Land form:
 Comments:

Tree Data - Plot #: 2

Species	Density # Live	Relative Density	Avg DBH	Dominance Basal Area/HA	Relative Dominance
Acer rubrum	4	7	25.73	4.85	10
CORNUS FLORIDA	28	48	7.93	2.66	6
CARYA GLABRA	9	16	11.13	1.70	4
NYSSA SYLVATICA	1	2	14.50	0.29	1
QUERCUS ALBA	4	7	41.83	9.67	21
QUERCUS PRINUS	5	9	33.72	8.99	19
Quercus rubra	3	5	47.53	9.27	20
QUERCUS VELUTINA	3	5	42.00	7.77	17
ROBINA PSEUDOCACIA	1	2	31.80	1.38	3

Shrub Data - Tree Plot #: 2 Shrub Plot #: 1

Species	Density # Stems	Relative Density
CORNUS FLORIDA	3	100

Ground Cover Percentages

Org.	Min	Woody	Squaw	5 Most Common Herbs
Rock	Litter	Soil	Debris	Forbes
Grass	Sedge	Root	Species	% Cover

Regen Data - Tree Plot #: 2 Shrub Plot #: 2 Herb Plot #: 2

Species	Density # Stems	Relative Density
AILANTHUS ALTISSIMA	4	13
Acer rubrum	1	3
CORNUS FLORIDA	1	3
CARYA GLABRA	1	3
FRAXINUS AMERICANA	2	6
LIRIODENDRON TULIPIF	7	22
PRUNUS SEROTINA	1	3
QUERCUS PRINUS	11	34
Quercus rubra	2	6
SASSAFRAS ALBIDUM	1	3
VITUS SPP.	1	3

Ground Cover Percentages

Org.	Min	Woody	Squaw	5 Most Common Herbs
Rock	Litter	Soil	Debris	Forbes
Grass	Sedge	Root	Species	% Cover

Shrub Data - Tree Plot #: 2 Shrub Plot #: 3

Species	Density # Stems	Relative Density
CORNUS FLORIDA	8	100

Regen Data - Tree Plot #: 2 Shrub Plot #: 3 Herb Plot #: 1

Species	Density # Stems	Relative Density
AILANTHUS ALTISSIMA	4	44
LIRIODENDRON TULIPIF	3	33

Regen Data - Tree Plot #: 2 Shrub Plot #: 3 Herb Plot #: 1

Species	Density # Stems	Relative Density
QUERCUS PRINUS	1	11
VITUS SPP.	1	11

Water Chemistry / Stream Habitat

Site: 1L307

Date: 04/21/87

Water Temperature (c): 10.0

pH: 6.94

Conductivity (umhos): 20

Dissolved Oxygen(mg/l): 9.9

Alkalinity (ueq/l): 76

Seston	Total (mg DW/l)	Organic (mg AFDW/l)	Inorganic (mg ADW/l)	Organic/ Inorganic
	4.27	2.04	2.23	0.91

Autotrophic Index: 3000

Mean Chlorophyll a (ug/cm2): 0.0236

Chlorophyll a (ug/cm2): #1: 0.0708

#2: 0.0000

#3: 0.0000

Discharge (c.m.s.): .133

Sulfate (mg/l): 7.5

Nitrate (mg/l): 0.43

Silicon Oxide(mg/l):

Chlorine(mg/l):

Calcium (mg/l):

Potassium (mg/l):

Magnesium(mg/l):

Sodium (mg/l):

Total Coliform(MPN/100ml): 790

Fecal Coliform(MPN/100ml): 0

Fecal Streptococcus(MPN/100ml): 0

Depth(cm): 15

Width(m): 3

Riparian Cover: 28

Riparian Type: T 100% S 0% GF 0% N 0%

Debris Retention: 2.7

Fish Cover: 1.9

Pool:Riffle: 02:8

Site Bottom: BR 2% B 45% C 41% PG 12% S 0%

Taxa Collected

Site: 1L307 on: 04/21/87 Stream: Land's Run - upper
 Elev Class: U Geologic Form: P Cover Type: 4400

Taxa	Sample Method			
	Aerial	Reared	Quantitative	Qualitative
CAMBARIDAE			X	X
Allonarcys proteus		X		
Pteronarcys			X	X
Amphinemura				X
Soyedina carolinensis	X			
Acroneuria			X	X
Yugus				X
Sweltsa			X	X
Leuctra			X	X
Paraleuctra sara	X			
Ephemera guttulata	X			
Ephemerella			X	X
Ameletus				X
Paraleptophlebia			X	X
Baetis			X	X
Stenonema pudicum		X		
Epeorus			X	X
Epeorus pleuralis		X		
Cinygmula			X	X
Heptagenia			X	
Hydropsyche			X	X
Diplectrona modesta			X	X
Rhyacophila			X	X
Dolophilodes distinctus	X			
Neophylax			X	
Pycnopsyche				X
Psephenus herricki			X	
Oulimnius latiusculus			X	
Blepharicera			X	X
Tipula				X
Antocha			X	
Dicranota			X	X
Hexatoma			X	X
Prosimulium			X	X
CHIRONOMIDAE			X	X
Clinocera			X	
Total Taxa				36

Community Structure of Benthic Invertebrates

Site: 1L307 on: 04/21/87 Stream: Land's Run - upper

Elev Class: U Geologic Form: P Cover Type: 4400 Sampler Type: PIB

Taxa	Replicate			Mean	Num/Sq. M
	1	2	3		
CAMBARIDAE	0	0	1	0.3	3
Pteronarcys	2	1	3	2.0	20
Acroneuria	12	3	1	5.3	53
Sweltsa	4	15	10	9.7	97
Leuctra	1	0	0	0.3	3
Ephemerella	8	15	4	9.0	90
Paraleptophlebia	0	1	6	2.3	23
Baetis	12	2	2	5.3	53
Epeorus	38	28	17	27.7	277
Cinygmula	4	12	6	7.3	73
Heptagenia	1	0	0	0.3	3
Hydropsyche	1	2	0	1.0	10
Diplectrona modesta	8	6	9	7.7	77
Rhyacophila	1	0	0	0.3	3
Neophylax	0	2	0	0.7	7
Psephenus herricki	1	0	1	0.7	7
Oulimnius latiusculus	2	4	4	3.3	33
Blepharicera	11	1	3	5.0	50
Antocha	1	1	0	0.7	7
Dicranota	0	1	0	0.3	3
Hexatoma	1	1	3	1.7	17
Prosimulium	11	13	9	11.0	110
CHIRONOMIDAE	3	27	3	11.0	110
Clinocera	0	1	0	0.3	3
Summary					
Density (Ind/Sample)	122	136	82	113.3	1133
Total Taxa	19	19	16	18.0	
Diversity	3.37	3.37	3.58	3.44	



As the nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural and cultural resources. This includes fostering wise use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for enjoyment of life through outdoor recreation. The department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people. The department also promotes the goals of the Take Pride in America campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

