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NATIONAL PARK SERVICE
ALASKA REGIONAL OFFICE
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IN REPLY REFER TO:

January 22, 1990

To: Natural Resource Management Specialists
ARO Natural Resource Division

From: Inventory and Monitoring Coordinator

Subject: Inventory and Monitoring Plan for Terrestrial Ecosystems

Please review the enclosed plan. It will form the basis for our discussions during the February 6 session at the workshop. If you have specific problems with the plan, certain sections of the plan, etc., please come to the workshop prepared to make constructive changes. Bring literature citations and documents that you feel will be useful.

The plan resulted from Rosa Meehan's work here last summer with some sections added by me in the past few weeks. Several of you conferred with Rosa and helped her over the summer. I hope you are pleased with the results.

If we follow the implementation section as outlined, then several protocols will need to be fleshed out during the next year. Think about which ones of these you would like to be involved with and be prepared to start forming working groups following the workshop. Final protocols should be short, simple and to the point.

I am going to recommend two projects for the 1990 funding request:

1. Finalizing the year one part of Implementation (p 34)

2. Completing a monitoring plan for glaciers involving KEFJ, WRST, DENA, AND LACL. This will dove-tail into work already in progress in those parks.

Rumor has it there will not be much money available from the WASO I & M funding source.

INVENTORY AND MONITORING PROPOSAL

ALASKA REGION

NATIONAL PARK SERVICE

DRAFT

In a speech prepared for the American Institute of Biological Sciences annual meeting, M. K. Tolba, Executive Director of the United Nations Environmental Program (1989) stated: "Time is running out. We are set on a collision course between a surging population and disappearing productive lands. The global population, currently at 5.1 billion, has doubled since 1954. It is now consuming, diverting, and wasting approximately 40% of the planet's entire net global photosynthetic production." By the middle of the next century these problems will be exacerbated by another doubling of the world human population (Tolba 1989). These statements are paralleled by Likens (1983) who wrote that few would have predicted 25 years ago that acid rain, ozone, toxic wastes, and changes in global climate would be major environmental issues. Further, Likes (1983) ask what will be the issues 5 or 25 years from now? Liken's questioned how we can predict or possibly avert such problems. His answer was that a major priority for ecology is to establish long-term studies, including high-quality monitoring programs, in a variety of ecological systems throughout the world.

The National Park Service (NPS) is in a position to contribute to long-term ecological monitoring. NPS is responsible for the management of natural resources in a manner that conserves them unimpaired for future generations. The relatively undisturbed National Park lands can be the "gold standard" against which change can be measured (Evison 1989). Establishment of inventory and monitoring activities on National

Park Service lands may be the greatest legacy it can leave the American people (NPS I&M Initiative 1987). To fit within the NPS national initiative, this paper describes a proposed inventory and monitoring strategy for the Alaska Region of the National Park Service, an area that encompasses 53 million acres of arctic and subarctic environments.

Strategy for Long-Term Ecological Studies

Definition. Strayer (198) states there are at least two different definitions of "long-term." He considers a study is long-term (1) if it continues for as long as the generation time of the dominant organism or long enough to include examples of the important processes that structure the ecosystem under study. The length of study is measured against the dynamic speed of the system being studied. His alternative definition is (2) to consider a long-term study simply as a study that has continued for a longer time than most ecological studies, and which has revealed attributes of the system that were not obvious on short time scales. Strayer's (198) examples of the two definitions are Gause's classic experiments on competitive exclusion which took only about 20 days, but covered many generation times of Paramecium and clearly elucidated the dynamics of the system under study (definition 1). The example for definition 2 was a 5-year study of pelagic bacterial communities where such studies typically do not extend for more than a year. The fact a study may go on for many years does not make it a long-term study. For example, Strayer concluded the first definition includes Gause's work (20 days), but does not include the 20 year study at Hubbard Brook in New Hampshire by Bormann and Likens (1979) because only 1/20 the time required to reach steady state had passed.

The National Park Service initiative for long-term monitoring, as yet, fits neither definition. The initiative describes long-term monitoring as the systematic collection and analysis of those resource data at regular intervals, in perpetuity, to predict or detect natural and human-induced changes, and to provide the basis for appropriate management response (NPS I&M Initiative 1987). It is the policy of the National Park Service to assemble baseline inventory data describing the natural resources under its stewardship, and to monitor those resources forever; to detect or predict changes that may require intervention, and to provide reference points to which comparison with other, more altered parts of the home of humankind may be made (NPS 75 & 77). Time will tell whether NPS will commit resources to make the initiative fit definition (1), just be an exercise carried out for 20 years or less (2), or another exercise with fitful starts and stops depending upon personalities involved. The NPS annual budget cycle and the short-term tenure for most resource management specialists in parks (average of four years in Alaska) will require careful attention by administrators to be sure NPS policy (NPS 75 & 77) is carried out. Strayer (1986) stated that one ingredient was invariably present in productive long-term studies:dedicated leadership. He found that every prominent long-term study he looked at had associated with it a good ecologist who made a long-term commitment to the project, who accepted personal responsibility for the quality of the data, who patched together long-term funding,etc.

The Ecosystem Concept

A basic premise, in terms of both ecological theory and inventory information is that the land and water resources operate as systems, not as independent entities (Hoekstra and Flather (1986).

In developing resource inventory and baseline study methods for developing countries, Conant, et al (1983) state a specifically defined ecosystem, which includes both the biotic and the non-biotic features of the environment, should be the basic functional unit of resource management. The ecosystem concept emphasizes the interrelationships and dependencies between these components. An ecosystem is defined as a biotic community in interaction with its nonliving environment; the latter, the abiotic sector, is composed of the basic elements and compounds of the environment (Odum 1966).

Agee and Johnson (1988) define an ecosystem as any part of the universe chosen as an area of interest, with the line around that area being the ecosystem boundary and anything crossing the line being input or output. They consider ecosystems as

-spatially variable

-temporally variable

-different ecosystem components may have different boundaries

-politically defined boundaries frequently do not contain all the ingredients necessary to resolve resource management issues.

-the ecosystem concept may be applied to all lands.

In a management context four biological and social system properties that underlie successful environmental assessment include (Agee and Johnson (1988)

1. Ecological systems are continually changing.
2. There may be substantial spatial heterogeneity in impacts from a particular action.
3. systems may exhibit several levels of stable behavior.
4. There is an organized connection between parts, but everything is not connected to everything else.

Conant, et al (1983) state the ecosystem concept is essential for understanding the relations between resources that are to be developed and for identifying functional services (such as nutrient cycling) necessary for the very existence of the resources. It is now recognized that the fundamental resource is not the "forest and its potential timber," etc., it is the systems functioning that weld life together. Given adequate monitoring, environmental degradation can be detected at early stages, and the enormous expense of resource reclamation can be avoided through conservation and wise development.

Inventory information Conant, et al (1983) recommend collecting for ecosystem studies includes:

-aquatic ecosystems: total and seasonal precipitation, runoff, evaporation rate, stream flow, and aspects of chemical and biological quality.

-soils: major soil complexes, general levels of productivity, and topographic relations of soil groups.

-plants: major vegetation types with their dominant species, estimated biomass production, per cent cover, and characteristics that influence utilization by wildlife.

-wildlife: principal species and their relative abundance, sex and age ratios, migration patterns, and types of habitats.

Ecological monitoring, if designed as an integral part of project management, can provide feedback information. Ecological changes of far reaching consequences may be expressed by a decrease in the number of valuable species or the invasion of undesirable species. A monitoring program should detect these changes (Conant, et al 1983).

<u>Demand for long-term studies.</u>

Demand for long-term studies is broad (Callahan, 1984; Likens 1983). The current environmental problems, such as acid rain and toxic wastes, would not be controversial issues if there had been long-term data from which trends and effects could be determined (Likens 1983). Long-term research has been proven at all levels of government because long-term research has predictive capabilities. Unfortunately, most impact analyses are little more then inventories and descriptions, and their functional ecological/environmental aspects have dealt with little more than obvious direct effects on ecosystems. Predictive capabilities of impact analyses is limited by lack of information (Callahan 1984).

According to Likens (1983) qualitative and quantitative observations over long periods are vital to formulate meaningful, testable hypotheses in ecology. Routine observations or analyses provide a base of information, and the necessary experience to develop meaningful hypotheses, and also generates significant new research questions (Loucks 1979). It is now recognized that human technology is bringing more subtle, long-term pressures on many natural populations, communities, ecosystems, and the earth's entire biogeochemistry (Loucks 1979).

The most important contribution from long-term monitoring is the general advance expected in scientific understanding of natural as opposed to anthropogenic variations induced in species, populations, and ecosystems. Their result is important to virtually everyone associated with biological resources (Loucks 1983).

Pit-falls from long-term studies.

Strayer (1986) states that if we accept the second definition we are accepting human institutions and constraints (such as human life span, funding cycles, graduate education), not the pace of natural processes, as the determinant of the length of ecological studies. He states it is not hard to study an ecological system for several generation times of the dominant organism, but it is hard to study an ecological system for several funding cycles or several human lifetimes. Strayer found the chief difficulty with doing a long-term study is that the continued commitment of money, time, staff, facilities, and so forth will prevent a scientist from pursuing other lines of research. The results from a long-term study may take years or decades to come in while it is frequently critical to provide answers to pressing environmental questions promptly.

Strayer (1986) found ecologists often use short-term approaches to investigate long-term phenomena, such as a series of well-matched sites that form a chronosequence, by using various records left by the ecosystem or by humans (such as paleolimnology and dendrochronology), mathematical modeling, and use of systems with fast dynamics as a substitute for systems with slow dynamics. All these approaches have draw-backs.

In reviewing National Science Foundation (NSF) funding, Callahan (1984) noted appraisals pointing out the inadequacy of historical environmental records and the effect of short-term support on research output and personnel could be viewed as an indictment. Short-term research cannot serve as a definitive basis for addressing societal concerns related to environmental biology nor for the substantial advancement of a science that deals with process occurring over long periods of time. Callahan points out the serious contradiction between the time scales of ecological phenomena and the support to finance their study. He states that funding cannot be guaranteed to any research undertaking for even tens of years, let alone for centuries or more. The typical two-or three-year cycle of funding is inappropriate when phenomena of interest occur over long periods of time.

The importance of a simple, accommodating design in long-term studies, the importance of a clear initial hypothesis, the

role of experimental manipulations, when to terminate a long-term
study, protection and management of study sites, choice of measurement variables, collection and management of data, sample banking, continuity of personnel, monitoring, and the role of self-evaluation and synthesis of project results were other topics Strayer (1986) found of importance in long-term studies.

Callahan (1984) states that projects must be designed at the beginning to make them comparable. This becomes more important with projects that are geographically and biologically disjunct. Comparability of data becomes especially important in biopshere reserves where long-term monitoring is to provide comparable data of global and regional nature while serving the needs of all countries (Tschirley 1979).

The ultimate value of long-term ecological research will depend upon standards that are set by the researchers.

Examples of long-term study designs

United States Arctic Research Plan (1990-1991)

The Arctic Research and Policy Act of 1984 requires a comprehensive Arctic research plan to be prepared by the Interagency Arctic Research Policy Committee to be submitted to the President who transmits it to Congress. Research mission and components for the 1990-1991 plan include arctic ocean and marginal seas, atmosphere and climate, land and offshore resources, land/atmosphere interactions, engineering and technology, and people and health. There are proposed interagency programs, including remote sensing.

Among the numerous recommendations are the following which have direct application to this proposal:

-to assure that biological resources are protected for future generations, management agencies must have adequate data and information on the biology and ecology of these species, as well as information on environmental parameters of importance to vital processes.
-increased knowledge of the current and potential productivity of arctic and subarctic forests and soils will lead to improved management practices for increased productivity of renewable resources.
-documentation of seasonal, interannual, and long-term trends in the physical environment of the arctic requires attention to seasonal and perennial snow and ice covers and glaciers.
-Reliable long-term information is needed on surface water quality and quantity.
-additional knowledge is needed about the temperature, distribution, thickness, and depth of permafrost through all geomorphic provinces of the arctic.
-modern geologic processes that are responsible for the present morphology and land surface need to be better understood.
-research is needed to improve understanding of the influence of climate on land and freshwater processes, including heat balance relationships, landscape alteration, the identification of biological indicators of change, and long-term trends in biological diversity, as well as managing living resources.

Each of the above is developed in more detail and specific agency programs and projects are reviewed where the recommendation can be carried out. Four principal and concurrent thrusts are recommended: (1) long-term observational programs, (2) process research, (3) intact ecosystem experiments, and (4) model development. Under long-term observations and monitoring, four goals are identified:

-for the hydrosphere the goal is to obtain baseline data sets of stream and groundwater hydrology. There is lack of knowledge of the relationship of environmental variables to seasonal, annual, and long-term hydrologic regimes and ability to predict hydrologic consequences of both regional and global anthropogenic changes.

-a more extensive meteorological monitoring program is required to obtain baseline data sets of air quality and meteorological conditions.

-an ecological monitoring program is required to obtain baseline data over decades in order to understand linkages between the abiotic and biotic components of the arctic ecosystem. These include ultraviolet radiation effects at long-term sites such as on the LTER and MAB Biosphere Reserves and along broad geographical transects.

-satellite monitoring using visible and near-infrared sensors to document spatial patterns and vegetation attributes on the regional landscape will be continued.

The planning and coordination section of the plan shows the National Park Service manages Biosphere Reserves and parks in Alaska which may be used for long-term research and monitoring.

Long-term Ecological Research Sites (LTER)

Following a series of NSF sponsored workshops held from 1977 through 1979, the LTER program began in 1980 with the funding of six sites (Loucks 1979; Callahan 1984; Swanson & Franklin 1988). About 20 sites that span a great array of terrestrial and aquatic ecosystems are now funded at about $365,000 per site per year. Common threads among these diverse ecosystem research sites include: established research sites with long-term records of environmental and biological variables, established interdisciplinary teams of researchers with stable leadership and institutional support, programs of research in five core areas, and a commitment to work with other sites in the LTER network (Swanson & Franklin 1988). Ecosystem manipulation is frequently a key area of research at LTER sites.

Five core areas of LTER research are oriented toward question/hypothesis formulation and resolution (Callahan 1984). They include pattern and control of primary production, spatial and temporal distribution of populations selected to represent trophic structure, pattern and control of organic accumulation in soil and sediment, patterns of inorganic input and movements through soils, groundwater, and surface waters, and patterns and frequency of disturbances, both natural and human caused.

From inception, it was recognized that not all ecosystems would be represented. There are two sites in Alaska, one at Toolik Lake representing the Alaska arctic tundra operated by WoodsHole Oceanographic Institute and one at Bonanza Creek, near Fairbanks, which represents a forest river that is operated by the University of Alaska and USDA Forest Service.

Common standards for meteorological monitoring and data management have been established. Joint research and exchange of scientists among sites are used for comparative studies and to test hypotheses (Swanson and Franklin 1988). According to Callahan (1984), the least that will come from these projects will be (1) careful inventories at each research site, (2) the inventories will have their value increased because the research will be at least partially controlled for physical variability,

(3) documenting the rates of various fundamental processes, such as organic decomposition, primary production, portions of herbivory, and atmospheric deposition of chemical elements, and (4) a measure of the effect of disturbance on the measured variables.

Shenandoah National Park

Shenandoah National Park has established a long-term ecological monitoring system (LTEMS) to collect inventory and long-term baseline monitoring data (Vaughn, et al., 1986). The goals of the park are to document specific ecosystem changes and impacts related to natural perturbations and the results of any management actions taken to minimize the effect of a given perturbation, and to collect appropriate ecological data in a systematic and coordinated manner throughout the park on a continuing basis. A system of comprehensive permanent plots will be used for baseline inventory and long-term monitoring of a wide range of environmental characteristics and ecological processes. Plots will be established using cluster sampling in place of completely random plot placement within each ecological land unit. Stand cover type is the parameter separating ecological land units.

The three objectives are to (1) document changes to various characteristics of basic environmental components over time and space and to better understand the associated basic ecosystem processes. (2) to identify and evaluate the effects of a perturbation, such as the gypsy moth and use this evaluation as a validation of the utility of the LTEMS. (3) to provide a comprehensive system for evaluating the effects of important natural impacts or man-caused disturbances on the park ecosystem, and to aid in the research of effects of management activities. Emphasis is toward understanding gypsy moth perturbation.

Channel Islands National Park

Channel Islands National Park is designing a long-term ecological monitoring program based on a system for monitoring population dynamics of index taxa. The system is used to evaluate ecosystem health and to explore cause-and-effect relationships among ecosystem components. Nearly 500 species of the 2000 known from the park are being tested for long-term monitoring. Insect species number 200, terrestrial plants 156, marine invertebrates 41, birds 23, marine algae 16, fishes 15, and mammals, reptiles and amphibians 12. Population parameters monitored include abundance, age structure, reproductive effort, recruitment, growth rate, mortality rate, and phenology. These parameters reflect population responses to dynamic environmental factors and indicate current and near-term future population conditions. (from abstract by Davis 1989).

Man and the Biosphere (MAB) Biosphere Reserves

The MAB program of UNESCO has increased the number worldwide of biosphere reserves to 266 in 70 countries. Krinitskiy (1980) described the program as a global network of natural territories representing characteristic samples of Earth biomes with two functions: conservation of biodiversity and systematically collecting long-term observations of the main characteristics of the environment and the condition of its natural components. Herrmann and Baron (1980) consider the networks in remote natural areas of parks/biosphere reserves as the early warning system that can detect small-scale change in environmental conditions before they become catastrophic changes affecting human health and environmental quality. They present a model (atmospheric deposition) by which long-term monitoring in biosphere reserves can proceed within the limits set by law. Parks/biosphere reserves are to be linked by a series of monitoring processes that are conducted in the same way and on the same time scale. To date, the process has been more of creating biosphere reserves than in establishing a monitoring program. A voluminous literature is available on the value and monitoring philosophy following several conferences, including US/USSR exchanges.

In 1983, an action plan for biosphere reserves was developed to make the network more functional, improve the quality of scientific work within biosphere reserves, and to strengthen the role of biosphere reserves in conserving biological diversity (Vernhes 1987). The US National MAB Committee has formed a Biosphere Reserve Committee charged with developing a program in biosphere reserves, i.e., biosphere reserves are to "do" as they were designed. There is one representative from NPS-Alaska (Taylor) on this committee.

There are four biosphere reserves in Alaska-Glacier Bay National Park/Admiralty Island, Denali National Park, Noatak National Preserve, and Aleutian Islands Biosphere Reserve (part of the Maritime National Wildlife Refuge).

PROPOSED STUDIES IN ALASKA PARKS

Purpose

The Park Service is mandated to "assure the continuation of geological and biological processes unimpaired by adverse human activity" within parks. Modern Man is superimposed on these processes through visitation and use (consumptive and nonconsumptive) through remote influences such as global warming and Arctic haze, and through more localized influences such as commercially fishing anadromous stocks, introduction of exotics, and activities near park boundaries. To accomplish that mandate, information is required. As the Gordon Report ( ) stated: " The National Park Service cannot manage what it does not understand." Inventory and subsequent monitoring of resources is necessary to provide information needed to understand and manage natural systems.

Parks in Alaska represent a diverse array of ecosystems with unique values and management concerns. The Alaska National Interest Lands Conservation Act (ANILCA) established national parks, preserves, monuments, and further defined existing parks in Alaska. As described in that legislation, Alaskan parks have significant natural, scenic, historic, cultural, archaeologic, geologic, scientific, wilderness, recreational and wildlife values and resources. The parks represent a variety of arctic and sub-arctic ecosystems; ranging from the mountains of the Brooks Range in Gates of the Arctic National Park, to glacial terrain in Kenai Fjords, Wrangell-Saint Elias, and Glacier Bay National Parks, to volcanic landscapes in Katmai National Park and Aniakchak National Monument, to watershed systems in Lake Clark National Park and Noatak National Preserve. Unique park systems include the Kobuk sand dunes in Kobuk Valley National Park and the ancient terrain of the Yukon-Charley Rivers National Preserve. Park management, in addition to the mandate of conserving natural resources unimpaired for future generations, must provide for continued subsistence hunting and trapping within most units. Sport hunting is permitted within national preserves.

Park managers need basic information about natural systems. Many Alaskan parks are vast and remote, and park values are not well known. Basic inventories are needed to identify resources. Park systems must be monitored to ensure maintenance of natural systems. Managers need to know if changes are occurring and why they occur, so that appropriate management strategies can be

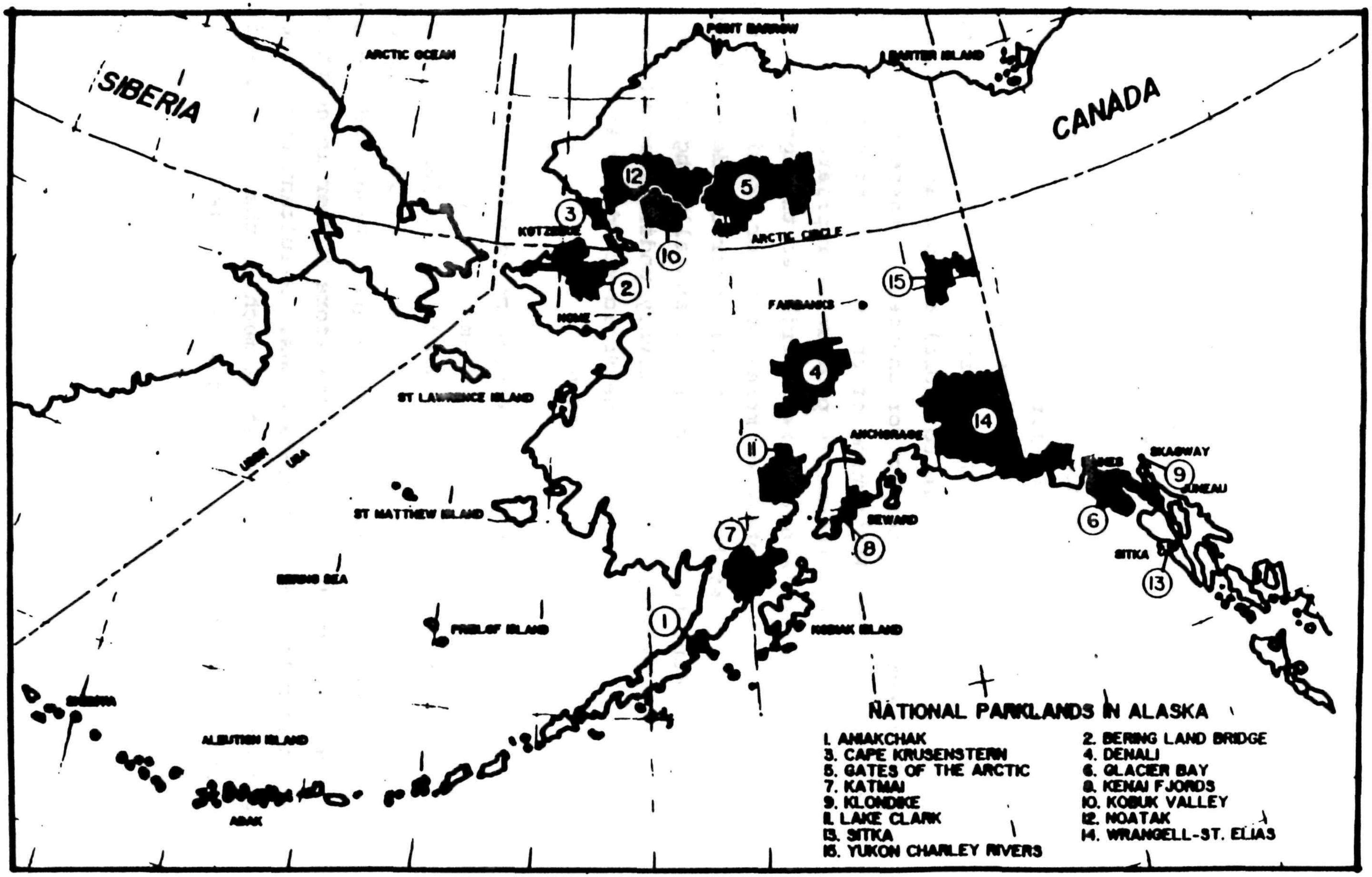

Figure 1. Location of National Park Service Areas in Alaska.

developed and employed to maintain natural systems and processes. Monitoring is particularly important as activities allowed within parks, such as subsistence hunting and mechanized travel, have the potential to cause significant changes.

Despite being remote, parks in Alaska are not immune to man-caused changes. Man's ability to alter the environment has increased dramatically, as illustrated by current predictions of global climate change. Arctic and sub-arctic environments may be particularly susceptible to global changes as they are extreme environments. Monitoring for changes in these extreme systems could provide early warning of changes and potential magnitude of the changes. Alaskan parks provide appropriate study areas to monitor changes as parks are distributed throughout the state (Figure 1.) and contain examples of major arctic ecosystems. In addition, park status prohibits or restricts development, ensuring continuity of study sites and allowing development of long-term databases. The relatively undisturbed status of Alaskan parks can serve as the "gold standard" against which more disturbed areas can be compared.

Potential rapid climatic warming predicted as part of the "greenhouse effect" may cause dramatic effects in arctic and sub-arctic systems. Due to the low angle of solar incidence in northern latitudes, reductions in atmospheric insulation from solar rays will be particularly acute. Predicted average temperature differences are therefore higher in northern latitudes than in temperate areas. Resultant environmental effects will likely be great as much of the landscape is dominated by frozen water, either as glaciers or as permafrost. Warming by even a few degrees celsius will dramatically alter natural systems in this type of landscape.

Current Research

The majority of current research is directed at highly visible species, such as wolves, bears, sheep and moose. They are of particular interest as many populations are hunted and the opportunity to view these species is a major attraction for park visitors. The justification for studies of highly visible species is based on these characteristics. The studies also provide important information for inventory and monitoring as these species are integral parts of the natural system.

Most studies address distribution and population composition, although some address population dynamics and ecologic requirements. Dall sheep have been surveyed repeatedly in Denali, Gates of the Arctic and Lake Clark, less extensively in Noatak, Wrangell-St. Elias and Yukon-Charley. Wolves are being studied in Gates of the Arctic, Yukon-Charley, Noatak, and an extensive study of wolf ecology is ongoing in Denali. Grizzly Bears have been studied in Noatak, Lake Clark, Katmai and Denali, with studies focussing on human-bear interactions in the latter two parks. Caribou surveys have been conducted in Lake Clark, Noatak, Denali, Gates of the Arctic, Bering Land Bridge and Cape Krusenstern. Moose have been surveyed in Glacier Bay, Katmai, and Yukon-Charley; and extensively surveyed in Lake Clark and Denali. Mountain goats have been surveyed in Glacier Bay, Kenai Fjords and Wrangell-St. Elias. Raptors have been studied in Yukon-Charley (Peregrine Falcon), Katmai (Bald Eagle), and an extensive study of Golden Eagles is beginning in Denali. Marine mammals have been studied in Kenai Fjords and Glacier Bay, with humpback whales studied extensively in Glacier Bay.

The level of detailed information varies between park. The three parks established before ANILCA (Denali, Glacier Bay, and Katmai) have probably received the most study. Denali, Glacier

Bay, and Noatak are also Man and the Biosphere sites and have a research emphasis associated with that program. Large mammals have been studied extensively in Denali, partly due to the park's accessibility and partly due to the infrastructure available for research. Another important characteristic is that it is one of the few areas in the state where hunting is prohibited (also prohibited in Kenai Fjords and the parts of Katmai and Glacier Bay created before ANILCA), therefore park populations provide a comparison for other hunted populations. Establishment of Glacier Bay was originally proposed by the Ecological Society of America as early theories of plant succession were developed there. Research is one of the primary purposes of the park. The geomorphically dynamic land and seascape of Glacier Bay has attracted biologic and geologic researchers since the late 1800's. Katmai has a long series of Brown bear and Bald Eagle surveys and recently studies of bear-human interactions have been conducted. The remaining parks and preserves (with the exception of Sitka and Klondike Gold Rush) were established in 1980 with the passage of ANILCA and much of the work has focussed on inventorying park resources, with an emphasis on large mammals. Noatak National Preserve and Biosphere Reserve was specifically cited in enabling legislation to provide opportunities for scientific research.

Fishery studies have been conducted in a number of parks. Fish stocks have been surveyed in Aniakchak, Yukon-Charley, Gates of the Arctic, Lake Clark, and Katmai. Water resources have been inventoried in Glacier Bay, Lake Clark and Denali. Water resource studies are ongoing in Noatak and about to begin in Katmai.

Additional Studies

A basic mandate of the parks is to protects and preserve natural systems and processes. To fully address this mandate, research programs need to be expanded to address other ecosystem components; such as bird communities, small mammals, vegetation patterns, and regional features. Managers need information on all resource values, how those values change over time, and why changes occur to develop appropriate management strategies. Natural systems may respond to environmental change in a variety of ways and responses shown at different levels in the system. It is likely that an understanding of landscape or vegetation changes will be necessary to interpret changes in vertebrate populations.

Studies to date have largely addressed a particular aspect of the natural system - highly visible species - and the information is not compiled in a common system. To be effective, a broader-based program needs to address all resources and have all information in an integrated system. An integrated system aids interpretation of changes and relationships between changes to different parts of the natural system. With an understanding of the relationships between changes, appropriate management strategies may be developed.

A well designed information system can be used to address broader questions of regional variation and distribution. Parks are distributed across Alaska and are located such that east-west and north-south transects can be described. Gaining regional information will aid our understanding of patterns seen within park boundaries and aid our interpretation of change.

Program Strategy

The purpose of this program is to monitor "[redacted]" ecosystem functioning as a standard against which to compare ecological

change over time, resource use and National Park Service practices.

There are 23 national park units in Alaska which comprise 53 million acres. To reduce this acreage into manageable size, each national park will be divided into watersheds by park staff. Watersheds will then be prioritized from 1 through n for the order in which they are to be sampled. The number of watersheds in each park will vary from a few (Cape Krusenstern) to many (Wrangells-St. Elias) depending upon the terrain and size of park. One watershed will be designated the primary study site within each park.

Ecosystems, based on dominant vegetation types, will be identified within each watershed. Major ecosystems, from the lowest elevation to the highest system within the watershed will be identified for intensive study. A plot system, using cluster plot sampling, will be established in each ecosystem. All samples will be collected from designated sites within or near these plots.

Program Goals

1. Develop a long-term data base of natural resource values useful for detecting changes to natural resources and processes.

2. Develop a geographic data base using the Geographic Information System to archive and maintain data sets in a retrievable format and to perform spatial analyses.

3. Provide information to Park Superintendents in useful formats for incorporation into interpretation materials, as background information for other studies, or for other purposes as identified by the superintendents.

4. Develop common or compatible sampling techniques for use in all parks that are scientifically sound and practical given the remote study areas.

5. Incorporate program with outside agencies

Terrestrial Program Summary

The following sections outline a terrestrial Inventory and Monitoring Program. The first section, Permanent Plots, presents a protocol for establishing and monitoring study plots repeatedly over time. The overall program is organized around permanent plots and program organization is discussed in this section. The discussion of individual park studies presents an outline of the types of studies that will be done in all parks rather than a presentation of a completed study design for specific parks. Exact details may vary between parks and specifics will need to be worked out on a park by park basis. Geographic Information System-Data Management briefly outlines use of the GIS. Earth processes are discussed in the final section. Suggested types of studies within selected parks are presented with a more detailed discussion of potential studies presented for Denali.

The terrestrial environment was chosen for initial program development because of the available background information. The aquatic environment is equally important. An equal amount of effort is needed to develop an aquatic inventory and monitoring program as a companion to the terrestrial program presented here.

PERMANENT PLOTS

Purpose

Permanent plots to monitor vegetation, soils, breeding birds and small mammals will help address aspects of natural systems not currently studied. Repeatedly measuring the same plots will develop a long-term data base that measures natural changes or variability in the system useful for interpreting changes due to man's influence.

General Study Guidance

The study should be the same from park to park to allow comparability of data. To achieve this, the following guidelines are provided:

1. Vegetation studies should follow methods used by LTER (Long-Term Ecological Research, funded by the National Science Foundation) and MAB (Man and the Biosphere Program).

2. The amount of sampling must be sufficient to account for natural variation (determinations on the amount of area sampled may need to be made on a park by park basis).

3. Initially, sampling should be done in the most dominant vegetation types in specified watersheds. As the program develops and based on park interest, sampling within other watersheds could be expanded.

4. Sample plots should be set along a gradient within a watershed as changes are easiest to measure along a natural gradient.

Guidelines that need to be developed:

5. Data collection must be designed for incorporation in the GIS, and the data collection system must be the same for all parks.

6. A set of standard parameters must be measured - at a consistent scale - in all parks. (Individual parks may do additional sampling; the standard parameters will be the

required minimum.) Study plots should be recommended to non-NPS researchers, who are conducting compatible research, to build upon existing data bases.

7. Sampling must be a scale appropriate for measuring long-term trends (not so specific that local variation masks regional change and not so general that regional change is not detected).

8. Methods used should be compatible with similar activity already in place or contemplated by other agencies and/or entities. Every opportunity for productive cooperation should be taken.

Program Organization

Logistics of accomplishing the program region-wide will require a regional office coordinator. The coordinator will interact with park staff, manage the data, and prepare annual reports. Communication with park staff is necessary to ensure the studies are producing information useful for the parks and that the parks are getting the information. Data management will become a major effort as the program develops, to keep the data set current and accessible. Annual reports will provide documentation of program progress. The coordinator will also be responsible for maintaining contact with other agencies and academic groups interested in long-term data sets and in developing cooperative studies. In addition, the coordinator will assemble all data pertaining to inventory and monitoring (much of the current research on highly visible animals) and incorporate that information into a common database.

Once established, permanent plots should be sampled on a five year sampling regime. (Permanent plots should be located in more stable vegetation types.) Sampling on this interval can be scheduled so that a sampling team can cover different parks each year, returning on a five year cycle. The approach is similar to that outlined for the vegetation mapping.

The amount of sampling required to measure all permanent plots within a park could be extensive. To minimize additional burdens on the parks, a core sampling team should be organized from the regional office. The regional office coordinator and seasonal technicians could be the core working in cooperation with the parks.

Individual Park Studies

Each park has a different amount of available information, ranging from the more extensively studied Denali to the remote and little known Aniakchak. Some parks, like Denali, Bering Land Bridge, and Glacier Bay have permanent plots established. Each park must take advantage of existing information and historical data bases. Logistic constraints also vary between parks and parks with road systems (Wrangell-St. Elias, Denali) have easier access to a greater amount of the park. Consequently study sites will need to be individually tailored for each park (within the guidance presented above) to work within logistic constraints and take advantage of existing information. The Basic study design for all parks is outlined below.

Landscape Dynamics

All parks are being mapped for vegetation with the classification developed from TM imagery. This basic inventory information will be used to analyze regional patterns within parks and to compare differences between parks. The classification is based on the Viereck, et al (1986) classification developed for Alaska. The initial mapping will be used to compare vegetation class composition and compare relative abundance of class types between parks. Comparisons will be made based on the appropriate level from the Viereck classification.

Appropriate imagery will be used to document changes in the coverage of communities over time. Time sequences of images will be overlain and analyzed for boundary changes. The interval selected for study will be related to expected rates of change.

Vegetation

Vegetation sampling will follow the Noatak MAB protocol. Plots will be established using cluster sampling in each unit. Study plots will be 25m by 25m. Parameters measured for trees will include density, canopy cover by species, overall canopy cover, height, dbh, and age (from tree cores). Trees will be numbered. All plots will be mapped including tree location and deadfall. Parameters measured for shrubs will include percent cover and mean height (by species). Subplots, placed at one meter intervals along two lines of the marcoplot, will be used to measure herbaceous, graminoid lichen and moss species. Percent cover by species will be measured. Non-vascular plants (lichen and mosses) will require an expert to initially identify and develop a reference collection.

Birds

Parameters measured for birds will include community composition, density and diversity determined from study plots and presence/absence in the area determined from a general list kept of all birds seen around the study area (a "camp list"). The study plots will be mapped with the Viereck classification and the vegetation and bird locations digitized to aid development of a habitat classification.

Small mammals

A standard snap-trapping grid will be developed in each ecosystem.

Soils

Soil types in the general study area will be mapped using the SCS classification. Soil chemical analyses will follow Cox, et al (1987).

Permafrost

Permafrost depth will be measured at each vegetation plot using standard methods.

Phenology

Each park will establish one or more phenology stations to measure time of "green-up," browning, flowering and fruiting. Plants to be measured will include Eriphorium vaginatium (cottongrass), Calamagrostis canadensis (bluejoint grass), Epilobium angustifolium (fire weed), Rubus chamaemorus (cloudberry), Vaccinium uliginosum (blueberry), Salix glauca and Salix alaxensis (willow), Alnus crispa (alder), Betula nana (paper birch), Betula papyifera (paper birch), Picea glauca (white spruce) and Picea mariana (black spruce). Determination of phenology will follow Gunderson, et al (1983).

Time of freeze-up and thawing of streams and lakes will be recorded.

Weather

Weather stations will be coordinated with the fire program to take advantage of the RAWS stations. Suggested weather parameters to measure include wind, solar radiation, precipitation, snow depth, and temperature.

Individual Species

As life history information becomes available, individual species may be selected for further detailed study. Selection will be based on the following criteria:

- sensitive to predicted or expected changes
- natural variation and causes well known
- permanent resident or migrant that returns to same breeding area
- representative of a guild or community

air quality

A proposal to address air quality monitoring is required.

GEOGRAPHIC INFORMATION SYSTEM-DATA MANAGEMENT

All data will be entered in the Geographic Information System (GIS). A base structure will be developed with input from the parks. The data base will be designed such that sub-sets of the data related to a specific topic can be easily retrieved. As systems become installed in the parks, appropriate parts of the data set will be copied to their systems.

The GIS is described in detail in the attached GIS Plan.

EARTH PROCESSES

Introduction

Earth processes are prominent natural features and processes that shape, or are characteristic of park landscapes. They include orogeny or tectonic activity, weathering and erosion, glacial and fluvial processes, coastline and ocean processes, volcanic activity, mass movements, and other processes that contribute to park scenery. While many of these processes are not usually dynamic in the short-term (indeed, many are long-term events and influences) they all set the stage and shape the environment for biotic and other resources. A basic inventory will be necessary to understand their influence on, and relationship with, other park resources. A monitoring program can then be developed to focus on general or specific change, whatever it's causes.

An earth process inventory program should encompass subjects or themes in measurable and comparable data forms as is conventional in the particular subject or field. Conventional themes, in the realm of the physical sciences, may include bedrock geology, structural controls, soils, topography, volcanology, glaciology, hydrology, geothermic conditions, limnology, and perhaps many others. The choice of what to inventory and how, will be done in consultation with experts in the field of study.

A systematic and representative inventory of the many themes and subthemes can be costly endeavor and require a lot of time. In many cases, much of this information is already collected in usable or adaptable forms. In other cases the data needs and collection methodologies are not within our means in terms of equipment, logistics or cost. However, the development of a long term database is essential to monitoring park conditions and perhaps global change.

Global Climatic Change

The attempt to understand global climatic change is especially suited to some elements of earth process inventory and monitoring. Some of these earth processes, or components of them, are in fact short-term dynamic, and may be in close harmony with local climate, and thus may be reasonable indicators of climatic change. Most visible examples of these changes are often considered to be: glacial advances and recessions, lake or sea level changes, or other shoreline or coastal processes. Principally, among the physical sciences, the best probable indicators of climatic change are hydrologic parameters such as stream flows and levels, water chemistry, and sediment transport quantity and quality. Ground water condition and migration, as well as changes in the permafrost regime, may also provide indications of global climatic change. In concert with weather data, particularly temperature, precipitation and snow pack, the hydrologic processes are perhaps the first level of the indication of climate conditions.

Elements of glaciology and hydroglaciology can also be key indicators of global climate change. For many areas, Landsat or other remotely sensed data exists which may provide time views of change in percent of ice cover, glacial advances/recessions or other global effect changes. Air photos can provide similar information and some areas have more intense studies in place which may provide more accurate ice mass information or other useful data.

General Study Guidance

1. All methods need to use minimal equipment. To the extent appropriate, studies should use data from remote sensors, e.g., satellite imagery or aerial photography.

2. Biologic processes are ultimately tied to the landscape and the information is important as reference material for other studies. Ties between studies - information exchange - is important and must be actively maintained.

3. All data needs to be stored as map based information in the GIS.

4. Earth process studies need to keep a focus on predicting and evaluating ecologic change and ecologic change may affect earth processes.

Individual Park Studies

In addition to watershed studies, additional studies of characteristic of individual parks are recommended. Examples follow:

Cape Krusenstern National Monument - Coastal Erosion

Beach ridges are a prominent feature of Cape Krusenstern. Coastal resources include extensive wetlands and archaeologic deposits related to the Bering Land Bridge. Both resources would be affected by shoreline changes.

Historic data sources include USGS maps (1950), Landsat (satellite imagery) and TM imagery. Using GIS, the coastline can be mapped from these data sources and the rate of change determined.

Wrangell-St. Elias National Park and Preserve - Glacial History

Glaciers are a prominent feature of WRST. Advance and retreat of glaciers formed much of the park landscape and continues to influence the land.

Historic data sources include extensive photographic documentation of glacial progression gathered by a glaciologist at the University of Alaska, Fairbanks.

Kenai Fjords National Park - Glacial History

Glaciers and glacial processes are prominent features of Kenai Fjords. A glacial monitoring program is recommended.

Denali National Park and Preserve

Climate
Year around in park weather data exists for the headquarters area continuous since 1923. Seasonal weather stations have been placed in the Kantishna Hills and the Toklat River basin in two previous seasons. Expanded coverage for both seasonal and year-round recording stations will be researched and implemented. Snow depth and density stations will also be considered.

Hydrology
There is some existing hydrologic data (USGS) available for the Teklanika River. A gaging station was established on the river some years ago near the park boundary which may be re-utilized. Hydrologic data are being collected on the Toklat River regarding sediment transport studies. These studies are in conjunction with USGS, University of Alaska, and Alaska state water resource personnel. Increased flows and other hydrologic changes in the Teklanika or Toklat basins may be indicators for short or long-term climate change.

A water resource inventory (NPS & USGS) was begun in select streams in the Kantishna Hills in the 1989 season. Sites selected will be monitored annually. Spot data collection for water flow and quality was initiated in various streams in the park. A complete river, stream and lake inventory is planned for the future. Stream and lake conditions, once inventoried, should be good indicators of local, regional or global change.

Glaciology
An estimated 20% of the park is covered by glaciers. Information on their extent and condition is available

in satellite imagery and some air photos. Extensive to intermittent data has been collected on some glaciers in the park (i.e., Muldrow & Peters) by U of A and possibly USGS. This information will be reviewed for inventory and monitoring suitability.

One concept proposed is to establish oblique photo sites at 10 or 20 glacial termini to document changes in the ice front and meltwater conditions.

Soils, Ground water, & Permafrost
Contacts with SCS and others shall be made to determine what soils data exists. Some information may exist in GIS format. An inventory of soils (agronomic and engineering) at various detail should be implemented.

Opportunities for ground water data are highly limited because of the limited development in the park area. NPS and private wells, primarily in the headquarters area, should be inventoried and, if practicable, monitored. Ground water characteristics and chemistry are commonly used for detecting subsurface (fault) activity and other conditions.

Permafrost and variable ice rich ground has been identified in several locations in the park. Construction and engineering related investigations of ice rich and suspected ice rich ground in a few locations has resulted in some knowledge and data collection. Two test holes with thermistors are still in place near the Rock Creek water line, and if they are still operable, a ground temperature effort will be re-initiated. Data collected here may show a change in the local (site) thermal regime which may contribute to global climate assumptions.

Numerous landslides (usually mudslump mud/debris flows) exist in the park which presumably are assisted by permafrost groundwater exchange. One of the largest slumps near headquarters has been monitored for movement since 1987. The degree of movement or other parameters of the slumps may have a connection with changes in air temperatures and/or precipitation.

Additionally, contact will be made with the Geophysical Institute and others concerning permafrost data collection methodology and interpretation.

Geological
Tectonic activity (plate and microplate tectonics) is generally considered to have a major effect on local, regional or global conditions only in the very long-

term. In locations where surface expressions of that activity have catastrophically occurred (I.E., San Andreas Fault), major changes to components of the environment have also occurred catastrophically or instantaneously. Denali National Park and Preserve contains five major active faults including three of the Denali Fault system which is considered an extension of the San Andreas. The USGS currently monitors movement on a small section of the McKinley Strand of the Denali Fault system within the park. Additional monitoring of faults could be useful as change indicators.

Geophysical
Seismic (earthquake) data for the state of Alaska is currently recorded and analyzed by the Geophysical Institute. Seismic events (magnitude, depth, time & location) from 1960 to 1988 in a core area around Denali are on record at the park. This information is currently analyzed by the park staff for potential significance and interpretive purposes. At 24 events per year (greater than 3.0 magnitude) and a mean magnitude of 4.07, Denali N.P. is very seismically active.

IMPLEMENTATION

YEAR 1

Establish data management procedures

Establish reporting procedures

Inventory each park to determine:

- -literature from previous studies will be reviewed and a computer based annotated bibliography will be prepared for each park.
- -weather records, status, storage, number of stations, and recommendation on new stations will be completed.
- -air quality records will be reviewed and a study plan for air quality completed.
- -quality and completeness of soil maps
- -quality and completeness of geologic maps
- -kind, status, purpose, data location, and data quality associated with each vegetation plot
- -kind of study site, status, purpose, data location, and data quality associated with each water study
- -kind of study site, status, purpose, data location, and data quality associated with each wildlife study

-kind, quality, coverage, and location (storage) of aerial photographs and satellite images
-develop computerized species lists and range maps

Develop watershed maps

Prioritize watersheds for order of study

Document monitoring protocols

YEARS 2 ON

Implement and institutionalize monitoring

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