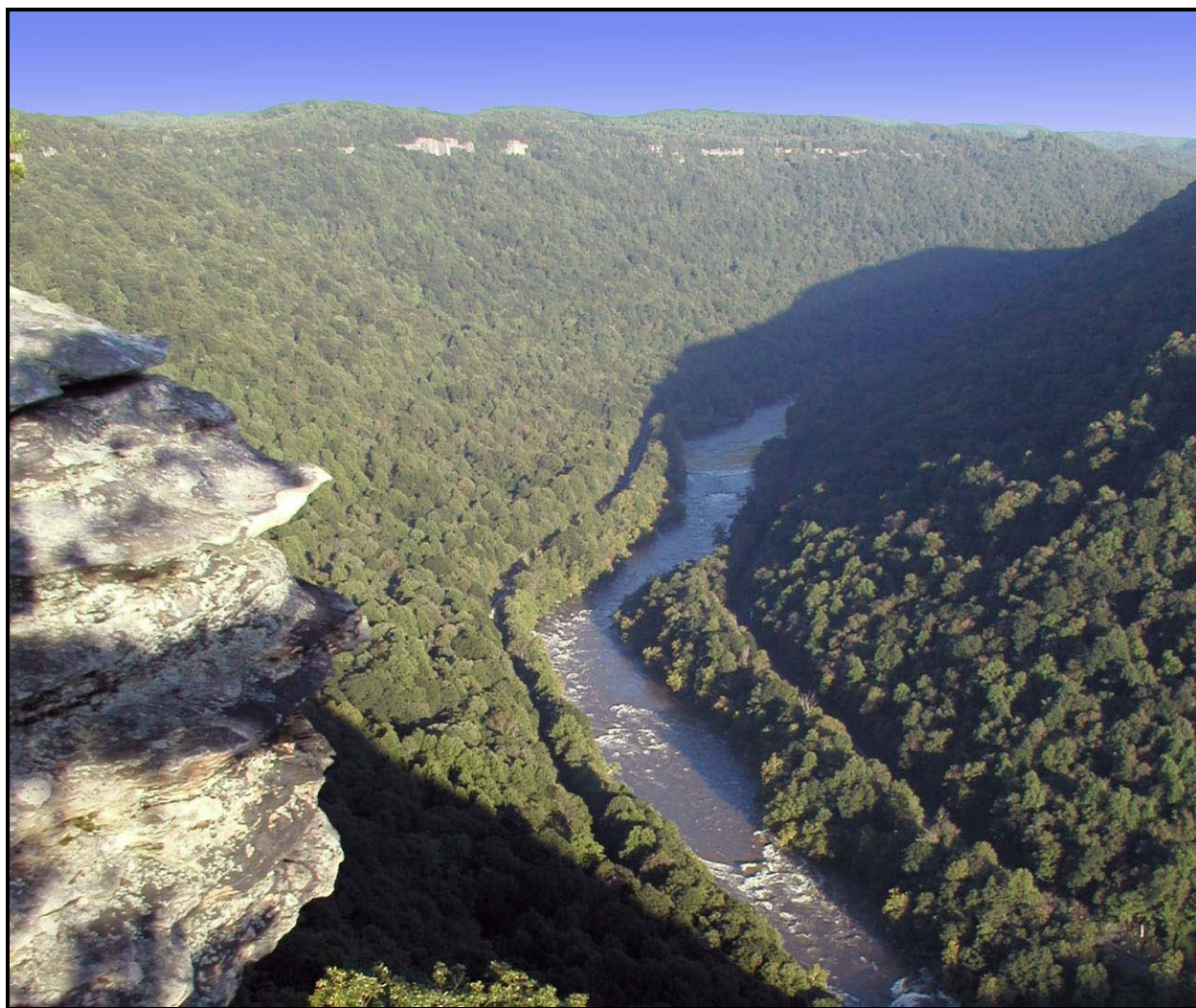




Eastern Rivers and Mountains Network Ecological Monitoring Plan

Natural Resource Report NPS/ERMN/NRR—2007/017



ON THE COVER

View of New River Gorge National River

Photograph courtesy of The National Park Service

Eastern Rivers and Mountains Network Ecological Monitoring Plan

Natural Resource Report NPS/ERMN/NRR—2007/017

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September 2007

U.S. Department of the Interior
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Fort Collins, Colorado

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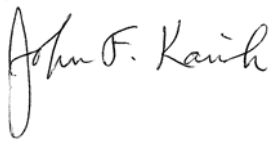
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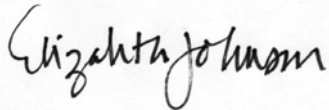
Signature Page



9/21/2007

Signatory, Network Board of Directors (John F. Karish, NER Chief Scientist)

Date



9/21/2007

Elizabeth Johnson, NER Regional Inventory and Monitoring Coordinator

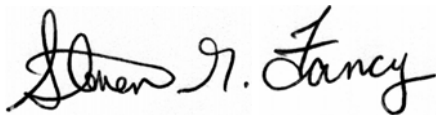
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9/21/2007

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Executive Summary

"To protect your rivers, protect your mountains"

- Emperor Yu, China, 1600 BC

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's (NPS) ability to manage park resources "unimpaired for the enjoyment of future generations." Beginning in 1992, with additional support by the 1999 Natural Resource Challenge, the NPS implemented a strategy to institutionalize natural resource inventory and monitoring. The effort was undertaken to ensure that the more than 270 park units with significant natural resources possess the information needed for effective, science-based resource management decision-making. The national strategy consists of a framework having three major components: 1) completion of basic resource inventories upon which monitoring efforts can be based; 2) creation of experimental prototype monitoring programs to evaluate alternative monitoring designs and strategies; and 3) implementation of ecological monitoring in all parks with significant natural resources.

Parks with significant natural resources were grouped into 32 monitoring networks linked by geography and shared natural resource characteristics. The network organization was created to facilitate collaboration, information sharing, and economies of scale in natural resource monitoring. Parks within each of the 32 networks work together and share funding and professional staff to plan, design, and implement an integrated long-term monitoring program. The primary role of the networks is to collect, analyze, and share new data. The Eastern Rivers and Mountains Network (ERMN) is composed of nine park units within the states of Pennsylvania, New York, New Jersey, and West Virginia. The network parks are Upper Delaware Scenic and Recreational River (UPDE), Delaware Water Gap National Recreation Area (DEWA), Allegheny Portage Railroad National Historic Site (ALPO), Johnstown Flood National Memorial (JOFL), Fort Necessity National Battlefield (FONE), Friendship Hill National Historic Site (FRHI), Gauley River National Recreation Area (GARI), New River Gorge National River (NERI), and Bluestone National Scenic River (BLUE).

The complex task of developing ecological monitoring requires a front-end investment in planning and design to ensure that monitoring will meet the most critical information needs and produce ecologically relevant and scientifically credible data that are accessible to managers in a timely manner. The ERMN "vital signs" monitoring program was developed over four years with specific objectives and reporting requirements for each of three planning phases. This document is the final monitoring plan. This plan: 1) outlines ERMN monitoring goals and the planning process used to develop the monitoring program; 2) summarizes existing information concerning park natural resources and resource management issues across the network; 3) provides a conceptual model framework for ERMN park ecosystems; 4) documents the effort to select and prioritize vital signs; 5) presents a sampling framework for aquatic and terrestrial ecosystems in parks; 6) summarizes monitoring protocols; 7) describes the network's approach to data management; and, 8) provides information on program administration, funding, and operations.

“Vital signs,” as used by this program, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored include water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization, including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

The diversity of ecosystems in ERMN parks, the geographic distribution of the parks, and differences in resource management priorities among parks are perhaps the greatest challenges facing the network. However, the vital signs selection process found that parks share a number of similar resource management issues and monitoring needs. The ERMN vital signs monitoring plan identifies a suite of common vital signs for monitoring. The network will prepare and implement monitoring protocols for the following 13 priority vital signs over the next 1–3 years (this information is presented in a national 3-level framework adopted by all networks as a way to consistently display and organize vital signs):

Level 1 Category	Level 2 Category	Level 3 Category	ERMN “Vital Sign” Name
Air and Climate	Air Quality	Wet Deposition	Air Quality
	Weather and Climate	Weather and Climate	Weather and Climate
Geology and Soils	Soil Quality	Soil Function and Dynamics	Soil Function and Dynamics
Water	Hydrology	Surface Water Dynamics	Surface Water Hydrology
	Water Quality	Water Chemistry - Core	Water Chemistry - Core
		Water Chemistry - Expanded	Water Chemistry - Expanded
		Aquatic macroinvertebrates	Aquatic macroinvertebrates
Biological Integrity	Invasive Species	Invasive/Exotic Plants and Animals	Invasive/Exotic Plants, Animals and Diseases - Status and Trends
		Invasive/Exotic Plants and Animals	Invasive/Exotic Plants, Animals and Diseases - Early Detection
	Focal Species or Communities	Shrubland Forest and Woodland Communities	Forest, woodland, shrubland, and riparian plant communities
		Riparian Communities	Rare, riparian plant communities
		Birds - Riparian Communities	Louisiana waterthrush
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Land Cover and Use	Landscape Dynamics
		Landscape Pattern	

Network parks and I&M staff and their cooperators will make thousands of observations each year about weather and climate, plant populations, aquatic macroinvertebrates, riparian birds, physical and chemical characteristics of water, and other attributes of our priority vital signs. The key to maintaining an accurate and complete record of those observations in perpetuity is in data management. The ERMN Data Management Plan identifies key data resources and processes to manage inventory and monitoring data. Assuring and maintaining data integrity is fundamental to the ERMN mission and requires a conscious and consistent effort to be successful. Data management procedures follow five key steps: acquisition, verification, validation, analysis, and dissemination. In addition, storage, maintenance, and security issues apply to all stages of the data flow.

Reporting is how park managers get information from the underlying data collection, analysis, and interpretation for use in decision-making. Network reporting will include: 1) annual summaries of progress and achievements in monitoring that include graphed results and summary statistics for vital signs; 2) multi-year status and trend reports that include correlation and trend analysis; and 3) concise resource “briefs” that contribute up-to-date summaries, data analysis, and interpretation for issues of concern. Routine reports will be automated as much as possible.

Administrative oversight for the program is by ERMN park superintendents and the Northeast Region Chief Scientist in a charter-driven Board of Directors (BOD). Technical oversight is by the Science Advisory Committee (SAC), comprised of natural resource managers and other expert NPS and government scientists who serve as the first level of scientific peer review for the vital signs program. In the organizational structure for the network, the Northeast Region I&M Coordinator supervises the ERMN Coordinator and the ERMN Coordinator supervises network professional staff: a data manager, a plant ecologist, a hydrologist/aquatic ecologist, term employees, and field crews. The network office is located on the campus of The Pennsylvania State University - the geographic center of ERMN parks. The Board of Directors selected this location by majority vote.

ERMN will be subject to periodic reviews to ensure high program quality and accountability. In 2010 and every fifth year thereafter, a comprehensive review of program operations will be conducted. Peer review of monitoring protocols, upon their completion and prior to full implementation, will be coordinated by the NER I&M Coordinator.

Acknowledgments

The Eastern Rivers and Mountains I&M Network would like to thank the park staff, Northeast regional staff, WASO staff, and collaborators outside of the National Park Service for their hard work, patience, cooperation, enthusiasm, and support in advancing this vital signs monitoring plan and program.

Because authorship of this document recognizes those who have simply brought to print the analysis, vision, and contributions of so many people, we wish acknowledge a few of those people here. It is impossible to thank everyone who has helped. We are indebted to Beth Johnson for her guidance and assistance as Northeast Region I&M Coordinator; her sound vision, tireless commitment to keeping our program development on track, and (most importantly) friendship has been invaluable. The network is also indebted to John Karish, Northeast Region Chief Scientist, for his leadership, wisdom, skill, and sense of humor navigating the world of contracting.

Park managers' consistent responses to inquiries and input at meetings and the contributions of the Science Advisory Committee, throughout the process, are the heart of this document. Special thanks to Richard Evans, Jeffrey Shreiner, Al Ambler, Don Hamilton, Jamie Myers, Ken Stephens, Jesse Purvis, John Perez, Gene Clare, Kathy Penrod and Connie Ranson. Dave Smith, Craig Snyder, John Young, Bill Lellis, Duane Diefenbach, Ray Hicks, Jim Rentch, Rob Brooks, Carolyn Mahan, and Alan Ellsworth also deserve special mention and thanks for their invaluable advice and contributions to program development.

We also wish to thank Gary Williams, Steve Fancy, John Gross, and many others with the National Inventory & Monitoring Program and Natural Resource Program Center for leadership, guidance, and support.

We also acknowledge the critical role of many other NPS I&M networks in paving the way and providing us with many vetted tables, figures, text, and other materials that simplified our task.

Our goal in producing this document has been to guide future natural resource monitoring to benefit natural resource management in network parks. We trust that the hard work and cooperation that has produced this plan will continue to move this network towards that end.

Chapter 1 Introduction and Background

“We have to know what we have, how and why it is changing, what changes we can accommodate, and which we must combat.”

- Fran Mainella, former Director, NPS

“Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions.”

- 2006 NPS Management Policies

The Inventory and Monitoring (I&M) Program is a major component of the National Park Service’s (NPS) strategy to improve park management through greater reliance on scientific information.

The I&M Program was initiated in 1992 with a focus on completion of basic resource inventories for all parks with significant natural resources and development of prototype monitoring programs in selected parks and park clusters. Additional program development came with the authorization of the National Parks Omnibus Management Act of 1998 that mandated the National Park Service “to establish baseline (resource) information and to provide information on the long-term trends in the condition of National Park System resources.” In response to this mandate, the National Park Service developed the 1999 Natural Resource Challenge - An Action Plan for Preserving Natural Resources.

Under the Challenge, more than 270 park units, grouped into 32 networks (Figure 1.1), were organized to support the development of integrated park natural resource inventory and monitoring and other strategic stewardship actions. A key function of the networks’ is to collect and analyze new data. The network approach is designed to minimize redundancy, maximize cost effectiveness, and increase consistency in data collection and information transfer. The amount of funding available for ecological monitoring would allow most parks to monitor only a few indicators. A key efficiency of the network approach is to identify and monitor a core set of ecosystem attributes and resource/stressor relationships that are important across a group of parks. In addition to increased efficiency, applying standard monitoring approaches across ecoregions will result in greater potential for comparison and explanation in the resulting datasets.

NPS resource monitoring is designed to inform park managers of the condition of water, air, and other biological and physical resources of value to park staff and visitors. The broad-based, scientific information obtained through monitoring has multiple applications for management decision making, research, education, and promoting public understanding of park resources.



Figure 1.1. Map of the 32 National Park Service Inventory and Monitoring Program Networks.

Establishment of the monitoring portion of the program has been directed by national-, regional-, and network-level guidance, articulated in a peer-reviewed ecological monitoring plan (this document), and culminates with the implementation of routine monitoring and integration of monitoring data into management decision-making.

1.1. Purpose of the Vital Signs Monitoring Program

The purpose of the Vital Signs Monitoring Program is to provide information to detect, predict, and understand changes in ecosystem resources of primary interest to the park(s) that contain them. In this section, we provide an overview of the Eastern Rivers and Mountains Network, review the justification for integrated natural resource monitoring, define “vital signs,” and summarize the substantial legal and policy framework in place supporting ecological monitoring in the National Park System.

1.1.1. General Overview of the Eastern Rivers and Mountains Network

The Eastern Rivers and Mountains Network (ERMN) includes nine parks in New York, New Jersey, Pennsylvania, and West Virginia (Figure 1.2), that together encompass roughly 60,000 ha (148,262 ac) of land area, 340 km (211 mi) of river, and more than 684 km (425 mi) of streams (Table 1.1). The ERMN includes a small segment of the Appalachian Trail; however, monitoring activities associated with the trail are currently coordinated by the Northeast Temperate Network. The four smallest parks in the network (Table 1.1) were established for the interpretation and preservation of cultural resources, including two National Historic Sites, one National Battlefield, and one National Memorial; yet, each also contains significant natural resources, including rare or regionally important plant and animal species and communities. The remaining five parks are river parks established primarily for recreation and preservation of natural resources. Some are designated under the National Wild and Scenic Rivers System. The river parks in the ERMN contain some of the most significant water resources and water-based recreational activities in the national park system.

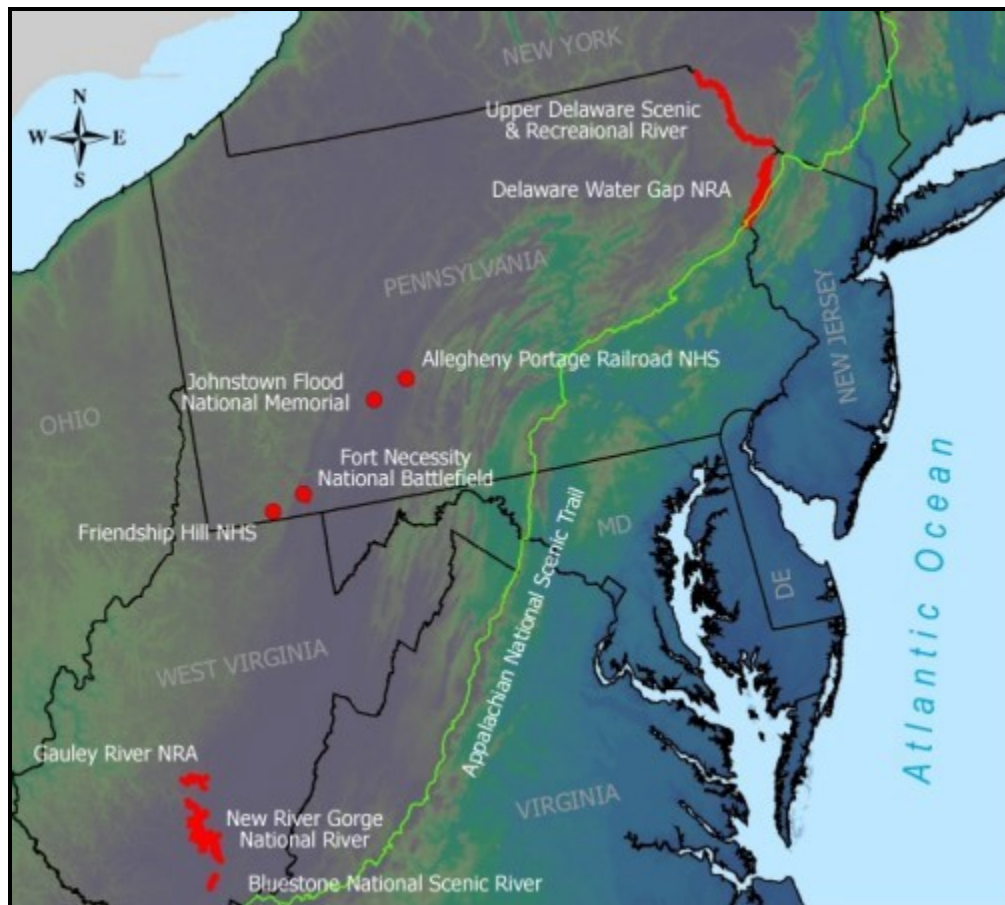


Figure 1.2. Location of Eastern Rivers and Mountains Network Parks.

Table 1.1. Overview statistics for Eastern Rivers and Mountain Network parks. Parks are organized geographically starting in the northeast and moving toward the southwest.

Park Name	Park Code	State(s)	Year Established	Visitors (2005)	Hectares (2005)	Acres (2005)	River Miles	Stream Miles
Upper Delaware Scenic and Recreational River	UPDE	PA/NY	1978	124,477	22,490	55,575	74	147
Delaware Water Gap National Recreation Area (Middle Delaware Scenic and Recreational River)	DEWA	PA/NJ	1965 (1978)	5,256,764	27,009	66,739	40	138
Allegheny Portage Railroad National Historic Site	ALPO	PA	1964	115,536	520	1,284	---	5.3
Johnstown Flood National Memorial	JOFL	PA	1964	222,241	72	178	---	0.9
Fort Necessity National Battlefield	FONE	PA	1931	102,004	364	902	---	3.7
Friendship Hill National Historic Site	FRHI	PA	1978	29,188	273	675	---	1.5
Gauley River National Recreation Area	GARI	WV	1988	128,796	4,656	11,507	31	15
New River Gorge National River	NERI	WV	1978	1,045,814	29,214	72,189	53	111
Bluestone National Scenic River	BLUE	WV	1988	45,146	1,744	4,310	13	4.5
Total				7,069,966	86,342	213,359	211	427

Major habitats range from broad rivers and floodplains to small ephemeral streams, high eastern mountains to deep gorges, and dry barrens to mesic forests. The broad, gently-rolling hills have rounded, usually dry-oak forested summits, with gradually sloping sides of mixed mesophytic forest that are separated by narrow valleys with well-drained, rich soils. Many areas are much more rugged, with steep gorges, talus slopes, and cliff faces. The maintenance of many of these habitats is dependent upon natural disturbances, such as fire, wind, flooding, landslides, ice storms, insects, and, occasionally, hurricanes. Ecologically, these natural disturbances have played a role in determining many of the intricate landscape patterns that characterize the ERMN, both spatially and temporally. A long legacy of human uses, including agriculture, logging, mining, and damming, has also shaped, and continues to influence, contemporary ecological systems from local to landscape scales. An understanding of current and future ecosystem properties must take into account these past and ongoing land uses.

1.1.2. Justification for Integrated Natural Resource Monitoring

Knowing the condition of natural resources in national parks is fundamental to the National Park Service's ability to manage park resources "unimpaired for the enjoyment of future generations" as mandated by the NPS 1916 Organic Act. Park managers across the country are confronted with increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources as a basis for making decisions and working with other agencies and the public for the benefit of park resources. For years, managers and scientists have sought a way to characterize and determine trends in the condition of parks and other protected areas to assess the efficacy of management practices and restoration efforts and to provide early warning of impending threats. The challenge of protecting and managing a park's natural resources requires a multi-agency, ecosystem approach, because most parks are open systems, with threats such as air and water pollution or invasive species originating outside of the park's boundaries. An ecosystem approach is further needed because no single spatial or temporal scale is appropriate for all system components and processes. The appropriate scale for understanding and effectively managing a resource might be at the population, species, community, or landscape level, and in some cases the resource may require a regional, national, or international effort to understand and manage. National parks are part of larger ecosystems and must be managed in that context.

Natural resource monitoring provides site-specific information needed to understand and identify changes in complex, variable, and imperfectly understood natural systems, and to determine whether observed changes are within acceptable levels of variability or may be indicators of unwanted influences. Understanding the dynamic nature of park ecosystems and the consequences of human activities is essential for management decision-making aimed to maintain, enhance, or restore the ecological integrity of park ecosystems and to avoid, minimize, or mitigate ecological threats to these systems (Roman and Barrett 1999).

"Vital signs," as used by this program, are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve "unimpaired for future generations," including water, air, geological resources, plants, and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization, including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

In situations where natural areas have been so highly altered that physical and biological processes no longer operate naturally (e.g., on park lands near developed areas where a history of damming rivers and streams has fundamentally altered natural disturbance regimes), information obtained through monitoring can help managers understand how to develop the most effective approach to restoration or, in cases where restoration is impossible, ecologically sound management.

1.1.3. Federal Legislation, Policy, and Guidance on Natural Resource Monitoring

In establishing the first national park in 1872, Congress “dedicated and set apart (nearly 1,000,000 acres of land) as a ... pleasuring ground for the benefit and enjoyment of the people” (16 U.S.C. 1 § 21). As other units were designated, each was to be administered according to its individual enabling legislation, but had been created with a common purpose of preserving the “precious” resources for public benefit. The passage of the NPS Organic Act of 1916 (16 U.S.C. 1 § 1) established and defined the mission of the NPS:

“The service thus established shall promote and regulate the use of the Federal areas known as national parks, monuments, and reservations hereinafter specified ... by such means and measures as conform to the fundamental purpose of the said parks, monuments, and reservations, which purpose is to conserve the scenery and the natural and historic objects and the wild life therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations.”

Congress reaffirmed the Organic Act with the General Authorities Act of 1970 (16U.S.C. 1a–1a8) and united all park units into the ‘National Park System’ by a common purpose of preservation, regardless of title or designation. In 1978, the NPS’s protective function was further strengthened by Congress stating “...the protection, management, and administration of these areas shall be conducted in light of the high public value and integrity of the National Park System and shall not be exercised in derogation of the values and purposes for which these various areas have been established...”. Two decades later, NPS Management Policies reiterated the importance of this protective function of the NPS to “understand, maintain, restore, and protect the inherent integrity of the natural resources” (NPS 2006). The approach to the management of park natural resources is clearly established in Chapter Four of the NPS Management Policies (NPS 2006):

“The Natural resources will be managed to preserve fundamental physical and biological processes, as well as individual species, features, and plant and animal communities. The Service will not attempt to solely preserve individual species (except threatened or endangered species) or individual natural processes; rather, it will try to maintain all the components and processes of naturally evolving park ecosystems, including the natural abundance, diversity, and genetic and ecological integrity of the plant and animal species native to those ecosystems. Just as all components of a natural system will be recognized as important, natural change will also be recognized as an integral part of the functioning of natural systems. By preserving these natural components and processes in their natural condition, the Service will prevent resource degradation, and therefore avoid any subsequent need for resource restoration. In managing parks to preserve naturally evolving ecosystems, and in accordance with requirements of the National Parks Omnibus Management Act of 1998, the Service will utilize the findings of science and the analyses of scientifically trained resource specialists in decision-making.”

Consistent with this policy, the NPS has adopted a science-based approach to natural resource management. NPS Management Policies (NPS 2006) further clarify the importance of ecosystem-based monitoring:

“Science has demonstrated that few if any park units can fully realize or maintain their physical and biological integrity if managed as biogeographic islands. Instead, park units must be managed in the context of their larger ecosystems. The ecosystem context for some species and processes may be relatively small, while for others this context is vast. In any case, superintendents face the challenge of placing each of the resources they protect in their appropriate ecosystem context and then working with all involved and affected parties to advance their shared conservation goals and avoid adverse impacts on these resources.”

Recent and specific requirements for a program of inventory and monitoring park resources are found in the National Parks Omnibus Management Act of 1998 (P.L. 105–391). In part, the intent of the act was to create an inventory and monitoring program that may be used “to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources.” NPS Management Policies (NPS 2006) direct the NPS to inventory and monitor natural systems in efforts to inform park management decisions:

“Natural systems in the national park system, and the human influences upon them, will be monitored to detect change. The Service will use the results of monitoring and research to understand the detected change and to develop appropriate management actions” (NPS 2006).

In addition to the legislation directing the formation and function of the National Park System, a number of laws protect not only the natural resources within national parks and other federal lands, but they address environmental compliance in the United States. Many of these federal laws require natural resource monitoring within national parks. A summary of legislation, policy, and executive guidance having a direct bearing on natural resource monitoring in the NPS is presented in Appendix A.

1.2. Natural Resource Monitoring Goals and Strategies

In this section, we first discuss the importance of inventory, monitoring, and research in stewarding natural resources. We then present the servicewide vital signs monitoring program goals and conclude with a conceptual approach for determining what to monitor (further developed in Chapters 2 and 3).

1.2.1. Interrelated Roles of Inventories, Monitoring, and Research

Monitoring is a central component of natural resource stewardship in the NPS, and in conjunction with natural resource inventories, management, and research, provides the information needed for effective, science-based managerial decision-making and resource protection (Figure 1.3).

Natural resource inventories are extensive point-in-time efforts to determine the location or condition of a resource, including the presence, class, distribution, and status of plants, animals, and abiotic components such as water, soils, landforms, and climate. Monitoring differs from inventories by adding the dimension of time; the general purpose of monitoring is to detect changes or trends in a resource. Elzinga et al. (1998) defined monitoring as “the collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective.” Detection of a change or trend may trigger a management action or it may generate a new line of inquiry. Research is generally defined as the

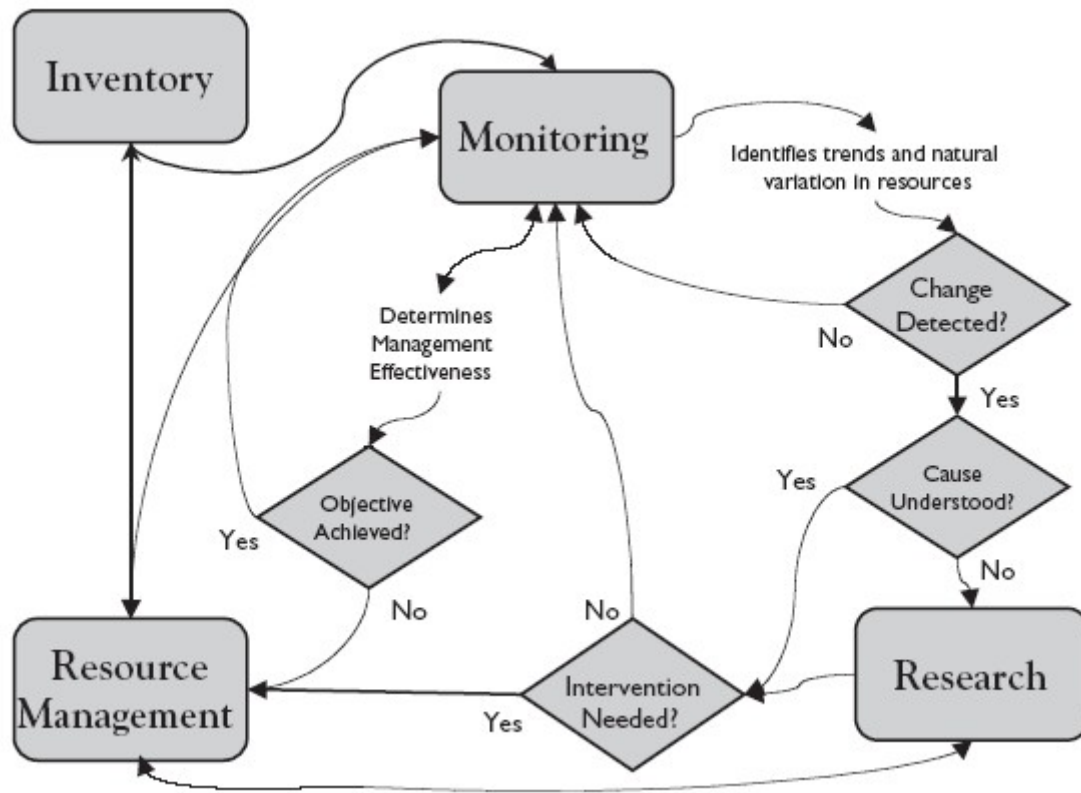


Figure 1.3. Relationships between monitoring, inventories, research, and natural resource management activities in national parks (modified from Jenkins et al. 2002).

systematic collection of data that produces new knowledge or relationships and usually involves an experimental approach, in which a hypothesis concerning the probable cause of an observation is tested in situations with and without the specified cause. A research design is usually required to determine the cause of changes observed by monitoring. The development of monitoring protocols also involves a research component to determine the appropriate spatial and temporal scale for monitoring.

1.2.2. Servicewide Vital Signs Monitoring Goals

The NPS I&M Program has developed the following long-term vital signs monitoring goals to comply with legal requirements, fully implement NPS policy, and provide park managers with the data required to understand and manage park resources:

1. Determine status and trends in selected indicators of the condition of park ecosystems to allow managers to make better-informed decisions and to work more effectively with other agencies and individuals for the benefit of park resources.
2. Provide early warning of abnormal conditions of selected resources to help develop effective mitigation measures and reduce costs of management.
3. Provide data to better understand the dynamic nature and condition of park ecosystems and to provide reference points for comparisons with other, altered environments.
4. Provide data to meet certain legal and congressional mandates related to natural resource protection and visitor enjoyment.
5. Provide a means of measuring progress toward performance goals.

1.2.3. Strategies for Determining What to Monitor

Effective monitoring programs provide information that can be used in multiple ways. The most widely identified application of monitoring information is that of enabling managers to make better-informed management decisions (White and Bratton 1980; Croze 1982; Jones 1986; Davis 1989; Quinn and van Riper 1990). Another use of monitoring information is to document changes primarily for the sake of familiarity with resources (Croze 1982; Halvorson 1984). By gathering data over long periods, correlations between different attributes become apparent, and resource managers gain a better general understanding of the ecosystem. A third use of monitoring information may be to convince others to make decisions benefiting national parks (Johnson and Bratton 1978; Croze 1982). Monitoring sensitive species, invasive species, culturally significant species, or entire communities can provide park managers, stakeholders, and the public with an early warning of the effects of human activities before they are noticed elsewhere (Davis 1989; Wiersma 1984). Finally, a monitoring program can provide basic background information that is needed by park researchers, public information officers, interpreters, and those wanting to know more about the area around them (Johnson and Bratton 1978).

Should vital signs monitoring focus on the effects of known threats to park resources or on general properties of ecosystem status? Woodley (1993), Woodward et al. (1999), Jenkins et al. (2002), and others have described some of the advantages and disadvantages of various monitoring approaches, including a strictly threats-based monitoring program, or alternate taxonomic, integrative, reductionist, or hypothesis-testing monitoring designs (Woodley 1993; Woodward et al. 1999). The approach adopted by ERMN agrees with the assertion that the best way to meet the challenges of monitoring in national parks and other protected areas is to achieve a balance among different monitoring approaches (termed the “hybrid approach” by Noon 2003), while recognizing that the program will not succeed without also considering

political issues. A multi-faceted approach for monitoring park resources was adapted, based on both integrated and threat-specific monitoring approaches and building upon concepts presented originally for the Canadian national parks (Figure 1.4.; Woodley 1993). This system segregates indicators into one or more of four broad categories:

1. ecosystem drivers that fundamentally affect park ecosystems,
2. stressors and their ecological effects,
3. focal resources of parks, and
4. key properties and processes of ecosystem integrity.

In cases where there is a good understanding of relationships between potential effects and responses by park resources (known effects), monitoring of system drivers, stressors, and affected park resources is conducted. A set of focal resources (including ecological processes) will be monitored to address both known and unknown effects of system drivers and stressors on park resources. Key properties and processes of ecosystem status and integrity will be monitored to improve long-term understanding and potential early warning of undesirable changes in park resources.

Natural ecosystem drivers are major external driving forces, such as weather and climate patterns, fire cycles, biological invasions, and hydrologic cycles, that have large-scale influences on natural systems (see Chapter 2). Trends in ecosystem drivers will have corresponding effects on ecosystem components and may provide early warning of presently unforeseen changes to ecosystems. Stressors are physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level (Barrett et al. 1976). Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include damming streams, water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution. Monitoring of stressors and their effects, where known, will ensure short-term relevance of the monitoring program and provide information useful to management of current issues.

Focal resources, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Collectively, these basic strategies for choosing monitoring indicators achieve the diverse monitoring goals of the National Park Service. Chapter 2 summarizes how we incorporated this approach into our understanding of ecosystem properties while Chapter 3 more fully describes the vital signs selection and prioritization process.

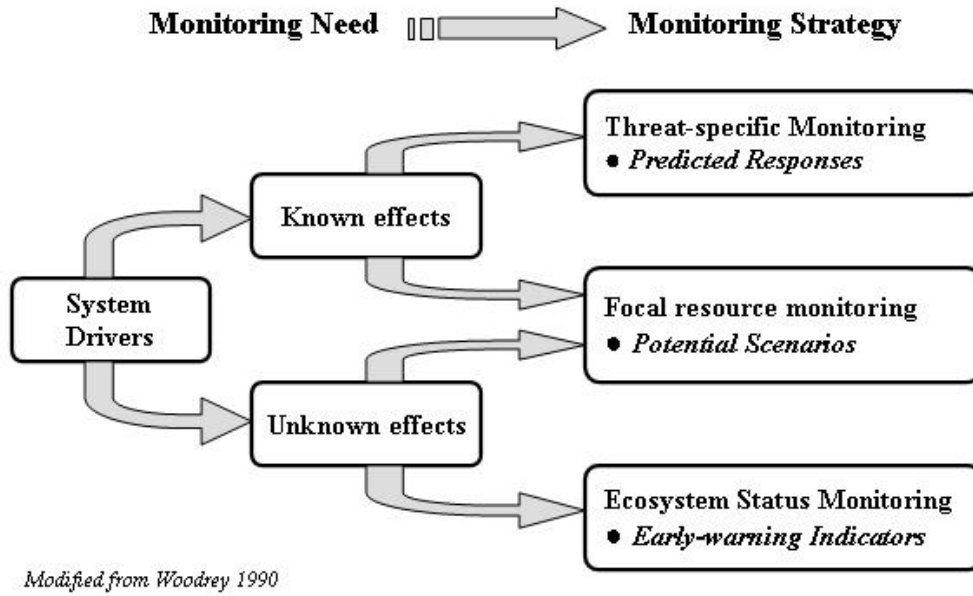


Figure 1.4. Conceptual approach for selecting Vital Signs.

1.3. Natural Resources of the Eastern Rivers and Mountains Network - What is Important?

One of the primary tasks in program development was to develop a comprehensive list of significant natural resources for network parks (and threats to those resources) that were candidates for resource monitoring. To start, resources were grouped into three categories: resources significant in the enabling legislation of the park, resources significant because of legal mandates or policy, and resources significant for other reasons such as regional or global rarity or importance. These resources, and others identified by subject matter experts, were then incorporated into the conceptual ecological models (Chapter 2) and vital signs prioritization process (Chapter 3). Verbal descriptions of each category follow and are also described in Tables 1.2 and 1.3. Resources listed under each category are named in Chapters 2 and 3 and the associated supporting appendixes. Source materials for the information not specifically cited include NPS General Management Plans (NPS 1982a, 1982b), Strategic Plans (NPS 1999), Resource Management Plans for the respective parks (NPS 1993, 1998, 2000, 2002a, 2002b, 2002c) and specific resource management plans such as the Water Resource Management Plans (e.g., Purvis 2002). We also explicitly discuss the integration of air- and water-quality monitoring into program development and summarize current park-based monitoring programs. We conclude this section with a summary of the dominant management issues of network parks.

Table 1.2. Significant natural resources summaries as they pertain to the enabling legislation of the park, to legal mandates or policy, or for other reasons such as global rarity.

Park	Reason Enabling Legislation	Natural Resources Significant to Legal Mandates/Policy	Natural Resources Significant for Other Reasons
UPDE	Public outdoor use and Wild and Scenic River designation (Natural/Recreational)	Scenic and Recreational River federally listed species special protection waters state impaired waters migratory birds	geologic resources globally rare species state rare species high quality streams
DEWA	Public outdoor use and Wild and Scenic River designation (Natural/Recreational)	Scenic and Recreational River federally listed species state listed species special protection waters state impaired waters wetlands migratory birds Appalachian Trail	hemlock ecosystems geologic resources globally rare species & communities state rare species high quality streams
ALPO	Preservation of Allegheny Portage Railroad trace (Historical/Cultural)	state listed plant species wetlands migratory birds	species of special concern Blair Gap Run and tributaries forest habitat
JOFL	Commemoration of 1889 Johnstown Flood (Historical/Cultural)	state listed plant species wetlands migratory birds state impaired waters	species of special concern wet meadow habitat
FONE	Commemoration of Battle of Fort Necessity (Historical/Cultural)	state listed species migratory birds wetlands	species of special concern shrubland habitat high quality streams
FRHI	Preservation of the home of Albert Gallatin (Historical/Cultural)	migratory birds wetlands	species of special concern floodplain forest
GARI	Preserve scenic, recreational, geological, fish and wildlife resources (Natural/Recreational)	federally listed species migratory birds state impaired waters	geologic resources globally rare species state rare species high quality streams
NERI	Conserve and interpret outstanding natural values and objects; preserve section of free-flowing river (Natural/Recreational)	federally listed species migratory birds state impaired waters American Heritage River	geologic resources globally rare species & communities state rare species large block of mixed mesophytic forest high quality streams
BLUE	Public outdoor use and Wild and Scenic River designation (Natural/Recreational)	federally listed species National Scenic River state impaired waters migratory birds	globally rare species state rare species high quality streams

Table 1.3. Summary of Eastern Rivers and Mountains Network water quality information based on the National Hydrography Dataset (NHD), Clean Water Act assessment data, and other pertinent state regulations (year 2004 data).

Park Code	Miles of Rivers and Streams	303(d) listed Streams (No.)	Impaired Length (stream-miles)	Criteria Affected	Cause	High Quality Streams (No.)	High Quality Miles (stream-miles)
UPDE	221.4	2	75.6	Mercury, PCB	Unknown	50 AA; N/A NY*	37.7
DEWA	178.6	4	59.5	Arsenic, Benthic Macroinvertebrates, Cadmium, Chromium, Copper, Dissolved Oxygen, Dissolved Solids, Fecal Coliform, Lead, Mercury, Nickel, Nitrate, PCB, pH, Phosphorus, Selenium, Silver, Temperature, Total Suspended Solids, Unionized Ammonia, Zinc	Unknown	46 in PA 24 in NJ	66.7
ALPO	5.3	0	0	None	None	0	0
JOFL	0.9	1	0.6	Metals, pH	Abandoned mine drainage	0	0
FONE	3.7	0	0	None	None	8	3.7
FRHI	1.6	0	0	None	None	0	0
GARI	45.5	3	31.8	Aluminum (dissolved), Fecal Coliform, Iron, Manganese	Mine drainage, unknown	8	34.2
NERI	164.5	14	76.1	Aluminum (dissolved), CNA-Biological, Fecal Coliform, Iron, Manganese, pH	Mine drainage, unknown	13	83.7
BLUE	17.6	3	12.7	Fecal Coliform	Unknown	3	12.4

*New York does not have a "High Quality" designation.

1.3.1. Natural Resources Significant to Enabling Legislation

Four parks in the network (UPDE, DEWA, GARI, and NERI) were established primarily for water-based recreation and/or to preserve important aquatic, terrestrial, and geologic resources (Table 1.2). River segments in three of the river parks in the network (UPDE, DEWA, and BLUE) are designated under the National Wild and Scenic Rivers Act and amendments. The 1978 Act, proclaims:

... that certain selected rivers of the Nation which, with their immediate environments, possess outstandingly remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural or other similar values, shall be preserved in free-flowing condition, and that they and their immediate environments shall be protected for the benefit and enjoyment of present and future

generations. The Congress declares that the established national policy of dams and other construction at appropriate sections of the rivers of the United States needs to be complemented by a policy that would preserve other selected rivers or sections thereof in their free-flowing condition to protect the water quality of such rivers and to fulfill other vital national conservation purposes.

The remaining four parks (ALPO, JOFL, FONE, and FRHI) were established to preserve and interpret cultural resources or events, although natural resources have since become part of the current management focus. In many cases, changes to the cultural landscape can influence (both positively and negatively) the natural resources of the park. Consequently, attempts to balance both cultural and natural resource objectives are critical.

1.3.2. Natural Resources Significant to Legal Mandates and Policy

Five ERMN parks (UPDE, DEWA, GARI, NERI, and BLUE) have at least one species that is Federally listed, including one bird species (bald eagle, *Haliaeetus leucocephalus*), one mussel (dwarf wedge mussel [*Alasmidonta heterodon*]), one plant (Virginia spirea [*Spiraea virginiana*]), two mammals (Indiana bat [*Myotis sodalis*] and Virginia big-eared bat [*Corynorhinus townsendii virginianus*]), and one reptile (bog turtle [*Clemmys muhlenbergii*]). All of the parks have at least one (and in many cases numerous) plant or animal species that is listed on a state-endangered or threatened species list (except parks in West Virginia, where no state list exists, but species are ranked according to their state and global rarity). As biological inventories continue throughout the parks, additional rare species and communities are likely to be found. See “Appendix B - Species of Special Concern” for a list of federally and state listed, and state and globally rare species found at each park as of September 2006.

Many parks have surface waters that are designated as high-quality or exceptional waters (or similar designation) and receive special protection and/or require that existing beneficial uses are maintained and protected. Within DEWA and UPDE, the Delaware River Basin Commission (DRBC) has adopted Special Protection Waters regulations for the Delaware River and its tributaries, designed to prevent degradation in streams and rivers considered to have exceptionally high scenic, recreational, and ecological values. See “Appendix C - Water Quality Summary” for park-specific water quality summaries and additional information on legal, regulatory, and specially designated waters in the ERMN.

River segments designated under the National Wild and Scenic River Act are not protected from development or use of the river system; however, the implicit goal is to protect the character and integrity of the river system.

According to mandates within the Clean Water Act, if water quality standards set forth by the Environmental Protection Agency (EPA) are violated, the waterbody is considered impaired and will be scheduled for Total Maximum Daily Load (TMDL) development. Each state is responsible for monitoring the waterways within their state and development of appropriate remediation. Several of the parks within the network contain waters that are listed on the state’s 303(d) list of impaired waterways (see “Appendix C - Water Quality Summary”).

1.3.3. Natural Resources Significant for Other Reasons

Many of the parks contain regionally and globally significant and/or rare natural resources (“Appendix B - Species of Special Concern”). The floral diversity at several network parks is of national significance and each of the parks also contains either globally rare or imperiled plant and animal species as well as state rare plant and animal species. For example, the globally significant natural resources at NERI include large, apparently stable populations of Allegheny woodrats (*Neotoma magister*), the rare Appalachian flatrock/riverscours plant community, and one of the largest remaining unfragmented blocks of mixed mesophytic forest in the nation (Mahan 2004). GARI, DEWA and, potentially, UPDE also contain populations of the globally rare flatrock/riverscours plant communities. DEWA and NERI also contain an abundance and diversity of breeding neotropical migratory birds of potentially global significance, as is the abundance and diversity of salamanders at NERI (Mahan 2004). DEWA also contains a globally rare limestone fen community. The unique geologic features of DEWA and NERI are of national significance, and many plant and animal populations and communities (such as the bat community at NERI) are of regional significance (Mahan 2004).

See “Appendix D - Park Natural Resource Profiles” for a more discussion of the significant natural resources at each of the parks.

1.3.4. Integrated Water Quality Monitoring

The water resources of the ERMN span a gradient from large (relatively) free flowing rivers providing passage to anadromous and catadromous fish species to small vernal ponds that provide vital habitat for breeding amphibians. Water resources, as precipitation, as rivers and streams influencing wetlands and riparian areas, or in water bodies, are a primary component of all the network ecosystems (see Chapter 2 for more detail). For these reasons, water monitoring is fully integrated into the network monitoring framework.

For monitoring design, water resources were categorized into large rivers, riparian/floodplain communities, and tributary watersheds and associated wetlands (see Chapter 2). Within categories, water quality monitoring will focus on the chemical composition of the water and on biological endpoints as well as anthropogenic stressors and atmospheric inputs to the system (see Chapter 2).

A summary of water resources policy and regulatory considerations and water quantity data used in the development of an integrated water quality monitoring program is presented in “Appendix C - Water Quality Regulations Summary” and summarized in Table 1.3. Water quality standards of the four network states were reviewed and summarized, as were other materials, including the park “Baseline Water Quality Data Inventory and Analysis” reports (a.k.a Horizon Reports), year 2004 state lists of impaired water bodies (303(d) lists) under the Clean Water Act, and data as of September 2004 retrieved from the EPA’s STORET (short for STOrage and RETrieval) water quality database. As part of these reports, information pertaining to site characteristics, past and current water quality problems, existing water quality monitoring stations and stream gages, and past and current water quality monitoring studies were summarized. This report was not intended to include and summarize park-based monitoring unless these data were uploaded to STORET.

The primary conclusions of this summary were:

- In general, the five riverine parks (UPDE, DEWA, GARI, NERI, and BLUE) have very good water quality.
- Surface waters within UPDE, DEWA, GARI, NERI, and BLUE have been impaired by fecal coliform bacteria. Private septic systems, out-dated, short-circuiting, and/or absent sewage treatment systems are the likely, and, in many cases, known cause of this impairment.
- Acid mine drainage has impaired waters within ALPO, JOFL and FRHI.
- UPDE and DEWA have a human health fish consumption advisory and are listed on the 2004 PA 303d list for mercury and PCB contamination. These constituents have been identified in fish tissue and do not imply elevated concentrations in the water column.
- Very limited water quality information is available for ALPO, JOFL, FONE, and FRHI.

1.3.5. Integrated Air Quality Monitoring

Under the Clean Air Act, park managers have a responsibility to protect air quality and related values from the adverse effects of air pollution. Protection of air quality in national parks requires knowledge about the origin, transport, and fate of air pollution, as well as its impacts on resources. To be effective advocates for the protection of park air resources, NPS managers need to know the air pollutants of concern, existing levels of air pollutants in parks, park resources at risk, and the potential or actual impact on these resources. Through the efforts of park personnel, support office staff, and the NPS Air Resources Division, the NPS meets its clean air responsibilities by obtaining critical data and using the results in regulatory-related activities.

To further support the development of an integrated air resources monitoring program, the NPS Air Resources Division's Air Resources Information System (ARIS) provides information on:

- Location of air quality (deposition, particulate matter, ozone, and visibility) monitoring stations in and around the ERMN.
- Ozone risk assessment for ERMN parks.
- Summary of ERMN Air Quality Related Values (AQRVs).
- Summary of air quality monitoring considerations for the ERMN.

ARIS is located at <http://www2.nature.nps.gov/air/Permits/ARIS/networks/ermn.cfm> and available data will be used to develop an integrated air quality monitoring program. ARIS also provides a link to Air Atlas, which contains estimates of a variety of air quality parameters for ERMN parks (<http://www2.nature.nps.gov/air/Maps/AirAtlas/index.cfm>).

The summary report describing the on-site and/or nearby off-site ambient air monitoring data relevant to ERMN parks accessible at the link above includes the following air quality findings. All nine units are designated Class II air quality areas. Few of the network parks have on-site

ambient air quality monitoring, but in most cases, there are nearby monitors. The air pollutants of significant concern for the ERMN are ozone and toxic pollutants. Six of the network parks are in designated 1-hour or proposed 8-hour ozone non-attainment areas. An ozone injury risk assessment indicates the risk of injury is moderate to high in ERMN parks. Fish consumption advisories for mercury, PCBs, and chlordane have been issued in Pennsylvania and West Virginia. Whether the major pathway for toxic pollutants in these states is airborne or waterborne is unknown.

Because of the expense of establishing an air quality monitoring station, air quality monitoring in the ERMN will be limited to synthesizing and reporting on data available from air quality monitoring stations near parks in collaboration with the NPS Air Resources Division.

1.3.6. Overview of Current Monitoring and Partnership Opportunities

The Vital Signs portion of the Natural Resource Challenge (NRC) is the first comprehensive NPS effort to design and implement long-term ecological monitoring and, where necessary, to augment or improve existing monitoring in parks with significant natural resources. It is important to examine past and current monitoring conducted by parks (Table 1.4) and cooperators to avoid duplication of effort and to add to the understanding of park natural resources.

This section documents responses from parks regarding monitoring conducted by network parks, partners, and neighbors. Park staff commented on monitoring programs that were occurring, as of September 2006, within park boundaries. The results of this inquiry and input from ERMN staff are summarized in Table 1.4 and “Appendix E - Park Monitoring Programs.” (Note that existing air quality monitoring stations are depicted in relation to ERMN parks and summarized at <http://www2.nature.nps.gov/air/permits/aris/networks/ermn.cfm>. Similarly, figures and descriptions of existing [does not include all NPS sites] water quality monitoring stations and flow gages are presented in “Appendix C - Water Quality Summary.”)

A list of national, state, and university organizations with monitoring (or other relevant) programs outside or adjacent to park boundaries, or which can be viewed as potential collaborators on future monitoring programs, can be found in “Appendix F - Outside Park Monitoring Programs and Potential Collaborators.”

1.3.7. Dominant Management Issues of Eastern Rivers and Mountains Network Parks

Five ERMN parks are dominated by large rivers (UPDE, DEWA, GARI, NERI, and BLUE) and protecting the ecological integrity of aquatic resources and water quality of these river systems is a principal management issue. There is concern about adequate flow, natural flow and dam releases, and the frequency, timing, and duration of high- and low-flow events, including catastrophic flooding and drought, the impact of treated and untreated sewage, acid mine drainage from abandoned mines and associated mining spoils, altered water chemistry and nutrient inputs from a variety of point and non-point sources, invasive exotic species, and the potential for a catastrophic chemical spill from neighboring highway and railway systems. River management is complicated by large drainage areas that often fall outside park boundaries. These

Table 1.4. Summary of Eastern Rivers and Mountains Network park-based monitoring prior to the Vital Signs Monitoring Program (2004). See “Appendix E -Park Monitoring Programs” for details and descriptions of these monitoring programs. This information is presented in a framework adopted by all I&M networks as a way to consistently display and organize vital signs.

Level 1 Category	Level 2 Category	Level 3 Category	ALPO	JOFL	FONE	FRHI	DEWA	UPDE	NERI	GARI	BLUE
Air and Climate	Air Quality	Ozone							X		
		Wet and Dry Deposition	X				X				
	Weather and Climate	Weather and Climate	X						X		
Water	Hydrology	Surface Water Dynamics					X	X			
	Water Quality	Water Chemistry - Core	X				X	X	X	X	X
		Water Chemistry - Expanded	X				X	X	X	X	X
		Aquatic Macroinvertebrates	X				X	X	X		
		Aquatic Periphyton							X		
Biological Integrity	Invasive Species	Invasive/Exotic Plants, Animals and Diseases - Status and Trends	X	X			X	X	X		
	Focal Species or Communities	Shrubland Forest and Woodland Communities					X		X	X	
		Riparian Communities							X		
		Birds - Riparian Communities							X		
		Birds - Breeding Communities					X		X	X	X
		Fish Communities - Rivers							X		
		Amphibians and Reptiles					X				
	At-risk Biota	T&E Species & Communities - State						X	X	X	
		T&E Species & Communities - Federal					X	X		X	X

“bottom-of-the-watershed” parks engage, and must continue to engage, in multi-agency, multi-stake holder, regional efforts for effective management of their water resources. Similar water quality issues surround management of tributary streams. River parks are narrow and linear in shape, so a large portion of each tributary watershed also falls outside of park boundaries. In the ERMN, headwaters often include more than two-thirds of the land area of a watershed, so streamwater quality is directly tied to land-use surrounding the park units. Tributary streamwater quality at GARI, NERI, and BLUE is threatened by a lack of adequate sewage treatment and septic facilities in West Virginia. High quality data becomes a very powerful tool in negotiating protection strategies.

Maintaining large, unbroken blocks of forested habitat is a regionally significant concern in the east. Minimizing impacts from changing land cover and land use, especially residential development, is a dominant issue facing network parks; albeit at different levels of urgency. Many of the ERMN parks are influenced by expanding metropolitan areas, such as New York, Washington, Baltimore, Pittsburgh, and Philadelphia, as forests and landscapes surrounding parks are increasingly altered. Most pressing is residential development (homes and associated infrastructure) around UPDE and DEWA due to the proximity of metropolitan New York and

New Jersey. Increasing development is also of concern at the four western Pennsylvania parks and more recently at GARI, NERI, and BLUE. Park staff are now reviewing subdivision plans and expect more vacation home development and infrastructure driven by outdoor recreation enthusiasts. Rapid urbanization of rural landscapes causes habitat loss and fragmentation and affects natural forest system functions through direct land conversion and the introduction of invasive exotic plants, insects, and diseases. Some parks have forested areas that may only maintain their significance as part of a much larger forested landscape.

Other threats, referred to as “terrestrial issues” include air pollution (ozone toxicity and acid and nutrient deposition), soil erosion, visitor overuse, and over-browsing of vegetation by white-tailed deer (*Odocoileus virginianus*). Many of these threats can emanate from outside the parks, including regional air pollution, outbreaks of exotic pests such as dogwood anthracnose (caused by the fungus *Discula* sp.), beech bark disease (caused when bark, attacked and altered by the beech scale [*Cryptococcus fagisuga* Lind.], is invaded and killed by fungi, primarily *Nectria coccinea* var. *faginata*), infestations of gypsy moth (*Lymantria dispar*), and hemlock wooly adelgid (*Adelges tsugae*). Overbrowsing by white-tailed deer has the potential to negatively affect forest regeneration and the viability and persistence of some rare plant species. Although hunting is permitted in the large ERMN parks, residential development at the park boundary facilitates deer movement to safe areas. The small parks prohibit hunting, and deer management may be more difficult.

Management of cultural landscapes is mandated in most ERMN parks for preservation and interpretation of the historic scene or rural landscape. Cultural landscapes are managed as agricultural fields, fallow fields, herbaceous meadows, and shrublands, creating habitat for some species. For example, shrubland birds and butterflies can flourish in these areas with only slight modifications to cultural management prescriptions.

Impact from recreational use is of concern in parks such as NERI and DEWA, with from over one million to almost six million visitors each year. UPDE, DEWA, NERI, and GARI are popular boating, rafting, and climbing (DEWA and NERI) destinations, and overuse or misuse by visitors can impact fragile communities and species within the park. All network parks have the potential for negative visitor impacts and all are used extensively for day uses, including hiking, camping, hunting (in some cases), fishing, and road travel.

See “Appendix D - ERMN Park Natural Resource Summary” for additional discussions of natural resources and prevalent management issues at each of the parks.

1.4 ERMN Monitoring Program Objectives and Questions

The ERMN program objectives and monitoring questions are specific to the ecological and scientific context and the desired outcome of the network monitoring program.

Program Objective 1: Monitor appropriate indicators of ecological integrity to help understand the relationships and long-term changes in the physical, chemical, and biotic components of stream and river ecosystems.

- How do water chemistry and macroinvertebrate biotic integrity change over time and in relation to habitat characteristics, stream conditions, weather patterns, and land use at local to watershed scales?
- Are water quality standards met for non-degradation regulations? For primary contact recreation? Are the waters suitable for aquatic life?
- How do changes in discharge over seasons and high rainfall events affect the chemical and physical properties of water, macroinvertebrate communities, and other biotic indicators in rivers and streams?

Program Objective 2: Monitor appropriate indicators of ecological integrity to help understand how environmental factors, ecosystem processes, land use, and resource management activities affect terrestrial vegetation.

- How is terrestrial vegetation composition, structure, and demography changing over time and in relation to weather and climate, landscape dynamics, invasive species, deer browsing, and natural processes such as gap formation and succession?
- Is the canopy regenerating?
- How are soil and soil fertility changing in relation to acid and nutrient deposition?

Program Objective 3: Monitor variation and trends in selected weather and climate parameters across the mid-Atlantic U.S. that affect network parks.

- What is the seasonal and annual variability in quantity, timing, and form of precipitation?
- What are the ranges and timing of seasonal temperature fluctuations?
- What is the seasonal and annual variability in selected climate factors affecting plant and animal populations, communities, and aquatic systems?
- What is the frequency and severity of extreme weather events (e.g., tornadoes, microbursts, floods, drought) that serve as important determinants of plant and animal community structure and composition?

Program Objective 4: Monitor variation and trends in select air quality parameters across the mid-Atlantic U.S. that affect network parks.

- How is the spatial and temporal pattern and trend in particulates, gases, and depositions changing?
- Are acid and nutrient inputs from atmospheric deposition changing soil and water chemistry?
- Do air quality variables exceed levels known to negatively affect plant and/or animal populations?

Program Objective 5: Monitor an appropriate, integrated suite of ecological indicators such that relationships among vegetation, soils, hydrology, water chemistry, landscape dynamics, weather patterns, and ecosystem functions are better understood.

1.4.1 Development of Monitoring, Management, and Sampling Objectives

The ERMN will develop, in conjunction with network parks, the three types of additional objectives that are commonly presented in the ecological monitoring literature (e.g., Elzinga et al 1998): management objectives, sampling objectives, and monitoring objectives. These objectives will be fleshed out and tested during development of protocols (Chapter 5) for ERMN priority vital signs(Chapter 3).

Management objectives provide focus about the desired state or condition of the resource, and provide a measure of management success. As described by Elzinga et al. (1998:46), management objectives can usually be classified as one of two types: (1) target/threshold objectives (e.g., increase the population size of Species A to 5000 individuals; maintain a population of a rare plant Species B at 2500 individuals or greater; keep Site C free of invasive weeds X and Y); or (2) change/trend objectives (e.g., increase mean density of Species A by 20%; decrease frequency of invasive weed X by 30% at Site C).

Monitoring objectives define the subject (species, population, parameter, etc) to be monitored, selected scale (location), and sensitive attribute. An example monitoring objective would be to detect a parkwide increase in nutrients in lotic surface waters as indicated by total phosphorous loads.

Sampling objectives are usually written as companion objectives to management or monitoring objectives. Sampling (or statistical) objectives specify information such as target levels of precision, power, acceptable Type I and II error rates, and magnitude of change you are hoping to detect. An example of a sampling objective would be to be 90% certain of detecting a 20% annual change in bird density and to be willing to accept a 10% chance of saying a change took place when it really did not.

Chapter 2 Conceptual Ecological Models

“All models are wrong, but some are useful”

- George E. P. Box 1979

Chapter 2 of the ERMN Monitoring Plan presents an overview of the conceptual ecological models developed (presented in detail as Appendixes G–I) to guide design of the program. These models, revisions, and updates also serve as the ecological foundation for interpreting monitoring data.

Conceptual models are important throughout all phases of development of a monitoring program. Early in the process, simple conceptual models provide a framework that relates information in discussions and literature reviews to a broader context - it is a way to organize information. The design, construction, and revision of conceptual models fosters a shared understanding of system dynamics and appreciation of the diversity of information needed to identify an appropriate suite of ecosystem indicators.

Conceptual models provide a mental picture of how something works, with the purpose of communicating that explanation to others. Models (of all types) work best when they include only the minimum amount of information needed to meet the model’s purpose (Starfield 1997). Conceptual models play several useful roles in monitoring program design, including:

- formalizing current understanding of the context and scope of the ecological processes important in the area of interest;
- expanding our consideration across traditional discipline boundaries, fostering integration of biotic and abiotic information; and
- facilitating communication among scientists from different disciplines, between scientists and managers, and between managers and the public (Thomas 2001).

The key point about conceptual models is their role in communication among people with different points of view (Abel et al. 1998). Conceptual models can take a variety of forms—from narrative descriptions to schematic diagrams or flowcharts with boxes and arrows. Regardless of form, the success of a model depends on its utility in sharing viewpoints and developing a common understanding based on multiple viewpoints.

Unfortunately, no single model can describe an entire system adequately. Model generality is needed to characterize broad-scale influences and relationships among park resources, while model specificity is required to identify detailed relationships and components in the system that can be effectively monitored (i.e., measured/sampled) and subsequently managed. Consequently, both broad-scale models and specific models are needed to adequately represent ecological systems contained within large areas the size of national parks. The ERMN used broad-scale models to support the selection of vital signs and will continue to develop more specific models, incorporating appropriate literature, to determine appropriate measures, detection limits, acceptable ranges of variation in those measures, and management trigger-points.

Conceptual models presented herein and in Appendixes G–I are not finished products; the process of developing, discussing, and revising conceptual models provides the greatest benefit to the users and should be considered an iterative process. Conceptual models are based on concepts that can and will change as monitoring provides new knowledge about ecosystem interactions.

The purpose of this chapter and the associated Appendixes is to explain our current understanding of ecological interactions, and how stressors and other agents of change affect selected natural resource components and processes in ERMN parks. The models are intended to serve as narrative and pictorial illustrations of the conceptual foundation for monitoring presented in Chapter 1 and support the identification and selection of ecological vital signs for long-term monitoring (Chapter 3).

2.1. ERMN Approach to Conceptual Model Development

As first discussed in Section 1.2.3, the ERMN grappled with the question; “Should vital signs monitoring focus on the effects of known threats to park resources or on general properties of ecosystem status?” The answer to this question seemed to dictate whether the network would develop stressor-based conceptual models (identifying ecosystem stressors and linkages to ecosystem components) or system-control type models (identifying ecosystem dynamics, feedbacks, controls, etc.). What was perceived as a mutually exclusive choice led to many fits and starts, dead ends, and frustrations with model development. It seemed logical to develop stressor-based models (as presented in the ERMN Phase I Report and available as Supplemental Document 03) since this approach would result in the selection of vital signs that provide data most directly relevant to management actions. Park managers generally wanted data to address whether the most critical threats (and their effects on park resources) that confront natural resources at a park were changing in their severity or geographic scope as a result of management actions (or lack thereof). Clearly, without minimizing threats to park natural resources, species and ecosystems that are the focus of park management will rapidly degrade or decline. While the stressor-based approach has value, the models as initially developed in the Phase I Report lacked the explicit link and description of how these stressors are believed to impact and alter ecological systems. These so called “ecological effects” were implied, rather than explicitly discussed.

Monitoring status and trends of threats or stressors alone is insufficient for several reasons. First, a focus on threats assumes that there is a clear, often linear, relationship between a threat and the status of the resource. This runs counter to recent evidence of the nonlinear dynamics of ecosystems, time lags in response, and threshold effects (e.g., Scheffer et al. 2001; Limburg et al. 2002). Second, a focus on current threats, while critical to prompt an appropriate management action, leaves a monitoring program vulnerable to the inability to detect future, currently unforeseen threats and issues.

A better way to meet the challenges of monitoring in national parks is to achieve a balance among different monitoring approaches (termed the “hybrid approach” by Noon 2003) and to include both threat-specific monitoring (monitor the threats and the ecological response) and also monitor a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall status or condition of park resources (as

described in Section 1.2.3). The network took a step back and revised the conceptual models to include ecosystem processes and dynamics in a more theoretical approach.

The following steps to develop our conceptual ecological models, while presented in sequential order for clarity, actually reflect a very dynamic and iterative process that will continue to be modified and revisited over time.

2.2. Overview of Conceptual Models

2.2.1. Identify Ecological Systems for Model Development

The first step in the development of conceptual models was to identify ecological systems with overall significance to the parks and to regional biodiversity or significance to another characteristic park attribute (see Chapter 1). Three dominant ecosystems were identified for initial, broad-scale conceptual modeling: large rivers, tributary watersheds (and associated wetlands), and terrestrial ecosystems. Later, it became apparent that a fourth critically important system in the network, riparian and floodplain communities, warranted independent model development (Figure 2.1).

2.2.2. Identify Theoretical Framework

The next step in model development was to identify a theoretical framework for ecosystem level models. In conjunction with the cooperators developing each of the system models, the network elected to build upon the theoretical frameworks developed by Jenny (1941, 1980) and Chapin et al. (1996) for the terrestrial and riparian ecosystems and those developed by Karr (1991, 1999) and others for river and tributary stream ecosystems. While these approaches differ, they both focus on key ecosystem “factors” essential to the conservation, maintenance, and sustainability of ecosystem properties.

Jenny (1941, 1980) and Chapin et al. (1996) proposed that a sustainable ecosystem is one that, over the normal cycle of disturbance events (i.e., decades to centuries), maintains its characteristic diversity of major functional groups, productivity, soil fertility, and rates of biogeochemical cycling. Ecosystem properties are governed by internal interactions and external factors. Five independent external *state factors* (parent material, climate, topography, potential biota, and time since disturbance) determine limits of ecosystem processes. These state factors are, in turn, modified by a set of four dynamic, *interactive controls*: local/regional climate, soil/water resource supply, major functional groups of organisms, and disturbance regime. In contrast to state factors, interactive controls both control and respond to ecosystem characteristics; they are both constrained by state factors and respond to ecosystem processes (Chapin et al. 1996). For vital signs monitoring, a key component of the Jenny-Chapin framework is the hypothesis that interactive controls must be conserved if an ecosystem is to be maintained, and that major changes in any interactive control will result in a new ecosystem with distinctly different properties.

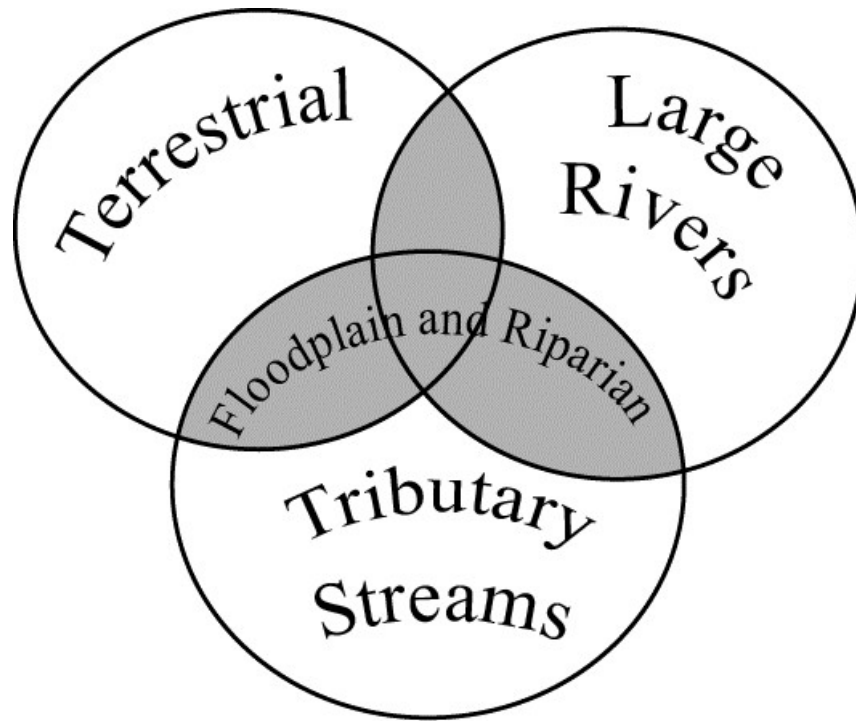


Figure 2.1. Broad-scale, dominant ecosystems within the Eastern Rivers and Mountains Network chosen for conceptual ecological model development.

The river and stream models are based on Karr's (1991, 1999) conceptual model of stream ecosystems. The model focuses on biological and ecological endpoints in the context of ecological integrity ("integrity" applies to the condition of systems at one end of a continuum of human influence: those that support biota that are the product of evolutionary and biogeographic processes with minimal influence from modern human society *sensu* Karr 1999) and five factors (flow regime, water quality, energy source, biological interactions, and physical habitat) that influence or modify the components of ecological integrity. Similar to the interactive controls of the Jenny-Chapin framework, these five factors provide a critical conceptual and analytical framework to judge (i.e., monitor) the interactions of human activities and ecological change.

Key ecosystem processes include geophysical/hydrological, biological, and ecological components. Geophysical processes include land cover, land use, and landscape patterns. Across a landscape, habitat diversity, connectivity, isolation, and landscape change are important components of the geophysical setting. Soil composition and chemistry, and the rate of weathering of parent material, and water quality all determine site productivity and quality. Biological processes are defined by compositional and structural characteristics of the biota on the individual, community, and landscape level. Taxonomic composition, fecundity, growth, health, vigor, and survival and mortality are components. Key indicators of a healthy and sustainable biota are biodiversity and compositional resilience, including both rare species and

invasive species populations. Ecological processes include those that cycle energy and materials through the system—the biogeochemical links between organisms and their environment. Primary productivity, nutrient cycling, water cycling, decomposition and mineralization, and food webs are key ecological processes.

Figure 2.2 puts the network’s dominant ecosystems in a Jenny-Chapin model framework explicitly designed to highlight key ecosystem “factors” or “controls” critical to the inherent character and sustainability of the system

2.2.3. Adding Anthropogenic Stressors and Known or Hypothesized Ecological Effects

With a theoretical framework was in place, stressors identified in the Phase I Report were used to describe expected changes in the system resulting in Figure 2.3. A summary of details including literature review and descriptions of the major agents of change, stressors and the known or hypothesized ecosystem response, or measurable change in the system structure, function, or process is found in Appendixes G–I.

2.2.4. Summary and Link to Vital Signs

The conceptual modeling exercise (summarizing key system properties, stressors, and the relationship among stressors, ecological effects, and responses) resulted in a candidate list of vital signs for consideration by the network and others (see Chapter 3). A shorter, summary narrative for each of these candidate vital signs is included the following appendixes for each conceptual model:

Appendix G - Terrestrial Ecosystems Conceptual Model (Rentch 2006)

Appendix H - Tributary Watersheds Conceptual Model (Brooks et al. 2006)

Appendix I - Large Rivers Conceptual Model (Marshall et al. 2006)

(Riparian/Floodplain community models are in draft form and not available at time of writing)

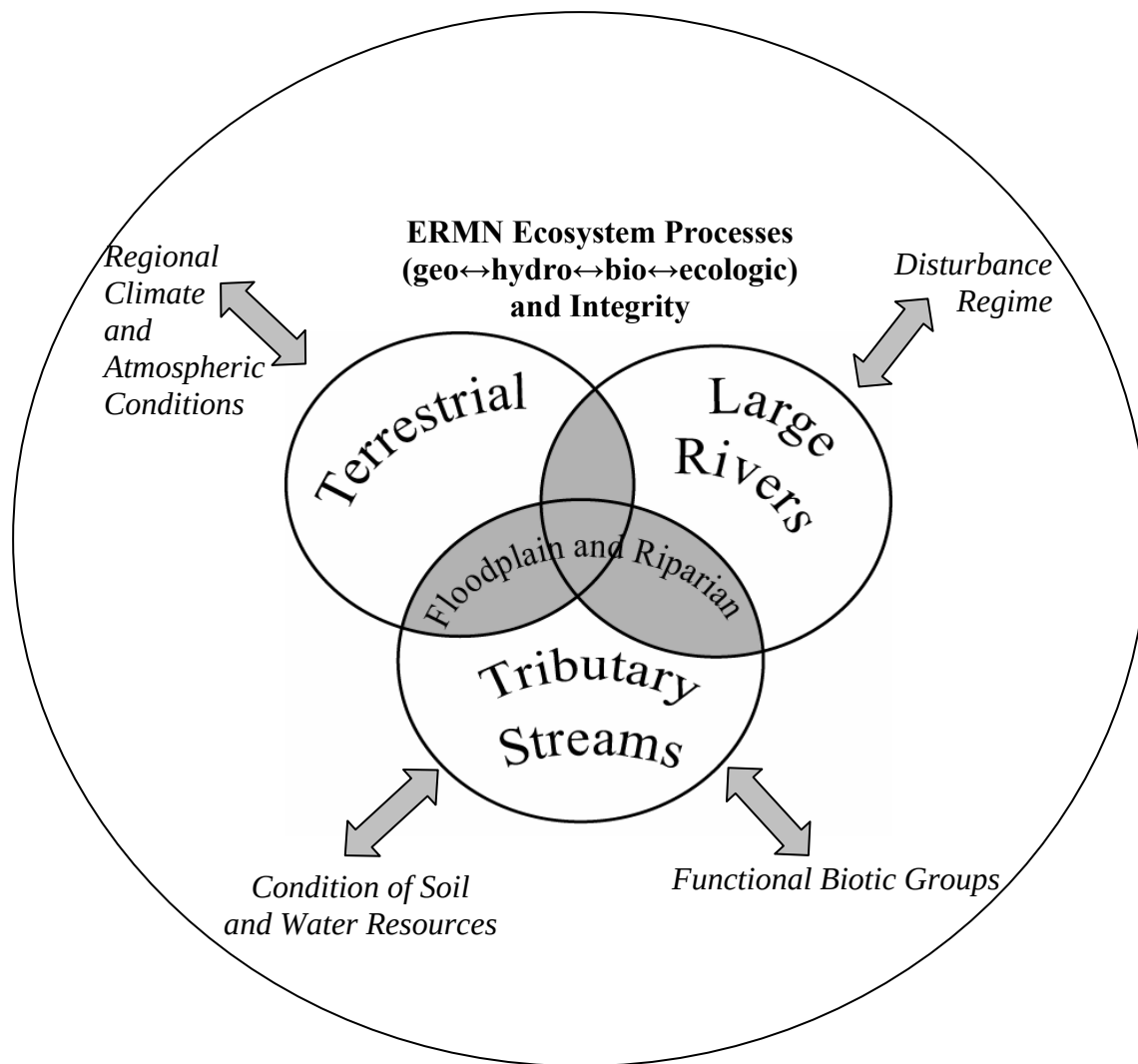


Figure 2.2. Modified Chapin et al. (1996) ecosystem model of relationship between interactive controls (*italicized*) and broad-scale ERMN ecosystems, processes, and integrity. Interactive controls must be conserved if ERMN ecosystems are to be maintained.

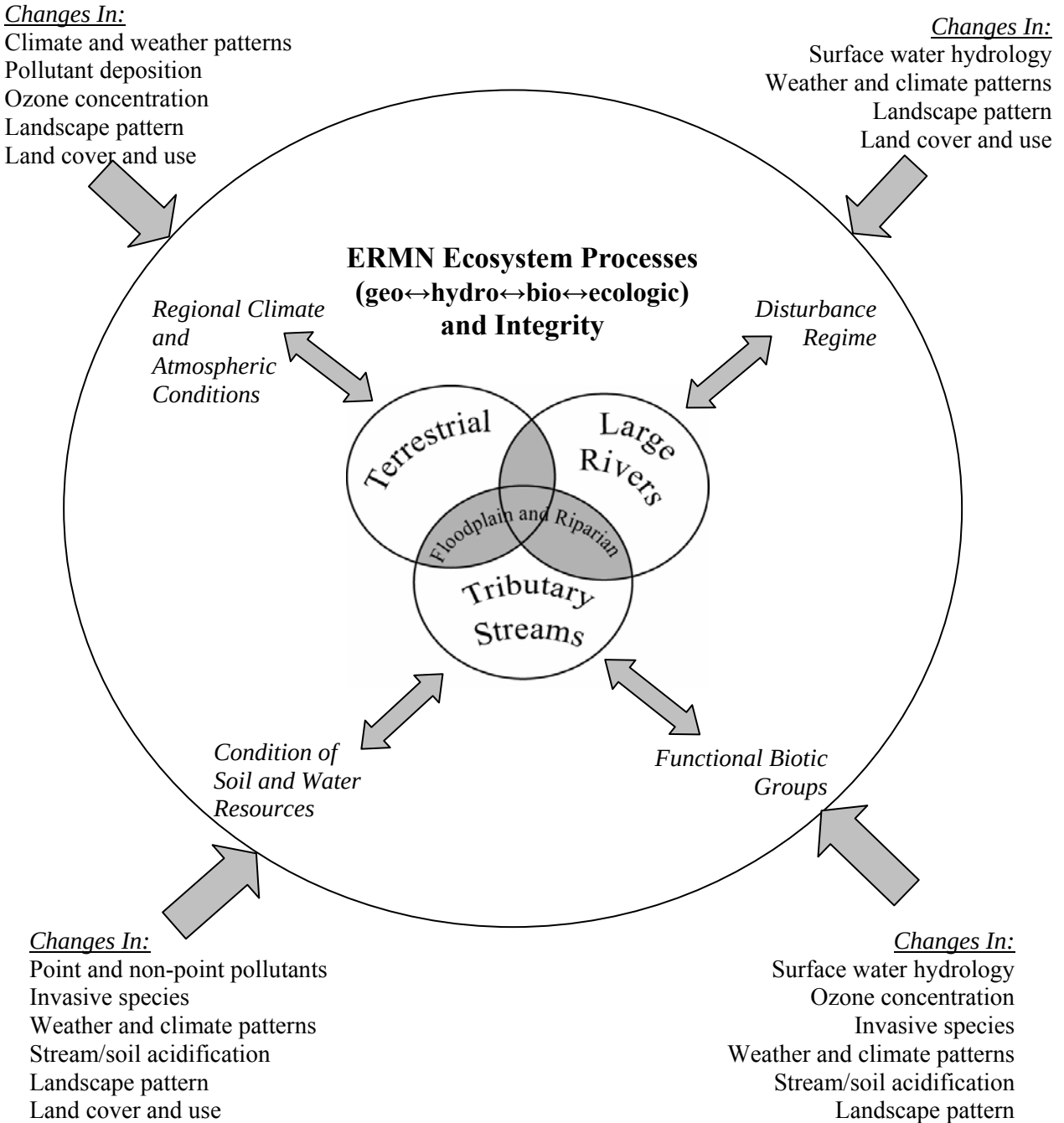


Figure 2.3. Modified Chapin et al. (1996) ecosystem model of relationship between interactive controls (italicized) and broad-scale ERMN ecosystems and processes and integrity. Interactive controls must be conserved if ERMN ecosystems are to be maintained. Major changes (natural or anthropogenic) in any interactive control will result in a new ecosystem with distinctly different properties.

Chapter 3 Vital Signs

“Designing a monitoring project is like getting a tattoo: you want to get it right the first time because making major changes later can be messy and painful.”

- Oakley et al. 2003

Vital signs, as used in this program (<http://science.nature.nps.gov/im/index.cfm/>), are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve “unimpaired for future generations,” including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization, including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

This chapter describes the vital signs for the ERMN and the process used to select and prioritize them. In summary, the network has identified 37 vital signs that represent a systems approach to our monitoring program. Three vital signs relate to air and climate, three relate to geology and soils, five relate to water, two relate to human use, four relate to ecosystem pattern and processes, and 20 relate to biological integrity. The network developed this master suite of 37 vital signs through a series of meetings and ranking exercises and ultimately narrowed the list to 13 priority vital signs for which protocols will be developed and implemented within three to five years.

3.1. Process for Choosing Vital Signs

The process for choosing and prioritizing vital signs was initiated within the Eastern Rivers and Mountains Network in the fall of 2003 and was a multifaceted process of park-level scoping workshops, subject matter expert evaluation, a broad vital signs prioritization workshop, park-level rankings, and Science Advisory Committee review and refinement. The process culminated on January 23, 2006 with the ERMN Board of Directors approval of the master suite of 37 vital signs including the 13 priority vital signs selected for initial protocol development. The following sections summarize the major steps in the ERMN process for choosing vital signs. The entire process is fully developed and available in Appendix J - ERMN Vital Signs Prioritization Process and Supplemental Documents 01–29.

3.1.1. Park Scoping Sessions

To initiate discussion of vital signs, we held park-level brainstorm sessions beginning in fall 2003 and culminating in winter 2005. The purpose of these sessions was to present the Vital Signs program to all interested park staff and to informally receive their input on these potential vital signs for the park and network. Based on these sessions, and especially the winter 2005

meetings, an initial list (n = 61) of potential vital signs was developed (see Appendix J for the full list).

This initial list was generated primarily through park scoping meetings to discuss park resources, management issues, and species or communities of special concern, and supplemented by review of park Resource Management Plans, Water Management Plans, and other reports and relevant documents such as Geologic Resource Evaluations (Summer 2004), discussions with and reports by ERMN inventory cooperators, and planned or opportunistic discussions with park natural resource staff and Regional staff. The initial draft of this master list was the best attempt by network staff to assimilate and interpret all the information gained on park resources and potential monitoring needs during the formulation of the initial draft of this monitoring plan. This initial list of potential vital signs was the first major milestone in the vital signs selection and prioritization process.

3.1.2. Science Advisory Committee Formulates Remaining Plan

The process by which the network shortened (or otherwise modified) the initial list of vital signs was based on guidance from the ERMN Science Advisory Committee (SAC) at a December 2004 meeting at University Park, Pennsylvania. Though some details were determined at a later date, the SAC suggested the following process (see Appendix K for a detailed description of the ERMN Prioritization Process):

- Pare down initial list to shorter list of candidate vital signs by subject matter experts based on ecological significance and potential as indicators;
- Hold vital signs prioritization workshop to peer review subject matter expert work by larger science and NPS communities;
- Prioritize shorter list of candidate vital signs by park staff based on management significance and legal mandate;
- Integrate park and workshop feedback at network and the SAC level to develop priority vital signs; and
- Present final list of priority vital signs for ERMN Board of Directors to review and approve.

The ERMN Board of Directors approved the vital signs prioritization process in January 2005 contingent on evaluation at Regional and National I&M levels.

3.1.3. Subject Matter Experts and Conceptual Ecological Models

Refining the initial list of 61 vital signs involved a core team of subject matter experts, detailed literature reviews, development and refinement of conceptual ecological models presented in Chapter 2, and best professional judgment. ERMN key resources were assigned to a dominant ecosystem type: large rivers, terrestrial, and tributary stream watersheds (following the established conceptual ecological model framework) and subject matter experts were solicited for each resource type. Teams were not limited to the initial list of 61 vital signs and could, if

desired, add additional vital signs to the list. Each team was to focus on ecological significance (as opposed to park management significance) and was provided with the following criteria on which to base their recommendations:

Ecological Significance:

- There is a strong, defensible linkage between the vital sign and the ecological function or critical resource it is intended to represent.
- The vital sign represents a resource or function of high ecological importance based on the conceptual model of the system and the supporting ecological literature.
- The vital sign provides early warning of undesirable changes to important resources. It can signify an impending change in the ecological system.
- The vital sign is sufficiently sensitive to detect specified change; has a high signal to noise ratio and does not exhibit large, naturally occurring variability.

The teams reduced the initial list of 61 vital signs to a list of 36 candidate vital signs and produced summary narratives for each that included the following topics:

- Brief Description of Vital Sign
- Significance/Justification
- Proposed Metrics
- Prospective Method(s) and Frequency of Measurement
- Limitations of Data and Monitoring
- Key References
- Related Environmental Issues and Linked Vital Signs
- Overall Assessment

These narratives are presented with the corresponding conceptual models in Appendixes G–I.

Creating a list of 36 candidate vital signs was the second major milestone in the vital signs selection and prioritization process.

3.1.4. Vital Signs Prioritization Workshop

On May 19–20, 2005, network staff held a vital signs prioritization workshop at The Pennsylvania State University that included 51 professionals with diverse backgrounds and expertise including the ERMN SAC and at least one representative from each ERMN park (see Appendix J for detailed summary of the agenda, participants, materials, and results of this workshop). The workshop was organized around the three dominant ecosystem types and working groups for each led by subject matter experts who did the initial paring down of vital signs (Section 3.1.3 above). This workshop provided an opportunity for subject matter experts to present the justification for paring down the master list of vital signs and development of linkages to the conceptual models for review by peers in the scientific community, and an opportunity for the scientific community to participate in the vital signs prioritization process for the network. During this workshop the list of candidate vital signs (from Section 3.1.3 above) could have been modified (additions/subtractions/etc.) depending on group process, discussion, and consensus.

The workshop was designed to meet two objectives. The first objective was to reach scientific consensus on a proposed short list of priority vital signs for the ERMN. The second objective was to further evaluate the merits of individual vital signs based on ecological significance and group them into “tiers” for implementation (with “tier 1” being the highest priority vital signs for protocol development and implementation and “tier 3” the lowest).

The final result of the ERMN vital signs prioritization workshop was a list of tier-ranked vital signs based on ecological significance that had been peer-reviewed, is justifiable, supported by conceptual ecosystem models, and upon which there is general scientific consensus.

The workshop participants started with the 36 candidate vital signs, dropped 3 from further consideration (White-tailed Deer, Mosses Lichens and Bryophytes, and Phenology), added two new vital signs (Indicator Taxa and Terrestrial Mammals), and also lumped and split several vital signs. The workshop ended with the same number (36) of vital signs, although some were changed (Table 3.1). See Appendix J for a more detailed summary of workshop events and outcomes.

This revised list of 36 candidate vital signs was the third major milestone in the vital signs selection and prioritization process.

3.1.5. Park Management Significance Rankings

Following the ‘ecological significance’ prioritization workshop, input was solicited from park staff on the list of 36 candidate vital signs. Parks were asked to prioritize vital signs according to management significance according to the following criteria and scoring (based on other national programs, including other NPS Vital Sign Monitoring Networks):

Park Management Significance:

- Legal/policy mandate: How important is monitoring this resource/vital sign for satisfying legal or policy mandates? [3=high importance (required); 2=moderate importance (specifically identified); 1=low importance (generally identified).]
- Potential to support management decisions: Does monitoring this vital sign directly link to the information needed for carrying out a key management decision or evaluating the outcome of a management decision? [3=strong application; 2=moderate application; 1=weak application.]
- Importance of resource management: How important (for management) is the resource or issue represented by the vital sign, relative to other resources or issues in the park? [3=high importance; 2=moderate importance; 1=low importance.]
- The indicator will produce results that are clearly understood and accepted by park managers, other policy makers, and the general public, all of whom should be able to recognize the implications of the indicator’s results for protecting and managing the park’s natural resources. [3=clearly understood; 2=generally understood; 3=poorly understood.]

Similar criteria were certainly used when creating the initial list of 61 vital signs (see Section 3.1.1), but without any priority setting. The criteria and scoring would result in a score ranging from a low of 4 to a high of 12. Park staffs were encouraged to rank only the list of 36 provided, but could propose that a new vital sign be added to the list (only one was added: Freshwater Communities: Mussels).

Once this park ranking process was underway, it became clear that it would also be useful for the parks to report management significance scores in the simple “tier 1–3” framework as was done at the workshop. Thus, each park ultimately provided scores under both ranking systems (Table 3.1).

The ranking of 37 candidate vital signs based on park management significance by ERMN park staff was the fourth major milestone in the vital signs selection and prioritization process.

3.1.6. Network Summarization and Internal Review

Following the management significance ranking process, we used the computing and discerning power of the human brain to assimilate the workshop (ecological significance) and park (management significance) ranks. It was not possible to take any straight “averages” (although basic summary statistics such as mean, median, mode, counts, etc., were used) because not each

Table 3.1. Vital Signs for the Eastern Rivers and Mountains Network presented in the national 3-category framework with associated ecological and management significance rankings. “Final” refers to the final network rank based on an assimilation of the workshop ecological significance ranking process (“Workshop”) and the respective park management significance ranking process (“Park Codes”). Tier-rankings (1 = highest; 3 = lowest) refer to the suggested priority in which vital signs should have protocols developed and implemented.

Level 1 Category	Level 2 Category	Level 3 Category	Tier Ranks (Final Network Rank, Workshop Rank, and Park Management Ranks)										
			Final Rank	Work Shop	ALPO	JOFL	FONE	FRHI	DEWA	UPDE	NERI	GARI	BLUE
Air and Climate	Air Quality	Ozone	2	2	2	2	2	3	3	3	3	3	3
		Wet and Dry Deposition	1	1	1	1	3	3	2	2	2	2	2
	Weather and Climate	Weather and Climate	1	2	1	2	3	3	2	3	1	1	1
Geology and Soils	Geomorphology	Stream/River Channel Characteristics	2	1.5	3	3	2	2	2	2	1	1	1
	Soil Quality	Soil Erosion and Compaction	3	3	3	3	3	3	3	3	2	2	2
		Soil Function and Dynamics	2	2	3	3	3	3	3	3	2	2	2
Water	Hydrology	Surface Water Dynamics	1	1	2	2	3	3	1	1	1	1	1
		Wetland Water Dynamics	2	1	2	1	1	2	3	3	2	2	2
		Groundwater Dynamics	2	3	3	3	1	2	3	2	2	2	2
	Water Quality	Water Chemistry - Core	1	1	1	1	1	1	1	1	1	1	1
		Water Chemistry - Expanded	1	1.5	1	1	2	1	1	1	1	1	1
		Aquatic Macroinvertebrates	1	1	2	2	1	1	1	1	1	1	1
		Aquatic Periphyton	3	2.5	3	3	3	3	3	2	3	3	3
Biological Integrity	Invasive Species	Invasive/Exotic Plants, Animals and Diseases - Status and Trends	1	1.5	1	1	1	1	1	1	1	1	1
		Invasive/Exotic Plants, Animals and Diseases - Early Detection	1	2	1	1	1	1	2	1	1	1	1
	Focal Species or Communities	Shrubland Forest and Woodland Communities	1	1	1	1	3	3	1	2	1	1	1
		Riparian Communities	1	1	2	1	1	1	2	2	2	2	2
		Birds - Riparian Communities	2	2	2	2	1	1	2	3	2	2	2
		Mammals - Riparian Communities	3	3	3	3	3	3	3	3	2	2	2
		Birds - Breeding Communities	1	1.5	1	2	2	2	3	3	1	1	1
		Terrestrial Invertebrates	2	2	3	3	3	3	3	3	2	2	2
		Freshwater Communities - Mussels**	.	.	.	.	.	.	.	.	.	.	.
		Freshwater Communities - Crayfish	3	3	3	3	3	3	3	3	2	2	2
		Freshwater Communities - Macrophytes	3	3	2	2	3	3	3	2	3	3	3
		Fish Communities - Streams	2	2	2	2	3	3	3	2	2	2	2
		Fish Communities - Rivers	2	1	3	3	3	3	2	1	2	2	2
		Amphibians and Reptiles - Vernal Pond	2	2	2	3	2	2	2	3	2	2	2

Eastern Rivers and Mountains Network - Vital Signs Monitoring Plan

Level 1 Category	Level 2 Category	Level 3 Category	Tier Ranks (Final Network Rank, Workshop Rank, and Park Management Ranks)										
			Final Rank	Work Shop	ALPO	JOFL	FONE	FRHI	DEWA	UPDE	NERI	GARI	BLUE
		Community											
		Amphibians and Reptiles - Streamside Salamander Community	2	2	3	3	2	2	3	3	2	2	2
		Amphibians and Reptiles	2	2	3	2	2	2	3	3	1	1	1
	At-risk Biota	T&E Species & Communities - State	1	2	1	1	1	1	2	2	1	1	1
		T&E Species & Communities - Federal	1	2	1	1	1	1	1	1	1	1	1
Human use	Point-Source Human Effects	Bioaccumulation	3	2	3	3	3	3	2	3	3	3	3
	Visitor and Recreation Use	Visitor Use	2	3	3	3	3	3	1	2	2	2	2
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Land Cover and Use	1	1	1	1	2	2	1	1	2	2	2
		Landscape Pattern	1	1	2	2	2	2	1	2	2	2	2
	Energy Flow	Primary Production	3	3	3	3	3	3	3	3	3	3	3
	Nutrient Dynamics	Nutrient Dynamics	3	2	3	3	3	3	3	2	3	3	3

**The vital sign “Freshwater Communities - Mussels” was proposed to be added during the park management significance ranking process resulting in a total of 37 candidate vital signs.

ecosystem working group at the workshop ranked each vital sign, and park managers ranked vital signs using two different ranking systems. As such, we took an overarching view of each rank and ranking system to assign the final network rank (Table 3.1). In almost all cases the various ranking processes complimented and reinforced each other and most final tier-ranks were obvious.

The final assimilation of ranks was the fifth major milestone in the vital signs selection and prioritization process.

3.1.7. Priority Vital Signs for the Eastern Rivers and Mountains Network

All 37 vital signs are important, considered high priority, and warrant protocol development and implementation, but additional prioritization was needed to clearly specify the most important vital signs given financial and logistical realities. The notion that a “tier 1” ranking carried substantial and significant weight for the future direction of the program was verbalized repeatedly throughout the workshop and park ranking processes.

The network proposed beginning protocol development on vital signs in the tier 1 category; then, if staffing and funding allow, or with additional assistance from parks or others, tier 2 and 3 vital signs might be implemented (Table 3.2). The network may collaborate with an existing national monitoring program(s) to implement air and climate vital signs or might efficiently and cost-effectively incorporate several vital signs into a single protocol. In these cases, lower tier vital signs may be incorporated sooner than their priority rank. Other tier 2 and 3 vital signs may be elevated based on SAC and BOD guidance. The network would look for all possible efficiencies and collaborations within and outside the NPS to implement as many of the network vital signs as possible.

3.1.8. Science Advisory Committee Review and Refinement

On December 16–17, 2005, the ERMN Science Advisory Committee met at University Park, PA to review the entire vital signs prioritization process, assess whether selected vital signs were supported by the conceptual models and would together constitute an integrated program. Based on the review, the SAC suggested a final prioritized list of 13 vital signs.

The SAC meeting was a planned part of the BOD approved prioritization process but was also important for refining vital signs. In particular, “T&E Species & Communities - Federal” and “T&E Species & Communities - State” were both prioritized as tier 1 vital signs yet 11 different species and/or communities were within these two catch-all vital signs throughout the process. Thus, it was an explicit objective of this 2-day meeting to propose which threatened, endangered, rare, unique, regional responsibility, etc. species and communities the network would include in protocol development.

Several major suggestions were made. The SAC reviewed the conceptual models and the prioritization process and quickly and easily suggested the network move forward on 11 of 13 tier 1 vital signs (all tier 1s except the two “T&E Species” and the “Breeding Birds” vital signs).. It was also recommended that “Soil Function and Dynamics” (a tier 2 vital sign) be elevated to tier 1 to provide a terrestrial equivalent to basic chemical and physical water quality. Review of the conceptual models (Figure 2.3) clearly identified the need to consider this

Table 3.2. List of 37 vital signs, including 14 tier 1 vital signs, for the Eastern Rivers and Mountains Network Parks including symbology for funding source and implementation priority.

Level 1 Category	Level 2 Category	Level 3 Category	Final Rank	ALPO	JOFL	FONE	FRHI	DEWA	UPDE	NERI	GARI	BLUE
Air and Climate	Air Quality	Ozone	2	•	•	•	•	•	•	•	•	•
		Wet and Dry Deposition	1	•	•	•	•	•	•	•	•	•
	Weather and Climate	Weather and Climate	1	+	+	+	+	+	+	•/+	•/+	•/+
Geology and Soils	Geomorphology	Stream/River Channel Characteristics	2	◇	◇	◇	◇	◇	◇	◇	◇	◇
	Soil Quality	Soil Erosion and Compaction	3	◇	◇	◇	◇	◇	◇	◇	◇	◇
		Soil Function and Dynamics	2	+	+	+	+	+	+	+	+	+
Water	Hydrology	Surface Water Dynamics	1	+	+	+	+	•/+	•/+	•/+	•/+	•/+
		Wetland Water Dynamics	2	◇	◇	◇	◇	◇	◇	◇	◇	◇
		Groundwater Dynamics	2	◇	◇	◇	◇	◇	◇	◇	◇	◇
	Water Quality	Water Chemistry - Core	1	+	+	+	+	•/+	•/+	•/+	•/+	•/+
		Water Chemistry - Expanded	1	+	+	+	+	•/+	•/+	•/+	•/+	•/+
		Aquatic Macroinvertebrates	1	+	+	+	+	+	+	•/+	•/+	•/+
		Aquatic Periphyton	3	◇	◇	◇	◇	◇	◇	◇	◇	◇
Biological Integrity	Invasive Species	Invasive/Exotic Plants, Animals and Diseases - Status and Trends	1	+	+	+	+	+	+	+	+	+
		Invasive/Exotic Plants, Animals and Diseases - Early Detection	1	+	+	+	+	+	+	+	+	+
	Focal Species or Communities	Shrubland Forest and Woodland Communities	1	+	+	+	+	+	+	+	+	+
		Riparian Communities	1				+	+	+	+	+	+
		Birds - Riparian Communities	2	◇	◇	◇	◇	◇	◇	◇	◇	◇
		Mammals - Riparian Communities	3	◇	◇	◇	◇	◇	◇	◇	◇	◇
		Birds - Breeding Communities	1	+	+	+	+	+	+	+	+	+
		Terrestrial Invertebrates	2	◇	◇	◇	◇	◇	◇	◇	◇	◇
		Freshwater Communities - Mussels	.					◇	◇	◇	◇	◇
		Freshwater Communities - Crayfish	3	◇	◇	◇	◇	◇	◇	◇	◇	◇
		Freshwater Communities - Macrophytes	3					◇	◇	◇	◇	◇
		Fish Communities - Streams	2	◇	◇	◇	◇	◇	◇	◇	◇	◇
		Fish Communities - Rivers	2					◇	◇	◇	◇	◇
		Amphibians and Reptiles - Vernal Pond Community	2	◇	◇	◇	◇	◇	◇	◇	◇	◇
		Amphibians and Reptiles - Streamside Salamander Community	2	◇	◇	◇	◇	◇	◇	◇	◇	◇
		Amphibians and Reptiles	2	◇	◇	◇	◇	◇	◇	◇	◇	◇

Eastern Rivers and Mountains Network - Vital Signs Monitoring Plan

Level 1 Category	Level 2 Category	Level 3 Category	Final Rank	ALPO	JOFL	FONE	FRHI	DEWA	UPDE	NERI	GARI	BLUE
	At-risk Biota	T&E Species & Communities - State	1	+	+	+	+	+	+	+	+	+
		T&E Species & Communities - Federal	1	+	+	+	+	+	+	+	+	+
Human use	Point-Source Human Effects	Bioaccumulation	3					◇	◇	◇	◇	◇
	Visitor and Recreation Use	Visitor Use	2	◇	◇	◇	◇	◇	◇	◇	◇	◇
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Land Cover and Use	1	+	+	+	+	+	+	+	+	+
		Landscape Pattern	1	+	+	+	+	+	+	+	+	+
	Energy Flow	Primary Production	3	◇	◇	◇	◇	◇	◇	◇	◇	◇
	Nutrient Dynamics	Nutrient Dynamics	3	◇	◇	◇	◇	◇	◇	◇	◇	◇

⊕ =Vital signs for which the network will develop protocols and implement monitoring using funding from the vital signs or water quality monitoring programs.

• = Vital signs that are monitored by a network park, another NPS program, or by another federal or state agency using other funding. The network will collaborate with these other monitoring efforts.

◇ = High-priority vital signs for which monitoring will likely be done in the future, but which cannot currently be implemented because of limited staff and funding.

<blank> = Vital sign does not apply to park, or for which there are no foreseeable plans to conduct monitoring.

interactive control. After considerable debate, the “Breeding birds” vital sign was demoted to tier 2 due the anticipated cost of monitoring this vital sign and the unanimous recognition that it was a lower priority than the other tier 1 vital signs. For “T&E Species & Communities” vital sign the decision was relatively easy once the SAC agreed that the selection criteria should be based on species/communities that are relatively unique to the ERMN and represented within the majority of the ERMN parks. That is, we took a network, rather than a park-specific, approach. Based on these criteria, the SAC recommended moving forward with monitoring of rare, riparian (including “riverscours”) plant communities (components of all five riverine parks in the ERMN) and the Louisiana waterthrush (*Seiurus motacilla*), an avian species present in all ERMN parks and an integrator of terrestrial and aquatic systems. It was also decided, in retrospect, that these vital signs are most appropriately categorized as “focal species or communities” in the National Vital Signs Framework, rather than as T&E Species & Communities. Details about this process and the full list of candidates are provided in Appendix J and other supplemental documents

The final priority list of vital signs for the ERMN, including the network vital sign name, after all refinements and clarifications as suggested by the SAC, is presented in Table 3.3.

3.1.9. Board of Directors Approval

On January 18, 2006, the ERMN Coordinator held a teleconference with natural resource managers representing all parks in the ERMN to discuss the outcome and recommendations of the December 16–17, 2005, Science Advisory Committee meeting. The resource managers were unanimously satisfied and pleased with the proposed vital signs (Table 3.3) and recommended proceeding with final approval by the ERMN Board of Directors.

On January 23, 2006, the ERMN Board of Directors approved 37 vital signs including the 13 priority vital signs selected for initial protocol development.

3.2. Relationship of the Proposed Vital Signs to Conceptual Ecological Models

Each of the 13 priority vital signs (Table 3.3) integrates elements of threat specific, ecosystem status and focal resource monitoring as shown in the general conceptual model (Figure 3.1).

Table 3.3. List of the 13 priority vital signs for the Eastern Rivers and Mountains Network for which protocol development will be initiated. The Board of Directors approved these vital signs on January 23, 2006 concluding the vital signs prioritization and selection process.

Level 1 Category	Level 2 Category	Level 3 Category	ERMN "Vital Sign" Name
Air and Climate	Air Quality	Wet Deposition	Air Quality
	Weather and Climate	Weather and Climate	Weather and Climate
Geology and Soils	Soil Quality	Soil Function and Dynamics	Soil Function and Dynamics
Water	Hydrology	Surface Water Dynamics	Surface Water Hydrology
	Water Quality	Water Chemistry - Core	Water Chemistry - Core
		Water Chemistry - Expanded	Water Chemistry - Expanded
		Aquatic macroinvertebrates	Aquatic macroinvertebrates
Biological Integrity	Invasive Species	Invasive/Exotic Plants and Animals	Invasive/Exotic Plants, Animals and Diseases - Status and Trends
		Invasive/Exotic Plants and Animals	Invasive/Exotic Plants, Animals and Diseases - Early Detection
	Focal Species or Communities	Shrubland Forest and Woodland Communities	Forest, woodland, shrubland, and riparian plant communities
		Riparian Communities	Rare, riparian plant communities
		Birds - Riparian Communities	Louisiana waterthrush
Landscapes (Ecosystem Pattern and Processes)	Landscape Dynamics	Land Cover and Use	Landscape Dynamics
		Landscape Pattern	

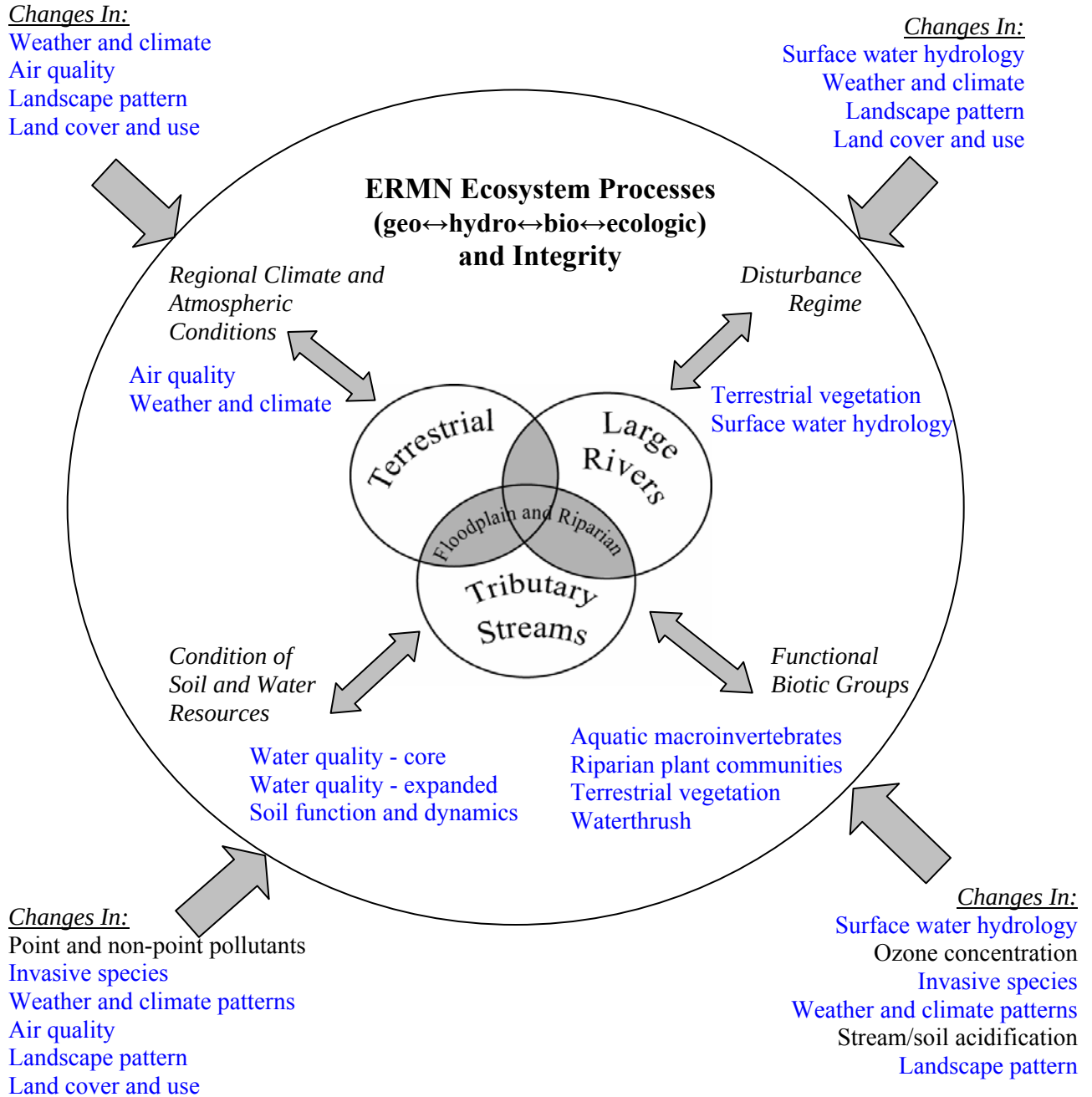


Figure 3.1. Modified Chapin et al. (1996) ecosystem model of relationship between interactive controls (italicized), broad-scale ERMN ecosystem processes and integrity, and vital signs (blue text). Interactive controls must be conserved if ERMN ecosystems are to be maintained. Major changes (natural or anthropogenic) in any interactive control will result in a new ecosystem with distinctly different properties.

Chapter 4 Sampling Design

“The consequences of poor study design are many: lost time and money, reduced credibility, incorrect (or no) management decisions, and unnecessary resource deterioration, to name just a few.”

- Caryl L. Elzinga, 1998

4.1. Introduction

The primary purpose of a monitoring protocol sampling design is to ensure that the data collected are representative of the resources of interest and that the number of samples taken are sufficient to meet the network’s monitoring objectives (Chapter 5). This chapter describes, in a general, way our current thinking on how spatial locations will be chosen for sampling ERMN vital signs and how sampling effort will be allocated to these sites. It is important to note that at the time of writing, summer and fall 2007, no single ERMN protocol has a fully specified sampling design precluding the presentation of many important details and decisions at this time. Regardless, the discussion in this chapter is conceptual in nature and is not intended to cover the details of sampling logistics or of data analysis methods. For example, detailed maps showing realized sample locations will be included in each vital sign protocol. Analysis plans are described generally in Chapter 7 and will be specifically described in the protocols. Here, we focus on the overall concepts and sampling designs that will permit statistical inferences to the specified, and often large, areas.

4.2. Sampling Concepts and Definitions

Subsequent sections of this chapter briefly describe various sampling approaches under consideration for ERMN vital signs monitoring. These sampling plans rely on a few underlying concepts and use specific statistical terms. This section describes some of the background concepts behind the designs being considered and defines sample unit, panel, rotation design, and membership design.

During development of the sample designs, our working definition of “monitoring” was the collection and analysis of repeated observations or measurements over a long period of time to document the status and trend in ecological parameters. Monitoring is usually designed to provide unbiased statistical estimates of status and trends in large areas or entire study units. Monitoring programs, in our minds, do not set out to investigate a single question or test a specific hypothesis; rather they attempt to collect objective and scientifically defensible data to answer wide-ranging broad hypotheses, some of which may not be finalized at the outset. Using data collected by monitoring programs, long-term correlations between management or natural changes and ecological parameters can occasionally be documented and can provide the most compelling and complete picture of ecosystems and ecosystem changes. Monitoring, however, in most cases will not establish statistical cause-and-effect relationships between external changes and the status of ecological parameters.

The monitoring plans under consideration for the ERMN rely on concepts in finite population sampling. In finite population sampling, the area for which inferences are desired (e.g., a rare plant community, or watershed, or park) is generally viewed as a finite collection of sample units (or just units). In general, sample units are the smallest entities upon which measurements are taken. The total collection of potential sample units is called the population or target population. Responses are defined to be measurements taken on the sample units. The subset of units from the population for which we collect responses is called the sample. If the sample is chosen using some type of random draw, the sample is said to be a probability sample. Whenever possible we will opt for a probability sample to monitor vital signs of the ERMN.

Some sample designs under consideration for the ERMN (e.g., Forest, Woodland, Shrubland and Riparian Vegetation Monitoring) will rotate field sampling efforts through various sets of sample units over time. In this situation, it is useful to define a panel of sample units to be a group of units that are always all sampled during the same sampling occasion or time period (McDonald 2003). Note that this definition does not preclude a sample unit from being a member of two different panels. The way in which sample units become members of a panel is called the membership design. The pattern of sampling visits through time is called a revisit design. MacDonald (2003) proposed a shorthand notation that is useful for describing revisit designs. The total number of panels in the sampling design is the sum of the digits in the notation. For example, the digit pair [1-2] means that a total of three panels will be visited on a “one on, two off” rotation (Figure 4.1.A). The notation [1-0, 1-1] indicates two different revisit designs: sample units in one panel will be visited on every sampling occasion, while units in two other panels will be visited on alternating occasions (Figure 4.1.B). The latter sampling design, called a split panel design, is a kind of compromise approach, which allows for monitoring trends efficiently (by sampling at least one panel on every sampling occasion), while also establishing the condition (status) of the resource at as many sites as feasible across the landscape.

4.3. Overview of Sampling Approaches

Because of the diversity of resources selected by the ERMN for monitoring, a single overarching sampling design for the network is not likely to be practical. At this time, three different schemes for collecting measurements in the field are being considered for the ERMN monitoring protocols. The first scheme (grid-based sampling) constructs a two-dimensional grid of either points or cells to use as sample units and draws a probability sample. This scheme is being considered for our “terrestrial” vital signs (Table 4.1). The second scheme (list-based sampling) constructs a one-dimensional list of sample units and either draws a probability sample or attempts to census all units. This scheme is being considered for our “aquatic” vital signs which are constrained to the linear stream and river networks. The third scheme collects information on areas or at points (index sites) that were hand-picked by lead investigators to yield data on a particular vital sign. This scheme is appropriate for our approach to air quality and weather/climate monitoring. While careful consideration is being paid to which existing stations are ultimately used for data analysis and inference, this approach still constitutes “hand-picking” or “judgment sampling” without a formal sample design with a random component. This is also true for a portion of the surface water hydrology vital sign where continuous flow data from USGS stream gages will be utilized by the ERMN.

A)

PANEL	SAMPLING OCCASION					
	1	2	3	4	5	6
1	X			X		
2		X			X	
3			X			X

B)

PANEL	SAMPLING OCCASION					
	1	2	3	4	5	6
1	X	X	X	X	X	X
2		X		X		X
3			X		X	

Figure 4.1. Examples of revisit designs. A) shows a “rotating panel” design with a “one on, two off” rotation (notation: [1-2]). B) is a “split panel” design, with one panel visited every year, and the other two on a “one on, one off” rotation (notation: [1-0, 1-1]).

Table 4.1. The sample design approach, methods for spatially allocating samples, and the revisit plan being considered for Eastern Rivers and Mountains Network vital signs monitoring.

Level 1 Category	Level 2 Category	Level 3 ERMN Vital Sign	Overall Sample Design Approach	Spatial Allocation	Revisit Plan
Air and Climate	Air Quality	Air Quality	Index	NA	Variable
	Weather and Climate	Weather and Climate	Index	NA	Variable
Geology and Soils	Soil Quality	Soil Function and Dynamics	Grid-based	TBD*	TBD
Water	Hydrology	Surface Water Hydrology	Index, in part.	NA	Variable
	Water Quality	Water Chemistry - Core	List-based; Index	GRTS; various	TBD
		Water Chemistry - Expanded	List-based; Index	GRTS; various	TBD
		Aquatic macroinvertebrates	List-based; Index	GRTS; various	TBD
Biological Integrity	Invasive Species	Invasive/Exotic Plants, Animals and Diseases - Status and Trends	Grid-based	GRTS	TBD
		Invasive/Exotic Plants, Animals and Diseases - Early Detection	NA	NA	TBD
	Focal Species or Communities	Forest, woodland, shrubland, and riparian plant communities	Grid-based	GRTS	TBD
		Rare, riparian plant communities	TBD	TBD	TBD
		Louisiana waterthrush	TBD	TBD	TBD
Landscapes	Landscape Dynamics	Landscape Dynamics	TBD	TBD	TBD

* TBD = to be determined as protocol development continues.

4.3.1. Grid-based Sampling for Terrestrial Systems

Vital signs measured under the terrestrial sampling design will include Forest, Woodland, Shrubland, and Riparian Vegetation; Soil Function and Dynamics; and the plant (and eventually insect and disease) portion of the Invasive Species - Status and Trends vital sign. These three vital signs are being developed as a common protocol (Chapter 5) and the ERMN is currently considering a grid-based sampling scheme. It is not yet known if a single grid and grid size is appropriate for all parks (unlikely, given the variability in park sizes across the network) and all components of the protocol. In this scheme, a GIS is used to overlay a grid on the map of the region of interest and the intersections of the grid are then used as candidate sampling points.

We are proposing to select for sampling among the candidate grid points (the target population) using a “Generalized Random - Tessellation Stratified” (GRTS) design (Stevens and Olsen 2004). GRTS is a procedure that can be used to pick points at random from the sampling grid or list (see List-based Sampling for Aquatic Systems below), and has several advantages over other selection methods such as a simple random sample. First, points selected using GRTS will be spatially balanced; that is, they will be well scattered/distributed throughout the specified area or unit to be sampled. This will prevent the specified area from having areas that are over- or under-sampled, which will strengthen the inferences made from the monitoring. Second, the GRTS process is designed to work well when some of the points selected may not be suitable for monitoring, but it is difficult to determine that before they are visited. GRTS produces an ordered list of sampling locations, and can select more locations than are actually needed for a

given protocol. If a particular location cannot be sampled, then the next location on the list can be used instead, and the spatial balance of the sampling design will be maintained. This is also important if it is found, later, that more (or fewer) points need to be sampled to meet stated monitoring objectives. One can add and subtract from the ordered list of sampling locations until the required number of sites are sampled in the field without losing the integrity and balance of the original design. Finally, as the GRTS points are all selected with a known probability, it will be easier to combine the data from the vital signs program with data collected by the individual parks or other agencies. A “regional grid” could be created to include areas that are adjacent to the ERMN parks, for example. Data collected in a manner compatible with ERMN monitoring could then be analyzed together with ERMN data. The expansion of the grid would allow us to calculate the new inclusion probabilities (weighting) of the combined data set. This will allow us to leverage outside data and improve our ability to detect trends.

4.3.2. List-based sampling for Aquatic Systems

Vital signs measured under the aquatic sampling design include Core and Expanded Water Chemistry, Surface Water Hydrology, Louisiana waterthrush, and Aquatic Macroinvertebrates. It is proposed that the sampling design will be a “hybrid” design consisting of a network of index sites for flow-related (i.e., collocated with existing USGS stream gages or new flow recording instrumentation) trends in water quality that are nested within a set of randomly selected sampling stations that are sampled periodically to define the state of the entire resource (i.e., the target population is the flowing waters within the park). The index-site network will include both within-park streams (i.e., the contributing area of the subwatershed is completely within the park boundary) that are protected from human disturbance of the watershed or channel, and stream and river reaches near the park boundary where the quality of water entering the park from private lands may be differentiated from within-park changes in water quality.

The random design component will allow us to make inferences to a larger population of sites within or draining through the parks. Where parks in the ERMN have limited lotic aquatic resources, the random design may not provide useful additional information; in which case, index sites will be selected deterministically to approximate the condition of the entire resource.

The sample design for aquatic systems will likely be based on the USGS National Hydrography Dataset (1:24,000 NHD, <http://nhd.usgs.gov/>). For example, each NHD stream segment could be assigned a unique ID and GRTS used to select among this one-dimensional list of potential stream segments. Unequal probability sampling could also be used to weight sampling by stream order, segment length, or any other stream characteristic. Alternatively, each tributary watershed could be the sampling unit with samples taken at the pour point of each watershed. In this case, watersheds could be assigned a unique ID and GRTS used to select among this list of sites. Much of these details will be determined as protocol development continues.

For the random component of this design, we are considering employing the GRTS approach for the reasons outlined above (Section 4.1), but spatial balance is important, too, because responses in these linear, aquatic systems are likely to be spatially autocorrelated (i.e., units close to one another tend to yield correlated responses). When responses are correlated in space, spatial balance can greatly improve precision of the resulting estimates. Additionally, because GRTS samples are not evenly spaced, it is not possible for sample locations to be in phase with a cyclic

response. This approach also allows multiple components (or vital signs) to maximize overlap of selected streams by utilizing a common sample, and allows units to be added easily after an initial sample has been drawn. For example, consider a hypothetical ERMN park, assume 20 stretches are to be surveyed by the macroinvertebrate and Louisiana waterthrush protocols, 15 stretches are to be surveyed by the expanded water quality parameters, and 25 stretches are to be surveyed by the core water quality parameters. Under the GRTS design, and assuming all three field protocols could be applied to all stretches, the macroinvertebrate/bird protocols would visit the first 20 stretches in the ordered sample. The expanded water chemistry parameters protocol would visit the first 15 stretches, and the core water quality protocol would visit the first 25 stretches in the list. In this way, overlap (co-location) is maximized because 20 of 25 core water quality stretches would also be sampled for macroinvertebrates/birds, and 15 of those 20 would also receive measures of expanded water quality parameters. Furthermore, the 15 expanded water chemistry, 20 macroinvertebrates/birds, and 25 core water quality stretches would be spatially balanced.

Chapter 5 Monitoring Protocols

“Protocols are necessary to be certain that changes detected by monitoring actually are occurring in nature and are not simply a result of measurements being taken by different people or in slightly different ways.”

- Oakley et al. 2003

Once a vital sign has been selected and an appropriate sampling design chosen, the next step is to develop a monitoring plan (protocol) for that vital sign. Monitoring protocols identify methods for gathering information on a resource or its stressor(s), outline a process to collect information, and establish how information will be analyzed and reported. Protocols are detailed study plans that are necessary to ensure that changes detected by monitoring actually are occurring in nature and do not stem from measurement variability introduced when different people or methods are used (Oakley et al. 2003). Protocols are essential for monitoring vital signs through time.

Monitoring protocols must include a narrative providing the rationale for vital sign selection, an overview of the monitoring protocol components, and a history of the development of the protocol. The narrative details protocol sampling objectives, sampling design (including location and time of sample collection), field methods, data analysis and reporting, staffing requirements, training procedures, and operational requirements (Oakley et al. 2003). Specific measurable objectives must be identified in the objective section of the narrative. Narratives also summarize the design phase of a protocol development and any decision-making that is relevant to the protocol. Documenting the history of a protocol during its development phase helps ensure future refinement of the protocol, continues to improve the protocol, and is not a mere repetition of previous trials or comparisons (Oakley et al. 2003). Narratives also provide a listing and brief summary of all standard operating procedures (SOPs), which are developed in detail as independent sections in the protocol.

SOPs carefully and thoroughly explain in a step-by-step manner how each procedure identified in the protocol narrative will be accomplished. At a minimum, SOPs address pre-sampling training requirements, data to be collected, equipment operations, data collection techniques, data management, data analysis, reporting, and any activities required at the end of a field season (i.e., equipment storage). One SOP identifies when and how revisions to the protocol are undertaken. As stand alone documents, SOPs are easily updated, compared to revising an entire monitoring protocol. A revision log for each SOP identifies any changes that are implemented.

Finally, monitoring protocols identify supporting materials critical to the development and implementation of the protocol (Oakley et al. 2003). Supporting materials are any materials developed or acquired during the development phase of a monitoring protocol. Examples of this material may include databases, reports, maps, geospatial information, species list, species guilds, analysis tools tested, and any decisions resulting from these exploratory analyses. Material not easily formatted for inclusion in the monitoring protocol also can be included in this section.

5.1. Summary of Protocol Development

A summary of the ERMN monitoring protocols for the priority vital signs (all scheduled for implementation within 1–3 years) is provided in this section. The protocol summaries include the vital signs to be monitored, a justification for monitoring, and a list of sampling objectives. With the exception of the rare, riparian plant communities vital sign (riverine parks only), all protocols are planned to be implemented in all ERMN parks. Full protocol development summaries (PDS) are available in Appendix K - ERMN Protocol Development Summaries. The PDS describes why the protocol is needed, the specific issues and questions being addressed, the specific measurable objectives, the proposed methodological approach, and other details.

The PDS includes the following material:

- **Protocol:** [title of the protocol]
- **Parks Where Protocol will be Implemented:** [names or 4-character codes for the parks where the protocol is likely to be implemented over the next five years]
- **Justification/Issues Being Addressed:** [a paragraph or two justifying why this protocol needs to be developed]
- **Monitoring Questions and Objectives to be Addressed by the Protocol:** [specifics if possible]
- **Basic Approach:** [description of any existing protocols or methods that will be incorporated into the protocol, the basic methodological approach, and sampling design]
- **Principal Investigators and NPS Lead:** [the name and contact information for the Principal Investigators and for whoever in the NPS is responsible for working with the P.I.s to ensure that the protocol meets network needs]
- **Development Schedule, Budget, and Expected Interim Products:** [describe costs, length of time, and interim products (annual reports, sampling designs, etc.) expected]
- **Key Citations**

The following sections are excerpted from Appendix K - ERMN Protocol Development Summaries to summarize each of the nine ERMN protocols.

5.1.1. Terrestrial Vegetation Monitoring

Vital Signs Included in the Protocol: Forest, Woodland, Shrubland, and Riparian Vegetation; Invasive Species - Status and Trends; Soil Function and Dynamics.

Justification/Issue being addressed: Monitoring of terrestrial vegetation and associated components of this protocol (such as soils and invasive plant and insect species) combines several vital signs that capture multiple high-priority interests of ERMN parks (e.g., Forest, Woodland, Shrubland and Riparian Vegetation was ranked No. 1 in the vital signs selection process - Chapter 3). Ecological factors affecting terrestrial vegetation include the underlying soils and geology, weather (rain, temperature, solar radiation) patterns, disturbance patterns, and nutrient availability. Anthropogenic stressors include air pollution (ozone toxicity, acid and nutrient deposition), loss and fragmentation of habitat due to development (inside and outside of parks), erosion, visitor overuse, exotic and invasive species, and over-browse by white-tailed deer. In particular, current and anticipated rapid urbanization of rural landscapes is affecting natural forest system functions through land conversion and the introduction of exotic plants, insects, and diseases. By measuring taxonomic, structural, and demographic features, an assessment can be made as to whether or not the ecosystem's parameters fall within expected or accepted norms and ranges of variability.

Specific monitoring objectives to be addressed by this protocol:

- Objective 1. Document status and long-term trends in canopy and understory¹ species composition, diversity, and nativity.
- Objective 2. Document status and long-term trends in composition, diversity, and nativity of select herbaceous species, guilds, or communities.²
- Objective 3. Document status and long-term trends in tree growth, mortality rates, and density of snags.
- Objective 4. Document status and long-term trends in tree species regeneration and seedling establishment.
- Objective 5. Determine status and current canopy age structure and document long-term changes.
- Objective 6. Document status and long-term trends in canopy structure, cover, and closure.

¹ A “canopy” and/or “shrub” strata will obviously not be present at all monitoring sites, given the diversity of successional stages within and among ERMN parks. In some cases “understory” may refer only to shrub and herbaceous or simply herbaceous vegetation. As such, particular measures and metrics will not be applicable throughout.

² This objective relates directly to three distinct herbaceous guilds (i.e., ephemerals, sedges, composites). Monitoring all three guilds would require multiple visits during the growing season. It may be necessary to incorporate this objective with other vital sign efforts or develop a separate protocol. In either case, the ERMN plans to begin with cover classes of broad herbaceous groups and then narrow and focus the scope of the objective to particular herbaceous species, guilds, or communities for additional measures.

³ The ERMN is primarily interested in soil chemistry as it relates to acid and nutrient deposition and therefore is considering changes in Ca:Al and C:N ratios to assess the extent to which cation depletion, increased aluminum availability, and/or nitrogen saturation are impacting ERMN soils and vegetation. This objective has, for the time being, been set aside as further research into costs and approaches are considered by other I&M Networks.

- Objective 7. Document status and long-term trends in the level of deer browse on select indicator plants most palatable to deer.
- Objective 8. Document status and long-term trends in basic soil chemistry.³
- Objective 9. Document status and long-term trends in coarse woody debris biomass/volume.
- Objective 10. Document status and long-term trends in the number, composition, and proportion of nonnative species.
- Objective 11. Document status and how park/network status and trends compare to regional trends.

5.1.2. Water Quality and Quantity Monitoring

Vital Signs Included in the Protocol: Water Chemistry - Core Parameters, Water Chemistry - Expanded Parameters; Surface Water Hydrology.

Justification/Issue being addressed: Surface water hydrology and chemical/physical water quality monitoring was recognized as a top priority at the network level during the vital signs prioritization process. The significance of water resources within ERMN (including roughly 340 km [211 mi] of river and more than 684 km [425 mi] of stream) is reflected in the network's ranking of river and stream hydrology and chemical/physical water quality as 2nd among all of the potential vital signs identified and prioritized by the ERMN. Flowing freshwater quality and quantity has *direct* impact on several other vital signs and park resources including fishes, crayfish, mussels, and salamander assemblages, several threatened and endangered aquatic species, riparian and floodplain vegetation and bird communities, and aquatic macroinvertebrates (these last three are also top priority vital signs for network monitoring). Freshwater quality and quantity has *indirect* impacts on all plant and animal life as well as human consumption, recreation, and enjoyment (i.e., the intrinsic value of water).

Specific monitoring objectives to be addressed by this protocol:

- Objective 1. Document status and long-term trends in the concentration of the “core” water quality parameters (dissolved oxygen, pH, water temperature, and specific conductance) at selected sites.
- Objective 2. Document status and long-term trends in seasonal and annual stream and river hydrology (velocity, discharge and flood characteristics) at selected sites.
- Objective 3. Document status and long-term trends in the concentration of several “expanded” water quality parameters (e.g., sediment [total suspended sediment, turbidity], acid neutralizing capacity, plant nutrients [total phosphorous, total nitrogen, nitrate + nitrogen], and human indicators [boron, chloride]) at selected sites.
- Objective 4. Document status and long-term trends in chemical *loadings* at selected sites.
- Objective 5. Document how park/network status and trends compare to regional and national trends.

5.1.3. Aquatic Macroinvertebrate Monitoring

Vital Signs Included in the Protocol: Aquatic Macroinvertebrates.

Justification/Issue being addressed: The significance of water resources within ERMN (including roughly 340 km [211 mi] of river and more than 684 km [425 mi] of stream) is reflected in the network's ranking of river and stream hydrology, chemical/physical water quality, and aquatic macroinvertebrates as 3 of the top 4 vital signs identified and prioritized by the ERMN. Aquatic macroinvertebrates refers to aquatic and semi-aquatic invertebrates that inhabit the stream bottom (i.e., benthic) and can be observed without the aid of a microscope. Based on the proven ability of measures of aquatic macroinvertebrate assemblage structure and composition to discern impact and change, combined with the relatively high degree of power to assess change and the relatively low cost to sample, aquatic macroinvertebrates are probably the single best biological group to monitor to assess the condition of small and mid-sized streams and rivers.

Specific monitoring objectives to be addressed by this protocol:

- Objective 1. Document status and long-term trends in the structure and composition of aquatic benthic macroinvertebrate communities at selected sites as expressed by relevant water quality biomonitoring metrics.
- Objective 2. Document how park/network status and trends compare to regional trends.

5.1.4. Louisiana Waterthrush and other Riparian Birds

Vital Signs Included in the Protocol: Louisiana Waterthrush; Breeding Birds, in part (tier 2 Vital Sign); Riparian Birds, in part (tier 2 Vital Sign).

Justification/Issue being addressed: Louisiana waterthrush (LOWA; *Seiurus motacilla*) monitoring was recognized as top priority at the network level during the vital signs prioritization process. This is the only bird species in the ERMN that depends on flowing waters for food and reproduction. As such, standardized monitoring of LOWA population parameters is becoming widely accepted as a desirable component of an integrated long-term water quality and watershed condition monitoring program. Monitoring the distribution and abundance of LOWAs alone will provide a cost-effective means of detecting major shifts in the benthic macroinvertebrate community and/or the riparian forest. Monitoring other bird species was identified initially as tier 2 vital sign at the network scale, and this approach can serve as a cost-effective means of assessing a broader range of landscape-scale conditions.

Specific monitoring objectives to be addressed by this protocol:

- Objective 1. Document status and long-term trends in the extent and frequency of stream use by Louisiana waterthrush at select sites in ERMN parks.
- Objective 2. Document status and long-term trends in the proportion of select stream sites occupied by riparian bird indicator species.
- Objective 3. Document status and long-term trends in rates of local extinction and colonization of select stream sites by riparian bird indicator species.
- Objective 4. Document how park/network status and trends compare to regional trends.

5.1.5. Early Detection of Invasive Species - Surveillance Monitoring and Rapid Response

Vital Signs Included in the Protocol: Invasive Species (plants, animals, and diseases) - Early Detection.

Justification/Issue being addressed: Early detection monitoring of incipient invasive plants, animals, and diseases was ranked among the top priorities in the ERMN in the vital signs selection process due to the clear identification of, and concern about, the effects these organisms can have on park ecosystems. The known ecological impacts of invasive species include loss of threatened and endangered species, altered structure and composition of terrestrial and aquatic communities, and reduction in overall species diversity. In addition, alteration of ecosystem processes occurs, such as the disruption of natural succession, prevention of seedling establishment of native plants, disruption of native insect-plant associations, alteration of natural fire regimes, hybridization with native plant species resulting in altered genomes, and introduction of reservoirs for harmful plant pathogens.

The ERMN will develop and maintain a list of target “watch” species that occur in localized areas of parks, are extremely rare, or are not currently present within a park, but have the potential to cause major ecological or economic problems if they were to become established. The purpose is to detect incipient populations (i.e., small or localized) and new introductions of these target nonnative species before they become established in areas of high and moderate management significance. The ERMN will also develop, maintain, and distribute appropriate target species identification information for all ERMN field crews, cooperators, resource managers, and volunteers, and develop and maintain an early detection tracking system.

Specific monitoring objectives to be addressed by this protocol:

- Objective 1. To reliably detect the presence of targeted nonnative species in areas of high and moderate management significance.

5.1.6. Weather and Climate Monitoring

Vital Signs Included in the Protocol: Weather and Climate

Justification/Issue being addressed: Weather and climate are key drivers in ecosystem structure and function. Climate is a dominant factor driving the physical and ecologic processes affecting the ERMN. Climate variations are responsible for short- and long-term changes in ecosystem fluxes of energy and matter and have profound effects on underlying geomorphic and biogeochemical processes. These global- and regional-scale climate variations will have a tremendous impact on the fundamental properties of ecologic systems, such as soil-water relationships, plant-soil processes, and nutrient cycling, as well as disturbance rates and intensity. These properties, in turn, influence the life-history strategies supported by a climatic regime. It is essential that park units within the ERMN have an effective climate-monitoring system in place to track climate changes and to aid in management decisions relating to these changes. The primary objective for climate and weather monitoring in the ERMN is to monitor key measurable climate parameters to determine rate and extent of climate trends.

Specific monitoring objectives to be addressed by this protocol:

- Objective 1. Document variability and long-term trends in weather and climate through seasonal and annual summaries of selected parameters (e.g., multiple forms of precipitation; temperature).
- Objective 2. Identify and document extremes and averages of climatic conditions for common parameters (e.g., precipitation and air temperature), and other parameters where sufficient data are available (e.g., wind speed and direction, solar radiation).
- Objective 3. To provide information on near real-time weather parameters, historical climate patterns, and climate station metadata from a single, easy-to-use, internet portal.

5.1.7. Air Quality Monitoring

Vital Signs Included in the Protocol: Ozone; Wet Deposition; Visibility, and Particulate Matter; Mercury Deposition.

Justification/Issue being addressed: Under the Clean Air Act, park managers have a responsibility to protect air quality and related values from the adverse effects of air pollution. Protection of air quality in national parks requires knowledge about the origin, transport, and fate of air pollution, as well as its impacts on resources. In order to be effective advocates for the protection of park air resources, NPS managers need to know the air pollutants of concern, existing levels of air pollutants in parks, park resources at risk, and the potential or actual impact on these resources. The ERMN will meet this need in collaboration with monitoring specialists at the NPS Air Resources Division (ARD) through the nationwide NPS air quality monitoring network and additional data sources.

Specific monitoring objectives to be addressed by this protocol:

- Objective 1. Document annual status and long-term trends in atmospheric ozone concentrations in ERMN parks using metrics that are indicative of human health (e.g., 8-hour average) and plant response (e.g., SUM06).
- Objective 2. Document annual status and long-term trends in wet deposition in ERMN parks of hydrogen (acidity as pH), sulfate (SO₄), nitrate (NO₃), ammonium (NH₄), chloride, and base cations (such as calcium, magnesium, potassium, and sodium).
- Objective 3. Document annual status and long-term trends in mercury concentration and deposition in precipitation in ERMN parks.
- Objective 4. Document annual status and long-term trends in fine particulate matter (PM_{2.5}) and coarse particulate matter (PM₁₀) concentrations and composition in ERMN parks as they pertain to visibility impairment and human health.

5.1.8. Landscape Dynamics

Vital Signs Included in the Protocol: Landscape Dynamics (Land Cover and Use; Landscape Pattern)

Justification/Issue being addressed: Many of the parks in the ERMN are subject to encroaching residential, urban, and, in some cases, agricultural development, and recognize that these landscape issues are closely linked to park ecosystem function. Thus, land cover and use and landscape pattern change are given a high priority for long-term monitoring within and around the ERMN. The ERMN also recognizes that human behaviors and activities are the significant drivers of landscape dynamics and can be represented by socio-economic indicators. The ERMN is therefore also interested in monitoring long-term local, regional, and national trends in population characteristics and human behaviors, as well as potential consequences of human activities, within and around ERMN ecosystems.

Specific monitoring objectives to be addressed by this protocol:

- Objective 1. Document status and long-term trends in land cover within and adjacent to ERMN park lands (i.e., how much land of a major cover type has changed over time?).
- Objective 2. Document status and long-term trends in habitat conversion to urban/suburban landscapes, creation of edge, reduction of functional ecosystem size, and elimination of important habitats.
- Objective 3. Document status and long-term trends in landscape pattern (contextual change) within and adjacent to park lands (i.e. what are average patch sizes, densities, edge/core areas, inter-patch distances, etc.).
- Objective 4. Document status and long-term trends in local, regional, and national population characteristics and human behaviors as represented by a suite of socio-economic indicators.

** Objective 4 is underway with the ERMN; Objectives 1–3 will be initiated in FY08.*

5.1.9. Rare Riparian Plant Communities

Vital Signs Included in the Protocol: Rare, Riparian Plant Communities including “Riverscour” Plant Communities.

ERMN Parks where protocol will be implemented: Delaware Water Gap National Recreation Area (DEWA), Upper Delaware National Scenic and Recreational River (UPDE), New River Gorge National River (NERI), Gauley River National Recreation Area (GARI), and Bluestone National Scenic River (BLUE).

Justification/Issue being addressed: The ERMN, with more than 340 km (211 mi) of river, contains diverse, unique, and globally significant plant communities associated with the floodplains and other geomorphic and hydrologic features of large rivers. The network is currently developing conceptual ecological models for riparian plant communities in general, and nine plant communities will be given special emphasis, due to their rarity and/or the presence of rare species.

Specific monitoring objectives to be addressed by this protocol:

To be determined.

The ERMN currently does not have a cooperator for protocol development; however, the ERMN is collaborating with Dr. Greg Podniesinski, Western Pennsylvania Conservancy, on conceptual ecological model development for these plant communities. Draft conceptual models and a workshop to review and discuss these models, as well move into objective-setting for protocol development, is expected to occur by January 2008.

** At the time of writing, development of this protocol is not yet underway.*

Chapter 6 Data Management

Collecting data on specific natural resource parameters is a first step toward improving our understanding of park ecosystems. We use these data in tandem with sound data management practices, to analyze, synthesize, and model aspects of ecosystems. We use analysis results and interpretations to make decisions about the parks' vital natural resources and how to manage them in accordance with the National Park Service (NPS) mission. Thus, data collected and maintained through sound data management practices become information through analyses, syntheses, and modeling. This can only be achieved through the development of a modern information management infrastructure (e.g., staffing, hardware, software) and procedures to ensure that relevant natural resource data collected by NPS staff, cooperators, researchers, and others are entered, quality-checked, analyzed, reported, archived, documented, cataloged, and made available to others for management decision-making, research, and education.

Eastern Rivers and Mountains Network Data Management Program Goals

The goals of the ERMN data management program are to make data and information:

- Available - We have the means of knowing that the data exist. Data are accessible and easily located
- Usable - Data are stored in a stable, reliable, and interpretable data retrieval system
- Shareable - Data products are complete, certified for quality assurance, screened for sensitive information, formatted for use, and documented for interpretation by others
- Integrated - Data products are consistent with data exchange standards, interoperable with related natural resource data sets, and are collected and stored in a way that optimizes the tradeoff between meeting local needs and achieving compatibility with other agencies and partners
- Interpreted - Data have been reviewed, summarized, and transformed into useful information

The ERMN data management strategy holds that all data and derived information generated or otherwise used by the program will meet a high level of quality standards. Further, all data and information the ERMN program deems necessary to meet its objectives, and that are not otherwise maintained, will be archived, documented, and made easily available and accessible. Data and information will be accompanied by supporting documentation (metadata) that provide context, value, utility, and longevity, thereby facilitating a broad understanding of ERMN program products for current and future end-users.

6.1. Data Defined

Natural resource data are the building blocks on which our evolving ecological understanding of park resources is built. The term "data" refers not only to tabular and spatial data, but also to other information recorded and stored alongside these data such as documentation. Data products fall into five general categories: raw data, derived data, documentation, reports, and administrative records shown in Table 6.1.

Table 6.1. Categories of data products

Category	Examples
Raw data	GPS files, field forms and notebooks, photographs and sound/video recordings, telemetry or remote-sensed data files, biological voucher specimens, etc.
Compiled/derived data	Relational databases, tabular data files, GIS layers, maps, species checklists, analyzed data
Documentation	Data collection protocols, data processing/analysis protocols, record of protocol changes, data dictionaries, FGDC/NBII metadata, data design documentation, quality assurance reports, catalogs of specimens/photographs etc.
Reports	Annual progress report, final report (technical or general audience), periodic trend analysis report, publications etc.
Administrative records	Contracts and agreements, study plans, research permit/applications, other critical administrative correspondences, etc.

There are also data from a variety of sources including those that originate from the I&M program and those that do not. Our highest priority is to produce and curate high-quality, well-documented data originating from the I&M Program. As time and resources permit, we will work toward raising the level of data management for current projects, legacy data, and data originating outside the I&M Program.

6.2. Roles and Responsibilities

Data management cannot be successful unless everyone takes it seriously; it is therefore *everyone's* responsibility. Data management is sometimes more about managing people than it is about managing data. A data manager by profession can provide the tools, education, and encouragement to facilitate good data management, but it is primarily the actions of others that will dictate the quality of data management. Table 6.2 shows primary data management responsibilities by position in the ERMN.

6.3. Data Life Cycle and Work Flow

There are two main types of projects in which the I&M program is involved: short-term and long-term. A primary difference between short and long-term projects is the importance of adhering to established detailed standards for long-term projects to ensure internal consistency and comparability through time. While the need to follow standards is still present for short-term projects, sometimes the cost of compliance will outweigh the benefits due to the scope, budget, and level of NPS influence over the project. Nevertheless, both short-term and long-term projects share many work flow characteristics, and both generate data products that must be managed and made available.

Table 6.2. ERMN staff data management roles and responsibilities.

Role	Primary responsibilities related to data management
Project Crew Member (Biotech GS-5/7)	Record and verify measurements and observations based on project objectives and protocols. Document methods, procedures, and anomalies
Botanist (Database Support)	Perform assigned level of data management, including data entry, conversion, and documentation
Network Data Manager	Provide overall network planning, training, and operational support for the awareness, coordination, and integration of data and information management activities
Plant/Aquatic Ecologists	Ensure useful data are collected and managed by integrating natural resource science in network activities and products, including objective setting, sample design, data analysis, synthesis, and reporting
Park Resource Specialist	Make decisions about data with regard to validity, utility, sensitivity, and availability.
Park or Other Curator	Oversee all aspects of the acquisition, documentation, preservation, and use of park collections
Statistician/Biometrician	Analyze data and present information, make suggestions on systematic data anomalies
Network Coordinator	Ensure programmatic data and information management requirements are met as part of overall network business

Projects can be divided into five primary stages: planning and approval; design and testing; implementation; product integration; evaluation and closure (Figure 6.1). Each stage is characterized by a set of activities carried out by staff involved in the project. Primary responsibility for these activities rests with different individuals according to the different phases of a project.

During various phases of a project, data take on different forms and are maintained in different places as they are acquired, processed, documented, and archived. This data life cycle is characterized by a sequence of events that we can model conceptually. Figure 6.2 models a typical data life cycle in the ERMN complete with relationships to national data servers and repositories.

6.4. Infrastructure and System Architecture

A complex system architecture and reliable computer infrastructure are necessary in order to support the data management program and its goals. The ERMN is in a unique situation in its duty-station at The Pennsylvania State University and relies on local university computer and hardware infrastructure on a daily basis to accomplish its mission. At the same time, ERMN staff also rely on data management system architecture developed and maintained at the national level of the I&M program for a variety of cataloging and data services. Data are generated, managed,

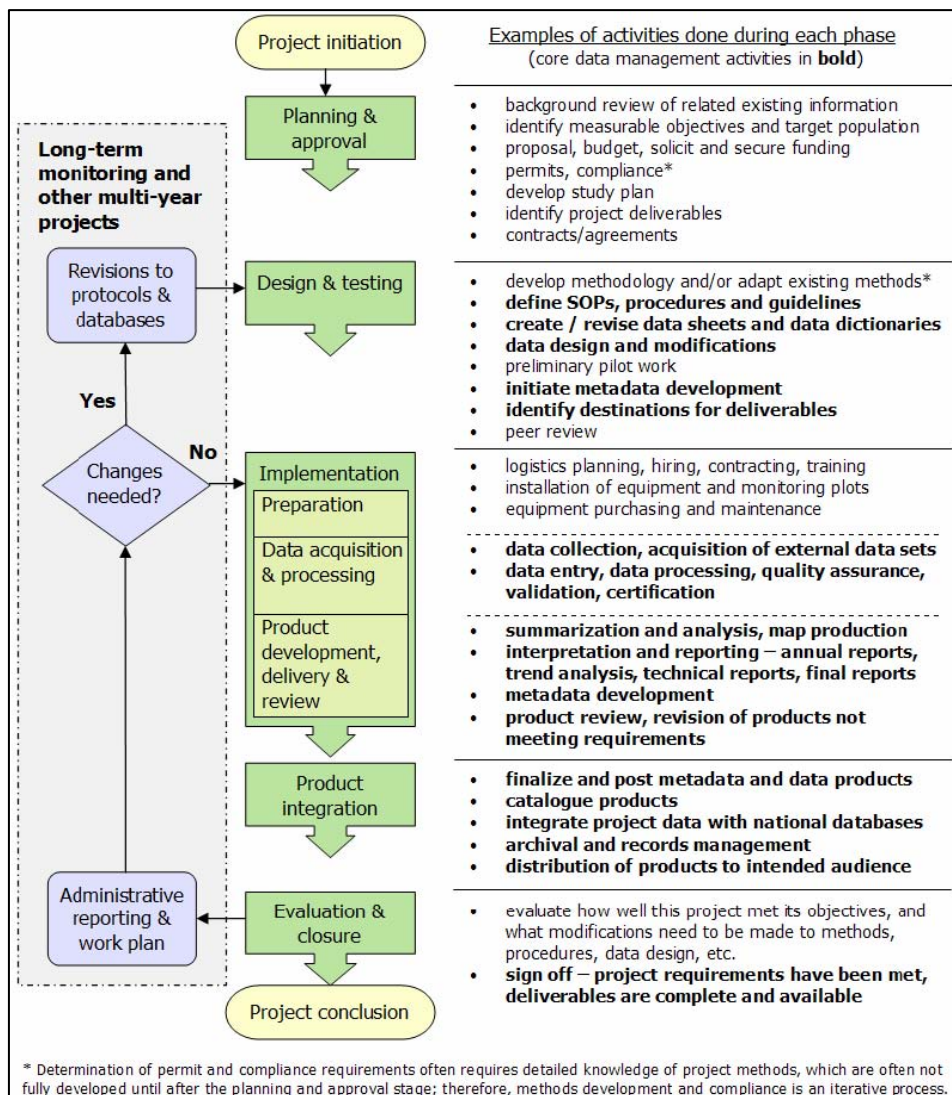


Figure 6.1. Project and data work flow.

and maintained at the local network level and sometimes uploaded to the national level. Aspects of the local ERMN system architecture are still under development, however. Figure 6.3 shows generically how these two architectures will integrate with one and other.

An additional and integral component of the I&M data management infrastructure is the NPS STORET application for managing all data acquired during network water quality monitoring. Water quality data collected as part of the network's monitoring program have distinct data management requirements. Data must be managed according to guidelines from the NPS Water Resources Division (WRD). This includes using the NPSTORET desktop database application to help manage data entry, documentation, and transfer to WRD. The ERMN will oversee the use

of NPSTORET according to the network's integrated water quality monitoring protocol. Figure 6.4 illustrates the flow of information and data between the network, national program offices and EPA's main STORET repository.

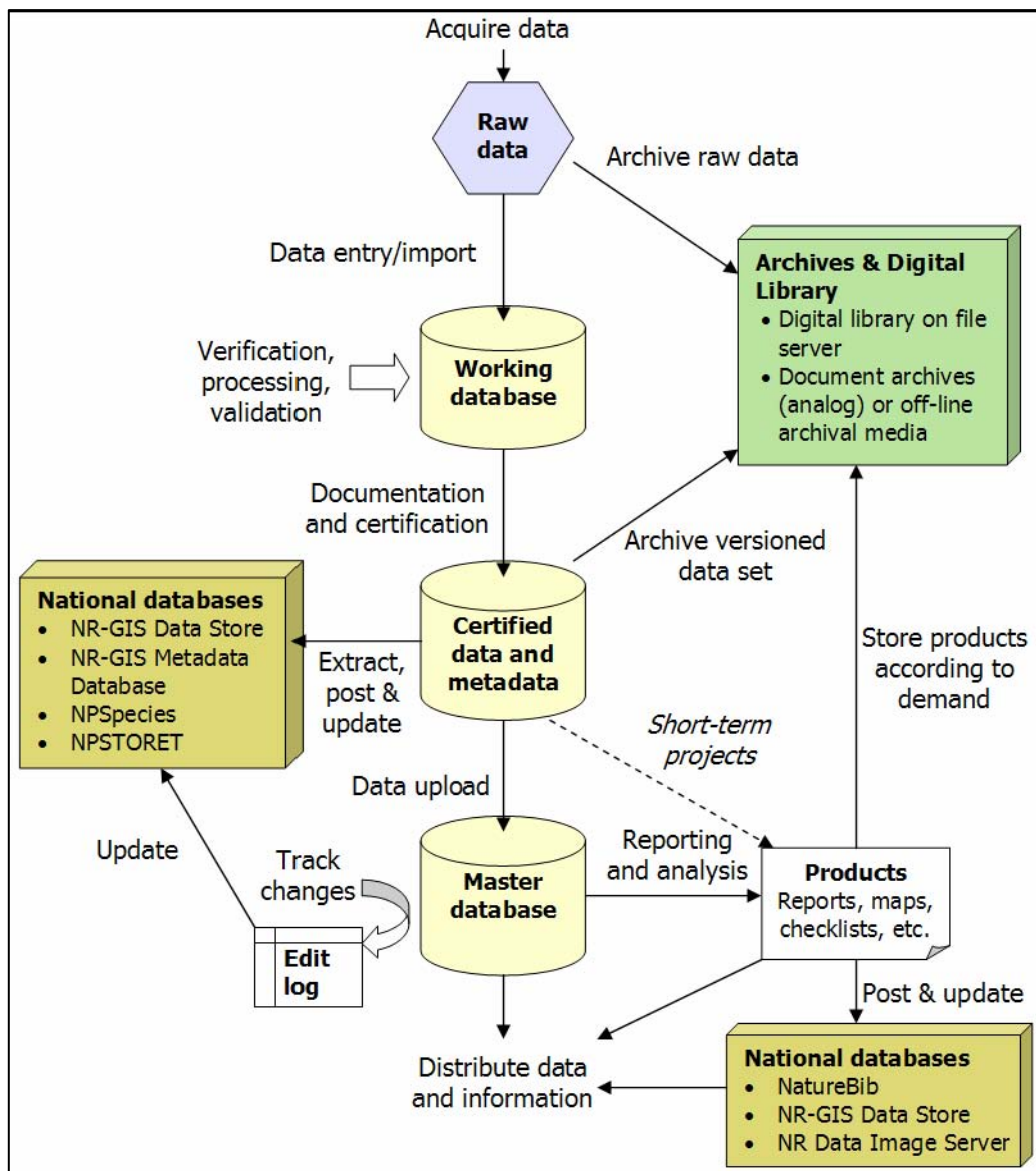


Figure 6.2. Diagram of typical data life cycle

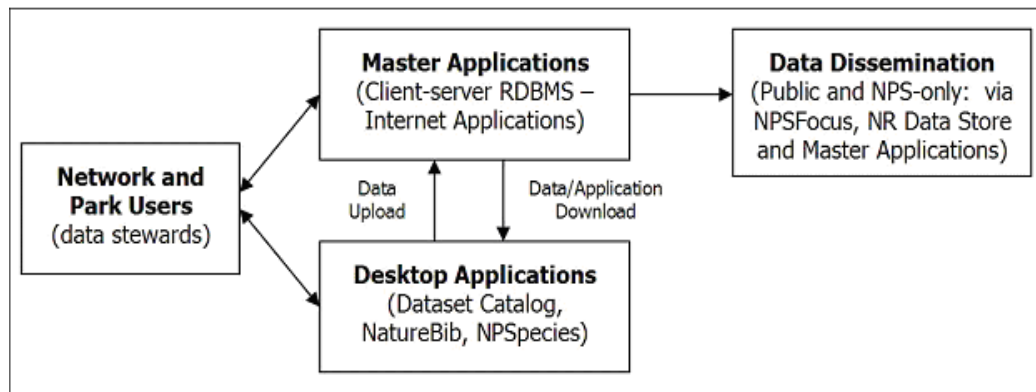


Figure 6.3. Sample conceptual model of I&M Program system architecture.

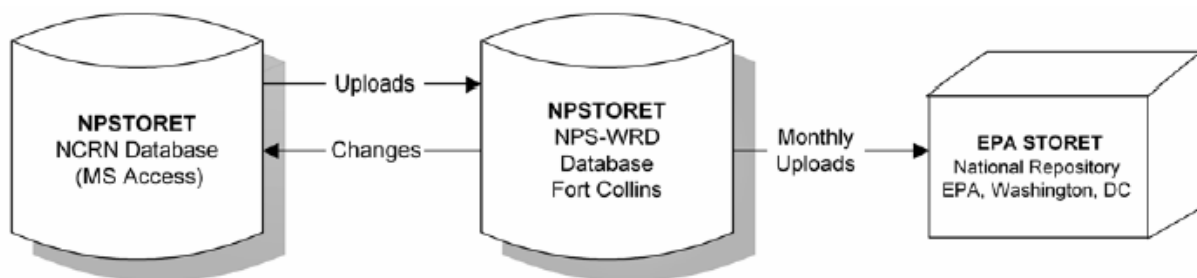


Figure 6.4. Sample conceptual model of NPSTORET system architecture.

6.5. Data Acquisition and Processing

Steps for acquiring and processing natural resource data will vary depending on the data source, which can be placed into three general categories:

- Eastern Rivers and Mountains Network data: data resulting from projects that are initiated, sponsored, or funded by the ERMN
- Other National Park Service (NPS) data: data resulting from projects that are initiated, sponsored, or funded by park units, or by regional or national NPS programs
- External data: data produced or managed by agencies, organizations, or individuals other than the NPS

ERMN staff has the most control over data produced by and for the network. They will, therefore, ensure that data meet all specifications laid out by the network, program, NPS, DOI, and federal government. These standards can include those for documentation, cataloging, and dissemination. Data falling into the second category of “Other NPS data” is often managed by the NPS entity most closely associated with the dataset. However, sometimes there are not the resources or expertise at these entities to manage the data properly. In these cases the ERMN will

evaluate the dataset's utility to the program or to natural resource management at an ERMN park, and manage these data as needed. ERMN staff will take the following action where appropriate, for data falling into the third category of "External data:"

Acquire data→Evaluate→Transform→Catalog→Make Available

6.6. Quality Assurance and Quality Control (QA/QC)

High quality data and information are mandated by national NPS directives and orders and are vital to the credibility and success of the I&M program. Quality can be defined as incorporating three key components-objectivity, utility, and integrity.

Objectivity consists of: 1) presentation, which focuses on whether disseminated information is being presented in an accurate, clear, complete, and unbiased manner within a proper context, and 2) substance, which focuses on ensuring accurate, usable, and reliable information.

Utility refers to the usefulness of the information to its intended users, from the perspectives of both the network, perhaps most importantly natural resource managers, and the general public.

Integrity refers to the security of information, which could entail protection from unauthorized access or revision to ensure that the information is not compromised through corruption or falsification.

Data quality is planned for throughout the entire data life cycle from training, to data collection, entry and input, verification and validation, documentation, communication, review, and all aspects of general operations. A variety of methods can be employed at each step along the way. As you apply more methods and move further along in the cycle, the more confidence you can have in the quality of your data as depicted in Figure 6.5.

As you become more familiar with and continually review the quality of your data, the effectiveness of your QA/QC procedures will become evident. Nevertheless, a formal and coordinated review and revision of QA/QC procedures should take place every several years to ensure the quality of data generated in the future.

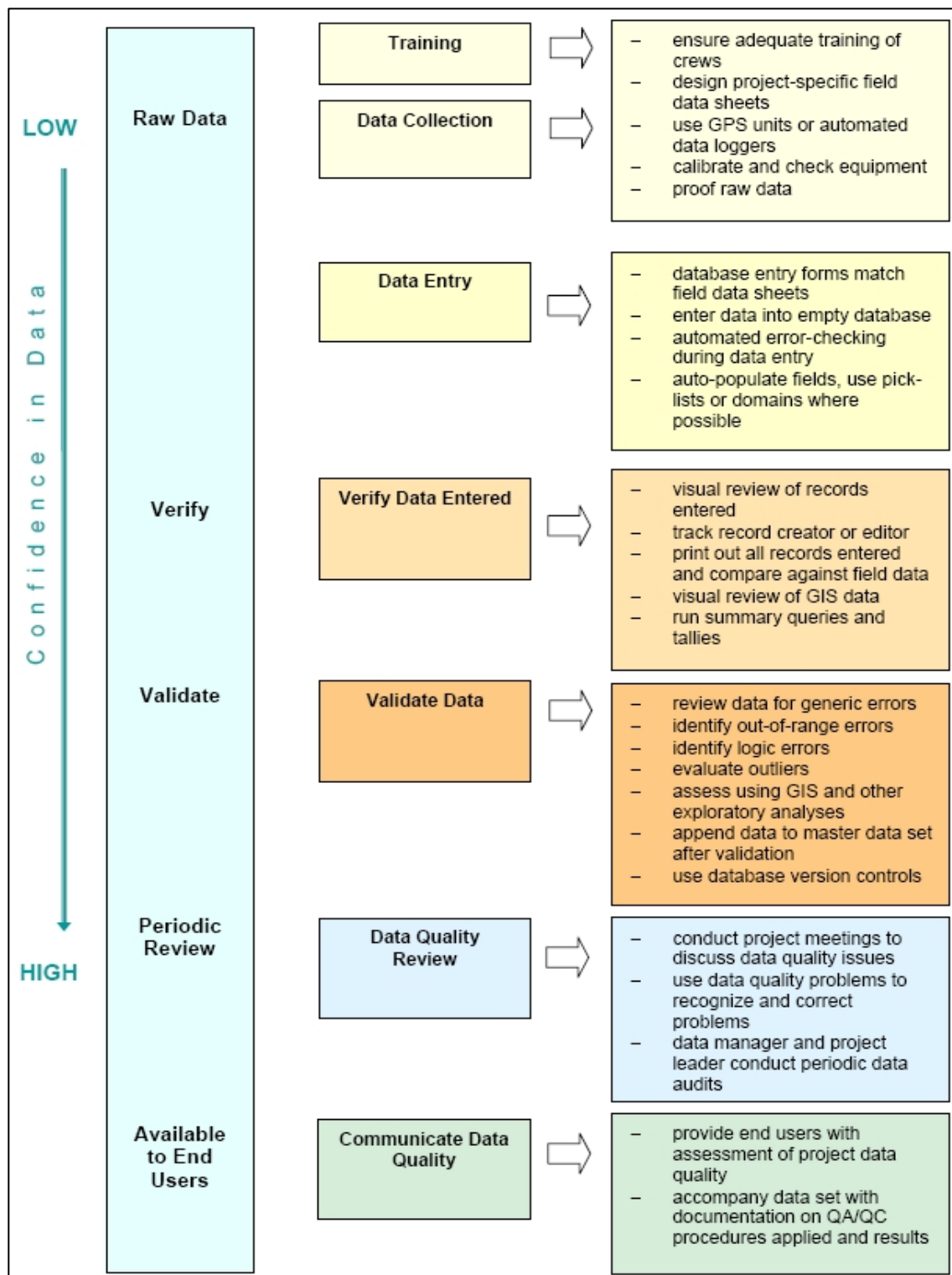


Figure 6.5. QA/QC controls and project work flow.

6.7. Data Documentation

Documenting data is the most important step toward ensuring that data sets are usable well into the future. Data longevity is directly related to the comprehensiveness of their documentation. There are a number of NPS and ERMN standards for documentation of spatial and tabular data, as well as projects, administrative records, vital signs protocols, and SOPs.

Overarching NPS standards include:

- Executive Order 12906, mandates federal agencies to “...document all new geospatial data it collects or produces, either directly or indirectly...” using the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (CSDGM).
- FGDC CSDGM extensions, such as the Biological Data Profile, Remote Sensing Extension, and Shoreline Data Profile are not required, but recommended where appropriate.
- NPS Geographic Information System (GIS) Committee requires all GIS data layers be described with FGDC standards and the NPS Metadata Profile.

ERMN standards include:

- Projects will be documented and organized in their appropriate “Projects” folder using standard folder organization as described in chapter 4 of the DM Plan
- Project finances will be tracked in the ERMN project tracking database as described in chapter 4 of the DM Plan
- Spatial data files will be documented in compliance with FGDC standards using the CSDGM
- Biological databases will be documented in compliance with FGDC standards using the NBII biological metadata profile.

Data documentation is perhaps the most undervalued data management activity. As such, it is the duty of the Network Data Manager to communicate, educate, and champion the importance of documentation, as well as sometimes to just make sure it gets done!

6.8. Data Dissemination

One of the most important goals of the Inventory and Monitoring Program is to *integrate natural resource inventory and monitoring information into National Park Service planning, management, and decision making.*

To accomplish this goal, procedures must be developed to ensure that relevant natural resource data collected by NPS staff, cooperators, researchers, and the public are entered, quality-checked, analyzed, documented, cataloged, archived, and made available for management decision-making, research, and education. Providing well-documented data in a timely manner to park managers is especially important to the success of the Program. The ERMN Program will make certain that:

- Data are easily discoverable and obtainable

- Data are subjected to full quality control or are NOT released
- Distributed data are accompanied by complete metadata that clearly establishes the data as a product of the NPS I&M Program
- Sensitive data are identified and protected from unauthorized access and inappropriate use
- A complete record of data distribution/dissemination is maintained

Data dissemination can be a complex task complete with considerations of data ownership, sensitivity, and access. All data and information generated by the I&M program should be property of the NPS and managed as such. This includes working closely with cooperators, contractors, experts, and park staff to assess sensitivity of data to public release and the potential for misuse. Data should be made accessible to the widest possible audience whenever prudent, providing for federal requirements to both protect (sensitive data), and release (according to the Freedom of Information Act), data.

6.9. Data Maintenance, Storage, and Archiving

Long-term maintenance and management of digital information are vital to the Inventory and Monitoring Program. This includes procedures for maintaining and managing digital data, documents, and objects that result from Network projects and activities. These procedures will help ensure the continued availability of crucial project information and permit a broad range of users to obtain, share, and properly interpret that information.

The ERMN has entered into a long-term agreement with North Carolina State University to serve as our primary digital archive. This archive along with a variety of ERMN and I&M national program resources, make up the various repositories that store and safeguard ERMN products for the future. Table 6.3 shows the various repositories and the ERMN products that can be found therein.

6.10. Feedback and Revisions

The ERMN Data Management (DM) Plan (Piekielek 2006; Appendix L), describes strategies that have been, and will be adopted by the ERMN. Appendixes to the DM Plan provide support and instruction on policies, specifications, and manuals. Whereas this chapter and the DM Plan outline general concepts and approaches, data management SOPs associated with each vital sign's monitoring protocol will provide detailed step-by-step instructions on specific data management procedures and methods for long-term monitoring projects. The DM Plan, appendixes, and SOPs work in tandem to present and document the evolving ERMN data management program.

Revisions to this chapter and its associated ERMN DM Plan will be made periodically or as needed, every several years. The Network Data Manager is responsible for initiating and coordinating revisions. Questions and comments about this chapter and the DM Plan are

Table 6.3. Principal repositories for project products.

Project Products	Repository
Tabular Data and Documentation	
Final Products	NCSU Digital Archive
	ERMN Physical Archive (on media)
	NPS Data Store
	NPSpecies
Draft Products	ERMN Physical Archive (Projects Folder on media)
Spatial Data	
Final Products	NCSU Digital Archive
	ERMN Physical Archive (on media)
	NPS Data Store
Draft Products	ERMN Physical Archive (Projects Folder on media)
Technical Reports	
digital	NPS Data Store, NPS Focus, NERO Science Website, E-TIC
hard copy	ERMN library
	Park library
	ERMN physical archive
	TIC
bibliography	NatureBib
Photographs	
Aerial hard copy	NCSU physical archive
Aerial digital	NCSU digital archive
Project Related	NCSU digital archive
	ERMN physical archive (on media)

welcome, as are suggestions on how to make it better, more clear, or more readable. Feedback should be directed to the Network Data Manager.

Efficient and effective data management methods, strategies, and procedures are vital to meeting I&M goals and maintaining programmatic support and relevance well into the future

Chapter 7 Data Analysis and Reporting

Monitoring results “*must be communicated to the public, for it is the broader public that will decide the fate of these resources.*”

- National Parks Advisory Board (2001)

This chapter, describes the considerations and approach to data analysis and reporting for the ERMN monitoring program. The contents, intended audience, and timing for production of reports and other products from the monitoring effort are described as much as possible. More detail will be added as protocols are developed and implemented.

7.1. Data Analysis

For the purposes of this program, data analysis is defined as the processes by which monitoring and other observations are turned into meaningful information. We have defined “data analysis” broadly to include all evaluations of data after the data are collected and entered into an electronic file. Thus, data analysis includes quality control checks that occur during summarization and exploratory data analysis and extends through to analytical procedures leading to conclusions and interpretations of the data. We present some general considerations on analysis of monitoring data and outline the general strategy that ERMN will take for all Vital Signs.

7.1.1. Analysis of Monitoring Data - General Considerations

Monitoring data pose challenges to analysis because of inherent temporal associations in the estimates. It is essential that we use statistical analyses that accommodate these associations. These approaches can include time series analyses, longitudinal data analysis (including repeated measures), trend estimation (many methods), direct estimation of change, and cumulative summary (CUSUM) techniques. Application of these analytical methods will require working closely with statisticians throughout the initial design process and during subsequent analyses of program data.

Many of the difficulties typically encountered in analysis of monitoring data can be avoided by proper planning, including the use of probabilistic sampling designs. Appropriate analysis of monitoring data is directly linked to the monitoring objectives, the spatial and temporal aspects of the sampling design used, and management uses of the data. Analysis methods need to be considered when the objectives are identified and the sampling design is selected, rather than after the data are collected. Failure to adequately consider analysis methods during monitoring program development could result in use of sampling designs that are either inadequate or too complex to meet the monitoring objectives. The purpose of this portion of the ERMN monitoring plan, and of the specific Standard Operating Procedures (SOPs) on data analysis for each ERMN protocol, is to ensure that the sampling designs and analysis methods we plan to use will allow us to meet our monitoring objectives.

A central tenet of the ERMN program is that data will be analyzed and reported promptly. Parks need to be alerted to changes in park ecosystems as soon as the changes can be detected—not several years after the fact. Thus, it is imperative that monitoring data be analyzed and reported on as soon as possible. Mechanisms to support prompt analysis and reporting have been built into the data management plan (e.g., data must be entered into the database within one month of returning from the field). Additional mechanisms will be established in the Data Analysis SOP for each Vital Sign to support prompt analysis and reporting.

One of the primary problems leading to long delays in analysis and reporting is a lack of explicit funding for this activity (Caughlan and Oakley 2001). Thus, the ERMN strategy includes providing adequate support to ERMN staff and/or principal investigators (PIs) for data analysis.

The first step in analysis is summarization (Mulder et al. 1999). This step is a critical part of overall quality control. The data need to be summarized promptly to identify missing values, outliers, and other problems related to data collection procedures and the data entry process (Jeffers 1994; Reid 2001). Routines for summarization will be prepared and codified in the SOPs for each Vital Sign. The exact form of the summaries will vary depending on the Vital Sign. In general, however, the approach will include use of graphical techniques to show the data in space and time, using measures of central tendency and variation.

The second step being considered in analysis of ERMN data sets will employ an analysis method that allows us to determine immediately if something has occurred that is out of the bounds of expected variation. Under consideration for this use are the conformance metric developed by CUSUM approach (Manly and Mackenzie 2003). The conformance metric separates out sampling variation from total variation to provide a measure of the natural variation in an attribute due to ecological processes. Once we establish a baseline to characterize “normal” variability, we can view new observations of the attribute and determine how well they conform to the documented history of the attribute. The conformance metric is the probability that a new observation comes from the same underlying process as the baseline. Hence, a small conformance indicates a change. Using conformance as a metric of change allows information from each Vital Sign to be translated to a common reporting system (i.e., is everything going about as expected or not?) and can be pooled hierarchically to any desired level. In the similar CUSUM approach, charts are created that allow systematic deviations to be easily seen. Both approaches are relatively easy to carry out and can complement other approaches to analysis of changes and trend.

The third step in analysis of ERMN data sets will be in-depth analyses of change over time. Specific methods of change, trend, or temporal pattern detection for each Vital Sign will be used and reported at predetermined intervals. When appropriate, other analyses such as species-habitat relationships or community ordinations may also occur.

We expect the analysis methods used in the program to change over time. During the first five to ten years of the program, the focus will be on summary of findings for a given year across the spatial scale of the network. Comparisons to previous years will be made if data are available. Once measurements have been made over three points in time, conformance can be calculated and analyses of trend can begin. After measurements have been made for longer periods,

modeling of relationships among Vital Signs can begin, and time series or other analyses can be approached.

7.2. Reporting

Communicating the findings of the monitoring program is reporting. In this section of the Monitoring Plan, we begin by discussing general considerations about reporting and identifying general ERMN strategies about reporting. We then identify the main methods we will use for reporting to specific audiences, as well as the specific reports to be generated.

7.2.1. Reporting Monitoring Data - General Considerations

Reporting is critical to the long-term success of the ERMN Vital Signs program. Results must be credible and delivered in a timely fashion to the appropriate audiences in a manner that is understandable to them. There are multiple audiences for monitoring data produced by the ERMN Vital Signs program, and each requires information formatted and presented in specific ways. The main audience for monitoring data is the resource managers of each network park, and other managers in the National Park Service system, who will use the information to assist with their management decisions.

Although making monitoring findings available to resource managers and other audiences is the underlying reason for monitoring programs, failure to report or long delays in reporting are common problems. Sometimes the reasons for not reporting do not lie in reporting mechanisms *per se*, but are the result of problems earlier in the monitoring process (e.g., setting measurable objectives, sampling design, feasibility of carrying out the work, data management, data analysis). Thus, for the reporting end of the monitoring program to work well, all other parts of the monitoring program must also be functioning properly as part of an integrated information management system (Figure 7.1). As with data analysis, reporting is an activity that needs to be adequately funded so that reports are produced on schedule (Caughlan and Oakley 2001). Too often, reports are delayed while the next cycle of data collection takes place.

Producing reports that effectively communicate findings from the monitoring program is also critical. In this regard, increasing use of visual methods for communicating results (i.e., graphical techniques) is a key strategy. The network will work towards improving data presentations using some of the graphic techniques suggested by Tufte (1983, 1990, 1997), Cleveland (1993, 1994), and others.

7.2.2. Initial Reporting Approaches

The list of reports to be produced by the ERMN is based on national guidance, modified to reflect ERMN reporting goals (Table 7.1). For administrative reporting, the network will rely on the “Annual Administrative Report and Work Plan” required to be prepared in the fall of each year. For reporting of monitoring results, the network will use a variety of annual and periodic written reports, a proposed biennial conference for the network, and participation in other scientific forums (e.g., scientific meetings, symposia, etc.). The network will also conduct periodic program and protocol reviews.



Figure 7.1. Monitoring as an integrated information management system. The various interconnected pieces of the information management system must be designed and implemented together to ensure that scientifically sound information obtained through monitoring is available for management decision-making, research, education, and promoting public understanding of park resources. Figure adapted from the National Water Quality Monitoring Council.

As discussed in previous chapters, the ERMN has structured its Vital Signs monitoring program around broad, general ecosystem types and has focused on creating an integrated program (Figure 7.1). The vision of an integrated program will be carried through in the reporting stage by the annual production of a “State of the Parks” type report for the network. Initially, this report will be constructed from the summaries provided in the annual reports produced for each Vital Sign protocol. The report will be short and will emphasize graphical summaries of the data. We will work toward incorporating conformance measures for each Vital Sign as an initial method of integrating monitoring findings. It is anticipated that the first “State of the Parks” report will be produced in March 2009, following the first full year of program implementation.

Table 7.1. Reports to be produced by the Eastern Rivers and Mountains Network.

Type of Report (primary author)	Purpose of Report	Primary Audience	How Often?	Peer Review Process
Annual Administrative Report and Work Plan (Coordinator)	Account for funds and FTEs expended; Describe objectives, tasks, accomplishments, products of the monitoring effort; Improves communication within park, network, region, program	Superintendents, network staff, regional coordinators, and Servicewide program managers; administrative report used for annual Report to Congress	Annual; due to WASO by November 8	Review and approval by Regional Office and Servicewide Program manager
Annual Reports for each Protocol or Project (Project Leader)	Archive annual data and document monitoring activities for the year; Describe current condition of the resource and provide alert if data are outside bounds of known variation; Document changes in monitoring protocols; Communication within the park or network	Park resource managers, network staff, external scientists, students	Annual	Peer reviewed at network level
Annual Report on the “State of the Parks” for the ERMN Vital Signs Program (Project Leaders and Coordinator)	Describes current conditions of park resources; Report interesting trends and highlights of monitoring activities; Identifies situations of concern; Explores future issues and directions	Superintendents; park resource managers, network staff; external scientists; students, public	Annual	Peer reviewed at the network level
ERMN Newsletter, Fact Sheets and Brochures (Project Leaders and Coordinator)	Review and summarize network activities and findings of general interest; Provide summaries of Annual Reports and Analysis and Synthesis Reports; Describe the role and purpose of the network to non-technical audiences	Superintendents, park resource managers, network staff, Servicewide Program managers, external scientists, students	Biannual	Peer reviewed at network level
Analysis and Synthesis reports - trends (Project Leaders and Coordinator; Statistician)	Determine patterns/trends in condition of resources being monitored; Discover new characteristics of resources and correlations among resources being monitored; Analyze data to determine amount of change that can be detected by this type and level of sampling; Context - interpret data for the park within a multi-park, regional or national context; Recommend changes to management of resources (feedback for adaptive management)	Superintendents, park resource managers, network staff, external scientists, students	3–5 year intervals for resources sampled annually	Peer reviewed at network level
Program and Protocol Review reports (Project Lead)	Periodic formal reviews of operations and results (5 year intervals); Review protocol design and products to determine if changes needed; Part of quality assurance - peer review process	Superintendents, park resource managers, network staff, Servicewide program managers, external scientists	5 year intervals	Peer reviewed at regional or national level
Scientific journal articles and book chapters (various)	Document and communicate advances in knowledge; Part of quality assurance - peer review process	External scientists, students, park resource managers, network staff	Varies	Peer reviewed by journal or book editor
ERMN Vital Signs Monitoring Summit (Project Leads and Coordinator)	Review and summarize information on ERMN Vital Signs; Helps identify emerging issues and generate new ideas	Park resource managers, network staff, external scientists, students	Biennial; TBD	Peer reviewed at the network level

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Type of Report (primary author)	Purpose of Report	Primary Audience	How Often?	Peer Review Process
Other symposia, conferences, and workshops (Project Leads and Coordinator)	Review and summarize information on a specific topic or subject area; Communication of latest findings with peers; Helps identify emerging issues and generate new ideas;	Park resource managers, network staff, external scientists	Varies	May be peer reviewed by editor if written papers are published
ERMN contributes to the national “State of the Parks” Report (Project Leads and Coordinator)	Describes current conditions of park resources; Report interesting trends and highlights of monitoring activities; Identifies situations of concern; Explores future issues and directions	Congress, budget office, NPS Leadership, superintendents, general public	Annual	Peer reviewed at the national level
ERMN Website and web-based media (Project Leads and Coordinator)	Centralized repository of all final reports to ensure products are easily accessible in commonly-used electronic formats	Superintendents, park resource managers, network staff, Servicewide Program managers, external scientists	Variable: posted after reports are completed	Only reviewed, finalized products will be posted

Chapter 8 Administration and Implementation of the Monitoring Program

This chapter describes the plan for administering the ERMN monitoring program. In this chapter, we describe the makeup of the Board of Directors and Science Advisory Committee and the decision-making process of the network; the tentative staffing plan; how network operations are integrated with other park operations; key partnerships; and the periodic review process for the program.

8.1. I&M Guidance

The Inventory and Monitoring (I&M) program receives guidance from both network and national levels. National guidance and direction is provided by the Associate Director of Natural Resources (ADNR), Inventory and Monitoring Advisory Council (IMAC), and the Natural Resources Program Center (NRPC) Office of Inventory, Monitoring, and Evaluation. At the network level, the Board of Directors (BOD) provides administrative and budgetary guidance and approval, while the Science Advisory Committee (SAC) provides technical guidance on the development and implementation of the monitoring plan (Figure 8.1).

8.1.1. Associate Director of Natural Resources, Inventory and Monitoring Advisory Council, and Natural Resource Program Center

The ADNR is directed to implement the National I&M program. The IMAC meets twice a year to make recommendations to the ADNR and resolve issues affecting all networks. The IMAC has two representatives from each region of the National Park Service (NPS) including the regional I&M Coordinator and one other person selected by the region. In addition, the IMAC is regularly attended by staff from the NRPC which is charged with providing guidance, vision, and technical support to implement the network I&M programs. The NRPC also provides day-to-day guidance, policy interpretation, and technical assistance to the ERMN program.

8.1.2. Board of Directors

The ERMN program is guided by the BOD. The BOD is composed of a superintendent or their designee from each park in the ERMN (Table 8.1), the NPS Northeast Region (NER) Chief Scientist, and the NER I&M Regional Coordinator. The BOD meets at least annually and approves the Annual Administrative Report and Work Plan (AARWP) and also approves decisions regarding budget, staffing, and project implementation. Their work is guided by a charter (Supplemental Document 31). A key feature of the charter governing the ERMN BOD decision-making is that all decisions are made by consensus. Membership periodically changes as staff changes occur in the parks; current membership is reported in the most recent AARWP. The most critical function of the BOD is to ensure that the monitoring program becomes integrated into the day-to-day activities of park planning and management including maintenance, interpretation, resource protection, and resource management.

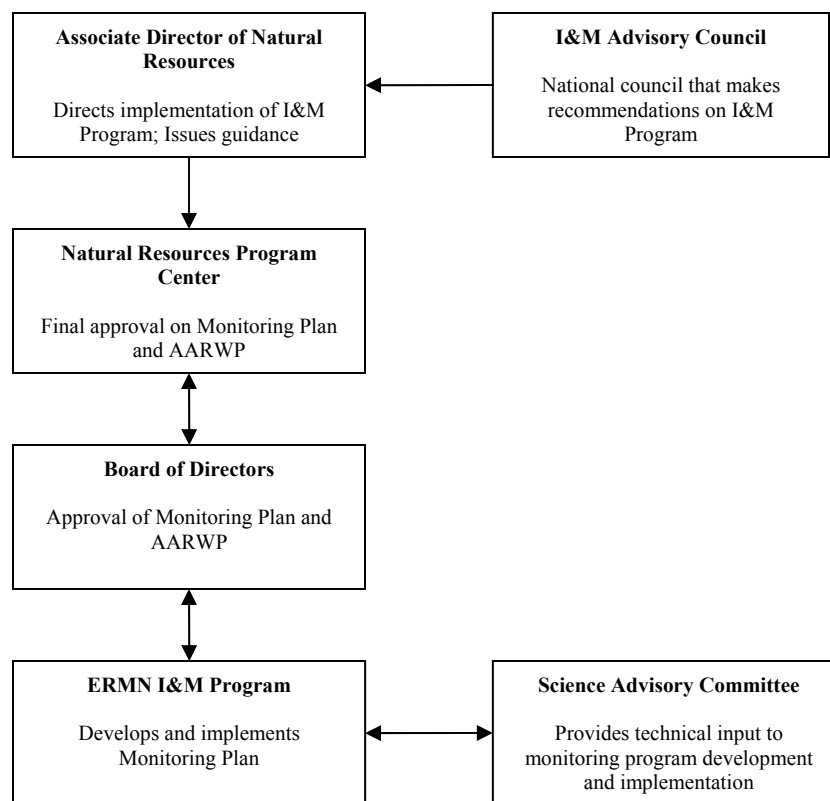


Figure 8.1. Relation of ADNR, IMAC, NRPC, BOD, and SAC with ERMN I&M.

Table 8.1. Eastern Rivers and Mountains Network Board of Directors membership at time of writing (August 2007).

Park	Title	Name
DEWA	Superintendent	John Donahue
UPDE	Superintendent	Dave Forney
ALPO, JOFL	Superintendent	Keith Newlin
FONE, FRHI	Superintendent	Jeff Reinbold (Acting)
NERI, GARI, BLUE	Superintendent	Don Striker
Northeast Region NPS	Chief Scientist	John Karish
Northeast Region NPS	I&M Regional Coordinator	Beth Johnson

8.1.3. Science Advisory Committee

The SAC was established by the ERMN Coordinator and approved by the BOD in order to provide technical guidance throughout the monitoring program planning and implementation process. The SAC meets at least annually (and additionally when their input is needed from the I&M staff) and is composed only of federal employees to comply with the Federal Advisory Committee Act. Participants include representatives from the resource management division of ERMN parks, NPS NER hydrologist, chief scientist, and I&M Coordinator, and employees from partner agencies (Table 8.2) including the U.S. Geological Survey. Subject matter experts (Table 8.3) are regularly brought in to share their knowledge on specific topics. The subject matter experts typically represent local universities, partnering agencies, and state or local government agencies. Current composition of the SAC is listed in the most recent AARWP.

8.2. Staffing

8.2.1. Network Program Location

The ERMN I&M Program is based at The Pennsylvania State University and housed within the University's School of Forest Resources. ERMN staff are duty stationed with additional NPS personnel including the Northeast Region's Chief Scientist, Integrated Pest Management Specialist, Wildlife Biologist, and Air Quality Specialist. The ERMN provides annual financial support to the School for telephone service, supplies such as copy services, and administrative support. It is envisioned that additional core ERMN staff will also be located at Pennsylvania State University (PSU). PSU offers a vast and renowned scientific community for the ERMN to interact and is also the geographic center of the network, facilitating efficiencies in travel and communication.

8.2.2. ERMN Staff

The ERMN I&M program is directed and supervised by the ERMN Coordinator with oversight by the NER Regional I&M Coordinator. The core network staff currently consists of two permanent positions including the network Coordinator and Data Manager. The core functions are currently augmented by expertise (Botanist/Database Support; Database Developer; and Statistician) via cooperative agreements with The Pennsylvania State University and The Virginia Polytechnic and State University. Various university and NPS regional staff also provide technical and administrative assistance to the program.

The ERMN's long-term staffing needs will be indeterminate for several more months as we learn more about costs and personnel requirements needed for the proposed monitoring protocols. We propose and describe below a "best estimate" staffing plan (Figure 8.2) based on the belief that a centralized staff made up of core, permanent, professional staff, coupled with seasonal/temporary employees would be the most productive, efficient, and cost-effective model. It is important to note that new positions in the plan are not yet approved and any new position must be approved by the BOD and Northeast Region. Short descriptions of these positions and their primary functions follow:

Table 8.2. Eastern Rivers and Mountains Network Science Advisory Committee membership at time of writing (August 2007).

Park/Agency	Title	Name
ERMN	Network Coordinator	Matt Marshall
Northeast Region NPS	Regional Hydrologist	Alan Ellsworth
Northeast Region NPS	Chief Scientist	John Karish
Northeast Region NPS	I&M Regional Coordinator	Beth Johnson
DEWA	Ecologist	Richard Evans
NERI GARI BLUE	Aquatic Ecologist	Jesse Purvis
USGS	PA COOP Unit Leader	Duane Diefenbach
USGS	Research Ecologist	Dave Smith

Table 8.3. Eastern Rivers and Mountains Network Subject Matter Experts (last updated August 2007).

Agency/University	Specialty	Name
The Pennsylvania State University	Landscape Ecology	Alan Taylor
The Pennsylvania State University	Ecology and Mammalogy	Carolyn Mahan
West Virginia University	Forest Ecology	Ray Hicks
Western Pennsylvania Conservancy	Plant Ecology	Greg Podniesinski

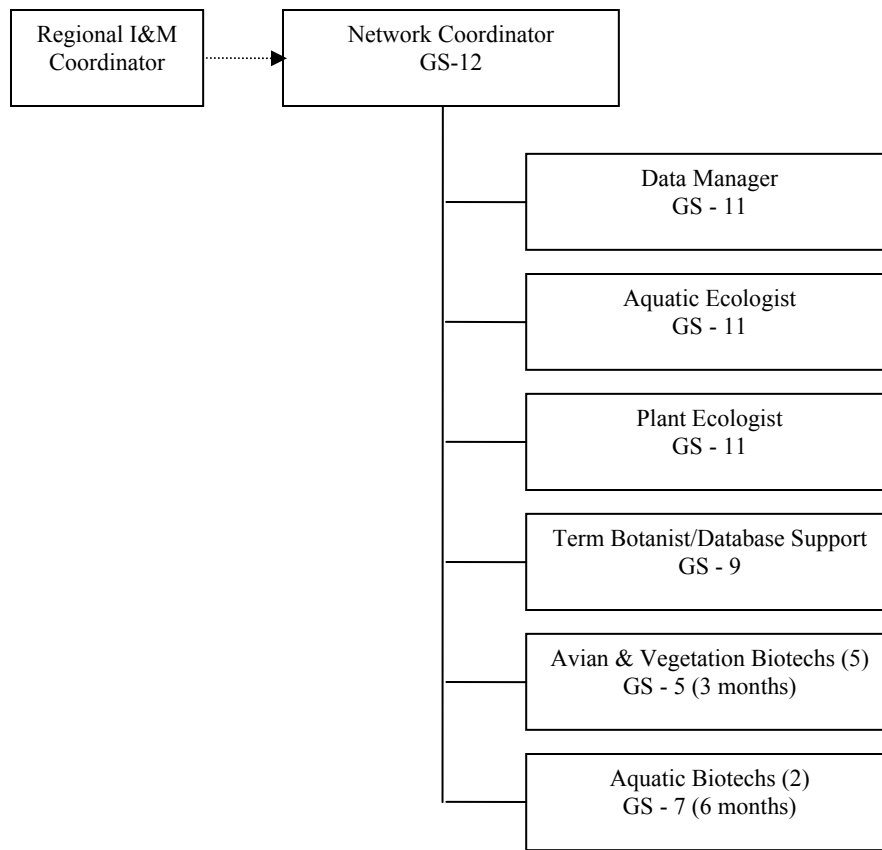


Figure 8.2. Proposed organizational chart for the Eastern Rivers and Mountains Network I&M program.

Coordinator (GS-12) - The network Coordinator provides the overall direction and guidance for the ERMN I&M program and also develops and oversees the implementation of the Monitoring Plan. The Coordinator acts as the liaison between ERMN staff and network parks, SAC, BOD, and the NER Regional I&M Coordinator. The Coordinator supervises the ERMN professional level positions and provides general oversight and accountability for the network program. It is also proposed that the Coordinator be the project lead on the Louisiana waterthrush monitoring program. This includes project-specific planning, execution, data analysis and reporting, and ensuring that information is provided to park managers in useful formats. The Coordinator will also be the point of contact for the NPS Air Resource Division and the Pennsylvania State Climatologist's Office on annual reporting of Air Quality and Weather and Climate protocols, respectively.

Data Manager (GS-11) - The data manager is responsible for the development, management, coordination, and implementation of natural resource information systems, including databases, data archives, and Geographic Information System (GIS). Responsibilities include creating new databases consistent with NPS standards, quality assurance/quality control (QA/QC) for new data, and generating metadata that is Federal Geographic Data Committee (FGDC) compliant. This position also assists project leads to make data accessible to parks by summarizing data and generating standard reports as identified by protocols, and shares data through the Internet or other media. It is also proposed that the Data Manager be the project lead on the Landscape Dynamics monitoring program.

Aquatic Ecologist (GS-11) - The aquatic ecologist will be the project lead for both the water quality and quantity as well as the aquatic macroinvertebrate monitoring programs. This includes planning yearly budgets and work schedules, executing data collection, analysis and reporting, and generally ensuring that monitoring objectives are met and results are routinely provided to park managers to aid in decision-making and are also made available to relevant NPS and professional audiences.

Plant Ecologist (GS-11) - The plant ecologist will be the project lead for the general vegetation monitoring program as well as monitoring of rare, riparian plant communities. This includes planning yearly budgets and work schedules, executing data collection, analysis and reporting, and generally ensuring that monitoring objectives are met and results are routinely provided to park managers to aid in decision-making and are also made available to relevant NPS and professional audiences.

Botanist/Database Support (GS-9 term) - The botanist will be the project lead for the invasive species early detection program and will also assist the Plant Ecologist, as needed, in all relevant aspects of the vegetation monitoring programs with special emphasis on the herbaceous strata which requires specific and specialized botanical expertise. The botanist will also be the network lead on the population and maintenance of NPSpecies and NatureBIB databases (including training of network and park staff) and will also organize the certification of all inventory data sets.

Seasonal Avian, Vegetation, and Aquatic Macroinvertebrate Biotechs (GS-5) - These are seasonal positions typically lasting three (3) months with data collection as their primary duty. It is anticipated that five (5) seasonal biotechs will be needed (2 for the vegetation sampling; 3 for

avian monitoring). The biotechnicians will be directed by the respective project lead and will follow existing protocols to gather data, record, verify and correct data values, and to perform regular data transfer and backup. These positions also assist with dataset and procedural documentation, and are responsible for documenting any deviations from protocols or study plans.

Aquatic Biotechs (GS-7) - These are seasonal positions (6 months) with water quality monitoring data collection, equipment maintenance, and laboratory work as their primary duty. The biotechnicians will be directed by the respective project leader and will generally follow existing protocols to gather data, record, verify and correct data values, and to perform regular data transfer and backup. These positions will also assist with anticipated annual collection of aquatic macroinvertebrate data. It is proposed that the ERMN support two positions with one duty stationed at DEWA or UPDE to service these two parks, and one duty stationed at NERI to service NERI, GARI, and BLUE (the Aquatic Ecologist will be responsible for servicing ALPO, JOFL, FONE, and FRHI).

8.2.3. Park Staff

Given staffing restraints, park support is extremely limited and it is not expected/anticipated that park staff will be involved with routine data collection, management, analyses, or reporting. Park staff including resource managers, however, will play a critical role in implementing the I&M program and we anticipate that each park will be responsible for the following tasks:

- **Issue Park Permits**—Along with issuing permits, parks will be responsible for handling compliance issues.
- **Review and Approve Investigator Annual Reports (IAR)**— Parks will be responsible for reviewing IARs submitted by the I&M program or by cooperators working for the I&M program.
- **Park Access**—Parks will be responsible for ensuring, to the best of their ability, that sampling sites can be accessed.
- **Park Housing**—For parks that have housing available, parks will do their best to make housing available to field crews, as needed.
- **Field Assistance**—Parks that are interested and have staff available are encouraged to participate in field work.

8.3. Program Implementation

Each project associated with the ERMN I&M program has an assigned lead. For any contracts, cooperative agreements, or inter-agency agreements, the official lead is the Key Official. Some projects may also have a project leader who oversees the day-to-day project oversight but works under the guidance of the key official.

8.3.1. Key Official

The key official is the Contracting Officer's Technical Representative (COTR) who signs all agreements and is ultimately responsible for the execution and administration of projects that fall under the scope of an agreement. The agreements may include contracts, cooperative agreements, or interagency agreements.

8.3.2. Project Lead

The project lead provides day-to-day oversight on any inventory and monitoring project. Project leads can be either network, park, or regional staff, but will typically be network staff. The project lead coordinates and supervises all phases of data collection, data entry, verification and validation, as well as data summary, analysis, and reporting. They also create the documentation and criteria needed to properly use and interpret the data. As such, this person is the primary point of contact for information about the project. Their active involvement determines the quality of the project and the overall success of our inventory and monitoring program.

Specifically, a project lead's role is to:

- Complete project documentation describing the “who, what, where, when, why, and how” of a project.
- Coordinate field data collection with parks and principal investigators, including training of any field help and biotechs.
- Maintain concise explanatory documentation of all deviations from standard procedures.
- Ensure documentation of important details of each field data collection period.
- Ensure proper records management, including archiving.
- Ensure adherence to protocol procedures, including timeline for data collection periods, data processing target dates, and reporting deadlines.
- Produce or collect annual reports and final reports.
- Provide summary reports for outreach communications. Coordinate data management and archiving with data manager.
- Oversee periodic trend analysis of data, store the resulting reports, and make them available to users.
- Increase the interpretability and accessibility of existing natural resource information.
- Act as the main point of contact concerning the project.

For most projects the key official and project lead may be the same person. If a specific technical background is needed to manage a project, the key official may assign a project manager. It is, however, still the key official's responsibility that the project is appropriately implemented.

8.4. Partnerships

Several partnerships are already in place to accomplish some components of the monitoring program. Protocols, for example, are being developed through partnerships with the University of Georgia, The Pennsylvania State University (School for Forest Resources; Department of Meteorology and the State Climatologist's office), USGS Leetown Science Center, and USGS NY Water Science Center. Data collection for the air vital signs is already being conducted by various agencies, including National Oceanic and Atmospheric Administration (NOAA) and the U.S. Environmental Protection Agency (EPA) through their CASTNet and NADP programs. Due to the iterative process used in developing the program, we will continue to enlist more partners as our protocol development continues.

8.5. Periodic Program and Protocol Review

We have developed an all-encompassing review process (Table 8.4) to evaluate the myriad facets of the program. On an annual basis, the Annual Administrative Report and Work Plan (AARWP) provides the ERMN parks and BOD with an opportunity to review what has taken place and what is planned. This provides an annual opportunity to review and evaluate the program. What we must ensure is that evaluation takes place at this juncture, and that we do not adopt a mindset of 'business as usual.' This will be particularly important during the next two- to four-year period as the actual monitoring of vital signs and operation of the program are established.

Table 8.4. Summary of periodic program reports and reviews.

Review	Timing	Who is Involved	Intent of Review
Annual Administrative Report and Work Plan	Annual	Regional Coordinator, I&M Staff, Park Staff, BOD, NRPC	Provide yearly accountability for program. Report on accomplishments and explain goals and projects for next fiscal year.
Report to Science Advisory Committee	Biannual	Regional Coordinator, I&M Staff, BOD, SAC, Park Staff	Provide technical details on results and status of all data collection within program. Evaluate if goals are being met appropriately and if focus of program is consistent with goals. Also evaluate if operations of program are working in concert with other aspects of program.
Three Year Program Review		National Monitoring Program Leader, Regional Coordinator, I&M Staff, Anonymous Reviewers	The review will focus on the operational and administrative aspects of the network's monitoring program (this is not a technical review), and will ask the basic question "Is the network set up to succeed?"

Our second level of review for the program will take the form of our biannual updates to the SAC. This will be a day-long symposium at which all I&M staff and cooperators conducting any portion of the program will give a technical presentation on results and the status of the work they are conducting. The symposium will include a discussion of the presentations to evaluate the merit of the work scientifically and operationally. The results and decisions from this review will be codified by subsequent presentation to the BOD for their endorsement.

Finally, our third level of review will be in the form of a 3-year program review. Each I&M network will undergo a “Start-up Review” within three years after their monitoring plan is accepted and implemented. The review will focus on the operational and administrative aspects of the network’s monitoring program (this is not a technical review), and will ask the basic question “Is the network set up to succeed?” The review will allow Network and park staff to step back and evaluate their initial progress against the objectives and schedule set forth in the Network’s monitoring plan, to develop a “road map” for completing and implementing the first set of protocols, and to make adjustments if needed.

Peer Review—Each protocol will be reviewed after five years of data are available. The review will be performed by subject matter experts who are not involved in the data collection but who analyze data and make recommendations to protocols, including all aspects of the standard operating procedures. Recommendations will be presented to the I&M staff, SAC, and the BOD for review.

Program Review—Every three to five years, the SAC will meet to hear a series of technical presentations from the I&M staff and discuss what we have learned from the data collected and its relevance to park management. Vital signs will be reviewed to make sure that they are still priorities. Data management will be reviewed to ensure that standards continue to be met and are adequate. The annual budgets and staffing plan will be revised if needed. All recommendations will be presented to the Regional Coordinator and the BOD for review.

8.6. Integration of Program with Park Operations

The ERMN I&M program has made a commitment to implement long-term monitoring, analyze data, and report findings to various audiences in the parks, including resource management, park administration, and interpretation. Integrating science into park management, however, is more complex than simply reporting results. The ERMN I&M Program will work diligently to ensure that all science products, including those from the long-term monitoring program, are fully integrated and used by park management. The integration strategy consists of a four-pronged approach that emphasizes: (1) technical assistance, (2) coordination, (3) communication, and (4) data sharing. As part of the five-year review, I&M will analyze how well I&M integration strategy works to meet park needs and how well I&M products have been used by park management.

Technical Assistance: Given the current and anticipated scientific and technical expertise within the I&M program, there are many opportunities to provide technical assistance to the parks. Technical assistance will be offered to parks in order to help:

- Identify clear objectives for research, monitoring, or management. Prioritize projects, solicit funding, and implement park projects.
- Support park planning efforts, including development of Resource Stewardship Strategies (RSS), General Management Plans (GMP), Fire Management Plans (FMP), and compliance needs
- Review data collected in parks and provide support for analysis and reporting results.

Coordination: The ERMN will closely coordinate implementation of the monitoring program with parks. Emphasis will be placed on coordinating field work with resource managers and coordinating and reviewing inventory and monitoring research permits.

Communication: Results from the monitoring program must be communicated in a timely manner and must be upheld to the rigorous scientific standards. In order to enhance communication, the I&M program will provide both oral and written communications to a variety of audiences. The I&M program will be generating a variety of reports including annual reporting such as the AARWP and State of the Parks report cards. See Chapters 6 and 7 for details on reporting and analysis. In addition, the I&M Program has made it a priority to develop outreach and education products such as fact sheets, brochures, or other products in order to promote the results and findings of long-term monitoring.

Data Sharing: Coordinate data sharing through regionally accessible online databases.

Chapter 9 Monitoring Schedule

This chapter describes the schedule for implementing the ERMN Vital Signs Monitoring program. For the protocols under development in the next two- to four-years ($n = 9$ protocols covering all 13 priority vital signs), we describe the key tasks or issues that must be addressed for each (Table 9.1). In FY08, the network plans to initiate monitoring of six protocols (covering 10 priority vital signs) with the remaining three vital signs/protocols ready for implementation in FY10; an annual schedule of the frequency and timing of sampling for the FY08 vital signs and the anticipated schedule for the remaining vital signs is shown in Table 9.2.

9.1 Establishing Protocols for Vital Signs

In Table 9.1 we describe key issues that must be addressed in establishing protocols for each of the 13 vital signs. For some vital signs this may simply entail some coordination with an entity already collecting data we want (e.g., air quality parameters). For others this will require a more detailed scoping of the vital sign, pilot data collection efforts, and/or determining analysis methods for the data (e.g., vegetation monitoring and most other protocols).

9.2 Sampling Schedule

Table 9.2 depicts the frequency and timing of sampling. While some data will be collected continuously (e.g., air quality and climate data), other data will likely be collected for several weeks at one time of year (e.g., macroinvertebrates).

Table 9.1. Schedule for development and completion of Eastern Rivers and Mountains Network monitoring protocols for 13 priority vital signs. More detail can be found in Chapter 5.

Vital Sign Name	Target year for protocol completion and implementation	Key issues to be addressed before implementation
Air Quality	FY 2008	The protocol outlining data management, analysis, and reporting is being developed by the NPS Air Resource Division.
Weather and Climate	FY 2008	A protocol outlining data management, analysis, and reporting is being developed by the Pennsylvania State Climatologist.
Soil Function and Dynamics	FY 2008	This vital sign is part of the Forest, woodland, Shrubland, and Riparian Vegetation monitoring protocol development. A protocol is being developed by the Pennsylvania State University with pilot work completed during summer 2007.
Surface Water Hydrology	FY 2008	This vital sign is part of the Water Quality and Quantity monitoring protocol development. A protocol is being developed by the USGS and Pennsylvania State University with pilot work completed during summer 2007. A workshop to discuss protocol development occurred on January 10–11, 2007 at Penn State University.
Water Chemistry - Core	FY 2008	This vital sign is part of the Water Quality and Quantity monitoring protocol development. A protocol is being developed by the USGS and Pennsylvania State University with pilot work completed during summer 2007. A workshop to discuss protocol development occurred on January 10–11, 2007 at Penn State University.
Water Chemistry - Expanded	FY 2008	This vital sign is part of the Water Quality and Quantity monitoring protocol development. A protocol is being developed by the USGS and Pennsylvania State University with pilot work completed during summer 2007. A workshop to discuss protocol development occurred on January 10–11, 2007 at Penn State University.
Aquatic macroinvertebrates	FY 2010	Protocol development will begin FY 2008 through a cooperative agreement with Pennsylvania State University. Additional protocol development support will come from the NPS/USGS status and trends program to develop macroinvertebrate ecological thresholds and management trigger points awarded to USGS Leetown Science Center in collaboration with the ERMN and MIDN.
Invasive/Exotic Plants, Animals and Diseases - Status and Trends	FY 2008	The invasive plant portion of this vital sign is part of the Forest, woodland, Shrubland, and Riparian Vegetation monitoring protocol development. A protocol is being developed by the Pennsylvania State University with pilot work completed during summer 2007.
Invasive/Exotic Plants, Animals and Diseases - Early Detection	FY 2008	A protocol is being developed by the Pennsylvania State University and should be ready for pilot work during summer 2008. An ERMN workshop to review and discuss this protocol will occur prior to pilot implementation.
Forest, woodland, shrubland, and riparian plant communities	FY 2008	A protocol is being developed by the Pennsylvania State University with pilot work completed during summer 2007.
Rare, riparian plant communities	FY 2010	Conceptual ecological models are being developed and will be available in FY 2008. It is anticipated that review and discussion of these models will lead to the development of clear monitoring objectives for these communities. A cooperator will then be solicited to develop a monitoring protocol.
Louisiana waterthrush	FY 2008	A protocol is being developed by the University of Georgia with pilot field work completed summer 2007.
Landscape Dynamics	FY 2010	Partial protocol development has begun for this vital sign (e.g., socio-economic indicators) and the ERMN is part of a large collaborative project funded by NASA projected to start in January 2007. The ERMN is also developing related projects for additional protocol development with anticipated funding in FY08.

Table 9.2. Anticipated annual schedule of Eastern Rivers and Mountains Network vital signs data collection.

Vital Sign Name	Sample type/interval	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Nov	Dec	Jan
Air Quality	Variable/continuous												
Weather and Climate	Variable/continuous												
Soil Function and Dynamics	Summer												
Surface Water Hydrology	Monthly/continuous												
Water Chemistry - Core	Monthly/continuous												
Water Chemistry - Expanded	Monthly/continuous												
Aquatic macroinvertebrates	Summer/Fall												
Invasive/Exotic Plants, Animals and Diseases - Status and Trends	Summer												
Invasive/Exotic Plants, Animals and Diseases - Early Detection	Continuous												
Forest, woodland, shrubland, and riparian plant communities	Spring - Fall												
Rare, riparian plant communities	TBD												
Louisiana waterthrush	Spring												
Landscape Dynamics	TBD												

Chapter 10 Budget

In this chapter we present the budget for the ERMN monitoring program during the first year of operation after review/approval of our plan. We anticipate this will be Fiscal Year (FY) 2008.

We first show the network budget by the same expense categories networks use in preparing the Annual Administrative Report and Work Plans that are submitted to WASO (Table 10.1). In Table 10.2 we show the same budget but with more detail, including our projections for network resources devoted to information management. The ERMN receives \$659,100 from the National Park Service Servicewide Inventory and Monitoring Vital Signs program and \$63,000 from the NPS Water Resources Division annually.

During our first year of implementation we anticipate allocating 52% (\$375,672) of the budget to core, permanent personnel. An additional 11% (\$80,094) will be allocated to seasonal biological technicians.

Travel costs constitute 7% of the budget, which is comparable to other I&M networks, while Equipment/Operations (Penn State support costs, initial vehicle purchases, field equipment, computer replacements, software, etc.) comprise 10% of the budget. To accomplish key portions of the monitoring program the network will establish Task Agreements via a Cooperative Ecosystems Studies Unit (CESU) or other entity. These projected agreements will comprise 13% (\$92,500) during the first year of the monitoring program and include agreements with the Pennsylvania State Climatologist's Office for weather and climate monitoring and estimated costs for water quality and soil chemistry laboratory analyses. Future agreements will likely include the purchase of aerial photography or satellite imagery as part of the landscape dynamics protocol.

Guidelines for developing a monitoring program suggest that approximately 30% of the budget should be allocated to information/data management so that information is not lost, results are communicated, and adequate reporting takes place. In Table 10.2 we provide the percent of time that each network position devotes to information/data management. The total estimated personnel budget dedicated to data management is 28% (\$203,662). We also include anticipated costs for hardware and software to manage and make information available.

Table 10.1. Anticipated budget for the Eastern Rivers and Mountains Network vital signs monitoring program for FY08.

Income	FY08
Vital Signs Monitoring	\$659,100
Water Quality Monitoring	\$63,000
Subtotal	\$722,100
Expenditures	FY08
Personnel - permanent (52%)	\$375,672
Personnel - seasonal (11%)	\$80,094
Travel (7%)	\$47,000
Operations/Equipment (10%)	\$74,442
Agreements (13%)	\$92,500
Other Projects (7%)	\$52,392
Subtotal	\$722,100

Table 10.2 Detailed budget for the Eastern Rivers and Mountains Network vital signs monitoring program during its first full year of implementation FY08.

Income		Percent of Time Dedicated to Information Management	Amount Dedicated to Information Management
Vital Signs Monitoring	\$659,100		
Water Quality Monitoring	\$63,000		
Subtotal	\$722,100		
Expenditures (Year-round Staff)			
Coordinator (GS-12)	\$96,269	20	\$19,254
Data Manager (GS-11)	\$73,018	90	\$65,716
Aquatic Ecologist (GS-11)	\$73,018	40	\$29,207
Plant Ecologist (GS-11)	\$73,018	40	\$29,207
Botanist/Database Support (GS-9 term)	\$60,349	60	\$36,210
Subtotal	\$375,672		
Expenditures (Seasonal Staff)			
Vegetation Biotech 1 (GS-5) 3 months	\$8,153	30	\$2,446
Vegetation Biotech 2 (GS-5) 3 months	\$8,153	30	\$2,446
Avian Biotech 1 (GS-5) 3 months	\$8,153	30	\$2,446
Avian Biotech 2 (GS-5) 3 months	\$8,153	30	\$2,446
Avian Biotech 3 (GS-5) 3 months	\$8,153	30	\$2,446
Aquatic Biotech 1 (GS-7) 6 months	\$19,664	30	\$5,899
Aquatic Biotech 2 (GS-7) 6 months	\$19,664	30	\$5,899
Subtotal	\$80,094		
Expenditures (Operations and Equipment)			
Software and computers	\$5,000		
Field supplies	\$10,000		
Penn State office support	\$15,000		
Other (2%)	\$14,442		
Initial vehicle purchase	\$30,000		
Subtotal	\$74,442		
Expenditures (Travel - estimated 5%)			
Field work and vehicle maintenance	\$35,000		
Meetings and conferences	\$12,000		
Subtotal	\$47,000		
Expenditures (Cooperative Agreements, Contracts, and Inter-Agency Agreements)			
Water lab analyses	\$60,000		
Soil lab analyses	\$15,000		
Penn State Climate Office	\$15,000		
Report formatting, certification, etc.	\$2,500		
Subtotal	\$92,500		
Other Projects	\$52,392		
Subtotal	\$144,892		
Total	\$722,100		

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Glossary

Adaptive Management: A systematic process for continually improving management policies and practices by learning from the outcomes of operational programs. Its most effective form—“active” adaptive management—employs management programs that are designed to experimentally compare selected policies or practices, by implementing management actions explicitly designed to generate information useful for evaluating alternative hypotheses about the system being managed.

Area Frame: A sampling frame that is designated by geographical boundaries within which the sampling units are defined as subareas.

Attributes: Any living or nonliving feature or process of the environment that can be measured or estimated and that provides insights into the state of the ecosystem. The term Indicator is reserved for a subset of attributes that is particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003). See Indicator.

Biological Significance: An important finding from a biological point of view that may or may not pass a test of statistical significance.

Co-location: Sampling of the same physical units in multiple monitoring protocols.

Conceptual Models: Purposeful representations of reality that provide a mental picture of how something works to communicate that explanation to others.

Driver: The major external driving forces that have large-scale influences on natural systems. Drivers can be natural forces or anthropogenic.

Ecological Integrity: A concept that expresses the degree to which the physical, chemical, and biological components (including composition, structure, and process) of an ecosystem and their relationships are present, functioning, and capable of self-renewal. Ecological integrity implies the presence of appropriate species, populations, and communities, and the occurrence of ecological processes at appropriate rates and scales, as well as the environmental conditions that support these taxa and processes.

Ecosystem: Defined as, “a spatially explicit unit of the Earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries” (Likens 1992).

Ecosystem Drivers: Major external driving forces, such as climate, fire cycles, biological invasions, hydrologic cycles, and natural disturbance events (e.g., earthquakes, droughts, floods), that have large-scale influences on natural systems.

Ecosystem Management: The process of land-use decision making and land-management practice that takes into account the full suite of organisms and processes that characterize and comprise the ecosystem. It is based on the best understanding currently available as to how the ecosystem works. Ecosystem management includes a primary goal to sustain ecosystem structure and function, a recognition that ecosystems are spatially and temporally dynamic, and acceptance of the dictum that ecosystem function depends on ecosystem structure and diversity. The whole-system focus of ecosystem management implies coordinated land-use decisions.

Focal Resources: Park resources that, by virtue of their special protection, public appeal, or other management significance, have paramount importance for monitoring regardless of current threats or whether they would be monitored as an indication of ecosystem integrity. Focal resources might include ecological processes such as deposition rates of nitrates and sulfates in certain parks, or they may be a species that is harvested, endemic, alien, or has protected status.

Indicators: A subset of monitoring attributes that are particularly information-rich in the sense that their values are somehow indicative of the quality, health, or integrity of the larger ecological system to which they belong (Noon 2003). Indicators are a selected subset of the physical, chemical, and biological elements and processes of natural systems that are selected to represent the overall health or condition of the system.

Inventory: An extensive point-in-time survey to determine the presence/absence, location or condition of a biotic or abiotic resource.

Measures: Specific feature(s) used to quantify an indicator, as specified in a sampling protocol. For example, pH, temperature, dissolved oxygen, and specific conductivity are all measures of water chemistry.

Metadata: Data about data. Metadata describes the content, quality, condition, and other characteristics of data. Its purpose is to help organize and maintain an organization's internal investment in spatial data, provide information about an organization's data holdings to data catalogues, clearinghouses, and brokerages, and provide information to process and interpret data received through a transfer from an external source.

Monitoring: Collection and analysis of repeated observations or measurements to evaluate changes in condition and progress toward meeting a management objective (Elzinga et al. 1998). Detection of a change or trend may trigger a management action, or it may generate a new line of inquiry. Monitoring is often done by sampling the same sites over time, and these sites may be a subset of the sites sampled for the initial inventory.

Protocols: As used by this program, are detailed study plans that explain how data are to be collected, managed, analyzed, and reported and are a key component of quality assurance for natural resource monitoring programs (Oakley et al. 2003).

Stressors: Physical, chemical, or biological perturbations to a system that are either (a) foreign to that system or (b) natural to the system but applied at an excessive [or deficient] level (Barrett et al. 1976:192). Stressors cause significant changes in the ecological components, patterns, and processes in natural systems. Examples include water withdrawal, pesticide use, timber harvesting, traffic emissions, stream acidification, trampling, poaching, land-use change, and air pollution.

Trend: As used by this program, refers to directional change measured in resources by monitoring their condition over time. Trends can be measured by examining individual change (change experienced by individual sample units) or by examining net change (change in mean response of all sample units).

Vital Signs: Are a subset of physical, chemical, and biological elements and processes of park ecosystems that are selected to represent the overall health or condition of park resources, known or hypothesized effects of stressors, or elements that have important human values. The elements and processes that are monitored are a subset of the total suite of natural resources that park managers are directed to preserve “unimpaired for future generations,” including water, air, geological resources, plants and animals, and the various ecological, biological, and physical processes that act on those resources. Vital signs may occur at any level of organization, including landscape, community, population, or genetic level, and may be compositional (referring to the variety of elements in the system), structural (referring to the organization or pattern of the system), or functional (referring to ecological processes).

The Department of the Interior protects and manages the nation's natural resources and cultural heritage; provides scientific and other information about those resources; and honors its special responsibilities to American Indians, Alaska Natives, and affiliated Island Communities.

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