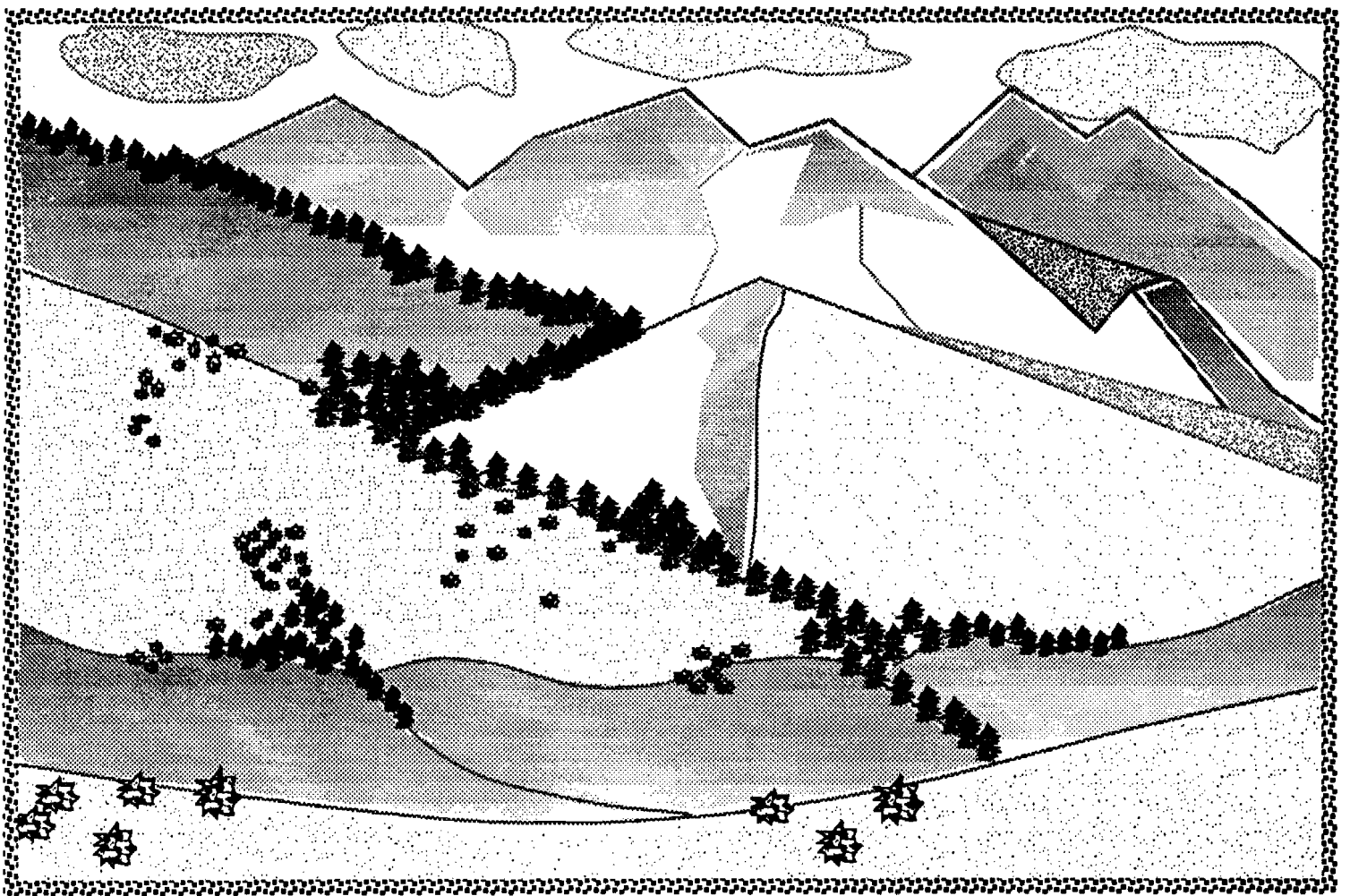


*Long Term
Ecological Monitoring
at
Craters of the Moon National Monument*



Introduction

Craters of the Moon National Monument (CRMO) is situated on the northern edge of the Snake River Basin (SRB) in southern Idaho and is part of the larger Great Basin Province (Fig. 1). The SRB is a broad high elevation semi-arid plateau bounded by the Snake River to the south and east and by extensions of the Rocky Mountains to the north. The 21,669 ha monument contains geologically recent cinder cones, lava flows, and other volcanic features set in a complex matrix of mixed shrub and grasslands interspersed with stands of limber pine. The northern portion of the monument contains two small streams and their associated riparian zones which are unique because of their pristine condition and the fact that the entire drainage lies within the borders of the monument. Many kipukas, or small islands which have been free of volcanic flows exist throughout the SRB as serve as remnant and pristine examples of native-ungrazed vegetation. The largest of these, Carey Kipuka is now a designated Research Natural Area.

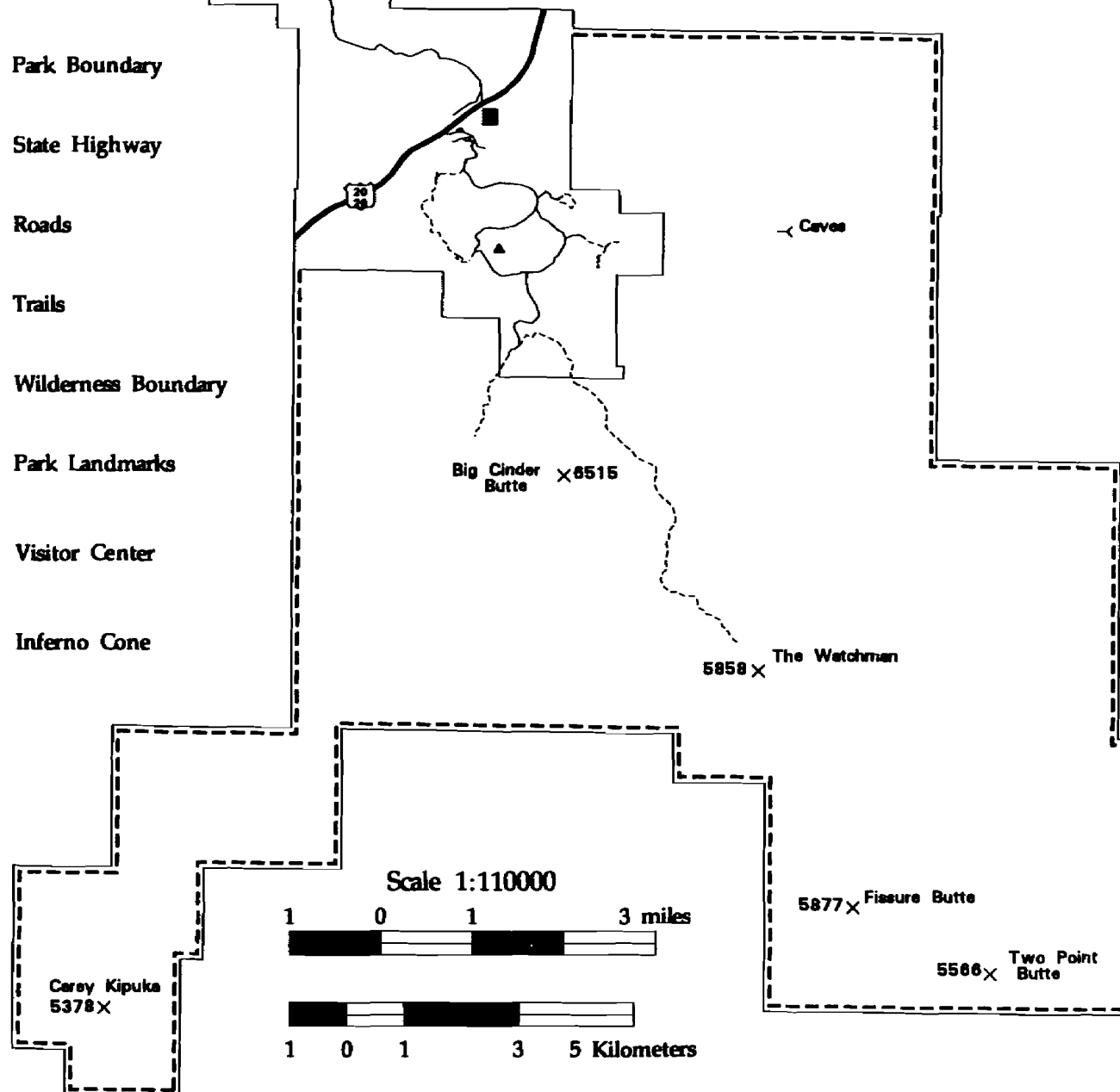
1. Recognized Management Need

Historically, research, inventory, and monitoring (RI&M) at CRMO, as in most parks, was subject specific - primarily driven by the need to deal with specific environmental or management problems. However, over the past decade, CRMO has broadened the

Craters of the Moon National Monument

Figure 1

-  Park Boundary
-  State Highway
-  Roads
-  Trails
-  Wilderness Boundary
-  Park Landmarks
-  Visitor Center
-  Inferno Cone



scope of its RI&M programs to include all aspects of the ecosystem. The current program is driven as much by the need to fill in gaps in basic ecological knowledge of the area as by the need to deal with specific management problems. This program has been primarily supported by the NPS through the University of Idaho Cooperative Park Studies Unit (UICPSU). This unit is being absorbed into the National Biological Survey (NBS) on October 1, 1993, and it is anticipated that it will continue to serve the RI&M needs of CRMO.

The current RI&M program is guided by the monument's Resource Management Plan (see Appendix), the NPS Natural Resource Inventory and Monitoring Guidelines (NPS-75), and the conceptual model shown in Figure 2. One of the initial assumptions of this model was that because parks like CRMO generally had little experience with large-scale monitoring programs, the programs and the support for them should be developed incrementally. As a consequence, the approach advocated that programs should start by collecting the most basic information and only expand as experience was gained (Quinn and van Riper 1990, Wright 1993). One of the first accomplishments at CRMO was the completion of a computerized resource database which located and summarized the results of all park and regional resource studies (Sparhawk and Wright 1990). This project was undertaken in part to help identify pertinent resource data that would be useful for incorporating in monitoring programs and thus to help avoid redundant data collection efforts.

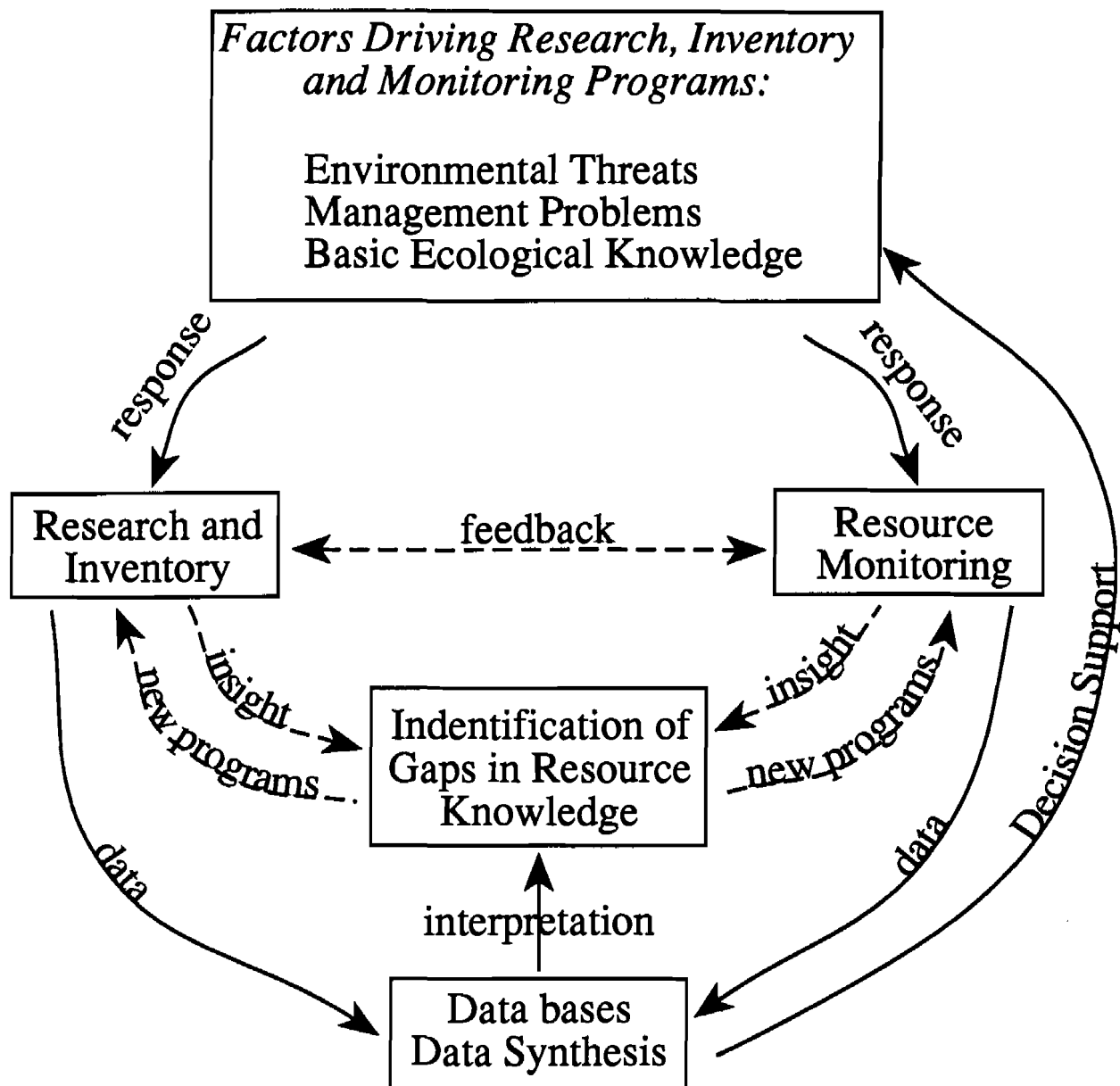


Figure 2. A conceptual model for the CRMO Monitoring Plan

2. Status of Inventory

CRMO has one of the most complete resource inventories of any unit in the national park system and has compiled the Phase I Inventory Database. One measure of the emphasis that has been devoted to completing the natural resource inventory at CRMO is seen in the listing of the number of studies that have been conducted in the monument and on adjacent lands. This list (Table 1) shows both the diversity of studies which have been carried out in the SRB and the level of effort that has been given to the various resources. Synthesis of these studies by Blakesley and Wright 1988) (Table 2) was the basis for assessing the level of knowledge relative to the different resources at CRMO. Additional inventory work is underway or planned to fill in the gaps identified in this table.

3. Program Readiness

The high degree of resource knowledge already accumulated at CRMO and on surrounding lands, combined with the high levels of park, regional, and external agency support described elsewhere in this proposal are positive indications that CRMO can initiate a successful broad-based monitoring program. A list of applicable cooperative agreements is found in Appendix II. One measure of CRMO's ability to conduct a large prototype monitoring program is evidenced by the breadth of its existing long-term

monitoring programs which are summarized in Appendix I. Many of these programs have been initiated in cooperation with other land and resource management agencies in Idaho. The experience gained in running these programs as well as the support provided by the park in terms of FTE's, project funding, logistical support, previous technical direction and funding through the UICPSU, and anticipated support through the NBS cooperative units both at the University of Idaho and Oregon State University (OSUCPSU) all provide good indicators that CRMO can successfully manage an expanded monitoring program. While it contains a diversity of resources, CRMO is still a small park. All of the monitoring sites - existing and proposed - are easily and quickly accessible. Unlike many parks CRMO is not beset by any onerous resource management issues which can dominate staff time and diminish the focus devoted to monitoring. Both of these factors will enable CRMO to rapidly enact specific elements of the plan.

4. Monitoring Program Design

Program Objectives

The importance of clearly defining the objectives of a monitoring program have been stressed by many authors (Goldsmith 1991, Silsbee and Peterson 1991). Clear objectives help define all aspects of a program including the choice of attributes to be monitored. The most commonly stated objective for NPS programs is to generate information that will help managers make better informed management decisions (Quinn and van Riper 1990). The

Table 1. Summary of the major types of resource studies at CRMO and on adjacent lands (from Sparhawk and Wright 1990).

<u>Resource Studied</u>	<u>Number of Studies</u>
1. FAUNA	
terrestrial invertebrates	13
reptiles and amphibians	6
birds	39
mammals	49
2. FLORA	
general description, habitat quality,	78
limber pine ecology and growth	9
plant succession	8
shrub ecology and habitat	13
grasses	6
lichens	7
3. GEOLOGY	
geologic characteristics and description	194
geologic processes	96
minerals	39
landscape features and landforms	29
soils	8
4. HYDROLOGIC FEATURES	
hydrology description and characteristics	18
water quality	9
5. ATMOSPHERIC AND METEOROLOGICAL	
general descriptive	37
air quality, climate and weather	38

Table 2. A qualitative assessment of the knowledge of various resource categories at CRMO (based on Blakesley and Wright 1988).

<u>Subject of Study</u>	<u>Degree of Completeness</u>										
	10	20	30	40	50	60	70	80	90	100	
GEOLOGY											
General Description	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX										
Geologic History	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX										
Substrate Composition	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX										
Cave Resources	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX										
FLORA											
Description	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX										
Species List	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX										
SUCCESSION											
Volcanic Areas	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX										
Other Areas	XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX										
Community Ecology	XXXXXXXXXXXXXXXXXXXXXXXXXXXX										
Fire History	XXXXXXXXXXXXXXXXXXXX										
Fire Effects	XXXXXXXXXXXX										
FAUNA											
Invertebrates	XXXXXX										
Reptiles	XX										
Birds	XXXXXXXXXXXXXXXXXXXXXXXXXXXX										
Mammals	XXXXXXXXXXXX										
AIR QUALITY											
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX											
WATER QUALITY											
XXXXXXXXXXXXXXXXXXXXXXXXXXXX											
SOILS											
XXXXXX											
CLIMATE											
XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX											
ARCHEOLOGY											
XXXXXXXXXXXXXXXXXXXX											

objectives of this program are, in part, based on this premise. A related objective is to document threats or the effects of activities outside the park. The objectives and the monitoring elements chosen also reflect these concerns. Finally, some authors have suggested that monitoring programs are important simply to document changes just for the sake of familiarity with the resources, to gain insights into how the ecosystem works, or to provide a reference point to which less pristine areas can be compared (Croze 1982, Silsbee and Peterson 1993). The objectives of the proposed program also reflect this intent. The broad objectives of this program are then to:

1. Detect the ecological effects of long-term environmental change and quantify trends associated with changes in climate, air quality, land use, and other factors on the resources and ecological processes in the SRB.
2. Detect changes and quantify trends in resource condition and ecological processes within and outside the monument which are associated with human use and management decisions.

Development of the Individual Elements of the Program

Guided by these objectives, the individual elements of the monitoring program are designed to address the three primary attributes of ecosystems; composition, structure, and process. Most park monitoring programs have typically addressed only ecosystem composition, focusing for example on the identification, number, and biomass of a particular species group while ignoring the complexity of habitats or topographic features that embody the structure - or the ecological processes that make

the ecosystem work. As a result, the traditional monitoring approaches may not detect losses of ecosystem structure or the disruption of fundamental ecological processes (Noss 1990). The proposed program therefore incorporates elements designed to monitor composition, structure, and process.

The individual elements of the monitoring program also incorporate different scales of space and time. For example, some ecological factors can only be understood by looking at broad landscapes, while other factors require intensive micro-site studies. The selection of the specific elements of the monitoring program, some representing individual organisms at a specific site, others representing communities of organisms at a landscape level are designed to address spatial concerns. Equivalently changes in some ecological phenomena can only be witnessed over long time intervals while others may change relatively quickly (Magnuson 1990). The selection of elements was therefore also designed to look at ecosystem changes which occur at various time scales. The program also recognizes that there are broadly three kinds of intrinsic changes which can occur in ecosystems: stochastic, successional and cyclical (Hellawell 1991). The program has tried to anticipate how the various resources in the ecoregion are affected by these types of changes and the individual elements have been chosen accordingly.

The monitoring program offered in this proposal is realistic in its goals and expectations. The program is based on the fundamental precept that no monitoring program can monitor

everything and that monitoring is cheaper, easier, and ultimately more successful when the techniques are simple to use and when they focus on specific components of the ecosystem. Techniques which are easy to use facilitate the collection, analysis, and interpretation of data, and lessen the problems associated with handing over program responsibility to subordinates. The latter is important in parks because as a long-term exercise, monitoring frequently involves many different people, each possibly only for a few years (Usher 1991).

The proposed program has 24 individual elements. As described above, a variety of factors influenced the choice of these elements. The elements were chosen to monitor the three specific characteristics of ecosystems as well as to incorporate different spatial and temporal scales (Tables 3, 4, and 5). All of the elements chosen are sufficiently sensitive to different environmental perturbations such that they can provide an early warning system. We chose elements that are easy and cost-effective to measure, analyze, and interpret. As a result, we did not include some factors in the program because they were difficult to measure or where the results of monitoring could have a high variance thus making it difficult to identify a significant change. We also selected elements tied into other agency monitoring programs or elements from which the data could be extrapolated to areas outside the monument. Finally, we chosen elements that were capable of providing information useful to management or which met an existing management need.

Table 3. Program elements proposed for monitoring ecosystem changes detectable at various time scales and at sites of different sizes.

CHANGES IN ECOSYSTEM COMPOSITION	
SIZE SCALE EXTENSIVE (REGIONAL) ----- INTENSIVE (PARK)	1) plant community distribution
	2) raptor numbers
	3) lagomorph #'s
	4) sage grouse numbers
	5) reptile numbers
	6) T&E species (Townsend's l.e. Bat) (blind cave beetle)
	7) mule deer
	8) climate measures
	9) air quality a) lichens
	10 neo-tropical birds
	11) plant species composition
	12) exotic plant species invasion
	13) water quality & quantity
Annual Decade Multiple Decades Time Scale at which Change can be Detected	

Table 4. Program elements proposed for monitoring ecosystem changes detectable at various time scales and at sites of different sizes.

SIZE SCALE INTENSIVE (PARK) ←-----→ EXTENSIVE	CHANGES IN ECOSYSTEM PROCESS		
		14) natural erosion & soil devel.	
		15) eruptive cycles	
	16) fire	17) plant succession	
	18) human disturbance		
	19) parasitism & disease		
	Annual	Decade	Multiple Decades
Time Scale for Change Detection			

Table 5. Program elements proposed for monitoring ecosystem changes detectable at various time scales and at sites of different sizes.

SIZE SCALE INTENSIVE (PARK) ←-----→ EXTENSIVE (REGIONAL)	CHANGES IN ECOSYSTEM STRUCTURE		
		20) land-use changes	
		21) changes in geologic landforms	
		22) changes in plant community patterns	
	23) cave structure & disturbance		
	24) riparian zone structure & disturb.		
	Annual	Decade	Multiple Decades
Time Scale for Change Detection			

The methods, i.e., the type of measure and units of analysis employed for each element of the program are described in Table 6. As indicated in NPS-75, there are no universal "off the shelf" technologies available to assess ecosystems. Thus the development of monitoring protocols may be an experimental endeavor. We attempted to minimize the experimental component of this program by relying as much as possible on proven techniques, many of which are specific to arid lands in the SRB, and all of which have extensive support in the scientific literature.

5. Scientific Credibility and Capability

The existing resource management program at CRMO is directed through a separate resource management division that reports directly to the Superintendent. This division includes a resource management specialist, biological technician, and a seasonal ranger. The UICPSU which has long supported the RI&M program at CRMO has two senior research scientists who will be transferring to the NBS in October 1993. This unit employs two full-time and four part-time research associates who have expertise to contribute to the project. Program support will also come from the existing NPS Cooperative Unit and the BLM Pacific Forest and Basin Rangeland Systems Cooperative Unit (PFBRSC) at Oregon State University. Staff of these units will also be joining NBS in October. The Idaho National Engineering Research Laboratory (INEL) which is part of the Department of

Energy and with which CRMO maintains cooperative agreements, supports a National Research Park and a large staff of scientists. This organization has been instrumental in helping to organize and fund several existing monitoring programs (Appendix I.) and will play a role in the execution of the proposed program. Individuals from these and several other organizations were instrumental in developing this proposal and helping to assure the objectives and standards of the program were logical, realistic, and clearly stated.

A technical review committee comprising staff from the above mentioned organizations will be established to guide the overall monitoring program. Participants will include:

- a) resource management specialist, CRMO
- b) Unit Leader, UICPSU (NBS)
- c) Unit Leader, OSUCPSU (NBS)
- d) Unit Leader BLM PFBRSC (NBS)
- e) principal biological scientist, INEL
- f) Shoshone District resource biologist, BLM
- g) district biologist, Idaho Fish and Game Dept.

The responsibility of the committee will be to assure sampling and analytical protocols are established and met, that the program is fully integrated into existing regional programs, and that it meets the needs of all management agencies in the region. Day to day program administration will be handled by a resource manager at CRMO and a full-time research associate employed through the UICPSU. Both are new positions and are listed in the budget. Their responsibilities will be to handle all sub-contracts, i.e., establishing specific monitoring protocols and writing of the handbooks, hiring and supervising

Table 6. Methods (measures and analysis), reference, and interval of measurement for proposed monitoring activities. (Activity numbers correspond to those in Tables 4, 5 & 6; reference numbers correspond to those in lit cited).

MONITORING ACTIVITIES	METHODS (REFERENCE #)	TIME INTERVAL
1) plant community distribution ¹	comparative analysis using GIS scanned images and photo interpretation from defined photo-points (Appendix) (53)	5 years
2) raptor numbers	population abundance indices from counts along established road transects using Ferruginous hawk as indicator sp. (4, 7)	May 2 weeks each year
3) lagomorphs	index of relative abundance; from evening spot-light road transects using black-tailed jackrabbit as indicator (14)	2 weeks each year
4) sage grouse population trends	population trend indices at on known breeding leks using sage grouse as indicator (23)	May; 10 days each year
5) reptile species trends	population censuses obtained from representative pitfall traps and drift fences (Appendix) (18, 5); sagebrush lizard as indicator	2 weeks year
6) T&E species	population censuses using harp-type bat traps situated in selected cave openings; and beetle pit traps to obtain data on density, population trend, & composition (15, 45)	2 weeks each year
7) mule deer ¹	observations along an established road transect (17, 8), and in known fawning areas.	1 week August & Sept. 1 week June
8) climate ¹	standard Class I measures (8)	daily

¹ Extensions of existing monitoring programs

Table 6. Continued

MONITORING ACTIVITIES	MEASUREMENTS (REFERENCE #)	TIME INTERVAL
9) air quality ¹	atmospheric particulates using high-volume gravimetric sampler, visibility use teleradiometer, acid deposition according to NADP standards, radionuclides using particulate beta activity & antimony levels (8)	daily
a) lichens	established plots in transects on rock out-crops & limber pine stands; abundance, composition, and pollution measures using scanning electron microscopy & X-ray energy dispersal analysis (34)	1 week a year
10) neo-tropical birds ¹	Indices of abundance & trend gained through station index techniques at 2 sampling stations in each of 17 vegetation types (8,20,29)	June 2 weeks/yr
11) plant species ¹ composition	100 1-meter plots along established transects measuring frequency of grass species & shrub basal area (8, 41)	rotating basis: 2 weeks, 2-3 years
12) exotic plant species ¹	plant community composition on Carey Kipuka using techniques as in # 14 (44, 8)	rotating 2 weeks; 2 years
13) water quality and quantity ¹	changes in nutrient, chemical composition, and flow of Little Cottonwood Creek (monument) & Big Cottonwood Creeks (BLM) (13)	June 1 year
14) natural erosion & soil development	network of established erosion-pins at sensitive sites (27); changes in soil depth at specific sites on newer lava flows using soil-depth pins (27)	2 years every 5 years
15) eruptive cycles	comparative analysis of periodic TM images (26) and continuation of seismic monitoring program	10 years or as needed

Table 6. Continued

MONITORING ACTIVITIES	MEASUREMENTS (REFERENCE #)	TIME INTERVAL
16) fire	frequency & extent of burns using aerial photos and GIS	5 years or as needed
a) vegetation response ¹	comparative analysis of burned plots on ungrazed (CRMO) land & grazed (BLM) plots using plant composition frequency (8)	2 weeks each year
17) plant succession ¹	comparative analysis of existing photo points (53); stem mapping plots of limber pine on cinder cones (51); changes in cinder cone/herbaceous plants (11,12)	5 years
18) human disturbance	erosion-pin transects & laser survey profiles of Inferno Cone; photo-point analysis of visitor disturbance of spatter cones (8)	2-3 years
19) parasitism & disease	abundance of dwarf mistletoe along established quadrats in limber pine stands (46) Collect blood tissue samples from road-killed m. deer & small mammals; test for presence of antibodies against selected pathogens of humans, wildlife, & domestic animals (1)	5 years opportunistic
20) land-use changes	GAP analysis of vegetation continuity; SNB TM images (38)	5 years
21) changes in geologic land forms & lava flows	TM, radiometry, and side-looking radar (30,37,48) infrared aerial photos, & comparative GIS analysis	10 years
22) plant community patterns	1:12000 aerial photos, comparative GIS analysis, fractal analysis (6)	5 years
23) cave structure and disturbance	comparative analysis of visitor use impacts and hazards using videographic methods; measures of radon 222 (9); abundance of lava tube beetles (35) in 5 caves with visitor use and 5 closed caves	rotating 2 weeks each year

Table 6. Continued

MONITORING ACTIVITIES	MEASUREMENTS (REFERENCE #)	TIME INTERVAL
24) riparian zone structure & disturbance	comparative analysis of the riparian zones of Little Cottonwood Cr. (CRMO) & Big Cottonwood Cr. (BLM). One ungrazed, one grazed. Both totally enclosed watersheds	

staff needed to test and carry out the individual programs, assuring that data archival and analysis protocols are met, and producing an annual report.

6. Budget and Cost Effectiveness

This program is cost effective because it builds on several existing monitoring programs. It incorporates the expertise and analytical capabilities from the staff already in place at the University of Idaho NPS-NBS Cooperative Unit, at the Cooperative Unit at Oregon State University, and at the monument. The program has access to a large array of computer hardware which is already in place. As a result, no computer hardware is included in the budget. The program also draws on the resources and the staff of several surrounding land and resource management agencies. Finally, the lack of logistic complexities at CRMO and on surrounding lands, i.e., there is no need for helicopter time or the establishment and equipping of back-country facilities, all reduce costs.

The total costs for the proposed program are summarized in Table 7. over a five-year period. Following this table is a three-page chart which shows the costs associated with each

element of the monitoring program over the five years.

Table 7. BUDGET

Category	<u>Funds Requested</u>				
	year 1	year 2	year 3	year 4	year 5
Salary					
GS-11 Biologist	48,500	49,955	51,455	52,998	54,587
GS-9 Research Associate (1/2 time)	16,000	16,480	16,975	17,483	18,008
Benefits (36%)	17,460	17,984	18,524	19,079	19,651
Benefits (36%)	5,760	5,932	6,110	6,294	6,483
Project Funds (From Attached)					
SOP Devel.	9,550				
Bio-Techs	24,200	27,300	27,300	25,000	27,300
Lab. Anal.	4,850	5,450	4,850	5,450	3,950
Equipment & aerial photos	3,800	21,200			
Travel	9,500	10,500	9,500	10,500	10,500
Project Vehicle	4,000	4,000	4,000	4,000	4,000
Miscellaneous	6,500	3,000	3,000	3,000	3,000
Report Production Supplies					
SubTotal	150,040	161,801	141,734	143,805	147,478
Overhead (15%)	22,508	24,270	21,260	21,570	22,122
Total	172,548	186,071	162,994	165,375	169,600
Grand Total:	\$856,588				

Project (#) Element	Tasks	Funds Year 1	Funds Year 2	Funds Year 3	Funds Year 4	Funds Yr 5
Plant Community Distrib. (1)	SOP Bio-Tech Scanner	0 1,200	1,200 1,800	1,200	1,200	1,200
Raptor Numbers (2)	SOP Bio-Tech	1,000 1,200	1,200	1,200	1,200	1,200
Logomorphs (3)	SOP Bio-Tech	750 1,200	1,200	1,200	1,200	1,200
Sage Grouse population trends (4)	SOP Bio-Tech	700 1,600	1,600	1,600	1,600	1,600
Reptiles trends (5)	SOP Bio-Tech Equipmt	1,100 1,600 1,300	1,600	1,600	1,600	1,600
T&E Species (6)	SOP Bio-Tech Traps	500 1,600	1,600 2,500	1,600	1,600	1,600
Mule deer population trends (7)	SOP Bio-Tech	0 800	800	800	800	800
Climate (8)	SOP Bio-Tech	0 0				
Air Quality (9) Lichen Trends (9a)	SOP Bio-Tech SOP Biolog. Lab Anal	0 0 1,100 1,500 1,000	1,500 1,000	1,500 1,000	1,500 1,000	1,500 1,000
Neo- Tropical Birds (10)	SOP Bio-Tech	0 2,400	2,400	2,400	2,400	2,400
Plant Sp. Composition (11)	SOP Bio-Tech	0 1,200	1,200	1,200	1,200	1,200
Exotic Pl. Plant (12) Species	SOP Bio-Tech	0 1,200	1,200	1,200	1,200	1,200

Project (#) Element	Tasks	Funds Year 1	Funds Year 2	Funds Year 3	Funds Year 4	Funds Yr 5
Water Quality & Quantity (13)	SOP Bio-Tech Lab Anal	0 800 950	800 950	800 950	800 950	800 950
Natural erosion & soil Devel. (14)	SOP Bio-Tech Equip	0	1,200 1,100	1,200	1,200	1,200
Eruptive Cycles (15)	SOP Bio-Tech TM imag. GIS anal	0	900	900 2,500	900 2,100	900
Fire & Vegetation Response (16)	SOP Bio-Tech Aerial photos	0 1,600	1,600 2,500	1,600	1,600 2,500	1,600
Plant Succession (17)	SOP Bio-Tech	0 1,200	1,200	1,200	1,200	1,200
Human Disturbance (18)	SOP Bio-Tech	1,200	800	800	800	800
Parasitism & Disease (19)	SOP Bio-Tech Lab Anal	2,400 1,200 2,000	1,200 2,000	1,200 2,000	1,200 2,000	1,200 2,000
Land-use Change (20)	SOP Bio-Tech GIS	0 1,200	1,200 1,500	1,200	1,500	1,200
Geological landforms and lava flows (21)	SOP TM imag. GIS Anal Radiomet	0		2,000 2,200		

Project (#) Element	Tasks	Funds Year 1	Funds Year 2	Funds Year 3	Funds Year 4	Funds Yr 5
Plant Community Patterns (22)	SOP Aerial photos GPS rec. Bio-Tech	700	6,500 6,800 1,100	1,100		1,100
Cave structure & disturb. (23)	SOP radon analysis video- equip. Tech	0 900 1,400 1,100	1,100	900 1,100	1,100	1,100
Riparian Zone Analysis (24)	SOP Sampling Equip. Bio-Tech	1,200 1,100 1,600	1,600	1,600	1,600	1,600

7. Service-wide or Multi-park Applicability

The CRMO monitoring program has a strong conceptual foundation. It emphasizes the measurement of the fundamental properties of an ecosystem and embodies both spatial and temporal scales. This approach, which is unique among most monitoring strategies, is worthy of testing and should have broad applicability to all parks in the national park system.

The specific elements of the monitoring plan were chosen in part because they were applicable to all arid lands. Therefore this proposal will provide support and guidance for the development of monitoring programs in other parks, monuments, and resource areas on the SRB, e.g., HAFO, CIRO, INEL, Snake River Birds of Prey, the Columbia and Great Basin region, e.g., WHMI, LABE, GRBA, and WHSA, as well as several arid land parks in Arizona and southern Utah.

8. Park Infrastructure and Organizational Structure

The Monument currently has a separate resource management division that reports directly to the Superintendent. The division is headed by a GS-401-9/2 resource management specialist. Other members of the division include a GS-404-7/4 biological technician, and a GS-025-4/1 seasonal ranger.

9. Data Management Plan

Data Management

An effective data management plan is an integral part of the

CRMO monitoring program. The CRMO data management plan is designed to assure that field data are accurately recorded, archived and available for use in analyses. The UICPSU has in the past managed most of the research and monitoring data that have been produced at CRMO and well as in several other parks in the region, and has developed protocols which address these needs. We anticipate that the incorporation of this unit into the NBS will only expand this responsibility. As an example of the UICPSU's expertise in data management, it has, over the past five years, developed and managed the largest basic resource database in the NPS (Wright 1993). This program is now being proposed as a prototype for the rest of the system.

In order to provide control and assure quality data collection, a series of handbooks (i.e., standard operating procedures) (SOP's) will be written for each of the monitoring programs prior to their initiation. Patterned after those that have been written for existing CRMO monitoring programs (e.g., Griffith 1984), these SOPs will provide explicit guidance on how, when, and where to collect data, appropriate analytical techniques, and proper archival procedures. The SOPs are designed to institutionalize the specific monitoring programs and provide consistency in the collection and analysis of data, especially when the field work is carried out by different technicians over the years. The SOPs will be written by specialists for the given technique and reviewed as necessary by statisticians. In some cases, the procedures may require pilot

studies or an analysis of existing data in order to work out the best sampling intensity, plot sizes, and other details.

Procedures for storing, archiving, and securing data are well established at the UICPSU GIS Lab. This lab has a large array of data storage devices including a read/write optical disk system, four cd-roms, three 8 mm tape drives, three 5 giga-byte harddrives, and one 9-track tape drive. We will also tie the CRMO project into computer networks available through the lab in order to facilitate data transfer among other agencies. These systems make the data broadly available in a virtually every type of medium.

Data Analysis

A major goal of monitoring is to detect and quantify changes in natural systems and to determine statistically what that causality is. Therefore a principal objective of the quality assurance/quality control components of the monitoring program is the production of accurate and precise data. Three factors influence the accuracy of monitoring data: trend, cycles and noise (West 1986). Analytical procedures will be established for each element of the monitoring program to identify and characterize the magnitude of these factors.

It is important to undertake early statistical analysis of the data collected from each of the elements in order to assure the level of accuracy is acceptable and the precision is adequate. For example, to determine the proper sampling frequency

for some elements we will explore the use of Bayesian statistics (Jameson 1985), a technique which allows one to estimate the number of samples that must be made and how often samples must be taken to maintain a predefined level of variance in the data. Time series analysis and simple correlation analysis will be used to describe changes in the data through time and these results can in turn be used in predictive models showing how the factors measured will change in the future.

The development of new models and the incorporation of existing models such as those which help define habitat suitability and evaluation will be an important part of the overall monitoring program. Such models can provide predictive capabilities and are powerful mechanisms with which to interpret the results of specific program elements, particularly those in which the finds are counter-intuitive to what is expected.

Finally, all monitoring and analysis routines will be structured to conform with existing national and regional schemes such as the national breeding bird atlas (Laughlin et al. 1982) and programs to monitor specific indicator species that are currently conducted by the Fish and Wildlife Service (Tate 1986).

10. GIS Support and Integration

As indicated in the methods (Table 6) GIS technology will be widely employed in the project. In the past, CRMO has relied on the UICPSU GIS lab which has served as the regional technical center for its GIS support. This fully equipped lab has three

Sun Sparc-10 workstations, 20 gigabytes of mass storage, input/output devices, and is supported by ARC-INFO, GRASS, ERDAS, IDRISI, and ATLAS GIS software. CRMO also has its own GIS workstation with mass storage and ARC-INFO and ARC-CAD software.

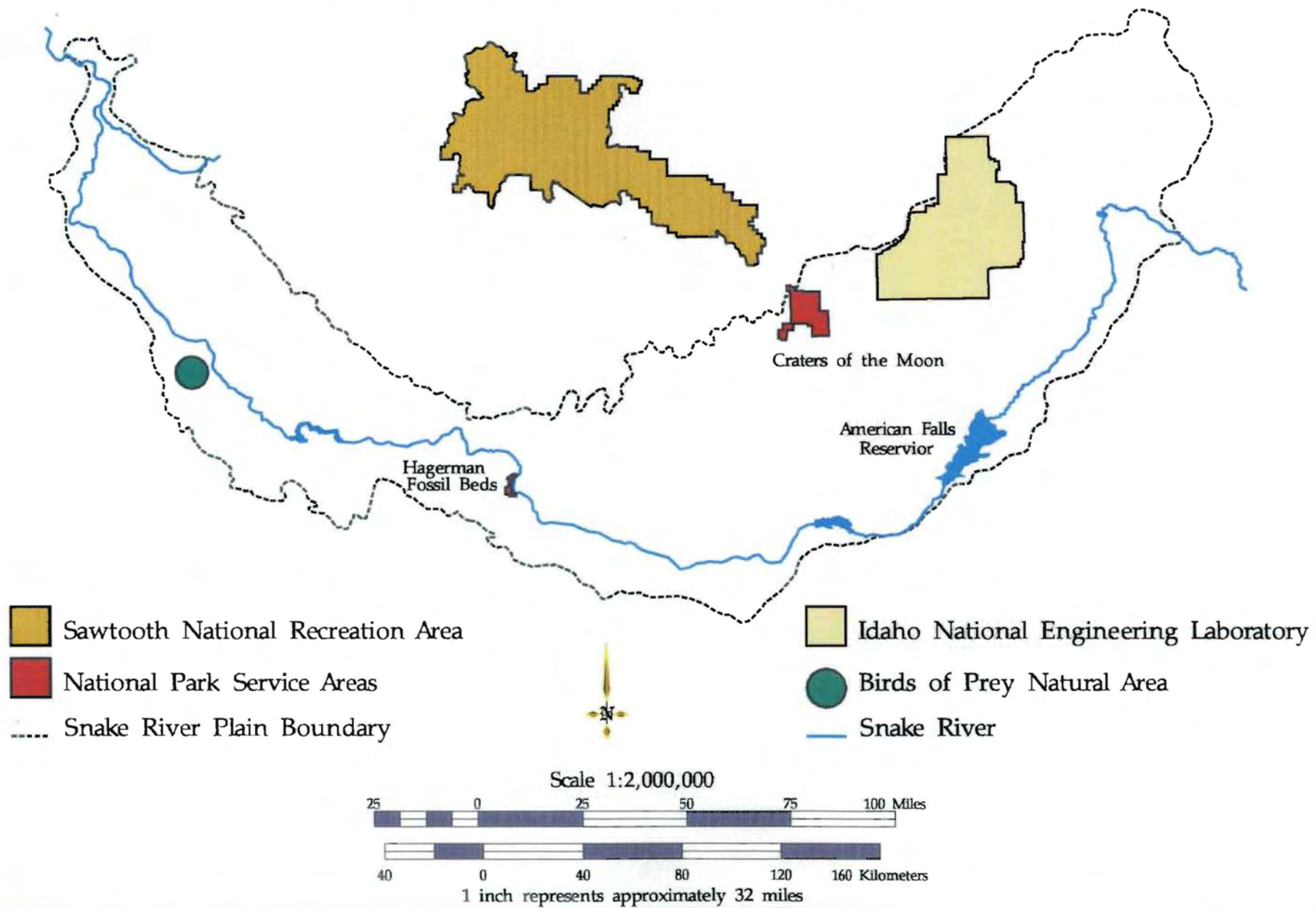
The baseline GIS for CRMO is virtually complete. Map themes, all at the 1:24,000 scale, include:

- a) park boundary, roads, trails, facilities
- b) existing vegetation
- c) geology, landforms
- d) lava flow distribution and ages
- e) elevation, aspect, slope (DEM)
- f) hydrology
- g) cave location and type
- h) archeological sites
- i) proposed park expansion boundary

11. Linkage and Leveraging

CRMO is situated amid a matrix of federal lands managed by the Bureau of Land Management (BLM) and the Department of Energy as the Idaho National Engineering Lab (INEL). The continuity of landforms, geologic structure, and plant communities have defined the SRB as a distinct "Ecoregion" (Fig. 3). (Omernik 1986). Approximately 350,000 ha of BLM lands surrounding the monument have been either recommended as wilderness or are wilderness study areas. Approximately 206,000 ha to the east and south of the monument have been proposed as the "Craters of the Moon National Park and Preserve" (Wright et al. 1993). An NPS study of the proposed expansion (NPS 1989) recognized the significance, feasibility, and suitability of these lands to be a part of the national park system but concluded they could be protected equally well under existing BLM management. The

Parks, Monuments, and Reserves on the Snake River Plain



important factor this study showed was that many of the lands outside the monument have resources equal in value to those within the monument.

From the start, this proposal was conceived as a regional (or eco-regional) plan. The concept of intensive monitoring on sites located within the existing monument complemented by extensive monitoring efforts on sites located throughout the SRB ecoregion was designed to take advantage of using CRMO as a control area for a large ecoregion.

12. Reporting System

One of the main responsibilities of this program will be to assure that the results of each of the individual programs are fully documented and reported. We envision a yearly report on the program that will summarize the findings and trends indicated by each of the monitoring elements. Because CRMO would be selected as a prototype park, this report will be written as much to serve as a guide for the other parks to learn from as it is to report on the given years' program.

The initial set of publications from this program will be a set of monitoring protocols (SOPs) for each of the 24 program elements.

13. Park Threats

The primary environmental threats to the integrity of CRMO and the SRB are air quality degradation from activities at INEL

and industrial sites in Pocatello, Idaho, human-use disturbances, changes in water quality outside the monument due to the effects of past mining activities and grazing. Other threats are occasional cattle trespass from neighboring allotments, gold mining (leach operations) on neighboring lands, exotic plant species invasions, deer poaching, and visitor impacts to geologic and cave resources. Several elements of the monument's current monitoring program that are already in place or which were developed in this proposal address these specific threats.

In many ways however, CRMO is not a park which is threatened by very many environmental problems. We are convinced that this situation lends strength to the proposed program. Rather than be sidled with the need to develop a program which contains specific elements needed to address different environmental threats, the situation has allowed us instead to develop a program which can look at all facets of the ecosystem.

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Appendix I. Existing Monitoring Programs at CRMO.

GEOLOGY

1. Seismicity

Components Monitored: Seismic activity along the Great Rift, monitored in the northern end of the monument.

Length of Program: Constant, with permanent station installed in 1992.

Comments: Sampling equipment loaned from INEL and incorporated in USGS Snake River Plain Seismic Activity Network.

2. Cave Monitoring

Components Monitored: Degradation of geologic features, abundance of Townsends long-eared bat, general cave features.

Length of Program: Begun in 1993 at CRMO, similar programs underway at caves on INEL.

Comments: Program carried out in cooperation with INEL and Idaho State University.

FLORA

3. Browse and vegetation composition

Components Monitored: Frequency of grasses and forbs, basal area and stem lengths of shrubs along established transects in known mule deer use areas.

Length of Program: Since 1984, every 2 years

4. Vegetation Change

Components Monitored: Plant density and fragmentation as observed from established photopoints.

Length of Program: Since 1986; every 5 years (see enclosed map of photopoints.

Appendix I. Continued

5 Limber Pine Succession

Components Monitored: Numbers and spatial patterns of limber pine in established 10 x 10 m stem plots.

Length of Program: Since 1985, every 5 years

PROCESSES

6 Fire and Fire Effects

Components Monitored: Vegetation trends on burned grass and shrublands using frequency (presence) of grasses and forbs and basal area of shrubs along established 100 m transects with exclosures in recent burn. Comparative study of fire effects in grazed and ungrazed burned areas at Laidlaw Park (BLM) and Little Prairie (CMRO)

Length of Program: Vegetation trends since 1984 on eight sites, each sampled every 3 years; comparative study since 1991.

FAUNA

7. Mule Deer

Components Monitored: Mule deer numbers, sex, and age class (fawn, yearling, adult) in the fall; spring over-winter survival (#'s of yearlings)

Length of Program: Since 1982; once a year one week in August and September; spring counts one week in June.

Comments: Results are used by Idaho Game and Fish Dept. to help assess regional harvest levels.

8. Neo-tropical Birds

Components Monitored: Presence/absence of all passerine species defined sampling locations in each of 17 vegetation types.

Length of Program: Since 1985; yearly 2 months in spring

Appendix I Continued

AIR QUALITY

9. Visibility

Components Monitored: atmospheric visibility using
teleradiometer and 35 mm camera

Length of Program: Since 1982; daily sampling

Comments: INEL has helped fund a variety of monitoring programs
that are located at the Monument. Cooperative ventures
include monitoring for radionuclides and particulates.

10. Atmospheric Particulates

Components Monitored: total suspected particulates using a hi-
volume gravimetric sampler

Length of Program: Since 1974; 2 days/week

Comments: Program run in cooperation with Idaho Air Quality
Bureau

11. Ozone Concentration

Components Monitored: daily ozone concentration and incident
solar radiation.

Length of Program: Since 1992; daily

12 Acid Deposition

Components Monitored: pH according to protocols of NADP program

Length of Program: Since 1980, daily

Comments: Operating in a joint effort with the BLM Idaho State
Office

13. Radionuclides

Components Monitored: Environmental radiation exposures,
particulate beta activity, antimony, from
two sites, one operated by State Dept.
Environ. Qual, second by INEL.

Length of Program: Since 1982, continuous monitoring

Comments: Operating jointly with INEL and State of Idaho

Appendix I. Continued

14. Radionuclides

Components Monitored: Thyroids from road-killed mule deer

Length of Program: Since 1989; as needed

Comments: Intent of the program is to monitor radionuclides in vegetation, analyses conducted by INEL.

CLIMATE

15. Climate

Components Monitored: Standard Class I weather station parameters

Length of Program: Since 1942, daily measurements at headquarters, since 1989 at a second station set up by INEL.

Comments: The only long-term climatic data available on this portion of the SRB

WATER QUALITY

16. Water Quality

Components Monitored: Standard water quality and water chemistry measures, and flow volumes on Little Cottonwood Creek in the Monument and Big Cottonwood Creek outside the Monument.

Length of Program: Inventory project establishing monitoring protocol begun in 1991.

Comments: Provides a comparison between two confined drainages

Appendix II.

CRATERS OF THE MOON NATIONAL MONUMENT COOPERATIVE AGREEMENTS

- I). Memorandum of Understanding with the Department of Energy at the Idaho National Engineering Laboratory

Purpose: For continued cooperation on air quality monitoring and other research of interest to both parties. Initiated 1992.

- II) Memorandum of Understanding with the Idaho Falls and Shoshone Districts of the Bureau of Land Management.

Purpose: For planning and program coordination. Initiated in 1989.

- III) Memorandum of Agreement with the Idaho State Office of the Bureau of Land Management.

Purpose: For operation of a National Atmospheric Deposition Program monitoring site at the Monument. Initiated 1990.

- IV) Memorandum of Agreement with the Butte County High School

Purpose: For revegetation research under the Challenge Cost Share Program. Initiated 1993.

- V) Memorandum of Agreement with the Craters of the Moon Natural History Association.

Purpose: For the operation of programs of benefit to the Monument. Initiated 1978

- VI) Memorandum of understanding with the Idaho Falls District of the Bureau of Land Management.

Purpose: For operation of exclosures on BLM land for vegetation monitoring. Initiated 1986.

- VII) Memorandum of Agreement with the Ketchum Chapter of the Idaho Native Plant Society.

Purpose: For the creation of a plant identification trail. Initiated in 1993.

- VIII) Memorandum of Understanding with the State of Idaho Department of Environmental Quality.

Purpose: For establishment and management of a smoke management program. Initiated in 1993.

- IX) Interagency Agreement with the Idaho Falls and Shoshone Districts of the Bureau of Land Management.

Purpose: For mutual aid in fire fighting. Initiated in 1978.

- X) Member of the East Idaho Fire Cooperative of the Southern Idaho Zone of the Great Basin Coordinating Committee.

Purpose: For fire fighting activities. Initiated in 1990.

Appendix III. Craters of the Moon National Monument Photo Point Monitoring Locations

- Park Boundary
- - - Wilderness Boundary
- State Highway
- Other Roads
- - - Trails
- == Inset Border
- Visitor Center
- Photo Points
- × Park Landmarks

