NATURAL RESOURCE INVENTORY
AND
LONG-TERM ECOLOGICAL MONITORING SYSTEM PLAN
FOR
SHENANDOAH NATIONAL PARK
AUGUST 1991

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I. INTRODUCTION

Shenandoah National Park's (SNP) Natural Resource Inventory and Long-Term Ecological Monitoring System (LTEMS) is the backbone of the natural resources management program. It provides the fundamental understanding of natural resources and processes that is essential to the development of management and mitigating actions. More commonly, traditional resource protection activities are not enough to retain the natural character of the land. Aggressive management activities that go beyond Park boundaries and innovative mitigating actions are needed to protect threatened values or to restore impacted resources to a natural condition. LTEMS is a long-term continuing process that stresses the use of standardized measurements and protocols. While measurements and protocols are standardized, priorities for monitoring will need to be evaluated and perhaps adjusted periodically to meet changing needs.

OBJECTIVES

The objectives of the Inventory and Monitoring (I&M) program define what is to be achieved and assists in laying the foundation for establishing priorities. It does not represent an end product because continual changes in natural systems will require that inventories be updated at some interval and monitoring priorities be altered to meet new threats or changing conditions. The SNP I&M objectives are:

1) Obtain and maintain a scientifically-based understanding of the type, abundance, and distribution of natural resources.

2) Monitor resource condition and changes through time.

3) Monitor natural processes and anthropogenic influences that maintain or affect ecosystem health.

RELATIONSHIP OF INVENTORY, MONITORING, RESEARCH AND MANAGEMENT

The Park's inventory and monitoring program contains two elements: a program to inventory the current resource base, and the Long-Term Ecological Monitoring System. Inventory, monitoring, and research are all critical, yet different types of activities, each of which have specific roles in management of the natural resources. It is important to have a thorough understanding of the underlying concepts of these three activities, 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 experiment has an important place in understanding ecology (and that the LTER program is making valuable contributions to ecology), the importance of monitoring has been greatly under-estimated (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 and allow for public use. 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. This is not to imply that passive management is the easier of the two roads to follow. It is increasingly more important and difficult for the NPS to "hold the line" on certain activities already allowed in the Parks that result in resource impacts and to actively oppose new activities that would compromise sensitive values than it is to carry out the above mentioned active management options.

There are feedback loops between monitoring, research, and management. It would not be possible for the NPS to accomplish its mandate without careful attention to all three components. As an example, data are being acquired on gypsy moth populations, components of stream ecosystems, and components of forest ecosystems throughout the Park. By reviewing the descriptive status reports generated from the monitoring program, changes might be detected in the macroinvertebrate communities of some streams that are suspected of being impacted by gypsy moth defoliation of 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 approach 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.

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. For example, 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.

REVIEW 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 the larger number of small variations frequently found within ecosystems.

There have been many success stories relative to long-term monitoring and studies. The Long-Term Ecological Research (LTER) program of the National Science Foundation is a recent effort that 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.

From the LTER program and others, certain basic requirements and principles have been derived. They are:

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 INVENTORY AND MONITORING BY THE NATIONAL PARK SERVICE

The National Park Service (NPS) has only recently made an effort to develop a sustained, comprehensive monitoring program. The monitoring that has been done in the past largely reflects the changing priorities and philosophies for managing natural resources in national parks. The following review is based upon publications by the Commission on Research and Resource Management Policy in the National Park System (1989), Stottlemyer (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 NPS 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 did not contribute 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 NPS. 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 assure 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 (NAPAP) to initiate long-term studies.

In the past three 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, and 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."

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.

Many students of NPS history and management describe the national parks as being at a crossroads. Significant management and protection problems 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 percent 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 percent of parks, air quality in more than 45 percent, and animal, plant, and freshwater resources in more than 40 percent. A clear indication of the need for long-term monitoring programs is that 75 percent 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 (Stottlemyer 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 1989, Agee and Johnson 1989). 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 (NPCA), 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 become 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."

II. SNP INVENTORY AND MONITORING PROGRAM

OVERVIEW

The decision was made in 1984 to develop a comprehensive I&M program for Shenandoah National Park. 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 evaluate the existing natural resource inventory and to design and implement a core monitoring program.

Park records were consolidated and a literature search was conducted to determine the current status of the natural resource inventory. A plan was developed to obtain the necessary data to fill in identified omissions and limitations in the inventory. Various types of agreements were developed with cooperating federal and state agencies to assist the Park staff in the collection of a broad range inventory data. The inventory process will be an ongoing activity. It will not be feasible to conduct an exhaustive search for all possible species. However, we expect that a comprehensive inventory of vascular flora and vertebrate fauna can be achieved within three years to coincide with the completion of Phase II of the monitoring program. Continued progress can be made on the remaining taxa. The outline for species inventory is similar to that described in the section on long-term monitoring.

The Phase I core of 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 discreet ecosystem parameters would be added later during Phase II. Of particular concern was the future impacts of the alien gypsy moth (Lymantria dispar) on forest systems. Therefore, much of the early 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 of this effort (1985-1987) were focused on the establishment of the Park's monitoring 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.

3) Species or processes that may impact on public health or safety or are locally controversial.

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.

INVENTORY PROGRAM

The primary focus of the natural resource inventory is to determine the presence or absence of species, their general abundance, and to delineate the range of each species or group of related species. Some inventory work has been done over the years. During Phase I, the status of the current inventory was defined, and an outline to guide the attainment of the total inventory was determined. The following outline includes a code that describes the current (1991) status of the inventory for each resource element.

The first character (letter) of the code identifies if a reasonable effort has been made to determine whether or not the species is present in the Park. The second character (number) defines the status of knowledge regarding the abundance, and the third character (number) defines the status of knowledge of the range.

Codes: First Character: (K) = Presence/absence known.
(P) = Presence partially known
(U) = Presence/absence unknown.

Second Character: (1) = Abundance known (surveyed).
(2) = Abundance partially known.
(3) = Abundance not known.

Third Character: (1) = Range known (surveyed).
(2) = Range partially known.
(3) = Range unknown.

INVENTORY OUTLINE

1. VASCULAR PLANT SECTION

   1.1 Forest Vegetation K11

   1.2 Unique Vegetation Areas

      1.2.1 The Big Meadow K11

      1.2.2 Big Meadows Swamp K11

      1.2.3 Limberlost Hemlock Grove U33

      1.2.4 Natural Heritage Species K22

2. NON-VASCULAR PLANT SECTION

   2.1 Fungi K22

   2.2 Ferns K12

2.3 Algae U33

2.4 Lichens P12

2.5 Mosses P13

3. VERTEBRATE FAUNA SECTION

3.1 Mammals

3.1.1 White-tailed Deer K12

3.1.2 Black Bear K11

3.1.3 Eastern Bobcat K33

3.1.4 Natural Heritage Species K11

3.2 Birds

3.2.1 General Resident Breeding Birds K12

3.2.2 Migratory Birds K22

3.2.3 Natural Heritage Species (NONE)

3.3 Fishes

3.3.1 Eastern Brook Trout K11

3.3.2 Fish (other) K13

3.4 Reptiles K22

3.5 Amphibians K22

4. INVERTEBRATE FAUNA SECTION

4.1 Mollusks P33

4.2 Crustacea P22

4.3 Arthropods (1) (spiders, millipedes, centipedes) U33

4.4 Arthropods (2) (terrestrial insects) P32

4.5 Arthropods (3) (aquatic insects) K22

5. GEOLOGY K11

6. SOILS P22

The inventory of most elements is expected to be completed by the end of the Phase II inventory. Some of the difficult ones such as fungi and arthropods may never be considered to be 100 percent complete.

LONG-TERM ECOLOGICAL MONITORING SYSTEM

An evaluation of the seven major priorities lead to a conceptual model of the complete I&M program. Divisions were made for sections and for individual monitoring elements that require specific data collection protocols. The outline for the monitoring program is as follows:

1. VASCULAR PLANT SECTION

    1.1 Forest Vegetation

    1.2 Unique Vegetation Areas

        1.2.1 The Big Meadow

        1.2.2 Big Meadows Swamp

        1.2.3 Limberlost Hemlock Grove

        1.2.4 Natural Heritage Species

2. NON-VASCULAR PLANT SECTION

    2.1 Fungi

    2.2 Ferns

    2.3 Algae

    2.4 Lichens

    2.5 Mosses

3. VERTEBRATE FAUNA SECTION

    3.1 Mammals

        3.1.1 White-tailed Deer

        3.1.2 Black Bear

        3.1.3 Eastern Bobcat

        3.1.4 Natural Heritage Species

3.2 Birds

3.2.1 General Resident Breeding Birds

3.2.2 Migratory Birds

3.2.3 Natural Heritage Species

3.3 Fishes

3.3.1 Eastern Brook Trout

3.3.2 Fish (other)

3.4 Reptiles

3.5 Amphibians

4. INVERTEBRATE FAUNA SECTION

4.1 Mollusks

4.2 Crustacea

4.3 Arthropods (1) (spiders, millipedes, centipedes)

4.4 Arthropods (2) (terrestrial insects)

4.5 Arthropods (3) (aquatic insects)

5. AIR QUALITY

5.1 Gaseous Pollutants (ozone, SO2)

5.2 Particulates

5.3 Acid Deposition (rain, snow)

5.4 Visibility

6. METEOROLOGY

6.1 Solar Radiation

6.2 Events (unusual storms, tornadoes, floods, earthquakes)

6.3 Wind (speed and direction)

6.4 Relative Humidity

6.5 Precipitation (rainfall, snowfall)

6.6 Dewpoint

6.7 Temperature

7. GEOLOGY

8. SOILS

9. WATER

9.1 Stream Discharge

9.2 Water Chemistry

9.3 Pollutants (bacterial, chemical)

10. ECOSYSTEM PROCESSES MONITORING SECTION

10.1 Forest Response to Gypsy Moth Infestation

10.2 Watershed Acidification

10.3 Deciduous Forest Watershed Dynamics

10.4 Stream Aquatic Habitat (physical structure, fish cover)

Following a rather lengthy period of study and analysis, a set of parameters that were both a high priority and were technically feasible within the projected budget and staffing constraints were selected for Phase I. These included broad parameters that were most likely to detect changes brought about by gypsy moth defoliation and other major disturbances. Others were set aside for inclusion in the program during later phases. The next step was to determine if the technology existed to accurately monitor the selected high priority parameters. 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.

PHASE I

The following resource elements were selected for monitoring in Phase I:

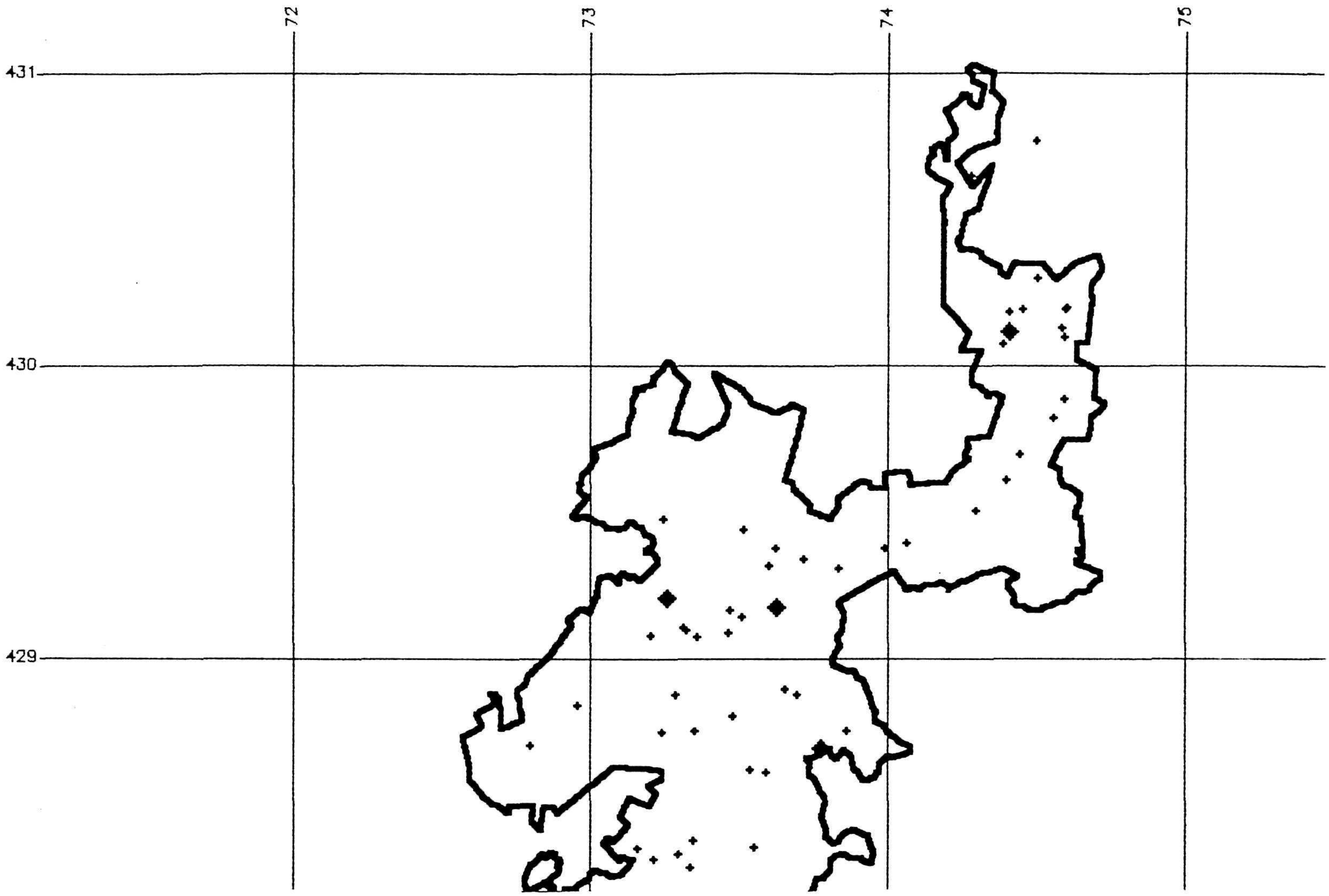
1.1	Forest Vegetation
4.1	Mollusks
4.2	Crustacea
4.5	Arthropods (3) (aquatic insects)
9.2	Water Chemistry
10.1	Forest Response to Gypsy Moth Infestation
10.4	Stream Aquatic Habitat

A cooperative agreement was established with Virginia Polytechnic Institute and State University (VPI&SU), to assist the Park staff in developing Phase I of the LTEMS and in the writing of the first users manual series.

Pilot measurement protocols for the selected Phase I elements were then designed and field tested. Numerous adjustments were made to perfect techniques. A great deal of care was taken to assure that all measurements would be both accurate and repeatable. Quality assurance and quality control (QA/QC) 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 Phase I program development was the structure and design of the database management system. It was recognized from the onset that custom designed database programs would be needed to store, analyze, and process the large amounts of data that would be collected in connection with the LTEMS program, and to prepare data summary reports. The database for Phase I parameters 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 Park's Geographic Information System (GIS) is used to store and spatially display the various inventory and monitoring data sets as they are developed.

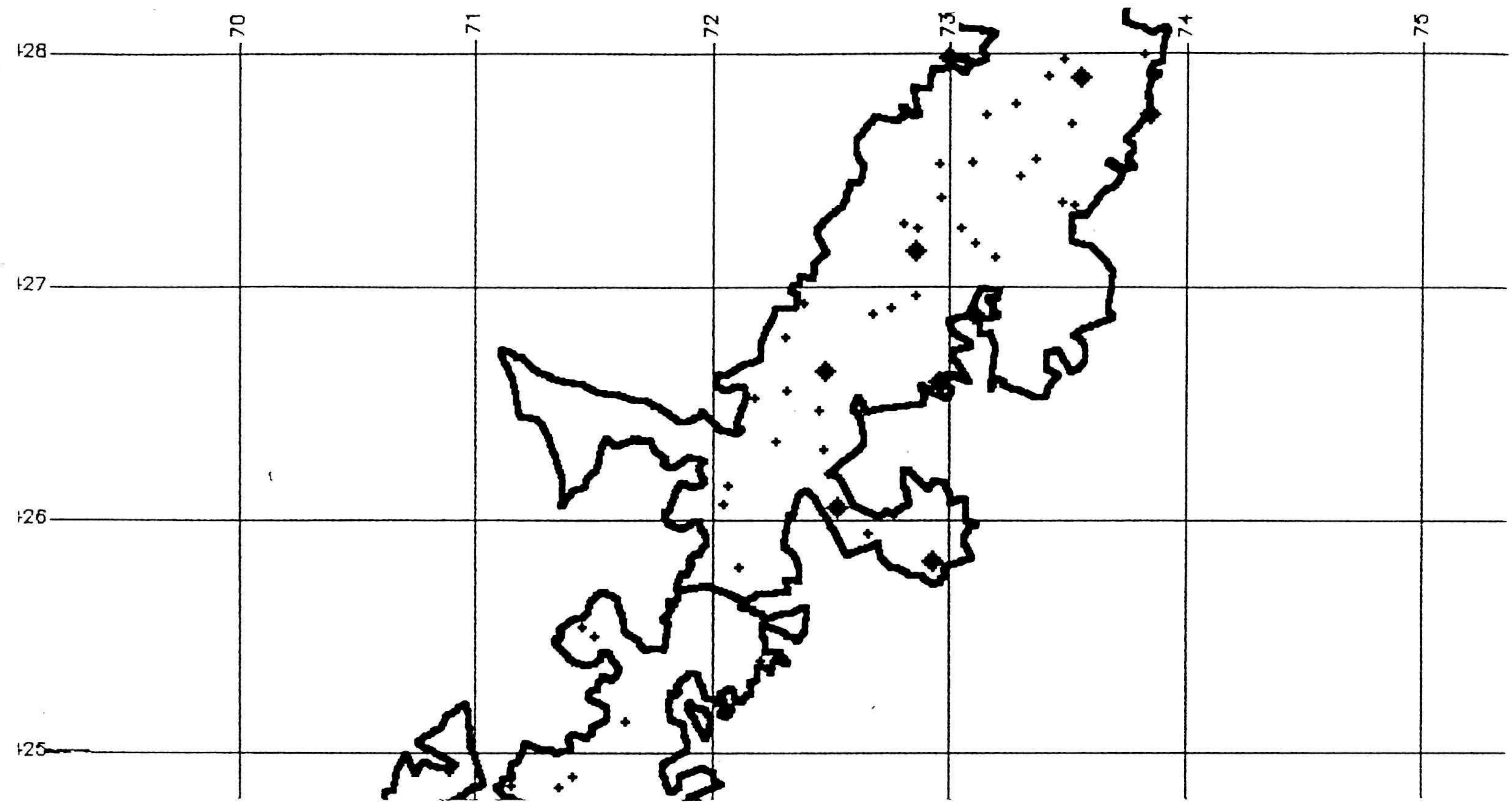


Shenandoah National Park

North District LTEM
Site Locations

Scale: 1:216747

+ = Terrestrial Sites
◆ = Aquatic Sites

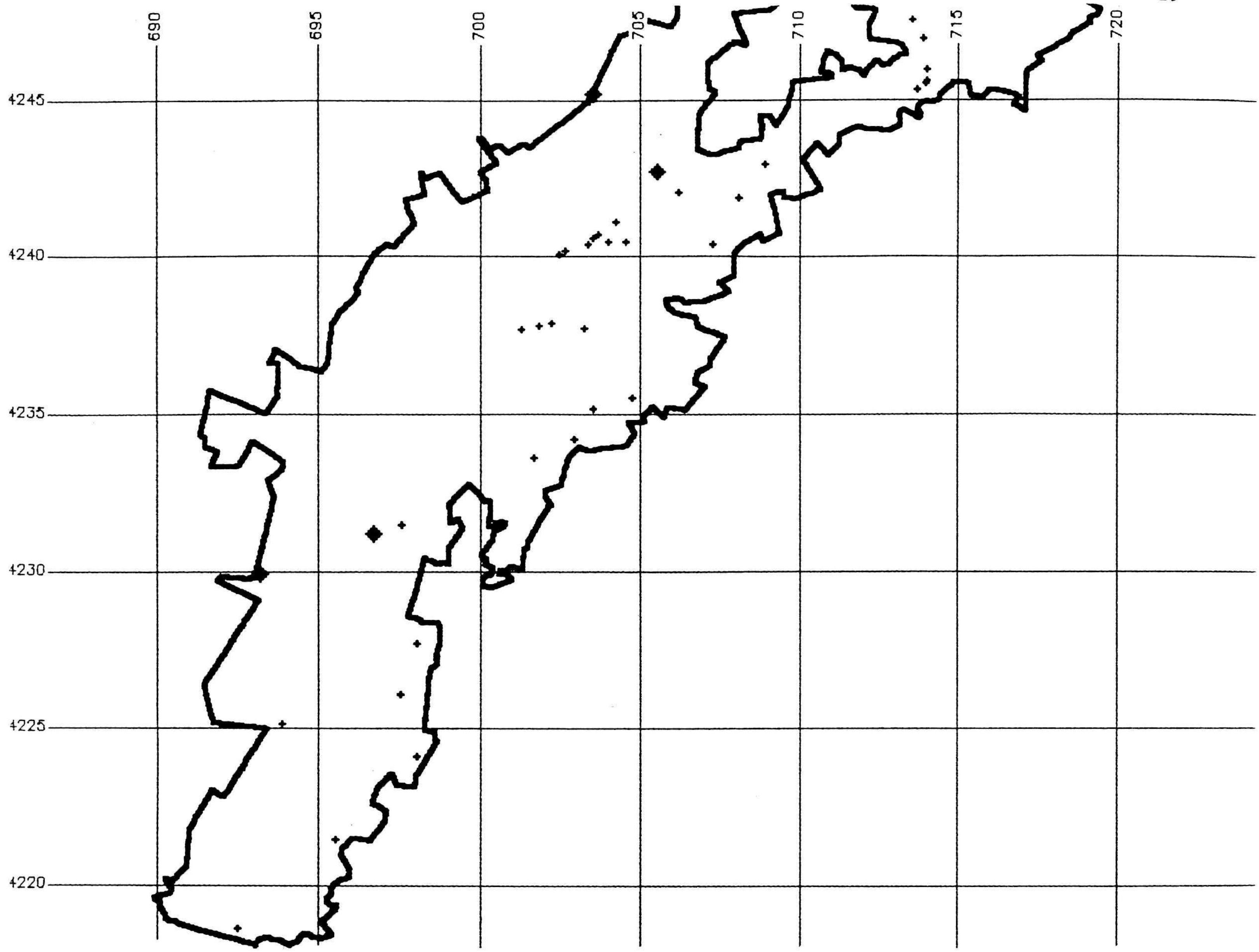


<u>Shenandoah National Park</u>

Central District LTEM
Site Locations

Scale: 1:309971

+ = Terrestrial Sites
◈ = Aquatic Sites



Shenandoah National Park

South District LTEM
Site Locations

Scale: 1:186449

+ = Terrestrial Sites
♦ = Aquatic Sites

The analytical capabilities of the GIS have been used on several occasions to determine where monitoring plots should be located. Themes that have been particularly useful for this purpose include: forest vegetation, soils, geology, and topography. The GIS will be used to support the inventory portion of the I&M program by storing a spatial record of each species recorded locations, densities, and critical habitats.

The goal of the second three-year period of Phase I (1988-1990) was to establish the core forest vegetation and aquatic plot systems which would facilitate the measurement of the selected elements. Since test plots were already worked out during previous years, little further modification was necessary. Three hundred sixty terrestrial plots were established on 120 sites. Baseline data was acquired during this period and some valuable inventory information was collected in the process. All of the 17 aquatic plots on 13 streams were established in the first year. One third of the forest plots were established each year so that the re-measurement 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.)

A monitoring program of this magnitude requires a considerable amount of dedicated staffing to maintain and operate. The staffing level for Phase I activities included:

.5 FTE Natural Resource Specialist, GS-12

I&M Program Manager: GS-11 Ecologist

GIS Support: .5 FTE GIS Technician

Field Technicians: 3 FTE Temporary Biological Technician

Total expenses including contracts for sample analysis to operate the Phase I program in 1990 was $230,000.

PHASE II

Phase II started in 1991, and includes the development or refinement of protocols and manuals for the following elements (*). This list also includes Phase I (**Bold**).

1.1 **Forest Vegetation**

1.2.1 The Big Meadow Ecosystem *

1.2.2 Big Meadows Swamp Ecosystem *

2.2.2 Ferns *

2.2.4 Lichens *

3.1.2 White-tailed Deer

3.1.3 Black Bear *

3.1.5 Natural Heritage Species (T&E vertebrates) *

3.2.1 Resident Breeding Birds *

3.2.2 Migratory Birds

3.3.1 Eastern Brook Trout *

3.3.2 Fish (other)

3.5 Amphibians *

4.1 **Mollusks**

4.2 **Crustacea**

4.4 Arthropods (2) (terrestrial insects)

4.5 **Arthropods (3) (aquatic insects)**

5.1 Gaseous Pollutants *

5.2 Particulates *

5.3 Acid Deposition *

5.4 Visibility *

6.1 Solar Radiation *

6.2 Events

6.3 Wind *

6.4 Relative Humidity *

6.5 Precipitation *

6.6 Dewpoint *

6.7 Temperature *

9.1 Stream Discharge

9.2 **Water Chemistry**

9.3 Pollutants

10.1 **Forest Response to Gypsy Moth Infestation**

10.2 Watershed Acidification *

10.3 Deciduous Forest Watershed Dynamics *

10.4 **Stream Aquatic Habitat**

Some of the actual monitoring of Phase II elements has already been initiated. The asterisk following the element indicates that most, if not all, of the element is currently being monitored. Some sort of written protocols exist for these elements, however, they may not be as complete as they need to be, have not been put in the Park's official manual series format, or have not been subjected to a peer review process. In addition, standardized data management programs have not been developed for many of them. In some cases, the management of data collected is being accomplished by the University staff that is cooperating in the monitoring, and we only need to transfer it into our data framework.

BUDGET

The staffing and funding level needed to accomplish Phase II is as follows:

Program Manager, Supervisory Ecologist GS-11/12............. $55,000

Database Manager, Ecologist GS-9/11......................... $45,000

AQ Monitoring Technician GS-7/9 and support................. $45,000

GIS Support, .5 FTE GS-7 Cartographic Technician............ $15,000

Field Supervision, 2 FTE, GS-7 Permanent Bio-Technician..... $60,000

Field Data Collection, 5 FTE GS-5 Seasonal Bio-Technician... $80,000

Support (vehicles, equipment, supplies, utilities, etc. [vehicles and equipment amortized]). Annual estimate....... $75,000

Contracts (water chemistry analysis, invertebrate I.D., aerial photography, protocol R&D, etc.).............. $120,000

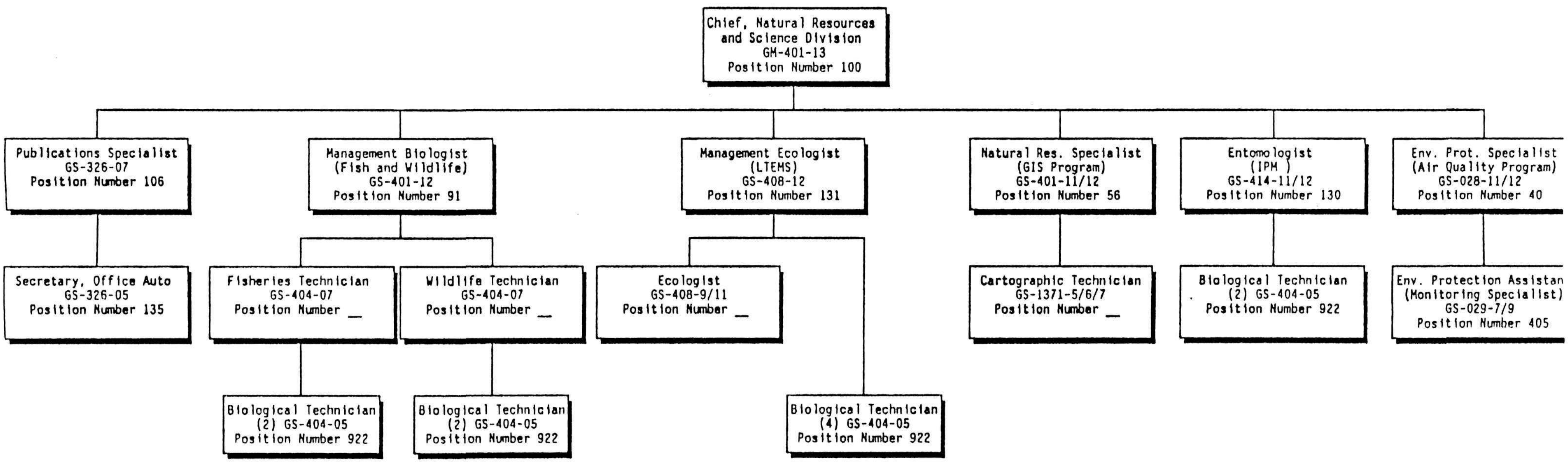
Publications Specialist, GS-7 (includes preparation of plans, manuals, special graphics, printing, etc.)........... $30,000

Administrative Support, .5 FTE GS-5 Secretary.............. $10,000

NR&S Division Office Expansion (One-time cost)............. $200,000

<u>Total</u>:	Costs First Year	<u>$735,000</u>
<u>Total</u>:	Sustaining Costs	<u>$535,000</u>

Natural Resources & Science Division
Shenandoah National Park
Target Organization



PHASE III

Phase III will include monitoring of the remaining resource elements and ecosystem process that are practical based on foreseeable budgetary and technological considerations. It is uncertain as to when Phase III will start primarily because we do not yet know how long it will take to bring Phase II on line. Obviously, a lot will depend on future budgets. If long-term monitoring becomes a sustainable NPS primary operational program that is solidly placed in Park operations, we can estimate that it is feasible for Phase II to be fully implemented within three years (by the end of 1994). The completion of Phase III will take a longer period of time to implement because new protocols will need to be developed for almost all of the elements.

It is not reasonable at this time to estimate what it will cost to carry out Phase III. However, incremental costs should be less than for the increase between Phase I and Phase II. Most of the overhead costs, including transportation and equipment, will not have to be substantially increased. Also, as the staff gains experience in monitoring program development, we should be able to make protocol decisions much more quickly.

DATA MANAGEMENT

The Inventory and Monitoring Program is primarily a data collection process. It is an understatement to say that there will be a very large volume of data collected. Since monitoring is an ongoing process, the data sets will continue to grow indefinitely. The need to establish a good data management process early on in the program is absolutely critical.

A very thorough and comprehensive database format and management system was developed in Phase I as a model. The Phase I database system is a customized software program written in dBASE III PLUS and compiled in Clipper. The emphasis of the Phase I database was to standardize the database variables and develop a user-friendly data entry system. The program has a set of menus to guide the user through the various data entry and correction processes. Each data entry screen is similar in appearance to the specific data sheet which data is being read from and as the user enters the data, the program error checks the entries for spelling errors and values which are out of range. Data entry is easy and can be mastered by a field technician in a few hours. The custom software program will produce basic summary reports by plot. The system also allows the user to download data for individual plots or a combination of plots based on a specified common variable or variables.

The database is housed in a Dell System 325 microcomputer with a 327 Mb hard drive. Data is backed up on 20 Mb Bernoulli cartridges after each data entry or modification session. Backup copies of the database system and data are housed in the safe at SNP Headquarters. Additional I&M data summaries and analysis will be completed using SPSS Inc.'s SPSS/PC+ Version 2.0 statistics software or Ashton Tate's DBASE STATS program.

Each resource section will have a dBASE III PLUS database (or dBASE IV when the program has proven to be reliable) developed to store, analyze and produce reports that are specific to the particular needs of the section. The initial approach to managing the Park's specialized database resulted in the present custom software program. Due to the dynamic process of monitoring, there will be a continued need to add data values to existing databases. The current software program does not allow for easy updating without having the original software developer rewrite the program. Future database efforts will concentrate on using simpler data entry approaches or preferably using hand-held electronic data entry devices in the field. Once the data is in a database, simple error checking programs could be used to verify data quality. Once the data is cleaned, error free data would then be summarized and analyzed using statistical analysis programs then appended to the original database for future use. Additional summary reports could also be written in dBASE III PLUS. With this procedure, an addition of one or more new variables will require only slight modifications to the summary programs rather than rewriting an entire data entry and summary program. Data collected will be entered into the computer during the field season so that huge volumes of data do not build up and become overwhelming.

The GIS will continue to be used to store, analyze and display selected data sets for which mapped information is useful.

QUALITY ASSURANCE AND CONTROL

Efficient design and appropriate standardization of monitoring methods 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 the LTEMS program, where the primary objective is to determine changes in the 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 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 ecosystems in question.

Phase I of the I&M program established standardized methods and procedures for monitoring forest ecosystems, aquatic ecosystems, and gypsy moth populations so that data quality is documented and can be assessed, and that future measurements will result in valid comparisons. In order to ensure that the most applicable techniques and methods were used, the Park contracted with leading researchers to develop those techniques which are most reliable and have the greatest precision. An example of this approach can be found in Appendix II-D of the forest section of the "Shenandoah National Park Long-Term Ecological Monitoring System User Manual" where standard operating procedures (SOPs) for individual measurement techniques are described. Use of SOPs should reduce inter- and intra-site variability, reduce documentation requirements for future monitoring elements, and provide the management team with information on defined and documented quality. Standard operating procedures were based on the document "Quality Assurance Methods Manual For Forest Site Classification and Field Measurements" by S. M. Zedaker, and N. S. Nicholas, November 1989. The standard operating procedures outlined for other forest measurement instruments have been used as a standard for other measurements not listed in the LTEMS manual.

One of the first steps in assuring quality data and repeatable measurements is an intensive training program for the employees who will collect the monitoring data. Before each field season begins, a training session is conducted which not only shows each participant the SOPs but also requires that each person demonstrate that they can carry out the procedures. Each crew member is also required to have a copy of the SOPs with them for reference when performing monitoring duties. Project managers also work with the crews on a regular basis to ensure that standard techniques are being adhered to and to resolve any discrepancies that arise in the field. Field technicians are also checked for accuracy on a regular basis.

During Phase II of the monitoring program, standardized methods and procedures as well as accuracy tolerance limits will be established for measurements associated with each resource element that will be monitored. Quality control guidelines are paramount for the success of a monitoring program. If accuracy limits are not adequate then it may be impossible to document change in the system being monitored.

A major concern for monitoring data is not only the quality but also compatibility. Efforts will be made to ensure that the data collected from new monitoring efforts will be compatible with information already collected or with other research being done. New monitoring protocols will be developed with the help of leading researchers and scientists through both contracts and informal consultation. Other outside researchers and resource managers will be used to review and critique the newly suggested monitoring protocols.

III. REPORTS AND PUBLICATIONS

An active I&M program is incomplete if the data that has been carefully collected and stored is not summarized and the results published and distributed and the information gained applied to management of the resources. The initial result of an inventory is a species list with abundance values and a set of locations that results in a range or distribution. The initial result of monitoring is usually a characterization of the resource element. The long-term objective of monitoring is to document changes in abundance, range or a relationship with an ecosystem process. It is recognized that several years or even decades of high quality monitoring data may need to be collected and analyzed for some elements before any significant trends can be detected. In spite of the long-term nature of monitoring, a program goal is to compile and analyze all data sets annually.

Phase I provided a basic resource inventory and the data necessary to characterize the forest vascular flora, and the several elements of the aquatic ecosystems. The next step is to generate the appropriate species lists and to complete a basic resource characterization. This process is underway and is scheduled for completion by the end of 1991. The same process will be used for Phase II, and III data sets.

The results of the Park's I&M program are and will continue to be distributed to a wide range of audiences. The following types of publications have been identified as potential outlets for I&M results:

1) Each year an annual report will be produced that will document the progress of the I&M program. This will be a summary report providing information of a general nature for internal and informal external informational uses.

2) Following the completion of an inventory project or the summary and analysis of a monitoring element, a special report will be written in an informative style and presented to the Division of Interpretation and Visitor Services (I&VS). The purpose of this report would be to provide a steady stream of information to the interpretive staff to be included in Park publications and interpretive activities.

3) The information summarized in number 1 and 2 above, as well as additional progress reports, will also be communicated to the public through short informative articles published through local newspapers and popular magazines. The objective of this effort would be to provide the public with pertinent information on the status and health of Park resources as well as to provide information about present and future threats. An ongoing effort will continue to be made to work with reporters and correspondents as they pursue stories which are of interest to the news media.

4) I&M protocols including methodology, techniques, and quality assurance requirements will continue to be published through the NPS Publications Office. New manuals would be added to the "Shenandoah National Park Long-Term Ecological System User Manuals" series.

5) The characterization of Park resources and eventually the documentation of trends will be published, when considered appropriate, as peer reviewed monographs, or will be submitted for publication in one of the more recently established popular journals. In this way, basic ecological information will be shared with other professionals dealing with research or management of natural areas, parks, rare species, and land preservation.

6) I&M results can potentially lead to uncovering new scientific information, the documentation of ecological cycles, and the

validation of ecological theories. Any new scientific information resulting from the I&M program would be published in peer reviewed articles in the appropriate scientific journals. The typical journals where some of the information would likely be published would be Castanea, Bulletin of the Torrey Botanical Club, Ecology, and Journal of Wildlife Management. Benefits associated with publishing in peer reviewed journals include: increased recognition that the NPS is producing scientifically-critiqued research and monitoring, a broader dissemination of scientific results to the scientific community, and the establishment of information which could potentially encourage additional research or monitoring in NPS areas. The additional activity that may be encouraged would highly benefit the SNP, especially since many of the research projects may be funded through grants from outside the NPS.

7) The other outlet where I&M information would be disseminated would be through the Biennial SNP Natural Resources and Science Research Symposium and other professional level meetings. A typical product associated with such a meeting would be the compilation of abstracts in a symposium summary document.

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