Inventory & Monitoring

National Park Service
U.S. Department of the Interior

Devils Postpile National Monument
Sequoia & Kings Canyon National Parks
Yosemite National Park

Sierra Nevada Network: Vital Signs Monitoring Plan

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Executive Summary

Chapter 1: Introduction and Background

The Sierra Nevada Network (SIEN), named after the mountain range in which these parks are located, comprises four park units:

- Devils Postpile National Monument
- Kings Canyon National Park
- Sequoia National Park
- Yosemite National Park

Collectively, these four park units contain 657,980 hectares—89 percent of which is designated Wilderness. Sequoia and Kings Canyon National Parks share a common border and are administered and managed jointly under one superintendent.

The mission of the Sierra Nevada Network is to develop and implement ecological monitoring under the National Park Service (NPS) Vital Signs Monitoring program. The focus of the SIEN program will be to monitor ecosystems and biotic elements to detect long-term change in ecological condition. The most significant stressors affecting Sierra Nevada ecosystems are: (1) altered fire regimes, (2) non-native invasive species, (3) air pollution, (4) habitat fragmentation, and (5) rapid anthropogenic climatic change. Many additional, more localized, stressors present significant management issues. These are summarized in this monitoring plan.

Because of the critical importance of Sierra Nevada water resources (both within our Network and to the region), the potential for climate change to alter hydrologic processes, and the national NPS Water Resources Division program to establish water quality monitoring in all networks, SIEN has placed particular emphasis on summarizing and evaluating existing information on water resources. Water quality monitoring is fully integrated within the SIEN monitoring program.

Companion Appendix A, "*Legislation*", Appendix B "*Parks and Ecosystems*", Appendix C, "*Air Resources*", Appendix D "*Water Resources*", and Appendix E "*Network Monitoring*" provide additional information and detail.

Chapter 2: Conceptual Models

SIEN has developed conceptual models to guide the development of the monitoring program. We use overview models to (1) highlight the ecosystem factors that interact with processes to structure the physical environment and its biotic communities, (2) illustrate inputs and outputs that affect the Sierra Nevada landscapes, (3) emphasize the most important stressors for the Sierra Nevada and their interactions, and (4) highlight the focal systems and processes we target for monitoring. More specific, detailed conceptual models focus on our vital signs

Companion Appendix F, "*Conceptual Models*", provides additional information and detail.

Chapter 3: Vital Signs

SIEN presents a list of 34 vital signs, representing a balance of ecosystem driving variables (e.g., weather, climate) and response variables (communities and species). These vital signs provide a focus for monitoring at different spatial and temporal scales, and they represent a mix of sensitive and early indicators with slower responding, integrative indicators. Although we realize it will not be possible to monitor all of these vital signs in the immediate future, they do represent a powerful and balanced guide for developing an integrated long term monitoring program. SIEN's science committee has identified 13 vital signs for which monitoring protocols are being developed:

- Weather & Climate
- Snowpack
- Surface water dynamics
- Water chemistry
- Non-native invasive Plants
- Forest stand population dynamics
- Landscape mosaics
- Fire Regimes
- Wetland water dynamics
- Wetland plant communities
- Wetland macro-invertebrates
- Amphibians
- Birds

Because funds are limited, we will strive to achieve monitoring of this subgroup through co-location and integration.

Companion Appendix G, "*Vital Signs*", provides additional information and detail.

Chapter 4: Sampling Design

The costs, benefits, and tradeoffs of sampling–particularly in SIEN ecosystems–are described in Chapter 4. Primarily, the use of survey/extensive sites (stratified random, spatially balanced)–enhanced by co-location and integration, and minimal index/sentinel sites (judgment-based), will be used by SIEN for vital signs' monitoring. Because of our extensive and logistically challenging landscapes, cost-benefit analyses will be applied to all vital signs to determine the appropriate target population(s). Protocol Development Summaries (comprising 13 vital signs) appear in Appendix H, including brief narratives on sample design decisions.

We include excerpts from the current sample design component of our Lake Monitoring Protocol (Heard et al., in prep) as an example of the level of thought and detail our monitoring protocols will contain.

Chapter 5: Monitoring Protocols

SIEN has created workgroups (for each protocol) whose purpose is to refine vital signs monitoring objectives, develop opportunities and methods for integration; workgroups are primarily composed of SIEN, SEKI, YOSE, and USGS-BRD staff, including subject-matter experts. A timeline for protocol development is included. Protocol Development

Summaries in Appendix H explain why the vital sign was selected as an "indicator of ecosystem condition", our monitoring objectives, and describes our general approach for monitoring protocol development, including sampling design.

As above (Chapter 4), we include excerpts from the current monitoring questions and objectives component of our Lake Monitoring Protocol (Heard et al., in prep) as an example of the level of thought and detail our monitoring protocols will contain.

Companion Appendix H, "*Protocol Development Summaries*", provides additional information and detail.

Chapter 6: Data Management

The Data Management Plan for the Sierra Nevada Network serves as the overarching strategy for ensuring data collected by the Inventory & Monitoring program are subjected to rigorous quality assurance and control procedures, and that data and information are made available to others for decision making, research, and education. SIEN's Plan is *unique* in NPS: it has been developed to include detailed strategies for data and information management for its individual park resources management programs as well.

A separate document, "*Sierra Nevada Network Data Management Plan*", and accompanying appendices, is available.

Chapter 7: Data Analysis and Reporting

As part of the Inventory & Monitoring Program, the National Park Service is committed to promoting the conduct of high quality projects in national parks. An essential element of any science or research program is peer review, thus schedules for peer review of SIEN proposals, study plans, and monitoring protocols are described. As part of its monitoring program, SIEN will ensure data are regularly analyzed, interpreted, and reported to park managers and interested parties. Further, these data will be made available in formats appropriate for each audience (e.g., park managers, scientists, students, and interested public).

As above (Chapter 4), we include excerpts from our current data analysis and reporting component of our Lake Monitoring Protocol (Heard et al., in prep) as an example of the level of thought and detail our monitoring protocols will contain.

Chapter 8: Administration and Implementation of the Monitoring Program

This chapter describes our plan for administering the SIEN monitoring program, including integration with individual park operations and other key partnerships (e.g., USGS). It describes a discussion of the SIEN Board of Directors, our Science Committee, and current and future roles (FY2007–F2011) in development of our Network monitoring program. It describes the Network location and organization; administrative structure and processes; our staffing plan; how Network operations will be integrated with other park operations; key partnerships; and periodic review processes for our program.

It also includes a discussion of the SIEN Board of Directors, our Science Committee, and current and future roles of Network and Park staff and cooperators in developing and implementing long-term monitoring.

Chapter 9: Schedule

A schedule for development, peer review, and implementation of each monitoring protocol is provided. The Network is developing eight protocols that encompass 13 vital signs over the next four years.

Chapter 10: Budget

In this chapter we present the budget for the SIEN monitoring program during the first year of implementation (after review and approval of our monitoring plan) A 5-year projected budget is available (please contact our Network Coordinator).
Our current annual operating budget includes $662,000 from the NPS Service-wide Inventory & Monitoring Vital Signs program and $61,500 from the NPS Water Resources Division for water quality monitoring. We consider the years 2008-2010 "transition years" in which we will have network staff devoted to complete protocol development and Data Management Plan implementation, as well as initial implementation of some protocols. During 2008-2010, we anticipate allocating approximately 65% of the budget to core network personnel. Program support from permanent park staff will also be important in providing depth and continuity to the program, by assisting with implementing some vital signs.

Chapter 11: Literature Cited

A "*Glossary*" is included as part of this chapter.

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The Sierra Nevada Network's (SIEN's) Vital Signs Monitoring Plan could not have been completed without the commitment, hard work, and generosity of many people.

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Other contributions to the vital signs monitoring plan include conceptual model development, writing appendices, contributing sections and editing to some monitoring plan chapters, acquiring and preparing images, and doing GIS maps. We thank the following Sierra Nevada staff or cooperators for their contributions: Tony Caprio, Laura Clor, Athena Demetry, Annie Esperanza, Sandy Graban, Sylvia Haultain, Bill Kuhn, Scott Martens, Tani Meadows, Barbara Moristch, Peter Rowlands, Don Schweizer, Sarah Stock, Steve Thompson, Liz van Mantgem, and Harold Werner. In addition, Justin Hofman was the artist who did a couple illustrations in chapters 1 and 2.

We thank Data Management Plan co-author Pat Lineback (Sequoia & Kings Canyon GIS Coordinator) and Leona Svancara (former Data Manager for Upper Columbia Basin Network-UCBN) for their contributions to SIEN's Data Management Plan (DMP). The Data Steering Team members and other data work groups provided park-specific information and feedback during the development of portions of the draft Data Management Plan. Additional people who made significant contributions to the DMP include: Bob Basham, Anne Birkholz, Ginger Bradshaw, Ward Eldredge, Paul Gallez, Anne Pfaff, and Dan Sohn. WASO Data Manager Margaret Beer also provided helpful guidance, and Appalachian Highlands Network Data Manager Patrick Flaherty served in a detail with SIEN to assist with finalizing our Data Management Plan.

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Preface

This document describes the long-term monitoring plan for four National Park Service (NPS) units in the Sierra Nevada of central California: Devils Postpile National Monument, Sequoia and Kings Canyon National Parks, and Yosemite National Park. Together these parks comprise the Sierra Nevada Network (SIEN), which the NPS created for the purpose of establishing and implementing an ecological inventory and monitoring program. Development of large-scale monitoring programs, to be carried out over long periods, requires investment in iterative strategic planning, over a period of several years. Establishment of the monitoring portion of the SIEN program is directed by national-level guidance. The monitoring plan for each of the 32 Inventory & Monitoring (I&M) networks around the country is written in "four" phases. Each phase corresponds to a phase of program development, over a period of approximately four years.

Earlier versions: The Phase I report (2004) introduced Chapters 1 (Introduction and Background) and 2 (Conceptual Models) of the monitoring plan. Phase I described the park resources and management issues, described existing natural resource monitoring and defined general monitoring objectives. The Phase II report (2005) built upon Phase I, adding details regarding vital signs selected by the Network, and describing their prioritization process. Phase III (2006) added sample design, monitoring protocol, data management, reporting, implementation, and staffing plans for the network's vital signs monitoring program. Phase III underwent extensive peer review.

This document incorporates the above, and is respectfully submitted as the "Sierra Nevada Network Vital Signs Monitoring Plan" (Mutch et al. 2007)

Chapter 1 INTRODUCTION AND BACKGROUND

"The misson of the National Park Service is to 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 purposes 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."
—National Park Service Organic Act 1916

"When I first enjoyed this superb view, one glowing April day, from the summit of the Pacheco Pass, the Central Valley, but little trampled or plowed as yet, was one furred, rich sheet of golden compositæ, and the luminous wall of the mountains shone in all its glory. Then it seemed to me the Sierra should be called not the Nevada, or Snowy Range, but the Range of Light."
—John Muir, "The Mountains of California" 1894

1.1 Purpose

The purpose of the Sierra Nevada Network (SIEN) Inventory & Monitoring Program (I&M) is to collect and provide relevant scientific and research information about the current status and long term trends in the composition, structure, and function of park ecosystems. In addition, the I&M program helps the Network determine how well current management practices are maintaining those ecosystems.

To be effective, the I&M program must be responsive and **adaptive** to current and potential threats to park ecosystems and to the concerns of park management. By collecting and evaluating information about natural resources at consistent and scientifically-determined time intervals, park managers will be able to make more effective decisions about how best to manage and protect these natural resources. The SIEN I&M program provides this vital information, and makes it available to managers, researchers, and the public in a timely manner. A scientifically-based I&M program increases the confidence of management in how it makes decisions, and it increases the confidence of others (e.g., the public) in the Network's decision making process.

1.2 Legislation, Policy, and Guidance

United States Federal law and National Park Service policies direct national park managers to know the status and trends in the condition of natural resources under their stewardship. When it amended the Organic Act in 1978, Congress strengthened the protective function of the National Park Service (NPS) and provided language important to recent decisions about resource impairment. The Organic Act states that

> *"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…."*

More recently, the National Parks Omnibus Management Act of 1998 established the framework for fully integrating natural resource monitoring and other science activities into the management processes of the National Park System. This Act charges the Secretary of the Interior to

> "*continually improve the ability of the National Park Service to provide state-of-the-art management, protection, and interpretation of and research on the resources of the National Park System*", and to *"… assure the full and proper utilization of the results of scientific studies for park management decisions*." Section 5934 of the Act requires the Secretary of the Interior to develop a program of "*inventory and monitoring of National Park System resources to establish baseline information and to provide information on the long-term trends in the condition of National Park System resources*."

On August 12, 1999, the National Park Service announced a major effort to improve substantially how it manages natural resources under its care. The Natural Resource Challenge (NRC) is the National Park Service's action plan for preserving natural resources, and it addresses the challenges of caring for our country's natural heritage within the complexities of today's modern landscapes. The NRC calls for substantially increasing the role of science in decision-making, revitalizing and expanding natural resource programs, gathering baseline data on resource conditions, strengthening partnerships with the scientific community, and sharing knowledge with educational institutions and public.

Congress reinforced the message of the National Parks Omnibus Management Act of 1998 in its text of the FY 2000 Appropriations bill

> *"The Committee applauds the Service for recognizing that the preservation of the diverse natural elements and the great scenic beauty of America's national parks and other units should be as high a priority in the Service as providing visitor services. A major part of protecting those resources is knowing what they are, where they are, how they interact with their environment and what condition they are in. This involves a serious commitment from the leadership of the National Park Service to insist that the superintendents carry out a systematic, consistent, professional inventory and monitoring program, along with other scientific activities, that is regularly updated to ensure that the Service makes sound resource decisions based on sound scientific data."*

In 2001, NPS Management Policies updated previous policy and specifically directed the NPS to inventory and monitor natural systems

> *"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."

Further, *"The Service will:*

- *Identify, acquire, and interpret needed inventory, monitoring, and research, including applicable traditional knowledge, to obtain information and data that will help park managers accomplish park management objectives provided for in law and planning documents*
- *Define, assemble, and synthesize comprehensive baseline inventory data describing the natural resources under its stewardship, and identify the processes that influence those resources*
- *Use qualitative and quantitative techniques to monitor key aspects of resources and processes at regular intervals*
- *Analyze the resulting information to detect or predict changes, including interrelationships with visitor carrying capacities, that may require management intervention, and to provide reference points for comparison with other environments and time frames*
- *Use the resulting information to maintain-and, where necessary, restore-the integrity of natural systems"*

Additional statutes (circa 1934–1990) provide legal direction for expending funds to determine the condition of natural resources in parks and to specifically guide the natural resource management of Network parks. *These statutes are described in detail in Appendix A, "Legislation."*

The Government Performance and Review Act of 1993 (GPRA) mandates that all federal agencies use Performance Management (i.e., measurable, results-oriented, goal-driven planning and management) to accomplish their missions. To implement this management system, the Results Act requires all agencies to develop long-range Strategic Plans, Annual Performance Plans, and Annual Performance Reports. In addition to the national strategic goals, each park has a five-year plan that includes specific park GPRA goals Table 1-1. Many of these park-specific goals are directly related to natural resources inventory and monitoring needs. In FY2004, land health goals relating to the condition of wetlands, riparian areas, upland areas, marine and coastal areas, and mined lands were added to national level strategic goals.

Table 1-1. Government Performance and Review Act (GPRA) goals for Sierra Nevada Network parks that relate to natural resource condition. (Closely associated park-specific goals are those that relate to the corresponding national-level goals, but use park-specific measures.)

GPRA Goal	Goal #	Parks
Resources maintained	Ia	DEPO, SEKI, YOSE
Disturbed lands restored	Ia1A	DEPO, SEKI, YOSE
Disturbed lands restored—fire regime restored	Ia01A	SEKI
Closely associated park-specific land health goal-wetlands	Ia01C	SEKI, YOSE
Closely associated park-specific land health goal-riparian	Ia01D	SEKI, YOSE
Closely associated park-specific land health goal-uplands --includes caves (SEKI) --includes fire regime (YOSE)	Ia01E	SEKI, YOSE
Wilderness character objectives met	Ia10	SEKI, YOSE
Exotic vegetation contained	Ia1B	DEPO, SEKI, YOSE
Improving federal T&E species or species of concern have improved status	Ia2A, Ia02A	SEKI, YOSE
Species of concern populations have improved status	Ia2B, Ia02B	SEKI, YOSE
Invasive animal species controlled	Ia2C	SEKI, YOSE
Air quality in Class I parks does not degrade	Ia3	SEKI, YOSE
Surface water quality- rivers and streams- does not degrade.	Ia4A	SEKI, YOSE
Surface water quality-lakes, reservoirs- does not degrade.	Ia4B	SEKI, YOSE
Ground water quality- maintained	Ia4C	YOSE
Natural resource datasets acquired or developed	Ib01	DEPO, SEKI
Vital signs identified	Ib3A	DEPO, SEKI, YOSE
Vital signs monitored	Ib3B	DEPO, SEKI, YOSE
Special Management Areas: Wild and Scenic Rivers	Ib4B	SEKI, YOSE
Visitor Und68erstanding and Appreciation (of park resources)	IIb1	DEPO, SEKI, YOSE

1.3 Justification for Integrated Natural Resource Monitoring

Knowing the condition of natural resources in its national parks is fundamental to the NPS's ability to manage park resources. National park managers confront increasingly complex and challenging issues that require a broad-based understanding of the status and trends of park resources. They need to assess the efficacy of management practices and restoration efforts and provide early warning of impending threats. Since most parks are open systems, the challenge of protecting and managing a park's natural resources hinges on a partnership-based, ecosystem-wide approach. Threats, such as air and water pollution or invasive species, often originate outside park boundaries. In these cases, understanding and managing resources may require a regional, national, or international effort.

NPS needs an ecosystem approach 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. National parks are part of larger ecosystems and must be managed in that context.

Understanding the dynamic nature of park ecosystems and the consequences of human activities is necessary for deciding how to maintain, enhance, and restore the ecological integrity of park ecosystems, while avoiding, minimizing, and mitigating ecological threats to these systems (Roman and Barrett 1999). Natural resource monitoring provides site-specific information needed to identify *meaningful changes* in complex, variable, and imperfectly understood natural systems. The information we obtain from monitoring may also be useful in determining what constitutes impairment and in identifying the need to initiate, adapt, or change management practices.

In highly altered environments where natural, physical, and biological processes no longer predominate (e.g., control of fires and floods in developed areas), information obtained through monitoring can help managers develop effective approaches to restoration and ecologically sound management.

1.4 The NPS Inventory and Monitoring Program Approach and Strategy

In establishing a Service-wide natural resources inventory and monitoring program, the National Park Service (NPS) created networks of parks that are linked by geography and shared natural resource characteristics. Working within networks improves the efficiency of inventory and monitoring because parks are able to share budgets, staffing, and other resources to plan and implement an integrated program. In all, the 32 Networks comprise approximately 270 parks with significant natural resources (with a total of 391 national park units). The Sierra Nevada Network (SIEN) is one of 32 networks included in the Service-wide Inventory and Monitoring (I&M) program and one of eight networks in the Pacific West Region of NPS.

Ecological monitoring is now a central component of natural resource stewardship in the NPS, and along with natural resource inventories and research, provides information needed for effective, science-based decision-making, leading to **adaptive management** for resource protection (Figure 1-1). This first necessitates a systematic inventory and plan for monitoring the condition of park resources.

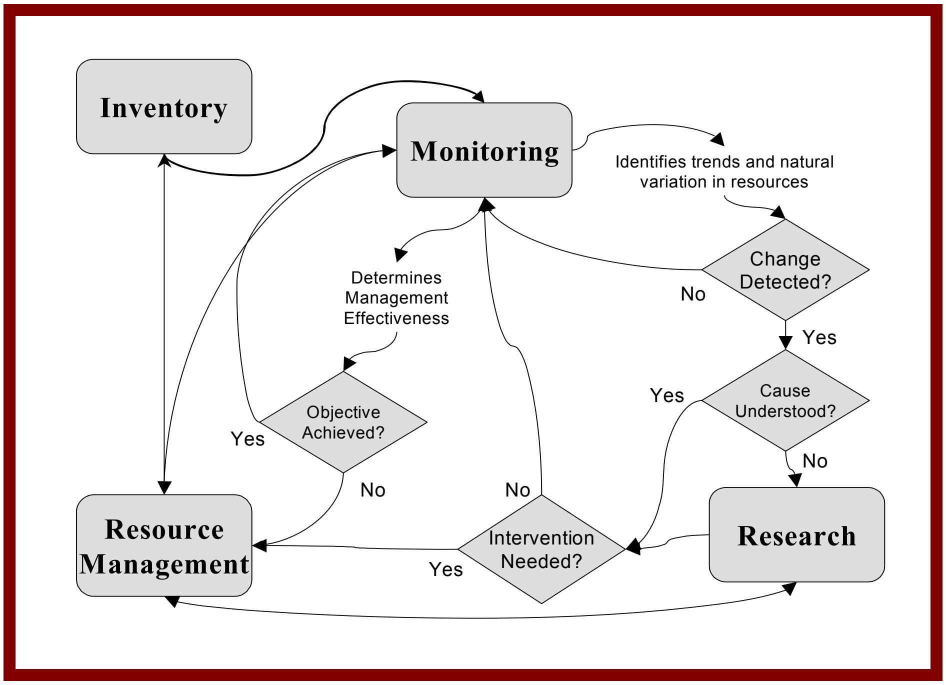


Figure 1-1. Adaptive management: relationships between monitoring, inventories, research, and natural resource management activities in National parks (modified from Jenkins *et al*. 2002).

The strategy of the NPS Inventory and Monitoring Program consists of a framework of three major components:

- Completion of 12 base resource inventories (e.g., vegetation map, soils map) upon which monitoring efforts can be based
- Eleven experimental or "prototype" long-term ecological monitoring (LTEM) programs
- Monitoring of **vital signs** by 32 Inventory and Monitoring networks

"**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…. 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)…."

1.5 Sierra Nevada Network Parks

Inspired by his explorations and wanderings in 'the Range of Light', John Muir, an early wilderness advocate, became a proponent of the National Park System. A century after his time in the Sierra Nevada, his passion for this mountain range lives on in the many people who visit Sierra Nevada parks each year. In 2004, the Sierra Nevada Network (SIEN) parks had 5,089,750 visitors (Table 1-2), a reflection of the attraction that the diverse and spectacular resources of the Sierra Nevada have for people throughout the world. This attraction also challenges park managers who must balance visitor enjoyment and resource protection.

The Sierra Nevada Network includes four NPS units: Devils Postpile National Monument (DEPO), Sequoia and Kings Canyon National Parks (SEKI), which are two distinct parks managed as one unit, and Yosemite National Park (YOSE). The parks cover approximately 658,000 hectares and are largely federally designated wilderness (Table 1-2).

Table 1-2. General statistics about Sierra Nevada Network parks as of 2006.

	DEPO	SEKI	YOSE
Size (hectares)	324	349,581	308,075
Percent Wilderness	75%	85%	94%
Elevation Range (m)	2200-2500	400-4417	610-3998
Number of Visitors (2006)	105,303	954.507 SEQU)[1] 522,706 (KICA)[2]	3,242,644

[1]SEQU: Sequoia National Park
[2]KICA: Kings Canyon National Park

The parks are located on the west slope of the Sierra Nevada, bounded primarily by US Forest Service lands (these lands are also mostly designated as wilderness with some timber harvest, grazing, reservoirs, and recreation)(See Figure 1-2). Private lands occur outside park boundaries, predominately below an elevation of 914 m along the western slope of the range (SNEP 1996a). The eastern boundary of YOSE and SEKI is the crest of the Sierra Nevada. The Network includes a wide elevation range (**Error! Reference source not found.**) and supports a diverse assemblage of plants and animals (see Section 1.6, *infra*).

Sierra Nevada Network parks were established to protect a variety of natural resources. These are discussed in the following sections.

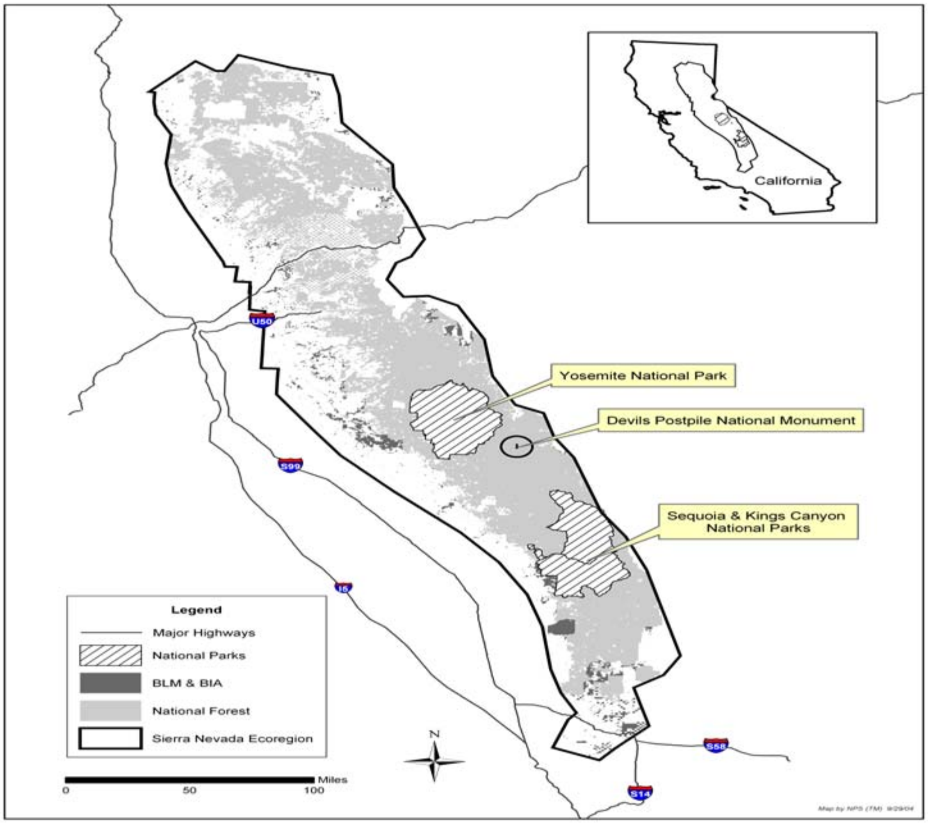


Figure 1-2. Sierra Nevada region showing Sierra Nevada Network parks and other federal lands.

1.5.1 Devils Postpile National Monument

See Appendix B, "Parks and Ecosystems," for more information on the landscape and ecology Devils Postpile National Monument.

Devils Postpile was established in 1911 to preserve "the natural formations known as the Devils Postpile and Rainbow Falls" for their scientific interest and for public inspiration and interpretation. The Devils Postpile formation is a dramatic mass of columnar-jointed basalt, the remnants of lava that flowed down the valley of the Middle Fork of the San Joaquin River less than 100,000 years ago. Nearly 20,000 years ago, a glacier overrode the fractured lava mass exposing a wall of columns 18 m high resembling a giant pipe organ. Devils Postpile is located high on the western slope of the Sierra Nevada in Madera County, California, near the headwaters of the Middle Fork of the San Joaquin River (Figure 1-2).

1.5.2 Sequoia and Kings Canyon National Parks

See Appendix B, "Park and Ecosystems," for more information on the landscape and ecology of Sequoia and Kings Canyon National Parks.

Sequoia and Kings Canyon National Parks protect a variety of landscapes containing biological and cultural resources in the southern Sierra Nevada of California. They are two separate national parks, created by acts of Congress fifty years apart. Today these parks are administered as a single unit. The parks are designated as an international Biosphere Reserve. Primary legislative purposes of the two parks are to preserve forest resources, particularly the giant sequoia groves, and to protect a vast wilderness for both scenic and recreational values.

Established September 25, 1890, Sequoia National Park is the second oldest national park in the United States (third if you include what is now Hot Springs National Park). The campaign to create the park was initiated and executed by San Joaquin Valley residents. It focused on preserving the scenic and inspirational values of the region's giant sequoia (*Sequoiadendron giganteum*) groves. Since 1890, Sequoia National Park has undergone two major enlargements, both of which added high-elevation Sierra lands to the park, preserving both the headwaters of the Kern and Kaweah river drainages and rugged, ice-sculptured alpine terrain that includes Mt. Whitney, the highest peak in the lower 48 states. Today, the best known features of Sequoia National Park remain the sequoia groves and high country. The Kern and Kings rivers are both designated national Wild and Scenic Rivers. Grant Grove National Park was designated in 1890. In 1940, this grove was incorporated into the much larger Kings Canyon National Park, whose features included other giant sequoia groves and great glacial canyons and scenic alpine headwaters of the South and Middle Forks of the Kings River. In 1965, the floors of Tehipite and Kings Canyon were added to protect scenic river segments from potential reservoir development.

1.5.3 Yosemite National Park

See Appendix B, "Parks and Ecosystems," for more information about the landscape and ecology of Yosemite National Park.

In 1864, Yosemite Valley and the Mariposa Grove of Big Trees were "granted" (known as the Yosemite Grant) by Act of the U.S. Congress to the State of California for "public use, resort and recreation," and to "be inalienable for all time." Notably, this was the first time the federal government set aside lands for protection. Thus, the significance of the area was recognized well before the establishment of Yosemite National Park itself, and nearly eight years before Yellowstone was set aside as the world's first "national park."

In 1906, Congress accepted transfer of the Yosemite Grant back to the United States, adding it to Yosemite National Park, which had subsequently been established in 1890 "to preserve from injury all timber, mineral deposits, natural curiosities or wonders within the park area and to retain them in their natural condition." Several changes to the park boundary have been made over the years, and in 1984, Yosemite was designated a World Heritage Site.

Yosemite is particularly noted for its textbook-perfect glacial features–domes, moraines, sheer rock walls, and hanging valleys–as well as its stunning waterfalls, "free-leaping" from the edges of hanging valleys over sheer granite walls. As John Muir noted, "…

[e]very peak, ridge, dome, canyon, lake, basin, garden, forest, and stream testify to the existence and modes of action of … scenery-making ice."

Yosemite protects a diversity of natural and cultural resources of the central Sierra Nevada, including the headwaters and portions of two national Wild and Scenic Rivers, the Merced and Tuolumne. The park also contains Hetch Hetchy Reservoir on the Tuolumne, one of the major water supplies for the City of San Francisco.

The construction of the Hetch Hetchy dam was controversial, and from 1901-1913, John Muir led the Sierra Club in a campaign to prevent the flooding of the Hetch Hetchy Valley, a part of Yosemite National Park, for a reservoir. The battle for Hetch Hetchy was perhaps the first effort of 'grassroots lobbying' where individual citizens contact elected officials to support or oppose legislation. Proponents of the dam argued that the valley would be even more beautiful with a lake. Muir predicted (correctly) that this lake would deposit an unsightly ring around its perimeter, which would be visible at low water. Since the valley belonged to the federal government, an act of Congress was required before the project could be started. The federal government decided the dispute in 1913, with the passage of the Raker Act, which permitted flooding of the valley.

1.6 Introduction to Sierra Nevada Ecosystems

See Appendix B, "Parks and Ecosystems," for more detailed and descriptive information about the climate, geology, air, biology, ecology, and physical processes of Sierra Nevada Network parks.

Sierra Nevada Network parks lie within the Sierra Nevada, the highest and most continuous mountain range in California. The range runs 692 km from north to south, is up to 113 km wide, and encompasses almost 75,520 sq. km. The range is flanked by California's Central Valley on the west and the arid western edge of the Great Basin on the east (Figure 1-2).

Humans have been part of Sierra Nevada ecosystems for at least 9,000 years B.P. (Roper Wickstrom 1992). Numerous, distinct American Indian groups were widely distributed throughout the region, well before settlement by Euramericans during the mid-19th century. Although the record is incomplete, archaeological evidence indicates that, prior to the 1850s, the American Indian population in the Sierra Nevada may have been as large as 90,000 to 100,000 people (Anderson and Moratto 1996).

Settlement patterns and resource use have historically reflected the export value of Sierra Nevada resources. The foothills became a focus of early attention for "Mother Lode" gold deposits, timber, water, and agriculture. An estimated 150,000-175,000 Euramericans moved into the Sierra Nevada from 1848 to 1860. The population in 1970 was about 300,000; by 1990, over 650,000 people were living in the Sierra. About 70% of the current population is located on the west-side foothills, with other concentrations in the vicinities of the main Sierran highways. Projections suggest that the Sierra Nevada population will grow between 1.5 and 2.4 million residents by 2040 (SNEP 1996a).

The following sections contain an overview of the physical environment, the important role of fire, biological diversity, and the major stressors and management issues for the Sierra Nevada region and parks. For additional information about the larger Sierra Nevada region, see Sierra Nevada Ecosystem Project (SNEP), a detailed report requested by Congress in the Conference Report for Interior and Related Agencies in 1993 Appropriation Act (H.R. 5503), which authorized funds for a "scientific review of the remaining old growth in the national forests of the Sierra Nevada…, and for a study of the entire Sierra Nevada ecosystem by an independent panel of scientists, with expertise in diverse areas related to this issue" (SNEP 1996b).

1.6.1 Physical Setting

The Sierra Nevada is a tilt block asymmetric mountain range with a short, steep east escarpment. The western flank has a longer and gentler slope in Yosemite and the northern Sierra Nevada. Farther south, in Sequoia National Park and elsewhere in the southern Sierra Nevada, the western flank is much steeper, rising from near sea level to 4,818 meters in less than 100 kilometers. This striking elevational gradient characterizes the physical environment in Network parks (YOSE, SEQU, KICA, and DEPO) and creates coincident gradients in climate that drive the distribution of plants and animals. Climatic, geologic, and hydrologic processes have dramatic effects in the Sierra Nevada (Figure 1-3); concomitantly, changes in these processes have dramatic effects on Sierra Nevada ecosystems.

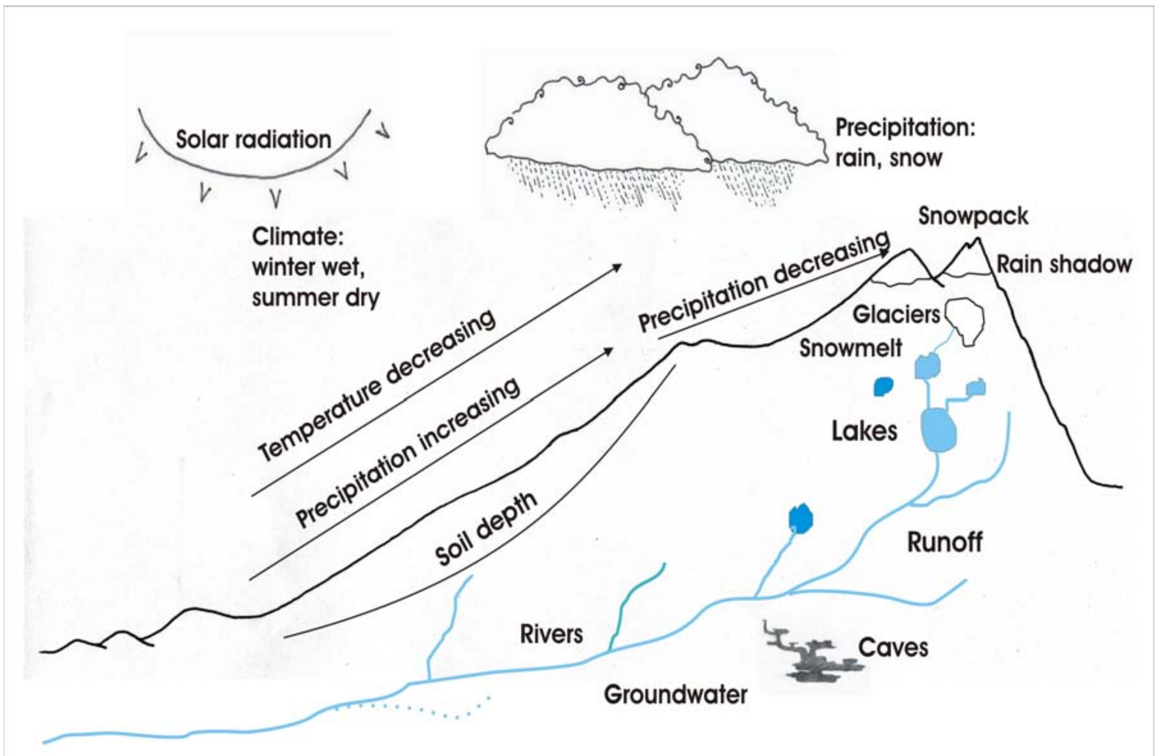


Figure 1-3. The Sierra Nevada physical setting illustrates the elevational gradient from the Central Valley and foothills (left side of image), up to the Sierra Nevada crest, and dropping back down more steeply along the east slope (right side of image). Climatic, geologic, and hydrologic processes and features change along this gradient.

1.6.2 Climate

Climatic forces are a major driver of Sierra Nevada ecosystems. Current patterns of vegetation, water dynamics, and animal distribution in the Sierra are determined largely by cumulative effects of past and present climates.

In the Sierra Nevada, strong climatic gradients develop with changing elevation from west to east. Low to mid-elevations have a Mediterranean climate, characterized by hot, dry summers and cool, wet winters. Higher elevations are dominated by a micro-thermal (or Boreal) climate with average temperatures below -3°C (26.6°F) during the coldest month. As a result, a steep temperature gradient parallels the elevation gradient as one climbs from the hot lowlands to the alpine crest (Stephenson 1988).

The west slope of the Sierra receives between 50 and 200 cm of rainfall each year, depending on elevation. Above 2,100 m on the western slope, about 50% of precipitation falls as snow (Stephenson 1988), creating a significant snowpack in the montane and subalpine elevations. East of the crest, the mountains create a rain shadow with significantly less moisture falling throughout the season. Across all elevations and latitudes, nearly 70% of precipitation falls from December through March and only about 4% from June through September (Stephenson 1988).

1.6.3 Geology

The Sierra Nevada batholith is part of a more or less continuous belt of plutonic rocks that extends from the Mojave Desert to northwestern Nevada (Bateman et al. 1963). Approximately ~215–70 millions years ago, magma intrusion resulted in uplift and tilting to the west, giving the range its asymmetric geometry: a short, steep east escarpment and a longer and gentler west slope (Whitney 1880, Lindgren 1911, Matthes 1960). With the onset of uplift, the erosive power of major streams was intensified due to their increased gradients, resulting in greater rates of incision and rolling hills that gave way to higher relief mountains with deep canyons cutting into the range's west flank (Huber 1987).

On the eastern flank of the mountains, volcanic activity at ~100 thousand years ago sent a lava flow into a valley, now designated Devil's Postpile NM, which cooled uniformly, contracted, and fractured into hexagonal columns. At ~10 thousand years ago, this formation was overridden by glaciers, exposing the columns. Evidence of the glacier–polish and scratches from glacial ice–remains atop the postpile (Clow and Collum 1986).

Several glacial periods in the Sierra Nevada, beginning at ~1 million years ago and continuing until ~10 thousand years ago, periodically covered much of the higher elevations of the Sierra Nevada parks and sent glaciers down many of the valleys (Yount and La Pointe 1997). Glacial ice transported vast volumes of rubble, which scoured and eroded the landscape; landforms resulting from glaciation include U-shaped canyons, jagged peaks, rounded domes, waterfalls, and moraines. The innumerable natural lakes (approximately 4,500), ponds, and other lotic habitats–bringing the combined total to over 6,650–in the high Sierra Nevada are the result of glacial activity forming their basins. Granite that has been highly polished by glaciers is common in the parks.

Sequoia and Kings Canyon National Parks contain more than 200 named caves (Despain 2003), including the longest cave in California, Lilburn Cave, with nearly 32 km of surveyed passage, and Crystal Cave, one of the area's most popular tourist destinations.

1.6.4 Air Resources

Kings Canyon, Sequoia, and Yosemite National Parks are designated Class I air sheds under the Clean Air Act (1977 amendment). As such, the parks are afforded the greatest degree of air quality protection, and the National Park Service is required to do all it can to ensure that air quality related values are not adversely affected by air pollutants. Devils Postpile National Monument is designated a Class II air shed. There is still a mandate to protect Class II air sheds, however, it is not as stringent. Despite these designations, air quality in the Sierra Nevada is impaired, threatening natural resources, human health, and visitor experiences *(See also section 1.9, Sierra Nevada Ecosystem Stressors, and Appendix C, "Air Quality Synthesis").*

In addition to air quality, Sierra Nevada parks contain other air resources, including night sky and natural soundscapes that are, like water and wildlife, intrinsic elements of the environment. Night sky visibility is an important aesthetic value of wilderness, and its protection has been added to the responsibilities of National Park Service managers.

1.6.5 Water Resources

See Appendix D, "Water," for a more detailed description of Sierra Nevada water resources.

SIEN parks span seven major watersheds: Tuolumne, Merced, San Joaquin, Kings, Kaweah, Kern and Tule (Figure 1-4). Runoff from these watersheds drains into the San Francisco Bay/Sacramento–San Joaquin Delta in the north and the Tulare Lake Basin in the south. Yosemite, Sequoia, and Kings Canyon parks contain most of the headwater streams. Devils Postpile National Monument is located within the upper Middle Fork of the San Joaquin watershed. The headwaters of the Middle Fork of the San Joaquin begin 14.1 km upstream of the monument.

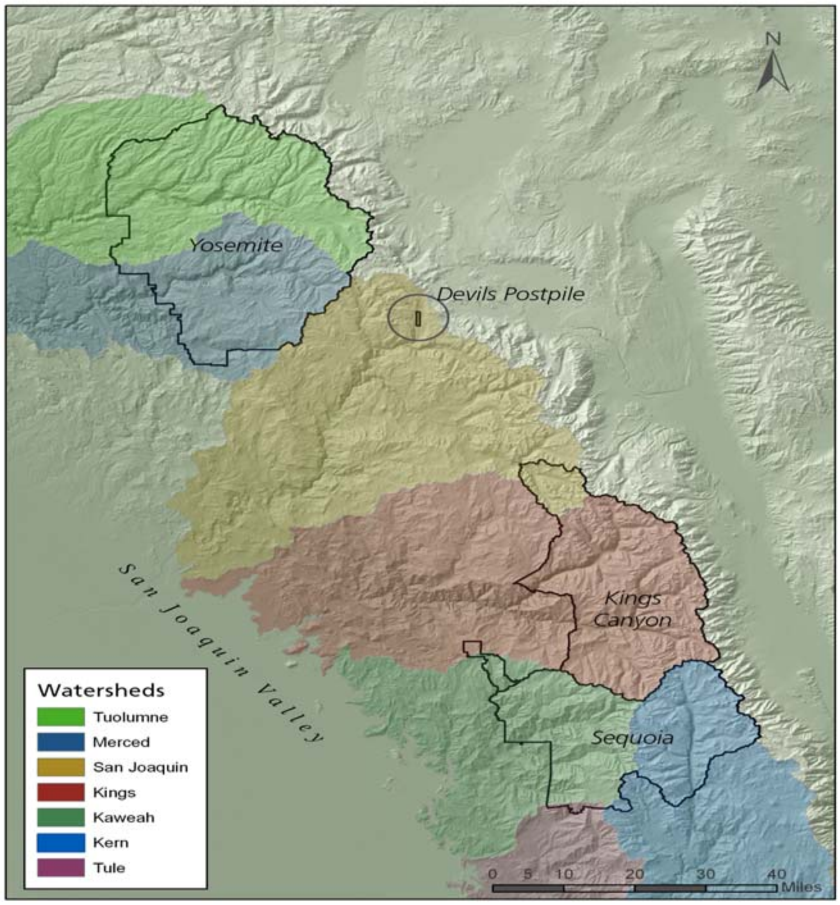


Figure 1-4. Watersheds in Sierra Nevada Network parks.

Sierra Nevada Network parks protect approximately 4,500 lakes and ponds, numerous other ephemeral waterbodies, and thousands of kilometers of rivers and streams that have some of the highest water quality in the Sierra Nevada. There are four Wild and Scenic Rivers in the parks: the Middle and South Forks of the Kings River (98.5 km) and the North Fork of the Kern River (46.5 km) in Sequoia and Kings Canyon, and the Merced (130.0 km) and Tuolumne (87.0 km) rivers in Yosemite.

Water dynamics in the Sierra Nevada are a critical component of both the parks' ecosystems and the larger California water infrastructure. The snow pack acts as a temporary reservoir, storing water that will be released during the warmer and drier months; peak runoff typically occurs late May to early June. Reservoirs are primarily located downstream of park boundaries, although there are exceptions, including Hetch Hetchy and Lake Eleanor in Yosemite and four small dams in Sequoia.

Water resources and associated aquatic and riparian habitats also have high ecological value. Approximately 21% of vertebrates and 17% of plants in the Sierra Nevada are associated with aquatic habitats (SNEP 1996b).

Under sections 305(b) and 303(d) of the Clean Water Act, California must assess overall health of the state's waters and identify waters that are not attaining water quality standards. Sierra Nevada Network parks do not contain any 303(d) listed waters (State Water Resources Control Board 2002).

The Sierra Nevada Ecosystem Project (SNEP) identified aquatic and riparian systems as the most altered and impaired habitats in the Sierra Nevada (SNEP 1996b). Primary reasons for deterioration are changes in flow regimes, disturbances from land use practices, and introduction of non-native organisms. Despite these impacts on aquatic and riparian habitats, basic hydrologic processes and water quality remain in relatively good condition (Kattelmann 1996), Devils Postpile, Sequoia, Kings Canyon, and Yosemite protect some of the least altered aquatic ecosystems in the Sierra Nevada.

1.7 Fire: A Key Process

Fire has played a pivotal role in shaping ecosystems and landscapes in the Sierra Nevada for many millennia (Davis and Moratto 1988, Smith and Anderson 1992, SNEP 1996a, Anderson and Smith 1997). It affects numerous aspects of ecosystem dynamics such as soil and nutrient cycling, decomposition, succession, vegetation structure and composition, biodiversity, insect outbreaks, and hydrology (Kilgore 1973, SNEP 1996a). Frequent surface fires in many vegetation types minimized fuel accumulation while their variable nature helped create diverse landscapes and forest conditions (Stephenson et al. 1991, SNEP 1996a). Historically, fire frequency, size, intensity, and severity varied spatially and temporally across the landscape depending on number of ignitions, climate, elevation, topography, vegetation, fuels, and edaphic conditions (Skinner and Chang 1996).

Prior to Euramerican settlement, fires were common, often burning for months and covering large areas. Extensive research in mixed-conifer forests has shown that low intensity surface fires were common and tended to keep the forests open (Biswell 1961, Hartesveldt and Harvey 1967, Weaver 1967, Kilgore 1971, 1972, Weaver 1974, Harvey et al. 1980).

Many species and most plant communities show clear evidence of adaptation to recurring fire, indicating that fire occurred regularly and frequently, particularly in the chaparral and mixed-conifer communities, where many plant species have life history attributes tied to fire for reproduction or as a means of competing with other biota. Many plants evolved fire-adapted traits, such as thick bark, and fire-stimulated flowering, sprouting, seed release, and/or germination (Chang 1996).

Short-term climatic variation had a significant impact on past burn patterns, fire regimes, and fire severity. Historically, specific fire-years throughout the southern Sierra Nevada's west slope–usually during dry years–have been identified (Brown et al. 1992, Swetnam et al. 1992, Swetnam 1993, Swetnam et al. 1998). Analysis of millennial-length fire histories for giant sequoias also document long-term variation (1,000–2,000 years) in the fire regime associated with climatic fluctuations (Swetnam 1993).

From the late 1890s through 1960s, Sierra Nevada park and national forest personnel attempted to suppress all fires, and these efforts met with a fair degree of success. Consequently, numerous ecosystems that had evolved with frequent fires have since experienced prolonged periods without fire (Swetnam et al. 1992, Swetnam 1993, Caprio and Graber 2000, Caprio et al. 2002, Caprio and Lineback 2002). This change in fire regime has severely modified ecosystems (*See section 1.9 Sierra Nevada Ecosystem Stressors and Chapter 2 (fire conceptual model).*

1.8 Plant and Animal Diversity

The striking elevational gradient and topographic variability in the Sierra Nevada result in a high diversity of habitats for plants and animals. Sequoia, Kings Canyon, and Yosemite National Parks, the largest and least fragmented habitat blocks in the Sierra Nevada, are recognized for their importance in protecting the long-term survival of certain species and the overall biodiversity of vegetation and wildlife in the region (SNEP 1996a).

The parks' vegetation can be categorized broadly into the following vegetation zones: oak woodland, chaparral scrubland, lower montane, upper montane, subalpine, and alpine (Figure 1-5). Vegetation changes dramatically along west-east elevation gradients from the lowest elevation oak woodlands up to ancient foxtail pines and western juniper, krummholtz whitebark pine, and alpine perennial herbs at the highest elevations. While the parks' eastern boundaries are along the Sierra Nevada crest, some areas have plant communities showing a mix of west and east slope affinities, such as Devils Postpile National Monument (Arnett and Haultain 2004). Sparse forests on the upper east slope of the Sierra Nevada grade into semi-arid Great Basin scrublands in the mountains' rain shadow (Figure 1-5).

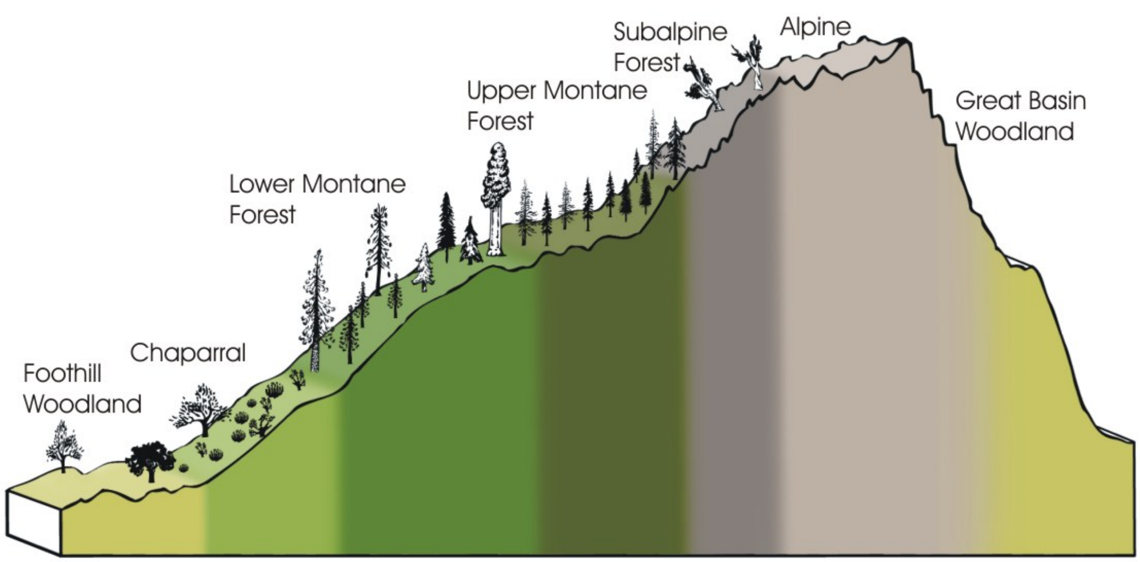


Figure 1-5. Sierra Nevada vegetation zones along its west-to-east elevation gradient, from the Central Valley and foothills, up to the Sierra Nevada crest, and down its east slope. The diverse topography results in high diversity of plants and animals. *Illustration by Justin Hofman*.

In its entirety, the Sierra Nevada region supports over 3,500 native vascular plant species, comprising half of the approximately 7,000 vascular plant species in California. Sierra Nevada parks support more than 20% of this California total. DEPO data (Arnett and Haultain 2004), SEKI data (Norris and Brennan 1982, Stokes 2003); YOSE data (Botti 2001, Gerlach et al. 2002, Jonson 2003, Moore 2003, Stokes 2003). See below (Table 1-3).

Table 1-3. Vascular plant species documented in Sierra Nevada parks.

	DEPO	SEKI	YOSE
Vascular Plant Taxa	380	1,500+	1,560
Special Status spp.	0	138	160
Non-native spp.	8	215[1]	160[2]

Data source: NPSpecies (https://science1.nature.nps.gov)
[1] Of these, 100 species do not occur in YOSE.
[2] Of these, 45 species do not occur in SEKI.

Bryophyte collections have been made in all Network parks (Steen 1988, Norris and Shevock 2004b, a, Shevock In progress). Surveys have documented 350 moss species in the southern Sierra Nevada region; 300+ species are estimated to occur in the central Sierra Nevada region (Shevock 2002). Lichen surveys have been limited (Smith 1980, Wetmore 1986); however, estimates suggest approximately 250 macrolichen and a similar number of crustose species could occur in Sierra Nevada parks (Neitlich 2004).

Table 1-4 lists vertebrate species documented in Sierra Nevada parks. The Sierra Nevada range includes about two-thirds of the bird and mammal species and about half the amphibians and reptiles in the state of California (Graber 1996), and supports over 280 native vertebrates, including fishes. Approximately 300 terrestrial vertebrate species use the Sierra Nevada as a significant part of their range; another 100 species use the Sierra Nevada as a minor part of more extensive home ranges: of 401 terrestrial species (not including fishes) documented for the Sierra Nevada, 232 are birds, 112 are mammals, 32 are reptiles, and 25 are amphibians (Graber 1996).

Table 1-4. Vertebrate species documented in Sierra Nevada parks.

	DEPO	SEKI	YOSE
Birds	118	220	283
Mammals.	35	91	88
Amphibians	1	13	13
Reptiles	8	26	23
Fishes	5	19	11

Data source: NPSpecies (https://science1.nature.nps.gov)

The foothills of the parks become increasingly important as similar areas outside park boundaries succumb to heavy grazing and residential development. Most plant communities in the parks are comprised of native plant species, but foothill woodlands are dominated by non-native annual grasses introduced to California during the mid 19th century.

Low-elevation chaparral communities are dominated by dense thickets of thick-leaved shrubs—an adaptation to fire and drought, both of which strongly influence the foothills environment.

The southern Sierra Nevada includes some of the most extensive alpine habitats in California. Tree line ranges from approximately 3,300 m in Sequoia National Park in the southern Sierra Nevada to approximately 3,200 m in Yosemite National Park (Major 1988a). The alpine zone extends above these elevations to the crest of the range.

Chaparral NPS Photo

Giant sequoia NPS Photo

Giant sequoia occur naturally only in the Sierra Nevada, where they are found in approximately 75 separate groves. The 42 named groves in Kings Canyon, Sequoia, and Yosemite contain roughly one-third of all naturally occurring sequoia trees.

Meadows and wetlands, while occupying a small fraction of the land area in the Sierra Nevada, are a key ecosystem element in the Sierra Nevada. Meadows are extremely productive ecosystems, and provide critical breeding and foraging habitat for a suite of animal species in the Sierra Nevada. Dozens of bird species, including the federally endangered Willow Flycatcher and the state-listed Great Grey Owl, use meadows for foraging, nesting, or both.

The parks support a large number of additional special status, rare, or endemic species *(see* NPSpecies http://science.nature.nps.gov/im/apps/npspp/*)*. Rare local geologic formations and the unique soils derived from them have led to the evolution of ensembles of plant species restricted to these habitats. These include limestone outcrops in Sequoia and Kings Canyon National Parks and a unique contact zone of metamorphic and granitic rock in the El Portal area of Yosemite National Park. Karst environments have recently been shown to harbor assemblages of rare and endemic invertebrates (Despain 2003, Krejca in progress) as well as providing roosting sites for bat colonies. Seventeen species of bats are documented for Sierra Nevada parks, nine of which are either Federal Species of Concern or California Species of Special Concern (Pierson et al. 2001, Pierson and Rainey 2003).

While Sierra Nevada parks offer important protected habitats for a diverse assemblage of plants and animals from direct pressures of development, logging, mining, extensive water diversions, and other human impacts, they do not protect park resources from the larger-scale systemic stressors of anthropogenic climate change, air pollution, altered fire regimes, and invasive non-native species.

1.9 Sierra Nevada Ecosystem Stressors and Resource Threats

Network park managers and researchers, using the best professional judgment available, a substantial supporting body of research, and findings from the Sierra Nevada Ecosystem Project (SNEP 1996a), have identified five systemic stressors posing the greatest threat to Sierra Nevada Network parks. Because of their potential to cause greater impact across a large landscape, and because they directly influenced our final list of vital signs, we discuss these systemic stressors briefly in the next sections. *See Appendix B, "Parks and Ecosystems" for a more detailed discussion of these stressors and their impact on Sierra Nevada ecosystems and management issues.*

Stressors are defined as 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.

1.9.1 Key Stressors

Five systemic stressors pose the greatest threat to Sierra Nevada Network parks:

- Climate change (rapid, anthropogenic)
- Altered fire regimes
- Non-native invasive species
- Air pollution
- Habitat fragmentation and human use

Climatic change may have the greatest potential to affect ecosystems in part because of its pervasiveness and extent across ecosystems as well as synergistic effects with other stressors (Figure 1-6).

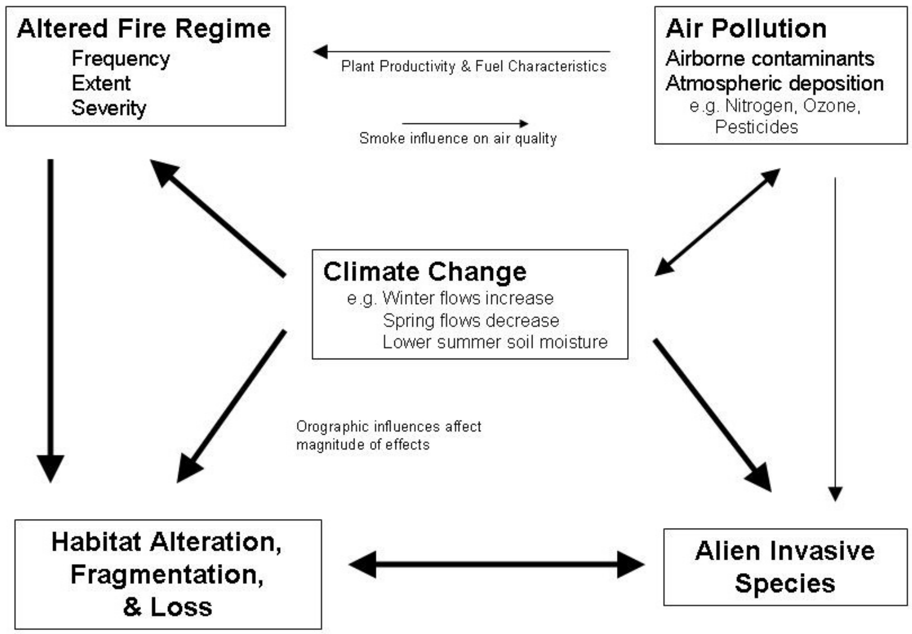


Figure 1-6. Sierra Nevada stressors and associative or synergistic effects.

1.9.2 Climate Change

The present CO_2 concentration has not been exceeded during the past 420,000 years and likely not during the past 20 million years; the current rate of increase is unprecedented during at least the last 20,000 years. The atmospheric concentration of carbon dioxide (CO_2) has increased by 31% since 1750. About three-quarters of anthropogenic emission of CO_2 to the atmosphere is due to fossil fuel burning; the rest is predominantly due to land-use change, especially deforestation (IPPC 2001, IPCC 2007).

The last several decades in the Sierra Nevada were among the warmest of the last millennium (Graumlich 1993). Recent simulations of climate change models suggest that by the years 2050 to 2100, average annual temperature in the Sierra Nevada could increase by as much as 3.8º C (6.8 ºF) (Snyder et al. 2002)—the equivalent of about an 800 m upward displacement in climatic zones. Average temperatures in May could increase by 9º C (16.2 ºF).

Paleoecological records show the early and middle Holocene (ca. 10,000 to 4,500 years ago) was a period of generally higher global summer temperatures (perhaps by 2º C)(3.6 ºF) and prolonged summer drought in California. During this period, fire regimes and plant community composition of Sierra Nevada forests differed from those of today (including some species combinations that no longer exist) (Anderson 1990, Anderson and Smith 1991, Anderson 1994, Anderson and Smith 1994, 1997). Although the past is an imperfect analog of the future, these and other paleoecological records indicate climatic change smaller than, or comparable to, those projected for the next century could profoundly alter Sierra Nevada ecosystems.

Researchers predict that even a relatively modest mean temperature increase (2.5 °C)(4.5 ºF) would significantly alter precipitation, snow pack, surface water dynamics (e.g., flow), and hydrologic processes in the Sierra Nevada. The most pronounced changes would probably be earlier snowmelt runoff and reduced summer base flows and soil moisture (IPCC 2007), a lower snowpack volume at mid-elevations (Knowles and Cayan 2001), and increased winter and spring flooding (Dettinger et al. 2004). Two climate models predict significant reductions in Sierra Nevada snowpack by the year 2100: one model predicts 30 –70% reduction, the other a 73 – 90% reduction (Hayhoe et al. 2004).

Flows in many western streams begin a week to almost three weeks earlier than they did in the mid 20th century (Cayan et al. 2001, Dettinger 2005). There is also a trend towards slightly later precipitation (Dettinger 2005). Changes in precipitation type and timing may result in longer and drier summers, i.e., less water available during the months when it is most needed (Dettinger 2005). Glacial extent in the Sierra Nevada has declined markedly in the past several decades (Basagic, in progress).

Changes in Sierra Nevada climate related to precipitation *quantity* (e.g., snowpack) are less certain (Howat and Tulaczyk 2005). If current trends continue, researchers predict that natural reservoirs provided by snowpack will become progressively less viable for water resources management. In addition, flood risk may change in unpredictable ways and Sierra Nevada ecosystems may experience increasingly severe summer-drought conditions (Dettinger 2005, Dettinger et al. 2005, Mote et al. 2005). Prolonged summer drought alters natural fire regime and would increase the potential for high-severity wildfires and further threaten water quality.

Phenological studies indicated that in much of the West, lilacs and honeysuckles are responding to the warming trend by blooming and leafing out earlier (Cayan et al. 2001). Human-influenced temperature patterns are significantly associated with discernible changes in plant and animal (invertebrate, bird, amphibian, tree, shrub) phenological traits (IPCC 2007). Some habitats (e.g., high alpine) may shrink dramatically or disappear entirely, leading to irreversible loss of some species (e.g., Clark's Nutcracker, pika). Two climate models predict significant reductions in Sierra Nevada alpine-subalpine forest by the year 2100: one model predicts 50–75% reduction, the other a 75–90% reduction (Hayhoe et al. 2004).

Global climate change is also likely to exacerbate three other systemic stressors of the Sierra Nevada: altered fire regime, air pollution, and non-native invasive species (IPCC 2007). Compounding a predicted increase in lightning strikes and resulting wildfire ignitions, extreme weather conditions such as drought are likely to result in fires burning larger areas, being more severe, and escaping containment more frequently (Price and Rind 1991, IPCC 2007). Warm temperatures create the perfect conditions for the production of smog and ground-level ozone. Global warming is therefore likely to make air pollution problems worse. A warmer climate would create conditions that would allow the expansion of species better adapted to such conditions (IPCC 2007).

1.9.3 Altered Fire Regimes

From the late 1890s through 1960s, Sierra Nevada park (and national forest) personnel attempted to suppress all fires, and these efforts were mostly successful. Consequently, numerous ecosystems that had evolved with frequent fires have since experienced prolonged periods without fire (Swetnam et al. 1992, Swetnam 1993, Caprio and Graber 2000, Caprio et al. 2002, Caprio and Lineback 2002).

Change in fire regime has modified Sierra Nevada ecosystems. In foothill grasslands for example, lack of fire encourages dominance by non-native invasive grasses (Parsons and Stohlgren 1989). Reproduction of shade-intolerant species (e.g., giant sequoia) has been reduced (Harvey et al. 1980, Stephenson 1994). More land is dominated by dense, intermediate-aged forest patches, and less by young patches (Bonnicksen and Stone 1978, Vankat and Major 1978, Bonnicksen and Stone 1982, Stephenson 1987). Forests are denser, dominated by shade-tolerant species, and shrubs and herbaceous plants may be less abundant (Kilgore and Biswell 1971, Harvey et al. 1980). A buildup of surface fuels has accumulated (Agee et al. 1978, van Wagtendonk 1985), and increasing numbers of small trees have created "ladder fuels", which carry fire into mature tree crowns (Kilgore and Sando 1975, Parsons and DeBenedetti 1979). These changes have led to a higher risk of high-severity wildfires than was present before European settlement and associated fire suppression activities (Kilgore and Sando 1975, Vankat 1977, Stephens 1995, Stephens 1998).

Lack of fire can affect water resources by reducing stream flows, altering biogeochemical cycling, and decreasing nutrient inputs to aquatic systems (Chorover et al. 1994, Williams and Melack 1997b, Hauer and Spencer 1998, Moore 2000). Less frequent but higher severity wildfires can also impair water resources, resulting in loss of vegetation cover, litter, and organic matter. The formation of these water repellant soil layers can affect evapotranspiration, infiltration, and snowmelt patterns (Helvey 1980, Inbar and Wittenberg 1998, DeBano 2000, Huffman et al. 2001). Potential impacts include increased flooding, erosion, sediment input, water temperatures, and nutrient and metal concentrations (Tiedemann et al. 1978, Helvey 1980, Riggan et al. 1994, Mac Donald and Stednick 2003, Heard 2005).

Lack of fire has reduced habitat (and food) for some wildlife species. Number and extent of forest openings have been reduced, which in turn has reduced key herbaceous and shrub species (e.g., nitrogen fixers such as *Ceanothus*) (Bonnicksen and Stone 1982). Wildlife that require these plants, such as deer, now have less habitat available. In 1968 (Sequoia & Kings Canyon) and 1970 (Yosemite), NPS staff began prescribed burning. After more than 30 years of prescribed fires, significant progress has been made, although park efforts are far from restoring natural fire regimes at the landscape level (e.g., (Caprio and Graber 2000, National Park Service 2004).

1.9.4 Non-native Invasive Species

There are numerous invasive vascular plant species in Sierra Nevada parks, and invasive plants can severely alter ecosystems. They can alter soil water dynamics, thereby stressing native species and perhaps increasing the potential for invasion by noxious species, e.g., yellow star-thistle (Gerlach 2004), which is already established in Yosemite, but not yet in Sequoia & Kings Canyon.

(*See* NPSpecies http://science.nature.nps.gov/im/apps/npspp/ *for more information.)*

1.9.4.1 Non-native Plants

Some of the most widespread invasive grasses first arrived in California during the 16th century as propagules hitchhiking on explorers; their spread was subsequently exacerbated by grazing, drought, and burning by American Indians (Hendry 1934, Heady et al. 1992). Parts of Sequoia National Park that have been severely grazed by cattle (trespassing) now harbor numerous invasive species.

Herbaceous biomass of foothill grasslands in Sequoia is 99% invasive species (Parsons and Stohlgren 1989), and altered fire regime (i.e., a particular fire frequency, intensity, or seasonal distribution) may be one of the causes (Parsons and Stohlgren 1989). However, reintroduction of fire onto the landscape may promote establishment of invasive species, particularly in resultant light gaps or areas of high fire severity (Keeley 2001). Because plant species evolve–not in association with fire per se–but within a particular fire regime, some highly fire-adapted plant communities (e.g., chaparral) may be vulnerable to invasive competition (Keeley 2001). Concomitantly, the presence of invasive plant can lead to altered fire regimes, including increased fire frequency (Keeley 2001)**.**

1.9.4.2 Non-native Invasive Animals

At least 30 invasive vertebrate species have been reported in Sequoia and Kings Canyon, and 21 have been reported in Yosemite (*see* NPSpecies, https://science1.nature.nps.gov, for details on species in SIEN parks). Many of these species are of concern to management because they have deleterious effects on native wildlife populations. The widespread introduction of brown, rainbow, and brook trout into high elevation lakes and streams has altered ecosystems, which were naturally without fish. Introduced fish and chytrid fungus are suspected of being leading factors in declines of native amphibian species in the Sierra Nevada, including the precipitous decline of the Sierran yellow-legged frog (Bradford 1989, Bradford et al. 1993, Knapp and Matthews 2000, Rachowicz and Vredenburg 2004, Rachowicz et al. In press). Extirpation of California red-legged frog (federally threatened) from Yosemite is attributed to non-native bullfrog presence (S. Thompson, Wildlife Biologist at Yosemite, pers. comm.).

1.9.5 Air Pollution: Air Contaminants and Atmospheric Deposition

The southern and central Sierra Nevada are subject to some of the worst air quality in the United States (Peterson and Arbaugh 1992, Cahill et al. 1996), particularly during summer months. Sequoia and Kings Canyon have the poorest air quality of SIEN parks, while Yosemite and Devils Postpile are affected, but to a lesser degree.

The San Joaquin Valley, west of Sierra Nevada Network parks, is a trap for air pollutants originating in the valley as well as pollutants from cities along the central California coast that are carried in on prevailing winds. Southward-flowing air currents enter California at the San Francisco Bay and move through the valley until they reach the mountains at the southern end of the basin, causing an eddy to form in the vicinity of Visalia and Fresno, just west of the southern Sierra Nevada (Lin and Jao 1995)(Figure 1-7). Airborne pollutants are then transported into the mountains when this air rises during the day.

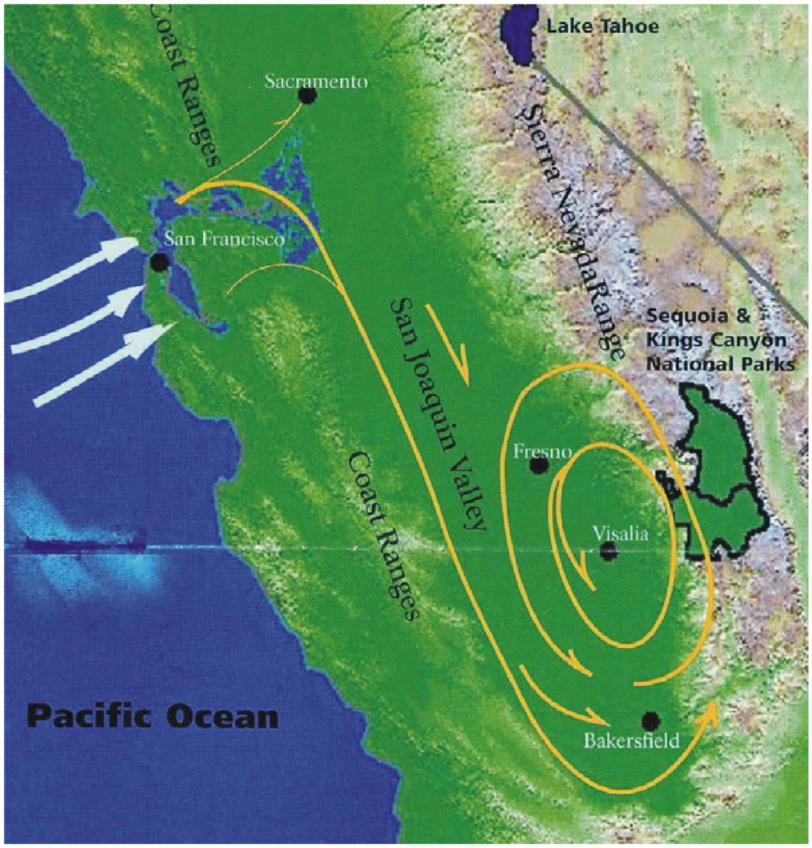


Figure 1-7. Air currents in the San Joaquin Valley, known as the Fresno eddy.

One of the most damaging air pollutants present is ozone. Research suggests chronic ozone pollution can lead to shifts in forest structure and composition. If current ozone concentrations remain relatively constant, or increase, they may lead to shifts in forest structure and composition, affect the genetic composition of pine and sequoia seedling populations, and contribute to increased susceptibility to fatal insect attacks, death rates, and decreased recruitment (Miller 1973, Ferrell 1996, Miller 1996). The effects of chronic ozone pollution on other species are not yet known.

There are resultant biological effects of nutrient deposition on aquatic and terrestrial ecosystems, and this enrichment can have considerable effects on sensitive organisms or communities (e.g., lichens and phytoplankton)—even at very low levels of atmospheric deposition (Fenn et al. 2003).

High-elevation aquatic ecosystems in the Sierra Nevada are particularly sensitive to change from atmospheric deposition because the waters are oligotrophic and have a low buffering capacity. In Yosemite, correlations between higher nitrate concentrations in sensitive surface waters and areas of higher nitrogen deposition have been observed (D. Clow, Hydrologist, USGS, pers. comm.). In contrast, decreased exports in dissolved nitrogen were observed in Emerald Lake, Sequoia National Park. The decrease was attributed to increased phosphorus inputs that caused a switch from a lake dominated by phosphorus limitation to one dominated by nitrogen limitation.

Mid-elevation, mixed-conifer watersheds in Sequoia's Giant Forest have shown net retention of nitrogen, with stream concentrations often below detection limits (Williams 1997). Giant sequoia forests are particularly effective at immobilizing nitrogen and reducing leaching losses; they may be adapted to even more nutrient poor environments than other coniferous ecosystems (Stohlgren 1988).

Nitrogen pollutants are likely to be important in causing changes in lichen communities—e.g., shifts to nitrophilous species or changes in abundance (Nash and Sigal 1999). Increased levels of soil nitrogen caused by atmospheric nitrogen deposition can increase the dominance of non-native invasive plants (Allen et al. 1988, increasing the risk of severe fire damage(Fenn et al. 2003), and decrease diversity of native plant communities (Vitousek and Howarth 1991, Vitousek et al. 1997).

High elevation lakes and streams in the parks are very dilute and sensitive to change from atmospheric deposition of nutrients, toxic substances, and acids. Episodic acidification occurs during what are known as "dirty rainstorms", i.e., rainstorms of summer and early fall (Stohlgren and Parsons 1987). Sequoia, Kings Canyon, and Yosemite are downwind of one of the most productive agricultural areas in the world, the San Joaquin Valley.

Every year, millions of pounds of pesticides (net weight of active ingredient) are applied to crops—9,872,707 pounds in 2003 alone (California Department of Pesticide Regulation, http://www.cdpr.ca.gov/). Pesticides volatilize (i.e., become suspended in the atmosphere as particulate matter that results in atmospheric contaminants), then drift into Network parks on prevailing winds. Organophosphates have been found in precipitation up to an elevation of 1,920 meters in Sequoia (Zabik and Seiber 1993). With continued urbanization of California's Central Valley, with increasing livestock operations, and with the possibility of transpacific N transport from Asia, it is probable that N deposition and its ecosystem effects in the high Sierra will increase in the next several decades (Fenn et al. 2003).

1.9.6 Habitat Fragmentation and Human Use

Population growth for the Sierra bioregion is forecasted to increase by over 50 percent in the next 20 years, from 717,400 in 1990 to 1,110,200 by 2020 (Fire and Resource Assessment Program 1997). This will pose increasing challenges for preserving park ecosystems and biodiversity.

Several species already have disappeared from the parks (e.g., California Condor, California red-legged frog), and others survive in greatly reduced numbers (e.g., Sierra yellow-legged frogs–two species, Yosemite toad, Western pond turtle, Willow

Flycatcher). These losses are partly due to habitat loss on adjacent lands, with park habitat being insufficient to support local populations over the long term (Graber 1996). This problem is particularly serious for foothill species. Declines in the populations of forest mesocarnivores (e.g., wolverine, fisher, red fox), bats, and owl species are attributed to forest structure changes in adjacent national forest (e.g., timber harvest, grazine, water diversions, etc.) (DeSante 1995, Graber 1996). Livestock grazing on non-park public land east of the Sierra Nevada crest has prevented re-establishment of healthy metapopulations of Sierra Nevada bighorn sheep (*Ovis canadensis* ssp. *nova*) within the parks, leading to their endangerment (Wehausen 2003).

Concomitant with population growth are changes in wilderness values such as dark night sky and the natural soundscape.

1.10 Developing a Monitoring Program

Monitoring at large geographic scales presents many challenges, including identifying clear goals and objectives and selecting attributes (**vital signs**) to monitor based on our knowledge of the ecosystem and the needs of management. Reviews of previous large-scale monitoring projects have identified failure in both content and process (Manley et al. 2000b). Frequently, monitoring efforts have been based on relatively poor ecological theory, little consideration of cause-effect relationships, and inadequate or uninformed approaches to selecting, justifying, and evaluating the specific indicators to monitor (National Research Council 1995, Bricker and Ruggiero 1998, Noon et al. 1999).

The National Park Service Washington Support Office (WASO) established a three-phase approach to developing a monitoring program to ensure that all networks invested significant time upfront in the design of their vital signs monitoring plans:

- **Phase I**: Overview of the understanding of ecosystem(s) using conceptual models, literature reviews, and local knowledge; defining goals and objectives for the monitoring program; beginning the process of identifying, documenting, evaluating, and synthesizing existing data; identifying the important resource management and scientific issues for the parks; and completing other background work that must be done before initial prioritization and selection of vital signs.
- **Phase II**: Process for identification, prioritization, and selection of vital signs; reduced list of vital signs that each network will pursue for protocol development; and list of vital signs being monitored through other programs, agencies, and funding sources.
- **Phase III**: Sample design; sampling protocols; plan for data management, analysis, and reporting; overview of program administration and implementation; budget and schedule.

Each phase builds upon the previous one, so that the final monitoring plan incorporates revisions and responses to peer reviews of all phases. In addition to a well-defined planning process, the NPS vital signs monitoring program also includes formation of a Board of Directors in each network that reviews program progress and a Science or Technical Committee that works with the Inventory & Monitoring staff to develop and implement the program.

1.10.1 Vital Signs Monitoring

The Sierra Nevada Network received funding for biological inventories from fiscal year (FY) 2001 through 2003, vital signs monitoring startup funds in FY2003, and full vital signs and water quality funds in FY2004. The Biological Inventory Plan (National Park Service 2001) was completed by a Sierra Nevada Network working group of NPS and US Geologic Survey (USGS) staff members from all network parks. The timeline for inventories and Phases I, II, and III of vital signs planning is summarized in Table 1-5.

Table 1-5. Timeline for the Sierra Nevada Network to conduct inventories and complete the planning process for vital signs monitoring.

	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007
Data documentation and summaries (ongoing)									
Inventories to support monitoring									
Individual park scoping workshops	SEKI			DEPO YOSE					
Conceptual Modeling (and refinement)									
Network workshops Vital sign prioritization and selection									
Data Management Plan									
Protocol Development, Monitoring Design									
Draft Monitoring Plan: Due-dates for Phases 1, 2, and 3							Phase 1 Oct 04	Phase 2 Oct 05	Phase 3 Dec 06
Final Monitoring Plan									Sept 07

Network and park staffs felt it was important that each park have an individual workshop prior to network-level scoping so that individual park resource issues and monitoring needs could be addressed and documented in detail. The scoping workshop for Sequoia and Kings Canyon National Parks was held in April 1999 in conjunction with a Resource Management Plan scoping workshop (Mutch and Lineback 2001, Mutch 2002, Mutch and Thompson 2003). Devils Postpile National Monument and Yosemite National Park vital signs workshops were held in April 2002 (Mutch and Lineback 2001, Mutch 2002, Mutch and Thompson 2003).

In general, the purpose of park vital signs workshops was (1) to bring together people with varied specialized knowledge of the Sierra Nevada ecosystem to identify ecosystem attributes and processes indicative of ecosystem change for Sierra Nevada parks and (2) to evaluate these indicators against specific ranking criteria. Workshop participants were also asked to add to a list of stressors (prepared by USGS-BRD and NPS staffs) and to identify any stressors known to be associated with vital signs identified in work groups. The objective of the workshops was to identify and prioritize ecosystem components and processes that, when monitored, would allow park managers—in a scientifically credible, quantifiable, legally defensible, and economical manner—to quickly and accurately detect changes in ecosystem integrity.

Vital signs generated at park-level workshops were summarized and consolidated by the Science Committee (described below) for Network-level prioritization through a series of meetings and discussions. Network prioritization occurred at a workshop with SIEN NPS and USGS staff in March 2005, when staff again reduced the number of vital signs. From these, the final group of vital signs were ultimately selected (**Error! Reference source not found.**) through a series of subsequent Science Committee meetings.

Staffing of the Network started with a temporary, then term, Network Coordinator in December 2000 and October 2001, respectively. The Network Coordinator (permanent) was hired in November 2003. Subsequent staff additions included:

- Term Biological Technician in October 2003
- Permanent Data Specialist in April 2004
- Term Physical Scientist in July 2004
- Term Ecologist in October 2004 (replacing term Biological Technician)
- Term, part-time Administrative Assistant in May 2006

The term positions are being hired to support the planning process. When vital signs are selected, the Network will re-evaluate needs for additional permanent or term staffing.

The Network's first charter was established in February 2002 (see Table 1-6 for timeline of events). The Board of Directors includes:

- Superintendents from Devils Postpile, Sequoia and Kings Canyon and Yosemite (voting)
- Resource Management Division Chiefs in Sequoia and Kings Canyon, and Yosemite (voting)
- Science Adviser from Sequoia and Kings Canyon (voting)
- Pacific West Region I&M Coordinator (non-voting)
- Deputy Regional Director (non-voting)
- Network Coordinator (non-voting, and staff to the Board)

The twelve-member Science Committee consists of two Resources Management staff members; one USGS scientist from both Sequoia and Kings Canyon and from Yosemite; the Science Adviser; Director of the UC Merced Sierra Nevada Research Institute; and the Network coordinator (who chairs the committed), data specialist, physical scientist, and ecologist.

Table 1-6. Timeline of events in the organization of the Sierra Nevada Network and monitoring planning.

Year and Month		Event
2000	December	Temporary Network Coordinator entered on duty
2001	January	Biological Inventory Plan approved
	October	Term Network Coordinator entered on duty
	December	SEKI 1999 vital signs scoping workshop report completed
2002	February	Network charter approved and signed by Superintendents
	April	Park-level vital signs scoping workshops held for Devils Postpile and Yosemite
	September	First Board of Directors meeting held
	November	First Science Committee meeting held
	December	DEPO and YOSE vital signs workshop reports completed
2003	Sept-Dec	Data mining and documentation
	October	Term Biological Technician entered on duty
	November	Permanent Network Coordinator entered on duty
	November	First (of a series) conceptual modeling workshop with Science Committee and cooperator
2004	Jan-June	Series of Science Committee planning meetings and conceptual modeling workshops; Data mining and documentation
	April	Permanent Data Specialist entered on duty
	June-August	Prepared Phase I report draft
	July	Term Physical Scientist entered on duty (see § 1.4.2 below)
	October	Term Ecologist enters on duty; Biological Technician position vacated
2005	March	Network vital signs prioritization workshop
	April-June	Science Committee meetings to select vital signs, prioritize pilot studies
	June-July	Phase II report drafted
	Oct-Sept	Data mining and documentation, preparation of data for NPSpecies; Natural Resource Database Template Committee database revisions
2006	Dec-Sept	Protocol development in progress
	May	Administrative Assistant enters on duty
	Sept	Draft Phase 3
2007	Sept	Final Vital Signs Monitoring Plan

1.10.2 Water Resources Monitoring

In addition to funding vital signs monitoring, the Natural Resource Challenge (NRC) includes separate funding earmarked for long-term water quality monitoring. The purpose of the funding is to track attainment of the Service-wide water quality strategic goal—'to improve the quality of impaired waters and to maintain the quality of pristine waters'.

Although the NRC allocates separate funding, it was anticipated that there would be full integration of water quality and vital signs monitoring (Miller 2000). In areas where water resources are identified as a high priority, water quality monitoring has been expanded.

Because of the significance of water resources, the Sierra Nevada I&M Network added funding to its water quality monitoring program and has produced a single, highly integrated vital signs water quality monitoring plan.

Sierra Nevada Network parks contain over 4,500 lakes and thousands of kilometers of rivers and streams, and these have some of the highest water quality in the Sierra Nevada. None of these are 'legally' impaired waters, but the Network has determined that integrating the water resources monitoring with vital signs monitoring was the most effective way to monitor and protect our parks' waters. In addition, other ecosystem components have been chosen to enhance water quality monitoring efforts. For example, forest demography monitoring can help explain trends in hydrology and water quality related to changes in evapotranspiration caused by changes in tree growth and mortality. In turn, water quantity and quality are critical components of the Sierra Nevada parks' ecosystems and good indicators of aquatic and terrestrial ecosystem condition. The largest threats to our waters—increasing nutrient and pesticide deposition, climate change, and altered fire regimes—are also major threats to the larger Sierra Nevada ecosystem.

Since water resources are critical in the Sierra Nevada, the Network has emphasized the development of water resources monitoring. Some of the main steps the Network has taken towards development of an integrated water resources monitoring program are:

- ***Evaluating Existing Water Resources Information in Sierra Nevada Network Parks***: In 2003, the Network established a Great Basin CESU Cooperative Agreement with Colorado State University to summarize existing water resources information for Sierra Nevada parks. This report has been expanded throughout 2004 and 2005. *See Appendix D, "Water*."
- ***Water quality geo-database***: The Sierra Nevada Network established an interagency agreement (2004) with the U.S. Geological Survey, Water Resources Division, to develop and populate a geo-database with existing water quality data. The database is currently being utilized by network staff to analyze existing water quality data, create maps, and identify information gaps.
- ***Physical scientist***: In 2004, the Network hired a term physical scientist to conduct planning and implementation of the SIEN water quality monitoring program.
- ***Long-term watershed study manuscript***: In 2005, the Network contributed a small amount of funding towards the completion of a manuscript synthesizing almost two decades of research in Tharp's and Log watersheds. This was a paired watershed study in the Giant Forest area of Sequoia National Park. Researchers studied biogeochemical processes within these watersheds with a focus on atmospheric deposition and prescribed fires.
- ***Vital signs selection***: Evaluation of water resource indicators has been fully integrated into the larger vital signs' ranking and selection process. In order to

gain more information to better evaluate candidate vital signs, the network is funding several projects targeted at indicator and feasibility evaluation and initial protocol development. For example, the Network is helping to fund a cooperative NPS-USGS project evaluating the suitability of stream chemistry as an indicator of elevated nitrogen fluxes to high elevation basins.

For information on other water projects, refer to SIEN Annual Administrative Report and Work Plans.

1.11 Monitoring Goals, Objectives, and Questions

This section is adapted from http://science.nature.nps.gov/im/monitor/ProgramGoals.cfm and the Southwest Alaska Network Monitoring Plan (Bennett et al. 2003)) http://www1.nrintra.nps.gov/im/monitor/docs/phase_reports/SWAN/SWAN_MonitoringPlan.pdf

The overall purpose of natural resource monitoring in parks is to:

> *Develop scientifically sound information on the current status and long term trends in the composition, structure, and function of park ecosystems, and to determine how well current management practices are sustaining those ecosystems. Use of monitoring information will increase confidence in management decision-making and improve their ability to manage park resources, while also allowing managers to confront and mitigate threats to the park and operate more effectively in legal and political arenas. To be effective, the monitoring program must be relevant to current management issues as well as anticipate future issues based on current and potential threats to park resources. The program must be scientifically credible, produce data of known quality that are accessible to managers and researchers in a timely manner, and linked explicitly to management decision-making processes.*

All 32 networks within NPS will address the following five Service-wide vital signs' monitoring goals in the planning, design, and implementation of integrated natural resources monitoring. The following section discusses the goals that guided the emphases and design of Sierra Nevada Network's monitoring program.

1.12 NPS Service-wide Vital Signs Monitoring Goals

The NPS decided on the following monitoring goals:

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 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 GPRA performance goals.

The Sierra Nevada Network parks protect large segments of Wilderness from direct human impacts such as logging, commercial development, and cattle grazing, and other impacts prohibited by the Wilderness Act. However, due to the geographic proximity of the Sierra Nevada to large population centers and highly productive agricultural lands, the parks are vulnerable to multiple stressors that are not excluded by laws or land management boundaries drawn on a map. The stressors of primary importance to the Sierra Nevada (SNEP 1996a) form a major portion of the framework for our thinking about vital signs monitoring. Our monitoring objectives reflect our dual interest in understanding the underlying dynamics and components of the ecosystem and the effects of major stressors upon those systems. However, scientific monitoring of these same ecosystems must be achieved in such a way as to not impact wilderness character or value.

Development of monitoring objectives and questions has been an iterative process, with the Science Committee developing the first set of monitoring objectives by consolidating monitoring questions developed at park-level vital signs workshops. The objectives below have been modified through development and revision of conceptual models and refining the focus of our monitoring questions through a network-level vital signs workshop and subsequent Science Committee and smaller work group meetings. Monitoring questions will continue to be modified, removed, or added as the planning process proceeds.

1.12.1 The Structure of a Monitoring Design

There is no single best model for the structure of a monitoring study. Like other forms of long-term research, the most important requirement is a personal or institutional commitment to sustain the program (Strayer et al. 1986). Successful monitoring programs have several important characteristics of design and implementation, which we summarize in Panel 1 (from Lovett et al. 2007).

Panel 1. The seven habits of highly effective monitoring programs (Lovett et al. 2007)

“(1) **Design the program around clear and compelling scientific questions**. Questions are crucial because they determine the variables measured, spatial extent of sampling, intensity and duration of the measurements, and, ultimately, usefulness of the data.

(2) **Include review, feedback, and adaptation in the design**. The guiding questions may change over time, and the measurements should be designed to accommodate such changes. The program leaders should continually ask "[a]re our questions still relevant and are the data still providing an answer?” The program should have the capacity to adapt to changing questions and incorporate changing technology without losing the continuity of its core measurements.

(3) **Choose measurements carefully and with the future in mind**. Not every variable can be monitored, and the core measurements selected should be important as either basic measures of system function, indicators of change, or variables of particular human interest. If the question involves monitoring change in a statistical population, measurements should be carefully chosen to provide a statistically representative sample of that population. Measurements should be as inexpensive as possible because the cost of the program may determine its long-term sustainability.

(4) **Maintain quality and consistency of the data**. The best way to ensure that data will not be used is to compromise quality or to change measurement methods or collection sites repeatedly. The confidence of future users of the data will depend entirely on the quality assurance program implemented at the outset. Sample collections and measurements should be rigorous, repeatable, well documented, and employ accepted methods. Methods should be changed only with great caution, and any changes should be recorded and accompanied by an extended period in which both the new and the old methods are used in parallel, to establish comparability.

(5) **Plan for long-term data accessibility and sample archiving**. Metadata should provide all the relevant details of collection, analysis, and data reduction. Raw data should be stored in an accessible form to allow new summaries or analyses if necessary. Raw data, metadata, and descriptions of procedures should be stored in multiple locations. Data collected with public funding should be made available promptly to the public. Policies of confidentiality, data ownership, and data hold-back times should be established at the outset. Archiving of soils, sediments, plant and animal material, and water and air samples provides an invaluable opportunity for re-analysis of these samples in the future.

(6) **Continually examine, interpret, and present the monitoring data**. The best way to catch errors or notice trends is for scientists and other concerned individuals to use the data rigorously and often. Adequate resources should be committed to managing data and evaluating, interpreting, and publishing results. These are crucial components of successful monitoring programs, but planning for them often receives low priority compared to actual data collection.

(7) **Include monitoring within an integrated research program.** An integrated program may include modeling, experimentation, and cross-site comparisons. This multi-faceted approach is the best way to ensure that the data are useful and. indeed, are used.”

1.12.2 Objectives

Objective 1: Understand the natural range of variation in annual and seasonal weather patterns, long-term trends in climate, and effects of global climate change on hydrologic regimes and biological processes.

- How do patterns of precipitation (type, duration, and intensity), seasonal temperature fluctuations, and other meteorological variables (solar radiation, wind speed and direction, relative humidity) vary spatially and temporally?

- Can changes in general and seasonal trends in temperature (warming or cooling) and precipitation (increased or decreased) be detected?

- How are these trends affecting regional hydrologic regimes (snowpack depth, snow water equivalent, snowmelt, glacial extent, frequency, and intensity of flood events and volume and timing of river and stream flows)?

- How are climate trends affecting the timing of key phenological events in plants and animals? Is the timing of onset and cessation of earlywood and latewood growth changing?
- How are the dynamics (establishment, growth, and death rates) of tree populations changing, and are any observed changes correlated with climate change?
- How resistant to change are Sierra Nevada ecosystems? What are the alternative stable states of Sierra Nevada ecosystems?

Objective 2: Understand patterns of spatial and temporal variation in fire regime characteristics and relationships to changes in climate and vegetation.

- How does fire regime (frequency, severity, and spatial extent) change in response to variation in climate and vegetation?
- Are changes in vegetation composition and stand structure, which are driven by global change, causing altered fire regimes in the Sierra Nevada?

Objective 3: Understand patterns of temporal and spatial distribution of air-borne pollutants, and their effects on aquatic and terrestrial systems.

<u>Ozone</u>

- How do ozone levels vary temporally and spatially and are trends detectable in these patterns?
- How are increasing levels of ozone affecting vegetation? Are concomitant changes in fatal insect attacks or tree population dynamics (recruitment and death rates) occurring, and are any observed changes correlated with ozone levels?

Air Contaminants

- How do concentrations of persistent organic pollutants (POPs) vary spatially and temporally in atmospheric, aquatic, and terrestrial systems?
- Are the concentrations of important POPs and other toxins (e.g., metals) increasing in the tissues of plants and animals? Are these changes associated with detectable changes in reproduction rate, longevity, genetic mutations, or other biological processes?

Atmospheric deposition

- How do depositional patterns of important nutrients (principally nitrogen and phosphorus compounds), hydrogen, and other major cations/anions vary along elevation gradients, in aquatic and terrestrial systems, and through time?
- How are patterns of nitrogen cycling changing?
- Are episodic acidification events increasing and are these events altering aquatic communities?

Objective 4: Understand natural patterns of variation in hydrology and how these processes respond to changes in climate and fire regime.

- How are stream and river discharge rates and the timing and magnitude of peak flows changing?
- How are water dynamics changing in response to climate and fire regimes?
- How are surface water volumes changing in lakes and wetlands?
- How are the height and supply of shallow groundwater and flow regimes changing in wet meadows and other wetlands?
- How are changes in hydrology affecting the dynamics and characteristics of stream/river channel morphology?

Objective 5: Monitor water quality and the response of native aquatic biota to changes in chemical and physical properties of aquatic systems.

- How does water chemistry (concentrations and fluxes) vary spatially and temporally across network parks?
- How is water quality changing with respect to water quality standards?
- How are sediment loads (concentration, turbidity) and sediment transport rates changing through time?
- How are toxin species and concentrations changing in network waters, animal tissue, and aquatic and riparian vegetation?

- How are plants and animals responding to changes in nutrient concentrations, heavy metals and toxins, sediment loads, and water temperature? What effects are these responses having on aquatic food chains and biological diversity?

Objective 6: Understand compositional and structural patterns of plant communities and their distribution on the landscape.

- What is the baseline spatial-temporal variation in community composition and relative abundance of native and non-native perennial plant species?
- What is the natural variation in community composition and relative abundance of perennial plant species?
- What non-native plant species have the potential to invade park ecosystems in the near future and how can we ensure early detection of their presence?

Objective 7: Document rates and types of change in plant communities in response to environmental factors and human effects.

- How do the structure, composition, and distribution of plant communities change in response to variation in climate, fire regime, and human use?
- How are abundance and distribution of non-native plant species changing, and what impacts are these having on native plant communities and animals?
- How are wetlands and wet meadows changing in size, species composition, and productivity in relation to changes in human use (such as stock grazing) and climate? How are associated animal communities affected by these changes?
- How is net primary productivity changing in aquatic and terrestrial systems in relation to changes in climate, fire regime, and human use?

Objective 8: Understand the ecological relationships between terrestrial landscape elements and animal distributions.

- How do abundance, distribution, and diversity of animal species (e.g., amphibians, land birds, bats) and communities vary spatially and temporally across park landscapes?
- How does the distribution of cave-adapted organisms change spatially and temporally within and among caves in a watershed?

Objective 9: Document rates and types of change in animal communities.

- How are abundance, diversity, and distribution of animal species (e.g., amphibians, land birds, and bats) and communities changing across network parks in response to changes in vegetation?

- How are avian productivity and survivorship changing?
- Are any new non-native animals establishing in the parks?
- How are the distribution and abundance of native amphibians and aquatic invertebrates changing in the response to the presence of non-native fish?
- How are the distribution and/or relative abundances of large and medium sized carnivores changing in response to changes in land use?

Objective 10: Monitor resources that have been identified as having unique values to the network parks. These resources may or may not be the best indicators of ecosystem condition, but are valued in and of themselves.

<u>Night sky</u>

- How is brightness of the night sky changing because of light intrusion from sources both inside and outside of parks; how is the visibility of stars affected?

<u>Visibility</u>

- How are the sources, amounts, and distribution of particulate matter changing seasonally, annually, and spatially? How is visibility in Class I air sheds affected by these changes?

<u>Soundscape</u>

- How are natural soundscapes changing because of increasing human activity (car traffic, construction, commercial and military air traffic)?

Objective 11: Monitor trends in the distribution and abundance of focal species.

- How are the distribution and abundance of special status species changing?

1.13 Overview of Past and Present Monitoring

Park-based monitoring and research projects likely to have the most value to Sierra Nevada Network's vital signs monitoring program are those pertaining to resources that have been identified as potential vital signs, indicators, or measures, and that have formal and well-documented data and protocols.

These projects (past and present) are summarized for Sierra Nevada Network parks (Table 1-8, at the end of this chapter). These and additional short-term monitoring (up to three years) and important baseline inventories and research projects that may have value in supporting Sierra Nevada Network's vital signs program are described in detail in *Appendix E, "Network Monitoring."*

1.13.1 Air

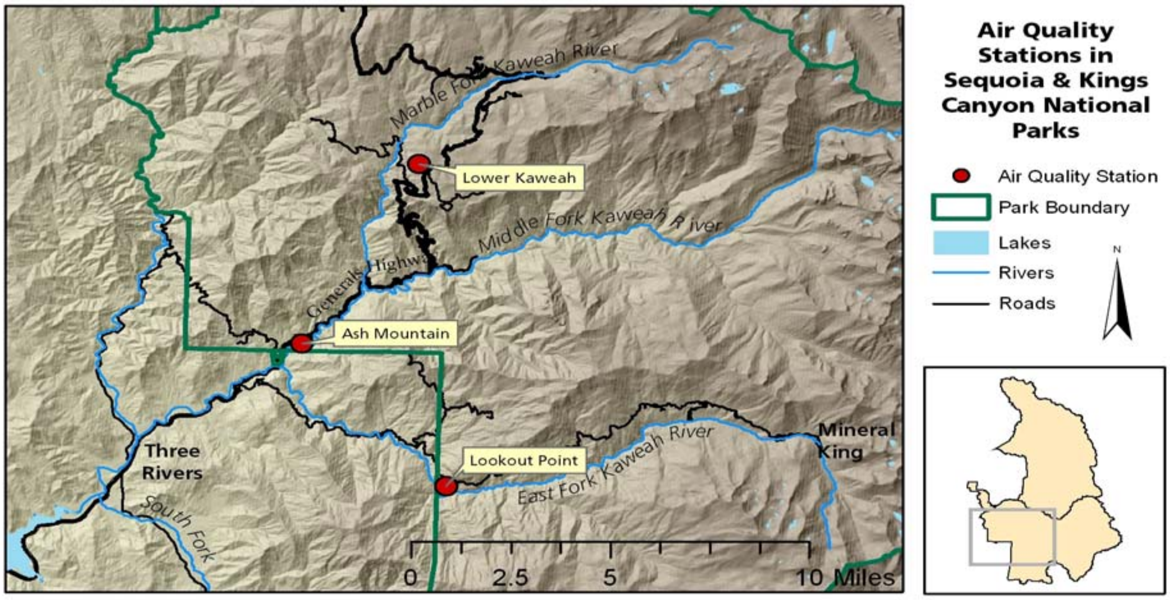
For detailed information on the atmospheric monitoring program in and around SIEN, please see Appendix C, "*Air Quality Synthesis*."

In the Sierra Nevada Network there are three Class I air sheds (YOSE, SEQU, KICA) and one Class II air shed (DEPO). According to the Clean Air Act and subsequent amendments, federal land mangers have responsibility to protect visibility, flora, fauna, waterbodies, and other resources that may be potentially affected by air pollution. Class I parks in the SIEN network have a complex air monitoring program (Table 1-7). Supported by the NPS Air Resources Division, these parks are included in several nationwide programs measuring wet and dry deposition, ozone, visibility, mercury, particulate matter, and meteorology.

Both Yosemite and Sequoia and Kings Canyon operate year-round air monitoring stations, some dating back to the early 1980s (Figure 1-8 *and Appendix C, "Air Quality Synthesis"*). Each site is unique in its array of monitoring equipment (inset). Devils Postpile National Monument does not currently conduct air monitoring within the boundaries of the monument.

Table 1-7. Air quality monitoring sites and variables measured.

Park	Site	Park	Site
Sequoia & Kings Canyon	**Ash Mountain** • Meterology • Ozone • Particulate Matter • PM 2.5 and 10	**Yosemite**	**Yosemite Valley** • Meterology • Ozone • Particulate Matter • PM 2.5 and 10 • NOX • Carbon Monoxide
	Lower Kaweah • Meterology • Ozone • Wet Deposition • Mercury • Webcam		**Turtleback Dome** • Meterology • Ozone • Dry Deposition • Visibility • Particulate Matter • Webcam
	Lookout Point • Meterology • Ozone • Dry Deposition		**Hodgdon Meadow** • Wet deposition



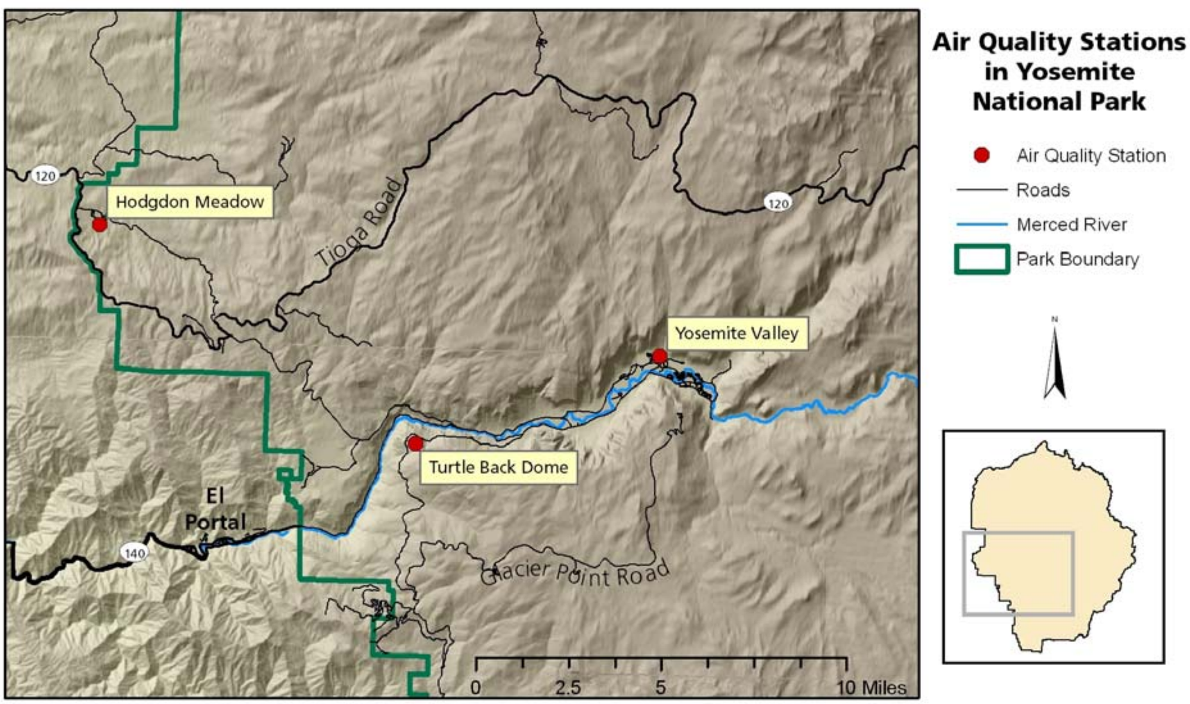


Figure 1-8. Air quality stations (●) in SIEN parks.

1.13.2 Wildlife (Terrestrial and Aquatic)

Most long-term monitoring of wildlife (terrestrial and aquatic) has been conducted on bears (interactions/incidents with humans), birds, and a few selected groups and taxa with special status (mountain yellow-legged frog, Sierra Nevada bighorn sheep) (**Error! Reference source not found.**).

Baseline or directed inventories have been conducted on many vertebrate groups (birds, mesocarnivores, bats, salamanders), and special status species (e.g., California Spotted Owl, Great Grey Owl, Western Pond Turtle, Mountain yellow-legged frog).

Invertebrates have generally been under-represented in inventory, monitoring, and other studies in Sierra Nevada Network parks.

1.13.3 Vegetation (Terrestrial)

Sequoia, Kings Canyon and Yosemite National Parks have a rich history of vegetation-related inventories, research, and monitoring projects. Most long-term vegetation monitoring in these parks has been related to measuring effects of resource management programs (especially fire, exotic plant control and restoration), recreation (especially pack stock grazing), and air pollution (described above). The USGS-Biological Resources Division also conducts long-term vegetation monitoring in Sequoia and Kings Canyon and Yosemite: forest demography across elevations is the longest term dataset. Aside from fire-effects plots established in 1992, Devils Postpile has not had staffing or resources to do long-term vegetation monitoring.

All parks have had vegetation inventories done that are of value as baseline data for long-term monitoring. These include vegetation maps, Natural Resource Inventories in the 1990s in Sequoia, Kings Canyon, and Yosemite (Graber et al. 1993), a vascular plant inventory in Devils Postpile (Arnett and Haultain 2004), and rare plant surveys for individual park units (in progress, and Moore 2006).

1.13.4 Fire

Detailed information on fire monitoring can be found in park Fire Management Plans (National Park Service 2003, 2004).

The parks' fire monitoring programs began in 1982 for Sequoia & Kings Canyon, 1978 for Yosemite, and 1992 for Devils Postpile. The programs in Sequoia & Kings Canyon and Yosemite initially focused on monitoring weather and fire behavior, vegetation, and dead and down surface fuels in giant sequoia groves and other early experimental prescribed burns in mixed-conifer forests. Over time, the monitoring programs expanded to other plant communities as the prescribed fire programs progressed. In recent years, Sierra Nevada fire-monitoring programs have broadened to include additional vegetation, wildlife, water, and/or fire regime components. Devils Postpile does not currently have a Fire and Fuels Management Plan (NPS, in progress); however, fire effects monitoring plots were established in association with a 1992 wildfire that burned approximately two-thirds of the monument.

Monitoring environmental and fire condition provides information to guide fire management strategies for both wildland and prescribed fires; such monitoring encompasses a wide variety of fire topics, including:

- Environmental and fire conditions
- Fire effects on vegetation and fuels
- Mechanical fuels-treatment monitoring
- Fire effects on animals
- Fires effects on water
- Fire regimes, restoration, baseline fire history

In addition to fire-related monitoring conducted by SIEN park staff, USGS-Western Ecological Research Center staff at both Sequoia and Kings Canyon and Yosemite Field Stations have contributed a huge amount of fire-related monitoring in SIEN parks and the greater Sierra Nevada region. USGS projects in our parks are an integral part of NPS resource management information and decision-making.

1.13.5 Aquatic

For detailed information on the water monitoring program in and around SIEN, please see Appendix D, "Water."

In Sequoia and Yosemite National Parks, long-term stream flow monitoring dates back to 1949 and 1918, respectively (Figure 1-9). Sequoia has twelve active gauging stations located in or near the park's boundary, with periods of record ranging from eight to 54 years. Yosemite has 48 active gauging stations with periods of record ranging from one to 96 years. Devils Postpile and Kings Canyon do not have long-term stream flow records, although a gauging station was recently installed on the Middle Fork of the San Joaquin River in Devils Postpile.

The longest network water-quality monitoring site is on the Merced River, at Happy Isles in Yosemite. Happy Isles is a USGS Hydrologic Benchmark Network site with water quality data from 1964 to present. In Sequoia National Park, there are four water-quality monitoring sites with 15-20 years of data, although only one site is currently monitored. In Devils Postpile, California Department of Fish and Game monitors basic water quality variables (pH, conductivity, temperature, and alkalinity) at eight different sites as part of a statewide fisheries monitoring program (National Park Service 1998).

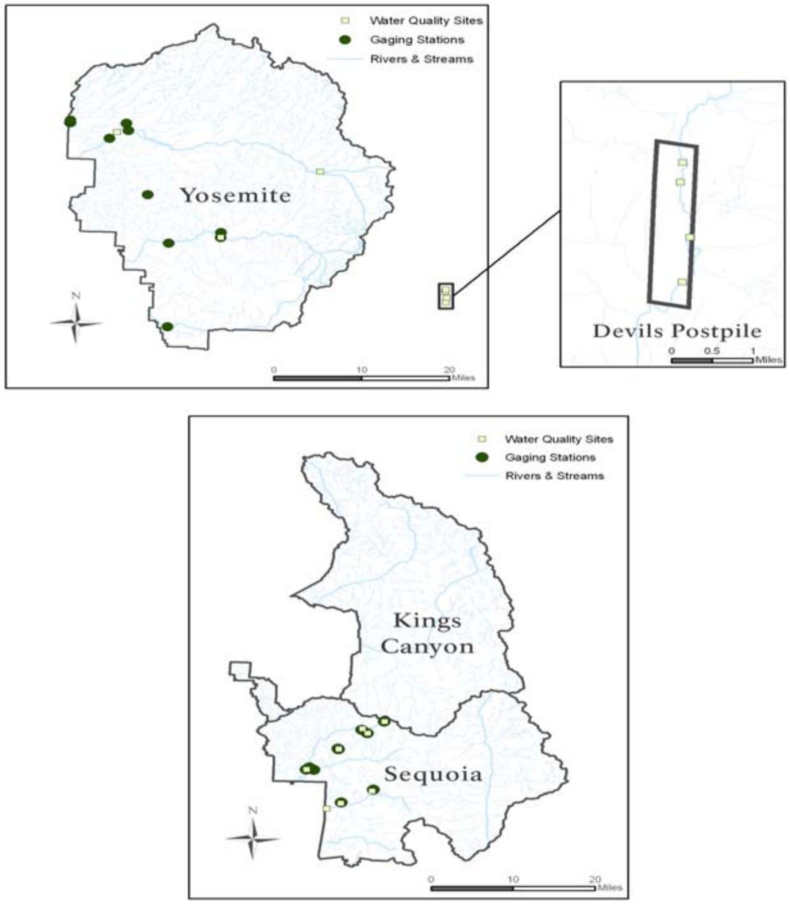


Figure 1-9. Gauging stations and water quality sites with long-term monitoring records.

1.13.6 Geologic and Other Physical Resources

For detailed information on monitoring of geology, geomorphology, physical cave resources and soils, please see Appendix E, "Network Monitoring."

1.13.7 Summary of Monitoring Related to Vital Signs Program

Current or past park-based monitoring projects, which may have the most value to Sierra Nevada Network's vital signs monitoring program, are those projects pertaining to resources that are closely aligned with Network vital signs (Table 1-8).

Text and tables describing or summarizing additional short-term monitoring projects (≤3 years) and baseline inventory projects, with potential value to the vital signs monitoring program (organized by topic and park), are also summarized in *Appendix E, "Network Monitoring."* Detailed descriptions of the Network's most evolved monitoring programs– air and water– can be found in *Appendices C ("Air Quality Synthesis") and D ("Water").*

Project details (e.g., abstract, purpose) and available metadata (e.g., duration of project, location of data) are described in the Network's data documentation database (originally developed and populated circa 2003). Additions to this database are ongoing.

Table 1-8. Summary of existing monitoring data in Network parks with most value to vital signs program.

		Network Park			
Monitoring Category	**Description**	**Devils Postpile**	**Sequoia & Kings Canyon**	**Yosemite**	**Notes**
Air	Air Quality (ozone, visibility, precipitation, chemistry)		●	●	Clean Air Act
Meterology & Climate	Meterological Variables (temperature, precipitation, relative humidity, radiation, wind speed and direction)	●	●	●	
	Snow: water equivalent, depth	●	●	●	Water supply: San Joaquin Valley, San Francisco
Water	Stream flow	●	●	●	
	Water Quality		●	●	
Caves	Visitation		●		
	Radon		●		
	Temperature		●		
Geomorphology	River Cross-section			●	
Animal	Wildlife Observation Database	●	●	●	DEPO: no formalized system
	Grinnell Survey			●	Resurvey of historic (circa 1917) trans-Sierra transects
	Annual Report			●	
	Mountain Yellow-legged frog		●		As part of non-native fish eradication project
	Western Pond Turtle		●		
	Avian Productivity & Survivorship				MAPS stations
	Breeding Bird Survey		●	●	As part of USGS program
	Christmas Bird Count		●	●	As part of Audubon Society program
	Peregrine Falcon		●	●	As part of federal delisting protocol
	Pacific Fisher, Red Fox, California Wolverine			●	
	Black Bear–Human Interactions		●	●	
	Sierra Nevada Bighorn Sheep		●	●	
	Bats			●	Anabat detectors
	Mule Deer			●	California Fish and Game

		Network Park			
Monitoring Category	**Description**	**Devils Postpile**	**Sequoia & Kings Canyon**	**Yosemite**	**Notes**
Animal (cont.)	Little Kern Golden Trout		●		
	Macroinvertebrates			●	Student-science program
	Fire Effects (birds, bark beetle, small mammals)		●		USGS: Fire and Fire-Surrogate study
Vegetation	Forest Demography		●	●	USGS
	Ozone effects (*Pinus* spp. and others)	●	●	●	Project FOREST
	Ozone effects (multiple species)		●		USDS Forest Service, Forest Inventory and Analysis plots
	White Pine Blister Rust		●	●	
	Vegetation Change		●		Repeat photography
	Fire: Effects on plant diversity and invasives		●		USGS
Fire: Environmental Conditions	Fire weather		●	●	
	Fire conditions (wildland, prescribed)		●	●	
	Burn severity		●	●	
	Fire behavior		●	●	USGS
	Fuels		●		USGS
	Soils, forest floor		●		USGS
	Pathogens		●		USGS
	Invasive annual grasses		●		USGS
Fire: Effects	Vegetation: pre-burn, post-burn		●	●	No pre-burn data for DEPO
	Repeat Photography	●	●	●	
	Hydrology, Hydrochemistry		●		USGS
Fire: Regime	Fire History	●	●	●	
	Cumulative accomplishments		●		
Mechanical Fuels Treatment	Effects of mechanical thinning		●	●	Including pre- and post-treatment data collection
	Repeat Photography		●	●	

1.13.8 USDA Forest Service Monitoring Program: Sierra Nevada Forests (1995 to present)

Details about the USDA Forest Service monitoring program, and other agencies, can be found in Appendix E, "Network Monitoring."

Chapter 2 CONCEPTUAL ECOSYSTEM MODELS

Conceptual models are working hypotheses about system form and function. They depict the essential attributes of a system, express ideas about important components and processes, document assumptions, identify gaps in knowledge, and evolve to capture an increasing understanding of the system (Manley et al. 2000a). Conceptual model development has been identified as a key component of a scientifically based monitoring plan (National Research Council 1995, Noon et al. 1999, National Park Service 2006).

Conceptual models help in the design and interpretation of long-term monitoring by identifying important biotic and environmental features and processes, providing insight into potential cause-and-effect relationships, and establishing standard formats and concepts for communication of complex ideas (Roman and Barrett 1999). Conceptual models serve as communication tools among scientists from different disciplines, between scientists and managers, and between managers and the public.

Conceptual models can take the form of any combination of narratives, tables, matrices of factors, or box-and-arrow diagrams. Jorgensen (1988) discusses ten kinds of models and evaluates their advantages and disadvantages. We use a combination of these forms as a means to summarize and illustrate large quantities of information.

This chapter describes (1) the purpose and goals of conceptual models, (2) the Network's approach to model development, (3) the most general models the Network has developed, and (4) an example of a more detailed conceptual model (Section 2.7.1, a meadow focal system). Additional detailed conceptual models are included in Appendix F, "*Conceptual Models*."

2.1 Conceptual Models: Purpose and Objectives

Conceptual models have served the following objectives in development of our monitoring program:

- Formalized current understanding of ecosystem structure and function as well as relationships among ecosystem components at various levels of organization (landscape, community, watershed, population)
- Highlighted effects of important drivers (see definition, next page) and stressors on park resources and ecosystem processes
- Identified and articulated relationships among ecosystem attributes of interest and vital signs (indicators)
- Allowed for a shared vision to be created: facilitate communication among participants in the iterative process of vital signs identification, prioritization, selection, and protocol development
- Used for integration and application—identify gaps, establish priorities, and solicit an agreed syntheses

As the Network progresses toward implementation of vital signs monitoring, the models will inform our thinking about sample design, facilitate integration and synthesis of data, and serve as communication tools about the program (Gross 2005). We hope that future models will assist us in communicating connections between management decisions and information gained from monitoring, such as identification of threshold conditions that could trigger a management action.

2.2 Approach to Conceptual Model Development

Development of models for the Sierra Nevada Network (SIEN) began with the Science Committee, during planning of Phases I and II of vital signs monitoring. Park, USGS and Network staff worked with a contractor to develop draft models that illustrated current understanding of key interactions among proposed vital signs and other ecosystem components and processes. These models helped inform vital signs prioritization processes, and, subsequently, the Science Committee's selection of a subset of vital signs for protocol development.

As we have progressed through Phases I, II and III of vital signs monitoring planning, we have worked to organize our models into a hierarchical framework, to standardize the format of systems models, and to learn from the approaches of other networks with similar ecosystems, ecosystem stressors, or monitoring interests (especially Rocky Mountain Network, Northern and Southern Colorado Plateau Networks, Mojave Network, and North Coast/Cascades Network).

Our model framework is organized into (1) *overview,* (2) *system*, and (3) *detailed* models (Table 2-1). We follow hierarchy theory, which provides a context for conceptualizing a complex system as a set of less complex sub-models spanning a range of scales and ecological levels (Allen and Hoekstra 1992). Our overview models provide context at broad spatial or temporal scales for Sierra Nevada ecosystem drivers, stressors, processes, and components. Our system models describe focal systems of interest for vital signs monitoring, and illustrate the core drivers, system components and functions, and major stressors that influence these systems. Our detailed models explain key processes (fire regimes, nitrogen deposition, hydrology) or illustrate relationships among drivers, stressors, system components, and functions in certain groups of organisms (invertebrates, amphibians, birds) or specific systems of interest for monitoring (meadows/wetlands, lakes, streams).

Table 2-1. Conceptual models included within this monitoring plan. Models are dynamic; as new relationships are elucidated, our models will evolve.

	Model	Location
Overview	Sierra Nevada Ecosystems	Chapter 2 and *Appendix F*
	Sierra Nevada Stressors	Chapter 1 and Appendix F
	Landscape Exchange	Chapter 2 and *Appendix F*
	Sierra Nevada Focal Systems	*Chapter 2*
System, Process, Population	Atmospheric System Nitrogen Deposition	*Appendix F*
	Hydrologic System	*Appendix F*
	Aquatic System Lakes Anuran Populations Rivers and Streams	*Appendix F* *Appendix F* *Appendix F* *Appendix F*
	Wetland System Invertebrates	*Appendix F*
	Forest System Fire Regimes	*Appendix F*
	Non-native Invasive Plant Populations Invasion Susceptibility	*Appendix F*
	Bird Populations	*Appendix F*

2.3 Overview Models

Below, we present three overview models to: (1) highlight ecosystem factors that interact with processes to structure the physical environment and its biotic communities, (2) illustrate inputs and outputs (i.e., exchanges of materials and organisms) that affect Sierra Nevada landscapes, (3) highlight the focal systems–their processes and indicators–targeted for monitoring, and (4) depict synergistic and associative effects of stressors (this stressor model, is discussed in Chapter 1, Section 1.9).

2.4 General Model for Sierra Nevada Ecosystems

SIEN has modified a general ecosystem model from Jenny (Jenny 1941) and Chapin et al. (Chapin et al. 1996) to serve as a foundation for our other models. This model (Figure 2-1**Error! Reference source not found.**) presents ecosystem processes as a function of hierarchical state factors and interactive controls. **State factors** operate at the largest (broadest) scales and include global climate, continental- and regional-scale topography, parent material (e.g., geologic substrate), time (e.g., age of the system), and the types and distributions of organisms within a landscape. **Interactive controls**—such as local climate patterns, soil function and development, and the type and distribution of organisms—control and respond to ecosystem characteristics, and are constrained by state factors (Chapin et al. 1996, Dale et al. 2000).

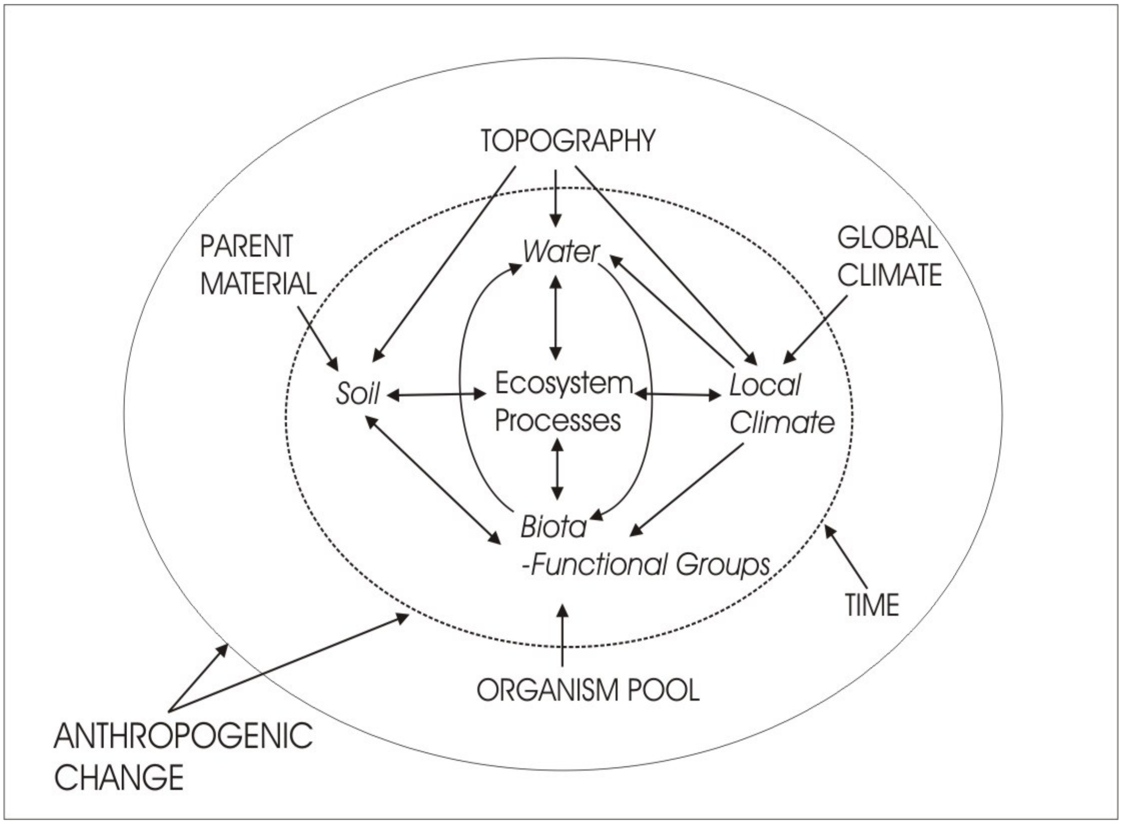


Figure 2-1 General model for Sierra Nevada ecosystems. The relationship among state factors, interactive controls, and ecosystem processes. See text for explanation. State factors are capitalized, interactive controls are italicized, the region (here = Sierra Nevada eco-region) is represented by the dashed circle, and the Earth is represented by the solid circle.

We modify the Jenny-Chapin model components in several ways to better represent Sierra Nevada park systems (Table 2-2):

1. We include "anthropogenic change"–influencing all other state factors and interactive controls–as another state factor that affects (a) most other state factors at a regional to global scale, and (b) affects the local interactive controls (see Chapter 1 for a discussion of the major stressors associated with anthropogenic change in the Sierra Nevada).
2. We add "ecosystem processes" as an interactive control.
3. We omit "disturbance regime" as an interactive control; instead, we place fire and flood disturbance regimes under "ecosystem processes" (we see these primarily as climate-driven processes of change that should not be considered separately from other ecosystem processes).
4. We make "water" explicit as an interactive control to emphasize its critical role as a limited–and limiting–resource in our Mediterranean climate regime.

Table 2-2 provides an overview of the functions and characteristics of interactive controls and ecosystem processes.

Table 2-2. Definition of SIEN ecosystem model "interactive controls" and their characteristics and function. Definitions primarily from (Chapin et al. 1996).

SIEN Interactive Controls	Characteristics and Functions of Interactive Controls
Climate • Strongly governs structure, productivity, and biogeochemistry of ecosystems.	• Mediterranean: dry summers/wet winters. • Affects dynamics of ecosystem processes, distribution of organisms, water availability.
Soil • Soil resource supply determines maximum productivity and structural diversity of vegetation.	• Characterized by physical structure and chemistry. • Functions include nutrient cycling and availability, water availability and loss, microorganism habitat • Soil type and depth affect vegetation distribution.
Water • A limiting resource in Mediterranean climate regimes; driver of productivity, abundance, and growth form.	• Surface water, snowpack, soil & ground water. • Characterized by temporal flow cycles, water quality; provides habitat for aquatic organisms, and is a driver for distribution of terrestrial organisms.
Biota (Functional Groups) • Groups of species that have similar effects on ecosystem processes.	• Ecosystem productivity, nutrient cycling, carbon fixation, evapotranspiration, herbivory, predation, decomposition, pollination, biodiversity.
Ecosystem Processes • Flows of energy and materials in an ecosystem; climate-driven processes of change.	• Climate-driven processes: fire, flood, avalanche. • Biogeochemical cycling, plant productivity, erosion, weathering, population dynamics.

2.5 Landscape Exchange

A landscape can be thought of as an "open" system that exchanges energy, materials, and organisms with its surroundings. The structure of a landscape (e.g., drainage networks, patches, mosaics, elevation gradients, and so on) influence the ecological processes within the landscape. These processes are linked by the movement of plants and animals, air, water, energy, and biogeochemical cycles (Turner 1989). Park "boundaries" are mostly arbitrary demarcations with respect to atmospheric, hydrologic, and other ecosystem processes.

The major interactions between park landscapes, with the larger surrounding Sierra Nevada eco-region, are illustrated in Figure 2-2. Many of the portrayed exchanges are common to all Sierra Nevada landscapes, regardless of shape, size, or locality. Some external inputs into parks are little-influenced by the parks themselves—these include meteorological inputs (e.g., precipitation, solar radiation) and airborne pollutants (e.g., nitrogen, persistent organic pollutants).

As depicted, park landscapes exchange energy, materials, organisms, and processes with the adjacent landscapes and larger eco-region (within which it is embedded). For example, birds and other animals freely cross the boundary between park and non-park habitats. Fire can propagate into or out of a park unit. Non-native invasive species present outside park boundaries can be transported into a park area by wind, animals, or human activities. River flows can originate within a park watershed, passing through its boundary on its way to lower elevations, or may only flow through a park and therefore not encompass the uppermost reach of the watershed (e.g., San Joaquin River through Devils Postpile). Park areas of smaller extent, such as Devils Postpile, may be more profoundly influenced by their surroundings than those of larger extent; larger parks may be better able to compensate for disturbances and other outside influences.

Implications of these exchanges (of materials, organisms, etc.) on park resources need to be explored and related to management concerns. Although we often cannot control what enters a park, we can monitor its effects, communicate that information widely, and mitigate, to some extent, through thoughtful management.

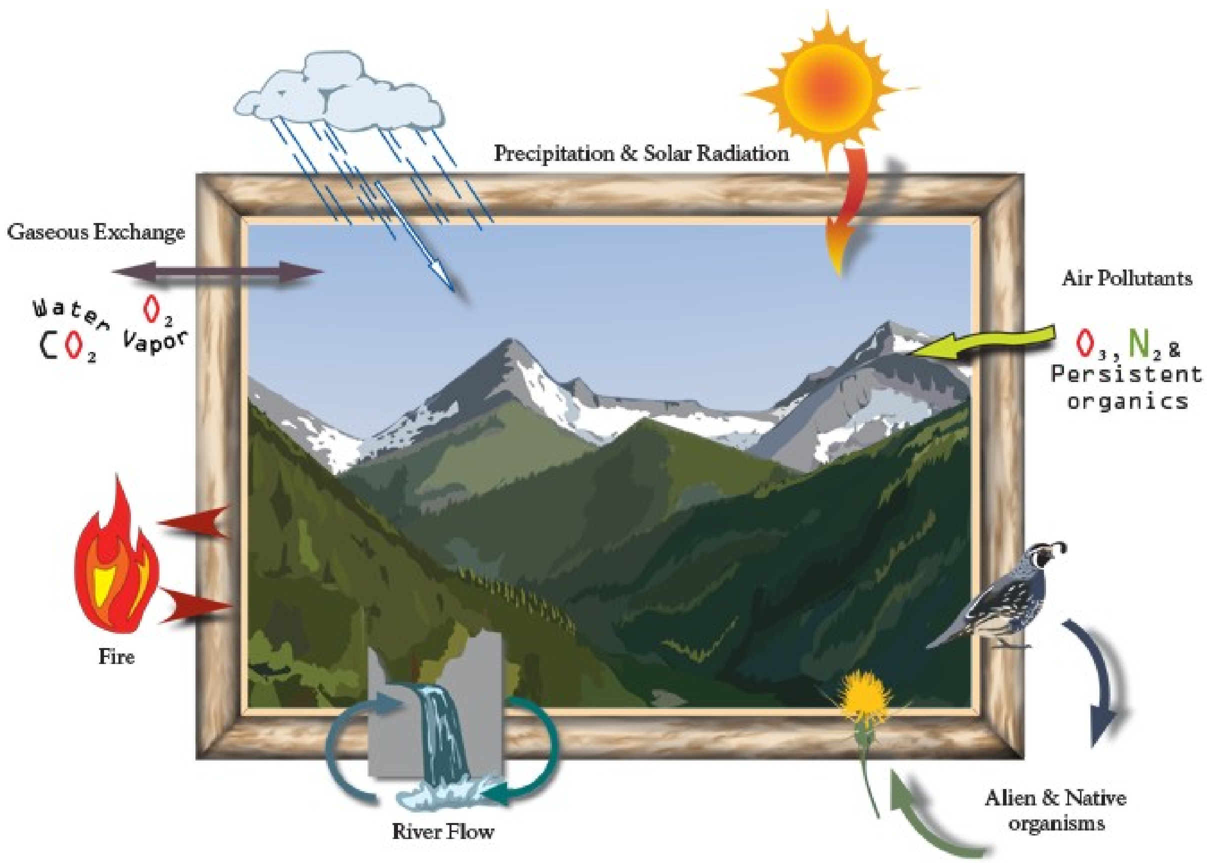


Figure 2-2. Major inputs and exchange of energy, materials, organisms, and processes for Sierra Nevada parklands (landscapes) and their physical surroundings. *Illustration by Justin Hofman (NPS intern*).

2.6 Sierra Nevada Focal Systems

While we would like to include the full complement of biotic and physical aspects of ecosystems in our monitoring program, the size and complexity of Sierra Nevada park landscapes require that we focus monitoring efforts on a few focal systems and drivers. Through a series of Network workshops, Science Committee meetings, and Board of Director review, over several years (which we describe in Chapter 3), we identified components of (1) aquatic, (2) coniferous forest, and (3) meadow/wetland systems as a focus for long-term monitoring due to their ecological significance, sensitivity to major drivers and linkage to anthropogenic stressors, and management priority. The interrelationships among these systems, as well as the major divers that influence them, are depicted in Figure 2-3.

2.6.1 Focal System: Wetlands

Wetlands (e.g., wet meadows, fens, riparian wetlands) concentrate resources, provide critical habitat for both resident and transient animals, are extremely productive, and have therefore been identified as key ecosystem elements in Sierra Nevada Network parks. Wetlands are diverse and complex ecosystems that vary widely in character and composition, although occupying only a relatively small fraction of our land surface of the Sierra Nevada (Benedict and Major 1982, Ratliff 1982).

Sierra Nevada meadows range in size from small patches to large expanses (e.g., Tuolumne Meadows in Yosemite National Park). Most Sierra Nevada wetlands occur above snowline, where snowmelt provides moisture during the summer growing season. In addition to surface flow, moisture enters wetlands from streams and sub-surface flows forced to the surface by local geomorphology. Meadows can be characterized as wet, or dry, reflecting the relative availability of moisture during the summer growing season. Other wetlands include fens and riparian wetlands. Sierra Nevada wetland vegetation is dominated by perennial graminoids, which reflect the relatively short growing season of middle and high elevations.

Field testing SIEN's meadow monitoring protocol in Yosemite National Park. Photo by Jutta Schmidt-Gengenbach.

Wet wetlands provide important ecological and cultural functions in the Sierra Nevada, including: (1) influencing regional water-flow regimes, including flood mitigation; (2) improving water quality by removing nutrients and toxic materials; (3) sediment trapping; (4) a source of some of the highest productivity in the parks; (5) important habitat for wildlife; and (6) aesthetic values to people (1993). A more complete description of meadow/wetland systems is included in Appendix F, "Conceptual Models." Figure 2-4 depicts our detailed meadow/wetland conceptual model as an example of the level of detail we provide for all vital sign models in Appendix F.

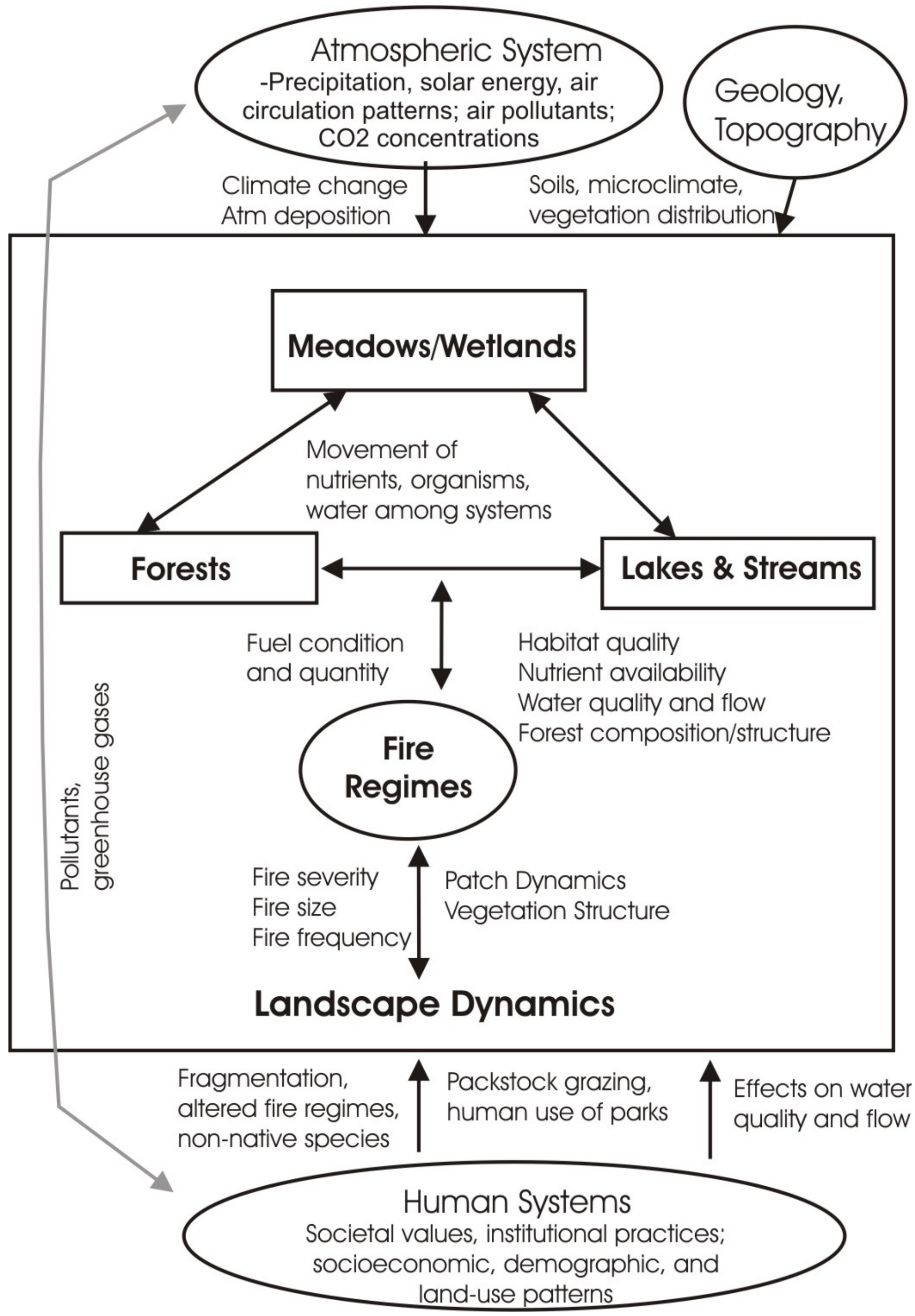


Figure 2-3. Landscape dynamics, along with aquatic, forest, and meadow/wetlands systems are the main focal systems for SIEN vital signs monitoring. Major drivers of Sierra Nevada systems are shown in ovals. (Major drivers are also a focus for vital signs monitoring and include, for example, invasive plants).

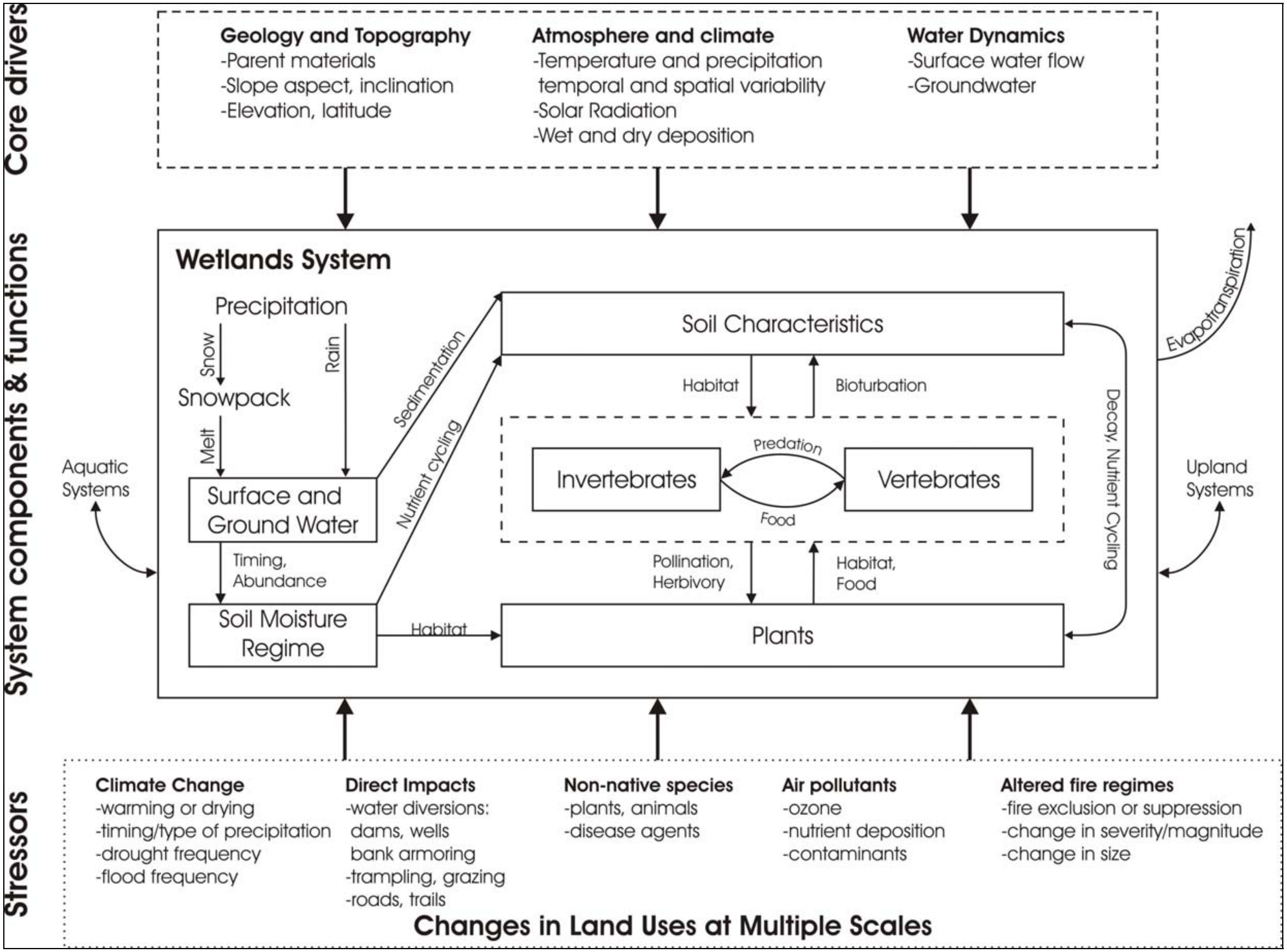


Figure 2-4. Detailed Meadow Model.

Water is linked to atmospheric and terrestrial systems (i.e., the hydrologic cycle). In the Sierra Nevada, snowpack that accumulates in the winter serves as a reservoir for water that is released gradually in the spring to the aquatic system (groundwater, wetlands, streams and lakes), thus available during the dry summer growing season. Both the quantity and quality of water help to determine the condition of terrestrial as well as aquatic biological systems.

Alpine lakes in Evolution Basin, Kings Canyon National Park. NPS photo.

High elevation lakes and streams in the Sierra Nevada are oligotrophic, have a low buffering capacity, and are sensitive to change from atmospheric deposition of nutrients, acids, and toxic substances, (Goldman et al. 1993, Leydecker et al. 1999, Davidson and Shaffer 2002, Sickman et al. 2003). Change detected in high-elevation lakes can be an early warning indication of change that may eventually occur at other elevations and ecosystem types. To complement monitoring of high-elevation aquatic systems, monitoring of water quality and quantity in mid- to low-elevation streams and rivers can indicate cumulative effects of changing terrestrial and aquatic ecosystem processes and disturbances throughout a watershed.

Water availability is a major driver in the distribution of plant communities. Thus, tracking water quantity changes over time may provide an early warning of later changes in soil moisture that could lead to gradual shifts in plant population dynamics and landscape community distributions.

2.6.2 System: Forests

Sierra Nevada montane and subalpine coniferous forests comprise one of the largest and most economically important vegetation regions in California (Rundel et al. 1988). They are very complex in composition, structure, and function (Franklin and Fites-Kaufmann 1996). We are interested in monitoring

Giant sequoia-mixed conifer forest.

forest dynamics of certain tree species—primarily birth, growth and death rates—because they are sensitive to changes in two major drivers in the Sierra Nevada: climate and fire regimes. These two drivers are subject to substantial alteration by human impacts, and in these altered states can act as stressors on forest systems.

Sierra Nevada forest distributions are linked to moisture availability as determined by topography, soil depth, and evaporative demand (Figure 2-5). Moisture availability affects growth, recruitment, and death rates of trees. In addition, Sierra Nevada montane forests are highly dependent on fire (See Chapter 1 and Appendix F, "*Conceptual Models,*" for more detail).

Monitoring of forest dynamics will be linked to monitoring of fire regime, fire effects, and climate to enable effective interpretation of trends in tree population dynamics and large-scale forest landscape changes in pattern and structure.

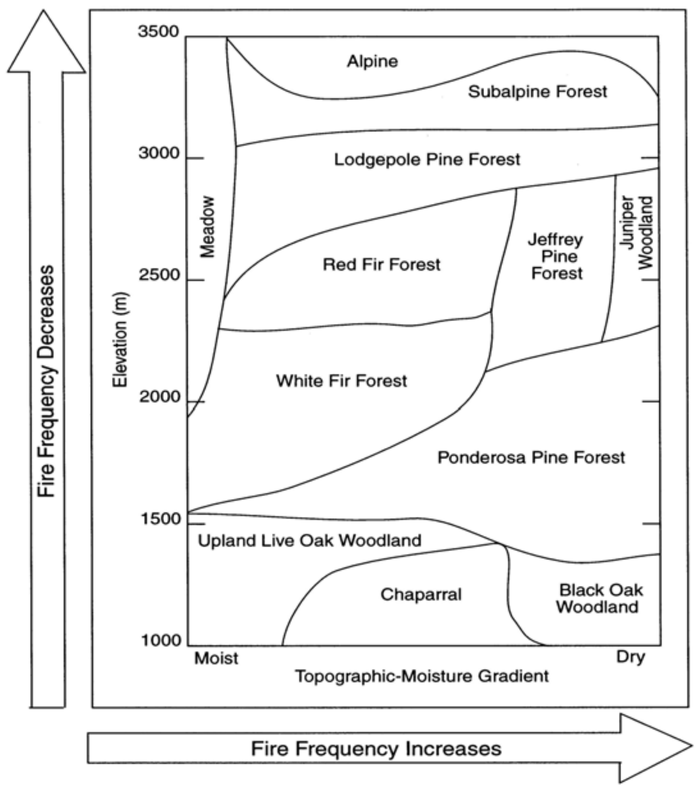


Figure 2-5. The distribution of general vegetation types (Vankat 1982) and the relationship of fire frequency to elevation and topographic gradients in Sequoia National Park (Miller and Urban 1999).

2.7 Major Drivers of the Sierra Nevada

This section highlights the major drivers that influence Sierra Nevada landscape dynamics and focal systems—aquatic, coniferous forest, wetland—components of which have been selected for monitoring. See Appendix F, "*Conceptual Models*", for a more detailed discussion of ecosystem drivers and focal systems.

Driver: The major external driving forces that have large-scale influences on natural systems. Drivers can be natural forces or anthropogenic. We frequently refer to *anthropogenic* drivers as stressors (see Chapter 1, Section 1.9)

2.7.1 Driver: Atmospheric System

The atmospheric system drives weather, and at longer time scales, climate. Climate strongly influences the landscape by determining the flux of both energy (solar radiation) and mass in the form of moisture (rain, snow, water vapor). Stine (1996) generalizes that climate exerts a predominant influence on the following components of the Sierra Nevada landscape:

- Vegetation (type, biomass, distribution)
- Hydrology (size, distribution, fluctuations, and water quality of lakes and streams)
- Soils (thickness, stability, nutrient capacity)
- Landforms (rates of formation and loss)
- Fire (location, frequency, seasonal timing, intensity and/or severity)

Climate varies spatially and at annual, decadal, centennial, and millennial time scales. Numerous paleo-ecological studies have documented changes in vegetation over the past many thousands of years in response to changes in climate. During the Quaternary period of the past 2.4 million years, at least six successive major glacial cycles covered the Sierra Nevada. These ice ages were interspersed with shorter warm intervals when habitats expanded into northerly latitudes and tree lines gained elevation. Species responded individualistically to these changes, sometimes assembling into communities with no modern analog (Woolfenden 1996).

Climate affects the distribution of forest types and other plant communities of the Sierra Nevada through its influence on the soil water balance (Stephenson (1988, 1998). With increasing elevation, precipitation increases and temperature decreases (causing decreasing evaporative demand). The mixed-conifer zone of the Sierra Nevada is sandwiched between low-elevation sites that are chronically droughty, and high-elevation sites that are too cold to be very productive (Urban et al. 2000). Thus, these zones are quite sensitive to climate variability (Graumlich 1993, Swetnam 1993).

Predicted potential effects of anthropogenic climate change on the Sierra Nevada were discussed in Chapter 1 (Section 1.9). These effects will likely be highly synergistic, affecting a host of physical and biological systems in unpredictable ways (CIRMOUNT Committee 2006).

In addition to its influence on weather and climate patterns, atmospheric dynamics interact with topography to influence air patterns, affecting the distribution and deposition of pollutants. Ozone, agricultural pesticides, particulate matter, and nitrogen compounds are a few examples of pollutants deposited through dry and wet deposition in Network parks *(see Chapter 1 Section 1.9 and* Appendix C*, "Air Quality Synthesis" for details about pollutants, sources, and air flow patterns).*

2.7.2 Drivers: Fire, Climate, and Moisture Gradients

The importance of fire as a key process and driver in the Sierra Nevada was discussed in Chapter 1. Here, we elaborate and emphasize the links between fire and climate and their roles in influencing vegetation pattern and various ecosystem processes. Climate primarily affects fire regime through its direct effects on fuel moisture. Climate also affects the geographic distribution of vegetation types and site productivity, and thus, indirectly influences the intensity, frequency, and size of fires (Miller and Urban 1999). Fire frequency tends to decrease with increasing elevation and soil moisture interacting with topographic moisture gradients and fuel availability to help shape vegetation distribution and landscape patterns (Figure 2-6). Over longer time scales, climatic fluctuations are responsible for variations in fire regimes (Clark 1988, Swetnam 1993).

Fire in giant sequoia-mixed conifer forest. NPS photo.

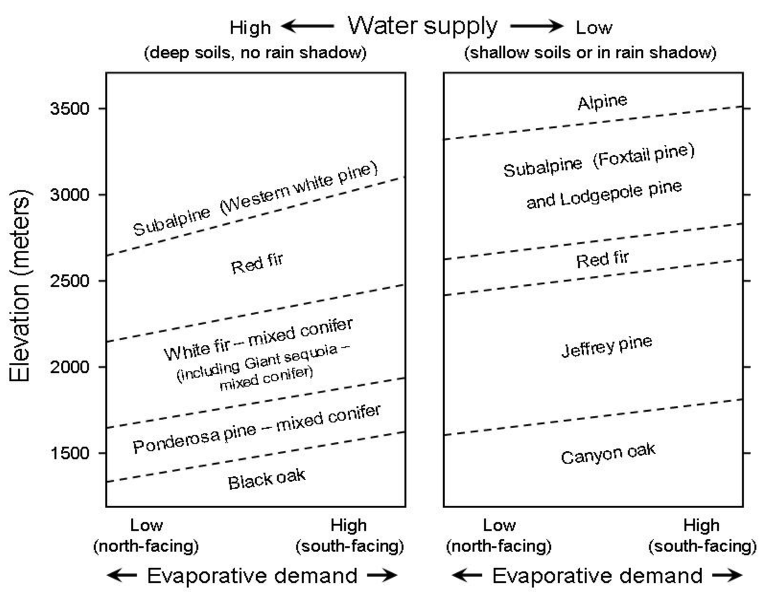


Figure 2-6. The approximate distribution of forest types in the southern Sierra Nevada relative to elevation, evaporative demand, and water supply. Only upland forest types (away from open water and wetland edges) are shown. Modified from Stephenson (1988).

Fire, as a process, helps link terrestrial, atmospheric, and aquatic systems through its role in moving nutrients across these systems. Several Sierra Nevada studies have documented increases in stream solute concentrations after fire (Chorover et al. 1994, Williams and Melack 1997a, b, Heard 2005). Although many elements are volatized (Covington and Sackett 1984, Caldwell et al. 2002), high concentrations of elements are also left behind in ash layers and partially combusted organic material (Blank and Zamudio 1998), rendering them available for plant and microbial uptake.

In summary, fire regimes–in combination with climate and topography (discussed below)–shape vegetation structure and pattern on the landscape, affect water quality and quantity, and indirectly affect wildlife habitat.

2.7.3 Driver: Geology and Topography

The Sierra Nevada physical landscape was shaped by glaciation, volcanism, erosion, and deposition. The resultant varied topography provides habitat diversity for plant and animal communities. As described in Chapter 1, elevation gradient influences local weather and climate patterns, with a general trend of decreasing temperatures and increasing precipitation with rising elevation. Because mountains create a rain shadow, significantly less moisture falls throughout the season east of the Sierra Nevada crest. Topography also influences microclimatic conditions due to variations in aspect (e.g., north aspects have lower temperatures and concomitant evaporative potential). As such, northern aspects tend to be moister and cooler than south-facing slopes. Soils vary in type and depth, influencing plant community distribution as a result of nutrient availability and water-holding capacity. (See Figure 2-6 for the influence of aspect and soil depth on forest distribution.)

Glacially-carved Tehipite Valley, Kings Canyon National Park. NPS photo.

2.7.4 Driver: Human Systems

California has 34 million people, by far the most populous state in the Union. The San Joaquin Valley (part of California's Central Valley), located to the west of the Sierra Nevada Network parks, has a population of 3.4 million–or ten percent of California's population. By 2020, the San Joaquin Valley is projected to have over six million people.

Regional topography, weather patterns, current population levels, agri-business, and other industries has lead to some of the worst air quality in the country (see Chapter 1 and Appendix C, "*Air Quality Synthesis*"). In addition, California agriculture uses a large percentage of state water resources. The predicted population doubling will inevitably change land use patterns and have a dramatic influence on the quantity of arable land, air and water quality and availability, energy resources, and biodiversity. These changes will have direct effects on park resources in the form of atmospheric transport and deposition of pollutants and nutrients, more greenhouse gas emissions, compromised dark night sky and soundscape, increased development and urbanization, and increased park visitation.

• A view from Sequoia National Park toward California's Central Valley, contrasting a good air quality day with a bad air quality day. Data entry/training

Societal values and social systems govern many of the interactions of the human system with the Sierra Nevada eco-region and parks. Future changes in socioeconomic, demographic, and land-use patterns, in combination with changes in social systems and values, will present many new challenges for Sierra Nevada Network parks.

2.8 Future Development and Applications of Models

As protocols are developed and implemented, they will correspondingly evolve to capture an increasing understanding of the system. Monitoring results will be analyzed and interpreted, and resultant information will be shared with a variety of audiences. The Sierra Nevada Network will further develop conceptual models for the following purposes:

- <u>Outreach/communication</u>: Attractive, simple pictorial models that explain focal systems and relationships of components and drivers for interpretive applications, general audiences, web pages, etc..
- <u>Information Interpretion/Gap Identification</u>: complete models that (1) elaborate more detailed relationships among components and drivers, (2) acquire insights from on-going research and monitoring projects, and (3) identify specific gaps in understanding in various systems.

- Prediction: Predictive models that use actual data to identify areas most sensitive to climatic change, most vulnerable to non-native plant invasions, or most affected by nitrogen deposition and ozone pollution.
- Simulation and analysis: Mathematical, statistical, or null models that predict patterns of species diversity, niche overlap, and species co-occurrence. Some networks in the NPS are beginning to use modeling simulation programs such as EcoSim (Gotelli and Entsminger 2006).

The Network will need to consider modeling capability in its development of university partnerships and long-term staffing, as conceptual and predictive modeling will be an integral part of monitoring program development, data analysis and interpretation, communication, and outreach.

Chapter 3 IDENTIFYING AND PRIORITIZING VITAL SIGNS

Identifying and selecting *vital signs* for the SIEN Inventory and Monitoring Program has required a process of research, multi-disciplinary workshops, evaluation, and teamwork. Scientists, managers, administrators, numerous partner agencies, and many others throughout the Sierra Nevada Network have worked together to select and prioritize vital signs. The current list of 34 candidate vital signs represents a balance of ecosystem driving variables (e.g., weather, climate) and response variables—communities and species (Bennett et al. 2003).

3.1 Summary of Vital Sign Prioritization Process

The vital signs selected provide a focus for monitoring at different spatial and temporal scales. They represent a mix of sensitive and early indicators, as well as slower responding, more integrative indicators. Although we realize it will not be possible to monitor all of these vital signs in the immediate future, they do represent a powerful and balanced guide for developing an integrated long term monitoring program.

Network staff and partners developed and refined this list through a process that included meetings, workshops, and ranking exercises to produce a shortened list of candidate vital signs for the Network to use for feasibility analyses. From this list, SIEN's science committee (comprised of I&M, park, and partner staff) chose twelve vital signs for developing and implementing monitoring protocols during the next two to three years (i.e., Phase III).

In this chapter, we describe how we identified and prioritized potential vital signs, and subsequently, selected a reduced working list of candidate vital signs for the Sierra Nevada Network. We also describe in more detail the twelve vital signs we will focus on during the next two years for protocol development and implementation. These descriptions include *definition*, *justification*, and *preliminary monitoring* objectives.

3.2 Selecting Vital Signs

Selecting and prioritizing vital signs has been a multifaceted process of park-level workshops, targeted scoping workshops, Science Committee meetings, literature review, and conceptual model development. During the past two years (thanks to program funding and hiring of the first permanent I&M staff), the Network has been able to further identify and refine Network-relevant vital signs. Development and refinement of the vital signs list was conducted in concert with development and refinement of conceptual models (see Chapter 2).

3.2.1 Preliminary Identification of Vital Signs

When Network-wide vital signs prioritization began, a list of 86 potential vital signs had been synthesized (development of this list is described below). Throughout the Network prioritization processes (see Table 3-1 and Figure 3-1), each of the 86 Network vital signs was evaluated in context of relevance:

- Is the vital sign relevant to National Park Service monitoring goals?
- Is the vital sign relevant to Network monitoring objectives?
- Is the vital sign relevant to Network resources management?
- Is the vital sign responsive to known Network anthropogenic stressors (as illustrated in the conceptual models of these stressors)?
- Does the vital sign provide information about Network key ecosystems, communities, or processes (as illustrated in the conceptual models of these ecosystems)?

Park-level workshops—comprised of staff from NPS, USGS-WERC, and outside researchers and subject-matter experts—generated the initial list(s) of Network vital signs. For several years, these workshops took place without the assistance of vital signs monitoring funds or a paid permanent staff dedicated to the project.

The Science Committee generated a Network-wide, broad and comprehensive list of 86 vital signs (see Appendix G, "*Network Vital Signs*") by refining the three individual park-based lists (i.e., combining similar vital signs, adding vital signs (e.g., air and water resources which are already being monitored within parks), reviewing the literature, and developing and refining conceptual models. The Science Committee gave special attention to the five major anthropogenic stressors of the ecology of the Sierra Nevada: (1) rapid anthropogenic climate change, (2) altered fire regimes, (3) non-native invasive species, (4) air pollution, and (5) habitat fragmentation and human use.

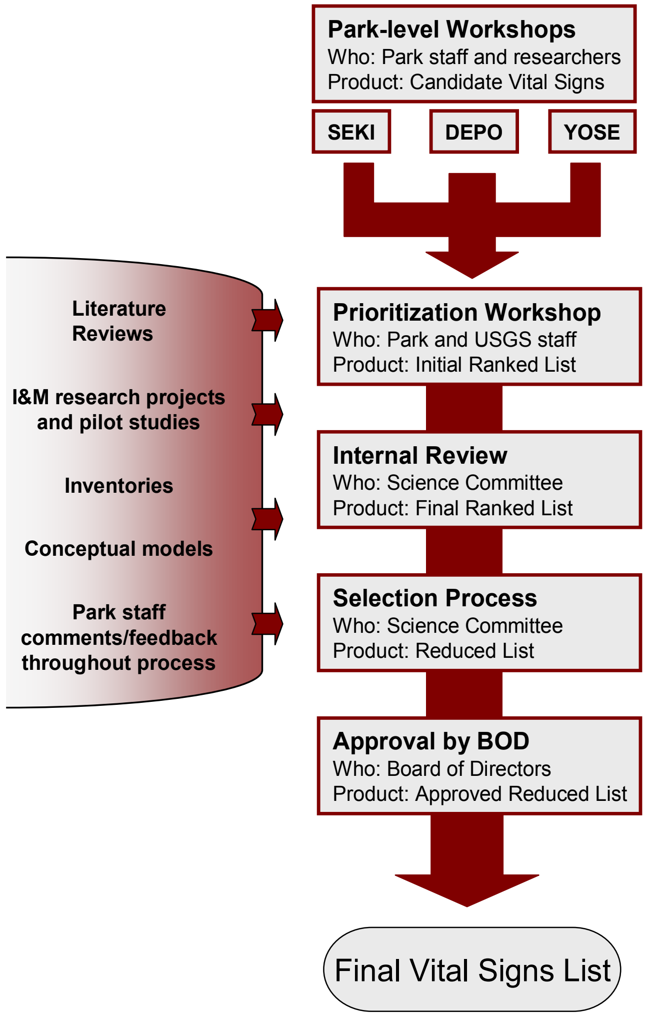


Figure 3-1. Vital signs identification, prioritization, and selection process for the Sierra Nevada Network.

Table 3-1. Timetable of meetings and workshops employed by Sierra Nevada Network staff to generate and prioritize vital signs.

Date	Event	Purpose	Product
April 1999	Park-level vital signs workshop (Sequoia & Kings Canyon)	Generate list of potential vital signs, via brainstorming, by subject-matter groups	Summary Report
April 2002	Park-level vital signs workshop (Devils Postpile)	Generate list of potential vital signs, via brainstorming, by subject-matter groups	Summary Report
April 2002	Park-level vital signs workshop (Yosemite)	Generate list of potential vital signs, via brainstorming, by subject-matter groups	Summary Report
January–December 2004	Interdisciplinary Committee: I&M staff and Science Committee synthesize Network list of Vital Signs	Synthesize network-level vital signs lists (using individual park-level lists). Network list comprises 86 candidate vital signs	Appendix G
January–October 2004	Science committee meetings with Sierra Sciences, Ltd.	Conceptual Model Development	Phase I Plan
March 2004	Network Vital Signs Prioritization Workshop attended by park resource, USGS, and I&M staff.	Rank list of 86 vital signs in four broad categories: physical, wildlife, vegetation, ecosystem process/human-use	Appendix G
April 2004	Science committee meetings and use of revised conceptual models, literature	Reduce candidate vital signs list	Table 3-3
November 2004–September 2005	Science committee and results of vital signs prioritization workshop, peer review, and WASO guidance	Conceptual Model development and revision, continued	Phase II Plan

Date	Event	Purpose	Product
Spring 2006	Formation of Network-level vital signs workgroups (discussed in Chapter 5)	Refine monitoring objectives; determine workgroup method for protocol development; work groups are composed of SIEN, SEKI, YOSE, and USGS-BRD staff	Protocol Development Summaries (FY2006) Monitoring Protocol(s) (FY2007-2010)
January–December 2006	Workgroup meetings; Science committee meetings	Examine opportunities for integration of vital signs (see Chapter 5)	Integration of vital signs (e.g., Wetland Ecological Integrity and Lake Protocols)
January–December 2006	SIEN staff (and SEKI–Pat Lineback)	Refine Chapters 1-3; Write Chapters 4, 5, 6, 7, 8, 9, and 10; refine Appendices	Phase III Plan
January–September 2007	All	Edit and revise (based on peer review)	Final SIEN Vital Signs Monitoring Plan

3.2.2 Prioritization

The next stage of the vital signs process was a Network-wide vital signs prioritization workshop held in March 2005. In two days, approximately 40 participants, divided into four subject-area workgroups (physical, wildlife, vegetation, and ecosystem process/human-use) ranked relevant subsets of vital signs generated from the broad, comprehensive list.

Detailed supporting information (*justification*) for each vital sign was provided, including a full description of the vital sign in context of the Network, stressors, and management issues. Potential monitoring questions, measures, and partnership opportunities (e.g., working with other agencies) were noted where appropriate. This information was entered into a Microsoft Access database, adapted from the Mojave Network. The database allowed groups to enter prioritization scores at the workshop based on a set of criteria (Table 3-2) compiled from the NPS Inventory and Monitoring Program (http://science.nature.nps.gov/im/monitor/docs/CriteriaExamples.doc). At the conclusion of the workshop, vital signs ranks could quickly be calculated in the database, enabling the group to view the resultant ranks and discuss them immediately. The ranked list of 86 vital signs is included in Appendix G, "*Network Vital Signs*."

Table 3-2. Criteria applied to each of the 86 candidate vital signs, including weighting applied to each criteria category for ranking purposes.

Category (weight)	Criteria if *strongly* agree (score=1), otherwise (score=0)
Ecological Relevance, Geographical Scope, Data Response & Sensitivity (60%)	• There is a strong, defensible linkage between the vital sign and the ecological function or critical resource it is intended to represent (as supported by conceptual models).
	• The vital sign represents a resource or function of high ecological importance based on the conceptual models of the system and the supporting ecological literature.
	• The vital sign has broad geographic scope—it occurs in at least two out of three network units (Devils Postpile, Sequoia & Kings Canyon, and Yosemite) <u>and</u> has broad spatial extent within the parks or across the region.
	• The vital sign is anticipatory. It can signify an impending change in the ecological system or in important resources.
	• The vital sign is sufficiently sensitive to small changes in linked or related resources or functions (as supported by conceptual models).
	• Baseline data exist within the region and/or threshold values are specified in the literature that can be used to measure deviance from a desired condition.
Management Relevance & Utility (40%)	• There is an obvious, direct application of the data to key current or future management decisions.
	• Monitoring results are likely to provide early warning of resource impairment, and will thereby save park resources and money.
	• Data are of high interest to the public.
	• There is a direct application of the data to performance (GPRA) goals and long-term planning.
	• The vital sign is an extremely vulnerable or at-risk resource or process.

Using the ranked results of the prioritization workshop, as well as comments and recommendations from workshop participants, the Science Committee reevaluated each vital sign and categorized them based on scientific merit and context. Vital signs that are already part of established ongoing monitoring programs were also included and categorized on merit, etc., as well.

Finalization of the candidate vital signs list (Table 3-3) occurred through several subsequent meetings of the Science Committee. **Vital signs** were categorized as follows:

Tier 1: Vital signs that we consider good indicators of the larger ecosystem or resource condition, and having a robust connection to the ecosystem as indicated by conceptual models (some of these are included in). Justifications of vital signs chosen for protocol development during the next two years are included in Appendix H, "*Protocol Development Summaries*."

Tier 2: Vital signs that we consider good indicators of the larger ecosystem, having a robust connection to the ecosystem, as indicated by conceptual models (see Appendix F, "*Conceptual Models*"), but whose protocol development will not proceed until on-going research indicates monitoring will be feasible or until additional funds are identified.

Tier 3: Vital signs not considered to be good indicators of the larger ecosystem (at least with information currently available), yet are resources that should be monitored (e.g., dark night sky, soundscape) (see Table 3-3 and Appendix G, "*Network Vital Signs*").

Tier 4: De-listed Vital Signs—those identified as a weak vital sign or a vital sign whose condition could be improved by straightforward management action (e.g., stock use). (See Appendix G).

Detailed descriptions of vital signs in Tier 1 can be found in Protocol Development Summaries (Appendix H).

Table 3-3. Reduced "working" list of vital signs generated by Network-wide prioritization efforts (workshop and Science Committee), and relevance to each park unit. Vital signs selected for protocol development in the next two years are **bolded** (and described in detail in Appendix H, "*Protocol Development Summaries*"). See key below the table for symbol explanation.

Level 1	Level 2	Vital Sign	DEPO	KICA	SEQU	YOSE
Air and Climate	Air Quality	Ozone	✧	✧	•	•
		Airborne contaminants	✧	✧	✧	✧
		Atmospheric deposition	✧	✧	•	•
		Particulate matter	✧	✧	•	•
		Visibility	✧	✧	•	•
	Weather and Climate	**Weather and climate**	✚	•	•	•
		Snowpack	✚	•	•	•
Geology and Soils	Geomorphology	Stream channel morphology	✧	✧	✧	•
	Subsurface Geologic Processes	Caves/karst physical processes	–	•	✧	✧
Water	Hydrology	**Surface water dynamics**	•	✚	✚	✚
		Wetland water dynamics	✚	✚	✚	✚
	Water Quality	**Water chemistry**	✚	✚	✚	✚
		Toxics	✧	✧	✧	✧
		Snow chemistry	✧	✧	✧	✧

Level 1	Level 2	Vital Sign	DEPO	KICA	SEQU	YOSE
		Macro-invertebrates	✧	✧	✧	✧
		Microorganisms	✧	✧	✧	✧
Biological Integrity	Invasive Species	**Non-native invasive plants**	–	✚	✚	✚
	Focal Species or Communities	Selected plant communities	✧	✧	✧	✧
		Forest dynamics	✚	✚	✚	✚
		Phenology	✧	✧	✧	✧
		Wetland plant communities	✚	✚	✚	✚
		Amphibians	–	✚	✚	✚
		Birds	✚	•	✧	•
		Macro-invertebrates (wetlands)	✚	✚	✚	✚
		Cave biota	✧	✧	✧	✧
		Bats	✧	✧	✧	✧
		Meso-carnivores	✧	✧	✧	✧
Landscapes (Ecosystem Pattern and Processes)	Fire and Fuel Dynamics	**Fire regimes**	•	✚	✚	✚
		Fire effects on plant communities	•	•	•	•
	Landscape Dynamics	**Landscape mosaics**	✚	✚	✚	✚
	Viewscape	Night sky	✧	✧	✧	✧
	Soundscape	Soundscape	✧	✧	✧	✧
	Nutrient Dynamics	Biogeochemical cycling	✧	✧	✧	✧
	Energy Flow	Net primary productivity	✧	✧	✧	✧

Legend:

- ✚ Vital signs that the Network will use to 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.
- – Vital sign does not apply to park, or for which there are no foreseeable plans to conduct monitoring.

3.3 Relationship of Vital Signs to Broad Monitoring Objectives

The Sierra Nevada ecosystem overview and broad monitoring objectives in Chapter 1 (Section 1.5: Sierra Nevada Network Parks) and the ecosystem conceptual models in

Chapter 2 and its companion *Appendix F, "Conceptual Models,"* provide the primary framework and context for the reduced list of vital signs. The reduced list of vital signs is well distributed across resource types—both physical and biotic—and includes key drivers, stressors, and ecosystem processes. In this section, we indicate the 34 candidate vital signs in context of the broad monitoring objectives outlined in Chapter 1 (Section 1-11: Monitoring Goals, Objectives, and Questions), and we provide specific descriptions and brief justifications for each vital sign.

Objective 1: Understand the natural range of variation in annual and seasonal weather patterns, long-term trends in climate, and effects of global climate change on hydrologic regimes and biological processes.

- **Weather and climate**
- **Snowpack**
- **Surface water dynamics**
- **Wetland water dynamics**
- Phenology

Objective 2: Understand patterns of spatial and temporal variation in fire regime characteristics and relationships to changes in climate and vegetation.

- **Fire regimes**
- Fire effects on plant communities
- Landscape mosaics

Objective 3: Understand patterns of temporal and spatial distribution of air-borne pollutants, and their effects on aquatic and terrestrial systems.

- **Water chemistry**
- Airborne contaminants
- Atmospheric deposition
- Toxics
- Particulate matter
- Snow chemistry
- Ozone

Objective 4: Understand natural patterns of variation in hydrology and how patterns and processes respond to changes in climate and fire regime.

- **Surface water dynamics**
- **Wetland water dynamics**
- Cave/karst physical processes
- Stream channel morphology

Objective 5: Monitor water quality and the response of native aquatic biota to changes in chemical and physical properties of aquatic systems.

- **Water chemistry**

- **Amphibians**
- Microorganisms
- Macro-invertebrates (aquatic)
- Cave biota
- Biogeochemical cycling

Objective 6: Understand compositional and structural patterns of plant communities and their distribution on the landscape.

- **Non-native invasive plants**
- **Landscape mosaics**
- Selected plant communities
- Fire effects on plant communities

Objective 7: Document rates and types of change in plant communities in response to environmental factors and human effects.

- **Landscape mosaics**
- Phenology
- Selected plant communities
- Forest stand population dynamics
- Fire effects on plant communities
- Net primary productivity

Objective 8: Understand the ecological relationships between terrestrial landscape elements and animal distributions.

- **Meadow/wetland plant communities**
- **Birds**
- Selected plant communities
- Bats
- Cave biota

Objective 9: Document rates and types of change in animal communities in response to changes in landscape characteristics, biotic interactions, and ecosystem stressors.

- **Amphibians**
- **Birds**
- **Macro-invertebrates (wetlands)**
- Bats
- Microorganisms
- Meso-carnivores (mid-sized)

Objective 10: Monitor resources that have been identified as having unique values to the network parks. These resources may or may not be the best indicators of ecosystem condition, but are valued in and of themselves.

- Night sky

- Visibility
- Soundscape

Objective 11: Monitor trends in the distribution and abundance of focal species.

- **Amphibians**
- **Birds**
- Giant sequoia (a component of **Forest Dynamics**)
- Bats
- Lichens (a component of Selected Plant Communities)
- Meso-carnivores (mid-sized)
- Cave Biota

3.4 How SIEN Will Monitor Vital Signs

SIEN will employ a wide variety of techniques and approaches for monitoring vital signs. SIEN has not yet determined the best technique(s) for measuring all its vital signs to achieve stated objectives. Where necessary, monitoring will include a mixture of field-based, automated, laboratory, and remote-sensing methods. Measurements will be made at appropriate spatial and temporal scales. Not all vital signs or their attributes need to be measured every year (e.g., landscape mosaics), while others may require measurements every hour (e.g., stream flow).

We present techniques and approaches for monitoring vital signs in Chapter 4. Specific variables, measures, and parameters, where determined, are described in Appendix H, "*Protocol Development Summaries*."

Chapter 4 SAMPLING DESIGN

(This chapter is modified and adapted from similar discussions within Upper Columbia Basin Network, Central Alaska Network, and Greater Yellowstone Network monitoring plans.)

> "Spatially balanced monitoring is the collection and analysis of repeated observations or measurements over a long period of time to document the status and trend of ecological parameters."
>
> —The National Park Service

4.1 Monitoring Programs and Sampling Design

Monitoring programs must provide unbiased and useful statistical estimates of the status and the changes in ecosystems across large areas or entire study sites. Unlike most short-term research, monitoring programs do not try to answer a single question nor test a specific hypothesis. Instead, they enable us to understand a broad and wide range of long-term hypotheses by uncovering correlations and patterns between ecological parameters and external factors. Although they do not establish cause and effect relationships (e.g., anthropogenic impact on the status of an ecosystem), they do show us a *big picture* of ecosystem dynamics, which can suggest experiments that test more specific hypotheses.

Because of its long-term nature (i.e., *decades*), monitoring programs incorporate sampling designs that focus on the properties of an ecosystem that are 'easy to measure' while still being meaningful and helpful to researchers and managers. These measurements should be repeatable and allow inference from smaller to larger areas. Although we typically want immediate results, we need to wait for complete information to allow us to make better decisions about preserving species and habitats. Long-term studies also require consistent motivational and financial support, as well as well-considered sampling designs.

This chapter presents an overview of the general approaches SIEN has taken to develop sampling designs for its suite of vital sign monitoring protocols scheduled to be implemented during the next five years. Table 4-2 (at the end of this chapter) summarizes basic design decisions that have been made to date (i.e., September 2007). Specific design and decision justifications are included in individual vital sign monitoring protocol development summaries presented in Appendix H, in Chapter 5–Monitoring Protocols (approach to development), and more formally in individual vital sign monitoring protocols (*in development*).

We begin with an overview of basic concepts and terminology, and then discuss basic sampling design strategies for SIEN vital signs.

4.2 Sampling Design

Detailed discussions of sampling-design considerations and decisions for SIEN vital signs are included within individual monitoring protocols (in development). Some additional vital sign sample design information is provided in Appendix H, "Protocol Development Summaries."

Sampling design is one of the primary means SIEN will use to ensure scientific reliability and defensibility of its monitoring program. The details of individual sampling designs are beyond the scope of this chapter, and are provided with individual monitoring protocols. However, we do describe here the major themes and concepts behind the sampling designs for SIEN vital signs.

Sampling designs encapsulate the series of decisions that dictate where, when, and how to sample a vital sign's indicator—e.g., the indicator nitrate is a measure of lake water chemistry (Elzinga et al. 2001). Their paramount purpose is to ensure collection of representative data of adequate scope to support defensible inference and draw conclusions about a population of interest. Nevertheless, deciding how to sample is often difficult because of the trade-offs between costs and benefits: any sampling design represents a balance between idealized objectives and the practical constraints of cost, time, logistics, safety, and existing technology.

We also must make numerous practical and statistical decisions to ensure confidence that our sampling design and indicator measurements are providing the vital sign information we need (Busch and Trexler 2003). The following questions can help us make those decisions:

- What are the defining boundaries of the ecological system?
- What is the appropriate temporal frame for sampling?
- What is the appropriate time interval between samples?
- What is the trade-off between gaining information about the condition of remote Wilderness ecosystems and the often-associated need for permanent or other scientific instrumentation?
- What sample size is necessary to estimate the value of the indicator? Is there an optimal sample unit size and shape for estimating the value of the indicator?
- What survey design is most efficient (random, systematic, stratified random)?
- What is the appropriate unit of measure for the indicator variable?
- What is the trade-off between gains in precision and statistical power and the additional costs per sample?
- How can the monitoring program best be designed so that sources of uncertainty about the true state of the ecological system are minimized?

We address many of these questions in this chapter, including those involving target populations and sampling frames (Figure 4-1), allocation and arrangement of samples (*membership design*), frequency of sampling occasions (*revisit design*), measurements to be taken at sampling locations (*response design*), and the number of samples required to meet stated objectives (*sample size*). Italicized terms are included in a text-box at the end of this chapter. We also discuss SIEN strategies for integrating sampling designs for groups of vital signs. To insure continuity among projects and consistency in data collection and analysis, we adhere to sample design guidelines of the NPS Inventory & Monitoring program (http://science.nature.nps.gov/im/monitor/SamplingDesign.cfm).

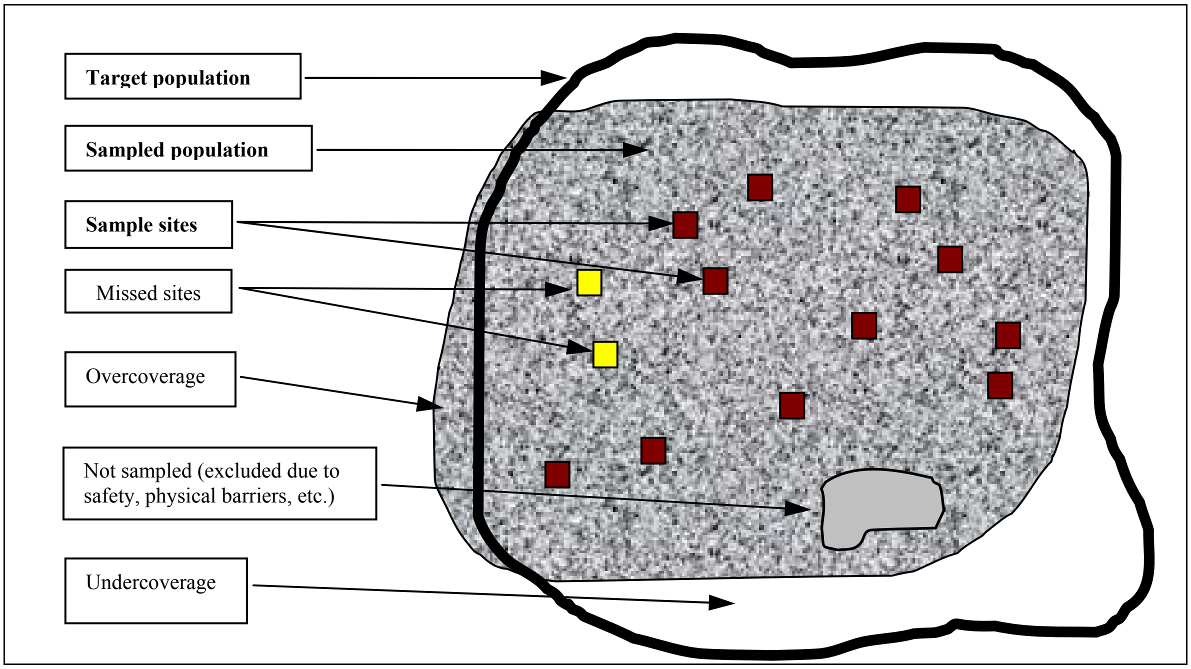


Figure 4-1. Conceptual illustration of terms used to describe various units associated with sampling a population of interest.

4.3 Sampling Design—Conceptual Framework

A good sampling design is based on clear and concise monitoring objectives. The development of the design is an iterative process—as we continue to refine our objectives, we gain new insights into particular vital signs and the needs of park management. Sampling designs must be flexible. Because we intend to develop a robust monitoring program that can meet the needs of NPS managers well into the future, our designs must be able to accommodate changes in the environment, and in management and funding priorities. Thus, our monitoring objectives must balance the needs of current and future park managers who can expect environmental and management challenges we cannot foresee now.

A good sampling design should also be understandable and manageable. We designed the SIEN monitoring program to focus on clear initial objectives, and then add complexity conservatively and only when needed to achieve objectives. Of course, to monitor ecosystem structure, function, and processes, some complexity cannot be avoided, particularly when dealing with large, remote, and difficult-to-access landscapes (McDonald and Geissler 2004).

As discussed in Chapters 1 and 3, our monitoring objectives call for the estimation of *status*, *trend*, or both. For these terms ('status', 'trend'), we follow definitions reviewed by (Urquhart et al. 1998) and (McDonald 2003). **Status** is a measure of a current attribute, condition, or state, and is typically measured with population means. **Trend** is a measure of directional change over time and can occur in some population parameter such as a mean (*net trend*), or in an individual member or unit of a population (*gross trend*). Status applies to specific points within a time-frame; trend requires measurements across multiple times. Typically, status works best when it uses a spatially extensive sample size. Trend is less reliant on large samples. This distinction creates an initial cost-benefit decision about sampling design, which we can assess through careful considerations of vital sign objectives. Sample size often depends on cost-benefit trade-offs.

Almost all monitoring proposed for SIEN vital signs relies on finite population sampling. In finite population sampling, the area for which inferences are designed (e.g., a park boundary) is viewed as a finite collection of sample **units** (Scheaffer et al. 1990), where we make measurements and collect other information. The **target population** is the complete collection of units to which we make inferences (see Figure 4-1). For some SIEN vital sign sample designs, the unit will be a 'lake or wetland' (water chemistry or plant community, respectively). In other designs, the sample unit will be a transect or small area (e.g., birds and forests, respectively).

The **sampling frame** is the collection of all possible sample units. The subset of units from the population for which we collect measurements is the **sample**; measurements taken on the sample are **responses**.

If we choose a sample using a random draw, the sample is probabilistic Table 4-1. **Probabilistic sampling** designs permit valid inference to the sampled population, whereas non-random judgment sampling allows inference only to individual sampling units. Because SIEN parks are large, we are using probabilistic sampling for most vital signs (see below, *membership design*). In a few cases, we will use non-random sampling to locate index sites (described below), which can help us determine trend, despite the limited statistical scope of inference.

In addition, because of the size and topographic complexity of our parks, it may be necessary and/or more efficient to **stratify** sampling based on elevation or ecosystem characteristics (e.g., lake versus pond, wet meadow versus fen).

A **census**, where we obtain a response from every element in the target population (rarely possible in most ecological applications), will be used to monitor some aspects of landscape dynamics (i.e., land cover change) through satellite imagery.

Once the target population and sampling frame have been determined, we design a strategy for drawing samples, allocating them appropriately across the sampling frame, and timing sampling events. Most sample designs proposed for SIEN will rotate field-sampling efforts through various sets of sample units over time. Therefore, it is useful to assign a **panel** of sample units to a group that is always sampled during the same sampling occasion or time period (Urquhart and Kincaid 1999, McDonald 2003). See Figure 4-2 for a schematic representation of different revisit designs.

The way units in the population become members of a panel is the **membership design** (McDonald 2003), which specifies the spatial allocation procedure. One commonly used membership design strategy is **simple random sampling**. Unfortunately, this often fails to produce an ideal spatial sample in ecological settings. An alternative, and one that SIEN intends to use for most applicable vital sign sample designs, is to draw a spatially-balanced random sample following the methods described by (Stevens Jr. and Olsen 2004). This sample design, known as Generalized Random-Tesselation Stratified (**GRTS**) results in a spatially balanced random draw of samples with variable inclusion probabilities and an ordered list of samples that can support additions and deletions of samples while retaining spatial balance. These features provide considerable flexibility and efficiency to the SIEN program.

Table 4-1. Advantages and disadvantages of major sample design options considered for SIEN vital signs monitoring.

Sampling Design	Major Advantages	Major Disadvantages
Complete Census	• No sampling error	• Seldom logistically or economically feasible, except for very small populations with limited distribution (except when remote sensing techniques are used). • Usually requires greater effort than needed for on-the-ground sampling
Simple Random Sample	• Simple and straightforward analysis • Does not require prior knowledge regarding sampling units	• Can result in poor spatial distribution, particularly with small samples • Can be inefficient for rare or highly-clumped resources
Systematic Sample, with random start	• Good spatial coverage • Simple, straightforward • Requires little or no prior knowledge regarding sampling units • Facilitates co-location of samples	• May not be as efficient as alternative designs, particularly if prior information about sampling units is available • If properties of interest are aligned, or there are periodicities with grid, then biased estimates are possible • A single systematic sample may not produce valid estimates of standard error under some circumstances
Stratified Random Sample	• Can reduce costs and sample sizes • Can increase precision	• Requires prior knowledge regarding sampling units • May reduce precision of criteria for strata assignment are uncorrelated
Generalized Random-Tesselation Stratified (GRTS)	• Samples are spatially balanced • Nested sub-samples easily accommodated • Good variance properties • Design can incorporate variable probability sampling	• The underlying sampling process is less intuitive to understand than alternative sampling schemes • Software to apply GRTS has only recently been made available

Monitoring is the collection and analysis of repeated observations or measurements over a long period to document the status and trend of ecological parameters. Careful monitoring should provide unbiased statistical estimates of status and trend of vital sign measures.

Survey (or *extensive*) sites are sampling locations where visits to collect data are less frequent, or where we make less detailed measurements. Conversely, **index** sites—also known as *sentinel* or *intensive* sites—are sampling locations that (i) are visited either more frequently, (ii) are sites where more detailed measures are made, or (iii) both. Generally, frequent visits to sampling sites is best for detecting temporal variation (or trend), but is less optimal for detecting spatial variation. Conversely, less frequent visits, coupled with visitation to more sampling sites, will provide more data on the status of a resource.

Once samples are drawn, we assign them to **panels** and schedule them for revisits over time (Figure 4-2). Currently, SIEN is proposing the inclusion of all samples from our smallest park, Devils Postpile, as one panel. In the case of our larger parks–Sequoia & Kings Canyon and Yosemite–multiple panels may be required to cover entire park landscapes of interest. The temporal scheduling of sampling, particularly when multiple panels are used, requires a **revisit design** (Urquhart and Kincaid 1999, McDonald 2003).

SIEN has adopted (McDonald 2003) notation for revisit designs for brevity and consistency. Under this notation, the revisit plan is represented by a pair of digits: the first is the number of consecutive occasions a panel will be sampled; the second is the number of consecutive occasions that a panel is not sampled before repeating the sequence. The total number of panels in the rotation design is normally the sum of digits in the notation. For example, using this notation the digit pair [1-2] means that members of three panels will be visited for one occasion, not visited for two occasions, then visited again for one occasion, not visited for two occasions, and so on. If a single panel is to be visited every sample occasion, its revisit design would be [1-0]. The notation [1-1] indicates that a panel is to be sampled on an alternating schedule. The notation [1-0, 1-5] means that units in one panel will be visited every occasion, while units in six other panels will be visited once every six years. We call this design a **split-panel**.

Panel	Sample Occasion									
#	1	2	3	4	5	6	7	8	9	10
Design [1-0]										
1	X	X	X	X	X	X	X	X	X	X
Design [1-n]										
1	X									
2		X								
3			X							
4				X						
5					X					
6						X				

Design [2-n]										
1	X									
2	X	X								
3		X	X							
4			X	X						
5				X	X					
6					X	X				

Design [2-3]										
1	X	X				X	X			
2		X	X				X	X		
3			X	X				X	X	
4				X	X				X	X
5					X	X				X
6	X	X				X	X			

Design [1-0, 2-3]										
1	X	X	X	X	X	X	X	X	X	X
2	X	X				X	X			
3		X	X				X	X		
4			X	X				X	X	
5				X	X				X	X
6	X				X	X				X

Figure 4-2. Examples of five different revisit designs, beginning with the simplest, in which a single panel or set of sampling units are visited on every sampling occasion [1-0], and ending with a complex split-panel design in which the first panel is sampled on every occasion and five panels are revisited on two consecutive occasions and then “rested” for three occasions.

Two essential components of any sampling design—**response design** (measurements taken at sampling locations) and **sample size** (the number of samples required to meet stated monitoring objectives)—are detailed in our individual monitoring protocols (under development; see also Appendix H, *“Protocol Development Summaries”*), but we introduce them here. In general, we develop response design and sample size components after making basic decisions about target and sampling population, spatial allocation and membership, and revisiting strategies. But this order of operations doesn’t always hold. Sometimes we need a response design before we can estimate sample size appropriately (e.g., plot shape and size strongly influence the variability of population estimates). But we must determine an appropriate sample size before we can determine membership and revisit design. Therefore, in practice, sampling designs arise out of an iterative process where the order of operations depends on the specific sampling scenario.

Also, other factors might affect our design choices, e.g., minimizing instrumentation in Wilderness. Therefore, our sampling designs should balance monitoring with other needs, such as those designated in the Wilderness Act.

4.4 Sample Size and Magnitude of Change

Populations in the real world are dynamic, and we expect them to change over time. However, what we need to know is whether or not there has been *meaningful* change to the ecosystem, and if this change is perceptible to the public or to park managers. If there has been meaningful change, we need to know what caused the change, and whether or not the resource being monitored is likely to change further.

To understand what constitutes a meaningful and significant change, we must differentiate between statistical significance and biological significance. Statistical significance relies on probability and is influenced by sample size. Thus, even minor changes (from a biological perspective) will be statistically significant if the sample size is large enough. Regardless of statistical significance, we would consider something biologically significant if it facilitates a major shift in ecosystem structure or function (e.g., loss of one or more species, addition of non-native species, changes in ecosystem processes, etc.).

When monitoring, we are concerned with both statistical and biological significance. Are the statistical changes we detect also biologically meaningful? To answer this question, we decide (1) what level of statistical significance we want to attain (i.e., our Type I error rate or α, discussed below), (2) what level of change we consider biologically meaningful and that we hope to detect, and (3) how variable the vital sign indicator (measure) is that we are trying to estimate.

In addition to monitoring objectives (Chapters 3 & 5), we define **sampling objectives,** which establish a desired level of **statistical power**. This 'power' is the capacity to detect a 'real' change or trend, a minimum detectable change or effect size, and acceptable levels of both a false-change (**α** or the probability of a **Type I error**) and a missed-change (**β** or the probability of a **Type II error**) (Elzinga et al. 2001).

A Type I error is a '**false positive**': the error of rejecting a null hypothesis when it is actually true. In other words, the error of accepting an alternative hypothesis (the real hypothesis of interest) when the results can be attributed to chance.

A Type II error is a '**false negative**': the error of accepting a null hypothesis when an alternative hypothesis is possibly the true state of nature. In other words, the error of failing to observe a difference when there is one.

Sample size is a function of each of these components; decreasing sample size, which can be desirable for cost effectiveness, will often force acceptance of higher error and lower power. These trade-offs are mitigated by reducing variance estimates, either through modifications in response design, another component (e.g., revisit design), or by accepting a higher minimum effect size (Steidl et al. 1997).

In general, sample size should be large enough to give a high probability of detecting any changes that are of management, conservation, or biological importance, but not unnecessarily large (Manly 2001). Scientists traditionally seek to reduce Type I errors, and accordingly prefer small alpha levels. However, in a monitoring program such as ours with a strong resource-conservation mandate, it is preferable to employ an early-warning philosophy by tolerating a higher alpha, while increasing the power to detect differences or trends (Sokal and Rohlf 1995, Roback and Askins 2005).

Statistical **power analysis** (Gerrodette 1993), Lewis 2006) is the usual approach to estimating sampling sizes for monitoring population trends. For our initial set of protocols (those for which appropriate datasets exist), we will use *a priori* power analyses of these datasets to determine the approximate sample size needed to detect meaningful (≥20%) levels of change. Given our specification of alpha, desired power, and effect size, combined with information on the variance of the response variable in question (obtained from available data or comparable analogous data, where available), it is possible to calculate the sample size required to achieve these results. Further, we will recalculate sample sizes periodically for individual vital signs as data become available in order to refine and revise sampling designs and ensure that objectives are being met.

4.5 Integration of SIEN Vital Signs

The possibility of monitoring more than one vital sign as part of a single monitoring protocol is dependent upon its monitoring and sampling objectives. We discuss how SIEN will integrate vital sign monitoring in Chapter 5.

Where possible and where appropriate, integration of SIEN vital signs will occur first during protocol design, and will continue during data collection, data management, data analysis, and reporting phases. Integration will primarily occur within individual protocols. We also explore other integration and coordination (e.g., data collection) opportunities among protocols, and between the Sierra Nevada Network and partner programs.

4.6 Integration of Fieldwork

NPS guidelines for developing an integrated monitoring program encourage co-location and co-visitation of sampling sites. Currently, we are designing several of our protocols to collect data simultaneously for more than a single vital sign (Table 4-2) such that they will be sampled at the same place (**co-location**) or time (**co-sampling**). Resulting information will provide a more holistic, ecological assessment of condition.

> Wetland Ecological Integrity: One example of this approach is the development of our Wetland Ecological Integrity Monitoring Protocol, which will integrate aspects of the following vital signs for wet meadows and fens: wetland plant communities, wetland water dynamics, and macroinvertebrates (wetlands). In addition, during data collection for the vegetation monitoring aspect of this protocol, we will also have the opportunity to monitor wetlands for early detection and trends in target invasive plants in order to meet an objective for that vital sign.

Lakes: We will also take an integrated approach with our Lake Monitoring Protocol, integrating aspects of data collection for the following vital signs: water chemistry, surface water dynamics, and amphibians. Third, we will acquire remotely sensed data for our land cover/land use protocol to support information necessary for our fire regime, climate, and forest dynamics vital signs. Ground-truth data will support the remote sensing products and directly link the two data sets.

Integration will also occur between SIEN monitoring and other national and regional monitoring programs. Water chemistry, for example, will be monitored in a way that yields statistically robust results for each park, yet these data will also be comparable with other national and regional programs. Some of these programs have accumulated data for many years at a large number of sites around the Sierra Nevada, including sites near SIEN parks. Integration at this level will provide a regional context for many SIEN vital signs.

Other vital signs are not well suited for co-location and co-visitation because they do not exhibit strong spatial or temporal links. In addition, the decision of whether to integrate also depends on the following: (1) whether it is ecologically appropriate for the metric(s) being monitored, (2) whether it is statistically appropriate (in terms of sample size and spatial allocation), and (3) whether it will affect the quality of other data being collected at those locations. Opportunities for integration of additional (i.e., Tier 2) vital signs may be realized during the first years of our monitoring program, for example, phenology as part of wetland ecological integrity or glaciers, as part of landscape mosaics.

4.7 Integration of Data

We will integrate analysis and interpretation approaches among protocols where possible. In Chapter 2, we discussed conceptual models illustrating links among vital signs. These links are based on known or proposed relationships among stressors, ecological processes, vital signs, and other factors that operate across spatial and temporal scales. In Chapter 3, we discussed our broad monitoring objectives for elucidating the relationships among SIEN vital signs, for example, how to:

1. Understand natural patterns of variation in hydrology and how these processes respond to changes in climate and fire regime

2. Monitor water quality and the response of native aquatic biota to changes in chemical and physical properties of aquatic systems

By using data collected within and among protocols, we can assess the presence and strength of these relationships using a diversity of statistical techniques, ranging from simple correlations to structural equation models. We note, however, that the primary goal of the protocols was to develop statistically sound monitoring methods; conversely, tests of causality require a very different sampling design. However, in many cases, we can still use GIS-based analyses, simple linear models, and perhaps more advanced techniques (e.g., multivariate analyses) to quantify relationships noted in our conceptual models.

4.8 Overview of Sampling Designs for SIEN Vital Signs

SIEN is striving for a balance between determining status and trend of its vital signs. Because SIEN parks are typically quite large, random probability-based sampling is being employed for most vital signs. We will supplement the random sampling with several non-random sampling points for our "index" (sentinel) sites (described above); such sites can be helpful in describing trend, despite their limited statistical scope of inference. Further, we will be using GRTS (Stevens Jr. and Olsen 2004) to generate a spatially balanced random draw of samples with variable inclusion probabilities and an ordered list of samples that can support additions and deletions of samples while retaining spatial balance. A rotating panel design will be employed for almost all vital signs; however specific revisit designs and schedules will be determined during protocol development.

Error! Reference source not found. summarizes basic design decisions made to date (i.e., September 2007). Specific design and decision justifications are included in individual vital sign monitoring protocol development summaries presented in Appendix H and in Chapter 5: Monitoring Protocols (approach to development), as well as formally in individual vital sign monitoring protocols (*in development*).

4.8.1 Schedule

Table 4-3 includes frequency, and month(s) of the year, that we anticipate sampling for each vital sign. Frequency of sampling will range from continuous (i.e., automated collection at weather and stream gauging stations) to once every few years (i.e., remote-sensing of land cover data).

As we implement monitoring, over the next several years, the Network will continually evaluate how well implementation of each protocol is progressing.

> We include the current sample design from our Lake Monitoring Protocol (Heard et al., in prep) as an example of the level of thought and detail our protocols will contain (Section 4.9, below).

Table 4-2. Proposed sampling design components for Sierra Nevada Network vital signs (scheduled for protocol development and implementation during the first five years of its monitoring program). Some vital signs with multiple objectives require different sampling strategies and membership design for different objectives.

Vital Sign	Target Population	Membership Design	Revisit Design	Co-location or Co-visitation (integration) Opportunities
Water Chemistry	• SIEN lakes (lakes defined as greater 8 ha in area and 2 m deep) • SIEN streams (to be determined)	• Index sites • Extensive sites: Random, with spatial allocation (GRTS)	• Frequency–multiple times per year)(index) • Serially augmented rotating panel design [(1-0), (1-3)] (extensive)	• Amphibians • Surface water dynamics
Surface Water Dynamics	• SIEN lakes (lakes defined as greater 8 ha in area and 2 m deep) • SIEN streams (to be determined)	• Index sites • Extensive sites: Random, with spatial allocation (GRTS)	• Frequency–multiple times per year)(index) • Serially augmented rotating panel design [(1-0), (1-3)] (extensive)	• Water chemistry • Amphibians
Weather and Climate	• Existing monitoring sites (judgment sampling) • Others to be determined	• Additional meteorological site installation under review	• Mostly continuous monitoring • Other to be determined	• None planned at this time

Vital Sign	Target Population	Membership Design	Revisit Design	Co-location or Co-visitation (integration) Opportunities
Wetland Water Dynamics	• All wetlands classified as wet meadows or fens	• Index sites • Extensive sites: Random, with spatial allocation (GRTS)	• Frequency TBD (index) • Serially augmented rotating panel design (extensive)	• Wetland Plant Communities • Macro-invertebrates (Wetland)
Wetland Plant Communities	• All wetlands classified as wet meadows or fens	• Index sites • Extensive sites: Random, with spatial allocation (GRTS)	• Frequency TBD (index) • Serially augmented rotating panel design (extensive)	• Macro-invertebrates • Wetland Water Dynamics • Invasive Non-native Plants
Macroinvertebrates (Wetland)	• Species occurring in all wetlands classified as wet meadows or fens	• Index sites • Extensive sites: Random, with spatial allocation (GRTS)	• Frequency TBD (index) • Serially augmented rotating panel design (extensive)	• Wetland Plant Communities • Wetland Water Dynamics
Landscape mosaics	• SIEN parks, including buffer encompassing lands surrounding park boundaries	• Census • Expert judgment • Other to be determined	• Dependent on measures (e.g., seasonal, annual, every 5–12 years	• Surface Water Dynamics (ice-out) • Glaciers • Fire regimes • Snowpack • Forest dynamics
Forest dynamics	• To be determined–may include certain forest types (giant sequoia, whitebark pine)	• TBD; most likely will include both index and extensive sites • Random, with spatial allocation (GRTS)	• Frequency TBD (index) • Serially augmented rotating panel design (extensive)	• Landscape mosaics
Fire regimes	• SIEN parks	• TBD	• Frequency TBD (index) • Serially augmented rotating panel design (extensive)	• Landscape mosaics

Vital Sign	Target Population	Membership Design	Revisit Design	Co-location or Co-visitation (integration) Opportunities
Amphibians	• SIEN lakes (lakes defined as greater 8 ha in area and 2 m deep)	• Index sites • Extensive sites: Random, with spatial allocation (GRTS)	• Frequency–multiple times per year)(index) • Serially augmented rotating panel design [(1-0), (1-3)] (extensive)	• Water chemistry • Surface water dynamics
Birds	• SIEN parks	• Random, with spatial allocation (GRTS) – SEKI, YOSE • Spatial Grid Design, Random Start–DEPO	• Serially augmented rotating panel; revisit design to be determined	• None planned at this time
Invasive / Exotic Plants	• SIEN "watch list" species • High-value resource areas • Naturally-disturbed areas	• Not applicable	• Not applicable	• Plant communities (Wetlands)

Table 4-3. Frequency and timing of vital signs monitoring. TBD or gray shading—indicates to be determined.

Vital Sign	Sampling Frequency	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Amphibians	• Index (lake): monthly May-Oct, if feasible to include amphibians					I	I	I	I	I	I		
Birds	• Annually					S	S	S	S	S			
Fire regimes	• TBD – remote sensing												
Forest dynamics	• TBD												
Landscape mosaics	• TBD – remote sensing												
Macro-invertebrates (wetlands)	• Index: monthly June-September • Survey: annually						I/S	I/S	I/S	I/S			
Non-native plants	• TBD												
Snowpack	• Index: continuous • TBD – remote-sensing												
Surface water dynamics	• Some index sites: continuous • Survey sites: annually	I	I	I	I	I	I	I	I/S	I/S	I	I	I
Water chemistry	• Index (lake): monthly May-Oct • Survey: annually					I	I	I	I/S	I/S	I		
Weather and climate	• Continuous	I	I	I	I	I	I	I	I	I	I	I	I
Wetland plant communities	• Annually						I/S	I/S	I/S	I/S			
Wetland water dynamics	• Index: continuous • Survey: annually	I	I	I	I	I	I/S	I/S	I/S	I/S	I	I	I

I=Index sites (judgment-selected, accessible sites that are sampled more regularly or continuously)
S=Survey sites (probabilistic, randomly allocated, spatially extensive sites)

4.9 *Example*: Lake Monitoring Protocol—Sample Design

The following text has been excerpted (and abbreviated) from SIEN's Lake Monitoring Protocol (Heard et al., in prep). This example illustrates our sample design for a portion of our water-monitoring program, specifically *integrated monitoring* for three vital signs: (1) water chemistry, (2) surface water dynamics, and (3) amphibians. Water monitoring will also be a part of our Rivers & Streams Monitoring Protocol (development planned for 2008). The following text largely refers to our extensive site sample design; additional details regarding our index/sentinel sites are included in the Protocol.

Our sample design was developed to answer the SIEN's monitoring questions and objectives. These questions, and our *response design* (parameters measured) is included at the end of Chaper 5 (see "*Lake Monitoring Protocol—Monitoring Questions, Monitoring Objectives, and Thresholds*").

4.9.1 Background and Objectives

Access, logistics, and safety were prominent considerations throughout our sample design development process. An additional and equally important requirement was a sampling design that would address both trend and status objectives. Balancing these trade-offs, we settled on a design that is comprised of two site types: (1) *extensive sites*, which are probabilistically selected and sampled once every 1-3 years and, (2) *index sites*, which are judgmentally selected and sampled multiple times each year. Incorporating a split-panel design for the extensive sites provided further flexibility (see below).

The Network worked closely with statisticians at Oregon State University and the University of Idaho to develop our sample design, perform power analyses, and identify data analysis approaches. Sample design, power analysis, and data analysis components were developed simultaneously through a very iterative process.

4.9.2 Target Population and Sampling Frame

The target population for inference on water chemistry in Sierra Nevada Network lakes includes all lakes in the network that are greater than or equal to 1.0 hectare in area *and* greater than or equal to 2.0 m in depth. These criteria yield a target population comprising approximately 1,800 lakes—see *Lake Monitoring Protocol* for map of target population (Heard et al., in prep.).

The population is sampled during late season–August and September–because late summer and fall sampling is a better indicator of lake ecological condition. The sampling frame will be constructed from two data sets that contain the necessary information to draw the sample (National Hydrography Dataset, Knapp 2003).

The sampling unit is 'lakes', with responses taken within lakes. Measurements are observed at the lake outlet for all panels and at both outlet and mid-lake for panel [1-0] (response design).

Membership Design

For lake monitoring, we elected to use a generalized random tessellation stratified design (GRTS) in conjunction with variable probability sampling based on travel time estimates from a cost-surface model. Inclusion probabilities are based on a cost-surface model (for SIEN) that computes relative travel times to sites based on factors such as presence/absence of trails, vegetation type, and slope (Frakes et al. 2007).

We will draw the GRTS sample in the winter of 2008, after peer-review is complete (drawing samples prior to peer-review would be premature—if reviewers suggest even minor changes concerning the target population or sample design, a new sample would need to be drawn). SIEN will use one of two tools available: (1) the R workspace 'spsurvey' (Kincaid 2006), or (2) RRQRR, an ArcGIS geoprocessing tool (Theobald and Norman 2006).

Revisit Design

We have selected a serial augmented panel design: [(1-0), (1-3)] (see Figure 4-2). This design means that units in one panel will be visited every occasion, while units in the four other panels will be visited once every four years.

Combinations of panel designs are seemingly unlimited. We selected four revisit designs that were appropriate for the lake protocol objectives: [1-0], [(1-0), (1-3)], [(1-0), (2-3)], and [(1-0), (2-5)]. To assist in selecting the optimal revisit design, we ran power simulations comparing the four designs (Starcevich 2007). Power differences between designs were not large. However, the [1-0] design, for most of the analytes, exhibited lower or equal power compared to the other three designs. The [(1-0), (1-3)] design was selected because the:

1. (1-0) panels provide year to year data connectivity and contribute to increasing power to detect trend by reducing temporal variability.
2. (1-3) panels increase the spatial sample size, reducing spatial variability, thus increasing power to detect trend and status.
3. (1-3) design was selected over the (2-3) design because it has a higher spatial sample size (increasing power for status estimates) and rotates through one year sooner.
4. (2-5) design was not selected because of the longer rotation time.

Data collected at index sites will enable SIEN to answer objectives at a finer temporal scale and examine intra-annual patterns. Index sites also provide an opportunity to pursue a more holistic monitoring approach. It is realistic to co-locate amphibian and hydrologic measures with water chemistry monitoring at index sites because there are far fewer of them and they are more accessible. Although it is not possible to make network-wide statistical inferences from these more intensively collected data, these data will inform results observed at extensive sites.

Minimum Detectable Difference

After much discussion and running of preliminary power analyses (below), we decided that the trend analysis would test for trend versus no trend (i.e., beta = 0). Testing for any trend (beta = 0), versus testing for a specific change (e.g., beta = .20), is more consistent with the objectives of a monitoring program and results in higher power. It is a conservative approach; providing managers with an early warning of change and with higher confidence. Managers will know the magnitude of the trend before deciding if, and when, to take management action.

4.9.3 Power Analysis

Power analysis provides a 'reality check' on project goals and objectives and an a priori understanding of the ability and confidence with which one can detect trends and estimate status over time. Power analysis results were used to inform sample design, sample size, and data analysis decisions. Power results at extensive sites are for trend tests only. SIEN's status objective, 'Determine the proportion of Sierra Nevada Network lakes above threshold values' could not be tested because thresholds have yet to be identified. Once threshold are identified (not a trivial task), we will run power analyses for status.

Power analyses were not computed for the index sites, because power simulation methods do not exist for the data analysis approach we are using—the Seasonal Kendall Test for trend. Hirsh and Slack (1984) recommend collecting a minimum of 5-10 years of data before running the Seasonal Kendall Test for trend.

Trend may be further defined in a number of ways and definitions should be clarified so that survey goals are clear. Surveys conducted over time may be used for estimation at particular points in time, to estimate average parameters over time, to measure net or annual change in a population, to measure factors contributing to individual change, or to measure durations of events (McDonald 2003). Individual change is measured at the level of the sampling unit. The measurement of net change includes all sources of change and is measured at the scale of the population. Therefore, individual change does not necessarily imply net change because trends at individual sites may vary and result in no net change. The power analysis targets net change in the population (i.e. SIEN Lakes). Net change may also be expressed in annual change so that power approximations for different time spans may be more directly compared. The detected population change is measured in linear trend; however, trend may be detected by measuring linear trend without asserting that trend is strictly linear (Urquhart and Kincaid 1999).

In the following section, we provide a summary of the power analysis methods and results *(please refer to Appendix B of our Lake Monitoring Protocol for the complete report on power analysis methods and results).*

Pilot Data, Methods, and Results

We were fortunate to have several high quality data sets with both temporal and spatial data that were used for the power analysis.

The Western Lake Survey, conducted in 1985 by the EPA with cooperating agencies, was a one-time regional sampling of high elevation lakes in the mountainous west. Seven hundred and nineteen lakes were sampled throughout the west, including in Yosemite, Sequoia, Kings Canyon and the upper Middle Fork of the San Joaquin above Devils

Postpile. Clow et al. (2002), in 1999, resurveyed a subset of these lakes (n=32) in Yosemite, Sequoia, and Kings Canyon.

Researchers from UC Santa Barbara measured atmospheric deposition and lake chemistry in seven alpine and subalpine watersheds in the Sierra Nevada as part of the "Seven Lakes Study" (Melack et al. 1998). The study watersheds span the Sierra Nevada and include sites in or near Lassen, Yosemite, and Sequoia. This data set contains both temporal and spatial data. The period of record for most of the lakes is approximately nine years. The exception is Emerald Lake in Sequoia National Park, which has been a long-term research and monitoring site for over 20 years.

Briefly, power analysis was conducted using a mixed linear model, proposed by VanLeeuwen et al. (1996) and Piepho and Ogutu (2002). A mixed model allows some effects to be considered fixed and some to be considered random. Fixed effects contribute to the mean of the outcome and random effects contribute to the variance. Random effects are used to estimate variation of linear trends among subjects (lakes) and over time (years). Estimates of the variance components and the fixed effects, calculated from the pilot data, were used to simulate similar populations with specific changes (i.e. 20%, 30%, and 40% change) in the responses over time. Trend was evaluated using this mixed linear model.

Results

Power analyses were run for the analytes using fall data (Starcevich 2007). Four revisit designs were compared and the results assisted the Network in selecting a final revisit design. Two approaches were used to calculate sample size. The first approach examined the number of lakes needed to obtain power to detect a given change over a set period of years. The second approach examined the number of consecutive years of surveys needed to obtain power to detect a population change for a fixed sample size. The results from these two approaches, in conjunction with sampling objectives, were used by the network to determine sample size, the % change we were willing to accept, and number of years to detect trend.

Terminology used in Chapter 4.

Alpha (α) – A predetermined threshold of statistical significance (null-hypothesis testing). This threshold is frequently set at 0.01, 0.05, or 0.1. P-values less than alpha suggest a result that would rarely occur by chance alone (e.g., a strong trend, relationship between variables, difference among groups). Tests with P-values greater than alpha are deemed "non-significant" (statistically), but may still be indicative of biological significance.

Element – The population of objects on which a measurement is taken. (Scheaffer et al. 1990). This is the basic "unit" of observation.

GRTS – Generalized random tessellation stratified (GRTS) sample design strategy. Results in allocation of sample sites in a spatially balanced manner to either linear systems (e.g., stream network) or other sampling areas (e.g., forest patches). Also *maintains* spatial balance with the addition or deletion of samples.

Index site – Known also as *sentinel* or *intensive* sites—are sampling locations that are (I) visited either more frequently, (ii) are sites where more detailed measures are made, or (iii) both.

Power (β) – The probability that a test will reject a false null hypothesis (i.e., that it will not make a Type II error). Power increases as sample size or effect size (e.g., magnitude of change) increases, variability in the indicator decreases, and as alpha is relaxed (= increased). Estimating power enables us to determine the sample size needed to detect a trend of a given magnitude with reasonable confidence. Thus, power is a function of sample size, sample variance, effect size, and alpha.

Power analysis – Calculation performed to estimate sample sizes needed to detect a desired level of change or determine how much change can be detected with a particular sample size.

Response design – Measurements taken at a sampling location.

Revisit design – Refers to temporal design themes/decisions. **Always revisit design**: results in each sampling unit is revisited on each occasion. **Never revisit design**: a different sampling units is visited on only a given sampling occasion, and never visited again.

Status – A measure of a current attribute, condition, or state, and is typically measured with population means., whereas **trend** is a measure of directional change over time and can occur in some population parameter such as a mean (*net trend*), or in an individual member or unit of a population (*gross trend*). Status applies to specific points in time, whereas trend pertains to measurements across multiple time periods. Status typically is served best by a spatially extensive sample size, while trend is less reliant on large samples.

Sample – A subset of units chosen to record a response through counts, observation, or other form of measurement. If the sample is generated using some type of random draw, the sample is said to be a **probability sample**.

Sampling unit – Refers to the unit actually sampled; they are non-overlapping collections of elements (in most cases, the sampling unit is the same as the element). Common examples of sampling units in SIEN's monitoring program include plots or quadrants, pixels on a digital map, or discrete phenomena such as lakes, wetlands, or stream segments.

Sampling frame – The collection of sampling units.

Sampling panel – A group of units that is always sampled during the same sampling occasion or time period (Urquhart and Kincaid 1999, McDonald 2003). For example, if sampling is conducted annually, then all units sampled during a given year comprise the panel for that year. If all units are sampled every year, then the sample design is a **single panel**. Most sample designs proposed for SIEN will rotate field-sampling efforts through various sets of sample units over time (**rotating panel**). See also, Figure 4-2.

Simple random sample – Sampling strategy in which the total number of sampling sites is selected from the sampling frame, such that each site has the sample probability of being selected.

Stratified random sample – Sampling strategy in which the sampling frame is divided into mutually exclusive subpopulations called strata (e.g., elevation, or ecosystem characteristic such as wet versus dry meadow).

Survey site –A site is one where visits to collect data are less frequent, or where less detailed measures are obtained. Generally, "always" visiting a sampling site is strongest for detecting temporal variation (or trend), but is weak for detecting spatial variation. Conversely, less frequent visits, coupled with visitation to more sampling sites, will provide more data on the status of a resource.

Target population – The complete collection of units to which inference is made. Note that this is a statistical population and it may or may not refer to a biological population.

Type I error – Incorrect rejection of a null hypothesis that is actually true; e.g., a trend is detected when, in fact, none exists.

Type II error – Failure to reject a false null hypothesis; e.g., concluding that no trend has occurred, although one actually has occurred.

Chapter 5 MONITORING PROTOCOLS

To produce high quality data and to detect long-term ecological trends, SIEN will develop and maintain comprehensive monitoring (or 'sampling') protocols. Well-constructed, relevant, and accurate protocols help ensure that the trends we detect are the result of 'true' ecological change and not the result of how we measure or observe. They help us detect changes over time and with changes in personnel, and they allow us to compare data among places, parks, and agencies. They instill confidence in the Network monitoring program.

The NPS Inventory and Monitoring (I&M) Program and the USGS Status and Trends Program developed guidelines and adopted standards that all I&M funded protocols must adhere to (Oakley et al. 2003). Developing a sampling protocol that meets these standards requires a large upfront investment and well-defined objectives. Protocols should be fully documented with enough detail to ensure that consistent measurements will be taken throughout the monitoring period. Protocols should be able to withstand potential employee turnover and decades of technological change. In addition, all I&M-funded protocols are peer-reviewed. (In the Pacific West Region, peer review is currently coordinated by Penny Latham, Regional I&M Coordinator, and Dr. James Agee, University of Washington.)

SIEN is developing *eight protocols* over the next five years. This chapter outlines the Network's protocol development approach and provides an overview of specific protocols.

5.1 Approach to Protocol Development

To enable and energize protocol development, the Network assembled a suite of diverse work groups, with each group focusing on one or more vital signs. These work groups comprise Network, park, and local USGS staff with expertise in appropriate fields of study. Under the direction of the Network Coordinator and Science Committee, these workgroups:

1. Review, refine, and prioritize current monitoring objectives and mandates for each vital sign
2. Review existing monitoring programs and protocols
3. Refine pertinent conceptual models where appropriate
4. Identify ways to integrate monitoring among/across vital signs
5. Develop plans to fill data gaps
6. Develop a general approach for monitoring and identify cooperators
7. Ensure completion of protocols that meet I&M standards and Network objectives by developing protocols in collaboration with cooperators or by overseeing protocol development agreements and contracts.

Nine work groups, each consisting of four to six people, were assembled in November 2005. These work groups focused on the following topics:

1. Amphibians
2. Fire regimes
3. Forest dynamics
4. Birds
5. Landscape dynamics
6. Wetlands
7. Non-native plants
8. Water
9. Weather and climate

The collaborative efforts of the work groups led to the development and collation of vital signs to be monitored via specific protocols. The work groups, along with the Science Committee, determined that *eight protocols* should be developed to include the Network's *top 13 vital signs* (Table 5-1). Several protocols contain more than one vital sign, and some vital signs are captured by more than one protocol. Amphibian and Lake workgroups are working together (amphibian monitoring has been integrated into our Lake protocol). The work groups will continue involvement throughout protocol development.

Table 5-1. Relationship between protocols (listed alphabetically), vital signs, and monitoring objectives. TBD=to be developed.

Protocol	Vital Signs	Monitoring Objectives
Birds	• birds	1. Detect trends in the density of those bird species monitored well by point counts, throughout accessible areas of SIEN parks during the breeding season. 2. Track changes in breeding-season distribution of bird species throughout accessible areas of SIEN parks.
Early Detection of Invasive Non-native Plants	• non-native plants	1. Periodically review park weed management databases and update NPSpecies with new taxa not yet vouchered and documented. 2. Create and periodically update a "watch list" of species that are not present in the parks but are known to exist in the region or to have the potential to become problematic in the region. 3. Create and periodically update early detection monitoring priorities for species in lists 1 and 2 using a transparent, documented system. 4. Compile and periodically update polygons of weed-free areas, high-value resources areas, and naturally-disturbed areas, from a defined set of criteria, using existing information. 5. Within the polygons defined in Objective 4, detect (1) watch-list species, and (2) new populations of priority species already present in the parks through either (a) complete search/census, or (b) sampling within search frames narrowed by selection criteria based on vectors, environmental factors, and other susceptibility measures. 6. Expand scope of personnel searching for watch-list species by developing SOPs and training materials to be included in other I&M protocols, in wilderness ranger duties, and in other park staff and volunteer efforts as appropriate.
Lakes	• surface water dynamics • water chemistry • amphibians	See section 5.4 **"Example: Lake Monitoring Protocol—Monitoring Questions, Monitoring Objectives, and Thresholds".**

Protocol	Vital Signs	Monitoring Objectives
Landscape Dynamics	• landscape mosaics • fire regimes • snowpack & glaciers	1. Determine how vegetation type and cover are changing over time on a 5-10 year interval. 2. As often as necessary, use remote sensing to detect the extent and severity of fire events and incorporate these into change detection maps. 3. Determine how snow cover within the parks is changing both inter-annually and intra-annually. This will be monitored on a 2-5 year interval. 4. Determine probable causation of changes detected in vegetation type and cover based on pilot studies of past disturbance events including fire and insect damage. 5. Determine changes in the distribution and abundance of vegetation and land cover classes over time. 6. Determine changes in vegetation health or condition over time on a 2-5 year interval. 7. Using change detection analysis, determine how vegetation phenology is changing over time. Phenology can include leafout, leaf senescence, and vegetation growth or activity.
Rivers and Streams	• surface water dynamics • water chemistry	TBD—Fall 2008
Weather and Climate	• weather and climate • snowpack	TBD—Winter 2009 Based on SIEN "Climate Monitoring Assessment" (Redmond and Edwards, in prep.)

Protocol	Vital Signs	Monitoring Objectives
Wetland Ecological Integrity	• wetland water dynamics • wetland plant communities • macro-invertebrates • non-native plants	1. Determine temporal changes in species composition and abundance of wetland vascular and non-vascular flora, including changes in exposed bare ground. 2. Determine temporal changes in the composition and relative abundance of above-ground wetland invertebrate populations at the level of Family (Order when necessary for efficiency) except for identifying ants to species. 3. Determine temporal changes in hydrology including the duration, depth, and timing of surface and ground water. 4. Document temporal changes in wet meadow geomorphic process to include sediment flux into wetlands and wetland soil density for sentinel sites and morphology and condition of meadow streams at all sites. 5. Document temporal changes in electrical conductivity and water temperature of wetland water. 6. Document temporal changes in coarse measures of anthropogenic influences to wetlands.

5.2 Protocol Development Summaries

The Network has developed protocol summaries (PDS) for all monitoring protocols that will be implemented in the next five years. These summaries describe why SIEN chose to develop each protocol and the protocol's monitoring objectives. Each PDS includes the following:

1. **Protocol:** Title
2. **Parks Where Protocol will be Implemented:** Four-character codes for the parks where the protocol will be implemented over the next five years
3. **Justification or Issues being Addressed:** A brief summary justifying why this protocol is being developed
4. **More Info:** Additional details for each vital sign
5. **Specific Monitoring Questions and Objectives:** As specific as possible, *to date*. Further refinements will be ongoing, including detailed *sampling objectives* (such information will be included in individual monitoring protocols).
6. **Basic Approach:** Description of any existing protocols or methods that will be incorporated into the protocol, the basic methodological approach and sampling design
7. **Protocol Development & Status**: A brief description of work accomplished to data
8. **Tentative Sampling Methods & Design:** A brief description of the sampling design decisions made for each vital sign (i.e., target population, sampling design, response design, etc.)
9. **Principal Investigators and NPS Lead:** Contact information for all collaborators
10. **Development Schedule, Budget, and Expected Interim Products:** Description of development costs, schedule with major milestones, and interim products
11. **Literature Cited**

SIEN developed a PDS for each of the eight protocols. Summaries for protocols that currently under *development* are more detailed than protocols scheduled to be developed later. Work groups will fill in gaps as these protocols move forward. (*For more detailed information, please see Appendix H: Protocol Development Summaries.)*

5.3 Protocol Overview

Each protocol is a separate document and is not included in the Vital Signs Monitoring Plan. Protocols consist of three main sections or "modules": Narrative, Standard Operating Procedures (SOPs), and Supplemental Materials (Oakley et al. 2003). The Inventory and Monitoring program is taking this modular approach to better accommodate future revisions. It is easier to change and track revisions for a module (i.e., a narrative or SOP) than it is to modify a single large document.

5.3.1 The Protocol Narrative

The protocol *narrative* provides background information and an overview of the protocol. It includes information on the resources being addressed, explains the rational for selecting and developing the protocol, and states the monitoring questions and measurable objectives. It describes the sampling design, including a justification for the selected design, criteria for site selection, description of the target population, sampling frequency, replication and timing, and number and location of sampling sites. The protocol narrative also provides an overview of field and laboratory methods, data handling, analysis, and reporting. Personnel and operational requirements are outlined, including roles and responsibilities, workloads, schedules, facility and equipment needs, and budget information.

5.3.2 Monitoring Questions and Objectives

Vital sign monitoring questions and objectives are included in (see Appendix H, "*Protocols*", for additional detail).

5.3.3 Standard Operating Procedures

The protocol details are found in the *Standard Operating Procedures* (*SOP*s). These are a series of documents following the narrative that provide detailed instructions on how to carry out all aspects of the protocol. SOPs cover the entire monitoring process and at a minimum will include instructions for training, field season preparation, field methods, equipment operations, QA/QC procedures, database entry, data analysis, and delivery of information. Each SOP has a revision history log that is updated as changes are made.

5.3.4 Supporting Materials

The protocols point to *supporting materials* needed for monitoring and program management. These may include databases, reports, maps, geospatial data, custom software tools, and photographs.

> We include the Monitoring Questions, Objectives, and Thresholds from our Lake Monitoring Protocol (Heard et al., in prep) as an example of the level of thought and detail our protocols will contain (Section 5.4, below).

5.4 *Example*: Lake Monitoring Protocol—Monitoring Questions, Monitoring Objectives, and Thresholds

Our Lake Monitoring Protocol Development Summary is included in Appendix H, "Protocols."

The following information has been excerpted (and abbreviated) from SIEN's Lake Monitoring Protocol (Heard et al., in prep). This example details our justification, monitoring questions, monitoring objectives, and thresholds for a portion of our water monitoring program, specifically integrated monitoring of three vital signs: (1) water chemistry, (2) surface water dynamics, and (3) amphibians. Water monitoring will also be a part of our Rivers & Streams Monitoring Protocol (under development 2008).

5.4.1 Lake Ecosystems Are Sensitive to Change

Sierra Nevada Network parks protect over 4,500 lakes and ponds and thousands of kilometers of rivers and streams that have some of the highest water quality in the Sierra Nevada. High-elevation lakes are critical components of the parks' ecosystems, popular visitor destinations, and habitat for aquatic and terrestrial organisms including declining amphibian species.

Lake ecosystems were selected for monitoring because they are (1) valued for their ecological importance, contribution to Wilderness character, recreational opportunities, and importance to regional water supplies, (2) threatened by multiple stressors, and (3) sensitive to change.

Water resources are critical components of the parks' ecosystems and indicators of aquatic and terrestrial ecosystem condition. Sierra Nevada lakes are very dilute and characterized as oligotrophic, especially in the sub-alpine and alpine basins where there is sparse vegetative cover, shallow soils, and small contributing area. Despite the low nutrient concentrations, these lakes still support a variety of flora and fauna. Aquatic wildlife include, amphibians, fish (primarily non-native), macro-invertebrates, zooplankton assemblages, and micro-crustaceans (Boiano et al. 2005).

Hydrological and water chemistry measures are good indicators of aquatic and terrestrial ecosystem condition and trend because they reflect changes within the larger watershed. High-elevation lakes of the western United States are especially sensitive to change because the waters are oligotrophic and have a low buffering capacity. Sierra Nevada lakes have some of the lowest acid neutralizing capacity (ANC) concentrations in the western U.S. (Eilers et al. 1989). Changes in nutrient cycles and shifts in phytoplankton communities in Sierra Nevada lakes have been previously detected and attributed to increased nutrient inputs (Goldman et al. 1993, Sickman et al. 2003).

It is well documented that amphibians are sensitive to ecosystem changes, are easy and relatively inexpensive to monitor, and measures are highly repeatable.
Lakes are habitat for three amphibian species that are candidates for listing as endangered under the federal Endangered Species Act—mountain yellow-legged frog (Rana muscosa

and Rana sierrae) and Yosemite toad (Bufo canorus). The yellow-legged frog, once the most common vertebrate in the high elevation Sierra Nevada, is a keystone species in high-elevation lakes. The loss of yellow-legged frogs is likely to have measurable impact on the natural functioning of lakes within their historic range.
Change detected in high-elevation lakes can be an early warning indication of change that may eventually occur at other elevations and ecosystem types. For example, elevated nitrate concentrations in surface waters are a primary symptom of N-saturated ecosystems (Fenn et al. 1998). Watersheds located near the elevational extremes are less effective at retaining nitrogen than mid-elevation ecosystems (Stohlgren 1988, Melack et al. 2002, Fenn et al. 2003). Alpine and sub-alpine watersheds have been shown to have a low capacity to retain nitrogen primarily due to steep talus slopes, shallow soils, and sparse vegetation (Clow and Sueker 2000). Increased nitrogen deposition in the Transverse Ranges of southern California, low elevations in the southern Sierra Nevada, and high-elevations in the Colorado Rocky Mountains has already led to excessive leaching of nitrate into receiving waters (Fenn et al. 2003).

5.4.2 Monitoring Questions and Measurable Objectives

Monitoring Questions

The Sierra Nevada Network identified a set of broad monitoring objectives and questions as part of the Vital Signs Monitoring Plan (Mutch et al. 2005). We used these to guide us in defining specific monitoring objectives. Lake monitoring, in conjunction with the other indicators, will provide information that will help the network answer these questions. SIEN's broad monitoring questions that pertain to the lake monitoring protocol are:

- How are climatic trends affecting regional hydrologic regimes (snowpack depth, snow water equivalent, snowmelt, glacial extent, frequency and intensity of flood events, and volume and timing of river and stream flows)?
- How do depositional patterns of nutrients (principally nitrogen and phosphorus) and other major cations/anions vary along elevation gradients, in aquatic and terrestrial systems, and through time?
- How are patterns of nitrogen cycling changing?
- Are episodic acidification events increasing and are these events altering aquatic communities?
- How are water dynamics changing in response to climate and fire regimes?
- How are surface water volumes changing in lakes and wetlands?
- How does water chemistry (concentrations and fluxes) vary spatially and temporally across network parks?
- How is water quality changing with respect to water quality standards?

- How are plants and animals responding to changes in nutrient concentrations, heavy metals and toxins, sediment loads, and water temperature? What effects are these responses having on aquatic food chains and biological diversity?

Monitoring Objectives

The Sierra Nevada Network's specific monitoring objectives are divided into two categories: (1) extensive sites, and (2) index sites.

<u>Extensive Sites:</u>

1. Detect long-term trends in lake water chemistry for Sierra Nevada Network lakes.
    - Temperature, pH, specific conductance, dissolved oxygen, acid neutralizing capacity
    - Major ions: Ca, Na, Mg, K, Cl, SO4
    - Nitrate, dissolved organic nitrogen, total dissolved nitrogen, particulate nitrogen, total nitrogen
    - Total dissolved phosphorus, particulate phosphorus, total phosphorus, particulate carbon
2. Characterize Sierra Nevada Network lakes.
3. Determine the proportion of Sierra Nevada Network lakes above threshold values for selected constituents.
4. Detect long-term trends and abundance of high-elevation anurans, particularly yellow-legged frog, Pacific treefrog, and Yosemite toad for Sierra Nevada Network lakes.

<u>Index Sites</u>: (a rationale for selected measures is included in our Lake Monitoring Protocol).

1. Detect intra- and inter-annual trends in lake water chemistry for Sierra Nevada Network index lakes.
    - Temperature, pH, specific conductance, dissolved oxygen, acid neutralizing capacity
    - Major ions: Ca, Na, Mg, K, Cl, SO4
    - Nitrate, dissolved organic nitrogen, total dissolved nitrogen, particulate nitrogen, total nitrogen
    - Total dissolved phosphorus, particulate phosphorus, total phosphorus
    - Particulate carbon
2. Detect intra- and inter-annual trends in lake level and outflow for Sierra Nevada Network index sites.
3. Detect inter-annual trends and abundance of high-elevation anurans, particularly yellow-legged frog, Yosemite toad, and Pacific treefrog for Sierra Nevada Network index sites.

5.4.3 Management Decisions and Thresholds

Parks will use status and trend information from the lake monitoring protocol to make park-level management decisions, monitor compliance with state water quality standards, inform regional permitting of point-source industrial emissions, influence regional, state, and national policies, meet Government Performance Results Act reporting requirements, and inform the public.

At the local park-level these data may be used to inform park planning projects, regulate visitor use, inform fire management, meet government reporting requirements, and contribute to the protection and restoration of aquatic ecosystems, including declining amphibian populations.

Establishing ecological thresholds and management triggers is not a trivial task. It will involve input from park staff and outside area experts and likely will require additional research. SIEN plans to identify threshold conditions and management triggers for water chemistry measures over the next several years. Water quality standards can and will be used as a management trigger. However, due to the dilute nature of Sierra Nevada lakes, ecological thresholds unique to these systems will be far more successful in protecting SIEN lakes.

Sequoia, Kings Canyon, and Yosemite are currently working with the University of California, Riverside, to develop critical nitrogen loads for Sierra Nevada lake ecosystems (Sickman et al. 2006). Once critical loads are identified, status and trend information from lake monitoring can be compared to these ecologically meaningful thresholds.

Parks will use the lake monitoring information to interpret the status and trends of aquatic resources to the public.

Chapter 6 DATA MANAGEMENT

Collecting data on natural resources is the first step toward understanding ecosystems within national parks. These "raw" data are used to analyze, synthesize, and model aspects of ecosystem components and processes. In turn, results and interpretations are used to make decisions concerning park resources. Thus, *data* collected and maintained by the Sierra Nevada Network (SIEN) will become *information* for decision-making through analysis, synthesis, and modeling.

Data management encompass the attitudes, habits, procedures, standards, and infrastructure related to the acquisition, maintenance, and disposition of data and its resulting information. Data management is not an end unto itself but, instead, a means of maximizing quality and utility of natural resource information.

This chapter summarizes the SIEN data management strategy which is more fully addressed in the SIEN Data Management Plan (DMP)(Cook and Lineback 2007). The DMP describes an overarching strategy for ensuring that program data are controlled for quality, well documented and secure, and remain accessible and useful for decades into the future. In turn, the DMP refers to more specific guidance documents and standard operating procedures applicable to individual vital signs monitoring protocols. The intended audience includes SIEN I&M Program; Network park natural resource management programs; USGS field stations located in YOSE and SEKI; and cooperators who have either a fiscal or formal agreement/relationship with these programs.

6.1 Goals and Objectives of Data Management

As part of the NPS effort to "improve park management through greater reliance on scientific knowledge," a primary purpose of the Inventory and Monitoring (I&M) Program is to develop, organize, and make available natural resource data and information to contribute to the Service's institutional knowledge.

In this context, "information" encompasses other types of products generated along with primary tabular and spatial data, such as metadata, maps, statistical models, diagrams, and reports. Meeting program goals for Vital Signs monitoring data and information requires the development of an integrated management system involving many components (Figure 6-1).

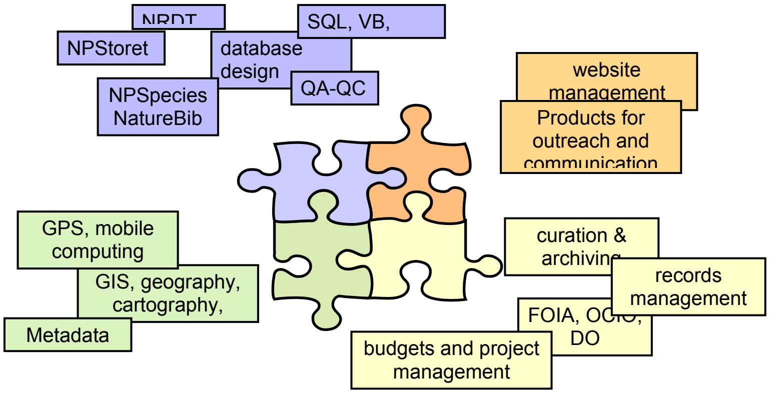


Figure 6-1. Vast array of data management puzzle pieces.

The goal of SIEN data management is to ensure the quality, interpretability, security, longevity and availability of ecological data and related information resulting from natural resource inventory and monitoring efforts. These fundamental concepts are defined as follows:

- *Quality* – Awareness of the quality of information and its underlying data is fundamental to its proper use. Our objective is to ensure that appropriate quality assurance measures are taken during all phases of project development, data acquisition, data handling, summary, and analysis, reporting, and archiving. These measures reflect current best practices and meet rigorous scientific standards.
- *Interpretability* – A data set is only useful if readily understood and appropriately interpreted in the context of its original scope and intent. Data taken out of context can lead to misinterpretation and misunderstanding. Our objective is to ensure that sufficient documentation accompanies each data set, and any reports and summaries derived from it, so users will be aware of its context, applicability, and limitations.
- *Security* – Our objective is to make certain that both digital and analog forms of source data are maintained and archived in an environment that provides appropriate levels of access to project managers, technicians, decision makers, and others.
- *Longevity* – Countless data sets have been lost over time simply due to insufficient documentation and organization. Our objective is to ensure that data sets are maintained in an accessible and interpretable format, and accompanied by sufficient documentation. Although this requires an initial investment of time and effort, this investment almost certainly pays off over time because the data set is much more likely to be used.
- *Availability* – Natural resource information can only be useful for informing decisions if it is available to managers at the appropriate time and in a usable form. Our objective is to expand the availability of natural resource information by ensuring that products of inventory and monitoring efforts are created, documented, and maintained in a manner that is transparent to the potential users of these products.

6.2 Systems Infrastructure and Architecture

A modern data management infrastructure (e.g., staffing, hardware, software) represents the foundation upon which our network information system is built. *Infrastructure* refers to the system of computers and servers that are functionally or directly linked through computer networking services. *Architecture* refers to the applications, database systems, repositories, and software tools that make up the framework of an information management system. SIEN relies on park, network, and national Information Technology (IT) personnel and resources to maintain a computer systems infrastructure and architecture. This includes but is not limited to hardware replacement, software updates and support, security updates, virus-protection, telecommunications networking, and server backups. Therefore communication with park and national personnel is essential to ensure adequate resources and service continuity.

An important element of an information management program is a reliable, secure network of computers and servers. Our digital infrastructure has three main components: a network-based local area network (LAN), a regional wide-area network (WAN), and servers maintained at the national level (Figure 6-2). Each of these components hosts different parts of our natural resource information system.

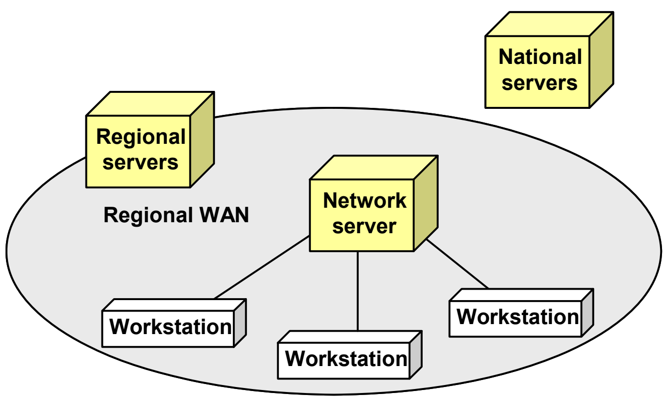


Figure 6-2. Main components of the Sierra Nevada Network.

IT duties for Network programs such as I&M are provided by the IT staff at SEKI and YOSE. These include hosting and managing Network electronic files being created, managed, and disseminated by Network staff and cooperators. SEKI staff provide IT support to Devils Postpile. The SEKI LAN will be the primary repository for I&M electronic files with access available to YOSE and DEPO staff and I&M employees working in these parks. Files will be managed within a standardized electronic directory structure organized by project. Long term plans for the Network include a content management system. It is anticipated that YOSE IT staff will provide additional, specialized support as Network parks begin implementing the Network's DMP, such as Citrix administration that will enable park employees to utilize ArcGIS software across wide area networks with low bandwidth connections. Security will be achieved through electronic file and directory permissions with administration rights controlled by IT personnel and a limited number of trained program staff.

Data management support from the Washington office includes hosting and maintaining several databases on national servers. These online databases will be used for summarizing park-level data at the national level, providing a means for storing and making accessible basic natural resource data and information for the parks. Sensitive data and information is prevented from public release through the implementation of a dual system of secure and public servers. Applications include:

- *NatureBib* – the master database for natural resource bibliographic references
- *NPSpecies* – a database application that lists the species that occur in or near each park, and the physical or written evidence for the occurrence of the species (i.e., references, vouchers, and observations)
- *Biodiversity Data Store* – a digital repository of documents, GIS and other data sets that contribute to the knowledge of biodiversity in National Park units, including presense/absence, distribution and abundance
- *NPS Data Store* – a centralized repository and graphical search interface that links data set metadata to a searchable data server on which data sets are organized by NPS units, offices, and programs.

The Biodiversity and NPS Data Stores contain sensitive data and information and access is available only through prior authorization. Unrestricted public outlets for digital data products include:

- *NPSFocus* – a decentralized digital image/resource management application that offers one-stop searching and browsing for digital imagery (pictorial, drawings, maps, texts, and GIS DOQ/DRG images) and metadata from separate image collections maintained by parks and NPS programs.
- *NPS GIS Clearinghouse* – a public repository of GIS products produced by the NPS, including a link to the NPS Data Store and the NPS Interactive Map Center which delivers base maps and park brochure maps for geographic reference and navigation. Non-sensitive GIS data uploaded to the NPS Data Store are automatically posted to this site.

Water quality monitoring data collected in and around national park units are disseminated through STORET (STORage and RETrieval), an interagency database developed and supported by the Environmental Protection Agency to house local, state, and federal water quality data collected in support of managing the nation's water resources under the Clean Water Act.

At the local level, park resources for data management include:

- ArcGIS for managing spatial data and metadata
- NPS Metadata Tools and Editor for editing and transferring metadata to the *NPS Data Store*

- Microsoft Access for developing project databases
- Microsoft Sharepoint Services, currently hosted by the PWR office
- Lotus Sametime Meeting for Internet and video conferencing

6.3 Project Workflow

From the perspective of managing work flow, there are two main types of projects:

- S*hort-term*, which may include individual park research projects, inventories, or pilot work in preparation for long-term monitoring,

- *Long-term*, which are mainly implemented monitoring projects central to the I&M program, but may also include multi-year research projects and monitoring performed by other agencies and cooperators. Long-term projects often require a higher level of documentation, peer review, and program support.

With respect to data management, a primary difference between short- and long-term projects is an increased need to adhere to standards for the latter to ensure internal compatibility over time.

Projects can be divided into five primary stages (Figure 6-3), each characterized by a set of activities carried out by involved staff:

- *Planning and approval* – Many preliminary decisions are made regarding project scope and objectives. Funding sources, permits, and compliance are also addressed at this stage.

- D*esign and testing* – Details regarding how data will be acquired, processed, analyzed, documented, reported and made available to others are worked out. Development of the data design and data dictionary is initiated, and specifics of protocol implementation and collected data parameters are defined in detail.

- *Implementation* – Data are acquired, processed, error-checked, and documented. Products such as reports, maps, GIS themes are developed and delivered. Data management staff function primarily as facilitators, providing training and support for: database applications, GIS, GPS and other data processing applications; facilitation of data summarization, validation and analysis; and assistance with the technical aspects of documentation and product development.

- *Product integration* – Data products and other deliverables are integrated into national and network databases, metadata records are finalized and posted in clearinghouses, and products are distributed or otherwise made available to their intended audience. Data from working databases are uploaded to the master database maintained on network servers.

- *Evaluation and closure* – Status of projects and their deliverables are updated in a network project tracking application. Program administrators, project leaders, and data managers assess how well projects have met their objectives.

Throughout the workflow of a project, data take different forms and are maintained in different places as they are acquired, processed, documented, and archived.

Key points of the data life cycle are as follows:

- All raw data are archived intact.
- Working databases are the focal point of all modification, processing, and documentation of data collected for a given time period.
- Upon certification, whereby all documentation and quality assurance requirements are satisfied, data are archived and posted or otherwise integrated with national applications and repositories.
- For long-term monitoring projects, data are uploaded into a master database that includes multiple years of data.
- Certified data sets are used to develop reports and other data products (maps, checklists, etc.). These products are also archived and posted to appropriate national applications and repositories.
- All subsequent changes to certified data sets are documented in an edit log, which is distributed with the data.

6.4 Information Stewardship Roles and Responsibilities

Nearly everyone in an organization manages data and information at some level. Good data stewardship is truly a collaborative endeavor that involves many people with a broad range of tasks and responsibilities. As such, a valid data management system must be developed and continually modified to meet the needs of everyone who has a role in coordinating, generating, maintaining, and using natural resource information in its many forms. For the I&M Program, this will constitute a diverse group of employees made up of park managers and scientists, data managers, GIS staff, IT specialists, project managers and technicians, and interpreters (Table 6-1).

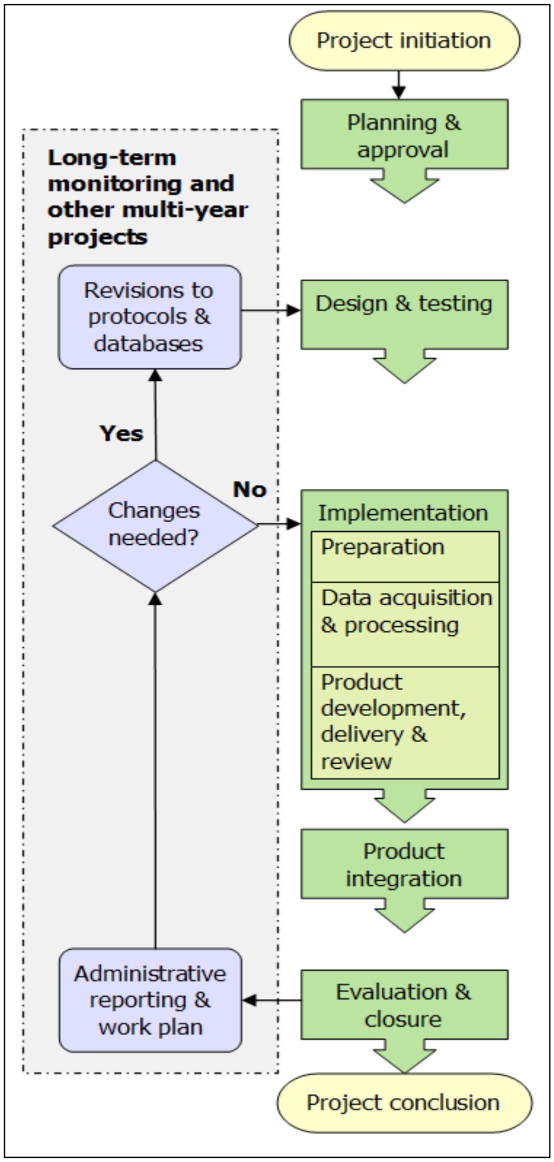


Figure 6-3. Primary Project Stages

6.5 Information Stewardship Roles and Responsibilities

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Table 6-1. I&M roles and responsibilities for data stewardship.

Role	Data Stewardship Responsibilities
Network Coordinator	Ensures programmatic requirements are met as part of overall Network business.
Network Data Manager	Ensures inventory and monitoring data are organized, useful, compliant, secure, and available.
Project Leader	Directs project operations. Communicates information management requirements and protocols to project staff, Network Data Manager, and resource specialist(s). Responsible for final submission and review of all products and deliverables.
Project Crew Leader	Supervises crew and ensures adherence to data collection and processing protocols, including data verification and documentation.
Project Crew Member	Collects, records and verifies measurements based on project objectives and protocols. Documents methods and procedures.
Data/GIS Technician	Processes and manages data.
Statistician/Biometrician/ Quantitative Ecologist	Analyzes data, consults on analyses, and document procedures.
Network Ecologist/Physical Scientist	Ensures useful data are collected and managed by integrating natural resource science into Network activities and products.
Park Resource Specialist	Understands project objectives, data, and management relevance. Makes decisions about validity, sensitivity, and availability of data.
Curator (Park or Region)	Manages collection, documentation, and preservation of specimens.
GIS Manager (Region)	Provides GIS support including long-term storage of data, updated software, and technical assistance.
Information Technology Specialist (Network or Region)	Provides IT support for hardware, software, and network.
I&M Data Manager (National)	Provides Service-wide database availability and support
End Users (managers, scientists, Interpreters, public)	Informs the scope and direction of science information needs and activities. Interprets information and applies to decisions.

6.6 Database Design

The SIEN strategy for managing project data relies upon standalone MS Access databases that share design standards, established by the Natural Resources Database Template (http://science.nature.nps.gov/im/apps/template/index.cfm), and links to centralized data tables for maintaining consistency in shared information (e.g., geographic place names, species taxonomic nomenclature). Individual project databases are developed, maintained, and archived separately. Advantages to this strategy include:

- Data sets that are modular, allowing greater flexibility in accommodating the needs of each project area.

- Individual project databases and protocols can be developed at different rates without a significant cost to data integration.
- Any project database can be modified without affecting the functionality of other project databases.
- Large initial investment in a centralized database and the concomitant difficulties of integrating among project areas with very different, and often unforeseen, structural requirements can be avoided.
- Potentially greater efficiency for interdisciplinary use.

6.7 Data Acquisition and Processing

Large, multi-scale natural resources programs, such as Vital Signs Monitoring, increasingly rely on data and information gathered from multiple sources. The SIEN DMP describes the general steps involved with acquiring, processing, and reporting data gathered as part of vital signs monitoring, along with legacy data gathered both from within and outside of the NPS, to meet standards established by the NPS I&M Program for quality, documentation, and preservation. Also included are guidelines for the acquisition and processing of physical objects (photographs, voucher specimens) which are often collected as part of resource management, inventory and monitoring, and other research projects. Instructions specific to particular projects will be developed and included with the protocols for those projects.

6.8 Quality Assurance and Quality Control

The success of the I&M Program will ultimately depend on the quality of the data that are collected, processed, and disseminated. To ensure data of the highest quality, procedures have been established to identify and minimize errors at each project stage associated with the data life cycle. Quality assurance and quality control protocols and execution are joint responsibilities, the results of which are documented to notify end users of the level of data quality.

Although some quality control procedures depend upon the nature of a specific project, some general concepts apply to all network projects (Table 6-4). To ensure that all SIEN vital signs monitoring projects produce and maintain data of the highest quality, a common set of procedures has been developed to identify and minimize both the frequency and significance of error at all stages in the data life cycle

Examples of quality assurance practices include:

- Field crew training
- Standardized field data forms with descriptive data dictionaries
- Use of handheld computers and data loggers with built-in controls
- Equipment maintenance and calibration
- Procedures for handling data in the field

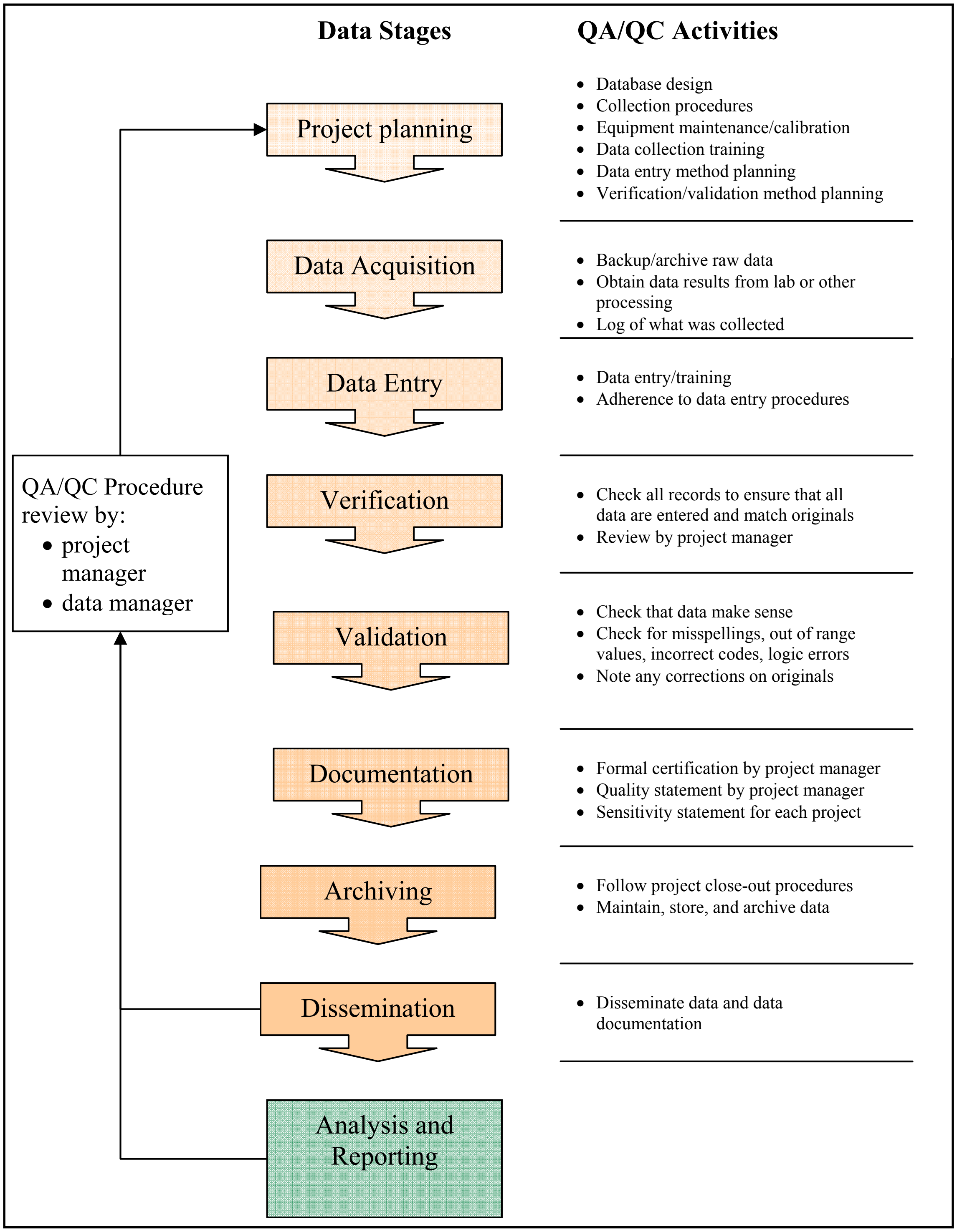

Figure 6-4. General course of data and associated Quality Assurance/Quality Control procedures.

Database features to minimize transcription errors, including range limits, pick lists, etc.

Verification and validation, including automated error-checking database routines and quality assurance methods should be in place at the inception of any project and continue through all project stages to final archiving of the data set.

As a final step, a statement of data quality will be composed by the Project Leader and incorporated into the formal metadata, which will include information on the specific quality assurance procedures applied and the results of the review.

6.9 Data Documentation

Documentation is essential to the longevity and value of project data. Anyone using these data in the future will need to know as much as possible about what, where, how, when, why, and by whom the data were collected, along with appropriate uses, including restrictions on sensitive information, and any known limitations. A good data management system cannot simply attend to the tables, fields, and values that comprise a data set. It also must provide a process for developing, preserving, and integrating the research context that makes data interpretable and useful. For the SIEN, this will involve the development of formal metadata—a detailed, structured set of information about the content, quality, condition, and other characteristics of project data.

The development of formal metadata which will following Federal Geographic Data Committee and NPS standards for content and format will also enable the cataloging of project data sets within intranet and internet systems, thereby making them available to a broad range of potential users.

Metadata for all SIEN monitoring projects will be parsed into two nested levels of detail, each with a specific audience in mind. Level 1, or "Manager Level" will present an overview of the product crafted to quickly convey the essentials needed to understand the context of the data. Level 2, or "Full Metadata" will contain all components of supporting information such that the data may be confidently manipulated, analyzed and synthesized.

There are a variety of software tools available for creating and maintaining metadata. The SIEN will use one or more of the following:

- ESRI's ArcCatalog
- NPS Metadata Tools and Editor
- The "Metadata in Plain Language" questionnaire

SIEN data management staff will provide training and support in the use of these tools to project leaders and will aid in metadata development where practical. Upon completion, metadata will be posted with project data so that they area available and searchable along with their constituent data sets data and reports via the SIEN Internet web site and the NPS Data Store.

6.10 Data Ownership and Sharing

SIEN data and information products are considered property of the NPS. However the Freedom of Information Act (FOIA) establishes access by any person to federal agency records that are not protected from disclosure by any exemption or by special law enforcement record exclusions. We will comply with all FOIA strictures regarding sensitive data. If the NPS determines that disclosure of information would be harmful, information may be withheld concerning the nature and specific location of:

- Endangered, threatened, rare or commercially valuable National Park System Resources (species and habitats)
- Mineral or paleontological objects
- Objects of cultural patrimony
- Significant caves

Each project leader, as the primary data steward, will determine data sensitivity in light of federal law, and will stipulate the conditions for release of the data in the project protocol and metadata. Network staff will classify sensitive data on a case by case, project by project, basis. They will work closely with investigators for each project to ensure that potentially sensitive park resources are identified, and that information about these resources is tracked throughout the project.

Network staff is also responsible for identifying all potentially sensitive resources to principal investigator(s) working on each project. Investigators, whether network employees or partners, will develop procedures to flag all potentially sensitive resources in any products that come from the project, including documents, maps, databases, and metadata. When submitting any products or results, investigators should specifically identify all records and other references to potentially sensitive resources. Partners should not release any information in a public forum before consulting with Network staff to ensure that the information is not classified as sensitive or protected.

The following guidance for determining whether information should be protected is suggested in the draft Director's Order #66 (the final guidance will be contained in Reference Manual 66):

- Has harm, theft, or destruction occurred to a similar resource on federal, state, or private lands?
- Has harm, theft, or destruction occurred to other types of resources of similar commercial value, cultural importance, rarity, or threatened or endangered status on federal, state, or private lands?
- Is information about locations of the park resource in the park specific enough so that the park resource is likely to be found at these locations at predictable times now or in the future?
- Would information about the nature of the park resource that is otherwise not of concern permit determining locations of the resource if the information were available in conjunction with other specific types or classes of information?
- Even where relatively out-dated, is there information that would reveal locations or characteristics of the park resource such that the information could be used to find the park resource as it exists now or is likely to exist in the future?

- Does NPS have the capacity to protect the park resource if the public knows its specific location?

Natural Resource information that is sensitive or protected requires the following steps:

- Identification of potentially sensitive resources.
- Compilation of all records relating to those resources.
- Determination of what data must not be released to the public.
- Management and archival of those records to avoid their unintentional release.

6.11 Data Dissemination

Public access to SIEN data and information products will be facilitated through a variety of information systems that allow users to browse, search and acquire I&M project data and supporting documents. These systems include the SIEN I&M data server, digital library, and website, and national applications with internet interfaces (Table 6-2).

Table 6-2. Public-access repositories for SIEN data and information.

ITEM	REPOSITORY
Reports (public) digital	SIEN network servers, SIEN public website, NPS Data Store, NPSFocus
• hard copy	SIEN I&M library, YOSE Library, USGS libraries
• bibliography	NatureBib
Network-generated digital datasets and data products (public, non-sensitive) • Certified data and data products (including photographs) • Metadata	SIEN network servers, NPS Data Store, Biodiversity Data Store, NPSpecies, NPS GIS Clearinghouse, EPA STORET

Network products also will be available via data requests fulfilled using either electronic file transfer protocol (FTP), email attachments for small file sizes, or shipment of digital media such as DVDs or CD-ROMs.

Water quality data collected to meet federal regulatory requirements are managed according to guidelines from the NPS Water Resources Division (WRD), which also oversees the integrated water-quality monitoring portion of the I&M Program. WRD requirements stipulate the use of the NPSTORET desktop database application by I&M networks to help manage data entry, documentation, and transfer. Data from NPSTORET are transferred periodically to the Environmental Protection Agency's STORET National Data Warehouse (Figure 6-5). Individual networks are free to use NPSTORET for data entry and maintenance, or to develop a customized database compatible for data exchange and delivery. The SIEN may choose the latter and build a desktop application that would also interface with the State of California's Environmental Data Exchange Network (CEDEN). Data would then be provided to WRD for upload to STORET on an annual basis in accordance with NPS STORET Electronic Data Deliverable file specifications.

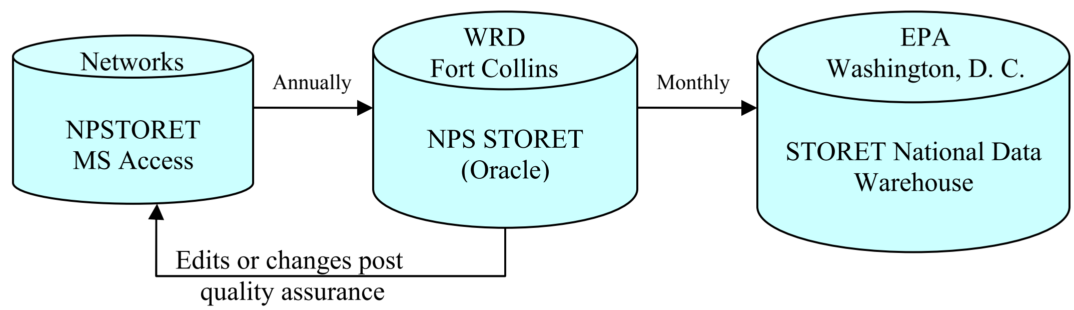

Figure 6-5. Flow diagram for water quality data from I&M networks to the National Data Warehouse.

6.12 Records Management and Object Storage

Data maintenance, storage and archiving procedures will ensure that data and related documents and associated physical objects are:

- Kept up-to-date with regards to content and format such that the data are easily accessed and their heritage and quality easily learned
- Physically secure against environmental hazards, catastrophe, and human malice

Technological obsolescence is a significant cause of information loss, and data can quickly become inaccessible to users if they are stored in out-of-date software programs or on outmoded media. Effective maintenance of digital files depends on the proper management of a continuously changing infrastructure of hardware, software, file formats, and storage media. Major changes in hardware can be expected every one to two years and in software every one to five years. As software and hardware evolve, data sets must be consistently migrated to new platforms, or they must be saved in formats that are independent of specific platforms or software (e.g., ASCII delimited files). Data maintenance schedules will be developed to ensure that data are migrated and kept up-to-date.

6.13 Implementation

The data management plans for each of the 32 I&M Networks are the first comprehensive documents of their kind in the NPS and contain practices that may be new to staff and cooperators. However, almost every requirement stems from federal law, Executive

Orders, Director's Orders, or national I&M Program guidance. The DMP helps put these requirements into context, and provides operational guidance for achieving them.

The main body of the plan broadly addresses relevant subjects, but directs most of the details into individual appendices that serve as stand-alone documents for ease of locating and retrieving specific information of greatest value to most users. The next plan revision should be completed within three years or by October 1, 2010, and then every five years afterward. Plan appendices, including SOPs, detailed guidelines, reference manuals, policy statements, etc., will likely require more frequent updates to account e.g., for changes in technology or availability of better information.

Implementation will require education and training in order to familiarize park staff and cooperators with the tools, procedures, and guidelines outlined in the plan. These efforts will begin in 2007 and be led, at least initially, by I&M data management staff and the SEKI GIS coordinator, with additional technical staff from all parks encouraged to participate. Full implementation will require the assistance of IT and curatorial staff at SEKI and YOSE as well. Goals for the first three years should include:

- All staff of targeted programs and their cooperators understand the fundamentals of data and information management, including
- File management
- Documentation
- Quality assurance and quality control
- Electronic storage
- Archive storage
- Data management practices are improved by implementing
- Accepted database design standards
- Thorough testing of databases, data collection methods, and their integration prior to field work
- Quality assurance and control procedures at every stage of project development
- Common SOPs and guidance documents for multiple protocols
- Detailed specifications for data management consistent with the DMP are included in every vital signs monitoring protocol
- Procedures and outlets for communication within and among Network parks and with the public

Beyond the first three years, goals should include the development and assessment of:

- Procedures to facilitate the summarization and reporting of monitoring data
- Framework and gateway for integration of monitoring data with other agencies or networks
- Methods for improving file management (e.g., a content management system), database administration and security (e.g., migration to SQL-Server), integration into the network of off-site users, and other needs identified in the DMP

Implementation and improvement of the data management system will be an ongoing process. The practices and procedures identified in this plan will continue to be encouraged broadly within the Network, and in time, we expect them to be widely accepted and adopted by all SIEN park programs.

> We include Data Management, Archiving, and Reporting excerpts from our Lake Monitoring Protocol (Heard et al., in prep) as an example of the level of thought and detail our protocols will contain (Section 6.14, below).

6.14 *Example*: Lake Monitoring Protocol—Data Management, Archiving, and Reporting

Data take on different forms during various phases of a project, and will be maintained in different places as they are acquired, processed, documented, analyzed, reported, and distributed. Flow of our lake monitoring data and associated information are presented visually, using a "data life cycle" conceptual diagram (Figure 6-6).

Data are stored locally in SIEN's Water Database (described below). Certified data are disseminated via national, state, and local avenues: (1) STORET, EPA's national water quality database; (2) California Environmental Data Exchange Center (CEDEN), the State's repository for aquatic data; (3) SIEN website; and (4) by direct request to the network. Products (e.g., report and summaries) will also be disseminated through multiple venues including SIEN website, NatureBib, and Dataset Catalog, etc…

Information management is considered throughout the protocol. There are also several Standard Operating Procedures (SOPs) that focus on data and information-management procedures (Table 6-3).

"SOP #15: Data Management" is the central data management reference and contains all details of data management—from acquisition to dissemination. It also directs the user to additional detailed procedures located in other SOPs.

Table 6-3. SOPs specific to Lake protocol data management.

SOP #4: Quality Assurance Project Plan
The Quality Assurance Project Plan (QAPP) describes quality assurance and quality control objectives and procedures. It covers an overview of data management, documentation and records, review, verification, validation, and reconciliation. The QAPP meets the State of California's Surface Water Ambient Monitoring Program (SWAMP) quality requirements so SIEN data are compatible with SWAMP.
SOP #15: Data Management
This is the central data management reference. It provides detailed directions through the data management steps (i.e., data life cycle), from acquisition to dissemination.

SOP #16: Database Users' Manual

This is the Users Manual for the SIEN Water Database. It contains all procedures for the database including entering, verifying, committing, and exporting water chemistry and streamflow data. It contains the data dictionary.

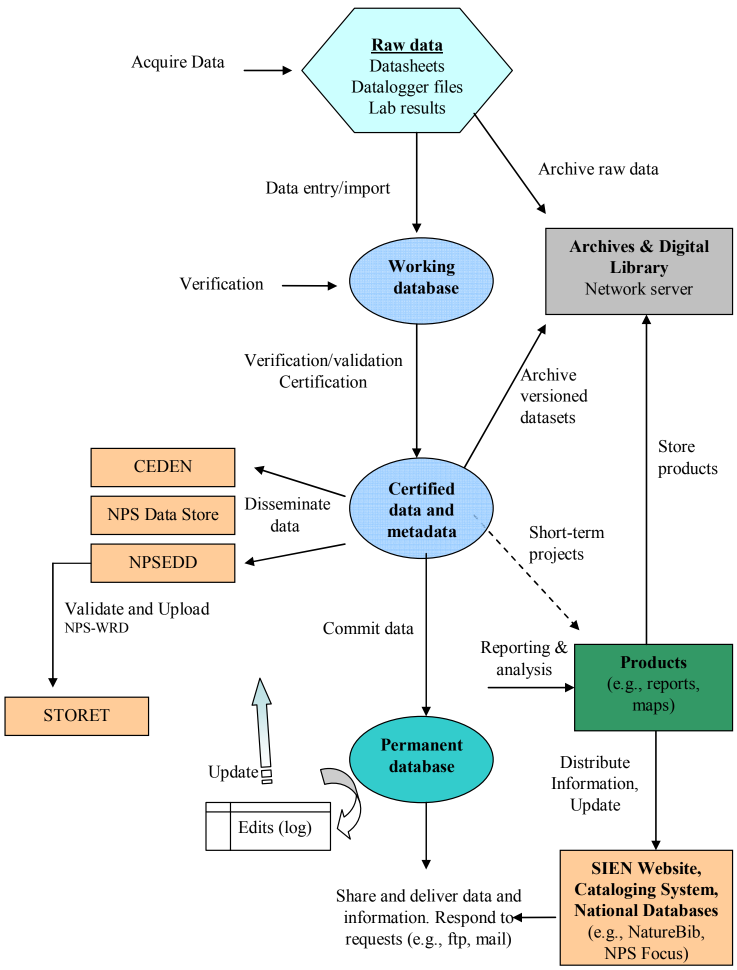

Figure 6-6. Flow chart for lake monitoring data.

6.14.1 SIEN Water Database

We are working with the State of California and the Surface Water Ambient Monitoring Program (SWAMP) to improve information sharing and facilitate the flow of data between NPS and the State. The State of California maintains the California Environmental Data Exchange Center (CEDEN) which is a state-wide database through which all water quality and aquatic biota data collected by water quality programs in the state are integrated and made publicly available. The Department of Water Resources has developed a desktop database application in MS Access that is used by the SWAMP program and their clients to store and deliver their data to CEDEN. The SWAMP database design is consistent with the Natural Resources Database Template (NRDT) and adheres to protocols established by the Environmental Protection Agency and State of California for data standardization and quality assurance.

The SIEN Water Database is a modified version of the SWAMP client database (version 2.2). We modified the SWAMP database to incorporate all metadata (required and optional) included in NPSTORET and to meet the specific requirements of our program, including the capacity to store continuous streamflow data. The result is a database that interfaces with the National Park Service-Water Resources Division NPSTORET, and thus STORET, and the State of California's CEDEN. Data are uploaded, via a built-in interface module, to Excel spreadsheets that meet the National Park Service STORET Electronic Data Deliverable (NPSEDD) specifications and submitted to NPS-WRD annually. The State of California will be designing the SIEN-CEDEN interface in 2008. Data are uploaded to CEDEN annually.

6.14.2 Data Quality Assurance and Quality Control

Data quality is appraised by applying verification and validation procedures as part of the quality control process. These procedures will be more successful because we precede them with effective quality assurance practices (i.e., planning). *Data verification* checks that digitized data match source data, while *data validation* checks that data make sense.

The verification method we are using is *visual review after data entry* to verify lake chemistry and stream flow data.

We use the following three validation methods:

1. Data entry application programming
2. Outlier Detection
3. Other exploratory data analyses, following Palmer and Landis ((2002).

Fields for QA/QC documentation (e.g., metadata, water quality QA/QC result codes, QA/QC samples) are built into the database, thus QA/QC information "travels" with the data. This enables end-users to assess data quality in the context of their specific uses.

SOP #4: QAPP contains (1) detailed verification and validation methods, and (2) roles and responsibilities (see Table 6-3 above).

Chapter 7 DATA ANALYSIS AND REPORTING

Data analysis, interpretation, and reporting are crucial and persistent components in the evolution and development of the Sierra Nevada Network's I&M program. Data compiled from monitoring projects will be used by diverse audiences—NPS, park managers and coordinators, scientific collaborators, educators—who might have different requirements and needs. Therefore, the Network will integrate its monitoring information with other research, make it as relevant as possible, and report results promptly. Robust and sound data management and analysis, interpretation, and communication of monitoring results are the backbone of the SIEN monitoring program.

This chapter summarizes the major themes and concepts of the Network's plan for analysis, review, communication, and reporting. Details of specific vital signs monitoring is beyond the scope of this chapter, and are included within the monitoring protocols that correspond to specific vital signs. Many of these are currently under development. Please refer to the Lake Monitoring protocol and its constituent vital signs for a detailed example of the concepts described in the following sections.

7.1 Introduction to SIEN Data Analysis and Reporting

As part of the NPS effort to "improve park management through greater reliance on scientific knowledge," a primary role of our Inventory and Monitoring Program is to develop, organize, and deliver natural resource information that will increase our knowledge of these natural resources. Clear and complete reporting facilitates the flow of information in all aspects of monitoring, e.g., analyses, syntheses, and modeling.

The data SIEN needs to better understand park ecosystems and to improve park management comes from many sources. These include data collected by:

1. SIEN's monitoring program to determine status and trend in condition of park resources
2. Other park projects and programs, other agencies, and the general scientific community. To the extent that staffing and funding are available, the Network I&M program will collaborate and coordinate its efforts with other available information, and will continue to promote the integration and synthesis of data across projects, programs, and disciplines.

To ensure that it is meeting program objectives, the SIEN monitoring program has established rigorous report and review requirements.

7.2 Analysis of Monitoring Data

Appropriate analysis of monitoring data is directly linked to our monitoring objectives, spatial and temporal aspects of the sampling design, the intended audiences, and how management will use the data. Therefore, it's essential that we consider our methods of analysis, identify objectives, and select our sampling design before we collect the data. Each monitoring protocol (see Chapter 5) will contain detailed information about the analytical tools we intend to use, as well as the rationale for data analysis and interpretation. Explanation of our rationale will include:

- Why a particular approach was chosen
- Advantages and limitations of each procedure
- Standard operating procedures (SOPs) for each prescribed analysis

Table 7-1 summarizes four general categories of analysis for SIEN vital signs, and the lead analyst responsible for each category. Lead analysts will ensure that data are analyzed and interpreted within the guidelines of the protocol and monitoring program, but they won't necessarily perform the analyses or interpret the results. For example, the Network coordinator might be the lead analyst who defers to a principal investigator to perform the analyses.

Table 7-1. General categories of analysis of monitoring data for SIEN vital signs.

Level of Analysis	General Description of Analysis	Lead Analyst
Data Summarization/ Characterization	• Calculation of basic statistics of interest from monitoring data • Summarization encompasses measured and derived variables specified in the monitoring protocol. Data summarization and characterization forms the basis of more comprehensive analyses, and for communicating results in both graphical and tabular formats.	• The Principal Investigator (e.g., I&M, NPS, or collaborator) for each monitoring protocol, working with the data management staff, will produce routine data summaries. • Parameters and procedures are specified within the monitoring protocols.
Status Determination	Analysis and interpretation of the ecological status (point in time) of a vital sign to address the following types of questions: • How do observed values for a vital sign compare with historical levels (where appropriate data are available)? • Do observed values exceed a regulatory standard, or known or hypothesized ecological threshold? What is the level of confidence that the standard has actually been exceeded? • What is the spatial distribution (within a park or the Network) of observed values for a given point in time? Do these patterns suggest directional relationships with other ecological factors? Status determination will involve both expert	• The Principal Investigator for each monitoring protocol is the lead analyst for status determination, although the Network coordinator, cooperators, partners or other network staff may conduct analyses and assist with interpreting results. Consultation with regulatory and subject matter experts will support status determination.

	interpretation of the basic statistics and statistical analysis to address these monitoring questions. Assumptions about the target population and the level of confidence in the estimates will be ascertained during the analysis.	
Trends Evaluation	• Analysis of trends will employ parametric, nonparametric, or mixed models. Evaluations of trends in vital signs will address: (1) the appropriate time or interval to assess the trend of a vital sign, (2) whether there is directional change in a vital sign over the period of measurement, (3) the rate of change (sudden vs. gradual), and how this pattern compares with trends over broader spatial scales, (4) whether there a similar trend in a known ecological relationships, (5) the level of confidence that an actual change (or lack thereof) has occurred.	• The Principal Investigator for each monitoring protocol is the lead analyst for status determination, although the network coordinator, cooperators, partners, or other network staff may conduct analyses and assist with interpreting results. Comparison with relevant long-term experimental results will aid interpretation.
Synthesis and Modeling	• Examination of patterns across vital signs and ecological factors to gain broad insights on ecosystem processes and integrity. Analyses may include: (1) Qualitative and quantitative comparisons of vital signs with known or hypothesized relationships, (2) Data exploration and confirmation (e.g., correlation, ordination, classification, multiple regression, structural equation modeling), & (3) Development of predictive models. Synthetic analysis has great potential to explain ecological relationships in the non-experimental context of vital signs monitoring and will require close interaction with academic and agency researchers.	• The Network coordinator is the lead analyst for data synthesis and modeling, although the PIs for various protocols and cooperators, partners, interns, and other Network staff may conduct analyses and assist with interpreting results. Integration with researchers and experimental results is critical.

7.3 Protocol and Program Review

Network protocols are either (1) those on SIENs "Tier-1 list" (see Chapter 3), which includes vital signs and protocols whose implementation we intend to fund in the near-to mid-term; or (2) those where SIEN collaborates with other network park(s), other NPS programs, or other federal or state agencies.

An essential element of any science or research program, including monitoring programs and protocols is peer review. The National Park Service (WASO office) is currently developing Peer Review Guidelines that will apply Service-wide. Meanwhile, given the importance of peer review in the development of Network monitoring plans and protocols, draft peer review guidelines (for the I&M Program) have been developed (See http://science.nature.nps.gov/im/monitor/docs/DraftPeerReviewGuidelines.doc)

7.3.1 Protocol Review

Peer review of SIEN proposals, study plans, monitoring plans, monitoring and sampling protocols, publications, reports, and other products will improve the quality of our scientific research by incorporating the knowledge of other expert scientists and by ensuring that studies conducted can withstand the rigorous scrutiny of other scientists. The credibility of scientific research is enhanced by conveying to other scientists, policy-makers, managers, and the public, the knowledge that work conducted has met accepted standards of rigor and accountability. Effective peer review can help foster research that is fundamentally sound and that increases the broad acceptance of management decisions.

Protocol reviews have two primary purposes:

- To review protocol design, logistics, SOPs, and products to determine whether changes are warranted
- As part of quality-assurance and peer-review processes

Informal protocol review will be ongoing during (1) development, (2) test, and (3) implementation phases. Also, because these protocol components are iterative, they will be continually reviewed, at least informally.

Formal protocol reviews will be conducted during the monitoring program's first five-year Analysis and Synthesis Reporting phase, and in conjunction with future Analysis and Synthesis Reports, as needed (minimally at ten-year intervals).

Reviews will include:

- Outside contractors or academics enlisted to conduct program assessment (e.g., power analyses of data) and report findings
- Broad spectrum of peers invited to review the Analysis and Synthesis Report, power analysis, and protocol
- Peers invited to a workshop to (1) discuss the protocol and analyses, (2) determine whether the protocol is meeting project goals, and (3) suggest improvements and changes
- Program manager or contractor hired to (1) write a report summarizing the workshop, (2) circulate the report to participants, (3) post a final report on the team web site, and (4) send the final report to NPS regional and WASO program offices

The Network will then implement the protocol based on the results of the review and recommendations.

Audience: protocol leads and Network Coordinator
Review: external, peer-review with at least three subject-matter experts (including one statistician). Internal review is continual and iterative. SOPs will be updated as often as necessary and appropriate.

7.3.2 Program Review

A report to the Network will be part of program review(s), the results of which will be incorporated in program operations. *See Chapter 8 for full description of program review processes.*

7.4 Communication and Reporting

For many of the following report categories we indicate the individual responsible for reporting (the initiator), analyses included, peer review requirements, and schedule. These considerations clarify expectations for reports and ensure sufficient program accountability, documentation, and evaluation. However, this declaration is dependent upon current levels of funding, staffing, and park-staff involvement.

7.4.1 Annual Reports

Annual reports are important reporting and summary mechanisms that:

- Summarize annual data and document monitoring activities for the year
- Describe current condition of the resource
- Document changes in monitoring protocols
- Increase communication within the Network and individual parks
- Provide up-to-date information to various audiences (e.g., website)

Many of our monitoring programs will be active each year, and those programs will generate simple summary reports annually (Table 7-2). Other vital sign sampling regimes do not require annual activity; some protocols will collect or analyze data every fifth year, or even every tenth year (e.g., Landscape Mosaics & Fire Regime). Those programs will produce reports when there are significant monitoring activities or results. Where possible and appropriate, we will generate many report components using automated data analyses developed for each monitoring project. We will also address estimates of status (and inferentially, trends), such as means, totals, and proportions. Estimates will be generally design-based or perhaps model-assisted.

For vital signs that are monitored by park staff or other programs, we will collaborate with principal investigators to integrate analysis and reporting of results with Network vital signs reporting. These include the following vital signs:

- Amphibians
- Birds
- Non-native invasive plants
- Air quality (ozone, airborne contaminants, atmospheric deposition, particulate matter, and visibility)
- Fire effects on plant communities

Audience: Network staff, park staff including administration, scientists working in parks
Review: Internal network review

Table 7-2. Overview of Vital Signs Monitoring Report Production.

Vital Sign	Initiator of Report	Peer-review Level	Schedule & Analyses
Primary Reporting Responsibility: Inventory & Monitoring Program			
Water Chemistry	Program Lead	Network & NPS-WRD	• Annual report: Summary statistics; % below or above pre-established thresholds; website update; others TBD or as necessary • Synthesis report: TBD
Surface Water Dynamics	Program Lead	Network & NPS-WRD; University and Agency Collaborators	• Annual report: Summary statistics; as above • Synthesis report: TBD
Weather and Climate	Program Lead	Network; Collaborators (e.g. Western Regional Climate Center)	• Annual report: Summary statistics; as necessary to support other vital signs • Synthesis report: every fifth year
Snowpack	TBD	Network; California Cooperative Snow Survey	• Annual report: Summary statistics; other reporting coordinated with State and weather & climate vital sign • Synthesis report: TBD
Wetland Water Dynamics	Wetland Ecological Integrity Program Lead	Network	• Annual report: Summary statistics; website update • Synthesis report: Every fifth year and/or based on panel design
Wetland Plant Communities	Wetland Ecological Integrity Program Lead; program leads for each park	Network	• Annual report: Summary statistics; website update • Synthesis report: Every fifth year and/or based on panel design
Macro-invertebrates (Wetland)	Wetland Ecological Integrity Program Lead	Network	• Annual report: Summary statistics; website update • Synthesis report: Every fifth year and/or based on panel design

Vital Sign	Initiator of Report	Peer-review Level	Schedule & Analyses
Landscape mosaics	Landscape Program Lead; park GIS specialists	Network; Collaborators (e.g., NASA, University)	• Annual report: Summary statistics; • website updates • Synthesis report: every tenth year, or as appropriate for landscape component of interest
Fire regimes	Landscape Program Lead; Park-based Fire Ecologist(s)	Network; USGS-WERC	• Annual report: Summary statistics; GIS maps; website updates • Synthesis report: TBD
Forest dynamics	Program Lead	USGS-WERC	• Annual report: Summary statistics; website updates • Synthesis report: every tenth year, or as appropriate for landscape component of interest
Primary Reporting Responsibility: Park-based Natural Resources Staff			
Amphibians (tentative vital sign; may be integrated with lake monitoring if possible)	Park-based Aquatic Ecologist(s) and Lake Protocol lead	Network; USFS & University Collaborators	• Annual report: Summary statistics; website updates • Synthesis report: as data permit
Birds	Park-based Wildlife Biologist(s) or Protocol Lead	Network; Not-for-profit & University Collaborators	• Annual report: Summary statistics; website update • Synthesis report: every fourth or fifth year of data collection
Nonnative–Invasive Plants	Park-based Restoration Ecologists; SIEN Data Manager	Network	• Annual report: Summary statistics; GIS maps; website updates • Synthesis report: As appropriate or noteworthy, based on species' ecology
Air Quality Ozone Airborne contaminants Atmospheric Deposition Particulate matter Visibility	Network Air Quality Specialists (at SEKI or YOSE)	Network; NPS-ARD	• Annual report: Summary statistics; website updates • Synthesis report: TBD or as required by Air Resources Division
Fire effects on plant communities	Park-based Fire Ecologist(s)	Network; USGS-WERC	• Annual report: Summary statistics; website updates • Synthesis report: TBD

7.4.2 Analysis and Synthesis Reports

The Network will use analysis and synthesis reports to:

- Examine 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 type and level of sampling
- Provide context and interpret data for the park within a multi-park, regional, or national context
- Recommend changes to management of resources (i.e., feedback for adaptive management)

Analysis and synthesis reports provide critical insight into vital sign status and trend, which are used to inform resource management efforts and regional resource analyses. This level of analysis will be more in-depth than analyses conducted for annual reporting and will typically require several seasons (e.g., years) of sampling data. Such analysis will be dependent upon the temporal scale of the vital sign(s) of interest. These reports will not typically be generated more frequently than every three to five years, for resources sampled annually (e.g., lake surface water dynamics, wetland hydrology). For resources sampled less frequently, or those with an intrinsic low rate of change (e.g., landscape mosaics, forest-stand population dynamics), intervals between reports may be longer. Trend analysis approaches will depend on the number of years of data available. As sample sizes increase, analyses that are more complex will be possible.

Exceptional circumstances may escalate individual schedules (e.g., precipitous degradation in vital sign being measured, specific reporting requests). A summary of anticipated SIEN analysis and synthesis reports is provided in Table 7-2. Initial monitoring program review may generate the need for supplementary synthesis and analysis.

Results from all monitoring projects within and across all parks should be integrated across disciplines in order to interpret overall changes to park resources. Thus, at approximately ten-year intervals, we will produce a Network-level synthesis report.

Audience: superintendents, park resource managers, network staff, and external scientists

Development and Review: internal and external, peer-review where appropriate by park staff and subject-matter experts, including statistician expertise.

7.4.3 Scientific Reports, Journal Articles, Professional Publications

This aspect of the I&M program will be directed by program managers (or park staff), and is more at their discretion than national I&M and WRD reporting requirements. Publishing scientific journal articles or other professional articles is primarily conducted to communicate advances in knowledge, and is an important, widely acknowledged means of quality assurance and quality control, namely through the academic peer-review process. Putting a program's methods, analyses, and conclusions under the scrutiny of a scientific journal's peer-review process is basic to science and one of the best ways to ensure scientific rigor.

Scientific journal articles and other publications (e.g., reports) produced by SIEN efforts will be tracked by the SIEN monitoring program; new publications are part of the Annual Administrative Report and Work Plan (see Annual Reports section), which is sent to the regional and national offices each year. Additionally, reports and scientific publications will be entered into the NatureBib database and available within SIEN's web pages. Principle Investigators of recently conducted (or published) work SIEN network parks frequently make presentations at professional workshops and conferences, and will be invited to present their findings at Science Committee, Board of Director, and park meetings.

Audience: scientific community
Review: peer-review conducted by scientific journal or similar professional

7.4.4 Interpretation and Outreach

Scientific information gained from monitoring programs usually requires a concerted effort to be translated for the public. Network staff speak at trainings for seasonal employees, park staff, and special interest groups (e.g., California Native Plant Society). Numerous interpretation and outreach opportunities exist by collaborating with NPS interpretive staff.

SIEN I&M is working to establish a science and education relationship with the newly established Sierra Nevada Research Institute, a partnership between the University of Merced, Network parks, and not-for-profit partners. Staff will continue to share discoveries with the public in written form by contributing articles to natural history newsletters and other interpretive media in the parks. SIEN web pages will serve as a major tool for serving of information (and data).

In the future, the Network plans to produce brochures, fact sheets, and newsletters about the inventory and monitoring program, SIEN vital signs, and the work of our partners.

Audience: park visitors, partners, and the scientific community
Review: peer-review, conducted by network, partner, and park (interpretation and education) staff

We include Data Analysis and Reporting excerpts from our Lake Monitoring Protocol (Heard et al., in prep) as an example of the level of thought and detail our protocols will contain (Section 7.5, below).

7.5 Example: Lake Monitoring Protocol—Data Analysis and Reporting

The following information regarding data management has been excerpted (and abbreviated) from SIEN's Lake Monitoring Protocol (Heard et al., in prep). This example illustrates the data analysis and reporting overview for a portion of our water monitoring program, specifically the integrated monitoring of three vital signs: (1) water chemistry, (2) surface water dynamics, and (3) amphibians. Water monitoring will also be a part of our Rivers & Streams Monitoring Protocol (under development 2008).

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7.5.1 Data Analysis and Reporting

Please refer to SOP #17 for a detailed description, including equations, for data analysis procedures (Heard et al., in prep).

7.5.1.1 Analysis

Data analysis approaches were developed in concert with sample design development and power analysis simulations. The protocol lead is responsible for performing the following pre-determined data analyses: descriptive statistics, time series, status estimates, and trend analysis

All analyses, with the exception of trend, are performed annually. Trend analyses are calculated every three years (beginning when there is a minimum of five years of data).

Descriptive statistics are computed, and time series plotted, annually for index and extensive sites. Statistics are computed using standard methods, except for variance, which is calculated using the GRTS neighborhood variance estimator (Stevens Jr. and Olsen 2003).

Status estimates are calculated on an annual basis for extensive sites. The proportion of lakes that exceed a given threshold condition are calculated, with the variance estimated using GRTS neighborhood variance estimator (Stevens Jr. and Olsen 2003). Before proportions can be computed, the Network will identify threshold conditions to which data are compared.

A mixed linear model is used to test for trend at the network scale (i.e. extensive sites) ($\alpha = 0.10$). VanLeeuwne et al. (1996) and Piepho and Ogutu (2002) developed this method specifically to estimate net trend for a population sampled using augmented serially alternating panels as the revisit design.

Trend at individual index sites is computed using the Seasonal Kendall Test (SKT) modified to account for serial correlation ($\alpha = 0.10$) (Hirsch and Slack 1984). The SKT is commonly used to test for long-term water quality trends at single sampling stations. The Sen Slope method is used to estimate magnitude of the trends.

Table 7-3. Data analysis procedures with corresponding monitoring objectives.

Analysis Procedure and Monitoring Objectives
Descriptive statistics • Characterize Sierra Nevada Network lakes • Quality control
Time series plots • Characterize Sierra Nevada Network lakes • Detect long-term trends in lake water chemistry for Sierra Nevada Network lakes • Detect intra- and inter-annual trends in lake water chemistry for Sierra Nevada Network index lakes • Detect intra- and inter-annual trends in lake level and outflow for Sierra Nevada Network index sites • Quality control
Status calculations • Determine the proportion of Sierra Nevada Network lakes above threshold values for selected constituents
Linear mixed-model • Detect long-term trends in lake water chemistry for Sierra Nevada Network lakes
Seasonal Kendall test • Detect intra- and inter-annual trends in lake water chemistry for Sierra Nevada Network index lakes
Other–TBD • Detect intra- and inter-annual trends in lake level and outflow for Sierra Nevada Network index sites

7.5.1.2 Reporting

The program will produce two types of reports, (1) annual summary reports (following each field season), and (2) comprehensive status and trend reports (every three years). Comprehensive reports will contain the following components:

1. Overview of the protocol status and major accomplishments.
2. Status and trend analysis results.
3. In depth, quality assurance and quality control analysis and discussion.
4. Discussion of results, including management implications.
5. Recommendations for future improvements.

Chapter 8 ADMINISTRATION AND IMPLEMENTATION OF THE SIEN MONITORING PROGRAM

This chapter details our plan for administering the Sierra Nevada Network monitoring program. We describe the Network's location and organization, its administrative structure and processes, and our staffing plan. We also describe how Network operations will be integrated with other park operations, including key partnerships and periodic review processes for our monitoring program.

8.1 Location and Organizational Context

SIEN is one of eight Inventory & Monitoring networks in the NPS Pacific West Region (PWR)(Figure 8-1). PWR contains a diverse assemblage of ecosystems—from Mojave Desert to Pacific Coast, Sierra Nevada to Cascades, Upper Columbia and Great Basins to the Pacific Islands. SIEN shares strongest ecological affinities with other Networks in PWR (Klamath, North Coast–Cascades, and Mediterranean Coast) and Intermountain regions (Rocky Mountain and Greater Yellowstone).

There are eight I&M Network Coordinators in the PWR region; they report to a single PWR Regional Inventory & Monitoring Coordinator (located in the Seattle Office). I&M Network Coordinators conduct monthly conference calls, and annual meetings are held to share information, to seek areas of common interest and collaboration, and to learn more about each other's monitoring programs.

SIEN staff are supervised through the PWR I&M Coordinator and are duty-stationed located in offices located at Sequoia & Kings Canyon (main office) and Yosemite (field station). SEKI provides the majority of the Network's administrative support through contracting, information technology, budget management, human resources, resources management, and building maintenance. The majority of Network staff are duty-stationed at SEKI. YOSE also provides office space and some support services to one or two Network staff.

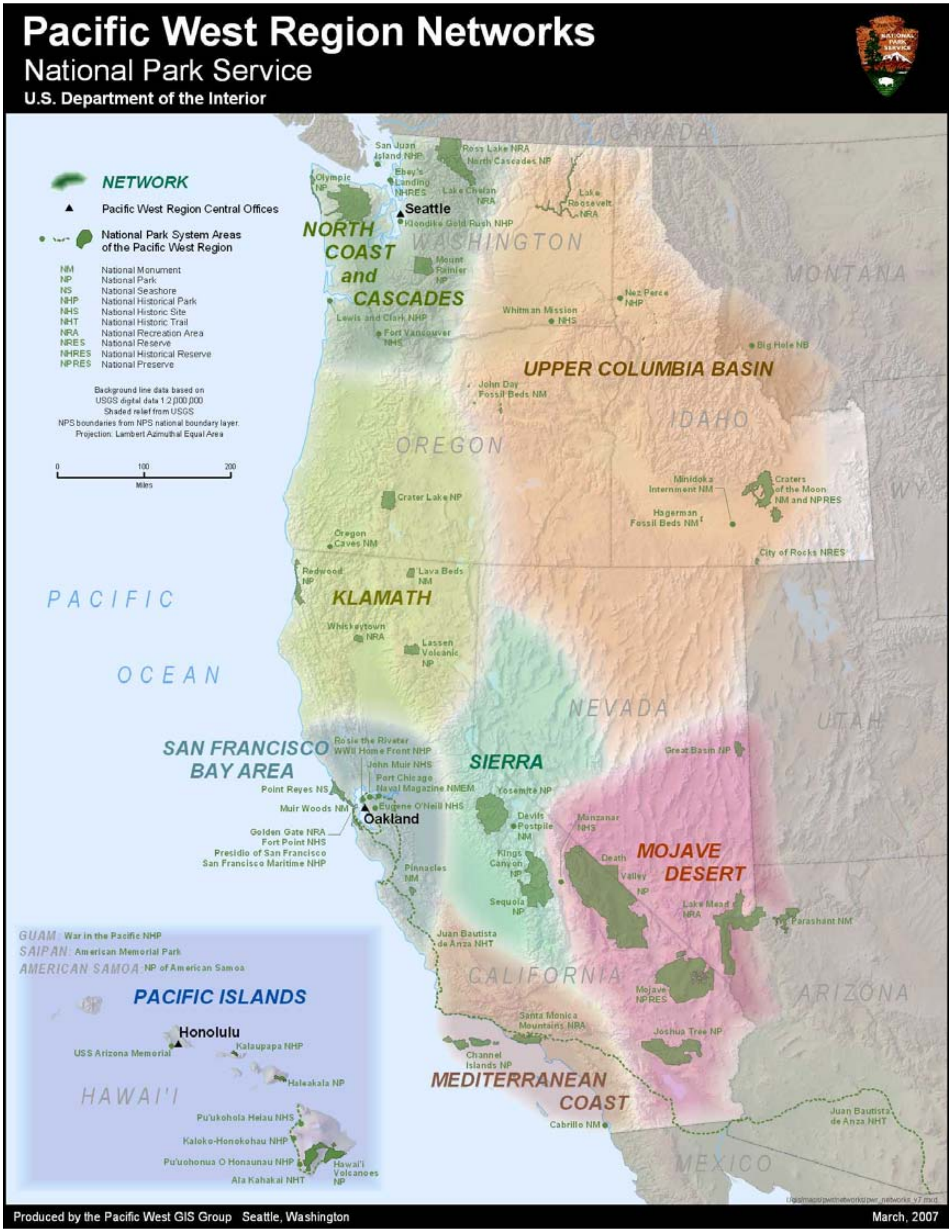

Figure 8-1. Pacific West Region Inventory & Monitoring Networks. Map courtesy of Pacific West Region GIS Group.

8.2 Administration and Operations

Program guidance and funding for SIEN come from the Washington Support Office (WASO), via the PWR office, as prescribed by the Service-wide Natural Resources Challenge funding initiative. The SIEN charter, signed by all network park superintendents in 2002, and revised by the Board of Directors (2006 and 2007), outlines the roles and responsibilities of the Board and Science Committee, and it provides the framework for decision-making. Our current Network organizational chart shows relationships among the Board of Directors, SIEN staff, Science Committee, PWR I&M Coordinator, NPS I&M program, work groups, and outside partners (Figure 8-2).

8.2.1 Board of Directors

The Board of Directors' primary roles and responsibilities are to:

- Provide leadership to conduct a credible network I&M program
- Promote accountability and effectiveness for the I&M program by reviewing progress and results to ensure goals and targets are being achieved
- Assist the Science Committee and resource managers in defining a vision and long-term goals and objectives for the program
- Decide on hiring of I&M personnel using funding provided to the Network and from other sources, commitment of existing park personnel, and facilities and equipment
- Seek additional funding from other sources to leverage the funds provided through the Service-wide program
- Assist with redefining objectives and realigning resources to meet new challenges and opportunities

Board members include the Superintendent from each park, the Deputy Superintendents of SEKI and YOSE, the Chiefs of Resources Management for SEKI and YOSE, the Chief Regional Scientist (position split between Sequoia & Kings Canyon National Parks and Pacific West Region), PWR Inventory and Monitoring Coordinator, PWR Deputy Director liaison for SIEN, and Network Coordinator as staff to the Board. The Deputy Superintendents from YOSE and SEKI attend most Board meetings and stand in as voting members when their respective Superintendents are unable to attend. If the DEPO Superintendent is unable to attend, the Deputy Regional Director represents the monument. One of the local Board members serves as Chair of the Board and this position rotates every two years. The Chair from 2006-2008 is YOSE Chief of Resources Management & Science. The Superintendents are the voting members of the Board, but the group makes most decisions by consensus.

The Board is ultimately responsible for decisions regarding SIEN work plans, budget, and long-term staffing. In general, the Board bases its decisions on recommendations from the Science Committee and SIEN Coordinator.

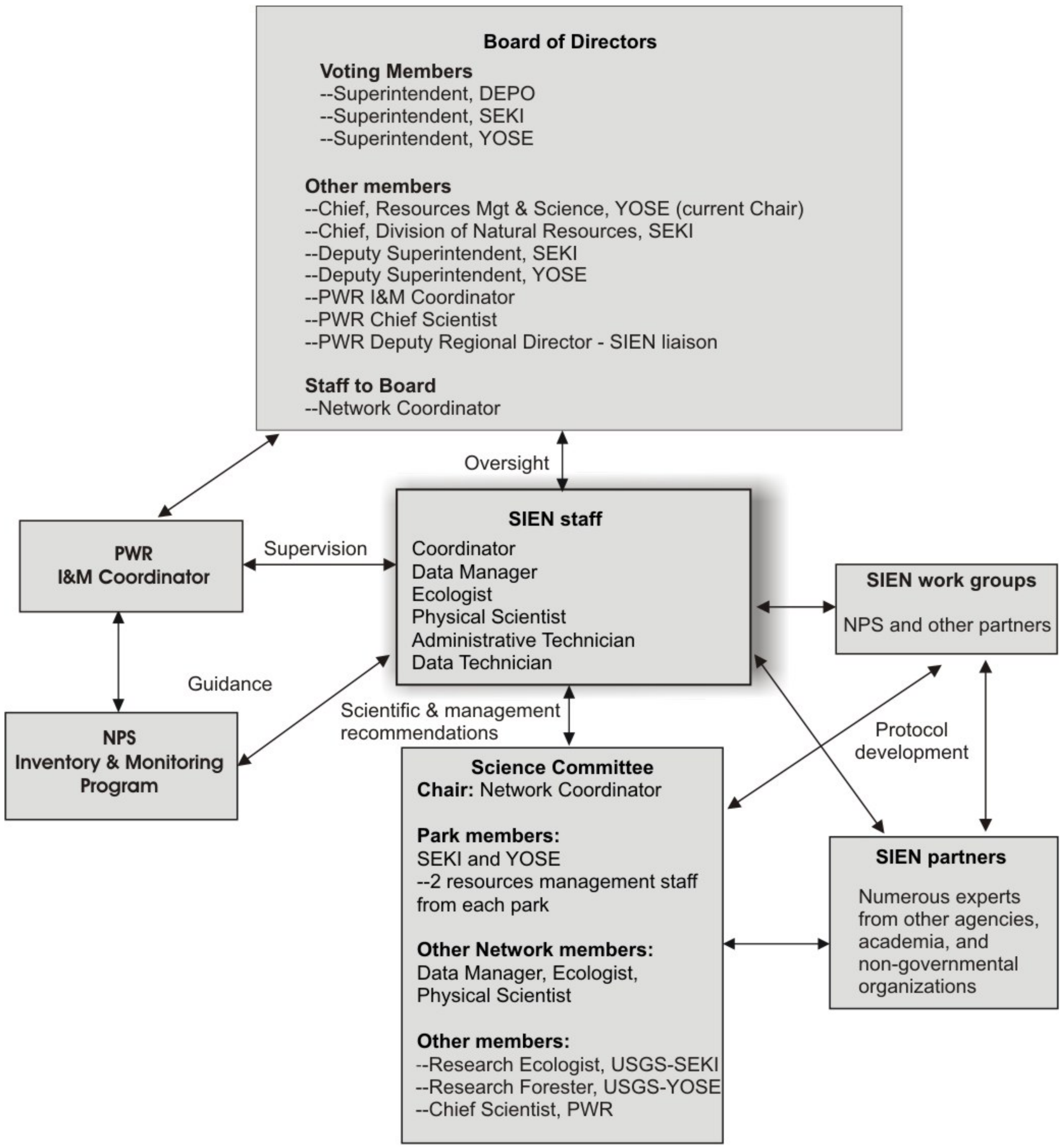

Figure 8-2. Sierra Nevada Network organizational chart.

8.2.2 Science Committee and Work Groups

The Science Committee works with the Network Coordinator to make recommendations for all aspects of the program and assists with the work of planning and implementation of inventory, monitoring and information management. The Network Coordinator presents the Science Committee's recommendations to the Board of Directors for review, input, and approval.

The Science Committee is composed of two Resources Management staff members from both SEKI and YOSE, the PWR Chief Scientist, one United States Geological Survey representative from both the SEKI and YOSE USGS-Western Ecological Research Center field stations, and four SIEN staff members—Network Coordinator, Data Manager, Ecologist, and Physical Scientist (Figure 8-2). SEKI and YOSE provide resources management support to DEPO. As part of that role they also represent DEPO, which has no resources managers, on the Science Committee. The Network Coordinator serves as the Chairperson for the Science Committee.

The Network also uses work groups composed of one or more Science Committee members and other park and USGS staff members to work on protocol development and data management topics of special interest to parks. These groups provide an opportunity for those not on the Science Committee to be involved with more focused aspects of monitoring program development. These groups and the Science Committee interact with outside partners who are assisting or taking a lead role in protocol development. In the future, work groups may address specific Network issues or assist with strategies for effectively implementing specific protocols or information management procedures.

Wetland Workgroup (NPS staff) and university cooperators discussing sampling design alternatives (Crane Flat Meadow, 2006) for 2007 pilot season in Yosemite. NPS Photo.

8.2.3 Sierra Nevada Network Staff

To meet national I&M program goals as well as local park priorities, Network activities revolve around five broad program functions (Table 8-1). The Network staffing plan is designed to support these functions and to provide subject-matter expertise to sustain a long-term monitoring program.

Table 8-1. SIEN I&M programmatic functions.

Functions	Descriptions
Develop data management and analysis systems	to facilitate information sharing and aid park managers in identifying, implementing, and evaluating management options
Develop an integrated, scientifically credible, long-term ecological monitoring program	to efficiently and effectively monitor status and trends of selected vital signs
Conduct baseline inventories of natural resources in the parks	to support evolving natural resource information needs in parks (as funds are available)
Integrate I&M programs	with park planning, interpretation, resources management, visitor protection, and maintenance activities to make natural resource interpretation and protection an integral part of overall park management
Cooperate with other agencies and organizations	to share resources, achieve common goals, and avoid unnecessary effort and expense

The proposed long-term staffing plan for the Network includes these core staff positions (describe in greater detail, below): (1) Network Coordinator, (2) Data Manager, (3) Ecologist, (4) Physical Scientist, (5) Data/Logistics Technician, (6) Administrative Technician, and (7) numerous seasonal biological and physical science technicians.

During the transition phase of FY2008-2010, when we are still developing protocols, we propose hiring the following additional short-term positions: Assistant Data Manager and Outreach Specialist (cost-shared with the Interpretative Division in one or more parks). In FY2010, our staffing plan will be re-evaluated to determine the most cost-effective staffing arrangement to sustain the vital signs monitoring program.

Following are proposed core and seasonal Network positions and their primary roles and responsibilities:

***Network Coordinator**:* Effective program administration requires the Network Coordinator to connect and *integrate* all facets of the program internally and externally—SIEN contains large parks, each comprising complex, and diverse operations, and a multitude of ongoing and past resources management programs, projects, monitoring, and research. One of the most important functions is to ensure dissemination of information among the many people and groups involved in the program and ensure full and open communication among participants. This includes the Board of Directors, Science Committee, national program, Network staff, vital sign workgroups, and cooperators in the program. Communication is accomplished in part by meetings or conference calls, frequent written updates (monthly reports and various e-mail communications), and both inter- and intranet websites: http://www1.nature.nps.gov/im/units/sien/index.cfm

This position oversees budget management, outreach and communication, project-specific data analysis and reporting, and ensures information is provided to park managers and the national program. The Coordinator supervises professional level positions and provides general oversight and accountability. As an ecologist, the Network Coordinator also serves as the project lead for several vital signs and protocols. The Coordinator is currently the lead on the forest dynamics protocol, co-lead for landscape dynamics, and participates as needed in other protocol work groups.

Data Manager*:* The Data Manager is responsible for planning and implementation of data and information management. This includes (1) ensuring that project data conform to program standards, (2) designing project databases, (3) disseminating data, and (4) ensuring long-term data integrity, security, and availability. The Data Manager maintains high data standards by working with project managers to develop data entry forms, QA/QC procedures, metadata, and automated reports. S/he maintains spatial data associated with Network I&M projects and incorporates spatial data into a Network Geographic Information System that can be easily shared with park staff and outside cooperators. The Data Manager works closely with the Science Committee, park staffs, cooperators, and other data managers at regional and WASO levels to stay current on best data management practices and meet local needs. The Data Manager works with other Network and park staff to make I&M information broadly available through local area network, internet, and intranet venues.

Ecologist*:* The Ecologist will be the principal investigator for vital signs associated with biological integrity of Sierra Nevada ecosystems. This involves leading the work groups and development associated with SIEN biological protocols. To date, the Ecologist has played a lead role in development of the bird protocol and the amphibian portion of the lake monitoring protocol, in addition to participating in invasive non-native plant, wetland ecological integrity, and landscape dynamics protocol work groups. The Ecologist plays a major role in working with statisticians to develop sample designs and analytical methods for long-term monitoring data and ensuring protocol design meets network monitoring objectives. In addition to recruitment and hiring, as protocols are implemented, the Ecologist will oversee field technicians in the collection and management of biological data, and will be the primary person responsible for data quality, project documentation and metadata, and preparation and dissemination of project analyses, reports, and general information to a variety of audiences. This position is a primary technical contact for partners working on related biological resource issues and cooperators who are engaged in Network biological vital signs monitoring.

Physical Scientist*:* The Physical Scientist will be the principal investigator for vital signs associated with physical resources and processes in Sierra Nevada ecosystems. This involves leading the work groups developing protocols associated with water resources (water chemistry and surface water dynamics of lakes, streams, and rivers) and weather & climate. The Physical Scientist also participates on Landscape Dynamics and Wetlands Ecological Integrity work groups to provide expertise on physical resources monitoring objectives associated with those protocols. The Physical Scientist is the primary author of the lake monitoring protocol and has initiated development of rivers & streams and weather & climate protocols. S/he works with statisticians to develop sample designs and analytical methods for long-term monitoring data and ensuring protocol design meets network monitoring objectives. In addition to recruitment and hiring, as protocols are implemented, the Physical Scientist will oversee field technicians in the collection and management of physical resources data, and will be the primary person responsible for data quality, project documentation and metadata, and preparation and dissemination of project analyses, reports and general information to a variety of audiences. This position is a primary contact for partners working on related physical resources issues and cooperators who are engaged in Network physical resources vital signs monitoring.

Data/Logistics Technician: This will be a position that works primarily with the Data Manager, Ecologist, and Physical Scientist. The Data/Logistics Technician will provide GIS and data management support to the Data Manager, particularly in developing and implementing standard operating procedures associated with monitoring protocols. This position will also assist the Ecologist and Physical Scientist with protocol implementation. For example: providing logistics support for field sampling, ordering and tracking supplies, assisting with pre-field preparation, shuttling water samples from wilderness sampling sites and trailheads to local park labs, shipping samples, and providing coordination with park staff involved with protocol implementation.

Administrative Technician: This is currently a part-time, subject-to-furlough position responsible for tracking and management of budgets, procurement, timekeeping, travel, and records management. The administrative technician also performs data entry (e.g., wildlife observations for NPSpecies) and updates NatureBib with new reports and articles, as time allows.

Biological and Physical Science Technicians: These are seasonal positions, and some of them may be cost-shared with parks, particularly where vital signs protocols will not require a full season of work. These positions work under the Ecologist, Physical Scientist, and in some cases, under Park staff members. Their primary duties include data collection and data verification. The technicians follow existing protocols to gather data, record, verify, and correct data values, and perform regular data transfer and backup. These positions assist with dataset and procedural documentation and are responsible for documenting deviations from established protocols.

Temporary positions, described below, are proposed to provide additional support during the transition period (circa 2008–2010) when some protocols are under development or beginning initial field implementation.

Assistant Data Manager: This temporary position will work closely with the Data Manager to provide data management support to protocol development (databases, SOPs) and implement our Data Management Plan. Implementation of the Data Management Plan will involve setting up and populating revised file directory structures, completing metadata, providing training to I&M and park staff in local and national database applications, developing web-based data-sharing mechanisms, and maintaining intranet pages for Network and local park use.

Outreach Specialist: This temporary position would provide liaison between I&M and Divisions of Interpretation to develop outreach products (brochures, improved internet and intranet pages, newsletters), to edit and format selected inventory reports for Technical Report series, and to distill information to interpret for the public from Inventory & Monitoring reports and data.

Table 8-2 provides a summary of SIEN core activities and proposed staffing, with estimates of Full-Time Equivalent (FTE) portions of positions needed to implement the program. The staffing plan may evolve as SIEN objectives as well as budgets and other resources, including partnership opportunities evolve over time.

Table 8-2. SIEN core activities and proposed staffing.

Permanent SIEN Staff			
Position	**Major role and functions**	**Appointment Type**	**FTE**
Network Coordinator	Program management, staff supervision, liaison with parks, other offices, and cooperators	Permanent	1.0
Data Manager	Network data management, integration with park and other data management operations	Permanent	1.0
Ecologist	Monitoring design, data analysis, and reporting – biological vital signs	Permanent	1.0
Physical Scientist	Monitoring design, data analysis, and reporting – physical vital signs	Permanent	1.0
Administrative Technician	Budget tracking and management, travel, timekeeping, records management, and some data entry	Permanent, part-time, subject-to-furlough	0.5
Data/Logistics Technician	Data management and GIS support, logistics support to protocols	Permanent, subject-to-furlough	0.85
Temporary SIEN Staff			
Position	**Major role and functions**	**Appointment Type**	**FTE**
Assistant Data Manager	Protocol data management support and data management plan implementation	Term, 2-year appointment	1.0
Outreach Specialist	Liaison between I&M and Interpretation, outreach product planning and development	Term, cost-shared position, 2-year appointment	0.25
Field Technicians	Field data collection and verification	Seasonal–variable lengths of time depending on protocol needs	0.5

8.2.4 Role of Park Staff in SIEN I&M Program

The Sierra Nevada Network has, from the start of the Inventory & Monitoring program, chosen to operate under the philosophy that park staff involvement with the program is integral to its success. Other Networks across the country follow different models.

Park staff involvement ensures that the program is relevant to park information needs. Moreover, the Sierra Network has large parks (658,000 hectares total) with rugged, remote landscapes. Consequently, the costs of implementing a monitoring program will be high. Park base-funded staff contributions, which augment the Network-funded operations, will be essential to implementation of the vital signs protocols. Without contributions from park staff, the Network will have to drop selected protocols or scale back a few protocols to index or sentinel sites that will not be able to provide reliable landscape-scale inference.

The benefits of park staff involvement in implementation of monitoring are substantial, but there are also risks to recognize and address. Park-level needs and priorities change, and although one park superintendent may be able to commit park staff to vital signs monitoring, a subsequent one may be faced with a combination of budget cuts and other urgent priorities that require re-directing staff away from the vital signs program. To mitigate this risk, we assume that park staff will not be protocol leads but will commit to a supporting role in most cases. Under this scenario, we therefore identify a core set of protocols we estimate can be implemented with *current* Network and Park resources and commitment (Table 8-3).

Further, the Network will likely need to invest more funds in logistics and field crew supervisory support in parks that contribute less to I&M protocol implementation, and cut back on numbers of sites sampled in those parks to stay within protocol budgets.

Parks–through discussions with their respective Chiefs of Resources–have estimated they can donate 1.2 FTE (SEKI), 0.5 FTE (YOSE), and 0.0 (DEPO) to vital signs protocol implementation and data management support. The Network's support needs from park staff include: Wilderness compliance and research permitting, logistics (housing, stock support, shared helicopter support, safety check-ins, assistance with route-planning and transportation), and direct protocol tasks, which may include field crew supervision in some cases, shared seasonal staffing between park and network field crews, assistance with index site sampling for some protocols, and Data Management Plan implementation. The Network may also pay for some time from park staff to assist with protocols, especially where we lack particular expertise on I&M staff that park staff may offer (remote-sensing and photo interpretation is one example). In these cases, tasks would be well-defined with specific products and timelines outlined to meet the protocol or data management need.

Table 8-3. Protocol implementation scenario that includes Network, park, contractor, and cooperator responsibilities.

Protocol	Network Responsibility	Park Responsibility	Cooperator
Lakes	• Protocol management (supervision, analysis, reporting)	• Logistics support, shared seasonals, permitting	• Water chemistry analysis
Wetlands	• Protocol management (supervision, analysis, reporting)	• Crew supervision, data management for 1 park • logistics and permitting support in all parks	• Support with invertebrate and non-vascular plant processing and identification
Forests	• Protocol management (supervision, analysis, reporting)	• Logistics support, permitting • crew supervisory support in 1 park	• Shared data and analyses across forest monitoring protocols (USGS, USFS)
Rivers & Streams	• Protocol management (supervision, analysis, reporting)	• Logistics support, permitting, shared seasonals • crew supervisory support in 1 park	• Water chemistry analysis
Landscape Dynamics	• Coordination with parks and cooperators • data management and reporting	• Staff support for image processing and management	• Image interpretation and analysis
Weather & Climate	• Data management, synthesis, reporting • Coordination with cooperators and parks • Maintenance of key stations	• Cost-sharing of station maintenance and equipment • data management support	• Cost-sharing of equipment and station maintenance; data serving and sharing (State, USGS, and universities)

8.3 Integration of Program with Park Operations

Implementing long-term monitoring in SIEN parks will require collaboration and cooperation with multiple park divisions and programs. As discussed above, we have long had participation from our natural resources management programs and USGS field stations in both the inventory and planning phases for long-term monitoring. Some participation will continue into the implementation of vital signs monitoring, as some park biologists, physical scientists, and GIS specialists will continue to play important roles in protocol development and implementation.

Cooperators, and Park, USGS, and Network staff, installing the Network's ***first*** long-term monitoring plot in a meadow within Mariposa Grove of Big Trees, Yosemite. *NPS Photo***.**

Another key area of integration will be with our parks' Divisions of Interpretation. The Outreach Specialist we plan to hire in FY 2008 will meet with Interpretive Divisions of the parks, Superintendent of Devils Postpile, and SIEN staff to identify ways to share information gained from vital signs monitoring with broader audiences—especially all park staff and the public. In addition to using our website (inter- and intranet), newsletters, fact sheets, and brochures to share information, we will work with the Interpretive Divisions to develop a Communication and Outreach Plan that outlines strategies for communicating vital signs monitoring results to diverse audiences.

Our parks are predominantly designated Wilderness. Any request to install permanent monitoring equipment (e.g., groundwater monitoring wells, stream gauging stations, or meteorological stations) will require extensive communication to discuss the benefits of conducting associated monitoring in Wilderness. A "minimal tool" analysis to demonstrate that what we propose is the least invasive means of obtaining the information we need to achieve protocol objectives. Wilderness Coordinators (Divisions of Fire and Visitor Management) have been involved with some of our planning meetings; the exchanges continued in earnest in FY 2007. we had two meetings with Wilderness managers to provide information on our program and to discuss minimizing our impact in Wilderness. We make a commitment to keeping Wilderness managers in the conversation as we further develop protocols, to minimizing our impact in Wilderness, to thoroughly documenting the location and types of equipment and installations, and to remove any equipment and installations that become obsolete.

There will be numerous logistical issues to resolve involving hiring, housing, and supervising field crews. To sample sites located in remote areas–and the majority of sites in the large parks are very remote–we will need to work closely with park staff involved with research, backcountry permitting, and stock and helicopter management. We will also work closely with parks and local Park Safety Officers to participate in safety programs and training–including backcountry communication procedures, helicopter safety, first aid, and development of job hazard analyses for each vital signs protocol. As part of the protocol development process, it will be important for protocol workgroups to identify areas of integration with park operations necessary to ensure the protocols are effectively implemented. Park housing will be needed for field crews, and this will require early communication with other park divisions (that compete each year for available housing slots), and park administrative and maintenance staff who manage housing.

All SIEN staff members play important roles in communication and integration with park-based staff. These efforts include participating in staff meetings, park workshops, strategic planning meetings, and lecture series, playing lead roles on work groups and protocol development and implementation, developing databases for park projects, and making sure that important park data are documented and made more accessible.

8.4 Partnerships

The Sierra Nevada Network has numerous current or planned partnerships for development of vital signs monitoring protocols. Many partnerships were developed during protocol development; partnerships may be continued during implementation; others will be implemented entirely with "in-house" Network and park staff. Partnerships include both those external to NPS as well as partnerships with other I&M networks (current partners are included in Appendix H, "*Protocol Development Summaries.*"

8.4.1 External Partnerships

Most partnerships summarized in Table 8-4 were established to assist us with development of portions of our monitoring program. Several USGS Biological Resources Division scientists, associated with Western Ecological Research Center Sequoia & Kings Canyon and Yosemite Field Stations, have participated in protocol development work groups at no cost to the Network. Scientists from Scripps Institution of Oceanography and the State Department of Water Resources/Cooperative Snow Surveys have donated time and equipment to begin meteorological monitoring at Devils Postpile National Monument.

Devils Postpile Meteorological Station. *NPS Photo*.

A partnership that we will develop further–as both programs mature–will be with UC Merced Sierra Nevada Research Institute, which recently established a field station in

Yosemite. The Institute could be a source of student assistance, library resources, and academic expertise in monitored resources (e.g., surface water dynamics, snowpack). The expertise of our partners has been *essential* towards development of our monitoring program.

Table 8-4. Important current external partnerships for the Sierra Nevada Network monitoring program.

Partner	Type of Relationship	Work Accomplished
US Geological Survey, Biological Resources Division	In-kind services	• Participate in wetlands ecological integrity, forest dynamics, non-native plants, and landscape dynamics protocol work groups and Network Science Committee.
University of California, Riverside	Cooperative Agreement (CESU)	• Assist with water chemistry/surface water dynamics protocol development for lakes.
Colorado State University, Ft. Collins	Cooperative Agreement (CESU)	• Develop wetlands ecological integrity (vegetation communities, wetland water dynamics) protocol with SIEN wetlands work group
UC White Mountain Research Station	Cooperative Agreement (CESU)	• Develop wetlands invertebrates monitoring protocol with SIEN wetlands work group and CSU-Ft. Collins.
The Institute for Bird Populations	Contract	• Develop bird monitoring protocol with SIEN bird work group.
Western Regional Climate Center/Desert Research Institute	Cooperative Agreement (CESU)	• Assess current climate monitoring in SIEN parks, provide analyses, and make recommendations for SIEN climate monitoring protocol.
Scripps Institution of Oceanography and California Dept. of Water Resources	In-kind services	• Donation of time and equipment to establishment of DEPO meteorological monitoring station and SOP.
NASA-Ames	NASA-funded project	• Advising on imagery and technology for addressing landscape dynamics protocol objectives.
US Forest Service	In-kind services	• Sharing peer-reviewed amphibian protocol; advising on amphibian monitoring sites and approaches. • Sharing approaches to monitoring landscape change in Sierra Nevada. • May seek information from USFS Forest Inventory & Assessment and Forest Health Monitoring program for Forest Dynamics monitoring work group.

University of Idaho–Moscow	Cooperative Agreement (CESU)	• Provide statistical support to protocols and monitoring plan. • Provide additional monitoring plan support.
Oregon State University	Cooperative Agreement (CESU)	• Assist SIEN staff and protocol work group with landscape dynamics protocol development
UC Merced–Sierra Nevada Research Institute	Cooperative Agreement (CESU)–planned	• Assist with implementation or evaluation of various aspects of vital signs monitoring program

8.4.2 Internal Partnerships

Sierra Nevada Network has established partnerships with other networks that have provided additional expertise in the area of statistical support for sample design and data analyses recommendations for monitoring protocols. These partnerships include cost-sharing statistical support through the University of Idaho with three other PWR Inventory & Monitoring networks (Klamath, Mojave Desert, and Upper Columbia Basin) and working closely with the Rocky Mountain Network (ROMN) on development of our Wetlands Ecological Integrity protocol. As we move forward in protocol implementation, we will likely find additional needs for inter-network collaboration—cost-sharing positions and expertise, and sharing information where protocol and monitoring interests overlap.

8.5 Program Review Process

A long-term monitoring program is required to schedule periodic evaluation and review to determine if monitoring objectives are being met (Chapter 7), and if staffing and management of the program are cost-effective. The Network must also ensure that the results of monitoring are accessible to park managers and other audiences. We summarize a variety of review mechanisms to evaluate different aspects of the program (Table 8-5).

By the end of FY 2010, we will evaluate existing staffing; with added information from more fully developed protocols, as well as additional knowledge regarding park-level capacity to contribute to the program, we will modify our staffing plan to best meet the needs of the Network. This includes Network staffing level, duty stations, roles & responsibilities for program management and protocol implementation, as well as finalizing park-based staff roles and responsibilities in the program.

Each fiscal year, we use our Annual Administrative Report and Work Plan (AARWP) as a means to provide the Science Committee, Board of Directors, and other Park staff with an opportunity to review work conducted during the past year *and* work planned for the next. The primary goal of this report is to provide accountability for Network activities and funds. Each AAWRP reports on Network accomplishments, provides details for all funds expended each fiscal year, and proposes specific Network activities and projects–linked to a budget–for the upcoming year. The AARWP also provides an administrative history for the Network and allows all SIEN activities to be tracked and evaluated. SIEN voting Board members, Board Chair, Network Coordinator, and PWR I&M Coordinator are all signatories to each AARWP.

Table 8-5. Review Mechanisms for the SIEN monitoring program.

Review	Timing	Author(s)	Reviewers	Intent of Review
Staffing Plan	FY 2010	Network Coordinator	Board of Directors, Science Committee	Review existing staffing plan for network and recommend any changes needed to fully implement monitoring.
Annual Administrative Report and Work Plan	Annual	Network Coordinator and staff	Science Committee, Board of Directors, WASO I&M Program	Provide yearly accountability for program. Report on accomplishments and explain goals and projects for the next fiscal year.
3-Year Start-up Review	FY 2010	WASO Monitoring Program Lead	WASO Monitoring Program Lead and Review Panel	Evaluate the operational and administrative aspects of the network's monitoring program and asks the basic question "Is the network positioned to succeed?"
Protocol review reports	After complete cycle for the protocol	SIEN protocol lead and other collaborators	Science Committee, select outside technical reviewers, PWR I&M Coordinator	Evaluate implementation of protocols, evaluate scientific and technical merits of protocols, evaluate information management and management relevance, make recommendations for improvement.
Program Review	5-year intervals, beginning in 2012	Network coordinator and staff	Science Committee, Board of Directors, WASO I&M Program	Provide technical details on results and status of all data collection within the program. Evaluate if program goals and objectives are being met, how well the program is integrated with other related park monitoring efforts, and if the information is effectively reaching intended audiences.

The ***3-year start-up review***, which occurs after the Network's first monitoring protocol is implemented, is coordinated through WASO's Monitoring Program Lead and is intended as a low-key, helpful reviews to give networks an opportunity to evaluate operational and administrative aspects of its monitoring program, and to make adjustments where necessary. The start-up review will be less formal than subsequent reviews, but will help the network develop a practical, sustainable monitoring program that provides parks with timely, relevant information. Such reviews also provide an opportunity to share successes and lessons learned with other networks.

Protocol-review reports document monitoring results and analyses, evaluate the performance of an individual protocol, and suggest revisions and improvements to the protocol. These reports will be produced in cooperation with scientific partners, after a complete monitoring cycle (i.e., rotation through panel design). They will be technical in nature, and reviewed by outside subject-matter experts, and park professional and management staffs.

The ***5-year program review*** will address efficacy, accountability, scientific rigor, contribution to adaptive park management and larger scientific endeavors, outreach, partnerships, and products. Program reviews will provide a synthesis of data collected by the program to date, and will also examine program structure and function, to determine whether the program is achieving its objectives, and whether those objectives are still relevant, realistic, and sufficient to meet park needs.

> *This chapter adapted from the Central Alaska Network's Vital Signs Monitoring Plan (MacCluskie and Oakley 2004) the Rocky Mountain Network's Phase III Draft Vital Signs Monitoring Plan (Britten et al. 2006) and Upper Columbia Basin Network's Vital Signs Monitoring Plan (Garrett et al. 2007).* *http://science.nature.nps.gov/im/monitor/MonitoringPlans.cfm*

Chapter 9 SCHEDULE

This chapter describes the schedule for implementing Sierra Nevada Network vital signs monitoring: (1) protocol development and projects, (2) peer review, and (3) initiation of formal monitoring. SIEN plans to develop eight protocols–incorporating 13 vital signs–during the next four years (Table 5-1).

Parts of this chapter were adapted from San Francisco Bay Area Network Monitoring Plan (Adams et al. 2004), Upper Columbia Basin Network Vital Signs Monitoring Plan (Garrett et al. 2007), and Rocky Mountain Network Vital Signs Monitoring Plan (Britten et al. 2007). http://science.nature.nps.gov/im/monito /MonitoringPlans.cfm

9.1 Monitoring Protocol Development

The WASO I&M program and PWR have established official protocol development and approval processes for networks. Protocol guidance provides an outline defining protocol content, and the PWR I&M Coordinator has established a scientific peer review process through the Pacific Northwest Cooperative Ecosystem Study Unit. The following protocol development schedule indicates when SIEN will complete our monitoring protocol and submit it for peer-review (Table 9-1).

The start and completion dates of protocols are staggered to manage staff workloads. Our start date indicates when significant resources are first directed towards protocol development and writing. Two protocols will go to peer-review in FY 2008—Lakes and Birds. Pilot data are being collected, as part of protocol development, for Wetland Ecological Integrity. For other protocols, we have initiated preliminary projects that will inform protocol development. For example, we have a cooperative agreement with the Western Regional Climate Center to assess current climate monitoring in the Sierra Nevada Network and to recommend how the Network can best allocate resources to enhance existing climate monitoring. This information will be used to guide the direction and development of the Weather and Climate monitoring protocol.

Key activities for protocol development and the corresponding proposed timeline are provided in Table 9-2. For some protocols, where extensive baseline data already exist, the protocol will be developed, and existing data will be assessed for statistical power estimates prior to collecting protocol pilot data (e.g., Lakes, Birds). Other protocols (e.g., Wetlands Ecological Integrity) require protocol testing and pilot data collection prior to finalizing the monitoring protocol for peer review. In general, monitoring protocol development requires well-defined monitoring objectives:

- Defining target populations
- Developing sample frames
- Determining sample size based on pre-existing or pilot data
- Estimating monitoring costs while balancing cost with sample size and time needed to detect trends in indicator measures
- Adopting or creating indices of ecological condition (where appropriate)

- Writing and reviewing detailed protocol Standard Operating Procedures (SOPs) and narratives
- Working with park staff to address management needs and minimize impacts of monitoring on Wilderness and park resources
- Revising protocols in response to internal and external peer reviews

Longer-term needs (after implementation) include: (1) researching and consulting with additional subject-matter experts to develop thresholds for vital signs measures, and (2) defining appropriate assessment points, including management responses when monitoring data indicate thresholds are reached or exceeded.

All protocols are scheduled to be implemented by FY 2010. However Board members expressed concern that there were not enough resources to implement all eight protocols (05 December 2006 Board of Directors meeting). The Board's recommendation to the SIEN staff and Science Committee was to move forward more quickly on protocols the Board identified as having the highest priority, and to decelerate protocols deemed lower-priority. As a result, we expect to have at least two protocols that will need to await additional resources or be reduced in scope before being implemented.

Table 9-1. Protocol Development Schedule ('D' is developing a protocol; 'I' is implementing a protocol).

Protocol	FY06	FY07	FY08	FY09	FY10	Target date for protocol review
Birds	-	D	I*	I*	I*	January 2008
Early Detection of Non-native Plants	-	D	D	D/I	I?	May 2009
Forest Dynamics	-	-	D	D	I	June 2009
Lakes	D	D	I	I	I	October 2007
Landscape Dynamics	-	D	D	D/I	I	June 2009
Rivers and Streams	-	-	D	D	I	April 2009
Weather and Climate	-	-	D	D	I	March 2009
Wetland Ecological Integrity	D	D	D	I	I	December 2008

* Implementation of monitoring at DEPO only (due to current funding shortages for implementation at other parks).
? protocol may not be fully developed or implemented; instead, monitoring may be integrated with other park or network monitoring (e.g., as SOPs), if funds remain limiting.

Table 9-2. Detailed protocol development and implementation schedule for the Sierra Nevada Network.

Monitoring Protocols	Winter 2006	Spring 2007	Summer 2007	Fall 2007	Winter 2007	Spring 2008	Summer 2008	Fall 2008	Winter 2008	Spring 2009	Summer 2009	Fall 2009	Winter 2009	Spring 2010	Summer 2010	Fall 2010	Winter 2010
Birds																	
Refine monitoring objectives	■																
Adapt NCCN bird protocol		■	■														
Internal and external peer review				■	■												
Revisions, adapt NCCN database					■	■											
Planned Field implementation (DEPO)							■				■				■		
Early Detection of Non-native Plants																	
Develop monitoring objectives	■																
ED monitoring prioritization SOPs		■															
Species abstracts, descriptions			■														
ED SOP for wetland protocol				■													
Data management tasks/SOP review				■	■	■											
Integrate SOPs into ED protocol								■	■								
External peer review and revision										■	■						
Implementation (by park staff or other)*														■	■		
Forest Dynamics																	
Review/revise monitoring objectives					■												
Assemble data for power analyses						■											
Work with statistician on power analyses							■										
Develop survey site sample design								■									
Select index sites								■									
Draft protocol SOPs and narrative									■	■							
Internal and external peer reviews											■	■					
Protocol revision													■				
Field implementation (SEKI, YOSE)															■		

Lakes (objectives developed 2005)																	
Determine target population																	
Sample design, data and power analyses																	
Adapt state water monitoring database																	
Draft protocol SOPs																	
Finalize sample design and index sites																	
Draft protocol narrative																	
Internal and external peer reviews																	
Field implementation (SEKI, YOSE)																	
Landscape Dynamics																	
Revise and prioritize objectives																	
Participate in national NASA project																	
Workshop with OSU collaborators																	
Draft study plan from OSU																	
Pilot studies to adapt existing NCCN and SWAN protocols																	
Revise existing SOPs, write new SOPs																	
Write protocol narrative																	
Internal and external peer reviews																	
Technology transfer & implementation (all parks)																	
Rivers & Streams																	
Develop monitoring objectives																	
Determine target population																	
Sample design, data and power analyses																	
Write SOPs and protocol narrative																	
Internal and external peer reviews																	
Field implementation (all parks)																	

Weather and Climate																	
Do weather/climate inventory	■	■	■														
Develop DEPO meteorological station SOP and interpretive signs	■	■															
Assess existing weather monitoring in SIEN parks	■		■	■													
Develop monitoring objectives					■												
Determine protocol development approach						■											
Write SOPs and protocol narrative								■	■	■							
Internal and external peer reviews										■	■						
implement protocol (all parks)													■	■	■	■	■
Wetlands Ecological Integrity																	
Draft protocol SOPs and narrative	■	■															
Establish YOSE index sites			■														
Pilot test protocol (YOSE)			■														
Power analyses and protocol revisions				■	■	■											
Finalize database, data SOPs and panel design					■	■											
Establish DEPO and SEKI index sites						■	■										
Pilot test protocol (SEKI)							■										
Revision and internal review								■									
External peer review									■								
Revision and full field implementation (all parks)										■	■			■	■		

*The Early Detection Non-native Plant protocol may be limited to SOPs within other protocols (e.g., Wetland Ecological Integrity), due to funding limitations. It is not yet determined if a full stand-alone early-detection protocol will be developed and peer-reviewed.

9.2 Monitoring Frequency Schedule

See Chapter 4, "*Sample Design*", (Table 4-2 and Table 4-3), for the Network's annual monitoring schedule depicting frequency and month(s) for individual vital signs sampling.

As we implement SIEN protocols over the next several years, the Network will continually evaluate how well implementation of each protocol, and the SIEN vital signs program as a whole, is succeeding. This evaluation will also occur individually for each vital sign.

Chapter 10 BUDGET

In this chapter, we present the budget for SIEN's monitoring program during the first year of operation, coincident with our first monitoring plans having been reviewed and approved (expected 2008). We show a simplified Network budget (Table 10-1) using the same expense categories in the Network Annual Administrative Report and Work Plans that were submitted to Congress. In Table 10-2 present the budget in more detail, including estimations for Network resources devoted to information and data management.

SIEN receives approximately $662,000 from the National Park Service Servicewide Inventory & Monitoring Vital Signs program, and approximately $61,500 from NPS Water Resources Division (annually). During the first year of monitoring program implementation (2008), we will also still be developing most of our monitoring protocols. We consider the years 2008-2010 "transition years," where both protocol development (new protocols) and implementation (approved protocols) co-occur. During this time, we will have additional core Network staff to complete both protocol development and Data Management Plan implementation. During this period, we anticipate allocating 65% of the budget to core Network Personnel. We anticipate some involvement from park staff in implementing protocols (see Chapter 8).

To complete protocol development, the Network recognizes the necessity of Cooperative Agreements, via Cooperative Ecosystem Studies Units (CESUs) or other entities. Aspects of some protocols (landscape dynamics, climate/weather) may require additional Cooperative Agreements for protocol implementation. From 2008-2010, we expect to allocate approximately 25% of the budget (annually) for Cooperative Agreements or Contracts. The Network currently participates in agreements with California, Great Basin, Pacific Northwest, and Rocky Mountain CESUs.

Table 10-1. Anticipated budget for the SIEN Vital Signs Monitoring Program in the first year of implementation after review and approval of the monitoring plan.

SIEN Vital Signs Monitoring Budget—2008			
Income			
Vital Signs Monitoring		$662,000	
Water Resources Division		61,500	
	Subtotal	**$723,500**	
Expenditures			**% by budget category**
Personnel (NPS)		$465,500	64%
Cooperative Agreements		173,800	24%
Contracts		13,000	2%
Operations/Equipment		42,000	6%
Travel		25,000	3%
Other		4,200	1%
	Subtotal	**$723,500**	

For our SIEN staffing plan to be successful, adequate travel funds are required to ensure staff participate in key training opportunities and meetings, and good quality monitoring data are collected. In FY 2008, approximately $20,000 of travel is anticipated for core staff, and an additional $5,000 for protocol development and implementation (field crew travel costs, work group travel for planning meetings, invitation travel for cooperators). Due to the remoteness of much of the landscape in our large parks, additional funds will be allocated (in future years) to field crew travel support when more protocols are being implemented.

Guidelines for monitoring programs suggest that approximately 30% of the overall budget should be allocated to information/data management (to prevent information loss, and to make sure adequate communication of monitoring results occurs). In **Error! Reference source not found.**, we provide the percent of time that each Network position is expected to devote to information and data management. Our estimate of 34% allocation of funds, overall, to information and data management may be underestimated; these projections of time do not reflect the time spent on information and data management by those park staff not paid for using Network funds. Network (and park) staff time devoted to information and data management will be clearly defined in work plans and performance plans, so that the responsibilities are understood and there is accountability for performing them.

10.1 Water Monitoring

We will allocate approximately 75% of our annual water quality budget to lakes monitoring and 25% to rivers and streams monitoring. Additional funds from the vital signs account (including a large portion of the salary of the Physical Scientist) will be used to supplement the water resources monitoring program.

After 2010, when protocols are further developed and costs associated with protocols can be more accurately estimated, we will review our staffing plan and budget, and make any needed adjustments for implementation of all the protocols that the budget can support. The budgetary challenge of a long-term monitoring program will be balancing fixed-costs (permanent staff and operational expenses) needed to sustain the program and provide consistency and longevity, with flexible spending needs (seasonals, cooperative agreements/contracts, travel, supplies, training, changing priorities, etc.).

Program support from permanent park-based staff will be important towards providing depth and continuity to the program through assistance with implementation of some vital signs. The proposed number of Network staff will not be sufficient to meet all of the program's needs for implementation of protocols and data and information management and delivery.

Table 10-2. Detailed budget for the SIEN Vital Signs Monitoring Program in the first year of implementation after review and approval of the monitoring plan.

SIEN Vital Signs Monitoring Budget	2008		
Income			
Vital Signs Monitoring	$662,000		
Water Resources Division	$61,500		
Subtotal	**$723,500**		
Expenditures			
Core Network Personnel		**Proportion Dedicated for Information Management**	
Network Coordinator (GS-12)	$96,000	20%	$19,200
Data Manager (GS-11)	$77,300	100%	$77,300
Ecologist (GS-11)	$73,200	30%	$21,960
Physical Scientist (GS-11)	$71,100	30%	$21,330
Administrative Technician (GS-06, .75 FTE)	$38,000	15%	$5,700
Data/GIS Technician (GS-07, .75 FTE)	$40,200	100%	$40,200
Landscape Ecologist-YOSE (GS-11, .1 FTE)	$8,700	20%	$1,740
Outreach Specialist (GS-09, .3 FTE)	$17,000	20%	$3,400
Lake monitoring seasonals	$44,000	30%	$13,200
Subtotal	**$465,500**	**44%**	**$204,030**
Cooperative Agreements			
Wetlands monitoring- protocol development			
•vegetation and water	$31,500	15%	$4,725
•macroinvertebrates	$52,800	15%	$7,920
Streams monitoring protocol development	$25,000	20%	$5,000
Forest monitoring protocol development	$34,500	20%	$6,900
Statistician support (protocols)	$30,000	20%	$6,000
Subtotal	**$173,800**	**18%**	**$30,545**
Contracts			
Water quality analyses (lab)	$10,500		
Report editing and formatting for publication	$2,500		
Subtotal	**$13,000**		
Operations/Equipment			
Protocol equipment	$15,000		
Office supplies and equipment	$4,000		
Computers, data storage, software	$12,000	100%	$12,000
Vehicles for seasonal and core staff	$11,000		
Subtotal	**$42,000**	**29%**	**$12,000**
Travel			
Protocol development and implementation	$5,000		
Core network staff	$20,000	10%	$2,000
Subtotal	**$25,000**	**8%**	**$2,000**
Other			
SCA housing	$2,500		
Miscellaneous	$1,700		
Subtotal	**$4,200**		
Total	**$723,500**	**34%**	**$248,575**

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GLOSSARY OF TERMS AND CONCEPTS

Concepts and definitions: http://science.nature.nps.gov/im/monitor/glossary.cfm

Adaptive Management is 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.

Attributes are any living or nonliving feature or process of the environment that can be measured or estimated and that provide insights into the state of the ecosystem. The term **Indicator** (see below) 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 2002).

A **Conceptual Model** is a visual or narrative summary that describes the important components of the ecosystem and the interactions among them. Development of a conceptual model helps in understanding how the diverse components of a monitoring program interact, and promotes integration and communication among scientists and managers from different disciplines. Conceptual model diagrams often take the form of a "boxes and arrows" diagram, whereby mutually exclusive components are shown in boxes and interactions among the components are shown with arrows, but many conceptual models include tables, matrices, sentences or paragraphs to summarize and communicate our understanding of the system.

Ecological integrity is 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 is 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 are 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 is 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 are 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 are a subset of monitoring attributes 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 2002). 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: A natural resource inventory is an extensive point-in-time effort to determine 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. Inventories contribute to a statement of park resources, which is best described in relation to a standard condition such as the natural or unimpaired state. Inventories may involve both the compilation of existing information and the acquisition of new information. They may be relative to either a particular point in space (synoptic) or time (temporal).

Measures are the specific variables used to quantify the condition or state of an Attribute or Indicator. These are specified in definitive sampling protocols. For example, stream acidity may be the indicator, while pH units are the measure.

Monitoring differs from inventory in adding the dimension of time, and 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. 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.

Natural resource monitoring is conducted primarily for two purposes: (1) to detect significant changes in resource abundance, condition, population structure, or ecological processes; or (2) to evaluate the effects of some management action on population or community dynamics or ecological processes. Monitoring should have a specific purpose, and is a prerequisite for management action, which is triggered when values reach or exceed some pre-determined threshold value. Monitoring cannot be a "I'll know it when I see it" process.

Monitoring data are most useful when the same methods are used to collect data at the same locations over a long time period (e.g. more than 10-12 years). It is important to note that cause and effect relationships usually cannot be demonstrated with monitoring data, but monitoring data might suggest a cause and effect relationship that can then be investigated with a research study. The key points in the definition of monitoring are that: (1) the same methods are used to take measurements over time; (2) monitoring is done for a specific purpose, usually to determine progress towards a management objective; and (3) some action will be taken based on the results, even if the action is to maintain the current management.

Monitoring Attributes are any living or nonliving feature or process of the environment that can be measured or estimated and that provide 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 2002). 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.

Research has the objective of understanding ecological processes and in some cases determining the cause of changes observed by monitoring. That understanding is needed for determining the appropriate management response to threats. Research is generally defined as the 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. The NPS monitoring program includes a research component to design sampling protocols for various types of park resources at different locations and spatial scales.

Research is usually short term; approximately 80% of research studies last only 1-2 years, and 75% of studies involve only 1 or 2 species. An important exception to this generalization is the collaborative “Long-Term Ecological Research” program funded by the National Science Foundation, which is conducting long-term research on such things as pattern and control of primary production, spatial and temporal distribution of selected populations, and patterns of nutrient influx and movement through soils, groundwater and surface waters.

Protocols and standard operating procedures used by researchers are usually based on the latest technology and are often too time consuming or expensive to provide data for a long-term monitoring program. The need to publish results in peer-reviewed journals, the measure of successful research, tends to require researchers to continually develop new sampling methods and to debate alternate models and analyses.

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. 1976:192). 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.

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). Because of the need to maximize the use and relevance of monitoring results for making management decisions, vital signs selected by parks may include elements that were selected because they have important human values (e.g., harvested or charismatic species) or because of some known or hypothesized threat or stressor/response relationship with a particular park resource.