U.S. Department of the Interior
National Park Service

Jewel Cave National Monument
Custer County, South Dakota

CAVE AND KARST MANAGEMENT PLAN

Environmental Assessment

August 2007

Photo Courtesy of Art Palmer

U.S. Department of the Interior
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Cave and Karst Management Plan
Environmental Assessment

Jewel Cave National Monument
Custer County, South Dakota

SUMMARY

Jewel Cave National Monument proposes to prepare a Cave and Karst Management Plan that addresses proposed changes in cave use and to guide activities that may have an effect on cave resources. Cave resources include not only the cave walls, floors, ceilings and speleothems, but any cultural or biological features contained within caves. Karst resources include all physical features that influence the underground system, including but not limited to soils, bedrock, and natural drainage systems.

This plan has been written to establish and formalize specific direction and appropriate policies for science-based management of the cave and karst resources of Jewel Cave National Monument and adjacent mineral withdrawals. The purpose of the plan is to provide a consistent framework for addressing Jewel Cave's increasingly complex cave and karst issues in accordance with all legal authorities and in the spirit of its enabling legislation. The objectives of this plan are to:

1. Provide for appropriate science-based management of cave and karst resources within the Monument.
2. Select key resource and impacts indicators based on the ability to detect change.
3. Establish appropriate surface/subsurface activities, access policies, and acceptable levels of use and impact.

The preferred alternative would have no impact on air quality, cultural and historical resources, archeological resources, paleontological resources, socioeconomics, threatened and endangered species, and environmental justice. Impacts to macrobiotic resources would be negligible and adverse in the long-term. Impacts to microbiotic resources would be negligible and adverse in the short- and long-term. Impacts to microclimate would be negligible and adverse in the short- and long-term. Impacts to physical cave resources would be minor and adverse in the long-term and moderate and beneficial in the long-term. Impacts to water resources would be minor and adverse in the short- and long-term. Impacts to exotic vegetation would be moderate and beneficial in the long-term. Impacts to public health and safety would be minor and adverse in the long-term. Impacts to visitor use and experience would be moderate and beneficial in the long-term.

Note Regarding Public Comment

The Environmental Assessment is made available on the Planning, Environment, and Public Comment (PEPC) web site at the following address: http://parkplanning.nps.gov/. If you wish to comment on the EA, you may send comments to the name and address below, or provide comments through the PEPC web site. This EA will be on public review for 30 days. Please note that names and addresses of people who comment become part of the public record. If you would like your name and/or address withheld, please state this prominently at the beginning of your comment. All submissions from individuals, organizations, and businesses will be made available in their entirety for public inspection.

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ACRONYMS AND ABBREVIATIONS

BHNF	Black Hills National Forest
BMP	Best Management Practices
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
DO	NPS Director's Order
EA	Environmental Assessment
IC	Incident Commander
IPM	Integrated Pest Management
IR	Initial Response
JECA	Jewel Cave National Monument
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NPS	National Park Service
NSS	National Speleological Society
PEPC	Planning, Environment, and Public Comment
SAR	Search and Rescue
SDWA	Safe Water Drinking Act
SHPO	State Historic Preservation Office
TS	Technical Specialist
USC	United States Code
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
VIP	Volunteers in Parks

PURPOSE AND NEED

PURPOSE AND NEED FOR ACTION

The National Park Service (NPS) has decided to prepare an Environmental Assessment (EA) for the Cave and Karst Management Plan at Jewel Cave National Monument (the Monument) that addresses proposed changes in cave use. Karst is a three-dimensional landscape shaped by the dissolution of a soluble layer or layers of bedrock, typically resulting in the development of caves and cave systems. These landscapes display distinctive surface features and underground drainages, often with enhanced hydrologic connections between surface and subsurface.

Jewel Cave is a characteristic Black Hills cave formed by the dissolution of the Mississippian Pahasapa Limestone. The cave is a complex three-dimensional maze beneath about three square miles of surface area. With more than 140 miles surveyed, Jewel Cave is recognized as the second longest cave in the world (NPS, 2007). Airflow within its passages indicates a vast area yet to be explored. Jewel Cave is a nearly pristine cave system that includes a variety of speleothems (cave formations) including stalactites, stalagmites, draperies, frostwork, flowstone, boxwork, and hydromagnesite balloons. The cave is also an important hibernaculum for several species of bats. Although Jewel Cave has many wilderness qualities, it is not a designated wilderness. However, the Monument strives to preserve the cave as a *de facto* wilderness.

Monument boundaries encompass 1,273.51 acres. The monument is surrounded by the Black Hills National Forest (BHNF). Over 45 percent of the known cave passages extend beyond NPS boundaries, beneath BHNF land and privately owned land. Both the United States Forest Service (USFS) and National Park Service (NPS) are mandated to protect cave and karst resources under the Federal Cave Resources Protection Act. The Black Hills National Forest established a mineral withdrawal in 1989 and 2006 for USFS managed land adjacent to the Monument to help protect the many miles of Jewel Cave that extends beyond the Monument boundaries. Today, the cave is managed under an Interagency Agreement with the Forest Service delegating responsibility for subsurface management to the NPS.

This plan has been written to establish and formalize specific direction and appropriate policies for science-based management of the cave and karst resources of Jewel Cave National Monument and adjacent mineral withdrawals. The purpose of the plan is to provide a consistent framework for addressing Jewel Cave's increasingly complex cave and karst issues in accordance with all legal authorities and in the spirit of its enabling legislation. The objectives of this plan are to:

1. Provide for appropriate science-based management of surface and subsurface resources within the Monument and in the adjacent mineral withdrawal areas.

2. Select key indicators of cave impacts based on detectable changes.

3. Establish appropriate surface/subsurface activities, access policies, and acceptable levels of use and impact.

The desired future conditions to be achieved through the Cave and Karst Management Plan are as follows:

Resource Condition
Cave resources will be maintained with a high level of integrity. This will involve managing access and use in a way that will minimize vandalism, tracking of manganese and other natural sediments, introduction of lint and other contaminants, ensure that the cave looks, smells, and sounds natural. Bat habitat will be maintained; and natural processes, including hydrologic patterns, in-cave airflow, and speleothem development will be preserved.

User Experience
The park desires a high quality experience for all users. Subsurface facilities and travel routes will be safe for visitors and staff, and cave travel guidelines will minimize the risk of accident or getting lost. Cave tour routes will be managed to ensure their aesthetic integrity and will be compatible with the karst ecosystem. A high level of integrity of natural cave resources will afford researchers the ability to study the characteristics of an unimpacted environment.

This management plan formalizes past practices that would continue under the proposed action, justifies to the caving community why decisions are made, guides future decisions, and sets a vision for long-term cave management at the Monument.

This environmental assessment (EA) analyzes the environmental impacts that would result from the alternatives considered, including the No Action alternative. This EA has been prepared in accordance with the National Environmental Policy Act (NEPA) of 1969 (42 United States Code (USC) 4321 et seq.), the Council on Environmental Quality (CEQ) regulations (40 Code of Federal Regulations (CFR) 1500 through 1508) for implementing NEPA, and the NPS NEPA compliance guidance handbook (DO-12, *Conservation Planning, Environmental Impact Analysis, and Decision-making*).

PARK PURPOSE AND SIGNIFICANCE

Jewel Cave National Monument (1,273.51 acres) was created on February 7, 1908, by a proclamation made by President Theodore Roosevelt (Presidential Proclamation 799, 35 Stat. 2180) under the authority of the Antiquities Act (34 Stat. 225, June 8, 1906). The purpose of the Monument is to preserve the Jewel Cave ecosystem, especially significant caverns and other geological features, for its scientific interests and for public enjoyment. Jewel Cave's length passage density, barometric wind, abundance of calcite crystals, and unique speleothems put it into the ranks of world-class caves.

Mission of the National Park Service at Jewel Cave National Monument
It is the mission of the National Park Service at Jewel Cave National Monument to preserve Jewel Cave, through management of the surface and subsurface ecosystem, while providing opportunities for the pursuit of scientific interests and public enjoyment.

The mission of the National Park Service at Jewel Cave National Monument is rooted in and grows from the Presidential Proclamation of February 7, 1908 and supplemented by the Organic Act of August 25, 1916. The Monument’s statement is a synthesis of this mandated purpose, plus the park’s primary significance as itemized below.

Legislative Intent
The laws creating Jewel Cave National Monument mandated the National Park Service to preserve and protect both surface and subsurface ecosystems for scientific research and provide for public use and enjoyment in ways that leave the resources unimpaired for future generations.

Purpose
Therefore, the purpose of Jewel Cave National Monument is to preserve the Jewel Cave ecosystem for its scientific interests and for public enjoyment.

Significance
At over 140 miles long, Jewel Cave is one of the most extensive and three-dimensionally complex caves in the world.

Jewel Cave is a nearly pristine and largely unexplored frontier providing unique opportunities for scientific study.

Jewel Cave provides the opportunity for people to experience an internationally significant cave.

BACKGROUND

SETTING

Jewel Cave National Monument is located in the southwest corner of South Dakota in Custer County and the Black Hills Region, 13 miles west of Custer (Figure 1). The region includes a large amount of public land including the Black Hills National Forest (of which Buffalo Gap National Grassland is a portion), the Pine Ridge Indian Reservation, Badlands National Park, Mount Rushmore National Memorial, Wind Cave National Park, and Devils Tower National Monument in Wyoming. In addition, the state of South Dakota administers the 73,000-acre Custer State Park. The scenic beauty of the area and extensive public lands provide wide ranging opportunities for outdoor recreation making the Black Hills a destination area for tourists.

A two square mile (1274 acres) area comprises the Monument, consisting of a broad plateau dissected by the steep-walled Lithograph Canyon and Hell Canyon (Figure 2). The average elevation is 5,200 feet, with about 400 feet of relief. The hilltops and the bottom of Hell Canyon form broad, flat meadows, while the hillsides are typically forested with ponderosa pine. The explored cave underlies the Monument surface area and extends into the adjacent Forest Service lands. The Historic Area occupies approximately 10 acres in the northwest portion of the Monument.

The only exposed rock units are the Mississippian Madison Formation – locally known as the Pahasapa Limestone – and the lower Pennsylvanian Minnelusa Formation. All known caves in the Monument are found in the Madison Formation. The climate is semi-arid, and the major surface drainages rarely carry water except during flash floods or after several years of above-average precipitation. Of the 17 inches of average annual precipitation in the southern Black Hills, much is lost to evapotranspiration, leaving only 0.6 inches available for recharge to groundwater (Rahn and Gries, 1973).

HISTORY

The first written record of Jewel Cave is a 1900 mining claim by Frank and Albert Michaud and Charles Bush. It has only one known natural entrance, which was enlarged in 1900 to allow human entry. In 1908, Jewel Cave was the first cave set aside as a National Monument. The administration of the Monument was transferred from the USFS to the NPS in 1933.

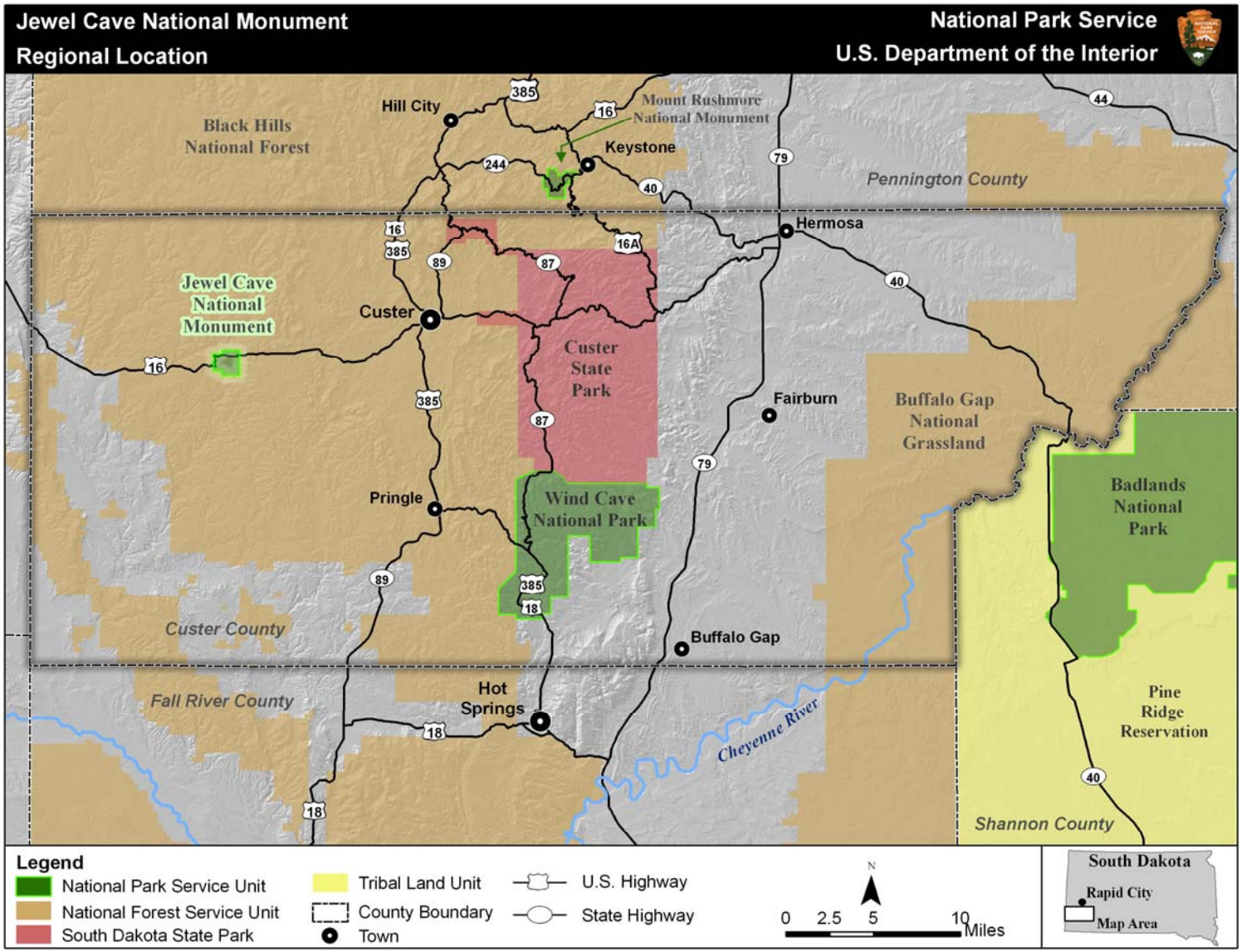

Figure 1. Jewel Cave National Monument and vicinity map.

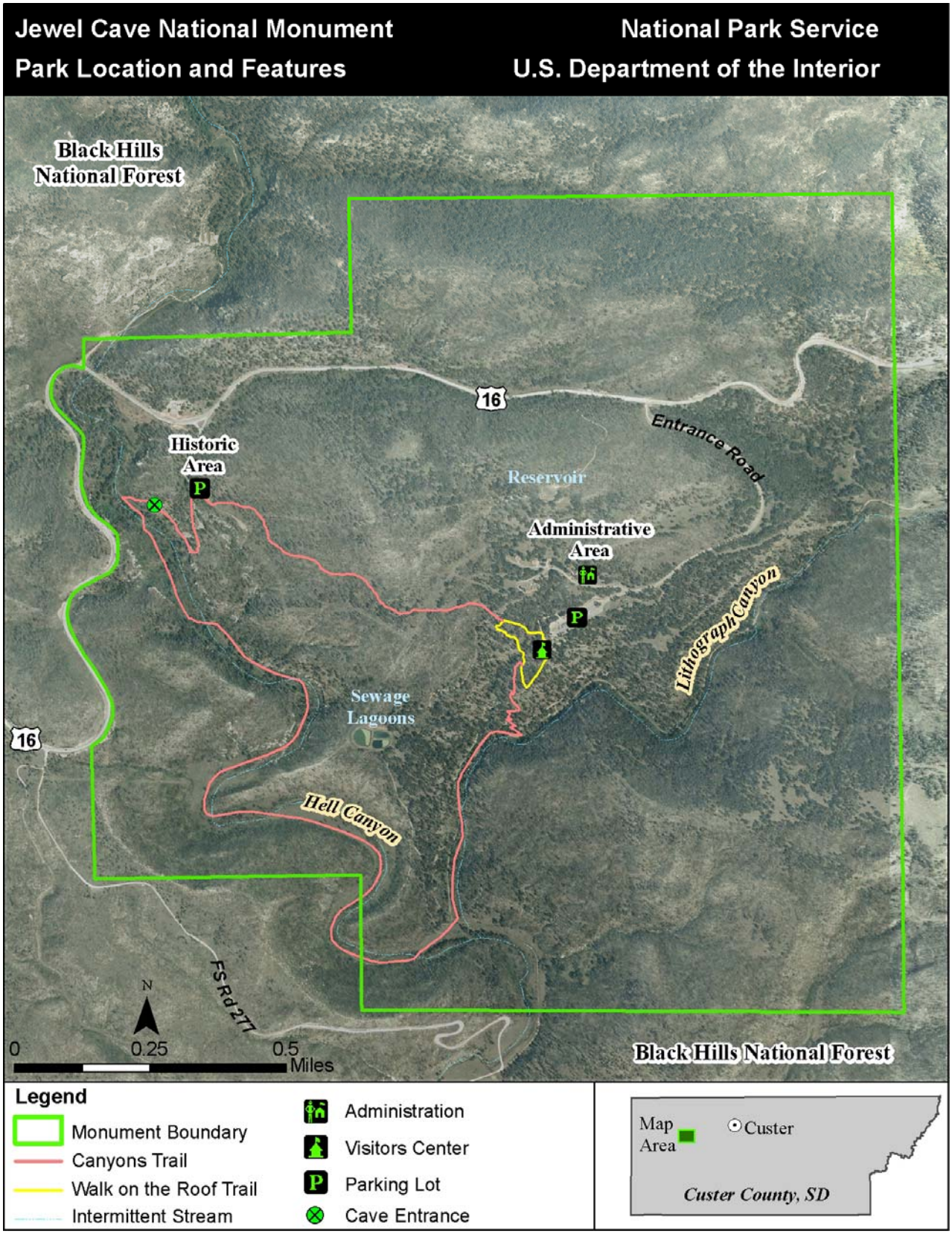

Figure 2. Jewel Cave National Monument with park locations and features.

Following is a brief history of the exploration efforts from 1900 to the present:

- 1900~1908 – The Michauds explored as far as the Forgotten Passage, but did no survey.
- 1916 – W.C. Danielson surveyed as far as the Gear Box.
- 1936 – H. Rolf (CCC) surveyed the tour routes as far as the Dungeon Room and Milk River.
- 1937-1957 – There is no record of exploration during this time.
- 1958 – Summer employee, Bill Eibert, explored and mapped as far as Duffy's. Later, the work was re-done because it lacked inclination measurements.
- 1959 – In September, Dwight Deal, a non-employee, began exploring under a Special Use permit. Herb and Jan Conn accompanied him on nearly every trip.
- 1960 – By June, Deal was no longer a regular participant. The Conns submitted the report for the permit at the end of 1960.
- 1961-1983 – The Conns explored under a Special Use permit.
- 1980 – The VISC was opened. Mike Wiles and Paul Wieland led exploration trips under the Conns' Special Use permit.
- 1981 – Conns' last year of active exploration
- 1984 – The Special Use permit was in the names of Mike Wiles and Ken Allgier.
- 1988 – Exploration was done under a volunteer agreement instead of a Special Use permit.
- 1988-2001 – Wiles led nearly all trips.
- 1991 – The Stopper was opened.
- 1994 – 100th mile
- 1996 – First camp trip
- 2006 – 135th mile, Jewel Cave becomes the second longest cave in the world.
- 2001-Present – In addition to Wiles, Rene Ohms, Dan Austin, Andy Armstrong, Larry Shaffer, and Stan Allison became trip leaders.

In 1965, a land exchange with the Forest Service changed the Monument's boundaries to encompass all of the cave passages known at that time, but the cave has since extended beyond the Monument once again. Over 45 percent of Jewel Cave's 140 miles of surveyed passages extend beneath adjacent Forest Service land. The entire cave system lies beneath an area of about three square miles.

In the mid-1960s, two artificial entrances were excavated at the site of the present visitor center, which serves most of the visiting public. One artificial entrance is an elevator shaft, used to access the tour route. The other is an entrance from Lithograph Canyon into the Target Room, used as an emergency exit and for maintenance purposes.

In 1966, Herb Conn mathematically modeled the response of airflow through the entrance to changes in barometric pressure, estimating a total minimum volume of four billion cubic feet needed to account for the observed air exchange. Based on the estimate and strong airflow at the ends of the known cave, it is apparent that most of the cave remains undiscovered.

In the early 1990s, cave exploration showed that some cave passages approached nearby private land. This provided incentive to initiate a land exchange with willing sellers. It was accomplished with the cooperation of the Monument, the Forest Service, The Nature Conservancy, and the Custer County Commission. The result was that the Forest Service now owns about one-fourth of the land that had been in private ownership in the area.

The Jasper Fire of August 2000 burned over 83,000 acres in the Black Hills, including all of the land above Jewel Cave. Although no changes have yet been noted in the cave, probably because of a drought

that began in 2000, there is great potential for increased water infiltration due to the fire. Over half of the pine trees above the cave were consumed by the fire, which translates to less evapotranspiration and more water available for recharge. Soil chemistry has changed because of the fire, and concentrations of certain elements may increase in cave waters. Also, noxious weeds have flourished as a result of fire-related disturbances.

CAVE ACCESS

Over the last 100 years, Jewel Cave has become a popular tourist destination, and annual visitation has in the past reached more than 100,000. Currently visitation is around 80,000 per year.

To ensure the protection of the cave and the safety of all trip participants, all access is overseen by qualified tour guides or off-trail trip leaders. Currently, access occurs as guided public tours through approximately 1½ miles of cave passages: the Scenic Tour, Discovery tour, the Lantern Tour, and the Spelunking Tour. Additionally, orientational and recreational caving trips are conducted along taped routes within the cave. Management, research, and exploration trips are conducted throughout the cave, as needed.

Certain natural characteristics of the undeveloped cave environment can make travel through the cave difficult; these include loose rocks, pits, and slippery surfaces. In order to facilitate exploration, handlines and/or ladders have been installed on some climbs, and loose rocks have been moved from main travel routes. Several passages in the cave have been enlarged to allow access, including the original cave entrance. Minor enlargement of small cave passages is sometimes necessary to facilitate exploration. All of these alterations can affect airflow patterns and change the microclimate, on which speleothem growth and cave biota depend.

LAWS, REGULATIONS, AND POLICIES

The following laws and associated regulations provided guidance for the development of this EA, design of the preferred alternative and alternatives, analysis of impacts, and creation of mitigation measures to be implemented as part of the preferred alternative.

The NPS Organic Act (1916) and the General Authorities Act (1970) prohibit impairment of park resources and values. The NPS 2006 Management Policies uses the terms “resources and values” to mean the full spectrum of tangible and intangible attributes for which the park was established and is managed, including the Organic Act’s fundamental purpose and any additional purposes as stated in the park’s establishing legislation. The impairment of park resources and values may not be allowed unless directly and specifically provided by statute. The primary responsibility of the NPS is to ensure that park resources and values will continue to exist in a condition that will allow everyone to have present and future opportunities to enjoy them.

An evaluation of whether impacts of a preferred alternative would lead to an impairment of park resources and values is included in this EA. Impairment is more likely when there are potential impacts to a resource or value whose conservation is:

- necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park;
- essential to the natural or cultural integrity of the park or to opportunities for enjoyment of the park; or
- identified as a goal in the park’s GMP or other relevant NPS planning documents.

NPS Management Policies 2006 (NPS, 2006) addresses caves in Section 4.8.2.2 "The Service will manage caves in accordance with approved cave management plans to perpetuate the natural systems associated with the caves, such as karst and other drainage patterns, air flows, mineral deposition, and plant and animal communities. Wilderness and cultural resources and values will also be protected."

Furthermore "Parks will manage the use of caves when such actions are required for the protection of cave resources or for human safety. Some caves or portions of caves may be managed exclusively for research, with access limited to permitted research personnel. In accordance with the Federal Cave Resources Protection Act of 1988, recreational use of undeveloped caves will be governed by a permit system, and cave use will be regulated or restricted if necessary to protect and preserve cave resources."

The Federal Cave Resources Protection Act of 1988 secures, protects, and preserves significant caves on Federal lands for the perpetual use, enjoyment, and benefit of all people. It also fosters increased cooperation and exchange of information between governmental authorities and those who utilize caves located on Federal lands for scientific, education, or recreational purposes.

SCOPING

Scoping is an open process that determines the breadth of environmental issues and alternatives to be addressed in an EA. Scoping involves obtaining internal and external input on project-related issues from resource specialists and the public, respectively. Public scoping for this EA was conducted from April 9, 2002 through July 25, 2002. The park hosted internal scoping meetings for the division chiefs and staff, three scoping meetings in neighboring communities for the general public and local caving community, a meeting for the extended local caving community, as well as at special sessions at the 2002-2005 and 2007 National Speleological Society (NSS) Conventions. It also solicited input via local newspapers, the NSS News, an electronic mailing list called the Cavers Digest, and all NPS cave parks. In addition, the park consulted with the Hell Canyon District Office of the Black Hills National Forest, which has jurisdiction over cave management and resource protection above portions of the cave that extend beyond the Monument boundaries. Consultation letters were also sent to the US Fish and Wildlife Service (USFWS), the State Historic Preservation Office (SHPO) and appropriate Tribal Governments. This scoping process resulted in definition of the purpose and need, identification of potential actions to address the need, and determination of what the likely issues and impact topics would be.

The following issues raised during scoping are addressed in this plan:

ADMINISTRATION AND INFRASTRUCTURE

Documentation
All in-cave activities should be documented and reported.

Trail Maintenance
Well-defined procedures for maintaining the public tour trails are needed to reduce the likelihood of impact to cave resources.

CAVE ACCESS

Trip Leader Training and Qualifications
Written qualifications must be established for those who lead trips into the cave to assure protection of cave resources.

Cave Use
A coherent policy for off-trail travel is needed to reduce the likelihood of impact to cave resources. Portions of Jewel Cave may require entry restrictions for protection of resource values.

Public Tours
Requirements for participation in some public tours could be based on experience and ability rather than minimum age, and changes to the use of public tour routes need to be made in accordance with resource protection needs.

Orientational Caving Trips
A fair and equitable policy is needed for the management of orientational caving trips.

Recreational Caving Trips
A fair and equitable policy is needed for the management of recreational caving trips.

Exploration Caving Trips
Exploration activities must be properly managed to reduce impact and ensure quality of data collection; it must accommodate qualified individuals who wish to be involved in cave exploration.

Management and Research Caving Trips
Management and research activities must be properly managed to reduce impact and ensure quality of data collection.

Other Caves
The lack of an access policy for un-gated caves within the Monument leaves them vulnerable to damage and is a safety concern.

Modifying Natural Characteristics of Cave Passages
Artificial enlargement of cave passages has the potential to change cave airflow and harm cave resources.

CULTURAL AND HISTORIC RESOURCES

A policy is needed to guide management decisions regarding cultural and historical resources found within the cave.

NATURAL RESOURCES AND PROCESSES

Biological Resources
Policies need to be established to ensure that use of the cave does not harm biological resources.

Discovery of New Caves
A policy is needed for the management of any new caves that are discovered within the Monument in order to protect them and the resources they contain.

Wilderness
Most of Jewel Cave has a wilderness quality that should be preserved.

Monitoring
A policy is needed to monitor changes in the cave environment and to determine whether observed changes are the result of human activity or are a part of a natural process. Monitoring tools are also needed to document the effectiveness of mitigation, restoration, and current management policies.

Mitigation
Mitigation measures are needed in order to reduce the effects of unavoidable recurring impacts.

Restoration
Restoration measures are needed to return impacted cave features to a near-natural condition, or to reverse non-recurring impacts.

Algae
Electric lighting along the Scenic Tour route encourages the unnatural growth of algae, which can harm cave resources and is aesthetically displeasing.

Manganese Tracking
Manganese tracking must be managed properly to confine footprints and handprints to well-established trails.

Airflow
Artificial changes to airflow have the potential to significantly alter the cave microclimate.

Water Flow
Altered water flow at water collection sites in the cave has the potential to harm cave resources, particularly cave biota.

The following issues raised during scoping **are not** addressed in this plan:

Develop an action plan to address impacts from parking lots, the elevator shaft, and the development footprint.
The visitor center parking lot is an impermeable surface that redirects water flow. This could cause naturally wet cave passages to become dry, and, naturally, dry passages to become wet. Such a change in infiltration patterns can alter speleothem development and impact cave biota. Parking lot runoff also contains contaminants, including metals and hydrocarbons. A dye trace in 1988 confirmed that runoff from the parking lot reaches cave passages within a few days. The Monument is concerned about impacts caused by surface development above the cave, and will work toward replacing the asphalt parking lot with concrete and an integrated filtration system. This situation will be evaluated in a parking lot replacement implementation plan, and is beyond the scope of this EA.

A 300-foot elevator shaft was constructed to facilitate cave tours in 1967. This shaft penetrated impermeable rock layers, causing changes in the quantity, quality, and patterns of surface water entering the cave. This has the potential to impact speleothem formation and cave biota. More information is needed, and research will be conducted to determine specific hydrologic patterns and impacts. This situation will be evaluated in an elevator shaft mitigation and implementation plan, and is beyond the scope of this EA.

The development footprint within the Monument includes the visitor center, administration building, maintenance shop, historic cabin, employee housing, paved road surfaces, and sewage lagoons, and could have impacts on the local hydrology. All surface developments above the cave impact water quantity, quality, and patterns and therefore have the potential to impact infiltration in the cave, speleothem development, and cave biota. Although the Monument's 1993 General Management Plan (GMP) established a plan for significant additional development of surface facilities, the Superintendent later saw the need to reduce development above the cave and took advantage of an opportunity to build new facilities (apartment buildings) off-site, where there was no chance of impacting cave resources. Moving employee apartments off-site also reduced the need to build additional office space, because unused housing units within the Monument were then converted to offices. Additional similar actions have been taken, such as removing part of a parking lot (including restoration of surface contours and revegetation with native seed) and reducing the need for additional building space by moving the monument's museum collection off-site.

Although the "developed zone" defined in the GMP is only 4% of the monument, much of it is above an area of extensive cave passages. Reducing the footprint would reduce risk of impact to the cave environment, but this is beyond the scope of this EA and should be addressed in the next revision of the GMP.

Place the gate at Jewel Cave's historic entrance in a museum and replace with a bat gate.
The gate has already been replaced through evaluation under the NEPA/106 process. The original gate has been accessioned into the museum collection. It was replaced with a more bat-friendly gate of similar design because the cave entrance, including the gate (c. 1940), is on the List of Classified Structures. It is being protected as a cultural resource, one of the FCRPA's listed values. Bat populations have been monitored annually since the gate replacement, and no significant changes have occurred. This issue has already been addressed by replacing the gate, and will therefore not be further analyzed in this EA.

A fair and equitable policy is needed for the public to take photographs in the cave, whether for profit or not.
The policy for in-cave photography is covered under existing NPS and Monument policies (Appendix J: Photography), and will therefore not be further analyzed in this EA.

Manage in-cave educational use in a manner that is consistent and fair.
This need is met by providing interpretive tours on already-established routes, which is covered in the Monument's Comprehensive Interpretive Plan and is beyond the scope of this EA.

IMPACT TOPICS

Issues and concerns with this project are grouped into distinct impact topics to aid in analyzing environmental consequences, which allows for a standardized comparison of alternatives based on the most relevant information. The impact topics were identified on the basis of federal laws, regulations and orders, *NPS Management Policies 2006*, and NPS knowledge of potentially affected resources. A brief rationale for selecting or dismissing each topic is provided below.

IMPACT TOPICS ANALYZED IN THIS ENVIRONMENTAL ASSESSMENT

Macrobiotic Resources
Jewel Cave contains macrobiota which could be impacted by cave visitation, maintenance, and pesticides in cave water. This impact topic is addressed in accordance with *NPS Management Policies 2006*,

Chapter 4, which directs the NPS to minimize human impacts to native animals, populations, communities, and ecosystems.

Microbiotic Resources
Preliminary studies suggest that microorganisms exist deep in Jewel Cave in areas previously thought to be devoid of life. These microbes or their habitats could be affected by cave exploration and the possible presence of chemicals in water infiltrating the cave. This impact topic is addressed in accordance with *NPS Management Policies 2006*, Chapter 4 and with NPS Reference Manual #77, which directs the NPS to prevent the disturbance of microbial communities through minimum impact caving techniques.

Microclimate
The cave microclimate (temperature, relative humidity, airflow) could be impacted by changes in cave visitation and the electrical lighting system. This impact topic is addressed in accordance with *NPS Management Policies 2006*, Chapter 4, which directs the NPS to return human-disturbed areas to natural conditions and processes, and with NPS Reference Manual #77.

Physical Cave Features
Jewel Cave contains extensive geologic and mineralogical resources and aesthetic values that could be impacted by cave visitation, exploration, maintenance, and monitoring. This impact topic is addressed in accordance with *NPS Management Policies 2006*, Chapter 4, which directs the NPS to maintain and restore the integrity of geologic resources, and with NPS Reference Manual #77, which directs the NPS to establish levels of maximum acceptable cumulative impact to caves.

Water Resources
Jewel Cave contains dripping water and small pools that could be impacted by pesticide application on the surface. This impact topic is addressed in accordance with *NPS Management Policies 2006*, Chapter 4, which directs the NPS to take all necessary actions to maintain or restore the quality of surface waters and ground waters within the parks, and with the Clean Water Act (as amended, 2002).

Exotic Vegetation
Exotic plants on the surface of the Monument would be impacted by the use of pesticides to control them. Additionally, any future pesticide treatment of exotic vegetation on the surface of the Monument could affect cave resources if water with chemicals infiltrates the cave system. This impact topic is addressed in accordance with *NPS Management Policies 2006*, Chapter 4, which directs the NPS to manage exotic species that have, or potentially could have, a substantial impact on park resources, and that can reasonably be expected to be successfully controlled.

Public Health and Safety
Public health and safety could be affected by the possible presence of pesticides in drip water used for drinking during exploration trip to remote areas of the cave. This impact topic is addressed in accordance with *NPS Management Policies 2006*, Chapter 8, which directs the NPS to seek to provide a safe and healthful environment for visitors and employees.

Visitor Use and Experience
The variety and quality of experiences available to visitors and levels of visitor use could be impacted by changes in recreation, orientation, and exploration policies. This impact topic is addressed in accordance with the 1916 Organic Act and with *NPS Management Policies 2006*, Chapter 8, which directs the NPS to impose management controls on all park uses and to provide appropriate, high quality opportunities for visitors to enjoy the parks. It also directs superintendents to establish visitor carrying capacities using the best available natural and social science and other information.

IMPACT TOPICS DISMISSED FROM FURTHER CONSIDERATION

Air Quality

The federal Clean Air Act *(42 U.S.C. 7401 et seq. as amended)*, stipulates that federal land managers have an affirmative responsibility to protect a park's air quality from adverse air pollution impacts. Air quality would not be affected by any of the proposed actions in this EA, so this topic was dismissed from consideration.

Cultural and Historical Resources

Jewel Cave contains items that may be of cultural and historic value. A few passages near the Historic entrance are known to have a few items from the early 1900s. These include such things as rotted rope, newspaper fragments, and other incidental objects. Potential impacts to cultural resources are dust accumulation, accidental breakage or trampling, and natural degradation in the cave environment. However, cavers would be required to avoid passing by any cultural resources if there was a possibility of impact. Cultural and historical resources would not be affected by any of the proposed actions in this EA, so this topic was dismissed from consideration.

Archeological Resources

There are 20 known archeological sites on the Monument. One is in a rock shelter, and several of the small caves are potential archeological sites. The entrance to Jewel Cave was humanly impassible until 1900, and there is no evidence of prehistoric occupation or use of the cave. None of the proposed actions have the potential to affect archeological resources in park caves, so this topic was dismissed from consideration.

Paleontological Resources

There is one known paleontological site on the Monument, located just inside the gated historic entrance. None of the proposed actions have the potential to affect this site, so this topic was dismissed from consideration.

Socioeconomics

NEPA requires an analysis of impacts to the "human environment" which includes economic, social and demographic elements in the affected area. There are two communities within 24 miles of the Monument. Changes in the cave and karst management program may bring a need for additional personnel in the park, but this would be minimal (one or two seasonal employees) and would not affect the communities' overall population, income and employment base, so this topic was dismissed from consideration.

Threatened and Endangered Species

The Endangered Species Act of 1973 requires disclosure of impacts of federal actions on all federally protected threatened or endangered species. NPS Management Policies 2006 requires assessment of impacts to certain rare, candidate, declining and sensitive species. The Monument is habitat for the bald eagle, which has recently been de-listed, and no nesting sites occur in the Monument. The bald eagle is no longer a threatened or endangered species and would not be affected by actions of this EA, so this topic was dismissed from consideration.

Environmental Justice

Presidential Executive Order 12898, *General Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, requires all Federal agencies to incorporate environmental justice into their missions by identifying and addressing the disproportionately high and/or adverse human health or environmental effects of their programs and policies on minorities and low-income populations and communities. The proposed project would not have disproportionate health or environmental effects

on minorities or low-income populations or communities as defined in the USEPA's Draft Environmental Justice Guidance (July 1996). Therefore, Environmental Justice was dismissed as an impact topic in this EA.

ALTERNATIVES

CEQ regulations for implementing NEPA require that Federal agencies explore and objectively evaluate all reasonable alternatives to the preferred alternative, and to briefly discuss the rationale for eliminating any alternatives that were not considered in detail. This chapter describes a range of reasonable alternatives, including the No Action Alternative and the Preferred Alternative. Discussions in this chapter use terms defined in the *Glossary*.

ACTIONS COMMON TO ALL ALTERNATIVES

ADMINISTRATION AND INFRASTRUCTURE

Certain administrative actions and activities related to maintaining the park infrastructure are not always thought of as relating to cave use, but can influence the effectiveness of cave management and/or actual impacts to the cave environment.

Documentation

All in-cave activities would be documented and reported. Copies would be kept in the cave management office and/or in the Monument's central files. All incidents involving impact to the cave would be reported in writing to the cave management staff that would investigate, document (including photographs) and make recommendations to the Superintendent.

Maintenance

Maintenance of the public tour routes would include such activities as changing light bulbs, emptying trash cans, routine cleaning and upkeep of tour structures. Structures on the Lantern Tour route include stairs and bridges made of treated wood that require periodic replacement; this would involve cutting some of the wood within the cave, which would produce sawdust; a tarp would be used to collect the sawdust. The wood stairs would be inspected annually to ensure they are in good condition. Mud would be scraped off the stairs as needed. A check for fallen rocks would be made each spring.

Structures on the Scenic Tour route consist of aluminum stairs, bridges, and platforms; replacement would sometimes require drilling new holes, producing aluminum shavings, which would be caught with tarps. The step and decking surfaces are aluminum and would be replaced periodically due to wear and corrosion; toe plates of the steps would be re-tightened as needed. The handrails are made of anodized aluminum and would be periodically replaced due to corrosion. They would be cleaned on a variable schedule (depending on location) or as needed, using a dry cloth. Urine would be treated with a 10% solution of household bleach (sodium hypochlorite) and rinsed away. Vomit would be treated with Barf-Clean and then rinsed with undiluted household bleach.

Visitation and electric lighting along the Scenic Tour route encourages the unnatural growth of algae. Small amounts of bleach would be used to remove algae, currently the most widely accepted method. Cave management staff would assist with cave maintenance in special circumstances, such as changing light bulbs in delicate areas. The cave management office would work with the maintenance division to establish 1) appropriate use of materials and chemicals, 2) acceptable off-trail routes and procedures, and 3) pre-work preparations, such as setting up plastic tarps to catch screws, shavings, or other debris.

Cave Lighting

Light fixtures consist of incandescent (75-150W) floodlights and spotlights, as well as mercury vapor (175-1000W) lights. These fixtures would be repaired or replaced on an as needed basis. Most of the light fixtures are off the trail and hidden from direct view. The Maintenance staff would use maps to locate each fixture and the associated wiring, switches, and transformers. Ladders would be stored in the cave, for use in accessing hard-to-reach light fixtures. New lighting technology would be implemented as needed and available.

CAVE ACCESS

In addition to Jewel Cave, there are several small caves within the Monument that are administratively closed. The following cave access discussion pertains mainly to Jewel Cave.

Tour Trails

Within Jewel Cave, the cave management staff would monitor the tour trails and document incidents to determine if there is any need for change of tour sizes. Cave management staff would be consulted before new tours are added or changes are made to tour procedures that could impact resources. Tour trails and tour sizes are described in the *Affected Environment* section.

Education/Interpretation trip leaders would be qualified to lead trips on the four public tours: the Scenic, Discovery, Lantern, and Spelunking Tours. Trip leaders in this category would be required to take the specific training for each of the four tours prior to leading a public tour. The Interpretation Division Chief or designee would train and approve staff for these education/interpretation tours.

Trip leaders would not be allowed to receive gifts or financial compensation for leading off-trail trips, beyond compensation due them as part of their normal duties as employees or volunteers, or beyond limits established in the Code of Federal Regulations.

No prior caving experience would be required for education/interpretation trip leaders.

Off-trail Travel

Off-trail travel would occur along narrow paths, some of which are marked as taped routes. Taped routes are trails marked with strips of vinyl flagging tape. Each tape is placed in sight of the previous one and has one pointed end that always points toward the easiest way out of the cave. When a route is complete, the tapes should be numbered with values decreasing toward the entrance, and they should be tied into the inventory system for easy correlation with survey locations. Various colors and color combinations are used to indicate different routes. A few colors are reserved for special uses:

White with blue dots:	Trail to water supply
White with orange dots:	Scenic spur from a main route
White with red dots:	Trail encounters drops that may require vertical gear
White with blue stripes:	Delicate features can be surrounded with flagging to delineate where to step or not to step.

Heavily traveled routes with a poorly defined path may be flagged with continuous white flagging tape on both sides of the trail.

Because the NPS is mandated to preserve natural characteristics of the undeveloped cave environment– including loose rocks, low ceilings, and radon – significant modification of cave passages would not normally be used to mitigate these concerns. Cavers should instead adapt their activities to the conditions. In some cases, the Monument would install handlines, ladders, or other aids to allow cavers to safely navigate climbs; this would be done only when necessary, and not to encourage caving beyond one's ability. The Cave Management Specialist could also authorize the stabilization of loose rocks along main travel routes to increase caver safety. Passage modification would be allowed only under certain circumstances related to cave exploration (see below for specific exploration guidelines).

Off-trail travel would have the following minimum requirements:

- All trip leaders must be at least 18 years of age.
- All participants would be required to be at least sixteen years of age. Participants under 18 years of age would need to have the signed permission from their parent or legal guardian.
- All participants in off-trail caving trips would be required to sign appropriate Waivers / Acknowledgements of Responsibility (Appendix A).
- Required equipment would include: a UIAA-approved hard hat; three independent sources of light; ankle-high, rubber-soled boots; knee pads and elbow pads; food and water (for longer trips). "Ceiling burner" carbide lamps would not be permitted because of the likelihood of leaving soot marks where the ceiling is low. All clothing, packs, pads, and gloves would need to be clean at the beginning of every trip. Side packs would be required to be used, with the exception of management, research, or overnight trips where larger packs would at times be needed.
- All human waste would be removed from the cave.
- Each group would need to establish a reliable surface contact. Upon completion of the trip, the trip leader would need to immediately inform the surface contact. The "out time" should represent the actual expected time of return with no more than one extra hour of leeway. All surface watches would have a copy of the current Emergency Contact Phone List. The contact would call the appropriate NPS employee no more than one hour after a caving group is past due, per the policy outlined in the Cave Search and Rescue Plan (Appendix B).
- The Spelunking Route and the Geologist's Delight (part of the Hub Loop) are the only off-trail Jewel Cave routes where people with no prior experience would be permitted to learn caving skills. All other off-trail routes would require demonstrable prior caving experience.
- Cave management trips would require prior caving experience that has adequately prepared the caver for the trip, and overnight trips have a prerequisite of a trip to Seventh Heaven. All camp trips would be conducted in accordance with the Monument's Underground Camping Policy (Appendix C).
- All off-trail trips would be made in groups of three to six people, including the trip leader(s). Some additional limitations might be imposed on group size, based on fragility of the area visited or logistics.

Orientation Caving Trips

The trip leader would be an on-duty, paid staff member who has met the taped route trip leader qualifications for taped routes. The participants would be off-duty. These trips would be scheduled by park management as optional training opportunities. The park would provide some caving equipment for these trips. First-time visits would be given first consideration. The number of trips permitted per year would be established based on measured impact and management constraints.

- Routes open for orientational use would be: Spelunking Route, Hub Loop, Bunyan's Loft, Japanese Gardens, Rambling Loft/Logomites, Hell's Half Acre, and Miseries to Metrecal Cavern (Figure 4).

- Hell's Half Acre would have a prerequisite of any three other recreation/orientation routes. The Miseries to Metrecal Cavern route would have a prerequisite of Hell's Half Acre.

Exploration Caving Trips

Each survey team would consist of two to four people, including the trip leader. The team would consist of those that had been approved to sketch, read instruments, and conduct the cave inventory. A survey team of two would be permitted only if they traveled with another survey team to and from the same general area. However, the combined group size could not exceed six.

Explorers would have permission to make enlargement of constrictions in newly discovered passages provided that all of the following criteria are met. If one or more of the following statements does not apply, the passages could not be enlarged without prior recommendation of the Cave Specialist and written approval by the Superintendent:

- the passage is near the "edge" of the cave
- there is good reason to believe more passages exist beyond the constriction
- no speleothems would be damaged
- a concerted effort would be made to find a larger bypass
- any change to the air flow would be immediately mitigated
- the work could be accomplished with no more than simple hand tools
- the work could be accomplished on a single trip
- all such modifications would be recorded in the trip report

Management and Research Caving Trips

These trips would be conducted on an as-needed basis to areas of concern using trip leaders who are qualified to lead to that area. The trips would be scheduled by the cave resource management staff.

CULTURAL AND HISTORIC RESOURCES

If a cultural or historical resource were encountered during any in-cave activity, that activity would be immediately discontinued if there is likelihood of damage to the resource. A report would be made to Jewel Cave's Cultural Resource Advisor (at the NPS Midwest Regional Office), and their input would be solicited before any more work or travel (if the travel is causing damage) is to be done in the area.

Any cultural resource could be removed from the cave at the park's discretion. Reasons for removing an item of cultural value from the cave would include degradation of the object itself and any resulting degradation of natural resources. Over the course of time, certain exploration aids (such as ladders) might

come to be considered historic. These would eventually need to be repaired or replaced; in such cases, the original item could be included in the park's museum collection after consultation with the Cultural Resource Advisor.

Before any object could be removed from the cave, it would need to be documented. Documentation would include a written description, photograph(s), and location. See Appendix D: Guidelines for In-Cave Cultural and Historical Resources.

NATURAL RESOURCES AND PROCESSES

Biological Resources

The presence of packrats, deer mice, and springtails would not require cave travel restrictions. To reduce the risk to hibernating bats, no exploration or public tours would be allowed through the historic entrance of the cave from October 1st to May 31st. Other activities in the vicinity of hibernating bats would be kept to an absolute minimum. Allowed activities would include the annual mid-winter bat count, research that does not involve traveling past hibernating bats, and seasonal staff training in late May – provided that spring weather conditions and bat activity demonstrate that this would not be detrimental to the bat population. Other uses could be allowed at the Superintendent's discretion if there is an immediate need.

To prevent impacts to native microorganisms, or the unnatural increase of non-native microorganisms, rest stops would be made only at established areas. Trip leaders would be trained to avoid corrosion residue sites and water when exploring away from travel corridors. Only water dripping from the cave ceiling would be collected and used for human consumption; to protect any native microorganisms that might be present, no pools (standing water) would be used for drinking. Established procedures would assure that all human waste is removed from the cave (See Appendix A: Acknowledgement of Risk / Waiver of Responsibility).

Discovery of New Caves

When a new cave is discovered, it would be immediately reported to the Cave Specialist. The cave would be given a name, and its location would be determined and recorded. The cave management staff would oversee an initial assessment of cave resources, including an initial survey and inventory. The cave would then be managed in a manner consistent with the rest of this plan.

Wilderness

Caves within the Monument would be managed as a *de facto* wilderness.

Algae

Algae would be removed along the Scenic Tour route annually, or more frequently if necessary. Each area illuminated by a light fixture would be checked for algae growth each year; if any is found, it would be sprayed with undiluted bleach in a spray bottle. The smallest amount of bleach necessary to kill the algae would be used. As new technology is developed, it would be used when appropriate. This could include the use of germicidal ultraviolet lights to kill algae, or new lighting technology that would reduce its growth.

Manganese Tracking

On heavily tracked routes, the Monument would pursue methods to clean unnecessary tracking and train trip leaders to follow the established routes and enforce that behavior among trip participants. Techniques for cleaning adjacent to each route would be developed and implemented when feasible. Any actions other than minor cleaning would require NEPA compliance.

New routes would continue to be established as needed. A variety of methods for flagging the routes would be used depending on the level of use and likelihood of manganese tracking. Those areas beyond the taped routes which are used much less frequently would be visited only by experienced cavers capable of identifying the mostly heavily-impacted cave surfaces and following the exact path to and from their destination.

Airflow
There are no actions common to both alternatives.

Water Flow
The Monument would reduce collection, redirection, and treatment of cave water to the minimum necessary to facilitate monitoring, research, and exploration needs; remove any collection devices that are not in current use; and replace any collection equipment that facilitates growth of biota.

Exotic Plant Control
An agreement between the Monument and the Forest Service specifies that only aminopyrlaid (Milestone) and imazapic (Plateau) would be used by the Forest Service to control exotic plants within the Jewel Cave Mineral Withdrawal boundary. Aminopyralid was chosen due to its low persistence (short half-life). As part of the agreement, Jewel Cave would hand-pull or cut exotics in a few small areas on Forest Service land adjacent to the Monument boundary.

ALTERNATIVE A – NO ACTION

CEQ regulations (40 CFR 1502.14) require the assessment of the No Action Alternative in NEPA documents. The No Action Alternative provides a basis for comparing the management direction and environmental consequences of the other action alternatives and must be considered in every EA.

ADMINISTRATION AND INFRASTRUCTURE

All actions pertaining to administration and infrastructure for the No Action Alternative would be the same as described above under Actions Common to All Alternatives, except for:

Cave Lighting

The configuration of the current lighting system for the Scenic Tour route is such that the lights would remain on for the entire half-mile loop whenever a single tour group is in the cave. This lighting scheme would remain in effect under Alternative A.

CAVE ACCESS

Tour Trails

All actions pertaining to tour trails for the No Action Alternative would be the same as described above under Actions Common to All Alternatives.

Off-trail Travel

All actions pertaining to off-trail travel routes for the No Action Alternative would be the same as described above under Actions Common to All Alternatives.

No formal park policies, procedures, or training requirements would be in place to allow for new exploration trip leaders. Informal survey trip leaders would exist to accommodate two survey parties per exploration trip.

Recreation/orientation trip leaders would be trained formally or informally before and during caving trips as part of seasonal training or standard job training. They would learn all the necessary requirements to meet park cave standards as applicable to the trip leader type.

Recreation/orientation trip leaders would be qualified to lead trips on designated recreation and orientation routes in Jewel Cave. These leaders would need to demonstrate their qualifications and knowledge of the route by leading a trip with the oversight of cave management staff. The proposed trip leader would have to complete the route successfully at least three times, and lead the last trip under the oversight of a qualified trip leader prior to approval. The Cave Management Specialist or designee would approve this type of trip leader. Recreation/orientation trip leaders would be required to stay current to maintain their trip leader status. Whether the trip leader is "current" would be a subjective decision.

Orientation Caving Trips

All actions pertaining to orientation caving trips for the No Action Alternative would be the same as described above under Actions Common to All Alternatives.

Recreation Caving Trips

The trip leader would be a volunteer who has met trip leader qualifications for taped routes. Participants would need to provide their own caving equipment for these trips. First-time visits would be given first consideration. The number of trips permitted per year would be established based on measured impact and management constraints. Some areas could be restricted due to fragile resources.

Routes open for recreational use would be: the Spelunking Route and Hub Loop (Figure 3). Recreational trips on the Spelunking Route and Hub Loop would be open to specially arranged events, such as the NSS Convention, Rocky Mountain Regional, and partners such as the Paha Sapa Grotto, all affiliated with the National Speleological Society. They would be scheduled by the park.

Exploration Caving Trips

Approval of exploration trips would be subject to available time and personnel needed to prepare maps, and survey and/or camp gear. Also, some areas could be restricted to provide for safety and protection of cave resources. Exploration would not be permitted through the historic entrance of Jewel Cave. Explorers would receive informal on-the-job training. Cavers with previous experience reading instruments could read instruments on their first survey trip in Jewel Cave under the guidance of another approved instrument reader. Each survey team could include one or more cavers without prior survey experience so that they could become familiar with the process. Under the guidance of an experienced surveyor, they could read instruments and tape, and/or collect inventory data. Those with previous sketching experience would be permitted to sketch at Jewel Cave under the guidance of a person experienced in sketching to Jewel Cave standards. After demonstrating their competence, they would then be permitted to sketch on their own.

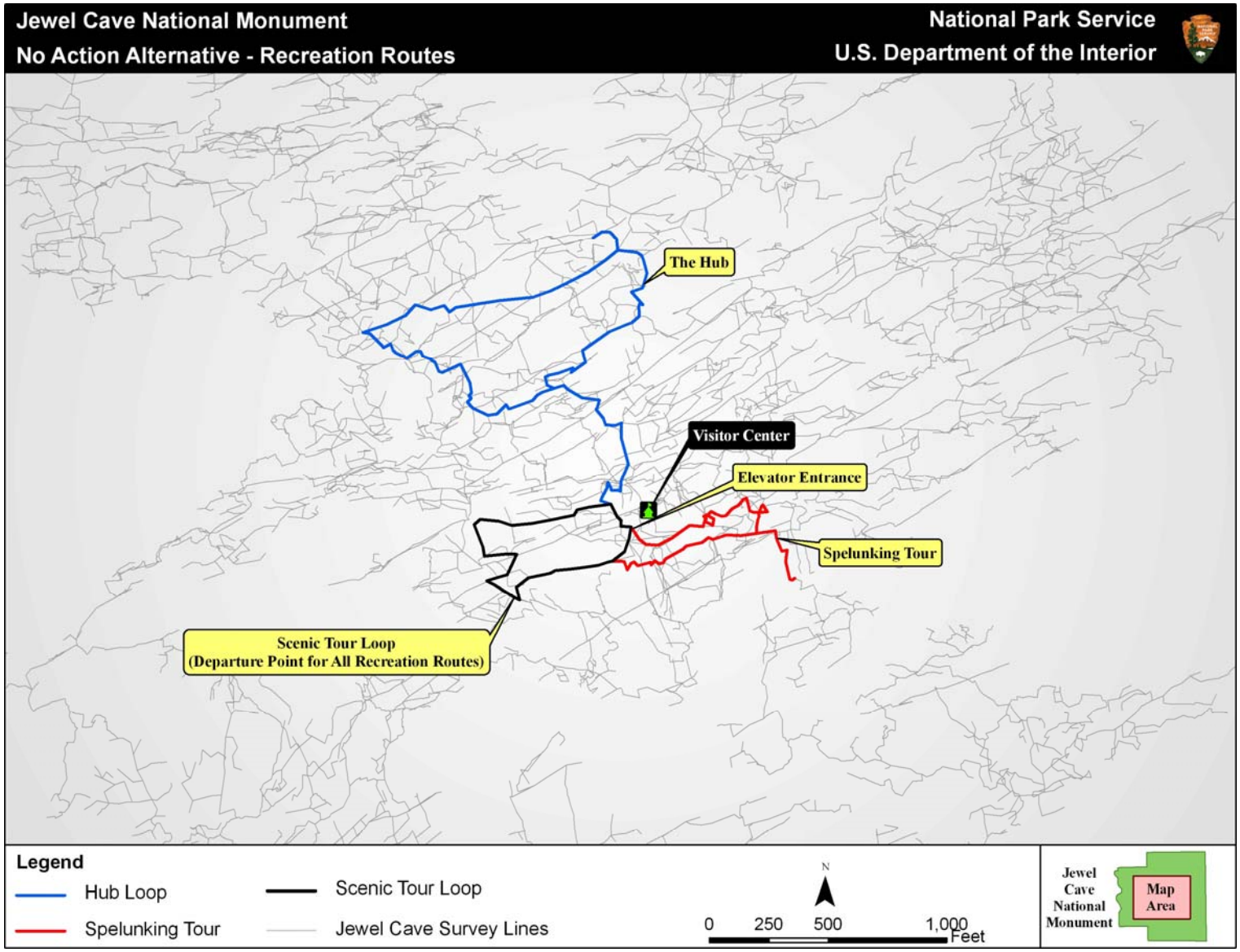

Figure 3. Recreation routes at Jewel Cave under the No Action Alternative.

Management and Research Caving Trips

All actions pertaining to management and research caving trips for the No Action Alternative would be the same as described above under Actions Common to All Alternatives.

CULTURAL AND HISTORIC RESOURCES

All actions pertaining to cultural and historic resources for the No Action Alternative would be the same as described above under Actions Common to All Alternatives.

NATURAL RESOURCES AND PROCESSES

All actions pertaining to natural resources and processes for the No Action Alternative would be the same as described above under Actions Common to All Alternatives, except for:

Airflow
The Monument would attempt to seal artificial entrances, except the Historic entrance, on an as-needed basis.

ALTERNATIVE B – NPS PREFERRED ALTERNATIVE

ADMINISTRATION AND INFRASTRUCTURE

Maintenance

To protect the cave, it is important that maintenance and related activities would be conducted in a manner that minimizes or eliminates impacts to the cave environment. This often means that "industry standard" practices would need to be adapted for use in the karst environment. Such practices would be implemented to a greater degree in the Preferred Alternative than are in current use.

The main concerns in the cave are:

Tracking of manganese and other sediments

Most maintenance activities in the cave would occur on developed tour routes. Sometimes park staff would need to leave the trail to work on the cave lighting or phone systems. This would require following specific paths to minimize tracking. Instructions would be provided to maintenance staff regarding the actual footpath to be taken from the concrete trail to service each light fixture. In some cases, rubber shoe covers would be worn when stepping off trail and removed before stepping back onto the trail to minimize tracking cave materials back onto the tour route.

Changing Lights

In a few instances, light fixtures can only be reached by crawling through extremely fragile areas. Servicing these fixtures would be done by (or at least supervised by) experienced cavers to avoid accidental manganese tracking or breakage of speleothems.

The lights in the cave have been carefully positioned to reduce the amount of algae growth or drying of wet surfaces. These positions would be maintained whenever the fixtures are serviced. For the same reason, bulbs would also be replaced according to their original specifications of wattage and bulb type.

On- and Off-trail Procedures

Various solvents, cleaning solutions, absorbents, etc. can impact the cave, even though they are appropriate for upkeep of buildings. The maintenance staff would be aware of what is or is not acceptable for cave use and should understand that resource management staff would be consulted before using new substances or techniques for which there is any doubt.

Special measures would be taken to prevent introduction of construction debris (e.g., sawdust, aluminum filings, stray bolts, nails, or wire insulation) into the cave environment because it would not be removed by natural processes. Spare parts for tour structures would not be stored in the cave for more than three months because they would be subject to deterioration from the constant high humidity of the cave environment before they are used.

Simple procedures, such as carrying a ladder, may need to be modified. While one person may be able to carry a ladder on the surface with no additional help, accidentally hitting a cave surface with the ladder could occur due to the close quarters of the cave. In this case, two people would carry a ladder to avoid damage from such an impact.

Similar considerations would be made whenever large objects are to be carried through the cave. In some cases, they would be tied in place when the work commences to keep them from falling down stairs or from steep drops.

Policy and Training Program

Although the cave management staff has advised the maintenance staff regarding these procedures in the past, instructions have never been formalized into a policy or training program. Consequently, unnecessary impacts have occurred when people forget a procedure or when new maintenance staff members are not adequately trained. Under this alternative, a maintenance training program would be formalized and maintenance instructions and procedures would be incorporated to include the following into a written policy:

> The Monument will use the least amount of chemicals needed for surface and subsurface activities. The chemicals will be the least toxic, least soluble, and most biodegradable that are available. These chemicals include: cleaning agents for the handrails along the Scenic Tour route, treated lumber along the Lantern Tour route, treatment chemicals for human waste left in the cave, de-icers, detergents for cleaning vehicles, sealants used for rooftops and underground utilities, and preservatives for wood power poles. Excess chemicals will immediately be removed from the site. The Maintenance staff will consult with the Resource Management staff to decide on which chemicals to use. Contractors will be required to follow these guidelines.

Surface Activities

The above principles for reducing cave impacts would also apply to surface activities since the surface and subsurface are hydrologically connected in the karst landscape. For example, it may not be appropriate to rinse certain detergents onto the ground or patch road surfaces with petroleum products (some techniques are better than others). Salting roads and sidewalks in the winter would be avoided when possible, and the chemistry of de-icers would be evaluated before they are used. Although these

procedures are currently in practice, without formalizing them into policy, they could be neglected in the future.

Other considerations involving the use of chemicals on the surface include such activities as evaluating the potential for impacting soil and groundwater when applying preservatives to wood utility poles or applying sealant to buried pipeline. Occasionally extra sealant spills into the trench where the pipe is laid. After burial, infiltrating water can leach chemicals from it and carry them into the cave. Such actions are generally implemented as a matter of standard practice without regard to the fact that the karst landscape poses some extra concerns. A Best Management Practice might be a requirement for contractors to catch excess sealant with a plastic drop cloth.

Cave Lighting

The lighting system along the Scenic Tour route would be redesigned so that only the sections occupied by a tour group would be turned on. The lights in unoccupied sections would be left off until a tour group arrives.

Ninety percent of the park's visitation takes place from Memorial Day to Labor Day, and the park must reasonably accommodate visitors who wish to see the cave. The volume of visitors requires that tours enter the cave every 20 minutes. Due to important stops along the way (to rest, and to interpret specific resources), tours cannot be taken any more frequently than every 15 minutes because they would run into each other. Thus in the summer during peak visitation, the lights of the tour route could not feasibly be turned off at any point during the day. However, in the remaining nine months of the year, the number of daily tours offered is less frequent and there are days when no tours enter the cave. When there are fewer daily tours, it would become feasible to turn off the lights in all areas except in the immediate vicinity of a tour group. The point of feasibility for turning off lights would be reached when tours enter the cave less frequently than every 45 minutes. The Monument would pursue making such an upgrade.

CAVE ACCESS

Several small caves within the Monument that are administratively closed would be inventoried and evaluated to determine if they should be gated to protect cave resources and/or provide for public safety.

Tour Trails

All actions pertaining to tour trails for the Preferred Alternative would be the same as described above under Actions Common to All Alternatives.

Off-trail Travel

All actions pertaining to off-trail travel routes for the Preferred Alternative would be the same as described above under Actions Common to All Alternatives. Additionally, existing off-trail routes would be treated as travel corridors defined as a system of foot trails not to exceed two feet in width with a two-foot shoulder on each side. The maximum allowable impact would be limited to the travel corridors, allowing essentially infinite impact to the actual foot trail in the form of compaction, tracked sediments and manganese, and worn rock surfaces. With cavers staying on this trail, the rest of the cave passage would receive none of this type of impact. The shoulder area would be subject to impact from airborne lint, dust, and fine sediments.

Although the cave management staff has advised trip leaders in the past as to needed training, experience, and skills, these factors have never been formalized into a policy or training program. Consequently, without a formal policy, unnecessary impacts may occur when people forget a procedure or when new trip leaders are not adequately trained. Under this alternative, a trip leader qualification program would be formalized and incorporated into a written policy. Appendix E outlines a trip leader training program for Jewel Cave.

Different types of cave use would require different sets of skills. The Scenic Tour route, for instance, would require the ability for the leader to follow the concrete trail and to know where one is on the loop at any given time. In all instances, the trip leader would be responsible for the actions of everyone in the party.

The travel on the taped routes would require the ability to follow the flagging tape, to understand how the tapes are used in a variety of situations, to know what do when a tape is missing or out of place, to be able to spot the connecting trail between two tapes (especially when manganese footprints are not present), and to minimize new tracking of manganese (handprints on the wall, etc.). In circumstances where the trail has "wandered" the trip leader would need to know how to determine the best of multiple routes to travel.

Many already-mapped passages are not taped. In the case of exploration trips, identifying and following the best trail becomes even more important. The critical concern would be that explorers go into passages that have never been visited before; therefore, trip leaders (and the whole team) would need to have a keen understanding of how to pick the first route. Virgin cave is perfectly pristine, and all impacts are cumulative and essentially permanent, thus explorers would carry the responsibility for making the best decisions the first time. Occasionally, the right decision would be to not continue into the passage (e.g. when it is particularly fragile) because the impacts would outweigh the benefits. This could be a difficult decision for explorers who often have a mind-set of surveying as much mileage as possible. The purpose of a training program would be to help explorers see things through the eyes of the cave managers. The (volunteer) explorers would serve as an extended staff to the park's resource management division and would need to be just as capable and accountable as would be required of any paid staff member.

In order to ensure safety for cavers, protection of cave resources, and quality of exploration and research, all cave access would be done with well-trained trip leaders who have an understanding of management needs and the ability to lead other cavers effectively during normal and emergency circumstances.

Trip leaders would serve as extended park staff on off-trail trips. They would be VIP's (Volunteers In Parks) and treated as park employees to the extent allowed by the NPS VIP program. Exceptions to VIP status exist for paid staff performing duties within the scope of their position description. Each trip leader for recreation, orientation and exploration trips would be responsible for ensuring that:

- a trip report is properly filled out
- trip members are prepared for the trip
- trip members are familiar with and comply with the off-trail policies
- there is an established surface watch (all surface watches must have a copy of the current Emergency Contact Phone List)
- all park-owned gear is cleaned and returned

There are two kinds of off-trail routes at Jewel Cave, requiring different skill levels: routes that are marked with vinyl flagging (a taped route), and those that are not taped. Trip leaders would be designated as those who can lead on taped routes, and those who can also lead off the taped routes. For convenience, they will be called "On-tape" trip leaders and "Off-tape" trip leaders.

On-tape trip leaders would be qualified to lead trips on taped routes within Jewel Cave. They would be required to take a basic two-hour class that would be offered by park staff at least annually.

Off-tape trip leaders would be qualified to lead trips both on and off the taped routes in Jewel Cave. They would be required to have six additional hours of specialized training that would be offered by park staff at least annually. Both On-tape and Off-tape trip leaders would be at least 18 years of age.

Prior to starting the On-tape trip leader training, the caver would be required to participate in at least three off-trail trips and exhibit leadership skills. These trip leaders would be required to have been on the requested taped route at least three times previously and demonstrated their qualifications and knowledge of the route by leading the trip with the oversight of an accompanying approved On-tape trip leader. The Cave Management Specialist or designee would approve this trip leader based on the recommendation of the trip leader(s) of the qualifying trips.

On-tape trip leaders would be required to lead or participate in at least one off-trail trip per calendar year to maintain their trip leader status. If an On-tape trip leader failed to go on at least one trip in a given year, their trip leader status would be revoked. Trip leader status could be renewed by going on one trip the following year (as a participant), and reviewing any recent policy changes with the cave management staff. If two years have elapsed, they would be required to retake the basic trip leader training class.

Unacceptable incidents on a trip or repeated problems would constitute grounds for revoking trip leader status. Examples of unacceptable incidents would include, but not be limited to: repeatedly getting out of the cave late, unacceptable resource impacts, violation of off-trail policies, repeatedly recording data improperly, entering closed areas, or failure to comply with instructions from Monument staff.

Generally, off-tape trip leaders would be required to spend 100 hours on caving trips in Jewel Cave prior to taking the trip leader training. Exploration trip leaders would need 100 hours of exploration experience, acquiring on-the-job experience in exploring and mapping to Jewel Cave standards. Time spent sleeping at camp would not count as qualifying hours. To lead an overnight camp trip, the Off-tape trip leader would be required to participate in at least three prior camp trips. Before leading a recreation or orientation trip, the Off-tape route trip leader would have to meet all requirements for On-tape trip leader. The Cave Management Specialist or designee would approve this trip leader. Leadership skills cannot be determined by just a number of hours of cave experience, hence the need for a training program. Trip leaders would be required to stay actively involved in exploration at Jewel Cave and take an annual refresher class to maintain their certification as a trip leader.

Off-tape trip leaders would be required to lead or participate in at least three off-trail trips per calendar year to maintain their trip leader status. For camp trips, each survey day counts as an individual trip. If an Off-tape trip leader fails to go on three trips during a given year, their trip leader status would be revoked. Trip leader status could be renewed by going on one trip the following year (as a participant), and reviewing any recent policy changes with the cave management staff. If two years have elapsed, they would be required to retake the trip leader training class.

Unacceptable incidents on a trip or repeated problems constitute grounds for revoking trip leader status. Examples of unacceptable incidents include, but are not limited to: repeatedly getting out of the cave late, unacceptable resource impacts, violation of off-trail policies, repeatedly recording data improperly, entering closed areas, not effectively ensuring protection of the cave or safety of group members, or failure to comply with instructions from Monument staff.

Orientation Caving Trips

All actions pertaining to orientation caving trips for the Preferred Alternative would be the same as described above under Actions Common to All Alternatives. Trip leaders on an orientation trip would be responsible for ensuring that cave trips are conducted safely and with minimal amount of impact to cave resources.

Recreation Caving Trips

Available routes for recreation caving trips would be increased from two (the Spelunking Route and the Hub Loop) to include five additional routes: Bunyan's Loft, Japanese Gardens, Rambling Loft/Logomites, Hell's Half Acre, and Miseries to Metrecal Cavern (Figure 4). Recreational trips would be open to on-tape trip leaders and the interested public who meet basic standards for all off-trail use (e.g., age, size, and equipment). Trip leaders requesting a trip would need to submit a Cave Entry Permit (Appendix F) at least three days prior to the planned trip.

Trip leaders on a recreation trip would be responsible for ensuring that cave trips are conducted safely with minimal amount of impact to cave resources and with properly collected data (if data is collected on the trip).

Exploration Caving Trips

Exploration would be allowed close in and peripherally for both "mopping up" and "pushing the edge." Exploration through the Historic Entrance would be restricted in winter to protect hibernating bats. Except at the periphery of the cave, areas that are actively being explored by a trip leader would be reserved for that trip leader until the trip leader no longer actively continues exploration in that area.

Initial one-day exploration trips would need to be requested at least one week prior to the scheduled date of the trip by submitting a Cave Entry Permit (Appendix F). Requests for return one-day trips requiring only minimal preparation time by the Cave Management staff would need to be requested at least one day ahead of the scheduled trip by submitting a Cave Entry Permit (Appendix F). Overnight exploration trips would require submitting a Cave Entry Permit (Appendix F) at least two weeks before the trip.

Trip leaders on an exploration trip would be responsible for ensuring that cave trips are conducted safely with minimal amount of impact to cave resources and with properly collected data (if data is collected on the trip). Specifically, each trip leader would be responsible for ensuring that:

- a trip report is properly filled out
- trip members are prepared for the trip
- trip members are familiar with and comply with the off-trail policies
- an approved sketcher is present (Only sketchers approved by the Cave Management staff may sketch.) To become approved, a sketcher must meet the requirements on the sketcher evaluation form in appendix G.
- all data is recorded according to Jewel Cave National Monument standards
- there is an established surface watch (all surface watches must have a copy of the current Emergency Contact Phone List)
- all park-owned gear is cleaned and returned

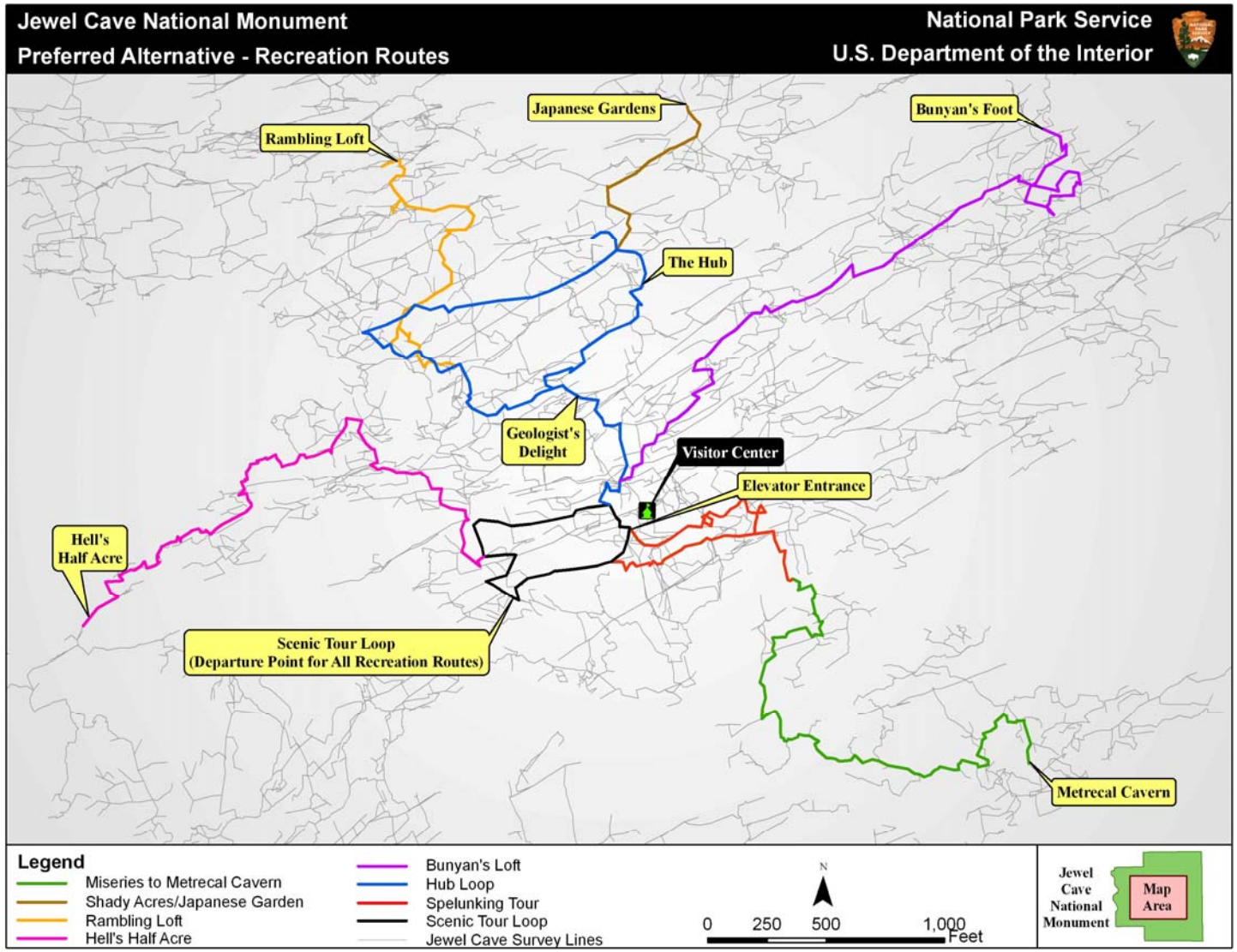

Figure 4. Recreation routes at Jewel Cave under the Preferred Alternative. These same routes would also be used as Orientation Routes for both the No Action and Preferred Alternatives.

The actual survey of the cave (and inventorying of cave features, which is an integral part of exploration at Jewel Cave) must be done by a competent survey team – people who already have experience in conducting the work accurately.

In order to provide a good product the first time, each survey team could include no more than one caver without prior survey experience and could thus gain familiarity with the process. This caver would be allowed to assist by setting stations and running the tape or laser meter, but could not sketch, read instruments, or do inventory. Sketching or instrument-reading skills could be gained by participating in practice sessions on established routes, or via prior experience gained elsewhere.

Management and Research Caving Trips

All actions pertaining to management and research caving trips for the Preferred Alternative would be the same as described above under Actions Common to All Alternatives.

CULTURAL AND HISTORIC RESOURCES

All actions pertaining to cultural and historic resources for the Preferred Alternative would be the same as described above under Actions Common to All Alternatives.

NATURAL RESOURCES AND PROCESSES

All actions pertaining to natural resources and processes for the Preferred Alternative would be the same as described above under Actions Common to All Alternatives, except for:

Airflow

The Monument would evaluate leaks in artificial entrances and seal them as needed; it would also evaluate changes in microclimate and airflow resulting from enlarged constrictions. If changes from original conditions were determined, inert constricting material would be put in place to restore the passage to its original cross-sectional area.

Exotic Plant Control

Use of pesticides to control noxious weeds could impact the water quality and resources in underlying cave passages, both known and as yet undiscovered. In 2005 the NPS completed a programmatic exoticplant management plan and EA which covered pesticide use in 13 national parks, including Jewel Cave (NPS, 2005). The plan established a need to delineate zones within the Monument where pesticides should not be applied due to water quality concerns. These zones would be established as part of the Preferred Alternative in this Cave and Karst Management Plan.

Park management is very cautious when deciding whether to use chemicals above the cave. Geologic and soil maps were used to determine pesticide use zones at Jewel Cave. The permeability of geologic layers is one of the most important factors to consider when applying pesticide in karst areas (EPA, 1999). Soil texture, depth, permeability, and composition are also important factors that need to be considered. Pesticides would not be used in areas of permeable geologic units or where the soil characteristics would create a risk of groundwater contamination.

Pesticides would only be used if it is necessary and other available options are either not acceptable or not feasible. Pesticides would only be applied via spot treatments and only in areas that pose the least risk to cave and karst resources. Chemical treatment of areas above known cave drip sites and areas where permeable rock layers are uncapped would be avoided. Based on these principles, the Monument has

delineated a "No-Pesticide Treatment Zone," an area where pesticides may not be used. The No-Pesticide Treatment Zone totals about 600 acres, or about half of the total area of the park (Figure 5).

Pesticide treatment zones would also be delineated to protect cave and karst resources. A "Minor Risk Treatment Zone" would designate areas where pesticides can be considered as part of the Integrated Pest Management (IPM) practices for the area. These zones would be areas that pose very minor risk to cave and karst resources. Pesticides would be applied in the Minor Risk Treatment Zone via spot treatments. They would be hand sprayed on individual plants. Broadcast spraying of pesticides would not be permitted in these zones.

The two species targeted for pesticide control are Canada thistle and leafy spurge, which are the only two exotic species in the park that are on the South Dakota noxious weed list. Canada thistle would be sprayed with aminopyralid (Milestone) or any other pesticide that may come out on the market in the future that has low leaching potential and low persistence. The use of any new pesticides would need to be approved by the Regional or National IPM Coordinator. Near water, glyphosate (Rodeo/Roundup) would be used, which is approved for use near water and has low leaching potential (due to high adsorption). There are currently approximately 18 acres of Canada thistle documented within the Minor Risk Treatment Zone. Plateau works well on leafy spurge; however, it is moderately persistent. There are currently less than 3 acres of leafy spurge in scattered sites throughout the Minor Risk Treatment Zone. If biological control of leafy spurge is not effective on some or all of these sites, chemical control with Plateau would be used.

A treatment schedule guides the seasonal vegetation management crew on mechanical control each year. Since every weed site in the park cannot be treated mechanically every summer due to time and staffing constraints, a rotating control schedule has been developed. Some sites are cut or pulled every year (i.e., in high visitation areas or very dense/large sites). The rest are treated every other year. With the addition of pesticide control, park staff would be able to treat more sites on a yearly basis, because applying pesticides takes less time than cutting or pulling plants.

ALTERNATIVE ACTIONS CONSIDERED BUT DISMISSED

The following issues that were brought up during scoping are either addressed as policy decisions, not applicable, or beyond the scope of this EA, and therefore are not further analyzed.

Expand the Monument boundary to encompass the entire known extent of the cave.

In 1965, a land exchange with the Forest Service changed the Monument's boundaries to encompass all of the cave passages known at that time, but cave passages have since been discovered to extend beyond the Monument boundaries. Currently, over 45% of Jewel Cave's 140 miles of surveyed passages extend beneath adjacent Forest Service land. The entire cave system lies beneath an area of about three square miles.

Both the Forest Service and the NPS are mandated to protect cave and karst resources under the Federal Cave Resources Protection Act. The Black Hills National Forest established a mineral withdrawal in 1989 for Forest Service-managed land adjacent to the Monument, to help protect the many miles of Jewel Cave that extends beyond Monument boundaries. Today, both parts of the cave are managed under an Interagency Agreement with the Forest Service (1998), which delegates responsibility for subsurface management to the Monument.

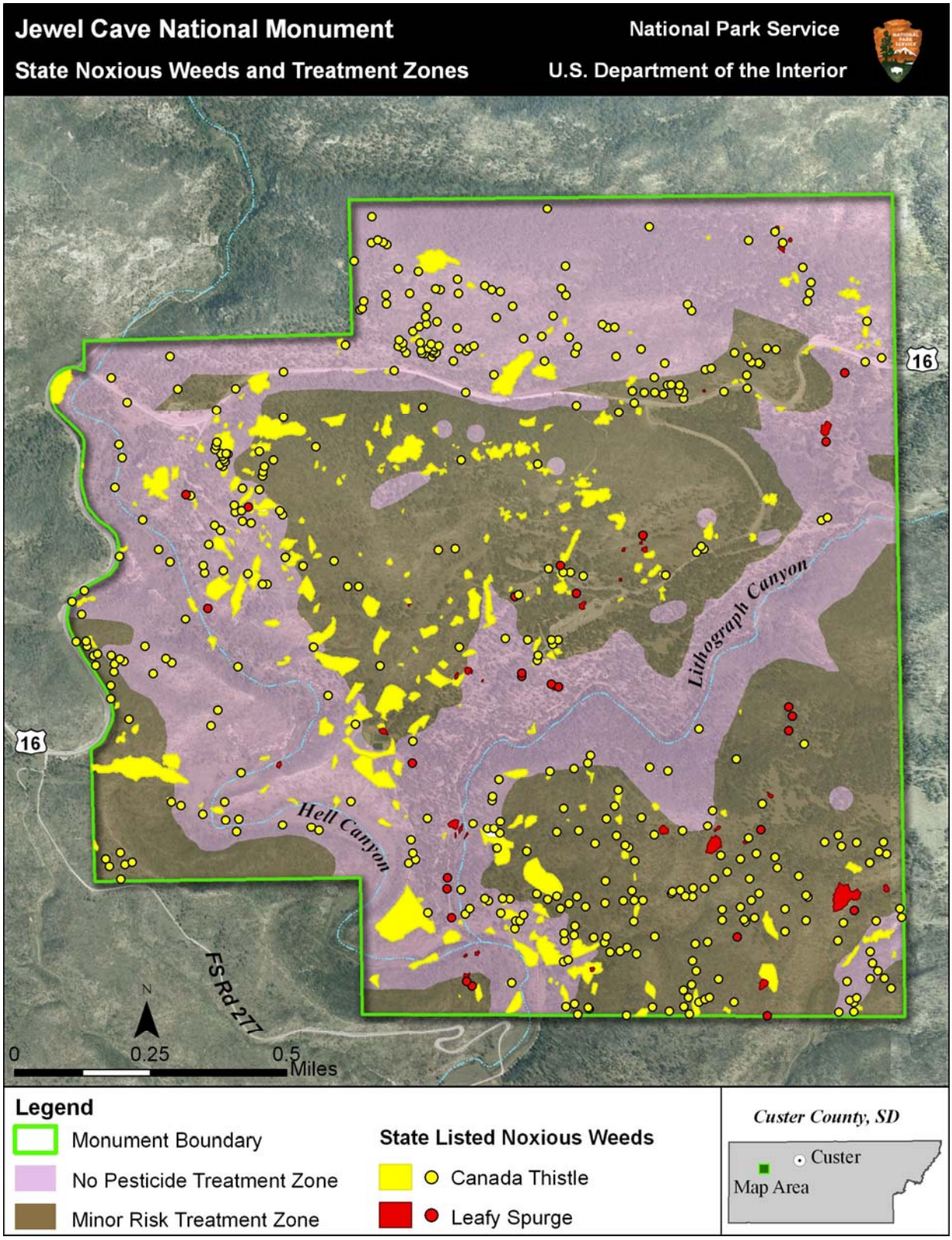

Figure 5. Exotic plant pesticide treatment zones and locations of South Dakota state listed noxious weeds at Jewel Cave National Monument.

In the early 1990s, cave exploration showed that some cave passages approached nearby private land. This provided incentive to initiate a land exchange with willing sellers. It was accomplished with the cooperation of the Monument, the Forest Service, The Nature Conservancy, and the Custer County Commission. The result was that the Forest Service now owns about one-fourth of the land that had been in private ownership in the area. The Monument will pursue protection via easements and/or additional willing-seller land exchanges that could result in private land becoming NPS or USFS federal land. The issue of acquiring additional land is beyond the scope of this EA.

Employees should not have to take annual leave to participate in exploration trips.

The majority of exploration is done by volunteers, and is not a normal duty of cave management personnel. However, when management needs dictate, exploration and survey may be done by paid staff. This is a personnel issue, and will therefore not be further analyzed in this EA.

Collect and distribute cave survey and cartographic data in a manner that will insure accuracy, thoroughness, consistency, and integrity, and which will meet all research and management needs.

As with technical matters in any discipline, standards for cave survey and cartography are subject to differing philosophies and professional debate. There is currently no national standard for the collection of cave survey and cartographic data; however, individual organizations have established their own guidelines. At Jewel Cave, cartographic symbology is based on NSS Standard Cave Map Symbols, but adapted to the unique needs of the Monument. The survey data collection standards are based on established methods. See Appendix G for Cave Survey and Cartography Standards. The selection of a particular standard is a procedural matter, and will therefore not be further analyzed in this EA.

The Federal Cave Resources Protection Act (FCRPA) of 1988 provides for the protection of sensitive data such as cave locations. At Jewel Cave, there is a need to limit the distribution of this data, including cave survey data and maps. See Appendix H: Policy for Distribution of Cave Data. Because this is described in an already-established park policy and is provided for in the FCRPA, this issue will not be further analyzed in this EA.

Collect cave feature inventory data in a manner that will ensure a high quality of data and that will meet current research and management needs.

While surveying and mapping produces information on the shape and extent of cave passages, it does not provide detailed information on the features found within them. The goal of the feature inventory is to collect broad-scale information, which can be recorded by someone with minimal expertise in the fields of geology, biology, mineralogy, etc.

There is currently no national standard for the collection of cave inventory data; however, individual organizations have established their own guidelines. At Jewel Cave, an inventory system has been created to meet unique needs of the Monument. See Appendix I for Cave Feature Inventory Standards. The use of this standard is a procedural matter, and will therefore not be further analyzed in this EA.

Conduct all research as part of a unified study and in such a way as to ensure protection of cave resources.

All research is evaluated against applicable policies and regulations via the Research Permitting and Reporting System (RPRS), reviewed, and permits are issued on a case-by-case basis. Priority is given to those projects likely to contribute to the management and understanding of Monument resources. Projects that involve destructive sampling are discouraged unless they clearly benefit management needs and the

benefits overwhelmingly outweigh the impacts. In compliance with 36CFR, sampling may only be done in Jewel Cave if no other cave would meet the specific goals of the research. Because evaluation and approval of research proposals is conducted under existing policies, this issue will not be further analyzed in this EA.

ENVIRONMENTALLY PREFERRED ALTERNATIVE

In accordance with DO-12, the NPS is required to identify the "environmentally preferred alternative" in all environmental documents, including EAs. The environmentally preferred alternative is determined by applying the criteria suggested in NEPA, which is guided by the CEQ. As stated in Section 2.7 (D) of the NPS DO-12 Handbook, "The environmentally preferred alternative is the alternative that will best promote the national environmental policy expressed in NEPA (Section 101(b))." This environmental policy is stated in six goal statements, which include:

1. Fulfill the responsibilities of each generation as trustee of the environment for succeeding generations;
2. Assure for all Americans safe, healthful, productive, and aesthetically and culturally pleasing surroundings;
3. Attain the widest range of beneficial uses of the environment without degradation, risk to health and safety, or other undesirable and unintended consequences;
4. Preserve important historic, cultural, and natural aspects of our national heritage, and maintain wherever possible, an environment which supports diversity and variety of individual choice;
5. Achieve a balance between population and resource use which will permit high standards of living and a wide sharing of life's amenities; and
6. Enhance the quality of renewable resources and approach the maximum attainable recycling of depletable resources (NEPA, 42 USC 4321-4347).

In sum, the environmentally-preferred alternative is the alternative that, not only results in the least damage to the biological and physical environment, but also that best protects, preserves, and enhances historic, cultural, and natural resources.

As evaluated against the CEQ regulations, Alternative B (the Preferred Alternative) is the Environmentally Preferred Alternative. The Alternative A (the No Action Alternative) represents the current situation of continuing cave management without a formalized policy, without a science based approach, and without a comprehensive monitoring and mitigation program to detect changes in the cave environment.

The Environmentally Preferred Alternative is Alternative B because it surpasses the No Action Alternative and the other action alternatives in realizing the full range of national environmental policy goals as stated in §101 of NEPA. This alternative also fulfills NPS responsibilities as trustees of the environment by providing vital resource information used to guide management decisions. The Preferred Alternative would not result in significant impact to the cave environment due to the management controls and mitigation measures put in place. The benefits of cave exploration and mapping would outweigh the environmental impacts of this activity.

Additionally, more off-trail cave routes would be open to recreation and orientation under the Preferred Alternative. Orientational use would provide a variety of caving experiences for the park staff, augmenting their understanding of cave resources and better preparing them for discussions with the visiting public. Recreational use would provide a variety of caving experiences for the caving public on the same fixed routes as the orientational use. These recreation trips would provide for greater

recreational opportunities than are currently offered and would also increase the number of cavers familiar with Jewel Cave who can assist the park (e.g. in a rescue situation). For both orientational and recreational uses, there would be no significant impact to the cave environment because the impacts would be confined to fixed travel corridors. In conclusion, Alternative B affords the highest level of protection of natural and cultural resources for Jewel Cave while providing for cave access on a variety of levels.

MITIGATION, MONITORING AND RESTORATION MEASURES

For all action alternatives, best management practices and mitigation measures would be used to prevent or minimize potential adverse effects associated with cave management of Jewel Cave. These practices and measures would be incorporated to reduce the magnitude of impacts and ensure that major adverse impacts would not occur. Mitigation measures undertaken during project implementation would include, but would not be limited to, those listed below. The impact analysis in the *Environmental Consequences* section was performed assuming that these best management practices and mitigation measures would be implemented as part of all action alternatives.

Currently, mitigation is used to reduce the effects of unavoidable recurring impacts. As an example, the Scenic Tour route which is used to provide for public enjoyment results in ongoing impacts. Mitigation includes such activities as lint and algae removal and reducing manganese tracking. Monitoring is an essential tool to document changes from impact, as well as the effectiveness of mitigation, restoration, and current management policies. It is commonly used to establish baseline trends and variability of natural conditions and processes. Monitoring can also help determine whether changes to cave features and trail conditions have been caused by human activity or are part of a natural process. Restoration is used to return impacted cave features to a near-natural condition, or to reverse non-recurring impacts. For example, a broken stalactite can be glued back together.

ALTERNATIVE A (NO ACTION) AND ALTERNATIVE B (PREFERRED)

Monitoring

Key indicators would be monitored in a systematic and reproducible manner to detect and document change resulting from both natural and artificial processes. These would include water quality, microclimate (temperature, relative humidity), air quality (such as radon concentration), and human impacts (lint, manganese tracking, etc.). Visual impacts would be monitored with the Monument's photo-monitoring program. Other parameters would be monitored as necessary.

In cases where the distinction between changes caused by human activity and those caused by natural processes was not clear, normal travel would be continued cautiously until the likelihood of human-caused damage was determined through photomonitoring, microclimate monitoring, and comparison with similar features along untraveled routes. Trip leaders would be trained to avoid prolonged visits to the area. Travel would be reduced or stopped if a likelihood of human-caused damage was determined, unless the impact could be mitigated.

Mitigation

The Monument would seek to mitigate any unavoidable impacts. The mitigation itself would be designed to cause no additional impact to the resource. If special circumstances required a trade-off, then the project would be peer-reviewed by at least two other NPS employees working with cave-related resource

management. An EA would be pursued for any controversial technique. In no case would impact of mitigation exceed the benefit of the mitigation activity.

Mitigation measures would be necessary in the case of unavoidable recurring impacts, such as public tours. Mitigation activities would be scheduled to avoid conflict with bat hibernation, interpretive programs, and maintenance activities. When necessary, interpretive and maintenance activities may have to be scheduled around mitigation projects. This would require careful prior planning between all divisions and consultation with the Superintendent. The cave management staff would maintain a permanent record of all mitigation activities, including dates, personnel, and techniques.

Restoration

Restoration techniques would follow those generally practiced within the cave management community. It is recognized that restoration is a continually evolving discipline, that practices in one cave might not apply in other situations, and that innovation is often required. All restoration activities would be planned using the NEPA/106 process. No objects of cultural or historic value would be damaged. Any decision to remove such artifacts would be based on adequate 106 consultation.

Restoration should cause no additional impact to the resource. If special circumstances require a trade-off, then the project would be peer-reviewed by at least two other NPS employees working with cave-related resource management. All activities would be scheduled to avoid conflict with bat hibernation, interpretive programs, and maintenance activities. When necessary, interpretive and maintenance activities may have to be scheduled around restoration. This would require careful prior planning between all divisions and in consultation with the Superintendent. The cave management staff would maintain a permanent record of all restoration activities, including dates, personnel, and techniques.

ALTERNATIVE B (PREFERRED)

Monitoring

Additional monitoring would be implemented as part of the Preferred Alternative to select key resource and impacts indicators based on the ability to detect change. New monitoring points would be added as needed. Photomonitoring would be supplemented using lint/sediment collection at representative points along established trails. Initially, particulate matter would be collected in Petri dishes and documented with digital photography; image arithmetic would be used to identify and quantify changes resulting from impact. These techniques would be evaluated and modified, supplemented, or replaced as needed. Measured impact would be determined using photo monitoring at existing sites.

Programs to monitor drip water in the cave would continue for detection of damage to corrosion residue, and could be established to analyze water quality so that the pesticide treatment zones could be re-evaluated if chemicals used by the park are detected in cave drip water.

Similar to the concept of “carrying capacity” (see the Glossary for definitions), a “maximum allowable impact” concept would be used to prevent any given area from becoming impaired over the years by small gradual impacts that would be virtually imperceptible without specific monitoring actions. The maximum acceptable coverage of rock surfaces with impacts such as manganese tracking would be set at 10% because that is the level when impacts start becoming visible to casual observation. A long-term timeframe (50-100 years) would be set as the target for such impact.

Every two to three years accumulated impacts would be measured and then extrapolated to future use so as to keep impacts below the 10% level for the next 50-100 years. For example, records would be

evaluated to determine that X number of cavers would result in Y% impact. For example, to detect the difference between a 5% impact and a 10% impact, park staff would place Petri dishes at representative locations along the travel corridors. Each year a high resolution close-up photo of the accumulated dust (against a background test pattern) would be taken. Staff would calibrate the percent coverage from No Coverage to Complete Coverage using photos standards. These standards would be made by sprinkling representative dust particles into the dish until the pattern is no longer visible. Digital image arithmetic would be used to objectively determine the percentage.

In theory, once the maximum allowable impact was reached, use of that part of the cave would stop unless the area was restored through management actions. Additionally, as the rate of impact is observed, appropriate actions would be taken to mitigate the impact. Mitigation or restoration could conceivably extend the period of use indefinitely. This would be done in an "adaptive management" sense: the technique could be reviewed every five years to evaluate its effectiveness and possibly to redefine the maximum allowable impact level or the target timeframe.

Mitigation

To minimize the potential impact of pesticides on surface water and ground water resources and cave resources, the following Best Management Practices (BMPs) would be implemented:

- Only pesticides that are registered for use in or near water would be used in those areas.
- Only those pesticides that have a low potential toxicity, such as glyphosate (Roundup Pro and Rodeo) would be used within areas near surface waters or in areas with a high leaching potential. Glyphosate is strongly adsorbed into soil, with little potential for leaching to ground water. Microbes in the soil readily and completely degrade it even in low temperatures. It tends to adhere to sediments when released to water and does not accumulate in aquatic life (Forest Service, 2004).
- Applications of pesticides would be avoided during periods and in areas where seasonal precipitation or excess irrigation water is likely to wash residual pesticides into waterways.
- Applications of pesticides within 50 feet of surface water bodies (including streams, rivers, lakes, and waterways) would be done by hand or with vehicle mounted ground equipment to minimize the potential impacts to surface waters.
- The park currently monitors potable drinking water quality. This monitoring would continue to confirm that potable water meets drinking water standards as outlined by the Safe Drinking Water Act (SDWA).
- Surface water and ground water monitoring programs would be implemented as appropriate to protect natural resources. Rigorous testing of pesticides is required prior to release as a registered product.
- When available from the Regional IPM Coordinator, vertical buffer zones to ground water would be used.
- "No-Pesticide Treatment Zones" would designate areas in which no pesticides would be applied. These zones would include areas above known cave drip sites, areas within the watersheds, which have potential to drain into cave and karst resources, and areas where permeable rock layers are uncapped.
- "Minor Risk Treatment Zones" would designate areas where pesticides can be considered as part of the IPM practices for the area. These zones would be areas that pose very minor risk to cave and karst resources. Chemicals with high specificity, low leaching potential, and low persistence would be preferred for use in these areas, and pesticides would be hand sprayed on individual plants. Broadcast spraying of pesticides would not be permitted in these zones.
- The park would develop programs to monitor water quality in the cave, and would re-evaluate the pesticide treatment zones if chemicals used by the park are detected in cave drip water.

COMPARISON OF ALTERNATIVES

Table 1 compares the potential environmental impacts resulting from the alternatives. Potential impacts are provided according to environmental resource topic. The *Environmental Consequences* section of this EA contains a detailed discussion of these potential impacts by resource topic.

Table 1. Summary Comparison of Impacts

Impact Topic	Alternative A: No Action	Alterative B: Preferred Alternative
Macrobiotic Resources	Long-term, negligible, local, direct, adverse impacts to macrobiotic resources due to cave visitation and maintenance activities *Minor adverse cumulative impacts on macrobiotic resources*	Long-term, negligible, local, direct, adverse impacts to macrobiotic resources due to cave visitation, maintenance activities, and possibly pesticides and other chemicals in cave water *Minor adverse cumulative impacts on macrobiotic resources*
Microbiotic Resources	Short- and long-term, minor, local, direct, adverse impacts to microbiotic resources due to cave visitation and lack of monitoring *Minor adverse cumulative impacts on microbiotic resources*	Short- and long-term, minor, local, direct, adverse impacts to microbiotic resources due to cave visitation and possible pesticides or other chemicals in cave water. Formalized trip leader training and maintenance policies, and monitoring of impacts would have long-term, minor, local, direct, beneficial effects *Minor adverse cumulative impacts on microbiotic resources*
Microclimate	Short- and long-term, minor, local and widespread, direct, adverse and beneficial impacts to microclimate due to cave visitation, the lighting system, and sealing of artificial entrances *Minor adverse cumulative impacts on microclimate*	Short- and long-term, negligible, local and widespread, direct, adverse and beneficial impacts to microclimate due to cave visitation, the modified lighting system, and sealing of artificial entrances. *Minor adverse cumulative impacts on microclimate*
Physical Cave Features	Long-term, minor to moderate, local and widespread, direct, adverse impacts to physical cave features due to cave visitation, lack of quantitative monitoring, informally trained trip leaders and maintenance staff, focus of exploration on peripheral areas, and the lighting system	Long-term, moderate, local and widespread, direct and indirect, beneficial impacts to physical cave features due to establishment of travel corridors, implementation of impact monitoring, and redesign of the lighting system; and long-term, minor, local and widespread, direct adverse impacts due to increased

Impact Topic	Alternative A: No Action	Alterative B: Preferred Alternative
	Moderate adverse cumulative impacts on physical cave features	recreational use on established routes *Minor adverse cumulative impacts on physical cave features*
Water Resources	Short- and long-term, minor, local and widespread, direct, adverse impacts to water resources due to possible contaminants in cave drip water infiltrating from the surface *Minor adverse cumulative impacts on water resources*	Short- and long-term, minor, local and widespread, direct, adverse impacts to water resources due to possible contamination of cave water with pesticides and surface chemicals *Minor adverse cumulative impacts on water resources*
Exotic Vegetation	Long-term, minor, local, direct, beneficial impacts on exotic vegetation due to mechanical and biological control of exotic plants *Minor beneficial cumulative impacts on exotic vegetation*	Long-term, moderate, local, direct, beneficial impacts on exotic vegetation due to comprehensive IPM control of exotic plants, including pesticide treatments *Moderate beneficial cumulative impacts on exotic vegetation*
Public Health and Safety	Long-term, minor, direct, adverse impacts on public health and safety due to continued opportunities for recreation, orientation, and exploration in Jewel Cave *Minor adverse cumulative impacts on public health and safety*	Long-term, minor, direct, adverse impacts on public health and safety due to continued opportunities for recreation, orientation, and exploration in Jewel Cave and possible pesticides in drinking water *Minor adverse cumulative impacts on public health and safety*
Visitor Use and Experience	Long-term, negligible, direct, beneficial impacts on visitor use and experience due to continued opportunities for recreation, orientation, and exploration in Jewel Cave. *Major beneficial cumulative impacts on visitor use and experience*	Long-term, moderate, direct, beneficial impacts on visitor use and experience due to continued and improved opportunities for recreation, orientation, and exploration in Jewel Cave. *Major beneficial cumulative impacts on visitor use and experience*

AFFECTED ENVIRONMENT

This section describes the characteristics of the environment at the park that could be affected by a cave and karst management plan.

In addition to Jewel Cave, the Monument contains nine other caves, all less than 300 feet in length. These caves contain biological resources, including small packrat, bat, and tiger salamander populations. A few caves also contain archaeological resources and may contain paleontological resources. None of the caves is currently gated, which could leave them vulnerable to damage and present a safety concern. Though not likely, because of the small size of the Monument, it is possible that additional small caves remain undiscovered. This management plan and EA, however, only focuses on known caves within the Monument.

MACROBIOTIC RESOURCES

Nine species of bats inhabit the Monument: *Lasionycteris noctivagans* (Silverhaired bat), *Lasiurus cinereus* (Hoary bat), *Eptesicus fuscus* (Big brown bat), *Myotis lucifugus* (Little brown myotis), *Myotis volans* (Long-legged myotis), *Myotis ciliolabrum* (Western small-footed myotis), *Myotis septentrionalis* (Northern long-eared myotis), *Myotis thysanodes* (fringe-tailed myotis), and *Corynorhinu townsendii* (Townsend's big-eared bat). The silver-haired and hoary bats roost in trees and snags during the summer months and migrate south for the winter. The other seven species use caves and can be found within the Monument year-round (Mattson and Bogan, 1994; Cryan, 1997). Several of these species have been given special designations. Four species have been designated US Fish and Wildlife Service "species of concern": *M. thysanodes, M. volans, M. ciliolabrum and C. townsendii.* Four species are monitored by the South Dakota Natural Heritage Program: *M. thysanodes pahasapensis, L. noctivagans, M. septentrionalis, and C. townsendii* (NPS, 2003).

A significant population of bats inhabits a portion of Jewel Cave near the Historic entrance. Over 1,000 bats use the cave as a hibernaculum each winter, including the world's largest known hibernating population of Townsend's big-eared bats, a species of special concern. Anecdotal evidence suggests the bats did not begin using the cave until after the entrance was artificially enlarged and probably not until the 1930s when a solid wood door was removed from the entrance.

Prior to 1992, eight bat counts were conducted. The first counts, in the 1960s, focused on Townsend's big-eared bats; other species were not recorded. Jewel Cave's bat count methodology was standardized in 1992, and has been used each year to track population changes. Using this methodology, the total number of bats counted each year has ranged from 1,072 to 1,605. All *C. townsendii, E. fuscus,* and *Myotis* spp. are now recorded.

Bats have been seen as far in as 1,000 feet from the Historic entrance, but do not generally inhabit passages beyond that point. Six bat species hibernate in Jewel Cave each winter between October and May; the cave is a hibernaculum for *C. townsendii*, with 600 to 1,100 individuals. These populations would be vulnerable to disturbance only in the wintertime. Although some bats use the cave as a roost during the summer months, the cave is not a maternity site. The bats are most vulnerable to disturbance in the winter time when they are hibernating.

Bushy-tailed woodrats, or packrats, (*Neotoma cinerea)* are often seen in Jewel Cave, usually within 300 feet of the Historic entrance. They have occasionally been sighted as far as 700 feet into the cave, near the Dungeon Room. Packrats have also been found deep inside Jewel Cave a few hundred feet from a small blowhole that connects to the surface but is not a human-sized entrance (Moore, et. al., 1996). Packrats

have been recorded in several other Monument caves, where they often create large nests. Deer mice (*Peromyscus maniculatus)* are also found inside Jewel Cave within 180 feet of the entrance and in several other caves in the Monument (Moore, et. al., 1996). Packrats and deer mice are commonly found elsewhere and are not at risk to occasional human traffic.

Some invertebrates have been found in the cave, but are not troglodytic (cave dwelling). Most are parasites to the mammals or others that wander into the cave. Springtails (*Collembola* spp.) are found near the Historic cave entrance and in the immediate vicinity of the Scenic Tour route. The springtails along the Scenic Tour route appear to be introduced via human activity. Three other sites in the cave support springtail populations (Moore, et. al., 1996). These sites are in wet areas along heavily traveled routes. They are located in isolated spots beyond the tour routes in the close-in portions of the cave; no springtails have been found in the peripheral areas.

Feral cats have been seen near and just inside the Historic entrance of Jewel Cave. They have been observed killing bats as they fly out of the cave. Due to this risk of bat predation, any cat found within the Monument is live-trapped and taken to an animal shelter.

MICROBIOTIC RESOURCES

The study of microbiotic resources in caves is in its infancy, and few details are known. Presently, most efforts have been directed to baseline inventories. Recent discoveries in other NPS caves have shown that microbiologic communities can exist in the low-energy environment present deep within the larger cave systems. These microbes are cave adapted and often differ uniquely from their surface counterparts.

The cost of analysis and logistics of cave travel make it infeasible to evaluate every location in Jewel Cave for the presence of microbiotic resources; so future research will be based on identified microenvironments. A single *in situ* sampling effort in 2001 (Northup and Spilde, 2002) confirmed the presence of microbes in corrosion residue at the farthest known reaches of Jewel Cave but did not attempt to culture, classify, or identify them.

Corrosion residue is a dark, fluffy substance that is occasionally found on the walls and ceilings of the upper levels of the cave in locations where the calcite crystal coating is absent. Its occurrence throughout the cave system is sparse and is documented in the cave inventory database which is compiled simultaneously with exploration and mapping.

The 2001 study concluded that:

> "There are definite similarities between the Jewel Cave and Lechuguilla/Spider Caves corrosion residues, including: 1) color; 2) mineral make-up; 3) the presence of star-shaped features, high in iron or manganese oxides; and 4) the presence of bacteria, including stalked bacteria. Such preliminary results warrant further study of additional sites and more in-depth study of the sites already sampled . . .
>
> ". . . Our initial examination of Jewel Cave corrosion residue indicates that microbial communities are present in the CR [corrosion residue]. If funds could be found, DNA could be extracted and sequenced from the enrichment cultures and from samples of corrosion residues from the cave. Sequences obtained could be matched against national sequence databases to reveal closest relatives and the extent to which organisms in Jewel Cave are novel. Additional staining studies would expand our knowledge of how extensive and numerous bacterial

communities are and could determine whether they are metabolically active." (Nothrup and Spilde, 2002)

More corrosion residue samples were taken in October, 2005 for DNA sequencing and bulk chemistry analysis. Results of this study are pending. Along the tour routes, Moore et al. (1996) found heterotrophic bacteria and fungi in densities approaching those found in soils collected outside the entrances. These high densities closely paralleled lint deposition from visitors traveling in those areas. Common protozoa were found throughout the cave. Nematode and arthropod populations were largely restricted to the entrances, tour routes, and well-traveled corridors. The ecosystem is largely detritus-based, probably as a result of human activity.

Based on studies done elsewhere, new microorganisms are expected to be found in areas with water and/or corrosion residue. Researchers at Wind Cave National Park have found several new subdivisions of the kingdom *Archea* (single-celled organisms generally similar to bacteria) in corrosion residue and in infiltrating water (Horrocks, 2005). Researchers at Carlsbad Caverns National Park have determined that the greatest numbers and the greatest diversity of cave-adapted bacteria are found in places where water is present (Allison, 2005).

MICROCLIMATE

Cave climate includes temperature, pressure, relative humidity, and airflow speed/direction. These parameters have been monitored for many years at Jewel Cave. In 1986, a weekly microclimate monitoring program was begun, measuring temperature and relative humidity at selected points along the Scenic Tour route. Little variation was seen in the recorded values from week to week, and so in 1996 the sampling was changed from weekly to monthly. In 1997 more sampling points were added, to include sites along the Lantern Tour routes.

There is normally little variance in the microclimate: temperatures are a near-constant 49 degrees Fahrenheit and the relative humidity is near 100%. On the Scenic Tour, the cave temperature averages 49 degrees Fahrenheit. Near the Historic entrance, along the Lantern Tour routes, the average is 47 degrees Fahrenheit. In most places the average relative humidity is consistently greater than 95%. Because the relative humidity is so high, evaporation occurs very slowly unless enhanced by heat input from people or electric lights, or by drier air entering through natural and artificial entrances. Except near the Historic Entrance where outside air often flows into the cave, the temperature and humidity is nearly constant in any one area of the cave, although the actual value can be different in one area than in another.

Jewel Cave's barometric wind was studied by Herb Conn in 1965. His work demonstrated that the cave's airflow is almost exclusively caused by changes in the outside air pressure. When the barometric pressure outside the cave is greater than the pressure inside, air rushes into the cave. When the pressure outside the cave is less than inside, air blows out. The air is never stationary along the main flow paths. It is always flowing in or out and commonly exceeds 20 miles-per-hour; in constrictions deep inside the cave speeds of up to 35 miles per hour have been recorded. It is possible that airflow dynamics could be changed because of artificial entrances and enlarged passages. This in turn has the potential to change the cave's microclimate significantly.

An additional property of the barometric wind is that its volumetric flow rate is proportional to the total volume of the cave, including the undiscovered portions. Conn developed an equation to model the behavior of the airflow at the entrance, and was able to use this model to estimate the volume of the cave. Dr. Andreas Pflitsch has been conducting similar airflow research in Jewel Cave since 2003, using

sensitive ultrasonic anemometers and taking long-term measurements at constrictions deep in the cave as well as at the entrance.

PHYSICAL CAVE FEATURES

At more than 140 miles, Jewel Cave is the second longest cave in the world. The elevational range within Jewel Cave spans 631 feet. This is its official "depth." The highest point in the cave is 5,406 feet above sea level, and the lowest point is at 4,775 feet. The cave's depth below the surface varies a great deal. The cave intersects the surface in Hell Canyon, at the only natural entrance. The deepest point in the cave is 749 feet below the ground surface. Except near the naturally lighted entrance and electrically-lit Scenic Tour route, the cave is in complete darkness. Most parts of the cave are completely silent, except for the sound of dripping water or wind blowing through constrictions.

Jewel Cave was formed by the gradual dissolution of limestone by slow moving, mildly acidic groundwater. The water enlarged a network of cracks that had formed during the Laramide uplift of the Black Hills. The layer of calcite crystals that covers much of the cave walls was created by the re-deposition of calcite from water saturated with the mineral. These calcite crystals are the "jewels" of Jewel Cave.

After the water that formed the cave drained, speleothems began to form. Jewel Cave contains all the common types of calcite formations, such as stalactites, stalagmites, flowstone, and frostwork. The cave is decorated with dripstone in the wet areas in less than 2% of the known cave. The dry parts of the cave contain some formations created by the deposition of gypsum, such as gypsum needles, beards, flowers, and spiders. Jewel Cave also contains very rare formations called a "hydromagnesite balloons." They are small, pearly white bubbles of hydromagnesite and are of unknown origin.

Deposits of manganese minerals (generically referred to as “manganese”) are found ubiquitously throughout the cave. The manganese is black and easily transferred to cleaner rock surfaces. If not managed properly by confining footprints and handprints to well-established trails, the manganese tracking becomes aesthetically displeasing because it leaves a permanent record of human activities and draws undue attention to even the slightest impacts.

WATER RESOURCES

Jewel Cave’s water resources consist of dripping water, a few small pools, and isolated locations with condensation droplets. There are no known streams or lakes inside the cave. Water is relatively uncommon in Jewel Cave; less than 2% of the know cave has water resources. Some areas are perennially wet, and some are seasonally wet. Virtually all drip sites are subject to changes in seasonal and long-term climate conditions.

Over fifty cave drip sites are currently known. Water collectors have been established at four of these sites. The collection system is used to gather water for drinking on exploration trips and for monitoring water quality to detect potential impacts. Each collector consists of a tarp, which directs the dripping water into a plastic container via a tube. Any excess water spills out of the container onto the cave floor as much as ten feet away from the location where it naturally drips from the ceiling.

Over time a slime mold forms on the water collection tubing, which is periodically replaced. In the case of the water supply near the cave’s only established camp site, the water collection mechanism is treated a few times each year with about 0.2 ounce of liquid bleach to kill the non-native slime mold. The active ingredients are diluted with 10-20 gallons of water over the course of a few weeks before spilling onto a

one-square-foot area of cave floor on a foot trail, several feet from the normal destination of the dripping water.

Most of the drip sites occur near surface valleys and draws where impermeable layers of a cap rock have been eroded away. The few exceptions seem to be associated with surface developments, such as buildings, paved surfaces, and the elevator shaft; and with naturally-occurring areas of intensely fractured bedrock.

Water quality and quantity is a critical factor affecting the cave. Impermeable structures, such as the Monument parking lot, have altered natural drainage patterns with unknown effects on cave resources. Pollutants carried by water may be affecting cave resources, but some of these effects are not well documented or understood. Hydrocarbons from parking lot runoff, nitrates, phosphates, and other contaminants may be infiltrating into the cave. Drip water samples have shown elevated chloride levels (most likely from road salts) at many cave drip sites. Dye traces have shown a direct hydrologic link between parking lot runoff and certain cave passages. Dye can travel from the surface to the cave in just a few days.

A soil survey published in 1990 mapped five distinct soil units within Jewel Cave National Monument. The survey was conducted on a broad scale, covering all of Pennington and Custer Counties. Some soils are particularly shallow, with depth to bedrock of less than 10 inches. The five units at Jewel Cave are described as having either “moderate” or “moderately rapid” permeability, with a permeability range of 0.6 to 6.0 inches/hour and either moderate or rapid runoff.

Some pesticides pose a greater risk to groundwater than others. Pesticides with very high adsorption coefficients, such as glyphosate (Roundup/Rodeo), adhere so tightly to soil particles that the potential for water contamination is minimal if the pesticide is applied according to the label instructions, and in areas with sufficient soil cover. These chemicals are considered to be “non-mobile” and are approved for use in and near aquatic areas.

Other chemicals are considered to be “mobile,” have relatively low adsorption coefficients, and are highly persistent, highly soluble, or both. Such chemicals can pose a greater risk to groundwater if applied inappropriately. Picloram (Tordon) residue, for example, was found 48 inches below the soil surface up to 2 years after application in a study conducted in Montana (Watson et al., 1989).

At Jewel Cave, where the soil is never 48 inches thick, this could present a serious environmental problem if a mobile pesticide were applied under the same environmental conditions as in the study. On the other hand, there are areas of the cave that do not experience infiltration of water, and exhibit no evidence of this happening in the past (by the presence of dry stalactites, drip holes in sediment, etc.).

Cave water can eventually make its way to an aquifer. At Jewel Cave, the Madison Limestone does not hold water; the park’s wells are in the Deadwood Aquifer, below the Madison Limestone. For contaminated water to reach the Deadwood Aquifer, it would need to first pass through the Englewood Formation, which acts like a confining layer in the vicinity of Jewel Cave. Davis et al. (2006) reported that “the wells in the Deadwood aquifer at Jewel Cave National Monument have a low to moderate vulnerability to contamination” and that “the Deadwood aquifer is artesian and is overlain by a confining bed, which could be expected to limit infiltration of surface water.”

EXOTIC VEGETATION

Vegetation management has implications for both surface and cave resources. The presence and management of exotic plants alters the vegetative cover, and this influences the quantity and patterns of surface water that infiltrates the cave.

In the last several years, noxious weeds have become an increasing concern throughout the country, including the Monument. Infestation by noxious weeds can change soil chemistry and hydrologic patterns, and in turn affect the natural karst system. Methods for controlling weeds, such as the use of chemicals, can also affect water chemistry. Jewel Cave National Monument uses an integrated pest management (IPM) approach to control noxious weeds. IPM includes manual / mechanical control (hand-pulling and cutting), chemical control (application of pesticides), and biocontrol (introducing insects which attack the plant).

More than 50 exotic plants have been identified at the Monument. Two exotic plant species are considered noxious weeds by the State of South Dakota. The Monument's general exotic plant management strategy, as described in the 2005 Northern Great Plains Exotic Plant Management Plan (NPS, 2005), focuses on exotic plants that pose the greatest threat to park resources; that are not yet widespread, but have the potential to become widespread; and that can potentially be controlled. The Monument employs a three- to four-person seasonal weed crew each summer. This crew is responsible for manually controlling exotic plants, documenting treated areas, and mapping new infestations.

Priorities for exotic plant management at Jewel Cave include Canada thistle, leafy spurge, and field bindweed. Other exotic plants of concern include musk thistle, common tansy, common mullein, houndstongue, bull thistle, and black henbane. Most control efforts at the Monument have focused on leafy spurge and Canada thistle. Field bindweed, musk thistle, bull thistle, houndstongue, black henbane, and common mullein have also been treated.

Approximately 60 acres are infested with Canada thistle and/or leafy spurge. Jewel Cave has developed integrated pest management work plans for leafy spurge and Canada thistle. Treatments used to manage these species have included mechanical, biological, and chemical methods. Leafy spurge has been managed by mechanically removing bracts and flowers at all sites; applying Plateau in the fall at all sites that lie outside of the pesticide no-treatment zone; and by releasing flea beetles at any sites that could support beetle populations. Leafy spurge treatment areas are monitored and new infestations are mapped annually. Canada thistle has been managed by cutting and bagging seedheads and cutting/pulling plants; releasing biological control agents such as weevils and gallflies; and chemically treating infestation areas using Transline or Rodeo. A large mapping project to document locations of Canada thistle infestations was completed in 2001, and a GIS database has been created from mapping data collected between 2000 and 2006.

An informal agreement with USFS stipulates that only aminopyrlaid (Milestone) and imazapic are to be used within the Jewel Cave Mineral Withdrawal boundary. As part of the agreement, Jewel Cave hand-pulls or cuts exotics in a few small areas on Forest Service land adjacent to the Monument boundary. No chemicals have been applied at the Monument since September 2005.

PUBLIC HEALTH AND SAFETY

Cave resources contain such features and conditions as confusing passages, low ceilings, loose rocks, unstable floor material, ledges and pits, tight constrictions, conditions conducive to hypothermia, and radon gas exposure. These are part of the natural environment which the Monument is mandated to

preserve. In order to facilitate exploration, handlines and/or ladders have been installed on some climbs, and loose rocks have been moved from main travel routes.

The radon gas found inside Jewel Cave is a natural part of the cave environment and does not require mitigation by artificial manipulation of the environment. It occurs in concentrations ranging from 29 to 169 picocuries per liter, varying geographically and with time. Exposure levels for any current staff or volunteer cave use is well below the limit of four working-level months per year.

There is no radio communication or cellular phone communication inside the cave, which would delay the initiation of search and rescue operations. Several locations in the cave are extremely remote; it currently takes highly skilled cavers 11 hours (one way) to reach the "end" of the cave.

VISITOR USE AND EXPERIENCE

Over the last 100 years, Jewel Cave has become a popular tourist destination, and annual visitation has in the past reached more than 100,000, of which 80,000 actually visited the cave. Currently, annual cave visitation has dropped below 80,000. From 2000 to 2005 there were 15 recreation trips (about 2.5 per year) with 40 unique participants. These occurred on the Spelunking Tour route and Hub Loop. During the same period, there were 45 exploration trips, with 32 unique participants.

About 90 percent of visitation occurs between May and September. July and August are generally the busiest months. Non-recreational use is minor and not a significant percentage of visitation. Local and regional visitors make up 6 percent of visitors, 91 percent of visitors travel from outside the region, while foreign visitors account for 3 percent of visitors.

Jewel Cave's physical challenges, its vast, silent, dark passages, and spectacular beauty afford visitors of all backgrounds and levels of experience the opportunity to experience a world like no other. The Scenic Tour is open to visitors of all ages, and is currently limited to 30 participants per tour; the tour duration is one hour and 20 minutes. This guided tour passes through ½-mile of large passages and shows visitors a variety of cave passages and speleothems. The route is electrically lit, with a concrete path, aluminum stairs, walkways, and platforms, and handrails.

The Discovery Tour is open to visitors of all ages, and is currently limited to 15 participants. The tour duration is 20 minutes. This guided tour allows visitors to see one large room, calcite spar crystals, and multiple cave levels. The tour is electrically lit, with a concrete path, a short flight of stairs, an aluminum platform, and handrails. Visitors with disabilities, including those in wheelchairs, can participate in this tour without needing to negotiate the stairs.

The Lantern Tour is open to visitors 6 years of age or older, and is currently limited to 20 participants; the tour duration is approximately 2 hours. This route is minimally developed, with steep wooden stairs and handrails, and no electric lights. Visitors carry an oil lantern to light their way, scramble over rocks and stoop under low ceilings. This guided tour offers visitors an opportunity to experience the cave as early visitors did. It includes a tour of an historic log cabin built by the Civilian Conservation Corps, and the guiding rangers lead the tour dressed in an NPS uniform from the 1940s.

The Spelunking Tour is open to visitors 16 years of age or older, who can fit through a space 8.5 inches high and 24 inches wide. This tour is limited to 5 participants. The tour duration is approximately 4 hours. This guided tour allows visitors with no prior caving experience or equipment to travel through the cave in its completely undeveloped state. Participants wear helmets, headlamps, gloves, and knee and elbow

pads. The tour is extremely strenuous, and involves climbing, chimneying, crawling, and squeezing through tight spaces.

The Interpretive Division provides fee-waived programs for *bona fide* educational groups. These visits are along the Scenic Tour route only. There are no self-guided tours of Jewel Cave. Experienced cavers have the opportunity to participate in ongoing exploration of the cave, as park volunteers. There is no charge for this type of use. Most areas of the cave are currently open only to survey, scientific research, or management uses. Experienced cavers wishing to have a purely recreational experience, without collecting survey data or assisting with research or management projects, can participate in recreational trips on the Spelunking Tour route or the Hub Loop. These trips are offered approximately annually, to members of the Paha Sapa Grotto (the local caving club) or for caving events such as the Black Hills Caver Classic or Rocky Mountain Regional. There is no charge for these trips. They are scheduled by the park and are led by volunteer trip leaders who know the route. Participants provide their own gear.

ENVIRONMENTAL CONSEQUENCES

This section describes the environmental consequences associated with the alternatives. It is organized by impact topic, which distills the issues and concerns into four distinct topics for discussion analysis. These topics focus on the presentation of the environmental consequences to allow a standardized comparison between alternatives.

METHODOLOGY

NEPA requires consideration of context, intensity, and duration of impacts, direct or indirect impacts, cumulative impacts, and measures to mitigate for impacts. NPS policy also requires that "impairment" of resources be evaluated in all environmental documents.

Overall, the NPS based the following impact analyses and conclusions on the review of existing literature and Jewel Cave National Monument studies, information provided by experts within the NPS and other agencies, professional judgments and park staff insights, and public input.

GENERAL IMPACT DEFINITIONS

Potential impacts are described in terms of type (beneficial or adverse), context, duration, intensity, and impairment. The following general definitions were used to evaluate the context, intensity, duration, and cumulative nature of impacts associated with project alternatives. Impairment is discussed below.

Context of Impact
Context is the setting within which an impact is analyzed, such as local, park-wide, or regional. Council of Environmental Quality (CEQ) requires that impact analysis include discussions of context. Localized impacts are those that affect the resource area only on the project site or its immediate surroundings, and would not extend park-wide or into the region. In this cave and karst plan the context would be either **local** (i.e., impacts affecting a site-specific area of the cave in the immediate vicinity where an action would occur) or **widespread** (i.e., impacts affecting many or most areas of the cave).

Intensity of Impact
Impact intensity is the degree to which a resource would be beneficially or adversely affected by an action. Impact intensities are quantified as negligible, minor, moderate, or major. Resource-specific criteria used to rate the intensity of project impacts are presented within each resource area impact analysis.

Duration of Impact
The duration of impact is measured as short-term and long-term. A short-term impact is defined as lasting for less than one year. A long-term impact is defined as lasting for greater than one year.

Direct verses Indirect Impacts
Direct effects are impacts caused by the alternative(s) at the same time and in the same location as the action. Indirect effects are impacts caused by the alternative(s) that occur later in time or farther in distance than the action, but still reasonably foreseeable. An indirect impact could occur because of a change to another resource or impact topic.

Cumulative Impacts
CEQ regulations (40 CFR 1508.7) require the assessment of cumulative impacts in the decision-making process for Federal projects. A cumulative impact is an impact on the environment that results from the

incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of which agency (Federal or non-Federal), organization, or person undertakes such other actions. Cumulative impacts can result from individually minor, but collectively significant, actions taking place over a period of time.

Any use of the cave will result in impact. Because all impacts to the cave are essentially cumulative and permanent, acceptable impacts must be carefully defined and levels of use must be managed so that cave resources and values are not impaired and their integrity is maintained.

Cumulative impacts are considered for all alternatives and are presented at the end of each impact topic discussion analysis. To determine potential cumulative impacts, known past, current, and reasonably foreseeable future projects and actions in Jewel Cave were identified. These cumulative actions are evaluated in the cumulative impact analysis in conjunction with the impacts of each alternative to determine if they would have any additive effects on natural resources, cultural resources, or visitor use. Listed here are cumulative actions that are evaluated in the impact analyses for each resource and alternative:

Past Cumulative Actions

- Initial Exploration
- Focus of exploration shifted to peripheral areas
- Exploration of the close-in areas was resumed
- Surface and subsurface development
- Establishment and use of off-trail routes
- Emphasis of exploration shifted to peripheral areas
- Emphasis of exploration shifted to include close-in areas again
- Establishment of permanent underground camp site
- Treatment of noxious weeds

Current Actions

- Cave tours
- Continuing recreation, orientation, and exploration
- Exotic Plant Management Plan (mechanical and biological control)

Reasonably Foreseeable Actions

- Facility construction
- Highway construction

IMPAIRMENT OF PARK RESOURCES

In addition to determining the environmental consequences of the Proposed Action and other alternatives, the NPS *Management Policies 2006* and DO-12 require analysis of potential effects to determine if actions would impair a park's resources.

The fundamental purpose of the National Park System, established by the Organic Act and reaffirmed by the General Authorities Act, as amended, begins with a mandate to conserve park resources and values. NPS managers must always seek ways to avoid or minimize to the greatest degree practicable adverse impacts on park resources and values. However, the laws do give NPS management discretion to allow impacts to park resources and values when necessary and appropriate to fulfill the purposes of a park, as long as the impact does not constitute impairment of the affected resources and values. Although Congress has given NPS management discretion to allow certain impacts within parks, that discretion is

limited by statutory requirement that the NPS must leave park resources and values unimpaired, unless a particular law directly and specifically provides otherwise. The prohibited impairment is an impact that, in the professional judgment of the responsible NPS manager, would harm the integrity of park resources or values, including opportunities that otherwise would be present for the enjoyment of those resources or values. An impact to any park resource or value may constitute an impairment. However, an impact would more likely constitute an impairment to the extent it affects a resource or value whose conservation is:

- Necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the park;
- Key to the natural or cultural integrity of the park or to opportunities for enjoyment of the park; or
- Identified as a goal in the park's Master Plan or General Management Plan (GMP) or other relevant NPS planning documents.

Impairment may result from NPS activities in managing the park, visitor activities, or activities undertaken by concessionaires, contractors, and others operating in the park. In this section, a determination on impairment is made in the conclusion statement of each resource area for each alternative. The NPS does not analyze the potential for impairment of recreational values/visitor experience (unless impacts are resource based), socioeconomic values, or park operations.

MACROBIOTIC RESOURCES

The thresholds of change for the intensity of an impact on macrobiotic resources are defined as follows:

Negligible: Macrobiotic resources would not be affected or the effects would be at or below the level of detection, would be short-term, and the changes would be so slight that they would not be of any measurable or perceptible consequence to the species' population within the project area. There would be no observable or measurable impacts to wildlife species, their habitats, or the natural processes sustaining them. Impacts would be well within the range of natural fluctuations.

Minor: Effects to macrobiotic resources would be detectable, although localized, small, and of little consequence to the species' population within the project area. Impacts would be detectable, but they would not be expected to be outside the natural range of variability and would not be expected to have any long-term effects on native species, their habitats, or the natural processes sustaining them. Population numbers, population structure, genetic variability, and other demographic factors for species may have small, short-term changes, but long-term characteristics remain stable and viable. Occasional responses to disturbance by some individuals could be expected, but without interference to feeding, reproduction, or other factors affecting population levels. Sufficient habitat would remain functional to maintain viability of all species within the project area. Impacts would be outside of critical reproduction periods for sensitive species.

Moderate: Effects to macrobiotic resources would be readily detectable, long-term, and project area-wide with consequences at the population level. Mortality or interference with activities necessary for survival can be expected on an occasional basis, but is not expected to threaten the continued existence of the species in the project area. Impacts on wildlife species, their habitats, or the natural processes sustaining them would be detectable, and they could be outside the natural range of variability for short periods of time. Population numbers, population structure, genetic variability, and other demographic factors for species may have short-term changes, but would be expected to rebound to pre-impact numbers and to remain stable and viable in the long-term. Frequent response to disturbance by some individuals could be expected, with some negative impacts to feeding, reproduction, or other factors affecting short-term

population levels. Sufficient habitat would remain functional to maintain variability of all wildlife species within the project area. Some impacts might occur during critical periods of reproduction or in key habitat for sensitive native species.

Major: Effects to macrobiotic resources would be obvious, long-term, and would have substantial consequences to wildlife populations within the project area. Extensive mitigation measures would be needed to offset any adverse effects and their success would not be guaranteed. Impacts on and wildlife species, their habitats, or the natural processes sustaining them would be detectable, and they would be expected to be outside the natural range of variability for long periods of time or to be permanent. Population numbers, population structure, genetic variability, and other demographic factors for species might have large, short-term declines with long-term population numbers significantly depressed. Frequent responses to disturbance by some individuals would be expected, with negative impacts to feeding, reproduction, or other factors resulting in a long- term decrease in population levels. Breeding colonies of native species might relocate to other portions of the park. Loss of habitat may affect the viability of at least some native species within the project area.

IMPACTS OF ALTERNATIVE A (NO ACTION)

Impacts Analysis

Macrobiotic resources would continue to be protected under current management. Specifically, to reduce the risk to hibernating bats, no exploration or public tours would be allowed through the historic entrance of the cave from October 1st to May 31st. Other activities in the vicinity of hibernating bats would be kept to an absolute minimum. The presence of packrats, deer mice, and springtails would not require cave travel restrictions, although these species may be temporarily displaced or disturbed by visitors and maintenance activities. These actions present long-term, negligible, adverse impacts because the sensitive bat species would not be disturbed and the other species may only be disturbed minimally and temporarily.

Cumulative Effects

Past, present, and future cave maintenance and recreation, orientation, and exploration trips contribute to the disturbance or displacement of macrobiotic resources such as springtails, deer mice, and pack rats. Restrictions on cave travel, which have been in effect for many years, help to minimize impacts on hibernating bats.

Surface activities may affect water infiltrating into the cave. In the past, drip water samples showed elevated chloride levels most likely from road salt, and dye traces have shown a direct hydrologic link between parking lot runoff and certain cave passages. Additionally, past pesticide practices in the park and within the Jewel Cave Mineral Withdrawal area on USFS land (prior to the IPM plan and agreement with USFS) may have led to contamination of cave drip water. Chemicals occurring in cave water could be harmful if bats and other wildlife drink it.

Cumulatively, these past, present and future actions would have minor, adverse impacts on macrobiotic resources. Since the No Action Alternative would continue the same visitation and maintenance practices as these other actions, but would not include application of pesticides in the park and only approved pesticides in the Mineral Withdrawal area, Alternative A would contribute negligible, adverse cumulative impacts on macrobiotic resources. In combination, these actions would result in minor, adverse cumulative impacts on macrobiotic resources.

Conclusion

There would be long-term, negligible, local, direct adverse impacts to macrobiotic resources as a result of the No Action Alternative due to cave visitation and maintenance activities. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to macrobiotic resources.

IMPACTS OF ALTERNATIVE B (PREFERRED)

Impacts Analysis

Macrobiotic resources would continue to be protected under Alternative B. Specifically, to reduce the risk to hibernating bats, no exploration or public tours would be allowed through the historic entrance of the cave from October 1st to May 31st. Other activities in the vicinity of hibernating bats would be kept to an absolute minimum. The presence of packrats, deer mice, and springtails would not require cave travel restrictions, although they may be temporarily displaced or disturbed by visitors and maintenance activities.

Bats that hibernate in Jewel Cave each winter rouse occasionally to drink or move to a more suitable location within the cave (Tigner, 2007). The bats drink water that drips from the cave ceiling, or lick droplets of condensation from the walls. Pesticides used on the surface to control exotic vegetation under this alternative could infiltrate into water entering the cave. High levels of pesticides in this water could be toxic to the bats. However, Best Management Practices (see BMP's listed on page 37 under *Mitigation*), along with the designation of pesticide treatment zones, should minimize if not preclude the presence of pesticides in cave water.

Other chemicals used on the surface for maintenance activities could reach the cave as well through groundwater. However, under this alternative, formalizing maintenance procedures into policy (see page 24 under *Policy and Training Program*) would help ensure that greater thought is given to such activities as salting and de-icing roads, or using detergents or petroleum based products that can contaminate groundwater. It is likely that these additional protection measures would considerably lower the risk of cave biota ingesting chemicals from cave water.

These actions present long-term, negligible, adverse impacts because sensitive bat species would not be disturbed, other species may only be disturbed minimally and temporarily, and there would be low risk that wildlife would be exposed to pesticides or chemicals in cave water.

Cumulative Effects

Past, present, and future cave maintenance and recreation, orientation, and exploration trips contribute to the disturbance or displacement of macrobiotic resources such as springtails, deer mice, and pack rats. Restrictions on cave travel, which have been in effect for many years, help to minimize impacts on hibernating bats.

Surface activities may affect water infiltrating into the cave. In the past, drip water samples showed elevated chloride levels most likely from road salt, and dye traces have shown a direct hydrologic link between parking lot runoff and certain cave passages. Additionally, past pesticide practices in the park and within the Jewel Cave Mineral Withdrawal area on USFS land (prior to the IPM plan and agreement with USFS) may have led to contaminants in cave drip water. Chemicals occurring in cave water could be harmful if bats and other wildlife drink it.

Cumulatively, these other actions would have minor, adverse impacts on macrobiotic resources. Since the Preferred Alternative would continue the same visitation and maintenance practices as these other actions, great caution would be taken with pesticide application, and new maintenance policies would reduce the likelihood that future cave water would contain harmful chemicals, Alternative B would contribute negligible, adverse cumulative impacts on macrobiotic resources. In combination, these actions would result in minor, adverse cumulative impacts on macrobiotic resources.

Conclusion
There would be long-term, negligible, local, direct adverse impacts to macrobiotic resources as a result of the Preferred Alternative due to cave visitation, maintenance activities, and possibly pesticides and other chemicals in cave water. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to macrobiotic resources.

MICROBIOTIC RESOURCES

Because so little is known about microbiotic resources, impact thresholds are established for the environments where they expected to be found: areas with corrosion residue and areas with moisture.

Negligible: Water resources are not manipulated by cavers; impacts to corrosion residue are not visible.

Minor: Water resources are manipulated by cavers for less than one year, resulting in no permanent changes; or impacts to corrosion residue are visible, but not extensive (less than 5% is disturbed in any one area).

Moderate: Water resources are manipulated by cavers for more than one year, resulting in less than 10% permanent changes (in any one area); or impacts to corrosion residue are visible, but not extensive (6-10% is disturbed in any one area).

Major: Water resources are manipulated by cavers for more than one year resulting in more than 10% permanent changes (in any one area); or impacts to corrosion residue are visible and extensive (6-10% is disturbed in any one area).

IMPACTS OF ALTERNATIVE A (NO ACTION)

Impacts Analysis
A preliminary study in 2001 showed that there are microbes in samples of corrosion residue taken from the cave. Research at Carlsbad Caverns National Park indicates that use of the cave has the potential to impact microbiotic resources, but such impact can be minimized if basic precautions are observed: heavy travel is restricted to specified corridors; rest stops are made in established areas; established procedures reduce the introduction of organic matter from food crumbs, bodily excretions, direct contact with water, and unnecessary contact with cave surfaces; and areas of known rich microbiotic resources are avoided as needed (Allison, 2005). Defining travel corridors, establishing protective procedures, limiting or avoiding areas of high resource value, and impact monitoring are accepted in the caving community, and throughout the NPS.

Alternative A restricts most travel to the travel corridors, with the exception of exploration and survey activities that would occur away from the corridors. Rest stops would be made only at established areas. Trip leaders are informally trained to avoid corrosion residue sites and water. Four drip sites in the cave (out of 50 known sites) are used on a long-term basis for drinking to facilitate exploration trips to the most remote areas of the cave. The redirection and collection of water at these few sites does not constitute a significant or permanent change in water quality or quantity, but could result in adverse impacts to microbial resources (less than 5% in any one area). Established procedures assure that all human waste is removed from the cave.

This alternative would not provide for monitoring to document physical damage to corrosion residue sites, but such damage could be precluded by informal trip leader training and avoidance of sensitive sites.

Under this alternative, impacts to microbiotic resources would be minor, short- and long-term, and adverse because many precautions would be in place to avoid or minimize contact with microbiota.

Cumulative Effects
Initial cave exploration, surface and subsurface development, the use of pesticides to treat noxious weeds, and the establishment of an underground campsite contribute adverse cumulative effects on microbial communities as a result of the re-direction of subsurface water and potential for water contamination.

Recent construction of a restroom facility in the Historic Area and future highway realignment have the potential to alter water quality and redirect subsurface water. The proposed relocation of the highway away from the cave could result in beneficial impacts to microbial resources due to an improvement in water quality and the restoration of natural hydrologic flow conditions. Restroom construction above the cave would redirect subsurface water and could result in adverse impacts to microbial resources.

Cumulatively, these other actions would have minor, adverse impacts on microbiotic resources. The current management actions that would continue under Alternative A would contribute minor, adverse cumulative impacts on microbiotic resources. In combination, these actions would result in minor, adverse cumulative impacts on microbiotic resources.

Conclusion
There would be short- and long-term, minor, local, direct adverse impacts to microbiotic resources as a result of the No Action Alternative due to cave visitation and lack of monitoring. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to microbiotic resources.

IMPACTS OF ALTERNATIVE B (PREFERRED)

Impacts Analysis
Little is known about microbiological resources in Jewel Cave; however, based on studies at Lechuguilla Cave, Wind Cave, and elsewhere, microbes are expected to be found in greatest numbers near water sources and in corrosion residue. The potential effect of chemicals on these organisms is not yet known, but cave microbiota, some potentially unique and cave adapted, may be threatened if pesticides or other chemicals occur in cave waters. Under this alternative, formalizing maintenance procedures into policy (see page 24 under *Policy and Training Program*) would help ensure that greater thought is given to such

surface activities as salting and de-icing roads, or using detergents or petroleum based products that can contaminate groundwater. The ecology and vulnerability of such organisms are not well-understood, and impacts could occur despite best efforts to prevent them.

Alternative B restricts most travel to the travel corridors, with the exception of exploration and survey activities that occur away from the corridors. Rest stops are made only at established areas. Trip leaders are formally trained to avoid corrosion residue sites and water. Four drip sites in the cave (out of 50 known sites) are used for drinking to facilitate exploration trips to the most remote areas of the cave. The redirection and collection of water at these few sites does not constitute a significant or permanent change in water quality or quantity, but could result in adverse impacts to microbial resources (less than 5% in any one area). Established procedures assure that all human waste is removed from the cave. This alternative provides for monitoring to document physical damage to corrosion residue sites, but would also preclude such damage by proper trip leader training and avoidance of sensitive sites.

Under this alternative, pesticides would be used to control exotic vegetation on the surface. Cave biota, some potentially unique and cave-adapted, may be threatened by pesticides in cave waters. However, Best Management Practices (see BMP's listed on page 37 under *Mitigation*), along with the designation of pesticide treatment zones, should minimize if not preclude the presence of pesticides in cave water.

Although some potential effects are unknown or difficult to determine, the impacts of pesticide use, cave visitation, and maintenance activities on microbiotic resources under this alternative would likely be adverse; however, these adverse actions would be offset by the benefits of a formalized maintenance policy, monitoring, and formal trip leader training. Overall, Alternative B would have short- and long-term, minor, and adverse impacts on microbiotic resources in Jewel Cave.

Cumulative Effects
Initial cave exploration, surface and subsurface development, the use of pesticides to treat noxious weeds, and the establishment of an underground campsite contribute adverse cumulative effects on microbial communities as a result of the re-direction of subsurface water and potential for water contamination.

Proposed restroom facility construction in the Historic Area and future highway realignment have the potential to alter water quality and redirect subsurface water. The proposed relocation of the highway away from the cave could result in beneficial impacts to microbial resources due to an improvement in water quality and the restoration of natural hydrologic flow conditions. Restroom construction above the cave would redirect subsurface water and could result in adverse impacts to microbial resources.

Cumulatively, these other actions would have minor, adverse impacts on microbiotic resources. The management actions that would occur under Alternative B, in addition to improved monitoring and formalized trip leader training and maintenance policies, would contribute negligible, adverse cumulative impacts on microbiotic resources. In combination, these actions would result in minor, adverse cumulative impacts on microbiotic resources.

Conclusion
There would be short- and long-term, minor, local, direct, adverse impacts to microbiotic resources as a result of the Preferred Alternative due to cave visitation and possible pesticides or other chemicals in cave water. Formalized trip leader training and maintenance policies, and monitoring of impacts would have long-term, minor, local, direct, beneficial effects. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the

Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to microbiotic resources.

MICROCLIMATE

The thresholds of change for the intensity of an impact on microclimate resources are defined as follows:

Negligible: Human-caused changes in airflow, temperature, or relative humidity are less than 2% of the annual average, and no other resources are affected.

Minor: Human-caused changes in airflow, temperature, or relative humidity are less than 5% of the annual average, and no other cave resources are affected.

Moderate: Human-caused changes in airflow, temperature, or relative humidity are greater than 5% of the annual average, and other cave resources are temporarily affected.

Major: Human-caused changes in airflow, temperature, or relative humidity are greater than 5% of the annual average, and other cave resources are permanently affected.

IMPACTS OF ALTERNATIVE A (NO ACTION)

Impacts Analysis
Under Alternative A, the Monument would attempt to seal artificial entrances, except the Historic entrance, on an as-needed basis, which would help in preserving the cave microclimate. Ongoing cave visitation would continue to alter the temperature and relative humidity of Jewel Cave. The lighting system, which would be on continuously during and between cave tours, would also add heat to the cave environment. These actions would cause changes totaling less than 5% of the annual average in airflow, temperature, and relative humidity. Alternative A presents short- and long-term minor adverse impacts on the cave microclimate.

Cumulative Effects
Initial and continuing exploration, subsurface development, establishment and use of off-trail routes, establishment of a permanent underground camp site, and ongoing cave tours have and continue to contribute to altering the microclimate in Jewel Cave. Additionally, two artificial entrances were excavated at the site of the present visitor center (the elevator shaft, used to access the tour route, and an entrance from Lithograph Canyon into the Target Room, used as an emergency exit and for maintenance purposes). Although these entrances are carefully controlled, they continue to alter air flow and change the microclimate.

Cumulatively, these other actions would have minor, adverse impacts on the cave microclimate. The management actions that would occur under Alternative A, as compared to past actions which have affected cave microclimate to a much greater degree, would contribute negligible, adverse cumulative impacts on the microclimate of Jewel Cave. In combination, these actions would result in minor, adverse cumulative impacts on microclimate.

Conclusion
There would be short- and long-term, minor, local and widespread, direct, adverse and beneficial impacts to the microclimate in Jewel Cave as a result of the No Action Alternative due to cave visitation, the lighting system, and sealing of artificial entrances. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the

establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument k; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to microclimate at Jewel Cave.

IMPACTS OF ALTERNATIVE B (PREFERRED)

Impacts Analysis
Under Alternative B, the Monument would evaluate leaks in artificial entrances and seal them as needed; it would also evaluate changes in microclimate and airflow resulting from enlarged constrictions. If changes from original conditions were determined, inert constricting material would be put in place to restore the passage to its original cross-sectional area. These actions would be beneficial in preserving the cave microclimate. Ongoing cave visitation would continue to alter the temperature and relative humidity of Jewel Cave. The lighting system, which would be turned off between cave tours, would still contribute heat to the cave environment but on a reduced basis compared to current conditions. These actions would cause changes totaling less than 2% of the annual average in airflow, temperature, and relative humidity. Alternative B would present short- and long-term, negligible, adverse and beneficial impacts on the cave microclimate.

Cumulative Effects
Initial and continuing exploration, subsurface development, establishment and use of off-trail routes, establishment of a permanent underground camp site, and ongoing cave tours have and continue to contribute to altering the microclimate in Jewel Cave. Additionally, two artificial entrances were excavated at the site of the present visitor center (the elevator shaft, used to access the tour route, and an entrance from Lithograph Canyon into the Target Room, used as an emergency exit and for maintenance purposes). Although these entrances are carefully controlled, they continue to alter air flow and change the microclimate.

Cumulatively, these other actions would have minor, adverse impacts on the cave microclimate. The management actions that would occur under Alternative B, as compared to past actions which have affected cave microclimate to a much greater degree, would contribute negligible, adverse cumulative impacts on the microclimate of Jewel Cave. In combination, these actions would result in minor, adverse cumulative impacts on microclimate.

Conclusion
There would be short- and long-term, negligible, local and widespread, direct, adverse and beneficial impacts to the microclimate in Jewel Cave as a result of the Preferred Alternative due to cave visitation, the modified lighting system, and sealing of artificial entrances. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to microclimate at Jewel Cave.

PHYSICAL CAVE FEATURES

The thresholds of change for the intensity of an impact on physical cave features are defined as follows:

Negligible: Cave features become dirty or damaged with use of the cave, but the effects are not visually detectable.

Minor: Cave features become dirty or damaged with use of the cave, the effects are visible under close examination, but they can be cleaned or repaired (e.g., a stalactite that can be cleaned if smudged with manganese, or glued back together if broken).

Moderate: Cave features become dirty or damaged with use of the cave, are plainly visible, but can be cleaned or repaired (e.g., a stalactite that can be cleaned if smudged with manganese, or glued back together if broken).

Major: Cave features become dirty or damaged with use of the cave, are plainly visible, but are either not cleanable or irreparable (e.g., frostwork or hydromagnesite balloons, which are too delicate to be cleaned or repaired).

IMPACTS OF ALTERNATIVE A (NO ACTION)

Impacts Analysis

Alternative A would not provide a mechanism for making management decisions based on measured impacts. Management decisions would be based on personal observation and professional judgment. Inadvertent damage would be minimized by continued informal training of trip leaders and maintenance staff and appropriately matching cavers' skills to the vulnerability of cave areas. Deliberate damage on exploration trips would be averted by having relatively few explorers with years of proven trustworthiness. On recreation and orientation trips, such damage would be averted by having experienced trip leaders in charge of small groups. Additionally, trip leaders are informally trained to avoid impacts to cave features.

All cave travel causes some degree of impact to cave features, including lint accumulation, worn rock surfaces, and manganese tracking. This alternative would provide for recreational use of two routes, which have already experienced heavy use, and therefore have a comparatively high level of impact; and orientational use of several routes, which have had moderate-to-heavy use in the past and are in areas that have a moderate-to-high degree of impact.

Impacts would be primarily constrained to travel corridors; newly explored areas beyond the corridors would be subject to additional impact from limited human presence. Continued exploration in any given area could result in a higher ratio of impact to benefit, eventually resulting in a point of diminishing returns.

Coverage of cave surfaces by particulate matter would not be detectable at the targeted 10% maximum allowable impact level due to a lack of monitoring. Widening of the travel corridors and stray footprints would be detectable but not quantifiable.

Without formal policy and training of maintenance staff, simple procedures such as carrying ladders, changing light bulbs and the use of cleaning solutions could have substantive adverse impacts on physical cave features. For example, fragile speleothems could be broken or damaged and certain solvents would be inappropriate for cave use.

Under this alternative, lights along the Scenic Tour route would stay on continuously during business hours. Visitation and electric lighting along the route would continue to encourage the unnatural growth of algae. The green color of the algae would be unsightly and unnatural, and would not give cave visitors a true impression of the natural cave environment. The algae are an organic substrate on which introduced fauna can thrive, and would produce organic acids that can cause degradation of bedrock and speleothems. These impacts would continue; however, algae is monitored and treated as appropriate.

Under this alternative, impacts to the physical cave environment would be minor to moderate, long-term, and adverse due to continuing cave visitation, lack of quantitative monitoring, informally trained trip leaders and maintenance staff, and the lighting system.

Cumulative Effects
Due to the lack of natural regenerative processes, Jewel Cave is a nonrenewable resource; all impacts are cumulative and essentially permanent.

Impacts include the physical degradation of cave surfaces from repeated travel over time, tracking of manganese or other staining minerals on to clean rock surfaces, and inadvertent or deliberate damage to speleothems or other cave features. The ubiquitous presence of manganese makes the matter of tracking one of the foremost management concerns. Some speleothems, such as hydromagnesite balloons, gypsum beards, and calcite rafts are extremely fragile and are particularly vulnerable to breakage. Human presence in the cave always results in the deposition of a small amount of detritus consisting of hair, skin cells, and lint from clothing. In many places, human travel stirs up fine sediments that settle onto adjacent cave surfaces. This redistributed dust can build up over time and affect the cave's aesthetics and damage delicate speleothems.

Rest stops used by cavers have a greater likelihood of impact or input of foreign material. A group of people tends to spread out when resting, resulting in a broader area of impact than would normally occur along a travel corridor. Additional foreign material may consist of dropped crumbs or spilled liquids, which can be introduced while cavers are eating.

Exploration of new (previously unknown) cave passages results in first-time impact. Oftentimes, this is a one-time impact, since the passage may not continue and there will be no need to return to it in the future. The level of impact increases with the amount of visitation.

Initial exploration, establishment of an underground campsite, subsurface development, the use of the Spelunking Route as a public caving tour route, and the use of established recreation and orientation routes have resulted in moderate to major, adverse cumulative impacts to physical cave features. The use of established travel corridors has produced a moderate, beneficial cumulative impact. No future actions are planned that would affect physical cave resources.

These same cumulative actions would continue under Alternative A; however, as many of the impacts already exist and are permanent, the No Action Alternative would in comparison contribute minor, adverse cumulative impacts on physical cave features. In combination, these actions would result in moderate, adverse cumulative impacts on physical cave features.

Conclusion
There would be long-term, minor to moderate, local and widespread, direct, adverse impacts to physical cave features as a result of the No Action Alternative due to cave visitation, lack of quantitative monitoring, informally trained trip leaders and maintenance staff, and the lighting system. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to physical cave features.

IMPACTS OF ALTERNATIVE B (PREFERRED)

Impacts Analysis

Alternative B would provide a means to evaluate physical degradation and allow for management decisions to curtail or redirect use based on measured impact. Inadvertent damage would be minimized by proper training of trip leaders and maintenance staff and appropriately matching cavers' skills to the vulnerability of cave areas. Deliberate damage would be very unlikely because of proper training for and supervision of off-trail travel.

Recreational use on established routes under the Preferred Alternative would increase throughout the cave. Recreational and orientational use would occur on several routes which have had moderate-to-heavy use in the past and are in areas that have a moderate-to-high degree of impact. Existing off-trail routes would be treated as travel corridors defined as a system of foot trails not to exceed two feet in width with a two-foot shoulder on each side. The maximum allowable impact would be limited to the travel corridors, allowing essentially infinite impact to the actual foot trail in the form of compaction, tracked sediments and manganese, and worn rock surfaces. With cavers staying on this trail, the rest of the cave passage would receive none of this type of impact. The shoulder area would be subject to impact from airborne lint, dust, and fine sediments.

Coverage of cave surfaces by particulate matter would be detectable with monitoring, well below the targeted 10% maximum allowable impact level. Widening of the travel corridor and stray footprints would be detectable and quantifiable.

Establishing a formal policy and training of maintenance staff (see page 24 under *Policy and Training Program*) would minimize impact to physical cave features from simple procedures such as carrying ladders, changing light bulbs and using cleaning solutions. For example, to reduce manganese tracking, specific paths would be designated for changing light bulbs, or to protect fragile speleothems, experienced cavers would service the light fixtures.

Redesigning the lighting system so that only the sections occupied by a tour group would be turned on (nine months of the year) would reduce the amount of heat input, and would reduce the ability of algae (which is not natural to the cave) to grow, by reducing amount of light available for photosynthesis. The lights in unoccupied sections would be left off until a tour group arrives.

Under this alternative, impacts to physical cave features would be both beneficial and adverse. The establishment of travel corridors, implementation of impact monitoring, formalized training, and redesign of the lighting system would have moderate, long-term, beneficial impacts. Increased exploration activity throughout the cave and increased recreational use on established routes would have minor, long-term, and adverse impacts.

Cumulative Effects

Due to the lack of natural regenerative processes, Jewel Cave is a nonrenewable resource; all impacts are cumulative and essentially permanent.

Impacts include the physical degradation of cave surfaces from repeated travel over time, tracking of manganese or other staining minerals on to clean rock surfaces, and inadvertent or deliberate damage to speleothems or other cave features. The ubiquitous presence of manganese makes the matter of tracking one of the foremost management concerns. Some speleothems, such as hydromagnesite balloons, gypsum beards, and calcite rafts are extremely fragile and are particularly vulnerable to breakage. Human presence in the cave always results in the deposition of a small amount of detritus consisting of hair, skin

cells, and lint from clothing. In many places, human travel stirs up fine sediments that settle onto adjacent cave surfaces. This redistributed dust can build up over time and affect the cave's aesthetics and damage delicate speleothems.

Rest stops used by cavers have a greater likelihood of impact or input of foreign material. A group of people tends to spread out when resting, resulting in a broader area of impact than would normally occur along a travel corridor. Additional foreign material may consist of dropped crumbs or spilled liquids, which can be introduced while cavers are eating.

Exploration of new (previously unknown) cave passages results in first-time impact. Oftentimes, this is a one-time impact, since the passage may not continue and there will be no need to return to it in the future. The level of impact increases with the amount of visitation.

Initial exploration, establishment of an underground campsite, subsurface development, the use of the Spelunking Route as a public caving tour route, and the use of established recreation and orientation routes have resulted in moderate to major, adverse cumulative impacts to physical cave features. The use of established travel corridors would produce a moderate, beneficial cumulative impact. The shift in exploration priorities to the peripheral cave areas (for about 20 years) resulted in a negligible, beneficial cumulative impact to about half of the known cave. No future actions are planned that would affect physical cave resources.

The Preferred Alternative would continue some of these cumulative actions that have adverse effects on physical cave features, and would also increase exploration and recreation/orientation opportunities. This alternative would also include beneficial actions, such as establishment of travel corridors, implementation of impact monitoring, formalized training, and redesign of the lighting system. Thus, Alternative B would contribute negligible, adverse and beneficial cumulative impacts. In combination, these actions would result in minor, adverse cumulative impacts on physical cave features.

Conclusion
There would be long-term, moderate, local and widespread, direct and indirect beneficial impacts to physical cave features as a result of the No Action Alternative due to establishment of travel corridors, implementation of impact monitoring, formalized training, and redesign of the lighting system; and long-term, minor, local and widespread, direct adverse impacts due to increased recreational use on established routes. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to physical cave features.

WATER RESOURCES

The thresholds of change for the intensity of an impact on water resources are defined as follows:

Negligible: Neither water quality nor hydrology would be affected, or changes would be non-detectable or, if detected, would have effects that would be considered slight and short-term. Chemical or physical changes to water quality would not be detectable, would be well below water quality standards or criteria, and would be within historical or desired water quality conditions.

Minor: Changes in water quality or hydrology would be measurable, although the changes would be small and would likely be short-term. No mitigation measure associated with water quality or hydrology would be necessary. Chemical or physical changes to water quality would be detectable, but would be well below water quality standards or criteria and within historical or desired water quality conditions.

Moderate: Changes in water quality or hydrology would be measurable and long-term. Mitigation measures associated with water quality or hydrology would be necessary and the measures would likely succeed. Chemical or physical changes to water quality would be detectable, but would be at or below water quality standards or criteria.

Major: Changes in water quality or hydrology would be readily measurable and would have substantial consequences to the project area. Mitigation measures would be necessary and their success would not be guaranteed. Chemical or physical changes to water quality would be detectable and would be frequently altered from desired water quality conditions. Chemical, physical, or biological water quality standards or criteria would be locally exceeded on a short-term and temporary basis.

IMPACTS OF ALTERNATIVE A (NO ACTION)

Impacts Analysis

As there would not be changes to management practices under the No Action Alternative, water resources in Jewel Cave would continue to be threatened by the possibility of chemicals from the surface infiltrating groundwater and entering the cave in drip water. Drip water samples in the past have showed elevated chloride levels most likely from road salt, and dye traces have shown a direct hydrologic link between parking lot runoff and certain cave passages. Under this alternative, maintenance procedures and training would not be formalized into policy, thus there would be an ongoing risk that the use of chemicals in surface activities would not be managed consistently and that chemicals could infiltrate groundwater and reach the cave. Furthermore, cave water could eventually make its way to the Deadwood aquifer which has a low to moderate vulnerability of contamination. However, basic water quality monitoring for chlorides and nitrates, which are generally indicative of human impact (e.g., road salt, leaking sewer lines) would continue on an as needed basis to detect any contaminants in drip water which would trigger mitigation or other management actions.

Four drip sites in the cave (out of 50 known sites) are used for drinking to facilitate exploration trips to the most remote areas of the cave. The redirection and collection of water at these few sites does not constitute a significant change in water quality or quantity. Under this alternative there would be minor, adverse, short- and long-term impacts on water resources due to possible chemicals reaching cave water from surface activities.

Cumulative Effects

Past, present, and future chemicals used in surface maintenance activities have the potential to infiltrate groundwater and reach Jewel Cave in drip water. Additionally, past pesticide practices in the park and within the Jewel Cave Mineral Withdrawal area on USFS land (prior to the IPM plan and agreement with USFS) may have led to pesticide contamination of cave water.

A recently constructed restroom facility in the Historic Area and future highway realignment have the potential to alter water quality and redirect subsurface water. The proposed relocation of the highway away from the cave could result in beneficial impacts to water resources due to an improvement in water quality and the restoration of natural hydrologic flow conditions.

Cumulatively, these other actions would have minor, adverse impacts on water resources. Since the No Action Alternative would continue the same use of chemicals in surface maintenance practices as these other actions, but would not apply pesticides in the park and only approved pesticides in the Mineral Withdrawal area, Alternative A would contribute negligible adverse cumulative impacts on water resources. In combination, these actions would result in minor, adverse cumulative impacts on water resources.

Conclusion
There would be short- and long-term, minor, local and widespread, direct adverse impacts to water resources as a result of the No Action Alternative due to possible contaminants in cave drip water infiltrating from the surface. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to water resources.

IMPACTS OF ALTERNATIVE B (PREFERRED)

Impacts Analysis
Under Alternative B, exotic vegetation in the Monument would be controlled using pesticides, among other methods. Pesticide use has the potential to impact water quality, especially in karst environments. Limestone areas are susceptible to the contamination of groundwater with pesticides because water moves quickly through fractures and caves with minimal filtration or breakdown of pesticide compounds. Where soils above limestone are thin, coarse, or sandy, contamination of groundwater is even more likely because water can move quickly through the soil layer directly into fractures in the underlying rock. Once the water has entered the limestone, there is little or no opportunity for degradation of pesticide chemicals by soil microbes or sunlight (EPA, 1999). At Jewel Cave, if water containing pesticide moves into the limestone, the pesticide can persist in the water and be carried with it into the cave system below.

Although limestone is highly susceptible to groundwater contamination, the overlying Minnelusa Formation contains a relatively impermeable sandstone layer that may prevent most water and pesticides from entering the cave. Park management would be very cautious when deciding whether or not to use chemicals above the cave. The Monument would implement measures to limit the potential for infiltration of contaminants into Jewel Cave by designating pesticide treatment zones. A "No Pesticide Treatment Zone" would restrict the use of pesticides in any areas of exposed limestone within the park. A "Minor Risk Treatment Zone" located in park areas capped with impermeable Minnelusa layers, would allow pesticide use that would pose a very minor risk to cave and karst resources, specifically, water reaching the cave. Pesticides would not be used in areas of permeable geologic units or where the soil type and thickness would create a risk of groundwater contamination.

With the implementation of Best Management Practices when applying pesticides near water sources (see BMP's listed on page 37 under *Mitigation*), the effect of chemical treatment on cave and water resources would be reduced. Although impacts would be difficult to determine, improved monitoring that would include water sampling would reveal any pesticides reaching the cave at selected drip sites and would allow management to re-evaluate pesticide use practices.

Another concern regarding exotic plants, in addition to the fate of pesticides used to control them, is that they may consume a large amount of surface water, which could alter the hydrology and the availability

of water in the cave. This adverse effect would be reduced with the exotic plant control program which would eliminate exotic plants more rapidly and over larger areas through the use of pesticides.

Other chemicals used on the surface for maintenance activities could reach the cave through groundwater as well. However, under this alternative, formalizing maintenance procedures into policy (see page 25 under Alternative B) would help ensure that greater thought is given to such activities as salting and de-icing roads, or using detergents or petroleum based products that can infiltrate groundwater. Thus, the risk of contaminating cave drip water with pesticides and other chemicals which could eventually reach the Deadwood aquifer, which has a low to moderate vulnerability of contamination, would be greatly reduced.

Although there are substantial risks to water resources with the application of pesticides, given the designation of pesticide treatment zones, implementation of BMP's, and monitoring of cave drip water for contaminants, Alternative B would have minor, adverse, short- and long-term impacts on water resources.

Cumulative Effects
Past, present, and future chemicals used in surface maintenance activities have the potential to infiltrate groundwater and reach Jewel Cave in drip water. Additionally, past pesticide practices in the park and within the Jewel Cave Mineral Withdrawal area on USFS land (prior to the IPM plan and agreement with USFS) may have led to pesticides contamination of cave water.

The recently constructed restroom facility in the Historic Area and future highway realignment have the potential to alter water quality and redirect subsurface water. The proposed relocation of the highway away from the cave could result in beneficial impacts to water resources due to an improvement in water quality and the restoration of natural hydrologic flow conditions.

Cumulatively, these other actions would have minor, adverse impacts on water resources. The additional action of controlling exotic plants with pesticides under the Preferred Alternative, given proposed monitoring and mitigation measures, would contribute minor adverse cumulative impacts on water resources. In combination, these actions would result in minor, adverse cumulative impacts on water resources.

Conclusion
There would be short- and long-term, minor, local and widespread, direct adverse impacts to water resources as a result of the Preferred Alternative due to possible contamination of cave water with pesticides and surface chemicals. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to water resources.

EXOTIC VEGETATION

The thresholds of change for the intensity of an impact on exotic vegetation are defined as follows:

Negligible: Exotic vegetation would be controlled on less than 1% of all known sites and acreage and any changes to the exotic plant populations may not be detectable.

Minor: Exotic vegetation would be controlled on 1-25% of all known sites and acreage. Effectiveness of control would likely be successful and detectable, and the effort to implement control would be highly-labor intensive.

Moderate: Exotic vegetation would be controlled on 25-50% of all known sites and acreage. Effectiveness of control would likely be successful and detectable, and the effort to implement control would be moderately-labor intensive.

Major: Exotic vegetation would be controlled on greater than 50% of all known sites and acreage. Effectiveness of control would be successful and detectable, and the effort to implement control would be low-labor intensive.

IMPACTS OF ALTERNATIVE A (NO ACTION)

Impacts Analysis

As of May 2007, the park had mapped 760 noxious weed sites (for three weed species) covering approximately 64 acres (see Figure 5 for the state listed noxious weed sites). Under the No Action Alternative, using only mechanical and biological control methods, the park's three-person seasonal vegetation crew would be able to treat an average of 200 of these sites each year. Although it has been shown to be effective where stem counts have been conducted, mechanical control would be highly labor-intensive and it would be difficult to reach every noxious weed site with current staffing levels and without pesticide application.

Infestation by noxious weeds can change soil chemistry and hydrologic patterns, and in turn affect the natural karst system. Exotic plants may consume a large amount of surface water, which could alter the hydrology and the availability of water in the caves. However, given that current management would continue to control exotic plants in the Monument without the use of pesticides, there would be minor, beneficial long-term impacts on exotic vegetation.

Cumulative Effects

The Monument has been using an integrated pest management (IPM) approach to control noxious weeds. IPM has included manual / mechanical control (hand-pulling and cutting), chemical control (application of pesticides), and biocontrol (introducing insects which attack the plant). The park has been employing a three- to four-person seasonal weed crew each summer responsible for manually controlling exotic plants, documenting treated areas, and mapping new infestations.

An agreement with USFS stipulated that only aminopyrlaid (Milestone) and imazapic would be used within the Jewel Cave Mineral Withdrawal boundary. As part of the agreement, the park has hand-pulled or cut exotics in a few small areas on Forest Service land adjacent to the Monument boundary. No chemicals have been applied at the Monument since September 2005.

Cumulatively, these other actions would have minor, beneficial impacts on exotic vegetation. Since the No Action Alternative would continue the same exotic control practices as these other actions, Alternative A would contribute minor, beneficial cumulative impacts on exotic vegetation. In combination, these actions would result in minor, beneficial cumulative impacts on exotic vegetation.

Conclusion

There would be long-term, minor, local, direct, beneficial impacts on exotic vegetation as a result of the No Action Alternative due to mechanical and biological control of exotic plants. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific

purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to exotic vegetation.

IMPACTS OF ALTERNATIVE B (PREFERRED)

Impacts Analysis

Under the Preferred Alternative, chemical control, along with mechanical and biological methods, would be used as part of the IPM approach to control exotic vegetation. Utilizing all three options in the integrated pest management strategy would allow the Monument to treat more sites per year and allow for better weed control. Controlling more exotic plants would help to restore vegetative cover to a natural condition. Exotic plants may consume a large amount of surface water, which could alter the hydrology and the availability of water in the caves. This adverse effect would be reduced or eliminated with the exotic plant control program which would eliminate exotic plants more rapidly and over larger areas through the use of pesticides. Natural hydrologic flow and infiltration patterns would be restored more rapidly, and the chemical composition of infiltrating water may change.

Of the 760 noxious weed sites (for three weed species) that have been mapped and which cover approximately 64 acres (see Figure 5 for the state listed noxious weed sites), approximately 18 acres of Canada thistle documented within the Minor Risk Treatment Zone would be treated with pesticides, as would approximately 3 acres of leafy spurge in scattered sites throughout the Minor Risk Treatment Zone. Thus approximately 21 acres out of the 64 acres infested with weeds would be treated more rapidly and efficiently with pesticide application. The remaining acres would continue to be mechanically and biologically treated.

The Preferred Alternative presents moderate, beneficial, long-term impacts on exotic vegetation as a more comprehensive IPM approach, which includes pesticide treatments, would be implemented to eliminate exotic plants.

Cumulative Effects

The Monument has been using an integrated pest management (IPM) approach to control noxious weeds. IPM has included manual / mechanical control (hand-pulling and cutting), chemical control (application of pesticides), and biocontrol (introducing insects which attack the plant). The park has been employing a three- to four-person seasonal weed crew each summer responsible for manually controlling exotic plants, documenting treated areas, and mapping new infestations.

An agreement with USFS stipulated that only aminopyrlaid (Milestone) and imazapic would be used within the Jewel Cave Mineral Withdrawal boundary. As part of the agreement, the park has hand-pulled or cut exotics in a few small areas on Forest Service land adjacent to the Monument boundary. No chemicals have been applied at the Monument since September 2005.

Cumulatively, these other actions would have minor, beneficial impacts on exotic vegetation. Since the Preferred Alternative would continue the same exotic control practices and also add pesticide treatment to the IPM toolkit to more effectively and rapidly eliminate weeds, Alternative B would contribute moderate, beneficial cumulative impacts on exotic vegetation. In combination, these actions would result in moderate, beneficial cumulative impacts on exotic vegetation.

Conclusion
There would be long-term, moderate, local, direct, beneficial impacts on exotic vegetation as a result of the Preferred Alternative due to comprehensive IPM control of exotic plants which would include pesticide treatments. Because there would be no major adverse impacts to a resource or value whose conservation is 1) necessary to fulfill specific purposes identified in the establishing legislation or proclamation of the Monument; 2) key to the natural or cultural integrity of the Monument or to opportunities for enjoyment of the Monument; or 3) identified as a goal in the Monument's GMP or other relevant NPS planning documents, there would be no impairment of the Monument's resources or values with respect to exotic vegetation.

PUBLIC HEALTH AND SAFETY

The thresholds of change for the intensity of an impact on public health and safety are defined as follows:

Negligible: Visitor safety would not be affected, or the effects would be at the lowest levels of detection and would not have an appreciable effect on visitor safety. Impacts to public health and safety would not be detectable as measured by standard incident reports or exposure to unsafe conditions.

Minor: The effect would be detectable but would not have an appreciable effect on visitor safety. Impacts to public health and safety would be detectable as measured by standard incident reports or exposure to unsafe conditions, but would not exceed acceptable standards. If mitigation were needed, it would be relatively simple and would likely be successful.

Moderate: The effects would be readily apparent and result in substantial, noticeable effects to visitor safety within the project area. Impacts to public health and safety would be detectable as measured by standard incident reports or exposure to unsafe conditions, and would exceed acceptable standards, but could be mitigated using standard emergency procedures.

Major: The effects would be readily apparent and result in substantial, noticeable effects to visitor safety within the project area. Impacts to public health and safety would be detectable as measured by standard incident reports or exposure to unsafe conditions, and would exceed acceptable standards, but could not be mitigated using standard emergency procedures.

IMPACTS OF ALTERNATIVE A (NO ACTION)

Impacts Analysis
Inherent risks exist with cave travel due to such conditions as confusing passages, low ceilings, loose rocks, unstable floor material, ledges, pits, tight constrictions, conditions conducive to hypothermia, and radon gas exposure. Cave travel requires special equipment and skills. To ensure the safety of all trip participants, all access would be overseen by qualified, informally trained tour guides or off-trail trip leaders.

As there would not be any new actions or changes in current management, Alternative A would not result in lower standards of public health and safety. Under this alternative, impacts to public health and safety would be minor, adverse, and long-term due to continuing cave visitation and informally (vs. formally) trained trip leaders.

Cumulative Effects
Past, present, and future recreation, orientation and exploration opportunities would continue to pose risks to public health and safety due to the dangers of traveling in Jewel Cave. These dangers include the

physical nature of the cave, the continuing lack of radio and cellular phone communication inside the cave which could delay the initiation of search and rescue operations, and possible chemicals from surface activities in drip water which is used for drinking on exploration trips. Although visitors to the cave are exposed to such dangers, precautions such as trained trip leaders, water quality testing, and a search and rescue plan have been in place and would continue to minimize impacts on human health and safety.

Cumulatively, these other actions would have minor, adverse impacts on public health and safety. Since the No Action Alternative would continue the same practices, Alternative A would contribute minor adverse cumulative impacts on public health and safety. In combination, these actions would result in minor, adverse cumulative impacts on public health and safety.

Conclusion
There would be long-term, minor, direct adverse impacts on public health and safety as a result of the No Action Alternative due to continued opportunities for recreation, orientation, and exploration in Jewel Cave.

IMPACTS OF ALTERNATIVE B (PREFERRED)

Impacts Analysis
Inherent dangers exist with cave travel due to such conditions as confusing passages, low ceilings, loose rocks, unstable floor material, ledges and pits, tight constrictions, conditions conducive to hypothermia, and radon gas exposure. Cave travel requires special equipment and skills. To ensure the safety of all trip participants, all access would be overseen by qualified, formally trained tour guides or off-trail trip leaders.

Dripping water in the cave is collected at four sites for cavers to drink on extended caving trips. This water must be kept safe for human consumption. Pesticides used on the surface to control exotic vegetation under this alternative could contaminate water entering the cave. However, Best Management Practices, along with the designation of pesticide treatment zones, should minimize if not preclude the presence of pesticides in cave water.

Other chemicals used on the surface for maintenance activities could reach the cave through groundwater as well. However, under this alternative, formalizing maintenance procedures into policy would help ensure that greater thought is given to such activities as salting and de-icing roads, or using detergents or petroleum based products that can infiltrate groundwater. These additional protection measures would likely cause very low risk of chemicals in cave drinking water.

Under this alternative, impacts to public health and safety would be minor, adverse, and long-term due to continuing cave visitation and possible presence of pesticides in cave drinking water, and they would be offset beneficially by formally (vs. informally) trained trip leaders.

Cumulative Effects
Past, present, and future recreation, orientation and exploration opportunities would continue to pose risks to public health and safety due to the dangers of traveling in Jewel Cave. These dangers include the physical nature of the cave, the continuing lack of radio and cellular phone communication inside the cave, which would delay the initiation of search and rescue operations, and possible chemicals from surface activities in drip water which is used for drinking on exploration trips. Although visitors to the cave are exposed to such dangers, precautions such as trained trip leaders, water quality testing, and a

search and rescue plan, have been in place, and would continue, to minimize impacts on human health and safety.

Cumulatively, these other actions would have minor adverse impacts on public health and safety. Although cave visitation would continue and there may be contamination of cave drinking water by pesticides, the Preferred Alternative would provide beneficial effects on public health and safety by formally training trip leaders and by formalizing maintenance procedures to prevent surface chemicals from infiltrating groundwater. Thus, Alternative B would contribute negligible, adverse cumulative impacts on public health and safety. In combination, these actions would result in minor, adverse cumulative impacts on public health and safety.

Conclusion
There would be long-term, minor, direct adverse impacts on public health and safety as a result of the Preferred Alternative due to continued opportunities for recreation, orientation, and exploration in Jewel Cave and possible pesticides in drinking water.

VISITOR USE AND EXPERIENCE

The thresholds of change for the intensity of an impact on public health and safety are defined as follows:
Negligible: Changes in visitor use and/or experience would be below or at the level of detection. The visitor would not likely be aware of the effects associated with the alternative. There would be no change in the number of off-trail recreational opportunities.

Minor: Changes in visitor use and/or experience would be detectable, although the changes would be slight. The visitor would be aware of the effects associated with the alternative, but the effects would be slight. There would be < 25% change in the number of off-trail recreational opportunities.

Moderate: Changes in visitor use and/or experience would be readily apparent. The visitor would be aware of the effects associated with the alternative and would likely be able to express an opinion about the changes. There would be a 25-50% change in the number of off-trail recreational opportunities.

Major: Changes in visitor use and/or experience would be readily apparent and severely adverse or exceptionally beneficial. The visitor would be aware of the effects associated with the alternative and would likely express a strong opinion about the changes. There would be >50% change in the number of off-trail recreational opportunities.

IMPACTS OF ALTERNATIVE A (NO ACTION)

Impacts Analysis
Alternative A would continue to provide recreational trips on two established routes, and there would be no change in the number of recreational trips currently offered. Seven routes would continue to be provided for orientation trips. Guided tours would also continue at current levels. The purpose of exploration in the peripheral cave areas would be primarily for “pushing the edge.” Exploration in the close-in areas would be for “mopping up.” Under this alternative, visitor use and experience would not change from current conditions, and impacts would be negligible, long-term, and beneficial as quality caving opportunities would continue to be provided.

Cumulative Effects
Past, current, and future recreation, orientation, and exploration opportunities have beneficial impacts on visitor use and experience. Surface and subsurface development, such as hardened trail routes and an

elevator to access the cave, establishment and use of off-trail routes, and establishment of a permanent underground camp site have added greatly to the visitor experience at Jewel Cave primarily by allowing easy access to the cave for many visitors. No future actions are planned that would affect visitor use and experience. Cumulatively, these other actions would have major beneficial impacts on visitor use and experience. Since the No Action Alternative would continue the same visitation practices as these other actions, Alternative A would contribute negligible, beneficial cumulative impacts on visitor use and experience. In combination, these actions would result in major, beneficial cumulative impacts on visitor use and experience.

Conclusion
There would be long-term, negligible, direct, beneficial impacts on visitor use and experience as a result of the No Action Alternative due to continued opportunities for recreation, orientation, and exploration in Jewel Cave.

IMPACTS OF ALTERNATIVE B (PREFERRED)

Impacts Analysis
Alternative B would provide an increased number of recreational trips and available routes (seven as compared to the current two). This would represent a 250% increase in the number of routes available for such use, and the number of recreational trips would be expected to increase by more than 50% with the general public able to participate without making special arrangements. Seven routes would continue to be provided for orientation trips. Guided tours would also continue at current levels. Exploration would be allowed close in for "mopping up," and peripherally for both "mopping up" and "pushing the edge". All of these would provide new or continued opportunities for quality visitation of Jewel Cave.

Implementation of the maximum allowable impact concept would insure that impacts in the cave do not exceed the 10% maximum acceptable coverage of rock surfaces with impacts. This standard could mean reducing or capping the number of cavers allowed in certain parts of the cave, which could diminish the visitor experience. However, insuring that impacts do not become significant would maintain or improve a positive experience for cavers who visit those areas of Jewel Cave.

Effective control with pesticides to reduced infestations of exotic plants would likely improve the quality of the visitor experience, particularly if coupled with education efforts that are part of the IPM plan for the Monument. Visitors would understand the importance of controlling exotic vegetation in favor of promoting the native flora. Additionally, exotic plant control would reduce or eliminate the visual impacts of unsightly infestations and further improve the visitor experience.

Under this alternative, impacts to visitor use and experience would be moderate, long-term, and beneficial as visitors would be able to experience more of the cave than under current management and impacts to physical cave features and from exotic vegetation would be managed so that they do not detract from the visitor experience.

Cumulative Effects
Past, current, and future recreation, orientation, and exploration opportunities have beneficial impacts on visitor use and experience. Surface and subsurface development, such as hardened trail routes and an elevator to access the cave, establishment and use of off-trail routes, and establishment of a permanent underground camp site have added greatly to the visitor experience at Jewel Cave primarily by allowing easy access to the cave for many visitors. No future actions are planned that would affect visitor use and experience. Cumulatively, these other actions would have major beneficial impacts on visitor use and experience. The Preferred Alternative would continue and improve these visitation practices, but in

comparison Alternative B would contribute minor, beneficial cumulative impacts on visitor use and experience. In combination, these actions would result in major, beneficial cumulative impacts on visitor use and experience.

Conclusion

There would be long-term, moderate, direct, beneficial impacts on visitor use and experience as a result of the Preferred Alternative due to continued and improved opportunities for recreation, orientation, and exploration in Jewel Cave.

CONSULTATION AND COORDINATION

Consultation and coordination among government agencies and the public were very important in the planning process for the Cave and Karst Management Plan. Interested citizens had several opportunities to share their views and concerns during this process. Additionally, the Monument consulted with other government agencies including the State Historic Preservation Officer, the U.S. Fish and Wildlife Service, and the U.S. Forest Service. Below is a list of key consultation and coordination activities:

February 15, 2002	Internal park scoping meeting
March 15, 2002	Staff/USFS scoping meeting
May 10, 2002	Colorado Grotto scoping meeting at Wind Cave
June 17, 2002	Rapid City scoping meeting. There were no attendees.
June 18, 2002	Custer scoping meeting in Pine Room. There were three attendees.
June 28, 2002	NSS Convention Scoping Meeting
September 9, 2002	Received response from Mike Lloyd (USFS) regarding surface management within the Jewel Cave mineral withdrawal.
August 6, 2003	CMP status meeting at NSS
February 3, 2004	Conversation with Scott Larson (USFWS)
July 14, 2004	Received verbal input from Ron Kerbo and Stan Allison at NSS Convention.
July 15, 2004	Public meeting (status report) at NSS convention.
November 3, 2004	Phone conversation with Doug Scott regarding historic and cultural resources in the cave.
July 6, 2005	NSS public meeting.
June 12, 2007	Consulted with Paige Hoskinson at the SD SHPO Office.
July 27, 2007	NSS public meeting.

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REFERENCES AND GLOSSARY

REFERENCES CITED

(Allison, 2005). United States Department of the Interior, National Park Service, Carlsbad Caverns National Park. April 2005. Personal communication with Stan Allison, Physical Science Technician.

(Cryan, 1997). Cryan, P.M. 1997. Distribution and Roosting Habits of Bats in the Southern Black Hills, South Dakota. MS Thesis, Biology, University of New Mexico.

(Davis et al., 2006). Davis, A.D, J.F. Valder, and K.D. Sarratt. 2006., Final Technical Report: Pumping Tests in the Deadwood Aquifer at Jewel Cave National Monument. Department of Geology and Geological Engineering, SDSM&T.

(EPA and Extension Service, 1999). U.S. Environmental Protection Agency and U.S. Department of Agriculture, Extension Service. September 1999. Applying Pesticides Correctly: A Guide for Private and Commercial Applicators. Distributed by the South Dakota Department of Agriculture, Pierre, and the Cooperative Extension Service, South Dakota State University, Brookings.

(Horrocks, 2005). United States Department of the Interior, National Park Service, Wind Cave National Park. April 2005. Personal communication with Rodney Horrocks, Cave Specialist.

(Mattson and Bogan, 1994). Mattson, T.A. and M. Bogan. 1994. Survey of Bats and Bat Roosts in the Southern Black Hills in 1993. University of Wyoming.

(Moore et al., 1996). Moore, J.C., J. Clarke, M. Heimbrook, and S. Mackessy, G. Finnoff, G. Lipari, R. Jesser, and C. Zavorskas. 1996. Survey of the Biota and Trophic Interactions Within Wind Cave and Jewel Cave, South Dakota.

(NPS, 2003). United States Department of the Interior, National Park Service, Jewel Cave National Monument. 2003. Bats at Jewel Cave National Monument. Web page. Available at: http://www.nps.gov/archive/jeca/bats.htm

(NPS, 2005). United States Department of the Interior, National Park Service, Northern Great Plains. March 2005. Northern Great Plains Exotic Plant Management Plan and Environmental Assessment.

(NPS, 2006). United States Department of the Interior, National Park Service. 2006. NPS Management Policies 2006. Available at: http://www.nps.gov/policy/mp2006.pdf

(NPS, 2007). United States Department of the Interior, National Park Service, Jewel Cave National Monument. 2007. Jewel Cave. Web page. Available at: http://www.nps.gov/jeca.

(Northup and Spilde, 2002). Northup, D. and Spilde, M. 2002. Jewel Cave Corrosion Residue Pilot Study Report. Jewel Cave National Monument. Custer, South Dakota.

(Rahn and Gries, 1973). Rahn, P.H. and J.P. Gries. 1973. Large Springs in the Black Hills, South Dakota and Wyoming.

(Tigner, 2007). Batworks. Janurary 2007. Personal communication with Joel Tigner, Bat Consultant.

(Watson, 1989). Watson, V.J., P.M. Rice, and E.C. Monnig. 1989. Environmental Fate of Picloram Used for Roadside Weed Control. Journal of Environmental Quality. Vol. 18 pp. 1989-205.

(Yocum and Wiles, 1997). Yocum, M. and M. Wiles. 1997. National Survey Data Collection Standards. *In* 1997 National Cave Management Symposium Proceedings.

GLOSSARY

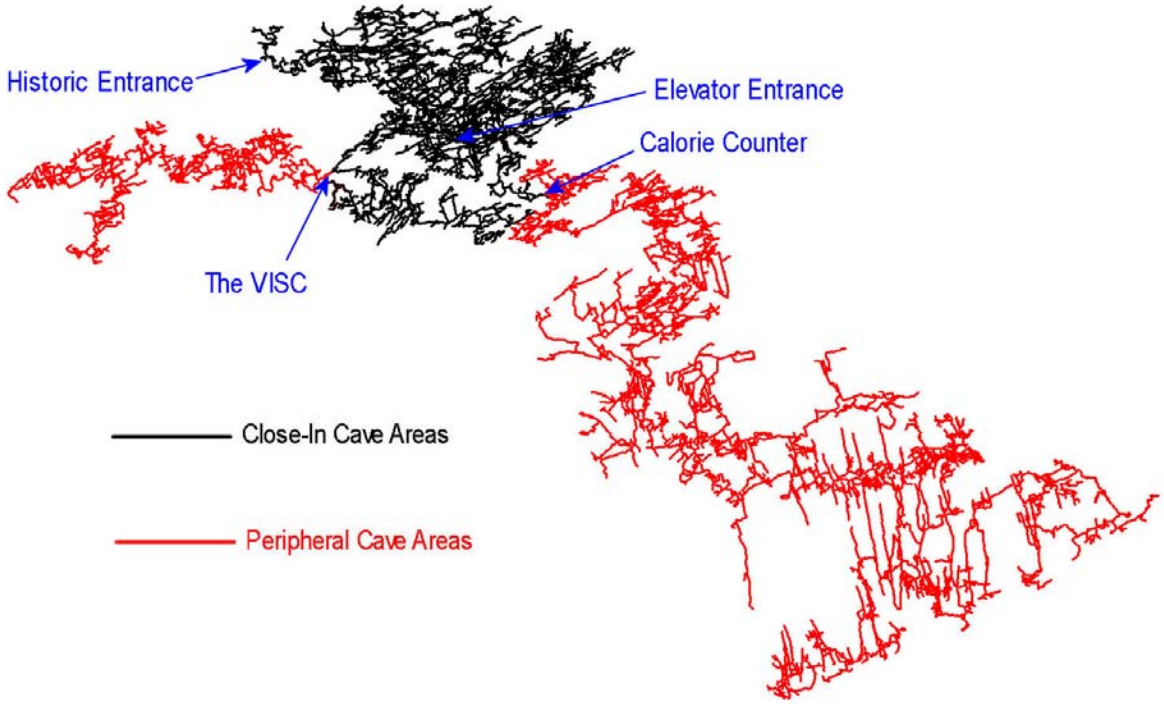
Benefits of Exploration
Exploration provides information that aids in the understanding and protection of cave resources, including:

- Knowledge of new cave passages
- Knowledge of new and unique resources, through cave feature inventory
- Geographical shape, pattern, and extent of the cave, in three dimensions

Carrying Capacity
In recreation management, the amount of use a recreation area can sustain without loss of quality. For any given environment, the carrying capacity is the amount of activity that can be supported in a sustainable manner. The complex concept of carrying capacity is often used in managing visitor use.

Cave Management
The purposes of cave management activities are to monitor, mitigate, and restore cave resources; obtain information to meet Monument needs, facilitate cave-related research, ensure the quality of the survey and inventory data, and to maintain the off-trail routes.

Close-In Cave Areas
The areas of the cave bounded by the Historic Entrance, The Calorie Counter, and The VISC. These areas are all relatively close to the cave's three entrances: the Historic Entrance, the Portal Entrance and the Elevator Entrance.



Exotic Vegetation
Non-native plants; may become invasive, meaning a plant which is able to proliferate and aggressively alter or displace indigenous biological communities.

Exploration
Exploration consists of searching out new passages, and surveying and inventorying them. The resulting information provides the fundamental framework of knowledge needed to accomplish the major purposes of cave management.

Surveys consist of establishing and labeling survey stations, measuring the distance, azimuth, and inclination between those stations, recording the data, and sketching the cave passage.

Reference to "exploring an area" means to go to an already known area and explore into the unknown from there. At Jewel Cave, exploration is management-driven, with two separate goals:

- "Pushing the edge" is to make a concerted effort to expand the lateral extent of known cave passages.
- "Mopping up" is to survey interconnecting passages as completely as is practical.

Karst
A three-dimensional landscape shaped by the dissolution of a soluble layer or layers of bedrock, typically resulting in the development of caves and cave systems.

Macrobiotic Resources
The living organisms of a region that are large enough to be seen with the naked eye.

Microbiotic Resources
The plants, animals, and microorganisms that can only be seen with the aid of a microscope.

Management Constraints
Limitations placed on any activity, based on the Monument's ability to monitor and mitigate impacts, oversee personnel issues, provide training, address safety issues, ensure quality work, and keep all records and documentation current, particularly cave maps and related data.

Maximum Allowable Impact
Maximum amount of impact allowed in any given area of the cave before further traffic is prohibited.

Measured Impact
Impact measured by photo-monitoring and dust-collection techniques.

Off-trail Routes
A travel path taken by cavers, which may be marked or unmarked. These do not include the developed Scenic, Discovery, or Lantern Tour routes.

Orientation
Park-provided training to augment understanding of cave resources and issues.

Peripheral Cave Areas
The parts of the cave that are more distant from the existing entrances: those areas beyond the VISC and beyond the Calorie Counter (see diagram above under Close-In Cave Areas).

Pesticide
A chemical used to kill undesirable or harmful animals or plants. "Pesticide" is a broad term which includes herbicides, insecticides, fungicides, and rodenticides.

Recreation
Activities undertaken for personal enjoyment, with no direct benefit to the Monument's cultural or natural resources.

Speleothem
A general term for all secondary mineral deposits in a cave. Includes stalactites, stalagmites, flowstone, and crystal growths. Terms such as 'formation' or 'decoration' are sometimes used in a similar manner, but can cause confusion, e.g. with geological formations.

Travel Corridor
An established path of travel that receives direct impact, and the adjacent "shoulder" areas which receive indirect disturbance from lint, kicked sediments, etc.

Troglodytic
Of or pertaining to a troglodyte, or cave dweller.

APPENDIX A: Acknowledgement of Risk / Waiver of Responsibility

This form is to be completed and signed by all persons taking part in any activity in undeveloped sections of Jewel Cave or any cave within Jewel Cave National Monument's boundaries.

I, the undersigned, have been warned and understand that the activity in which I am about to participate is strenuous and can be hazardous. I will abide by all applicable Monument rules and regulations.

Below is a list of the most pertinent rules and regulations which you are to observe:

1. No cave formations, rocks, or historical materials will be disturbed or removed from the cave.

2. Trash and human wastes will be removed from the cave. Items approved by the park, including survey markers, are excepted.

3. Signs, notes, maps, directional arrows, etc., will not be scratched or marked on cave surfaces.

4. Hard hats will be worn at all times.

5. Each person will have at least three independent light sources when in the cave.

6. Each group will have an adequate first aid kit or knowledge of the location of in-cave rescue stashes.

7. No passages will be enlarged or modified prior to official approval.

8. Group leaders are responsible for group conduct.

9. Photography is permitted if it does not significantly impact the purpose of the trip. The photographs may not be used for commercial purposes unless the photographer has obtained a filming permit.

_____ _____ _____
Your Signature Date Signature of Parent or Guardian if under 18

Please print:

Name_____ D.O.B. _____

Address_____ City_____ State_____

Zip_____

Phone_____ Affiliation (if any)_____

Emergency Contact _____ Phone_____

Acknowledgement of Trip Leader Responsibility

As a trip leader at Jewel Cave National Monument, I promise to abide by all park-wide regulations, and to follow the guidelines established in trip leader training. Specifically, I will:

- Ensure safety of group members at all times
- Ensure protection of cave resources
- Properly care for equipment
- Communicate with cave management staff regarding impacts, injuries, or other problems, or any unusual circumstances.
- Ensure quality of survey, inventory, or other work (if applicable).
- Properly plan trips to maximize efficiency and productivity (i.e. bring adequate maps)
- Ensure the protection of sensitive data

_____ _____
Your Signature Date

Please print:

Name_____

Address_____ City_____ State_____

Zip_____

Phone_____

APPENDIX B: Cave Search and Rescue Plan

CAVE SEARCH AND RESCUE PLAN
Jewel Cave National Monument
(updated July 2007)

Recommended: _____ _____
Cave Specialist, Jewel Cave National Monument Date

Approved: _____ _____
Superintendent, Jewel Cave National Monument Date

Jewel Cave National Monument
Cave Search and Rescue Plan

Due to the nature of caves and the special conditions found within them, cave search and rescue (SAR) can vary significantly from traditional SAR activities. This plan highlights the special concerns and situations inherent in a cave SAR incident at Jewel Cave.

Difficult Nature of Cave SAR at Jewel Cave

Parts of Jewel Cave are extremely remote, requiring many hours of physically demanding travel for even highly skilled cavers. The park and cavers both must be aware that rescue in many parts of the cave will be slow and difficult. Moving an injured caver in a stretcher from the end of the cave would take *at least* three days, and could potentially involve the use of over 100 cavers. There are some situations where the body of a deceased caver would be interred within the cave, rather than needlessly endangering cavers to attempt a body recovery.

Fragile Nature of Jewel Cave

Parts of Jewel Cave are exceedingly fragile. SAR activities are likely to result in resource damage, and could severely impact areas where delicate formations are abundant. While the well-being of the patient will always be the top priority, NPS resource preservation mandates must be considered as well. These concerns may slow the progress of rescue teams through some areas.

Common Scenarios

The most likely cave SAR scenarios will be relatively low-profile events. Often these events will occur when a caving party fails to exit the cave at the pre-appointed time. This will usually be due to a slowly moving group (due to exhaustion or a slight injury to a group member), or possibly, miscommunications with the surface contact. The chances of an entire caving party failing to exit the cave are very low. Other possibilities include an individual becoming separated from the rest of the party and getting lost, or someone falling in the cave and becoming injured. In most instances, a reporting party from the group would exit the cave to notify the park.

Critical Resources

Information related to local and regional cavers, maps, taped routes, obstacles, rescue cache locations/contents, etc., are available in the Cave Search and Rescue file in the Resource Management Office.

Getting the First Teams In

Hypothermia concerns make it important to respond to a cave emergency as quickly as possible. However, an Initial Response Team should be dispatched *only after* certain conditions have been met:

1. First Notice

Either the trip's designated surface watch, or a returning member of a caving trip will contact a responsible NPS employee (see *Appendix 1*), who will assume the role of initial Incident Commander (IC).

2. First Actions

The initial IC's first actions should be to: 1) secure the reporting party to ensure that a detailed debriefing will be possible, and 2) to contact the initial Technical Specialist (TS) (see *Appendix 2*), who will aid the IC in assessing the situation and performing the initial callout. The TS will be a caver with extensive knowledge of the cave, its obstacles, and the cavers capable of overcoming those obstacles.

3. Entrance Control
Entrance control **must be established** before anyone enters or leaves the cave[1]. All personnel are to be logged in and out, using an Entrance Control Log. It is essential to know who is in the cave, their destination, time of departure / expected return, and the equipment they are carrying[2]. There are four entrances into Jewel Cave that will need to be secured in any incident: The Main and Basement elevator lobbies, the Portal Entrance, and the Historic Entrance. The Portal and Historic Entrances should be secured, regardless of the location of the incident.

4. Initial Callout
The IC, in consultation with the TS, assesses the situation and decides whether to call local cavers to be members of an Initial Response Team, or to put them on standby (see *Appendix 3*). The response plan can then be formulated during the time it takes the IR Team to prepare for action[3].

5. Initial Response Plan
The type of initial response can be greatly influenced by information received from the returning member of the caving party. The plan should consider any known medical condition or injury sustained by the subject, and must **always anticipate hypothermia**. If available information indicates the need for a search, the IR Team must be properly instructed and qualified to conduct the search. A search in the cave environment is complicated by its remoteness, its three-dimensional complexity, and the fact that many existing passages do not appear on any map. Extensive resource lists containing information on taped routes, obstacles, rescue cache locations and contents, etc., are available in the Cave Search and Rescue file in the Resource Management Office.

6. Communications
The IR Team should not be sent in until an initial communications plan has been developed and communicated. There are a limited number of ways to establish *any* kind of communications in most parts of the cave. In the initial phases of a cave search or rescue, the IC's available communication methods will likely be limited to written messages issued by teams going in or out of the cave. This requires very careful planning and debriefing. Field phones can be used, although the plan must address the difficult and time-consuming nature of stringing wires through the cave. Jewel Cave has a cave radio that operates with Morse code communications. Its use requires transporting an antenna, transmitter, and battery to a predetermined spot in the cave, located precisely below a pre-determined spot on the surface. Maps showing these locations are in the Cave Search and Rescue file.

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[1] This simply means that the IC must ensure that no unauthorized entry or exit occurs during the SAR operation. Control can be established by stationing personnel, physically blocking an entrance, or by switching locks. In the initial stages, the IC may elect to actively secure only one entrance. But control should be established at all the others as soon as possible.

[2] For example, entrance log information can be used to force tired people to come out of the cave for sleep.

[3] This will be *at least* 2 hours, and as many as 10 hours, after the incident is reported.

7. Deploy Initial Response Team
The IR Team may enter the cave only after the above concerns have been addressed. The IR Team must be thoroughly briefed and an expected return time decided upon. Once the patient is reached, the team may need to split up. Two cavers should carry messages to the surface, especially those regarding the patient's medical condition. They will also provide information on cave conditions and extrication problems, and inform the IC of any hazards or needed equipment. The other team members will attempt to stabilize the patient. All team members will be debriefed immediately upon their return, by the IC or Documentation Coordinator.

General Callout
Once the IR Team has been deployed, the IC and TS will need to determine if a larger callout will be necessary. If so, several things must be kept in mind. First, word travels very quickly in the caving community, making it likely that many cavers will call to volunteer their services. It must be understood that many cavers are not physically up to the challenge of traveling to remote parts of the cave. The TS will be invaluable in advising the IC to avoid these individuals, who may inadvertently endanger themselves or others. Also, members of local surface search and rescue teams may begin to arrive or volunteer their services. While some of these individuals may be helpful for some tasks, **it is essential that these individuals be teamed with knowledgeable cavers, if they are used at all**. Jewel Cave presents other challenges, such as the potential for severe dehydration, especially to those not familiar with Black Hills caving. It is best to use cavers with extensive Black Hills caving experience, even if it means having to wait a little longer for them to arrive. General callout lists are available in the Cave Search and Rescue file in the Resources Management Office.

Jewel Cave National Monument
Cave Search and Rescue Plan

Appendix 1
Initial Incident Commander List

An initial Incident Commander (IC) for each cave SAR incident in Jewel Cave should be chosen (in priority order) from the following list:

Note: Contact information has been intentionally omitted from this draft.

Name	Address	Phone
Rick Mossman	Wind Cave	
Mike Henry	Wind Cave	
Mike Pflaum	Mt. Rushmore	
Don Hart	Mt. Rushmore	
Todd Suess	Jewel Cave	
Mike Wiles	Jewel Cave	
Rod Horrocks	Wind Cave	
Rene Ohms	Jewel Cave	
Marc Ohms	Wind Cave	
Dan Foster	Wind Cave	

Jewel Cave National Monument
Cave Search and Rescue Plan

Appendix 2
Technical Specialist List

A Technical Specialist (TS) for each cave SAR incident in Jewel Cave should be chosen (in priority order) from the following list:

Note: Contact information has been intentionally omitted from this draft.

Name	Address	Phone Number
Mike Wiles		
Rene Ohms		
Marc Ohms		
Larry Shaffer		
Stan Allison		
Dan Austin		
Kelly Mathis		
Herb and Jan Conn		
Paul Burger		
Steve Baldwin		
Dave Springhetti		

Jewel Cave National Monument
Cave Search and Rescue Plan

Appendix 3
Local Resources

Below are the names and phone numbers of local and regional cavers capable of assisting in the early hours of a cave SAR incident at Jewel Cave National Monument. Not all of these cavers can be used in an incident at the far reaches of the cave.

Note: Contact information has been intentionally omitted from this draft.

Name	Phone Numbers	Where
Mike Wiles		Entire Cave
Rene Ohms		Entire Cave
Marc Ohms		Entire Cave
Larry Shaffer		Entire Cave
Dan Austin		Entire Cave
Andy Armstrong		Entire Cave
Bonny Armstrong		East and West
Jason Walz		East and West
Matt Busch		East and West
Todd Suess		East and West
Carl Bern		East
Dave Springhetti		Some East and West
Steve Baldwin		Entire Cave
Sammi Langendorf		Some East

APPENDIX C: Underground Camping Policy

Updated July 2007

Introduction
Multi-day trips in Jewel Cave began in 1997, and have proven to be a productive aid to exploration and management efforts. Camping allows cave explorers to discover and survey a large amount of cave passage; on average, it would take at least five single-day trips to accomplish the same amount of surveying done on one four-day camp trip. This results in less impact to passages along the travel route. Camping also provides an extra measure of safety to the explorers, who are rested and refreshed as they make the return trip to the entrance from camp, rather than tiredly making their way out at the end of a 20-hour day. Without proper planning and preparation, camping can be a high impact activity. This document contains policies that will keep this impact to an absolute minimum.

Camp Sites
A written justification must be approved by the Cave Specialist in order to establish a new campsite. The number of sites will be kept to a bare minimum; currently there is only one campsite in Jewel Cave, at survey station TT2 near the Big Duh. Sites will normally be established in areas where round trip travel time[1] exceeds 12 hours. They will be permanent, rather than mobile, and established, when possible, on solid rock rather than in sediments -- to reduce physical and organic impact.[2] All camping activities will take place in a single area, not to exceed 300 square feet. This precludes individuals from sleeping in various locations scattered throughout a room.

Site Preparation
The entire site will be covered with plastic tarps with no intervening gaps. The site should be near a water source so that water will not have to be carried long distances. Supplies and equipment that will not deteriorate can be left at camp between trips. However, no garbage, human waste, or discarded or unserviceable equipment is to be left behind, either at camp or elsewhere in the cave. Jewel Cave has a firm policy of removing all human waste.

Procedures
The NPS will provide six sets of sleeping gear,[3] as well as desiccant to keep them dry. Individuals must use a clean sleeping bag liner. Inexpensive liners will be provided by the park, but cavers may use their own liner if they have one. Cavers must bring clean camp clothes, which will be removed from the cave at the end of each trip. Equipment packs should be no larger than a Lost Creek Monster TAG pack or equivalent. Packs should not be worn on the back through delicate crawls, because dirt on a pack will easily transfer to the ceiling. Cavers should spot each other and pass packs along to each other as needed. The longest trip will be four days. This limitation is based primarily on the amount of urine that can be practically removed from the cave.

When settling into camp, cavers must remove caving clothes while standing on the trail and put on camp clothes before stepping into the plastic-covered camp area. All camping/cooking gear and supplies will be kept within the designated camp area.

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[1] This relates to the travel time of experienced cavers who are familiar with the route.

[2] Organisms are more likely to flourish where a sediment substrate is found.

[3] To be left at camp. This reduces the size of packs needed. Hauling heavy packs slows the trip unnecessarily and poses greater threats of impact along the travel route.

Group Camping Gear (these items remain in the cave)

Cooking Gear: 3 alcohol stoves (one per two people)
1 quart denatured alcohol (for six people on a four-day trip)
3 quart pots with 3 lids
2 lighters

Sleeping Gear: 6 full-length sleeping pads
6 20-degree synthetic fill sleeping bags

Individual Camping Gear (these items are not left in the cave)

Sleeping gear: 1 clean sleeping bag liner
1 balaclava

Camp Clothing: 1 polypro top
1 pair polypro bottoms
1 pair clean socks
Clean, smooth-soled, wipeable footwear[4]

Food: 2 dehydrated meals per day[5]
Sufficient supplemental food each day for a 12-hour caving trip.[6]
Container to eat from[7]
1 plastic spoon

Toiletries: Antibacterial baby-wipes to clean up before going to sleep
Toothbrush/toothpaste
4 - 6 cubitainers ("cubies") for urine
4 fecal bags (each triple-bagged in heavy-duty zip-lock bags)
Several sheets of paper towels or toilet paper

Light Sources: Enough for at least 24 hours more than expected trip length.

Other: Personal first-aid kit
Wristwatch with alarm

[4] For walking around camp (provided by park).

[5] Usually oatmeal for breakfast and a freeze-dried backpacking meal for dinner

[6] For example, energy bars, trail mix, tortilla sandwiches, etc.

[7] Heavy-duty zip-lock bag, bowl, etc.

APPENDIX D: Guidelines for In-Cave Cultural and Historical Resources

Introduction
Jewel Cave's human history extends back to about 1900; the first time humans were able to enter the cave. The cave passages in the "historic section" may contain items of cultural and historic value. A small subset of this area is known to have a few items from the early 1900s. These include such things as rotted rope, newspaper fragments, and other incidental objects.

Beginning in the late 1950s, there was a significant increase in exploration activity, by Bill Eibert, then Dwight Deal – along with Herb and Jan Conn. The Conns conducted the majority of the work in the ensuing 20+ years. In the course of their caving activities, they placed signs and carbide markings, rope, rock cairns, and tools, etc., some of which are currently over 40 years old.

Since the time of the Conns, objects such as plaques, cairns, signs, ropes, and ladders have occasionally been left in the cave by explorers. These items have been placed in the cave over the last 25 years.

Potential Impacts
Potential impacts to cultural resources are dust accumulation, accidental breakage or trampling, and natural degradation in the cave environment. In some cases, a cultural resource may impact cave resources as it degrades (i.e. molds, rusts, etc.).

Policy
If a cultural or historical resource is encountered during any in-cave activity, that activity will be immediately discontinued if it would damage the resource. A report will be made to Jewel Cave's Cultural Resource Advisor (at the NPS Midwest Regional Office), and their input will be solicited before any more work is done.

Any cultural resource may be removed from the cave at the park's discretion. Reasons for removing an item of cultural value from the cave include degradation of the object itself and any resulting degradation of natural resources. Over the course of time, certain exploration aids (such as ladders) may come to be considered historic. These will occasionally need to be repaired or replaced; in such cases, the original item may be included in the park's museum collection after consultation with the Cultural Resource Advisor.

Before any object is removed from the cave, it must be documented. Documentation will include a written description, photograph(s), and location.

APPENDIX E: Trip Leader Training Program Outline

A. Working at Jewel Cave National Monument
- 1. NPS Mission
- 2. Cave management's responsibility
- 3. Significance of Jewel Cave
- 4. Legal issues
  - a. What does "Trip Leader" status mean
  - b. VIP Status (VIP Form, off-trail forms)
    - 1) Maintaining and losing status
    - 2) Nominating others for trip leader training
    - 3) Other training classes (sketcher, rescue, and inventory classes)

B. Rules and Policies
- 1. Camp Manager position (Coordinates use of surface facilities on a weekend devoted to exploration.)
  - a. Inventory of gear and checkout
  - b. Trip reports
  - c. Dry-erase board and checkout times and returns
  - d. Cleaning
  - e. Park liaison
  - f. Keys
  - g. Quiet hours
- 2. Park Conduct
  - a. Park buildings
  - b. Driving
  - c. Changing clothes in public
  - d. Drugs and alcohol
  - e. Dealing with public/tours

C. Jewel Cave Special Issues
- 1. Historic materials
- 2. Formations and delicate areas
- 3. Manganese tracking
- 4. Digging policy
- 5. Drinking water sites
- 6. Flagged trails
- 7. Packs (side mounted)
- 8.Travel (single file)
- 9. Closed areas
- 10. Wet areas, mud
- 11. Rescue caches
- 12. Waste disposal

D. Trip Leader Responsibilities
- 1. Cave management decisions
- 2. Arranging trips
- 3. Trip reports (Include a list of party members, survey totals, reasons for naming areas, accidents, leads, impact noticed, unusual speleothems or minerals.)

4. Computer and typing in survey data
5. Park equipment
    a. Check out gear
    b. Report broken or lost equipment to camp manager (including pencils & sharpies)
6. Rescue
    a. In Cave:
        1) Lost team member
        2) Injury
        3) Fatigue
        4) Hypothermia
    b. Callouts
    c. First aid caches
        1) Contents
        2) Locations
7. Personnel issues
    a. When to call off a trip
    b. Breaking rules – consequences

E. Survey and Inventory
1. Survey policies
    a. Project areas
    b. Utilizing lineplots, maps, survey notes, trip reports
2. Survey procedures
    a. Park equipment only
    b. Compass course – we take care of that
    c. Backsights – when and how to use
    d. Common compass errors, and how to avoid them
    e. Survey designations, choosing prefixes and suffixes
    f. Marking stations
3. Major discoveries
    a. Borehole fever
    b. Survey everything you find
    c. Project areas, keeping secrets, newsletter reports
    d. Virgin cave – pick wisely, ensure the least amount of impact.
    e. Breakouts – area belongs to discoverers
4. Examples of good and bad surveys

F. Inventory procedures
1. How the data is used, Access database
    a. Who should complete
    b. Procedures
    c. Using notes and comments
2. Use of photos

G. NPS Support
Survey support: lineplots, survey designation lists, individual surveys, maps, trip reports, equipment

APPENDIX F: Cave Entry Permit and Trip Report

JEWEL CAVE NATIONAL MONUMENT
CAVE ENTRY PERMIT

Permit #_____

Permission is requested to enter the following undeveloped section of Jewel Cave:

_____

_____

Purpose:_____

Participants: _____ (leader)

_____ _____

_____ _____

_____

The group will ENTER the cave at _____ on _____.
The group will EXIT the cave at _____ on _____.

SURFACE CONTACT: _____ Phone:_____

It is understood that those taking this trip are doing so at their own risk. Each member must have on file a Waiver of Responsibility and agree to abide by the terms and limitations stated therein. The trip leader is responsible for the proper care of government-owned equipment used on this trip, for the overall conduct of the group, and for returning no later than the specified time. The trip leader agrees to submit a full report of the trip to the Superintendent within one week. It is understood that this permit, when approved, covers only one cave trip on the date and to the place indicated above.

I agree to the above conditions, and to ensure that all group members do likewise.

Requested By:	Recommended By:	Approved By:
_____	_____	_____
Trip Leader	Cave Specialist	Superintendent
_____	_____	_____
Date	Date	Date
_____		
Affiliation		

TRIP REPORT

Actual Time in:_____ Actual Time out:_____

Date of trip leader's last visit to this section of the cave: _____

Observations and comments:_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

Circle the categories to which your comments pertain:

Survey	Historic	Trail
Inventory	Biologic	Impact
Map	Hydrologic	Personnel
Hazards	Geologic	Procedures

Other (specify):_____

APPENDIX G: Cave Survey Standards and Cartographic Guidelines

Jewel Cave National Monument
April 2007

Introduction
The proper collection, maintenance, and safeguarding of data are essential to the effective management and protection of caves and karst resources. Map data provide the fundamental framework of knowledge needed to accomplish the major purposes of cave management: preservation, advancing scientific knowledge and understanding (including further exploration), and providing for the enjoyment of the public.

Maps aid in navigating through the cave, facilitating exploration, and establishing spatial relationships, particularly between the cave and the surface. They serve to document the extent and nature of cave passages.

As cave exploration progresses, newly discovered passages are documented by compass-and-tape survey. The methods used to collect the data, sketch the cave passages to scale, and incorporate this information into a master map meet the standards proposed in *National Cave Survey Data Collection Standards* (Yocum and Wiles, 1997). Symbology is based on NSS Standard Cave Map Symbols, but adapted to the unique needs of the Jewel Cave system.

Over 140 miles of passages have been surveyed at Jewel Cave, using standards that were originally adopted and developed by Herb and Jan Conn. The result is that Jewel Cave has an excellent survey, with good-to-excellent loop closures and complete records of all surveys. Because of the high integrity of the data, Jewel Cave has never needed a resurvey. All future data collection will meet or exceed the minimum standards proposed by Yocum and Wiles (1997).

Cartographic standards are designed to meet the specific management needs of Jewel Cave National Monument. They ensure that the map represents, to scale, the walls and floor morphology, at as many as five overlapping levels, in a single black-and-white drawing. With a master map of over 60 quadrangles drafted according to this standard, it is important to maintain substantial compatibility with these hand-drafted quadrangles – even as improvements are developed.

To this end, for all new surveys, sketches will include more floor detail than has been previously recorded, and will be based on the NSS Standard Map Symbols; cross-sections will be made at every survey station, and additional symbols denoting changes in ceiling height, ledge heights, and lead notation (such as “TT” for “too tight”) will be incorporated. The sketches will be archived separately from the master map, and any additional information that is not used on the hand-drawn quadrangles may then be incorporated in future digitized maps with layers. The archived survey notes will be scanned into PDF files.

Cave Survey Data Collection Standards

April 2007

Information Included with Each Survey

Cave Name
Survey notes of caves other than Jewel Cave will be kept separate, with the cave name at the beginning of each survey.

Date
Full date: mm/dd/yyyy

Personnel
Include the full name or initials of personnel in the sketch book. (If initials are used, the full name can be later determined from the cave trip permit or database.)

Duties
List the function(s) performed by each team member. Basic duties include:

- Book
- Compass/Clinometer
- Tape
- Inventory

These duties may be abbreviated: B = Book, C = Compass/Clinometer, T = Tape, I = Inventory.

Instruments
The serial number of each compass and clinometer must be recorded. If a laser distance meter is used, its number must also be recorded.

Procedures

Equipment
- Survey books, instruments, and tapes will be provided and maintained by the Monument.
- Instruments used at Jewel Cave will be calibrated annually.
- Broken survey tapes will be taken out of service.

Survey Designations
- New survey designations should be used sparingly. An extra effort should be made to use suffixes of the main survey for branching leads (but without fragmenting the survey – see below). New designations may be initiated when surveyors are reasonably sure the area they are mapping is really going somewhere.
- New survey designations should consist of two characters from the standard ASCII character set, which includes upper and lower case letters (so “AA” and “aa” are different), and punctuation. Examples include the “XO,” “db,” and “!!” surveys. These characters are followed by a number, from 1 to 999. For side passages, this number may be followed by one or two upper-case letters.
- Surveyors should avoid fragmenting the survey, especially a main survey; correct numerical order should be maintained. Obvious side leads should be sequenced with a single suffix (e.g. “XO121A,” “XO121B”). Side leads branching from a side lead should be named with a double

suffix (e.g. "XO121BA," "XO121BB"). A fragmented sequence should only be used after a third level of branching.
- When possible, use the above "tree" format rather than "jumping around."
- Do not follow a lettered suffix with a number.

Stations and Labels
- Each survey must begin at an existing unambiguous tie-in station that is clearly marked in the cave.
- Each shot will consist of a unique combination of "from" and "to" stations.
- All survey stations must be permanently marked, except in delicate areas, or in places where it is not possible (e.g., where the bedrock is crumbly).
- Stations must be marked with a prominent bull's eye (currently with a permanent marker) on bedrock, a loose rock, or rock cairn. The label should be written on a loose rock, which may be either the same rock as the station, or a separate one. In delicate areas, a smaller mark is preferred. The main shortcoming of using a permanent marker is that it does not mark well on punky bedrock, so an alternative method will be pursued, and adopted when available.
- When using a suffixed survey, just the suffix will suffice (e.g. "XO121A" can be labeled as "A"), except in confusing areas (e.g. where two suffixed surveys are near each other), in which case the full station name should be labeled.

Measurements
- Distance must be measured in decimal feet (feet and tenths) to the nearest .05 feet (e.g., 12.75).
- Azimuth must be measured in degrees to the nearest 0.5 degrees (e.g., 125.0 or 125.5)
- Inclination must be measured in degrees to the nearest 0.5 degrees (e.g. +9 or - 8.5)
- Passage dimensions may be either estimated or measured. The latter is preferred when a laser distance meter is being used.
- The compass should be set for 0 degrees magnetic declination, when applicable. Declination, determined annually to the nearest 0.25 degrees, will later be set in the cave survey software.
- Loops under 500 feet should close with less than 2% error. Loops over 500 feet should close with less than 1% error.

Backsights
- Normally, only foresights are used to process the survey data, to ensure the consistency of a single compass reader. The backsight reading is used to check for gross reading errors ("blunders"). If both readings are within two degrees of one another, there is no blunder; if the readings do not agree, both readings must be repeated. If no agreement can be reached, the reading from the station that was easiest to read from should be used.
- A backsight must be read for every survey shot, when possible. These readings may be taken with the same set of instruments, by the same person who read the foresight; or by two different people using two sets of instruments. If two sets are used, they must be checked before the trip to be sure they agree within one degree.
- Backsights are not necessary for dead-end shots.
- When backsights are used, the uncorrected values should be recorded. Each backsight must be denoted by a circled, upper case "B" before the station names, and the station names must *not* be reversed in the survey book.

Reading and Recording Data

- Instrument readings will be recorded as read. A backsight will be uncorrected, and the compass/clinometer reader will notify the note-taker of the fact that the reading is a backsight.
- All data must be clear and legible: decimal points must be dark, and each number or letter must be neatly written.
- Distances will be recorded with two digits after the decimal point; passage dimensions will be recorded with one digit after the decimal point, when not a whole integer. Azimuths must be recorded with one digit after the decimal point. A "+" or "-" must precede all inclinations.
- Each shot must be recorded on pre-printed survey sheets, either offset station format or in-line station format. A blank entry must be inserted between all non-consecutive shots.
- The first station name on each page must be written using the full station name. The remaining station names may be abbreviated.

Sketching

- Each page of the sketch should include an arrow pointing towards **magnetic** north (not corrected for the current declination), labeled as such in the survey book.
- Each page of the sketch should include a labeled bar scale, for distance. The default scale is 1 inch on the sketch equals 50 feet in the cave. The scale may be changed as needed, as long as this is clearly indicated.
- Cross-sections must be done at every survey station, at the same scale as the plan view. If a different scale is chosen, this must be clearly indicated.
- Each survey point or station should be labeled on the sketch, and station symbols should be placed at the correct distance and direction relative to one another. Distances should be foreshortened for vertical angles greater than or equal to 30 degree, and azimuths may be estimated to the nearest 10 degrees. Use of a protractor and ruler are encouraged.
- All text should be written so that, with the north arrow up, everything is easily readable.
- Sketches should conform to Jewel Cave standards, adapted from the NSS Standard Cave Map Symbols Any non-standard symbols must be defined in a legend.

Checking Leads

- Checking leads with no intention of survey ("scooping") is not permitted.
- It is sometimes necessary for a member of the survey team to check a lead before it is surveyed ("scouting"), in order to determine which lead should be surveyed first, or how to efficiently place the stations. All passages entered by any member of the survey team must be documented, by either survey, sketch, and/or written description.
- Although it is preferable to survey all passages, there are times when the nature of the passage would make for difficult survey, the passage is too delicate, or it has a constriction where not every member of the survey team can fit. These need not be surveyed, but should be documented as thoroughly as possible.
- The person checking a particular lead should generally go no more than 100 feet before assessing a passage's potential and turning around to report to the rest of the group.
- It is the sketcher's ultimate responsibility to ensure that all lead-checking is carefully controlled and judicious. The main goal of any survey trip is to survey.

Passage Names

- The survey team that discovers a cave passage has the privilege of naming it.
- Carefully thought-out thematic names are encouraged, and must be agreed upon by all team members. Selected names should, in most cases, relate to the character of the passage, the features found in it, or significant events occurring on the trip.

- Cavers should strive for names that are "G-rated," keeping in mind that these names may eventually appear on a map viewed by the general public. Any names deemed inappropriate or distasteful would not be accepted.

Guidelines for Cartographic Passage Representation

April 2005

Introduction

The following cartographic guidelines are for drafting the working maps of the cave on mylar quadrangles. Sketchers do not need to follow these specific guidelines, which differ from the NSS Standard Cave Map Symbols, but should be aware of them so they know how their sketch will ultimately be translated into a final map.

Drawing Standards

- Walls, passage names, and passage detail are drawn with the 0.30 mm pen
- Survey stations, survey lines, station labels, ceiling heights, and notes are drawn with the 0.25 mm pen
- All ceiling heights and station labels should be shown, unless the survey is overly complex
- Even line width and density should be maintained

Levels

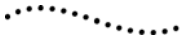
Walls should be drawn as follows:

Loft:

Chert:

Main:

Lower:



Basement:

Symbols

- Dashes line up end-for-end:

Yes:  No: 

- Holes in the Floor:
  - Lines completely cross holes, and are evenly spaced (see images below):

    Drawing a hole in a loft level:

    Drawing a hole in a chert or sub-chert level:

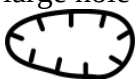
    Drawing a hole in a main level:

    Drawing a hole in a lower level:

    Drawing a large hole (lines do not need to cross entire hole):

- Holes Up:

- Hatch Marks on Ledges:
  - Hatch marks should be same length
  - Hatch marks should be perpendicular to edge line

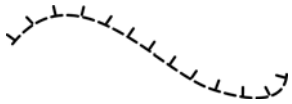
    Hatch marks in a loft level:

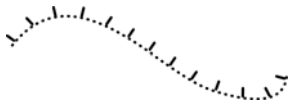
    Hatch marks in a chert or sub-chert level:

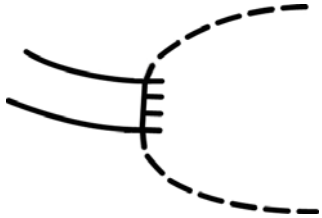
Hatch marks in a main level (hatches do not directly correspond to the dashes, to avoid misinterpretation as "T"s):



Hatch marks in a lower level:



- Extend walls of upper passage into hatch marks at each end of ledge:



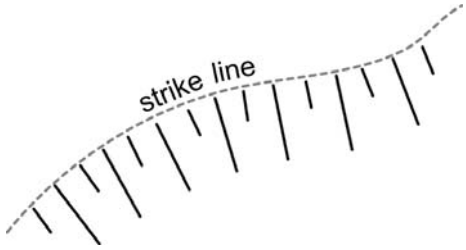
- Lines have smooth curvature

  Proper line curvature:

  Yes:  No: 

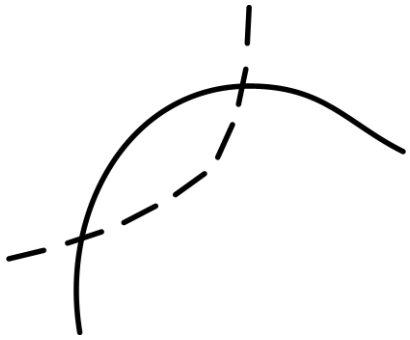
- Slopes:
  - Have invisible "strike" line
  - Hatches are evenly spaced
  - Hatches are of two lengths, which are consistent across the entire slope
  - Hatches should be perpendicular to the strike line
  - Hatches at either end should be short segments

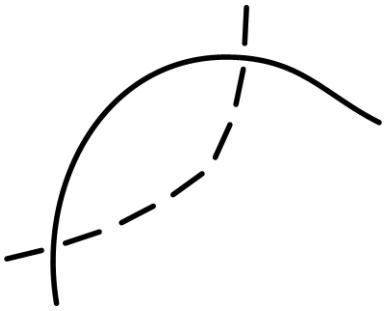
  Proper slope representation ("strike" line is imaginary):



- Crossing levels: Sub-chert level (for example) should cross directly over hatches of main level, *not* through spaces between hatches

  Crossing levels (different level types):

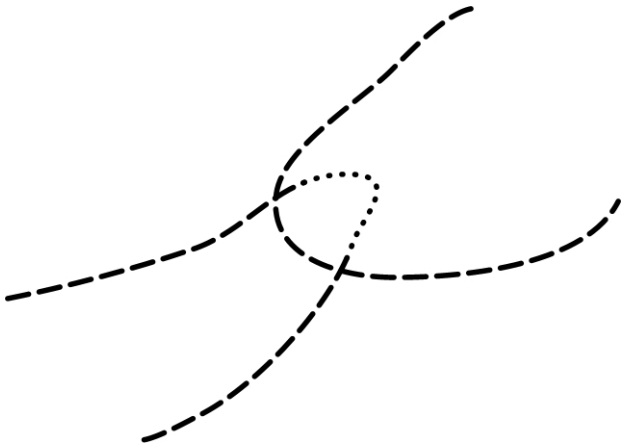
  Yes: 

  No: 

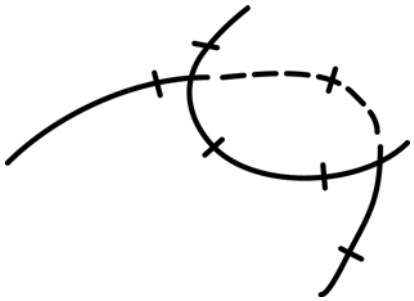
- Overlap of two passages of the same level type: Lower passage should be represented as if it were the next-lowest level where it crosses under the upper passage. The loft level (see below), is an exception.

  Crossing levels (chert/sub-chert level over chert/sub-chert level):

  Crossing levels (main level over main level):

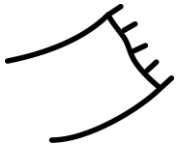


Crossing levels (loft level over loft level):



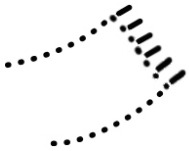
Ledges:

Ledge in a solid-line level:



Ledge in a hatched-line level:

Ledge in a dotted-line level:



Ledge heights
Use average or representative distance from edge of ledge to floor.

Ceiling Heights
When a passage's ceiling height is 1-19 feet, measurements are rounded in one-foot increments.

When a passage's ceiling height is 20 or more feet, measurements are rounded in five-foot increments.

Fonts

Names of rooms and passages will be written with all capital letters. Notes will be written with all lower-case letters. Station labels will consist of mixed upper- case, lower-case, and numeric characters.

Capitals:

ABCDEFGHIJKLMNOPQRSTUVWXYZ

Lower Case:

abcdefghijklmnopqrstuvwxyz

Numeric:

0 or Ø 123456789

I use **I** in labels, **l** in names, and **i** in text

L use **l** in labels, **L** in names, and ℓ in text

zero use Ø in ambiguous situations

SKETCHER EVALUATION SHEET
Jewel Cave National Monument
August 6, 2007

SKETCHER:	**CAVE:**	**EVALUATED BY:**
SURVEY:	**DATE:**	

This sheet is designed to evaluate the pre-printed Cave Survey sheets (2/1/07)	YES	PARTIAL	NO	COMMENTS
SURVEY SHEETS				
Were the pre-printed pages used as designed?				
Is the title page completely filled out?				
DATA PAGES				
Is the data complete, legible, and straightforward?				
Have passage dimensions been recorded for each station?				
Have all the pages been numbered? (Example: 1 of 3)				
Have backsights been recorded on all shots?				
Have distances been carried out to two decimal points, and azimuths and inclinations to one decimal point? (Example: 4.35 ft., 25.0 °, and –3.5 °)				
Do foresights and backsights agree within 2° for azimuth and inclination?				
SKETCH				
Is the cave name and date filled out for each page?				
Is the passage drawn to scale, and survey lines drawn in at the proper orientation (within 10°)?				
Are the stations clearly labeled?				
Is the sketch legible?				
Are standard symbols used?				
Are any non-standard symbols defined in a legend?				
Is there adequate floor and ceiling detail?				
Does the sketch contain sufficient cross sections?				
Is the nature of all leads indicated? (Example: “dig,” “too tight,” etc.)				
Have sufficient ceiling and ledge heights been included?				

Additional Comments:

APPENDIX H: Policy for Distribution of Cave Data

Jewel Cave is a significant cave under federal lands, and is therefore protected by the Federal Cave Resources Protection Act (FCRPA) of 1988. The FCRPA exempts cave location data from Freedom of Information Act (FOIA) requests. Cave location data is sensitive information. Over 45% of the known cave passages lie outside the NPS boundary, and unauthorized distribution could increase the potential for resource damage.

Jewel Cave National Monument will practice the following policy of limiting the distribution of cave location data, including maps:

General Public
Requests for cave maps or location data require the approval of the superintendent and may be denied.

Visiting Public
Map data in the Visitor Center will be limited to the wall map, a portion of the PowerPoint presentation in the Display Room, and the 1992 and 2007 sales maps. Brochures and other publications may contain subsets of maps, approved by the superintendent on a case-by-case basis. No other information may be disseminated.

Explorers
Individuals assisting the park in exploration do so under a Volunteer Agreement. Some cave location data may be distributed to current explorers. Subsets of digital survey data may be distributed when there is a demonstrable need. Subsets of the raw (hard copy) data may be exchanged to locate survey errors, etc. Appropriate subsets of detailed maps and line plots may be distributed to prepare for exploration trips, and to indicate the results of recent mapping. The Volunteer Agreements for exploration will specify that this information may not be reproduced or distributed in any way.

Researchers
Researchers may be given subsets of the survey data that meet a justifiable need in a park-approved project, provided that the cave specialist and superintendent determine that this will cause no significant risk of misusing the data in ways that could cause impact to the cave system.

Each researcher will sign an Agreement to 1) not copy, reprint, or distribute any cave location information (or any intermediate forms of the data) without the approval of the Superintendent, 2) to keep all data (digital or hardcopy) secure at all times, and 3) to completely destroy remaining data once the research is concluded.

The Superintendent has the authority to alter this policy when necessary.

APPENDIX I: Cave Feature Inventory Standards

Introduction
While surveying and mapping produces information on the shape and extent of cave passages, it does not provide detailed information on the features found within them. To meet this need, feature inventory data has been collected at Jewel Cave since 1987. The goal of the inventory is to collect broad-scale information, which can be recorded by someone with minimal expertise in the fields of geology, biology, mineralogy, etc. More detailed research or analyses may require additional trips to the area to collect additional data, but the initial inventory is still of great value. It delineates areas of interest for future study and also provides management with essential information, such as locations of dripping water.

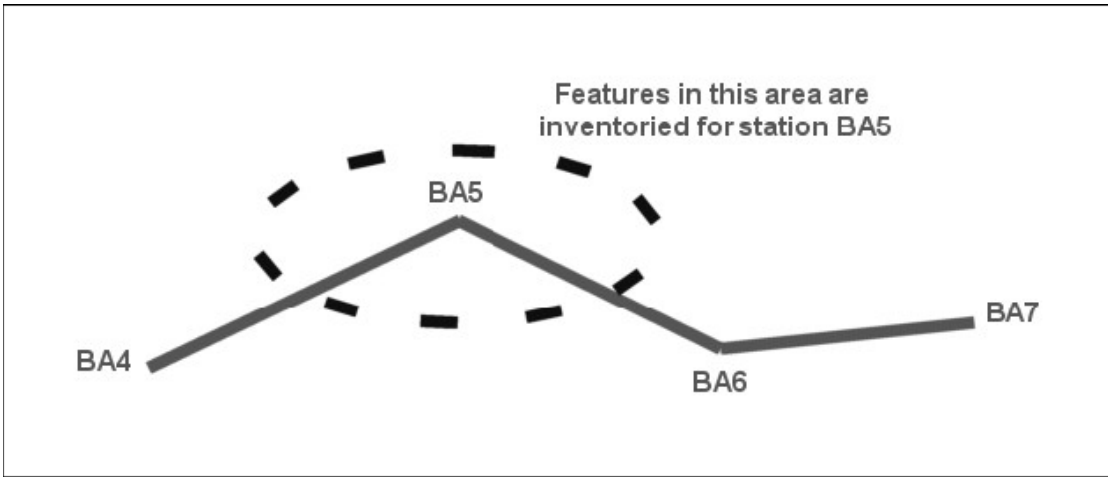
Inventory data is always collected on exploration trips, simultaneously with the survey data. Although many survey stations in the cave have not yet been inventoried, there are no current plans to collect this data through dedicated inventory trips.

Data Collection
To simplify data collection, the most commonly found features in the cave are assigned two-letter codes, and the cave levels are assigned numbers. A list of these codes is in the front of each inventory book. The initials of the person collecting inventory data and the date are recorded at the top of the inventory data collection form.

The survey station name is recorded in the “Station” column. The stratigraphic level of the passage (at the floor elevation) is recorded in the “Level” column, as a number. The next column, “BD” is used to record the size (S, M, or L) of any breakdown found near the survey station. Small breakdown is smaller than a person; medium breakdown is person-to-car sized; large breakdown is bigger than a car. If no breakdown is present, a dash is placed in this column. The remaining columns are used to record two-letter codes of features found near the survey station. Comments can be recorded in the “Comments” column, in this format: “GN: up to 3” long.”

A digital camera (provided by the park) is used on every trip to document unusual inventory features. When a photograph is taken, the code “PH” is used, and the photo number must be recorded in the “Comments” field.

All features are inventoried in association with the station they are closest to. The halfway point between any two survey stations is the inventory boundary:



Example inventory form:

NAME: J E C

DATE: 4 2 05

Station	Level	INVENTORY CODES												COMMENTS
		BD												
BA4	4	S	MN	GF	GN	FW	GL							GF: 14" long GN: hundreds, 1"-3" long
BA5	4	S	MN	GN	GL									
BA6	4	L	MN	GL										
BA7	3	S	MN	GL	CH	WR	WS							MN: calcified chunks
BA8	3	—	CH	WS										
BA9	3	M	CH	WS										
BA10	4	L	MN	GL	FW									

Data Management

Inventory data is currently entered in a Microsoft Access database designed by the park. The data is then linked to the cave survey data in GIS and complex queries can reveal spatial relationships of inventoried features.

Jewel Cave Inventory Codes

Level

1	Loft
2	Chert
3	Sub-Chert
4	Main
5	Lower
6	Basement

Speleogens

BP	Bedding Planes
BX	Boxwork
BR	Breccia
CH	Chert
FL	Fossil
PF	Paleofill
SS	Slickensides

Speleoclasts

BD	Breakdown
CT	Crust
DD	Dendrites
MN	Manganese
MD	Mud
SD	Sediment

Weathering Products

CN	Conulites
DH	Driphole
VG	Van Gogh Weathering
WR	Weathered Rock

Seepage/Evaporation Speleothems

HB	Hydromagnesite Balloons
FW	Frostwork
MM	Moonmilk
PC	Popcorn
SH	Shards
VT	Vent/Rim
WS	White Stuff

Crystal Speleothems

CX	Crystal
DS	Dogtooth Spar
NS	Nailhead Spar
QC	Quartz Crystal
QS	Scintillites

Gypsum Speleothems

CC	Cave Cotton
GB	Gypsum Beard
GC	Gypsum Crust
GF	Gypsum Flower
GH	Gypsum Hair
GL	Gypsum Luster
GY	Gypsum Misc.
GN	Gypsum Needles

Dripstone Speleothems

CF	Calcite Flakes
CI	Calcite Ice/Rafts
CP	Cave Pearls
CL	Column
DR	Drapery/Ribbon
FS	Flowstone
RS	Rimstone Dam
ST	Shelfstone
HL	Helictite
LG	Logomite
PS	Pseudomite (Popcorn Stalagmite)
SC	Stalactite
SG	Stalagmite

Water

PD	Pool Dry
PI	Pool Intermittent
PL	Pool Present
WC	Water Condensation
WD	Water Dripping
WL	Water Line
WM	Water Moist
WT	Water Trickling

Miscellaneous

CR	Corrosion Residue
BS	Bat Scratches
BI	Biological
CA	Carbide Markings
DT	Dirty
FG	Flagging
FR	Fragile
GA	Garbage
HZ	Hazard
HS	Historical
OH	Other
PH	Photo

Tape Color

BB	Black & Blue
BW	Black & White
BL	Blue
DB	Blue Dots
GR	Green
OR	Orange
OB	Orange & Black
OW	Orange & White
OD	Orange Dots
PK	Pink
RR	Red
RW	Red & White
RD	Red Dots
WH	White
WB	White & Blue
YL	Yellow
GS	Gypsum Snow
SP	Gypsum Spiders

APPENDIX J: Photography

The following guidelines will be observed for in-cave photography:

- Photography may be done on any trip, as long as it does not significantly detract from the purpose of the trip.
- If the photography is done with park equipment, the photographs belong to the park.
- If the photography is done with the photographer's own equipment, the photographer may donate photos or duplicate photos at his or her discretion. The park may then use the photographs as needed, with credit given to the photographer. The park may reimburse the cost of duplication.
- A filming permit will be required for commercial photography; to do trips for the sole purpose of amateur photography; or on other trips, if additional time, equipment, or setup procedures would be needed. There may be a monetary cost associated with a filming permit.