Oregon Caves National Monument
Subsurface Management Plan

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I. INTRODUCTION

Oregon Caves National Monument, in southwestern Oregon, is located in the Siskiyou Mountains. Of the caves on the Monument, Oregon Caves, hereafter referred to as the Cave, is by far the largest and the only one in which public tours are given. With about 4.8 kilometers (three miles) of known passage, it is also one of the largest caves in the Pacific Northwest. The Monument's subsurface has complex geologic and biologic features and processes, most of which are explained more fully in the glossary and other sections of this document.

A. Purpose and Significance

The purpose of the Monument is defined by President William H. Taft's 1909 proclamation that established Oregon Caves as a National Monument:

"Oregon Caves...are of unusual scientific interest and importance, and it appears that the public interests will be promoted by reserving these caves with as much land as may be necessary for the proper protection thereof."

Underwater and stream solution enlarged narrow crack in marble to form the Cave sometime between a few million to half a million years ago. Bedrock, water, climate, and human developments are the main influences on the subsurface. A year-round underground stream and seepage from the Cave's ceiling both respond within hours to weeks to a rainfall or snow melting event. Although not noted for large, cave-adapted animals, the Cave supports subspecies of the Townsend's Big-eared Bat, which is state listed, and several cave-adapted arthropods endemic to the Monument. Many subsurface processes are closely tied to the surface. Natural subsurface communities are largely dependent on food from the surface and outside air strongly affects formation growth.

Even though the focus of the Monument is that of its showcave, there are other caves and underground resources that the Park Service is mandated to protect. For examples, a family of soil millipedes is known only from the Monument, there likely is a groundwater amphipod known only from the Monument, and the hyporheic in sediment in streams likely has geographically restricted water mites. Although surface processes also affect subsurface areas, the inclusion of subsurface areas with similar geological processes and biologic groups of animals (guilds) and the exclusion of the surface make this management plan manageable in congruence and size, respectively.

B. Legislative and Administrative Requirements

The plan follows various laws, regulations, policies and other guidelines. All or most topics are covered in Director's Order #2 (Park Planning), #6 (Interpretation), #7 (Volunteers in Parks), #9 (Law Enforcement Program), #12 (Conservation Planning, Environmental Impact Analysis and Decision Making), #14 (Resource Damage Assessment and Restoration), #20

(Agreements), #24 Museum Collections Management), #25 (Land Protection), 42 (Accessibility for Visitors with Disabilities in NPS Programs, Facilities and Services), #48A (Concession Management), #48B (Commercial Use Authorizations), #50D (Smoking Policy), 52C (Park Signage), 53 (Special Park Uses), #55 (Interpreting the NPS Organic Act), #66 (FOIA and Protected Resource Information), #74 (Studies and Collecting), #75 (Media Relations), #75A Civic Engagement and Public Involvement), #77 (Natural Resource Protection), #77-6 (Comprehensive Research and Development Agreements), #84 (Library Management), #90 (Value Analysis), #92 (Human Resources), #93 (Conflict Resolution).

National Parks and Recreation Act of 1978 (P.L. 95-625); Federal Caves Resources Protection Act (P.L. 100-691); Lechuguilla Cave Protection Act of 1993 (P.L. 103-169); National Parks and Recreation Act of 1978 (P.L. 95-625); National Environmental Policy Act of 1969 (1970) (P. L. 91-184); Federal Advisory Committee Act; NPS Organic Act; General Authorities Act (16 USC 1a-8);

Air Quality: Clean Air Act (33USC 1251 et seq.); Director's Order #47 (Sound Preservation and Noise Management

Cave Formations: Federal Caves Resources Protection Act (P.L. 100-691)

Cultural Values: Archaeological Resources Protection Act of 1979 (P.L. 96-95): Historic Sites Act of 1935 (P.L. 86-523); Director's Order #28B (Archeology); #28 (Cultural Resource Management)m abd #71A (Relationships with Indian Tribes) and #78 (Social Science); Native American Graves Protection and Repatriation Act of 1990 (P.L. 101-601)

Education: Director's Orders #6 (Interpretation), #29 (Ethnography Program), #52A (Communicating the NPS Mission), 52B (Graphic Design Standards), #70 (Internet and Intranet Publishing), #78 (Social Science), #82 (Public Use Reporting); National Parks and Recreation Act of 1978 (P.L. 95-625); NPS-77

Fossils: NPS Organic Act; General Authorities Act (16 USC 1a-8); NPS-77
Mineralogy: Federal Caves Resources Protection Act (P.L. 100-691)

Safety: Director's Order #50B (Occupational Safety and Health Program, #51 (Emergency Medical Services), #59 (Search and Rescue), #83 (Public Health Program)

Sediments: Federal Caves Resources Protection Act (P.L. 100-691**)**
Water: Clean Water Act (33USC 1251 et seq.)

Wildlife: Endangered Species Act of 1973 (P.L. 93-205, amended 1982; Director's Order #47 (Sound Preservation and Noise Management), #77-5 (Animal Capture/ Eradication), #77-7 (Integrated Pest Management), #77-8 (Endangered Species), #77-9 (In-Park Borrow Material)

The Federal Cave Resources Protection Act (PL 100-691), hereafter known as FCRPA, directs federal agencies "to secure, protect, and preserve significant caves on Federal lands for the perpetual use, enjoyment, and benefit of all people." The Act states "that Federal lands be managed in a manner which protects and maintains, to the extent practical, significant caves."

FCRPA defines a cave as "any naturally occurring void, cavity, recess, or system of interconnected passageways beneath the surface of the earth or within a cliff or ledge that is large enough to be traversed by people, whether or not the entrance is naturally formed or manmade."

The National Park Service (NPS) has been directed by Congress to manage the parks "To conserve the natural scenery and the natural and historic objects and wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." (The National Park Service Organic Act of 1916 - PL 64-235.)

The mandate to protect caves is further defined in the NPS Management Policies Handbook (1988) which states that -

"Caves will be managed to perpetuate their atmospheric, geologic, biological, ecological, and cultural resources in accordance with the action plans within this document. Natural drainage patterns, air flows, and plant and animal communities will be protected."

II. PRESENT RESOURCE STATUS

Significance: The Cave is nationally significant for its diverse wallrock, sediments, and species. The wallrock is composed of the 210-171 million year-old Rattlesnake Creek Terrane. A terrane is a group of rock formations with a similar geologic history. This terrane had one of the most complex and longest journey of any such rock mass; first as a mid-ocean ridge, then as coastal curved island chains, a deep ocean trench, and sediments mashed between colliding rock masses, and then as or under basins expanding and deepening over both land and sea. The collision of North America with such volcanic island arcs and the welding of those island chains to the continent apparently is the main way that Western North America has enlarged to over twice its original size (English 2004).

Sediments are also diverse and include redeposited glacial loess, volcanic ash, stream cobbles, collapse debris, and fossils or subfossils such as the remains of a 38,600 year-old jaguar, a greater than 50,000 year-old bear, and more amphibian species than known from any or nearly any other cave in North America. The Cave also has more recorded living species and single-cave endemics than is known from nearly any other cave.

Air Quality: The air quality at Oregon Caves has been designated class II. Air quality is moderately affected by local slash burning in spring and at times by regional fires in summer. No other major diffuse or point sources of particulates occur upwind. Increasing residential development in the adjacent Illinois Valley may increase presently minor effects from winter wood burning. Enough airflow exists so that cave radon concentrations are low in nearly all places in the Cave. Cave temperatures beyond the twilight zone ranges from 32 to 49^0F. It is usually around 43^0F along most routes in the winter and increases to an average of around 46^0F during summer.

Cave Formations: Oregon Caves' wall rock likely is composed of late Triassic (~210 million years ago) metamorphosed sedimentary rock (mostly marble, with some argillite (slightly metamorphosed mudstones) and metachert (metamorphosed quartz rock). Metamorphism of rock occurs when a rock is recrystallized due to heat and/or pressure up to but not including that which would cause melting of the rock. Regionally, metamorphism is low grade (mostly mid-level in the greenschist facies), meaning that the rock has been subject to moderate amounts of heat and/or pressure. Higher grade metamorphosed sedimentary rocks (evidenced by the presence of minerals such as garnet, biotite and actinolite) can be seen in the cave near granitic (granite or granite-like) batholiths and dikes. A batholith is a large body of once molten and now usually crystallized rock. A dike is a narrow band of rock that cuts across other rock at a high angle (usually greater than 45 degrees from the horizontal). They usually form when rock breaks along a fault, thereby allowing other material into the crack caused by the fault. Bedding planes between rock layers have faulted as well.

A similar orientation of major faults, bedding, and steep water gradients, enabled ground-water dissolution of the bedrock. The cave formed mostly underwater as a braided passage network. Fluctuations in groundwater levels and flow behavior have left their mark on the cave where passages show subsurface stream piracy, vertical shafts, incised corrosion bevels (horizontal notches) from flooding, and smooth ceilings from atmospheric corrosion.

Cave formations in the main cave include speleothems that result from deposition, bedrock and fill features, and cave features that result from solution. Most of the fragile formations, especially stalactites, are broken near the 2400-foot long paved trail. Cave features that are either rare or rarely reported elsewhere include cave crusts derived from a calcite-rich powder called Mundmilch, squiggly sediment lines (vermiculations) covered with flowstone, flexible and and below water flowstone, quartz dikes; and stalactites smaller in diameter than a water droplet. The shape and color of many features changes with depth and nearness to entrances. The other known caves on the Monument are much smaller and have few formations or cave-adapted animals.

Cave Formations: Speleothems are materials naturally deposited in the cave. They include canopies, cave pearls, dripstone (columns, stalactites, stalagmites, and draperies), flowstone, shelfstone, silticicles, coralloids, conulites, helictites, microgours, Mundmilch, rimstone, and vermiculations. Speleogens are cave features caused by solution and they include arches, anastomoses, bevels, boxwork, canyons, domes, domepits, meanders, meander niches, natural bridges, palettes, vugs, pendants, pillars, potholes, rills, and scallops. Surface karst and karren include rills, sinks, and what may be relict alpine karst. Sediments include hoodoos, talus, conglomerates, bones, breakdown, vermiculations, and imbricated cobbles. All of these terms are defined in the glossary accompanying the environmental assessment of this plan but are included here to emphasize the Cave's geologic diversity, one of the Monument's main themes

Clastics are broken or rounded bits of rock that come from all the major rock units on the surface. A variety of cave features that include bedded silts, volcanic ash, congelifracts (rock broken by ice wedging), exfoliated (broken sheets of rock) flowstone, and solution/deposition flowstone cycles record Ice Age glacial, periglacial (near glaciated areas), and climate affects. Nearly all of the formations and bedrock of the Cave are calcite. Exceptions are the clay or silt vermiculations, ice formations near cave entrances, gypsum crusts, and argillite, quartz, and chert layers reliefed out from the marble wallrock. Geologic structures include breccias (broken pieces of rock now cemented), dikes, faults, slickensides (striated fault surfaces), stylolites (solutional concentration of insoluble residues in this case in marble), joints, sills (like dikes but more horizontal), and soft sediment deformation.

In summary, specific geologic and climatic conditions have significantly influenced the formation and shape of Oregon Caves. These are: (1) a small, tilted and faulted marble block (a soluble rock with cracks to allow water to penetrate); (2) inclined bedding (along which ground-water flows and cave passages develop); (3) adjacent non-carbonate rock (which sheds surface runoff onto the marble block); (4) elevation and steep mountain slopes (which provide a steep gradient for water to rapidly infiltrate into and flow through the cave); and (5) climate change (which provides broad-scale fluctuations in subsurface water and air flow).

Climate: Oregon Caves has wet, mild winters and warm dry summers. Annual precipitation at 4,000 feet elevation averages 45 inches but often varies. Most of the precipitation is in the form of rain and wet snow with an average total accumulation of about seven feet. Fog usually occurs only a few days out of the year. Surface temperatures typically range from the 20s-40s F in winter and from the high 40s-80s F in the summer. Moderate winds are common, especially prevailing winds from the west, storm winds from the south, up-canyon winds (from the northwest) during the day and down-canyon winds (from the southeast) in the evening.

Water Quality and Quantity: Five small springs begin and flow most years in the Monument. The first becomes Upper Cave Creek. It sinks into its bed and emerges as Cave Creek from the Cave's main entrance. Surface streams that mostly dry up after spring snowmelt recharge the present cave stream. When the vertical joints stop dripping in early summer, the cave partly dries out except in areas of the stream, vertical shafts, bedding plane dripping, and the deeper areas of the cave. Cave water has been tested for major ions, pH, temperatures, flow rates, important biological nutrients (phosphate, phosphorus), and the presence of long chain hydrocarbons. No data so far received indicates that any significant pollution from humans occurs. There may have been a slight increase in zinc levels, but the removal of most galvanized iron from the old trail system should have eliminated most zinc leakage from railings in the cave.

Paleontology: The Monument may be of national significance in terms of its mammalian fossils. A radiocarbon date of more than 50,000 years was determined from what appears to be a grizzly bone in the cave. This is one of the oldest records of in the Western Hemisphere. A 38,600 year old jaguar skeleton was found at the northernmost jaguar fossil site. It may be the most complete jaguar fossil skeleton ever found. Scratches from bears have been found on cave sediment and appear to be very old as well. A paw print is likely from a member of the cat family. Other rare fossils found in the Cave include those belonging to mountain beavers (also called aplodontia), blue grouse, and several amphibians. A species list is included in the appendices.

Wildlife: The Cave has eight bat species, the most abundant being the long-eared myotis (*Myotis evotis*). It and many of the other species are most active in the Cave in the middle of the night during early fall and, therefore, are not usually disturbed by visitors. Large tours have disturbed Townsend's big-eared bats during previous winters, but with the termination of winter tours beginning in 1998, the main disturbance now is to approximately 10-20 bats during the annual initiation of tours in late March. Declines of fringed, long-eared, and long-legged myotis bats in parts of the Pacific Northwest may be from loss of old growth and riparian areas outside the Monument. However, apparent declines within the Cave may be a sampling artifact, that is, only sampling the Exit Tunnel (more bats now seem to be using the 110 Exit).

Out of about 110 known arthropods, subsurface species endemic to the Monument include flies, beetles, millipedes, grylloblatids, springtails, and water mites. Based on identifications by Dr. Rod Crawford (1994), from the Burke Museum in Seattle, Oregon Caves has at least eight or nine invertebrate species that so far are only known from the caves. The cave's age (likely a few million years), moderate size, and nearness to organic soils results in a moderately high biodiversity. Well-developed zonation of formations and life forms occur near entrances and with depth.

Fast growing/recycling populations of cave pool bacteria appear healthy although slow-growing cave wall actinomycetes (cave slime) and cave-adapted arthropods appear to be impacted from human-introduced organics near the developed cave trail.

Special Status Species: There are no known federally listed threatened and endangered species within the subsurface of the Monument. Given the specifics of subsurface evolution and migration, no federally listed threatened and endangered subsurface species are likely to be found in the Monument. The federally listed northern spotted owl and state or federal species of concern (mountain kingsnake, tailed frog, Del Norte salamander, northern goshawk, bald eagle, olive-sided and little willow flycatchers, Siskiyou gazelle beetle, and Pacific fisher) are known or may occur in the Monument. However, none of these species are known to exist within the subsurface. Five state or federal species of concern (Pacific western big-eared bat and long-eared, fringed, long-legged and Yuma myotis) do occur in the subsurface during part of their lifecycles.

III. DATA COLLECTION

Information will be gathered about subsurface resources and the people who interact with them. This information will provide the basis for management decisions.

A computerized database allows easy storage, retrieval, and updating of data. This database includes subsurface specific information (such as that found on inventory forms), cave visitation data, monitoring data, a directory of resource people, and a bibliography. GIS computer files can be found in the Monument's natural resources vivisions computers on the network server. Most text files are found in W\RM documents/*.*. Hereafter, only the *.* part of each file name will be used. Descriptions of many computer files can be located in ASKME. Park specific and cave specific publications and unpublished material are found in the Park Service's NATUREBIB. GSA Federal Information Resources Management Regulations will be followed in regard to most data.

In addition, open and closed paper files are maintained with alphabetized filenames (FILENAME) and henceforth are described as OPEN*.*. This material includes raw research and monitoring data, a duplicate set of which often will be in the museum safe under the appropriate accession folder. Other material unsuitable for computer storage, such as certain maps, will be kept in a subsurface-specific file folder in a map cabinet in the park museum.

A cave directory (address-geoandbio), includes the names and addresses of persons with expertise in relevant fields such as subsurface management, cave interpretation, natural and social sciences, persons who know park caves well (such as regular visitors and cavers), and any persons who are interested in assisting with subsurface related projects. The directory also contains persons available to assist managers with subsurface-related search and rescue operations. Files contain the person's name, group affiliation, and field of expertise or specialized skills.

A separate directory (W:\RM Documents\EACave Tours\NSS_Members) contains the e-mail and post mail addresses of NSS members in California, Oregon and Washington, the post-mail addresses of other organizations or individuals normally included in NEPA mailings lists, and other individuals or organizations that have requested to be put on the NEPA mailing list.

Research is recognized as a necessary management strategy and is vital to a subsurface management program. Research is guided by policies identified in the NPS Management Policies. Guidance and procedures for the issuance of Collecting Permits is provided for in CFR-36 and the FCRPA and can be found at https://science1.nature.nps.gov/research/ac/ResearchIndex.

The NPS will fund studies to aid in solving subsurface management problems. However, any competent researcher with a proposed project consistent with NPS policies and likely to contribute to the management and understanding of park resources will be encouraged to work in the park. Research proposals shall be approved or denied by the Monument's Superintendent.

A. <u>Cave Classification</u>

Since human safety is a prime NPS concern and rescues can impact even sturdy formations, access to a cave or cave passage depends on the sum of its fragility and hazard ratings as defined in Chapter VII (inventory and monitoring). A cave's rating may be changed seasonally, as a result of further inventory, or by the alteration or removal of a hazard or resource responsible for the initial rating.

B. **<u>Inventories</u>**

Standardized and accurate surveys and inventories are crucial for establishing baselines and monitoring and mitigating human-caused changes in any cave. All cave inventories and monitoring in Monument caves will be tied into the nearest survey station or stainless steel permanent markers and put into the park’s GIS system. All future surveys will be combined with on-site inventories. Data will be entered on site on personal data devices written survey and inventory forms and/or notebooks.

IV. RESOURCE PROTECTION

A. **<u>Visitor Use</u>**

Payment of a user fee authorizes visitor entry along the developed trail in the Cave during normal visiting hours with a park ranger guide.

The National Park Service Management Policies Handbook (1988) states that -

"Caves or portions of caves will be closed to public use, or use will be restricted to conducted tours, when such actions are required for human safety or the protection of cave resources. Some caves or portions of caves may be managed exclusively for research, with access limited to authorized research personnel."

1. Carrying Capacity

Subsurface study and recreation use that do not cause impairment of Monument resources are appropriate activities in the Monument. Yet, balancing resource preservation and user-caused impacts is a challenge, especially in caves, where any use can cause cumulative impacts. Increased use, such as larger or more frequent cave tours, can also exceed social carrying capacity as well, resulting in unpleasant experiences to the visitor. The manager must set limits of acceptable change for each cave, then implement strategies to keep change below the threshold of impairment. A measure of change shall be based on known visitor use, current degradation, sensitivity of the resource, and the relative value of visitor use and cave preservation. Ultimately, determination of acceptable change may vary and is within the discretion of the NPS management.

2. Caving Permits

For resource protection and visitor safety, many caves or cave passages may be closed to regular or general entry. It is expected that programs will be implemented that will allow entry into and the use of some, if not all, of a park’s caves or cave passages. If a park does allow entry into undeveloped caves or off-trail areas of developed caves for recreation, research, interpretation, or other reasons, such entry will be regulated by a cave entry permit program.

In a developed cave, trips off of the established visitor trails will require a written permit, approved by the superintendent or a designee. Anyone failing to comply with park policies regarding conservation of cave resources and/or safety guidelines for cave entry will be denied a cave permit. Any incident shall be documented and the appropriate park staff notified as soon as possible.

Management strategies shall be determined through resource evaluations and inventories to determine the method best suited for a given cave. Key information for this determination includes cave inventory records, consultations with those people who are most familiar with the cave, and firsthand knowledge of the cave.

A permitting system shall be able to change with changes in cave conditions and patterns of use, or as new information becomes available. Such changes will require reevaluation and possible adjustments to the management prescription.

The Code of Federal Regulations (36 CFR, Section 7.49) states that:

"No person or persons shall be permitted to enter Oregon Caves unless accompanied by an approved National Park Service or concession employee who has successfully completed the training prescribed by the National Park Service."

This regulation applies to both paved trail and off-trail trips. The main training for paved-trail guides is approximately two weeks long and is initiated upon the arrival of a park ranger to the Monument.
Rangers who have worked previously at the Monument and rangers who start work in the middle of the main season usually have only about a week in training. A training program also exists for all National Park Service employees who apply as a trip leader to lead trips off the paved trail. Each applicant accompanies the natural resources specialist on at least one trip off the paved trail in the cave and guides the tour group back to the paved trail. The length of the tour will be at least one hour. Based on his/her observations, the Chief of Interpretation and Visitor Services or the Natural Resources Specialist will recommend to the Superintendent that the individual be certified as a trip leader. If certified, the individual can lead a trip of other park staff to those Zone 3 areas for which he or she is certified. In Zone 3 Caves and Cave Passages the fragility/hazard sum is 5. .

Zone 4 Caves and Cave Passages
The fragility/hazard sum is 6. Prior to a proposed trip, a written application shall be submitted for review by the Superintendent. Permits for Zone 3 and caves shall be approved by the Superintendent. A signature of approval on the application form constitutes a valid permit under the conditions of the form. Solo expeditions will not be permitted. No undeveloped cave or cave passage may be entered without an approved cave permit except for:

a. Maintenance of the lighting and trail system near the main trail in the Cave.

b. Public tours led by NPS staff to a Zone 3 area.

c. Administrative trips led by park staff.

d. Zone 1 or 2 areas outside the Cave.

Approval of permits is contingent on:

Hazard 1 trips will consist of at least two cavers, who observe safe caving rules and use hard hats, three light sources per person, boots with non-skid soles, and protective clothing. Hazard 1 caves or cave passages offer the least hazard to the caver. Hazard 1 characteristics include:

1) No known loose ceiling rocks.
2) Well-defined main passageways with only dead-end lateralpassages.
3) No drop over three meters (10 feet).

Hazard 2 trips will consist of at least three cavers, two of whom have moderate caving experience (including vertical descent and climbing), who observe caving safety and vertical safety rules, and use the following basic equipment: hard hats, three light sources per person, boots with non-skid soles, vertical descent and climbing gear, and protective clothing with no loose or protruding attachments that might become entangled while doing vertical work. Each caver will have a complete set of climbing equipment. Vertical equipment may not be needed in some Zone 4 caves or cave passages. Hazard 2 caves contain structural hazards not found in Hazard 1 caves.

Hazard 3 trips will consist of at least three cavers, all of whom have more than 40 hours of caving experience (including vertical descent and climbing), who observe caving safety and vertical safety rules, and use the following basic equipment: hard hats, three light sources per person, with no loose or protruding attachments that might become entangled while doing vertical work, and vertical descent and climbing gear. Each caver will have a complete set of climbing equipment. Hazard 3 characteristics include:

1) Maze-type passageways.
2) Vertical drops to 9 meters (30 feet).
3) Loose rocks on ceilings over two meters in height. No known loose rocks on passages less than two meters (six feet).
4) Balanced rocks on uneven floor.

e. Zone 3 and 4 trips.

Groups inexperienced in caving techniques will be accompanied by at least two experienced leaders to assist the group, help with emergencies and, in the event that one leader has to accompany someone back to the entrance, to assure that no one remains underground unescorted. In Zone 4 Caves and Cave Passages, the fragility/hazard sum is 6.

Anyone that demonstrates incompetence, failure to cooperate, negligence or other actions detrimental to their own or the group's safety, or to the cave resources, will be decertified as a trip leader and/or denied a cave permit for a period of time based on the severity of the action. Enforcement actions will be taken if CFR regulations are violated. All incidents will be documented and the Superintendent notified as soon as possible. Evidence of incompetence or past negligence will result in future denial of a permit request. Failure of all members of a trip to sign the permit request before entry into a cave invalidates the permit.

If hikers or cave explorers find a previously unknown cave it shall be reported to park personnel. Exploration of the cave will not be permitted without approval by the Superintendent. Exploration will be conducted in the presence of the Superintendent or his/her designee.

B. **Interpretation**

Interpretation is an extremely important management tool since it encourages voluntary compliance and cooperation in protecting essentially nonrenewable resources at the

Monument as well as reducing human-caused impacts outside the Monument that affect Monument resources. People entering the interagency visitor center, contact stations at the Monument, or a cave should feel that caves in general are an important resource to Americans, that the Monument's Cave is nationally significant in regards to its resources, and that every user is personally responsible for maintaining the Cave's integrity, beauty, and naturalness.

Subsurface management actions and non-actions that affect park interpretation and resource management will follow Director's Order #6 (Interpretation) and #11B (Ensuring Quality of Information Disseminated by the NPS). The latter order follows government-wide guidelines that "provide policy and procedural guidance to Federal agencies for ensuring and maximizing the quality, objectivity, utility, and integrity of information (including statistical information) disseminated by Federal agencies."

Visitor contact methods include:

1. **Publications**

Free interpretive media include general information brochures, brochures on geology and life of the subsurface, foreign language handouts, an interpretive sign system over the Cave, and the park newspaper. All will carry a subsurface preservation message and many will have information on subsurface restoration. The Monument, the concessionaire, or the Natural History Association will not sell publications that support or encourage destructive use or activities detrimental to Monument resources.

2. **Interpretive Tours**

60,000 to 80,000 visitors participate yearly in NPS-guided tours or activities related to the Cave. This is about 90% of the total estimated annual visitation to the Monument. Greater than 80% of the visitation both to the Cave and the Monument occurs during June, July, and August.

NPS staff conducts interpretive tours through the Cave for the general public and as curriculum based education for school groups. The standards require tour guides to present a theme that supports subsurface conservation and outlines some aspect that is significant about the Monument's subsurface. The guides also must have sufficient communication skills to protect park resources and ensure visitor safety and enjoyment. A visitor who learns about subsurface conservation and some of the features and processes that make the subsurface special and worthy of protection will likely appreciate and understand the subsurface more. Such appreciation is likely to lead to greater protection of both the subsurface and subsurface in general. The Natural Resources Specialist will ensure that resource protection and interpretive information in trail guides of routes in the Cave reflects both studies done in the cave as well as relevant studies in other caves.

3. **Outreach Programs**

Each year, at least one outreach program and one regularly scheduled evening program will deal mainly with subsurface preservation and/or restoration. Monument or community sponsored contests (art, writing, etc.) and field seminars or special programs conducted by knowledgeable persons will be encouraged, including appropriate programs sponsored by the concessionaire or other contractors. All programs will carry a general conservation message.

4. **Audio-visual**

Most future exhibits, videos, slide programs, and sign systems on the Cave will contain a subsurface conservation and/or restoration message.

5. **Visitor Surveys**

Studies need to identify visitor expectations, so as to develop and promote new recreational opportunities that will increase visitor enjoyment, protection of park lands, and support from a tourism-dependent local economy. Special visitor populations and their values and attitudes must be known and their needs addressed. The last visitor survey was completed in 2003 (Hoger, Littlejohn and Hollenhorst). Tallies have been made of visitor comments in drop boxes from 2000 to 2003. Formal interviews authorized by the Office of Personnel Management include yearly Government Performance and Results Act (GPRA) interviews with summer visitors and two extended interviews conducted in 1995 and 2003. All such interviews supply systematic, statistically valid information.

C. **Ranger Patrols**

Periodic ranger patrols in the Cave and above the Cave will supplement both cyclic monitoring of possible degradation, as well as announced and unannounced audits that evaluate the effectiveness of tour guides in protecting cave resources.

Federal regulations which can be specifically applied to the subsurface at Oregon Caves National Monument are listed in the "Code of Federal Regulations, Part 36, Parks, Forests, and Public Property" include:

Section 2.1 (1): preservation of natural, cultural and archeological resources
Section 2.1(3): throwing rocks inside caves
Section 2.10(1): camping outside designated sites or areas
Section 2.21(b): smoking prohibited in caves

D. **Cave Locations**

The FCRPA states that "information concerning the specific location of any significant cave may not be made available to the public under section 552 of title 5, US Code, unless the Secretary determines that disclosure of such information would further the purposes of this Act and would not create a substantial risk of harm, theft, or destruction of such cave."

Since confidentiality of cave locations and survey data is critical to the protection of cave resources, cave maps showing ungated entrances will not be available for public review. Cave locations will not be advertised except for interpretive signs along Cave Exit trail and Cliff Nature Trail in front of obvious cave entrances next to the historic trails.

All cave entrances will be photographed with digital cameras. The color prints from the digital images will be compiled into a notebook and indexed to appropriate maps or sketches of cave interiors to aid in identification of specific caves. An additional copy of the photograph will be placed in each cave file. Cave name and UTM coordinates will be recorded on each entrance photograph.

A Global Positioning System (GPS) device will be used to locate each cave as exactly as possible. GPS units attached to long poles may have to be used to record entrances under heavy tree cover. UTM coordinates will then be recorded on the Master Cave inventory and in each individual cave file. All cave locations will be plotted on a current USGS topographic map as well as in the GIS program.

E. **Gates**

Gates are an obtrusion on the aesthetic and historical integrity of the cave entrance, and are often deleterious to the ecology of a natural cave, hindering or entirely impeding airflow and the movement of bats and other organisms into and out of the cave. The use of gates to prohibit unauthorized entry is often unsuccessful against determined cavers. This technique will be used to protect park caves only where natural or cultural resources are threatened and an almost biologically neutral gate can be constructed. Interior gates may be used to restrict access to areas of significant hazards (e.g. Hazard 3) or which merit special resource protection (e.g. Fragility 3).

The location and composition of gates may be changed if an analysis shows that such changes will reduce human-impacts on Monument caves.

F. **Cave Alteration**

During cave exploration an area may require enlarging to permit entry into virgin passageways or chambers. Permission to enlarge a constriction, or to dig through breakdown or cave fill, shall be obtained in writing from the park Superintendent. Environmental alterations and potential damage to cave resources will be given the highest priority considerations before permission to alter a cave is given.

If sediment removal is involved, an archeological clearance must first be given by an archeologist on the Pacific West Region's staff or by the next most pertinent person on the Regional staff, accompanied by a on-site survey if deemed necessary by the Regional specialist. Exceptions may be allowed when small amounts of such sediment are carefully searched for archeological, fossil, or subfossil material under an approved collecting permit.

Explosive charges or mechanical devices, such as "rock splitters" or "jackhammers," will not be permitted for use in Monument caves. The only exceptions will be construction on the main public tour route that results in reduced human-caused impact, the reduction of which outweighs construction damage to the cave and which are pre-approved by the Monument’s superintendent.
For example, marble steps may be lightly scoured by an electric jackhammer in order to increase traction and reduce safety hazards.

G. **Maintenance**

The FCRPA states that:

"Developments such as artificial entrances, enlarged natural entrances, pathways, lighting, interpretive devices, ventilation systems, and elevator shafts, will be permitted only where necessary for general public use and when such development will not significantly alter any conditions perpetuating the natural subsurface environment or harm cultural resources. No potentially harmful development will be undertaken in, above, or adjacent to caves until it can be demonstrated that it will not significantly affect natural cave conditions, including subsurface water movements, or visitor use opportunities. Developments already in place above caves will be removed if they are significantly altering natural conditions."

The Maintenance Division is responsible for the upkeep of all underground facilities. This includes the necessary cleaning, repair and renovation of Cave trails, electrical systems, communication systems and lights.

Any maintenance project in the subsurface will employ methods that will result in the least amount of impact to subsurface resources. Routine maintenance, such as changing lights, repair of electrical wiring, and trash collection, often require stepping off developed trails. In these instances every effort will be made to obliterate footprints on Cave floors, especially those visible from the paved trail. The bottom of footwear will be cleaned before stepping back onto the trail or rubber booties will be used, as during the completion of a caving trip. Visible footprints on or off the trail could encourage visitors to leave the trail and damage delicate Cave areas. The current lighting system has been installed with the view of minimizing damage to cave resource. Routes for replacing each light will be used so as to avoid delicate formations, unsafe areas, and disturbance of historical or potential/actual archeological or paleontologic resources.

During maintenance projects in the Cave, tools and materials left in work areas for extended periods and not in actual use will be concealed from public view. Organic materials associated with cave restoration or maintenance project will be removed from the Cave after each use.

Cave trails may be washed to remove silt and foreign material buildups that create a slick and hazardous trail surface. The liquid will be collected and/or filtered and removed from the Cave. Human-made foreign objects are to be concealed using natural features to the extent feasible, as long as the Cave is not significantly altered by such action. Flexible plastic or detachable cement/wire mesh layers will be used to hide wires if they cannot be otherwise hidden from view.

The use of any type of combustion, including smoking or internal combustion engines, will not be permitted in a subsurface environment. Such use would harm the biota of caves and be a health hazard.

De-icers will not be used in the cave. The use of de-icers over the cave will be limited in location (the exit trail from the 110 Exit) and duration (November to December, March to April). The de-icer presently used is a calcium-magnesium acetate which likely has less impact on the cave than more common de-icers such as salt and potassium chloride.

H. **Subsurface Restoration**

Like the term resource management, restoration is anthropocentric (human oriented or biased) because it implies that we know what is the prehistoric state of natural processes. However, when there is substantial evidence of significant human-caused impacts on natural processes, then well thought out attempts at mitigating these impacts usually are better than doing nothing at all.

Cave restoration in North America has an advantage over surface processes in that prehistoric human impacts on cave processes, as opposed to impacts on rock shelters, have been minimal, especially if a cave area is far from an entrance. Cave processes for the most part have evolved without human impacts. Consequently, there often is no need to sort out which human actions are "natural" and which ones are not. Nearly all human impacts are foreign and will be mitigated or avoided if possible.

Exceptions inside Oregon Caves include historic items and possible archeological items with possibly substantial cultural integrity, such as the stone steps and Ghost Room platform. Removal of such items would also significantly impact cave resources either directly or through the loss of historic context.

Other human-caused impacts include movement of subsurface material, changes in water and species movement, and the introduction of non-native species. To help maintain a natural environment, foreign materials will be routinely removed. Where possible native material displaced by past human activities will be moved back to their original locations.

Resource management staff will supervise subsurface restoration work in developed and undeveloped caves. Restoration projects requiring specialized knowledge or skills not found among NPS staff will be performed by experienced persons on a contract basis.

No chemicals, aside from water and diluted solutions of sodium hypochlorite and/or hydrogen peroxide (Faimon 2003) will be used in restoration work. Other substances may be approved for use if it can be shown that the chemicals will not spread in the subsurface, are safe when used as directed, will restore damaged formations, will leave no or virtually no residue, and do not significantly adversely affect subsurface life or geology. Direct and indirect effects of all restoration techniques shall be carefully monitored to help insure protection of the subsurface environment. A subsurface restoration log will be maintained to document both the details of restoration activities and the results of restoration impact monitoring. Individuals or groups involved in subsurface restoration work will be responsible for the removal of all evidence of their activities (e.g. footprints, muddy handrails, tools, etc.) from work areas.

1. **Rubble Removal**

Human-introduced materials that are not part of a present trail system and are without cultural, historical or archeological significance will be removed from all caves. Obvious exceptions would include retaining walls that protect the trail from rockslides and material whose removal would damage natural cave surfaces. The park curator will evaluate any object of possible historical or archeological interest before removal.

Removal will include introduced materials that were attached to cave formations or naturally cemented by flowstone, unless removal results in pitting of original flowstone or breakage of speleothems. The order of removal will begin at a point furthest from the trail to material closest to the trail in each particular area. Naturally occurring materials that had been displaced by human activities will be moved back to their original sites if possible. Where this is not possible, as in cave fill removed from a trail route to allow the public to walk through, then it will be removed from the Cave. This includes rock that has been blasted and shows more than 40% fresh surfaces. Breakdown with mostly natural surfaces can be moved to approximate the original contour of the Cave. For example, the amount of breakdown in many caves is roughly proportional to the size of the passage in which it occurs.

The final manicuring of each area will be a separate process from the fill removal process, and will not be done until it can be determined that there will be no or very limited future traffic near or over that particular area.

Washing will be done by using subsurface water whenever possible. The resulting water, if possible, will be contained, and removed from the Cave. If the waste water used for cleaning cannot be removed from the Cave, then it will be filtered before allowing it to re-enter the cave water system. Stiff nylon brushes will be used for a final manicuring. Variable pressure cleaning systems using small amounts of water, such as the "Hotsy" cleaning machine, will clean accumulated debris from most formations and walls without any abrasive contact. Wet-dry vacuum cleaners can be used in association with the cleaning machine to catch the water and debris. A significant concern with vacuum pickup machines is that the exhaust may just redeposit small material in the Cave. If the material picked up is wet, the risk is substantially reduced. If dry material is vacuumed up, machines with very effective filters will be considered. Such machines are available and are most often used in such hazardous material fields as asbestos removal or hazardous chemicals. These same vacuum cleaners can also be utilized for routine trail maintenance and are available in large wheel mounted and smaller backpack versions. All restored areas larger than ten square feet will be documented by still and video photography when possible. "Before"-still photographs will be double bracketed (three shots at different f-stops). "After" photographs will not need this bracketing. When using a video camera, documentation will include both close-ups (frame less than one foot square) and overall scenes of a particular area. No "after"-restoration documentation will take place until the "before-"documentation photos and filming have been processed or developed. They can then be used in composing the after-restoration shots and the video filming.

All criteria will be considered together in determining whether there has been human disturbance to cave fill. Usually no single criterion is sufficient. Criteria for determining whether fill has been placed by people into previously empty space include:

a) Covering of flowstone, dripstone, and/or cave popcorn (coralloids);

b) Numerous small voids between wall rock and fill;

c) Large numbers of buried, broken formations in uncemented fill;

d) Radical vertical changes in fill material;

e) Easily removed clay and silt contacting wall rock;

f) Pebbles have disintegrated in place (some shales and fractured cherts can fall apart within 50 years in a humid cave);

g) Lack of distinct horizontal layering;

h) Fresh exposures in pieces of rock on all or nearly all sides (e.g. blasted rock), and edges are sharp;

i) Lack of bedding in the sediments and no sorting of materials or highly disturbed bedding;

j) Numerous point impact marks on rock, such as pickaxe marks on fine-grained fill. Such marks will usually be light in color;

k) Lack of cementation of fill material except in areas of high air flow;

l) Loose fill that can be removed by hand, and clay films, layers and/or stains that are easily removed by hand or by washing.

Criteria for determining whether fill has been previously removed include:

a) Vertical or near-vertical cuts in flowstone. Edges of flowstone are sharp and fresh looking. Flowstone fragments are common;

b) Vertical or near-vertical cuts in loose fill;

c) Lack of natural means for transport of material;

d) Lack of flowstone and/or other cave formations.

2. Non-native Species Control

Plant growth made possible by artificial light systems can dissolve cave formations, discolor cave walls, and add organics to communities adapted to food-poor conditions. Detergent-rich lint from clothing helps fertilize these plants. Both blue-green algae (cyanobacteria) and a mixture of fungi, dust, and lint can also blacken Cave walls. Surface soil changes from forest fires, tree or shrub cuttings, altered plant growth and patterns, and acid rain may alter organic acids or minerals that color cave formations. However, only color changes caused by alien plants, fungi, or microbes can be readily treated. Alien plants on the surface have the potential to alter subsurface conditions. For example, one study indicated that alien plants are less likely to form water-holding soil aggregates than native plant communities.

Except for possible changes in lighting, the most effective/ less impacting treatment in the subsurface appears to be hydrogen peroxide (Faimon et al. 2003) or a combination of sodium hypochlorite and hydrogen peroxide. However, light filters, diodes of certain wavelengths and arranging lights differently can reduce algal growth. From 1987 to 2003 household bleach (5.25% sodium hypochlorite) was used for algae and bacterial removal at Oregon Caves as well as at most other Park Service and Forest Service show caves. Unlike chlorine residues from bleach, hydrogen peroxide leaves no physical residue. Several years of testing with different spraying regimes was needed to find the least amount of bleach needed to control non-natives. The same will be true of hydrogen peroxide. The slightly greater calcite corrosion ability of hydrogen peroxide will be mitigated by adding marble fragments into the solution at least 10 hours prior to its application (Faimon et al. 2003).

The growth rate of non-native species is largely dependent on temperature, nutrients, moisture, airflow, and the effectiveness of the previous spraying. Spraying regimes in the Cave range from once a year to once every few weeks; spraying may be conducted more often in the summer when algal growth rates tend to be higher. An more comprehensive spraying of non-native plants (mostly algae and diatoms) and bacteria will be done every few years to reduce spore dispersal. This is especially important in parts of the Cave with low airflow. Bright flashlight or portable floodlight examination of all dark cave surfaces is needed to locate at least 90% of the surfaces colored by non-natives.

Non-natives is defined in this document as those species and population sizes that would not be present in a particular area without the impact of past or present human activities. All of the species whose individuals are killed by spraying were likely present in the cave or the surface but the numbers of the individuals in the cave have been greatly increased by the artificial lighting or by organics introduced into the cave by humans.

All spraying, pulling, and eradication work will be conducted by at least two persons. Cave personnel or volunteers spraying hydrogen peroxide or sodium hypochlorite solution will wear goggles, acid-resistant rubber gloves, hard hats, headlamps, and a dust respirator. The respirator and goggles may be removed temporarily to improve visibility when moving from one spray area to another. Filling the spray containers and cleaning of equipment will be done on the surface. All spray equipment, containers, protective clothing, etc., will be removed from the Cave at the end of each spraying session. Any spillage in the Cave or excessive run-off of hydrogen peroxide or bleach shall be cleaned up immediately. Any container of hydrogen peroxide or bleach taken into the Cave shall be in a non-breakable container. A portable eye/skin wash station shall be carried and ready for use at all times. All equipment shall be thoroughly flushed with clear water at the end of each shift. Special attention shall be given to the sprayer and the sprayer orifice. When working with hydrogen peroxide or bleach, exposure shall be minimized. Spraying shall be upwind and from bottom to top of a cave passage. The actual spraying time will not exceed two hours for any one worker or volunteer. If fumes pose a problem to other personnel or cave visitors, work will be delayed until after visitor hours to allow for overnight ventilation. Where airflow is variable or there is little air moving through the Cave, the project will be postponed until the air flow increases. The maximum amount of hydrogen peroxide solution used during any one period will be one gallon or less to keep the Ph balance in the Cave within normal range. The minimum time between spray periods shall be 24 hours.

Only safe, efficient methods of application will be used. Mist spraying will be adequate unless the sprayer can get no closer than four feet. Areas will be sponged where possible. Successive application trips on a tour route will be in opposite directions in order to see and treat surfaces from different perspectives. Techniques described above for removing general debris will be used as a guide for cleanup.

Anyone experiencing ill effects from the fumes or personal contact with hydrogen peroxide or bleach will notify their supervisor immediately and complete a CA-1 form.

Incandescent lights over 50 watts should not be used in the Cave because they can produce noticeable temperature changes, alter or damage nearby minerals, and cause drying circles on flowstone. Compact fluorescents or light emitting diodes (LEDs) are preferred because most give off very little heat and use less than 80 watts of energy. Compact fluorescents last approximately 2 1/2 to three years for eight-hour-a-day use while E-bulbs and diodes may last up to 14 years. Changing to longer-lasting bulbs reduces costs and reduces foot-traffic impact.

Hours of illumination will be determined by the frequency and timing of tours during the off-season and by total illumination during the summer. Although early summer is when algae grow fastest in the Cave, turning lights off between tours is not practical because of the close spacing of the tours. The exception is where additional lights exceeding a total of ten candle power averaged on cave surfaces are used in rooms to highlight certain areas for interpretive purposes. These will be turned on for no more than ten minutes at a time.

3. **Electrical Features**

Flexible plastic layers, similar to those used in stage sets, can hide wire where shadows or in-place natural features cannot be used. Concrete "snakes" are unsightly, but may be better than naked cables as long as the cave is not impacted from such materials as calcium hydroxide. The concrete will be poured on thick plastic and then the plastic removed so as to facilitate removal of the "snake" at some later date without damaging the underlying cave surface. An effort has been made to route cables in shadows so as to avoid covering them.

4. **Cave Pools**

The major impacts to cave pools likely are human detritus from cave visitors. The total amount of dissolved ions has been measured in several of the Caves’ pools adjacent to the paved trail and it is higher on average than pools further away from the trail. However, oxygen demand can measure roughly the number of active bacteria and there seems to be no difference between the oxygen demand of sites near and far from the trail.

5. **Particulates**

Airborne lint, hair, and skin cells are generated, primarily from the constant rubbing and abrasive movement of clothing worn by visitors. This constant rubbing and abrasive movement generates small cumulative quantities of lint along the trail system. The walking action generates a slight current along the trail and these currents then carry the lint and associated debris up and away from the trail. These currents send the lint onto cave formations and surrounding walls especially on rough surfaced, constricted passages or at the downwind end of a constricted passage. Light to moderate amounts of lint are not easily detected with the naked eye, but under a long-wave ultraviolet light, the deposits show up quite readily. Lint serves as the basis for alien communities that can include spiders, mites, ants, and other non-native invertebrates. When wet, it can increase the numbers of naturally occurring and non-native bacteria and fungus. Except in very dry conditions, at least 80% of all lint from visitors clothing falls within four feet of the center of the trail. Installing curbs along the trail can inhibit movement of lint and confine a major portion of it on the trail where, with a regular maintenance program, a good percentage of any lint accumulations can be collected. A rough trail surface before the cave entrance and grates within the cave help clean the bottom of shoes just before entering a cave and thus help prevent the spread of foreign matter into the cave. Two plastic tarps have been installed under two portions of the trail in order to catch and isolate particulates from the cave. More tarps will be installed as needed.

6. **Air Flow**

Local additions or removal of material may change airflow patterns within that area, especially if the passages are small. Increasing the size of entrances increases upward airflow in winter and downward airflow in summer. This can increase air pollutants, which will darken upward-facing cave surface further from entrances. Enlarged cave entrances increase safety hazards due to increased frost wedging. Greater airflow can cause erosion of formations by freezing, dehydration, or dissolving of formations due to an increased carbon dioxide level. Cave species adapted to high humidity may be forced to retreat to small crevices in the cave or die off.

To restore naturally occurring airflow, airlock systems have been installed in tunnels. The doors and frames are constructed using materials with low oxidation rates, ie., with low rust formation. PVC plastic with stainless steel fittings and pressure-operated shut mechanisms work well. PVC plastic is a good insulator and therefore retards heat transfer between a cave and the surface or between different parts of a cave that normally would be separated by thick layers of insulating rock. Provided that they produce few volatile compounds, plastics other than PVC may be needed for entrances subjected to very low temperatures. Cement used to surround the door will be of a type that contains little calcium hydroxide, which is more soluble than calcite and can increase speleothem growth. Clear lexan can be used as air restrictors on the sides of artificially deepened trails to restore the original cross-section of the passage. Placement will occur so as to avoid acidic condensation.

7. **Speleothem and Wallrock Repair**

Graffiti vandalism is sometimes difficult to distinguish from historical graffiti (more than 50 years old). As with coin tossing, graffiti not promptly removed or obscured will induce further graffiti. Graffiti can usually be removed by stiff nylon brushes and vinegar, but a 5% solution of sulfuric acid may be needed if the graffiti proves too stubborn for nylon brushes and vinegar or where mud splattered during blasting has hardened on cave walls. The acid can be used with a CO2 powered pressure washer such as those used to remove paint. All or most run-off will be trapped and collected if using these cleaning techniques. Safety protocols outlined in a specific job hazard analysis will be followed when using acid solutions.

Care will be taken to make sure that features other than non-native species, non-historic graffiti, or lint are not removed. Some black cyanobacteria does occur near lights but such bacteria away from lights may be native to the Cave and will not be sprayed. Lint and algae globs can resemble poorly formed vermiculations, also called clay worms. These vermiculations usually are rounded, unconnected, dark clumps with a high water content and greasy feel. The naturally formed clay worms usually have more complex forms, are mostly clay, and have a nearby source of clay. The globs also can resemble "cave slime," which are rounded, light-colored films of actinomycetes bacteria. Native to caves, these bacteria resemble very thin lichens and feed on incoming organics. They grow very slowly and as a result usually are not found on cave walls undergoing lint or travertine deposition or atmospheric corrosion. The lint may foster bacterial growth that competes with cave slime.

An ongoing inventory includes a count of broken formations, regrowth measurements, and a photo and video documentation of a cave's formations and artifacts. The inventory has mostly been completed within a few feet of the trail but some of the writings of off-trail areas have not been recorded. The completed inventory will insure that only graffiti vandalism is promptly removed, not historical graffiti. All graffiti dated to less than fifty years ago will also be removed. A broken formation count will be conducted every three years after the initial one is completed. Only after two to three surveys will a fairly accurate baseline be established.

Surveys will be done with headlamps since having the Cave's lights on will most likely result in only partial coverage. A minimum size of broken formations will be chosen, below which the breakage is not counted. Grouping of small, broken formations, such as popcorn, will be done. The diameter of the groups to be counted will vary from cave to cave but usually averages a few inches. Photography and video taping will be used on delicate formations for which marking is not appropriate.

Broken formations can be repaired during the driest time of the year by a combination of fast-drying glue in the center of a broken area and slow-drying glues surrounding that area. Structural epoxies used in historic preservation can be adapted for speleothem repair by using crushed calcite as a base. The size of the calcite particles will be reduced until the mixture approximates the texture of the formation. Epoxies used in structural bonding also work. For stalactites and draperies, especially those with very small attachment areas, holes can be drilled for the attachment of expansion bolts, steel pins or screws. Because calcite cleaves easily, very small holes will be drilled and progressively enlarged with larger drill bits.

Drill holes, steps cut into flowstone, and other manmade modifications can be repaired by using terrazzo or a 5/1 ratio of cave mud to cement. Terrazzo is mostly crushed, bleached calcite and, therefore, closely resembles limestone cave formations. Altering its color to match adjacent cave features is easier to do than altering the color of most types of cements.

8. **Water Flow**

Some trails that have been artificially deepened require retaining walls to prevent loose cave fill from falling onto the trail. If a naturally occurring water flow is inhibited because of the retaining wall then puncturing this wall may help restore water flow and still hold back sediments.

Water flow from surface structures (if any) and water flow from trails shall be dispersed so as to prevent concentrated discharge that can erode natural sediments and cause sinkholes, etc.

Subsurface waterflow in noncave areas is affected by concentration and deprivation of flow due to human structures such as buildings and parking lots.

9. **Oxidation**

Oxidation of skin oils and flakes can blacken formations after they have been touched only a few hundred times. Given protection, some blackened formations will return to their original colors in about fifty years. Abrasion and polishing occurs especially if rock fragments harder than limestone are present, such as minute grains of chert inadvertently rubbed on formations by visitor's hands. As in most cases, prevention through education, use of handrails and physical barriers deals with the problem best.

10. **Organics**

Organics (non-native plants, lint, skin flakes and oils, asphalt, temporary wooden walkways, slash burning on the surface, etc.) can cause subsurface animals adapted to a low-energy food environment to be out-competed by surface-adapted animals. Human-caused toxins are most likely to damage subsurface communities through bioaccumulation (because subsurface species tend to be long lived) and, to a lesser extent, through biomagnification (because some subsurface species are near the top of the food chain).

Because of their higher metabolisms, subterranean adapted species may be the most vulnerable to toxins. Removal of organic debris, such as wooden boards, older than 50 years, but not of historic value, will be gradual, as abrupt removal may disrupt subsurface communities. However, some biologists argue that such debris shall be left in place.

As spent calcium carbide less than a year old is toxic to cave life and there often is incomplete combustion of acetylene gas produced by carbide lamps, only lighting devices using batteries or relatively smokeless candles within protective lamps that prevent wax spillage will be allowed in the Cave.

I. **Health and Safety**

Caves are natural features, which inherently pose potential dangers to those who choose to visit them. Following are recommended guidelines to be used when traveling through undeveloped caves. Due to the wide variety of terrain found within caves, knowledge of accepted practices and techniques is necessary for assessing the requirements of individual situations. In most cases, unsafe situations can be avoided by enforcing good off-trail policies and insisting on qualified trip leaders. Trip-leader criteria shall be established and training provided.

Group Size: Off-trail caving trips should normally range from three to six people. A large group is difficult to manage and can result in resource damage or personal injury, especially through miscommunication. A group size of one or two greatly reduces the ability for cavers to deal with emergency circumstance. Any search and rescue (SAR) activity will result in unnecessary and frequently heavy impact on the cave and usually can be avoided by ensuring prudent caving practices. Cave-related search and rescue activities and tactics are outlined in the park's search and rescue plan, as an appendix to the emergency operations plan. It addresses protection of cave resources to the extent possible. The plan should also address the park's interaction with outside cave rescue groups.

Radon*:* Levels of alpha radiation within some caves are sufficiently high to warrant setting limits of exposure based on the highest monthly readings recorded within the cave (29 CFR 1910.1096 Airborne Radiation Hazards). . The radiation is caused primarily by the radioactive decay of radon 222. Some additional radiation is generated by the radioactive decay of radon 220 (thoron). Working levels of alpha radiation are measured from the radon and thorium decay products (particulates), and exposure records are maintained for all employees routinely exposed to the cave atmosphere. Backcountry caves are monitored when feasible. In managing alpha radiation hazards, the park must follow the procedures specified in DO/RM 50B Occupational Safety and Health Program. Due to brief exposure times, alpha radiation is not considered a threat to park visitors. The only known health effect associated with exposure to radon and radon decay products is an increased risk of developing lung cancer. Due to the potential hazard of exposure to radon and radon progeny to NPS employees, special use visitors, and contractors of the NPS, radon exposure records and monitoring shall be done in accordance with guidance described DO/RM 50B. As required by 36 CFR 2.21(B), smoking by employees and visitors in caves is prohibited, because of the synergistic health effect of smoking and exposure to radon decay products and to preserve cave resources.

Bad air*:* The most common problem associated with air in caves is the buildup of CO_2 in low-lying areas of rotting vegetation. Cavers shall be able to recognize the effects of elevated CO_2 concentrations and must immediately leave the affected area. There are presently no known caves in the Monument with such high carbon dioxide.

Rockfall*:* Rockfall is usually the result of caver activity. To avoid injury, cavers should move carefully, and should always wear an approved helmet and stay out from under others who may be climbing a rock or a rope. Natural rockfall occurs most frequently near entrances where weather rates are higher.

Infectious disease*:* Most infectious diseases associated with caves involve the animals that live in caves. Avoiding contact with animals and their feces will offer the best level of protection. Because bats in the Cave are either hibernating or are using the cave as a temporary night roost between feeding bouts, there is not enough guano in the cave to pose a health hazard. Bats may be removed from the main trail using gloves and long sleeve shirts to avoid bites. Anyone who is bitten or scratched by a bat needs to get rabies shots, even if they've already had the pre-exposure shots.

Getting lost*:* Some cave passages consist of a multitude of junctions and possible travel routes. In such situations, it is best to always have a member of the caving party who is familiar with the cave and to devise memory methods for retracing your steps. Foodstuff, strings, etc., can attract animals and may not remain in place. If lost, it is best to remain in one place. If this is not possible, carry a watch and paper and leave notes with the time as you travel; this will be of great assistance in helping searchers know where you have been and when you were last there.

Getting stuck*:* In most cases, an individual can get out of any passage that they can get into. (One exception may be a narrow slot in the bottom of a keyhole passage). Problems occur when gravity or apprehension become a factor in the situation. Calming the person down and/or removing some of their clothing can alleviate most situations. When in doubt, do not try to squeeze through a tight hole.

Darkness*:* Caves are dark. Even lighting of various sections of the paved trail is uncertain as power outages can occur or an individual can turn off lights in a section of the Cave and not be visible to or aware of other individuals in the Cave. Therefore all park staff entering the cave must have at least one light source that can be quickly deployed. All staff that is leading other individuals without their own lights, as in a public tour, shall carry at least 11 lights. All persons that enter caves in the Monument other than the main cave or who leave the paved trail in the main cave shall carry enough light to last longer than twice the trip's expected duration. A minimum of three independent light sources shall be carried by anyone traveling off the public tour route.

Hypothermia*:* Proper clothing shall be worn when entering a cave. Hypothermia can become a problem when water is encountered or when the group moves too slowly. It is wise to carry spare clothing. This is especially true for the caves on the Monument for they are generally in the low forties F. and are usually wet. Care should be taken to ensure that exertion expended while traveling through the cave is not so great as to cause extensive sweating. This is because such sweat can accelerate the onset of hypothermia once the exertion is over.

Dehydration*:* Dehydration can lead to many other complications, including hypothermia. Sometimes trips can run longer than expected. Carry enough food and water to last longer than the trip's expected duration. This is generally not an expected hazard in Oregon Caves due to the high humidity and short caving trips.

V. NPS STAFF RESPONSIBILITIES

The following may be modified when Director’s Order #3 (Delegation of Authority) is completed and approved.

Individual Position Responsibilities

Superintendent

- Is directly responsible to the Regional Director for all subsurface management activities within the park.
- Approves or disapproves management zone ratings, group size and trip frequency (where applicable) for each cave or cave passage.
- Approves or disapproves permit applications to enter Zone 4 areas.
- Approves or disapproves enlargement of a cave passage or modification of the subsurface previously undisturbed.
- Recommends revisions of the monument's subsurface management plan to the Regional Director.
- Supervises the natural resources specialist.
- Provides for law enforcement officers to enforce subsurface regulations.
  Policies regarding law enforcement follow Director’s Order #7 (Law Enforcement Program).
- Provides personnel for cave rescue operations.
- Assists the park in acquiring funds for subsurface management projects.
- Monitors overall condition of subsurface resources.
- Approves press releases and interviews relating to the resources management of Monument caves and other underground areas.

Natural Resources Specialist

- <u>Advises</u> and consults the Superintendent on subsurface-related resource management problems or actions, including mitigation, research, restoration, maintenance, interpretation, and protection.

- <u>Reviews</u> cave use permit applications and recommends approval or disapproval.

- <u>Serves</u> as National Park Service liaison with subsurface researchers and volunteers.

- <u>Conducts</u> special trips and attends to the needs of special populations (researchers, VIP's, school and disabled groups, etc.).

- <u>Conducts</u> training programs for personnel on safe caving practices, and cave and mountain rescue techniques.

- <u>Attends</u> professional meetings on subsurface management, science, and research.

- <u>Recommends</u> trip leaders.

- <u>Supervises</u> resource management seasonals and VIPs working on subsurface related projects.

- <u>Manages</u> the subsurface management budget.

- <u>Prepares</u>, reviews annually, updates, and revises the Subsurface Management Plan in collaboration with the monument's Superintendent and other members of an interdisciplinary team.

- <u>Identifies</u> necessary cave research.

- <u>Prepares</u> pertinent news releases on subsurface management activities within the park.

- <u>Develops</u> subsurface management goals in conjunction with the monument's superintendent and implements subsurface management programs and projects to accomplish these goals.

Park Ranger/Safety Officer

- <u>Provides</u> personnel to patrol trails in and above the caves and encourage compliance with park rules and regulations.

- <u>Responsible</u> for enhancing visitor knowledge and respect for subsurface resources through interpretive media.

- <u>Conducts</u> special trips and attends to the needs of special populations (researchers, VIP's, school and disabled groups, etc.).

- <u>Provides</u> personnel for guided cave trips.

- <u>Renders</u> EMS services.

- Maintains the cave rescue cache so that equipment is always ready to be used.

- Coordinates scheduling of rope training and cave rescue training with other divisions, members of the National Cave Rescue Commission and the concession.

Physical Science Technician

- Assists the natural resources specialist in subsurface research, exploration, mapping, restoration, interpretive, and volunteer projects. Recommends modification of existing studies as data is received and analyzed.

- Assists the natural resources specialist in training and supervising personnel in caving, subsurface restoration, cave rescue, interpretive, and inventorying skills and techniques.

- Conducts day-to-day subsurface management activities in those areas in which the physical science technician has subject matter expertise. This may include managing the GIS, subsurface restoration, and museum programs.

- Prepares and maintains subsurface maps and information pertinent to subsurface inventories.

- Inventories all known caves and keeps cave inventory files up-to-date with all pertinent information.

- Monitors resource impacts in all park subsurfaces by use of photopoints, video monitoring and other techniques.

- Monitors restoration projects staffed by park personnel to insure resources are being protected.

- Provides technical expertise on radon, providing information to employees and management.
- Attends professional meetings on subsurface management, science, and research.

- Recommends trip leaders.

- Supervises resource management seasonals and VIPs working on subsurface related projects.

Resource Management Seasonal(s)

- Assists the natural resources specialist in subsurface research, exploration, mapping, restoration, interpretive, and volunteer projects. Recommends modification of existing studies as data is received and analyzed.

- Assists the natural resources specialist in training and supervising personnel in caving, subsurface restoration, cave rescue, interpretive, and inventorying skills and techniques.

Facility Manager

- Responsible for the maintenance of subsurface facilities.

- Notifies the natural resources specialist of any maintenance problem or job that may substantially impact subsurface resources.

Volunteers

- Assists other park staff in subsurface research, exploration, mapping, restoration, and interpretive projects. Guidelines follow Director's Order #7 (Volunteers in Parks).

Training

Search and Rescue: A small team of park staff will be trained to conduct cave search and rescue operations (see park's Safety Plan). Cave search and rescue training that includes an in-cave mock rescue will be conducted at least once a year using the best human and technical resources readily available, such as using members of the National Cave Rescue Committee as trainers. The session will cover equipment use, organization, hypothermia, stabilization, transport and dealing with bystanders and the media.

Trip leaders for cave trips will receive training in proper caving techniques and safety. Their knowledge of subsurface geology, formation development and subsurface conservation practices will be supplemented with training sessions.

K. **Interagency Collaboration**

When appropriate to do so, the National Park Service will collaborate with U.S. Forest Service (Siskiyou National Forest), the US Fish and Wildlife Service, and the Bureau of Land Management on subsurface management activities.

VI. MANAGEMENT OBJECTIVES

A. **Protect** and maintain natural subsurface systems and historical features that they contain.

B. **Provide** education and recreational opportunities for a broad spectrum of visitors to discover, study, respect, appreciate, and enjoy the park's underground at their individual levels of interest.

C. **Provide** opportunities for scientific study that will better protect subsurfaces and subsurface processes and increase interpretive effectiveness, credibility, and opportunities.

D. **Classify** caves in management categories based on their resource and hazard characteristics and in accordance with the FCRPA.

E. **Establish** regulations, guidelines and a permit system that balances maximum safety for cave visitors to park caves and preservation of park natural and cultural resources while recognizing that no subsurface can ever be completely safe, and that hazards are part of the caving experience.

CHAPTER VII - INVENTORY AND MONITORING

Introduction:

The focus of inventory and monitoring will follow cluster-wide priorities. The Klamath Cluster consists of the Monument, Whiskeytown National Recreation Area, Redwood National and State Parks, Crater Lake and Lassen Volcanic National Parks, and Lava Beds National Monument. Cluster and individual unit priorities rely on the use of vital signs to best measure the effect of human-caused stressors to park ecosystems. The identification of the most important vital signs and how to measure change in them is still an evolving process, but the following outline depicts some of the topics considered so far.

i. Monitor water quality and quantity
    1. pH
    2. Major ions
    3. Temperature.
    4. Precipitation
    5. Groundwater and cave infiltration rates

ii. Monitor air quality and quantity
    1. Movement
    2. Humidity
    3. Carbon dioxide
    4. Radon
    5. Temperature

iii. Geological Processes
    1. Depositional rates (both calcite and bones) and types
    2. Soil
    3. Dissolution
    4. Weathering

iv. Biotic Communities
    1. Which organisms shall be targeted?
        a. Should monitor things that can be easily measured or are more revealing of biotic integrity
            i. Best to monitor organisms whose populations do not have large fluctuations under natural conditions
            ii. Truffles and false-truffles
            iii. Specialists like troglobites and stygobites

        b. Rare habitats (including T and E species)
        c. Biodiversity hotspots
        (As in soil fauna, cave organics, and underground mushrooms)

        d. Bats

        e. Troglobites (if enough individuals and with non-lethal sampling) as they tend to have the most stable populations. Also population changes from migration from the surface doesn't occur and therefore doesn't have to be separated out from mortality and reproduction rates)

        f. Mycorrhizae (DNA and abundance data can detect changes in and from invasive and native species, fire, climate change, water infiltration and nutrient flow, ie. many of the main stressors in the Klamath Network)

v. Human Uses (may be considered stressors)
    1. Visitation
        a. inside caves
        b. outside of caves
    2. Recreation
    3. Land use practices at larger geographic scales
    4. Researchers may impact what they're trying to study
    5. Vandalism
    6. Historical and cultural uses of caves

vi. Other Considerations
    1. Nutrient flow can be considered along with other monitoring activities
    2. There is a general need for more baseline inventories to further guide monitoring needs
    3. Challenges to Monitoring
        a. Sampling techniques and design—need to make sure sampling techniques relate to monitoring question
        b. Funding

Policies, Regulations, and Laws: NPS policy states that "The National Park Service will assemble baseline inventory data describing the natural resources under its stewardship and will monitor those resources...to detect or predict changes. The resulting information will be analyzed to detect changes that may require intervention and to provide reference points for comparison with other, more altered environments." (NPS Management Policies, Chapter 4:4, 1988).

Thus, NPS policy directs that park managers know the nature and condition of the natural and cultural resources under its stewardship, have the means to detect and document changes in those resources, and understand the forces driving the changes, in order to fulfill the NPS mission of conserving parks unimpaired.

Various laws require certain knowledge of resource conditions to direct and evaluate management and other actions. These include, but are not limited to:

Antiquities Act of 1906 (P.L. 59-209)
Archaeological Resources Protection Act of 1979 (P>L. 96-95)
Clean Air Act
Clean Water Act (33USC 1251 et seq.)
Eastern Wilderness Act of 1975 (P.L. 59-209)
Endangered American Wilderness Act of 1978 (P.L. 95-237)
Endangered Species Act of 1973 (P.L. 93-205, amended 1982)
Federal Caves Resources Protection Act (P.L. 100-691)
Lechuguilla Cave Protection Act of 1993 (P.L. 103-169)
Historic Sties Act of 1935 (P.L. 86-523)
Native American Graves Protection and Repatriation Act of 1990 (P.L. 101-601)
National Environmental Policy Act of 1969 (1970) (P. L. 91-184)
National Historic Preservation Acts of 1966 and of 1976 (P.L. 89-669)
National Park Service Act of 1916 (P.L. 64-235)
National Parks and Recreation Act of 1978 (P.L. 95-625)
Wild and Scenic Rivers Acts of 1968 (P.L. 90-542)
Wilderness Act of 1964 (P.L. 8-577)

Data Collection: "Day to day" research activities are included on the list of Categorical Exclusions (Section 7.4, E, 2) under implementation procedures (516 DM 6, Appendix 7) of the National Environmental Policy Act (NEPA). As such, research is exempted from routine Environmental Assessments. It is up to the resource management staff to insure that significant resources are not adversely impacted by the proposed project. Answers to all questions on the NEPA Categorical Exclusion Determination Checklist shall be "No," or else an Environmental Assessment shall be done.

The value or outcome of the research, in terms of resource protection, should more than equal likely impacts to park resources. For example, research done mainly to complete a collection at a university or museum is not acceptable. Any research in parks shall be in accordance with park management objectives and approved resource management plans that document possible negative and positive impacts from research.

Any research proposal, whether from NPS staff or outside researchers, should include a clear statement of the questions being asked, a fairly comprehensive literature review, discussion of previous work, a detailed description of all methods to be employed and how sensitive resources will be protected, a schedule from beginning to end, an account of necessary collection and fate of samples (see 36 CFR 2.5 g), a list of expected products with dates, and an explanation of why this work needs to be conducted within an NPS unit. A proposal need not be long, but shall be well written and shall be accompanied by a resume for each participant.

Where to Start: A comprehensive literature review and compilation of existing data into usable and lasting forms is a prerequisite to designing a park-specific monitoring program. Depending on which method is most cost effective, the Monument will subscribe to Digital Dissertations, GeoRef, and/or Biosis for extended coverage of relevant citations and/or journey to universities where such services are available free of charge. The Monument currently contains a bibliographic database of references on American and Canadian cave sciences of approximately 2,400 pages and a library of about 2,000 articles or books. The biology section of the database can be subdivided into various categories, such as bats, for easier searching and retrieval. The geology section of the reference database needs to be tagged in a similar fashion.

Park staffs cannot inventory and monitor everything. This is especially true for underground areas as most have very incomplete databases and working inside them is very labor-intensive and hard on equipment. Therefore, the Monument's subsurface inventory and monitoring program is and will be further designed to address critical resource management issues and concerns, those that involve significant human-caused impacts both ongoing and with a high potential of occurring.

Low-energy subsurface ecosystems tend to have both low resistance to human-caused impacts and a slow return to original conditions after a disturbance. The same conditions that preserve a wide range of resources from surface erosion, etc. will also preserve human impacts for a long time. Regeneration after impact either doesn't occur or usually occurs very slowly. These general considerations should guide subsurface management, including research, prevention, mitigation, and restoration.

GIS: Standardized and accurate surveys and inventories are crucial for establishing baselines, directing future monitoring, and preventing or mitigating human-caused changes. All subsurface inventories, monitoring, sampling shall be tied by azimuth, inclination, and distance to the nearest semi-permanent survey station/marker. Most surveys shall be combined with on-site inventories.

Protection: Data collection sites shall be secured as well as possible from disturbance, especially from humans and small mammals. Placement of equipment, inventory markers, and the handling of fossils and historic or prehistoric artifacts shall be done with latex gloves to reduce salt, skin oils and other inadvertent biological attractants, deteriorants, or contaminants that could compromise location, curation, dye tracing, microbial cultures or dating. In some cases, filter masks may have to be used as well.

Consistency: Duplicate sampling shall be at least 5%. This includes sending different parts of the same sample to different labs, sending duplicate samples to the same lab, and inventorying the same area using different teams one after another. Inventory items for which there is too great a range of duplicated data shall be either thrown out or revised.

Data Storage: Data storage will follow Director's Order #5 (Paper and Electronic Communications) and #11 (Information Management). Data can be entered on site into a palm pilot, except where physical conditions or the unavailability of equipment warrant temporary storage on written survey and inventory forms and/or notebooks that are water resistant, such as "Rite in the Rain" paper. Hard and digital copies shall be produced within one week of data collection and kept in a building not adjacent to where primary data is curated. See Wilen and Rodiek (1980) for details on data collection and information management.

Purpose: It is hard to protect some things if you don't know they exist. Nearly all subsurface inventories turn up unknown or poorly understood features and processes. By discovering previously unrecognized human impacts, inventories identify gaps in monitoring, mitigation, restoration and prevention programs. High correlation between very common and less common cave features can help focus the search for rare cave features or ones that are commonly overlooked, such as speleogens (cave features caused by solution). Inventories and detailed maps are essential for determining stratified sampling points. For example, knowing where most of the dome pits are will allow a random sampling of water quality from an adequate size group of dome pits.

Priorities: Inventory priorities shall be based on a sum of 1) significance of known human impacts (coverage, bottlenecks, rarity, threatened and endangered status, etc.), 2) projected and/or postulated human impacts, and 3) lack of knowledge. Generally, #1 should have about double the priority weight of #2 and #3. Most subsurface mostly contain low energy systems while humans are a high-energy species. Consequently, monitoring high energy human impacts often should have priority, such as the effects of trail erosion, vandalism, tunnels, and increased organics, light and vibrations in the cave, and human-caused disturbances above the cave or within its watershed. An important first step for #3 is to document the status of each park's knowledge so that important gaps in that knowledge can be identified.

Size: A comprehensive inventory would never be used for a single cave or cave system but items could be chosen relevant to a particular subsurface and set of management concerns. Field-testing indicates that 100 items is the maximum number of items that can be done at any one time without significantly degrading data due to fatigue. The much larger number of items in recently compiled inventories allows each area to choose items pertinent to their needs yet allows some cross-subsurface comparisons between different areas for those inventory items held in common.

Selection: Even using a very restricted inventory helps to determine when more detailed and/or quantified inventories are needed. The subsurface significance of certain features can be determined by a simple threshold number of items present or by using more complex indices similar to those used in determining biological diversity or integrity or ecological value. The latter could be determined on the basis of how natural the cave or cave feature is, its rarity, and its diversity (Ammer and Utschick, 1982). A certain score on a very cursory inventory could then indicate that a more detailed inventory needed to be done. A cursory inventory would also help in determining what to list on a more comprehensive inventory. Garton (1984) discusses cost-efficient inventories.

An inventory list structure can be developed with 1) use of common terms with secondary definitions if terms overlap, 2) subdivisions so that no or very few categories have more than 10 or so items, and 3) duplication of terms in the list so as to increase flexibility and ease of locating items. Without commonly accepted definitions, symbology, and demarcations of what constitutes certain subsurface features, few comparisons between different inventories are possible.

Relationships: The main importance of the distribution of a feature is its relationship to other features. This is largely how processes are identified. The abundance or absence of troglobites, bats, cave slime, white flowstone, staining, humidity, biofilms, sharp edged exfoliation, soil compaction, erosion, or vandalism near trails or artificial entrances can suggest hypotheses that can be tested through experiment, mitigation, etc. Exfoliation occurs when rock breaks more or less parallel to its surface, usually the result of size changes in minerals undergoing chemical changes, such as ice or rust.

Inventories can help differentiate subsurface features through both direct measurements and by differences in habitat and season. For example, there are dimensional discontinuities between microgours and rimstone dams as well as differences spatially (areas of laminar sheet flow on flowstone versus turbulent stream flow).

The absence of features in certain areas can reveal important data. For example, the absence of easily destroyed or removable cave formations in areas where they normally would occur may indicate vandalism, as may be the case with helictites and cave pearls in the Cave. Negative correlations may give clues to speleogenesis, geo-mineralogy, etc.

Frequency: Inventory items shall be divided into those that only need to be inventoried once and those that need to be done more than once, especially air, water, and biological items. Even some speleothems, such as cave rafts and humidity-dependent minerals (mirabolite/thenardite, epsomite/hexadrite, etc.), can be present or absent depending on humidity, temperature, evaporation rates, etc. and therefore necessitate at least two inventories (winter/summer) or four, one for each season. An example at the Cave is gypsum crusts. A weekly inventory is conducted for easily visible populations of bats, harvestmen, moths, and crickets.

Scale: Establishing extensive monitoring within infrequently visited caves may cause greater impacts to resources than the limited visitation. The magnitude and detail of the inventory and monitoring process also depends on the size of the cave or cave systems, past data accumulation, predicted or observed human impacts, and the amount and training of people who do the inventories. The latter factor can range from comments on registers by cavers, to use of whatever volunteers are available, to weekend subsurface projects, to monitoring projects by volunteer groups, such as Cave Research Foundation (CRF), National Speleological Society (NSS), EARTHWATCH and Earth Corps, to contracts with research grade scientists. At what detail a particular inventory needs to be done will largely determine which people can do the inventory and how much training they need to do the inventory.

Quantification: An inventory where a feature is only noted as being present, as opposed to a quantifiable inventory, has many disadvantages. For example, human-caused changes cannot be detected by a present/absent inventory until a particular feature has been completely wiped out in a part of a cave monitored after the initial inventory. The disadvantages of quantifiable inventories are that they are time-consuming and can yield false conclusions. Most minimal inventories should note whether an inventory item is absent, rare, or common. This minimal quantification may be the limit to reliability for certain cave features. However, many features can be quantified where the limits and units are greater than 10%, 30%, 60% and 90%.

Dimensions: The shape of a cave feature should largely determine how it is quantified. Point features, such as bats can be counted. Linear features such as rimstone dams can be measured linearly. Flowstone has surface area and sediments have volume. In general, the more dimensions used, the less accurate will be the dimensional estimates. For example, even with test pits, construction rubble volume to be moved during cave restoration is often underestimated.

Bias: If there is a great disparity in the volume of the inventory units (such as around survey points) then biases affect statistical analysis of distribution patterns of various cave features. Square foot coverage of certain features, such as flowstone, can overemphasize the effects of large rooms. A percent coverage can overemphasize the effects of small rooms. A combination of the two methods may have to be used.

Descriptive Inventories: An alternative to a checklist inventory is to be more descriptive (House, 1995). Features are noted and then tied to survey stations rather than the reverse method as is used for checklists.

Pros and Cons: One advantage to this method is that it takes less time than using extensive or quantifiable checklists. Time is not wasted learning the descriptions of rare features and checking for rare cave features unlikely to occur in a particular part of the cave. Another advantage is that undescribed and unlisted features are less likely to be lumped with listed and described features. Quality control can be difficult with the checklist format since anyone can make a check mark whether it is appropriate or not.

Compared to a checklist inventory, a disadvantage of a more descriptive one may be that distributions and common features may not be recorded. Unusual or noteworthy features may be those features most likely to be noted. However, if you don't know what you are looking for, you may not find it. Correlations may not be possible and bias could increase. A great deal of information can be gathered by a descriptive system in a short period of time but that information may not be very useful until that information is classified and linked to a GIS program.

Descriptive inventories may be best for basic inventories or for noteworthy features while more detailed and specialized inventories might use quantitative checklists. The best inventories also balance between description and genesis of the items covered.

Location: Detailed maps that can be easily accessed, modified, or layered are the basis for all subsurface inventory and monitoring. A great deal of contextual information is lost without precise location of sampling sites. Materials such as bones and artifacts may have to be removed from a subsurface for analysis. Without detailed maps and directions, they cannot be returned to the precise subsurface conditions that have preserved them for so long. For example, placing fossil bone just inches from its original location can put it in the path of increased airflow, condensation, and subsequent deterioration.

AutoCAD or an equivalent program shall be used (see the mapping section). The least utilized person employed in mapping can also be doing inventory or monitoring during the mapping project.

Points around which inventories are made should have markers that will stay in place and last long enough until detailed map sketches can reduce the need for such markers. Some or all of the markers may have to be retained, especially if certain inventory units have no natural, fixed feature point that can serve as a marker to locate sampling sites or photo points.

All marked stations shall be inventoried up to halfway to all other stations, both vertically and horizontally. This involves finding such sequences in the cave before any inventory can be done. Obvious alcoves or side leads that can be entered will have their own separate station. Both sides of the tag shall be checked to eliminate ambiguity and read the station correctly.

A PDA will be used to record survey data. On the tour route, tags can be painted and may lack flagging to make them less conspicuous. Sequential station numbers shall be followed. An incorrect station number shall be crossed out with a single line and a correct one added beside the incorrect number.

Other data bases should include a list of inventory equipment and companies, a list of map symbols for many of the inventory items, and a list of addresses of those individuals conducting or knowledgeable of specialized or detailed subsurface inventory and monitoring, cave visitation data, and a bibliography.

The following is the most basic of inventories needed to manage and mitigate human access and impacts to the subsurface.

Cave and Cave Passage Classification: Since human safety is a prime NPS concern and rescues can impact even sturdy formations, access to a cave or cave passage depends on the sum of its fragility and hazard ratings. A cave's rating may be changed seasonally, as a result of further inventory, or by the alteration or removal of a hazard or resource responsible for the initial rating. If it is determined that human use is adversely affecting cave resources, the zone category for that cave will be reviewed for possible change to a zone that better protects the cave.

Fragility 1 Caves and Cave Passages

Fragility 1 caves or cave passages contain resources that, due to their size or their location within the cave, are not easily subject to vandalism, disruption or destruction. These are areas in which frequent visitation by cavers or other visitors may involve an acceptable level of human impact.

Fragility 2 Caves and Cave Passages

Fragility 2 caves or cave passages have resources so positioned that they are vulnerable to breakage, disturbance and/or vandalism. Examples include tubular stalactites less than 1.8 meters (six feet) from the floor.

Fragility 3 Caves and Cave Passages

Fragility 3 caves or cave passages have resources that are of unusual quality or rarity and which are delicate and susceptible to disturbance, or areas for which no inventories exist. Examples include calcite needle clusters in the middle of a floor.

Hazard 1 Caves and Cave Passages

Hazard 1 caves or cave passages offer the least hazard to the caver. Hazard 1 characteristics include:

1) No known loose ceiling rocks.
2) Well-defined main passageways with only dead-end lateral passages.
3) No drop over three meters (10 feet).

Hazard 2 Caves and Cave Passages

Hazard 2 caves contain structural hazards not found in Hazard 1 caves. Class 3 characteristics include

1) Maze-type passageways.
2) Vertical drops between three and nine 9 meters (10-30 feet).
3) Loose rocks on ceilings over two meters in height. No known loose rocks on passages less than two meters (six feet).
4) Balanced rocks on uneven floor.

Hazard 3 Caves and Cave Passages

Hazard 3 caves or cave passages are potentially the most hazardous. Characteristics include

1) Vertical drops over nine meters (30 feet).
2) Loose ceiling rocks in crawlways under 1.5 meters (four feet).

Zone 1 Caves and Cave Passages

The fragility/hazard sum is 2 or 3. These developed areas include most public use areas that provide visitors with comfort and convenience (for example, hard surfaced trails, handrails, and electric lights). No special clothing, equipment, knowledge or skills is needed. Park Service staff must accompany all visitors.

Zone 2 Caves and Cave Passages

The fragility/hazard sum is 4. These areas may be visited by permit without an NPS escort. Permittees are responsible for providing their own equipment. Evidence of incompetence, previous cave abuse or disregard for park regulations are grounds for denying a permit. All members of the group will stay within the trail zone bounded by markers.

Zone 3 Caves and Cave Passages

The fragility/hazard sum is 5. These areas may be visited only when scheduled in advance and when a designated National Park Service trip leader accompanies the visitor.

Zone 4 Caves and Cave Passages

The fragility/hazard sum is 6. To obtain access, the Superintendent must approve a collection permit. The researcher must show in writing how potential damage to resources from research in a specific part of a cave will be more than balanced by knowledge gained that would protect park resources. Zone 4 designation does not exclude administrative entry to monitor research activity and impacts upon these caves. All newly discovered caves or cave passages will be initially assigned a Zone 4 designation.

Taping or other marking is an important part of both mitigation and future inventory and monitoring. Orange tape shall be placed along the sides of trails or routes. Tape designating trails, shall be placed in a way which clearly delineates between areas to be protected and areas to be traveled through. Ending or beginning the line of tape at a wall or other prominent feature can best do this. Green or blue tape can be used for survey stations. White flagging will designate hazards, such as loose rocks, sudden drop-offs or other dangers. Red or red/white stripped flagging would mark out fragile “hands-off” and “foot-off” areas. Detailed mapping and inventory should eventually eliminate the need for much of the taping.

Writing on tape with indelible markers can be used to locate "boots off" areas, the location of low, delicate ceiling features, and in areas of confusion, which side of the tape the trail is on. Routes may be altered if a more appropriate alternative is found.

1. Cave Identification

a. Cave Name: When a cave has an established name, it will be retained. In the case of a cave without an established name, one will be assigned.

b. Cave Markers: A brass cap will be set at the entrance of each cave. The cave name will be stamped on the cap.

c. Cave Map: Cave entrance locations are maintained as point features in the GIS. Cave names will be shown on the maps.

2. Survey and Exploration Standards

Cave surveying and mapping are fields whose methods and results are subject to large amounts of variation. Different groups of surveyors use different equipment, different amounts of information are included in the survey, and different degrees of accuracy are obtained. Accurate and detailed maps are becoming increasingly important to cave management, making this degree of variability undesirable. What follows is a minimum set of standards which shall be met by every survey party involved in the exploration of the Cave or other caves on the Monument.

Due to the nature of cave surveying, no map of a cave can be said to be truly precise. There are only varying degrees of precision accuracy. It has been traditional to use loop closure as a means of measuring the accuracy of a survey. In the past, loops that failed to close to within 1% of their total length were deemed inaccurate, requiring resurveying. Studies have shown, however, that closure error is directly related to the length of the loop. Loops of shorter length are far more likely to have greater closure error. This is because of the error that is built into the instruments used in cave surveying. In a long loop, errors are more likely to cancel out. Therefore, it is more reasonable to have a scale of acceptable error based on loop length, rather than one standard with which all loops must comply. For the Monument, less than 1% closure error will be the target for all loops greater than 500 feet in length. For loops of less than 500 feet in length, 2% closure error will be acceptable.

Any equipment which meets the following minimum set of conditions and which consistently performs within the acceptable range of accuracy may be used in the survey of Monument caves.

Compass - Declination settings on the compass (if they exist) shall be set to 0 degrees. In other words, all compass readings recorded in the notes will be relative to magnetic north.

Inclinometer - As with the compass, only inclinometers with output in degrees will be used. Percentage of grade or mils will not be acceptable.

Tape - Monument caves are currently measured in feet. All future measurement will be made in meters. Only metric tapes will be allowed.

All NPS equipment must stay within the Monument at all times. Tapes that have been broken are another major source of error. Therefore, any tape used in the survey of Monument caves shall be absolutely complete from beginning to end. Since resource inventory will be tied to survey stations, no tape greater than 100 feet in length will be used.

Survey book - All survey books will be provided by ORCA, and will remain the property of the park. Survey books must remain in the park at all times. Only photocopies of the original books will be allowed outside the park. Photocopies of survey notes will be provided to surveyors upon request. All maps and survey notes will be the property of the US government and will not be copyrighted.

Writing Instruments - For neater notes, only pencils will be used to record notes on surveys. Mechanical pencils with lead diameters of less than .7mm are required.

Station Markers - To avoid unnecessary damage to the cave resources, the burning of station names onto cave rock is not allowed. Survey stations will consist of a small, unobtrusive indelible mark along with a reflective tape wrapped around a small loose rock located within one meter of the survey point. The tape will have the station name printed in indelible ink and repeated continuously on the entire length of the tape.

All new surveys will include an inventory of the newly discovered passages. The park will provide special forms for this purpose. In general, the regular note taker for the survey will not perform this duty. Ideally, the tape person, or a fourth person not involved with the survey, will do the inventory.

The preferred size for survey crews will be 3-5 persons. **The most highly skilled teams will be the only ones allowed into sensitive and/or promising sections of the cave**. The following will be the minimum standards of performance for each of the duties.

Tape/Inventory - Traditionally, this has been the easiest duty to perform on a survey. Careful distance readings to the nearest tenth of a foot, and wise placement of stations were the only requirements of the position. The relative level of inactivity that was usual for this position made it an ideal target for an additional responsibility - inventory. The importance of inventory cannot be overstated. Therefore, this person must be familiar not only with Oregon Caves, but with the inventory standards of the park as well. **An inexperienced person will not occupy this position!** Any person who fails to provide inventory information in a satisfactory form will not be allowed to occupy this position.

Instruments - This duty will be performed by a person with experience with the type of instruments being used. Careful readings accurate to the nearest half degree are required. Any person who consistently fails to close loops to within acceptable limits will not be allowed to read instruments in Monument Caves.

Notes - Survey notes are of critical importance to a successful mapping effort. A good set of notes can provide far more information about the cave than simply where it is going. Properly taken notes can aid in detecting survey blunders (both in the cave and out). They can also provide managers with information on what resources are contained in the newly discovered passages. The following will be considered the minimum amount of information to be included in the notes of all surveys in Monument caves:

Date - The date (month, day, and year) of the survey shall be recorded somewhere in the notes for that day, preferably on the top of each page. This information is used in determining the correction factor for declination, which changes from year to year.

Personnel - The names of all the individuals involved with the survey shall be included. Initials or nicknames are not acceptable. The duty that each person performed on the survey will be recorded next to his or her name.

Survey Name - The survey name, together with an explanation for that name (if there is one) will be included in the notes. A list of available survey names will be included in each survey book, and used surveys will be crossed off the list as they are used.

Equipment - The type of equipment used will be recorded. The type of tape used will be recorded, along with the units used. The color of the reflective tape on the station markers will also be noted.

North Arrow - A north arrow will be included on each page of the notes see below for more on the orientation of the sketch).

Scale - An indication of scale will be included on each page of the notes. This scale may change from page to page if desired.

Sketch - Of all duties which shall be performed on a survey, sketching requires the most patience. The sketch person must not be rushed, so it shall be accepted that he/she will be the person setting the pace of the survey. All sketches will be oriented with magnetic north being the top of the book. Each station will be drawn and labeled **and placed at the proper distance and angle from the previous station.** Angles shall be estimated to within 10 degrees maximum, and plotted distances must take slope into consideration (to within reason, of course). Note takers unfamiliar with estimating angles to this degree of accuracy will use a protractor. Loops will come reasonably close to closing on sketches. This allows error checking to be performed in the cave as well as out. Passage dimensions will be drawn to scale, and ceiling heights will be noted at regular intervals (at least every 50 feet). The distance from the station to the right and left walls, as well as to the ceiling and floor will be included in the notes. Items of special interest in the inventory will be included in the sketch. Room names will be highlighted on the sketch. If non-standard symbols are used in the sketch, a legend will be included.

Miscellaneous - To avoid overcrowding on the sketch, no more than sixteen stations will be recorded on each page of the notes. All distances will be of absolutely consistent form. For example, if distances are recorded in feet and decimal form, all distances will have the decimal - even those that come out to an even foot (that is, 11.0', not 11'). All compass readings will be three digit numbers (with leading zeroes if necessary) followed by one decimal place. All inclinometer readings will be preceded by either a "+" or "-" and will be followed by one decimal place. This standardized form of recording numbers makes interpretation of sloppy handwriting much easier, and results in fewer errors. All backshots will be noted for each individual measurement in which it takes place (both azimuth and inclination if necessary) and only when readings have not been corrected in the field.

All note takers in the Monument will be assigned a rating based on their adherence to the standards outlined in this document. The park's cave specialist will assign the ratings. Possible ratings, and the areas of the cave these ratings allow a note taker to sketch in, are as follows:

Level 1: Note takers assigned to this level consistently meet and exceed these standards. Notes are never confusing and easily readable. Sketches show extreme attention to detail, and are always neat. Level 1 note takers seldom, if ever, require critical evaluations of their work.

Because of their abilities, Level 1 note takers may perform their duties in all Zones in the Monument.

<u>Level 2</u>: Note takers assigned to this level usually meet, and sometimes exceed, these standards. Sketches are neat, but may lack detail in one respect or another. Notes are usually not confusing and if they are not neat, they are at least readable. Level 2 note takers occasionally require critical evaluations of their work, but the recommendations for improvement are usually minor in nature. Level 2 note takers are allowed to take notes in all previously surveyed passages.

<u>Level 3</u>: A level 3 note taker often fails to meet the standards set for note taking in the Monument. Sketches are messy and often confusing, with little attention to detail. Notes are also messy and frequently confusing. Because they have demonstrated an inability to meet the minimum standards for note taking, Level 3 note takers are not allowed to take notes in the Monument until they have demonstrated the ability, through discussions with the park's resources management specialist, to do an acceptable job.

An identical rating system will be applied to inventory work as well. As above, Level 1 inventory personnel may perform inventory in all sections of the Monument's caves, including new ones. Level 2 inventory personnel may perform inventory only in previously surveyed areas. Level 3 inventory personnel are not allowed to perform inventories in the Monument until they have demonstrated the ability to perform acceptable work.

Cavers who have never performed note taking or inventory duties before in the Monument are automatically assigned to Level 2. This enables new cavers to try their hand at these duties. However, at least one Level 2 (or better) caver for the duty being tried will be present on the same trip to provide guidance and answer questions.

Cavers can move up (or down) this scale by demonstrating the ability to perform better (or worse).

All survey trips in Monument caves will have note takers and inventory personnel who are eligible for the area where the survey will take place. Specifically, all trips into Zone 3 or 4 areas will have a Level 1 note taker and a Level 1 then need to perform both duties - a difficult and time consuming proposition at best. Survey trips to unsurveyed areas must have a Level 2 (or better) note taker and inventory person.

Resurveying will never be performed without prior approval from the park. No resurveying will be approved until evidence has been produced that firmly suggests a previous survey is both inaccurate and is not correctable with standard blunder searching routines. If resurveying occurs, all old stations will be obliterated or removed, and all surveys and inventories which reference the old survey will reference the new one.

Since a lot of resurveying has been performed in the Cave over the years - usually without removing the old stations – many stations may be found in the cave which are not used on the map. A list of these "bad surveys" will be included in each book, and will be consulted before tying in to any survey.

It is almost **never** necessary to travel through an area which would require breaking sensitive cave features which include, but are not limited to, all types of speleothems, extensive or unique sediments, historical items, or items of biological interest. A caver entering an area that would requires destruction or modification of a sensitive cave feature will **turn around**. The chances are excellent that there is another way of getting to the room or passage beyond the sensitive area. Even if a caver cannot find an alternate path, approval of the Superintendent or a designated representative will be required prior to entering any sensitive area.

3. **Cave Files**

A file for each cave will be maintained separately from other files. Each cave file will contain the following:

a. When found

b. By whom

c. Other people present

d. How located

e. How and why named

f. Topographical map of area: showing the location of the cave.

g. Directions for reaching the cave entrance

(1) Walking distance, both vertical and horizontal from permanent and significant landmarks
(2) Approximate walking time at an average pace.
(3) Pedometer log and step log.

h. Hazards
Detailed descriptions of hazards present within the cave and/or in reaching the cave entrance, including recommended equipment and procedures for reaching, entering, and exploring the cave.

i. Inventory
Detailed description of major features of the cave, including biology, water, geology, climate, cultural, and fossils. The Monument's basic cave inventory contains 100 data points (CRM-INV) which are entered into the park's GIS.

j. Restrictions
Recommendations on type and amount of use restrictions.

k. Map of the cave, including plan view, vertical section, and all survey computation notes.

l. Photographs showing the cave's entrance and the cave's major areas and features. Notation will include the photographer and the date the photograph was taken.

m. Significant trip reports and a permanent record, listing date of each cave entry and number of cavers on each trip.

Subsurface management files will be created and maintained in the monument's Natural Resource Specialist's office. The files will be separated into two groups. The first group, Open Files, is available for public inspection upon request and will be posted, when possible, on ORCA website. Open Files will contain all non-confidential Subsurface Resource Files and any materials pertinent to those subsurface resources. The second group, Confidential Files, will be established to store files pertaining to caves, cave passages, or tour routes with confidential locations. These are areas with a Zone 4 rating. Secured under lock and key, access to confidential files will be limited to authorized personnel. Specific information stored in these files may be released to individuals after execution of a Cave Resource Access Request (CRAR). Under no circumstances will persons other than those authorized be allowed unsupervised access to the contents of the Confidential Files.

4. **Monitoring**

Monitoring is necessary for determining the sustainability of natural populations, ecosystems, and processes and for evaluating the success of subsurface restoration and mitigation management.

a. Visitor Use

Due to the nonrenewable nature of most cave resources, it is important that the impact of various types and intensities of use be carefully and systematically documented so that acceptable levels of use can be anticipated and a reasonable carrying capacity established for each cave before irreparable damage is done. This process needs to be initiated in all caves and cave passages as soon as possible, particularly in newly discovered areas. Due to individual variation, each cave shall be monitored and its management evaluated separately.

Carrying capacity is established from the correlation of cave use and the measured condition of the resource associated with various levels of use. The resource used to evaluate impact shall be accurately measurable with a consistent technique, and its condition shall be correlated with the presence of people in each cave. Before sufficient data is available, carrying capacity will be set based on conservative estimates. Then, as data becomes available, visitation levels can be adjusted as necessary.

Tour guides counting the number of people on each tour determine use at the Cave. The cave permit provides use data for undeveloped caves or cave passages. In this way the impact of cave use can be tracked and the cave inventory constantly updated regarding the status of the features of the Cave. Some of the Cave areas where use is regulated are not gated; therefore, the accuracy of use data generated from approved permits is dependent largely on voluntary compliance with entry procedures.

At present the amount of use other than guided tours appears to be minimal. However, the Natural Resources Specialist will develop a priority list of caves, cave passages, or travel routes that will be monitored as funding for electronic surveillance devices becomes available. The priority of each area will depend on the zone rating and the likelihood that there may be future or present unauthorized entry into those areas.

b. Audio-Visual

Quantitative and qualitative measurement of subsurface resources is generally more difficult than measuring visitation. Within the park, video and photo inventories and, when possible, water quality and indicator species are principal indices of subsurface use impacts. In the Cave, cave microclimate and formation damage is also monitored.

Vistas are measured using a system of fixed photopoints and/or videopoints established at selected sites within the Cave. Each site is marked with an unobtrusive identification tag and inventoried as to the nearest survey point. Distance and orientation to the nearest survey point and direction the camera is pointing to, and height of the camera from the ground will be recorded.

Even with this information, a slide from a previous inventory will have to be taken into the Cave in order to position and frame the camera accurately. These photos and videos provide comparative qualitative and quantitative data for any resources visible within the photograph. A specific digital camera, a 50mm fixed lens and the same flash unit will be used. Two identical shots should be taken of each photopoint every five to ten years.

c. Water

Aquatic systems are vulnerable to alteration by people and include indices of change that are relatively easy to measure. Ions, turbidity, Ph, temperature, and other parameters likely to be altered by human activity will be monitored periodically where feasible to quantitatively measure any change within the Cave. Since all waters in Monument caves come from the surface, the basic Monument's water monitoring plan is detailed in Chapter VII of this document.

d. Microclimate

Because of their visibility, vandalism and the paved trail appear to be the greatest impact on the Cave. However, changes in airflow, caused by construction of the present trail, has had a greater human impact on the Cave due to its effects on both species and formation growth. Based on a 1989-1992 study of airflow at five stations within the Cave (Watson's Grotto, River Styx, Imagination, Miller's Chapel, and Wedding Cake Rooms) continuous readout hygrothermograph data indicate that about 90% of the airflow in the Cave has been restored due to installation of one airlock door each in the Connecting and Exit Tunnels. Airflow monitoring will continue at least until radon, carbon dioxide levels, and water quality data can be integrated with airflow data.

5. **Safety**

a. Caving and climbing

The Natural resources specialist and/or his or her designee will train all prospective off-trail cave guides and other park staff in safe, efficient, and relatively non-impacting methods of traversing uneven cave floors, crawling, and climbing. Standards will be derived from the most current National Speleological Society publications on caving techniques,

b. Search and Rescue

Cave related search and rescue activities and tactics are outlined in the park's Search and Rescue Plan, an appendix to the Emergency Operations Plan.

c. Radon

Cave radiation is caused primarily by radon 222. Some additional radiation is generated by radon 220 (Thorium). Working levels of alpha radiation are measured from the radon daughters and exposure records are maintained for all employees. In managing alpha radiation hazards, the park will follow procedures specified in the NPS Cave Radiation Safety and Occupational Health Management Guidelines (NPS-14). Based on a 2002-2003 year monthly resurvey of radon along the paved trail and a 2002-2003 survey of sites along the proposed caving route, alpha radiation in the Cave does not pose a threat to park visitors. The increase in health effects to even long term employees appears to be minimal.

d. Rock Stress

Alongside the main trail in the Cave are boulders that have fallen from the ceiling. Rock falls in caves are inevitable, natural, and rare processes. Rock stress recorders may be installed to monitor vertical, horizontal and perpendicular movement in joints. The recorders can document past geologic activity at specific sites, but they cannot predict where rock falls might occur. Every ten years a USFS mining safety expert or equivalent should check whether any large rocks are likely to fall on the main trail, given moderate stress (such as a small earthquake), and make recommendations for their removal or support.

During wet periods of freeze thaw, park maintenance will inspect the main Cave entrance for ice stalactites overhanging the trail and knock them down. During extreme conditions, the Superintendent may order the main entrance closed and the 110 Exit used instead.

Monitoring is indispensable to determine desired conditions; to diagnose human impacts; to direct management intervention; and to measure subsequent success or failure of that intervention (Goldsmith, 1991). Inventories and monitoring may be used to detect correlation and pose research hypotheses to establish causal relationships, to evaluate the effects of management activities, and to develop and evaluate mitigation of specific human-caused changes.

Specificity: Monitoring shall be hypothesis-based or driven by a "monitoring question," such as "Is this particular resource or process being significantly altered by present or future human-caused change?" Devoting part of the inventory and monitoring program towards anticipating change is crucial because such research can be difficult and because prevention of human impacts in caves usually is much easier to accomplish than restoration.

Impacts: Monitoring occurs when the type and quantity of human visitation or other impacts is such as to warrant measurements that can be compared to baseline inventories. A monitoring system shall be started in those parts of caves with the most types of or adjacent to widespread human use both intentional and inadvertent. Monitoring efforts shall be evaluated often to assure that selected monitoring elements are sensitive to human-caused change.

Scale: In general, monitoring is easier and cheaper when performed at lower levels of complexity, such as individuals or populations, than at higher levels, such as communities and ecosystems. Furthermore, results are easier to interpret and explain to managers at lower levels of complexity. Individual and population level effects of stress are likely to appear sooner than effects on ecosystem function, providing a better early warning of problems. Conversely, broader measures of ecosystem function integrate a variety of species and processes and detect changes that may be beyond the scope of a program oriented towards specific species. Observable changes in functional characteristics of an ecosystem may also be a more definitive sign of a serious problem than would be simple changes in species composition (Spellerberg, 1991).

Sampling, collecting, monitoring, inventories, and analysis beyond that of the more basic inventories are dictated by objectives, cost limitations, and the intensity of research needed to give useful results. It usually requires supervision by park staff and should follow established protocols. The following covers more general considerations.

Airflow: Air in large volume caves with small entrances is driven by barometric changes and, to a lesser extent, by geothermal gradients if there is substantial vertical extent to a cave, as is the case with Oregon Caves. Ancient flowstone breakage and current temperature ranges indicate that the Cave, with its large entrances, has and has had cold traps because an entrance is near the Cave's highest vertical extent. Large entrances near the top and bottom of a vertical caves result in the cave having chimney and reverse chimney airflow; depending on outside temperatures.

Other airflows are minor and usually do not need to be monitored. Microscale disturbances in the atmosphere range from three seconds to three minutes and include microbaroms, those arising from sea storms. Others include falls, earthquakes, and cave resonance (all one second or less), volcanic and man-made explosions and other noises. Cave resonance ("cave breathing") can occur from outside winds perpendicular to the entrance, waterfalls, or surface atmospherics but it does not appear to be present in Oregon Caves. Water flow in the River Styx creates a small amount of outgoing wind, especially during flooding. Any removal or addition of material from or to a cave changes barometric airflow by changing the total volume of a cave. Usually this effect is very minor for the cave as a whole, including this one.

Changes in airflow often are the greatest and most widespread human impacts on developed or breached caves, especially on bats, cave-adapted arthropods, and both speleothem and speleogen formation and continued growth. Desiccation, corrosion, and/or frost damage to cave formations can result.

Recording airflow past and present can involve both inventories and direct measurement of various air columns in a cave using small amounts of smoke sidelighted and/or very sensitive anemometers.

Helium, radon, and ethyl mercaptan has been used in broader studies. However, airflows in Oregon Caves often are so low that the appropriate anemometers for measuring these winds are so delicate that they cannot be left for long periods in the Cave, unlike Hobo dataloggers for temperature and relative humidity or radon detectors. Therefore, like carbon dioxide detectors, only spot checks can be made. However, such spot checks should be integrated into a larger scheme of a cave climate with parameters that can be measured.

Inventories of directional coralloids, eucladioliths, phytokarst, prehistoric frost exfoliation and debris, case hardening, aerosol sinter, anemolites, cave ghosts, moonmilk distributions (see glossary), and previous bat roosts may be needed to determine the prehistoric extent of cave openings, airflow, and the extent of the associated zones (twilight zone, variable temperature zone, etc.). Eucladioliths are tube-shaped calcareous deposits oriented toward the source of light in a cave entrance and formed by encrustation of bacteria, mosses, or algae by organic sinter. Phytokarst occurs where algal attack produces randomly oriented spongelike surfaces like lacework. Radon deposited deep in flowstone can record the amount of prehistoric air exchange with the surface atmosphere over time spans of hundreds of thousands of years.

Airflow patterns and regrowth measurements of broken speleothems are helpful in determining which areas of cleanup shall be the highest priority, that is, those windy areas where calcite crystallization is most likely to trap in flowstone mud spread by cavers. Regrowth calcite from formations dated as to their breakage can be used to calibrate dating of other formations by uranium/thorium or other methods.

Local additions or removal of material within a cave can change airflow patterns within that area, especially if the passages are small. Changing the size and location of the entrances can alter upward airflow in winter and downward airflow in summer. Air pollutants, organic deposition, atmospheric corrosion, condensation, visibility, and radon may also increase or decrease from airflow changes.

Impacts from airflow changes, human breathing, and global atmospheric increases in carbon dioxide in the last century can greatly impact caves. A delicate carbon dioxide balance controls much formation deposition and solution. Such balances are disrupted by airflow changes. Increased carbon dioxide in the atmosphere probably will favor increased non-native plant growth as well as total plant growth on the surface. This could result in increased carbonic acid reaching caves and other subsurface areas, which could dissolve calcite at upper levels and increase formation growth at lower levels. Acid rain could have similar effects. Vegetation patterns may be affected, with efficient CO_2 users (CAM, C_4, etc.) and other slow growing plants outcompeted by less efficient users of carbon dioxide. Fortunately, studies indicate that Northwest forests may be more limited by water and soil nutrient supply than by the amount of carbon dioxide. Increased flow of oxygen or nutrients could increase bacterial concentrations in groundwater, causing changes in flow.

Carbon dioxide concentration in the subsurface depends largely on the source and how much mixing with outside air occurs. Sources include degassing from incoming water (especially in vadose shafts) and the decomposition of organic debris. Identifying sources can be helped by three factors: 1) radon gas production occurs at a fairly steady rate, 2) radon and carbon dioxide gas sources usually are separate, and 3) mixing with surface air somewhat equally affects both gases. Therefore, changes in radon concentrations can be subtracted from carbon dioxide changes to arrive at changes in carbon dioxide production. The Cave appears to have the greatest carbon dioxide production during the greatest input of dissolved organics. This normally occurs in late spring or early summer during summer droughts or in mid-summer with more evenly distributed rainfall.

The low exercise level involved in most monitoring can make carbon dioxide a hazard if levels exceed 2% for exposures of more than 12 hours, and 3% or higher for shorter exposure times (a butane lighter won't light at concentrations of 4% or higher). Symptoms and signs of metabolic alkalosis (high blood Ph) are pale and clammy skin, feeling of coldness, constricted pupils and irregular heartbeat. Written justifications shall be made for entering a cave if the known concentrations of carbon dioxide are 1% or higher. Although such concentrations have not been found in Oregon Caves, spot checks of carbon dioxide concentrations are important to ensure that there is not an unexpected buildup of carbon dioxide to concentrations that pose a health hazard.

Air pollution can affect subsurfaces both by precipitation scrubbing and subsequent water entry of dissolved pollutants through soils and by direct passage of air pollutants through cave passages and their subsequent attachment to moist walls or affects on atmospheric corrosion and visibility. Measurements of air pollution when air is moving in or out of the Cave can help determine how much pollution and other particulates the latter process is absorbing.

The amount of airborne organics, whether natural or otherwise, can be estimated by sampling with open glass petri dishes placed in areas not accessible to animal disturbance. Seasonal sampling could help distinguish between human and other organic sources but the usual slow deposition rates may only allow sampling of annual or longer duration. Firing glass petri dishes can help determine organic/inorganic ratios of the deposited material.

Evaporation rates and whether or not they correspond with extant cave features can be determined through geologic inventories of cave formations caused in part by evaporation, the use of evaporation pans, and calculations dependent on knowing wind speed, air temperature and volume.

Cave radiation is caused primarily by radon 222. Some additional radiation is generated by radon 220 (Thorium). Working levels of alpha radiation shall be measured from the radon daughters and exposure records shall be maintained for all employees. Inventory procedures shall be followed as specified in the NPS Cave Radiation Safety and Occupational Health Management Guidelines (NPS-14).

Ionization has not been studied in Oregon Caves but it likely affects condensation-corrosion and radon concentrations. Crystallization rates and distribution may also be affected.

Biological: The most basic inventory shall be a list of at least 90% of species present. A graphing of number of species found over time versus the amount of visual searches or other methods can indicate approximately when that level is reached (Schneider & Culver 2004). The low-density sites commonly found in caves generally require more sampling than high-density sites to accurately assess species richness. For example, some invertebrates may require 200 samples at lower-density sites compared to 40 samples at high-density sites (Miller and Hartfield, 1988). Although sampling in 1992 and 1993 with limburger cheese and resulting fungi as an attractant may have sampled greater than 90% of the cave-adapted species (based on comparison with sampling methods described by Schneider & Culver 2004), trogloxenes, accidentals, and those species such as spiders that are not attracted to the cheese have not likely been sampled to the 90% level. The latter conclusion is based on identification of species not previously known from the cave during 2003-4 search sampling in the Cave, sampling that involves visual searches but without the use of attractants. Sampling should focus on the Cave rather than smaller caves on the Monument as the Cave is likely to yield more species per unit time of sampling than the smaller caves (Schneider & Culver 2004).

A good inventory also includes habitats and map locations in which biota are found, a trophic level list, the measurement of abiotic factors, and the identification of seasonal trends in populations (Braithwaite (1984) and Chamberlin (1981)). For inventories of small vertebrates -see Cooperrider, Boyd, and Stuart (1986); Halvorson (1984), Taylor and Friend, (1984), and Yahner, et.al. (1994-1995).

About 264 species or their remains are recorded from inside Oregon Caves. List compiled by John Roth, 7/28/03

Location of electronic files containing species data:
HQ-DATA on inporcahq1
O:/RM Documents/Natural Resources/Species inside Oregon Caves

BACTERIA (23 species, most species worldwide)

Actinomycetaceae (also put in fungi)
Actinomyces undetermined species (in moonmilk; also in Mammoth Cave water)

Alcaligenaceae
Achromobacter undetermined species (also in groundwater)

Azotobacteraceae
Azotobacter undetermined species (cave stream water, feces, and cave slime)

Chromobacteraceae (also put in Neisseriaceae)
Chromobacterium undetermined species (US groundwater; water in Mammoth Caves; in aphotic (no light) Edwards Aquifer, Texas)

Chroococcaceae
Aphanothece gelatinosa (by lights, alien?)
Aphanothece castaqnei (by lights, alien?, also in Carlsbad Caverns in New Mexico)
Aphanothece nidulans (by lights, alien?, also in Carlsbad Caverns in New Mexico)
Aphanocapsa delacatissima (by lights, alien?)
Chroococcus cohaerens

Corynebacteriaceae
Corynebacterium undetermined species (moonmilk; also in water in Mammoth Cave & on Oklahoma *Myotis velifer* bats; common in soils)

Flexibacteraceae
Runella undetermined species (in moonmilk & in suspected feces on sediment)

Micrococcaceae
Arthrobacter undetermined species (cave pool water, also in Lechuguilla (NM), & Mammoth (KY) Caves; deep US groundwater; ID basalt aquifer; TN cave stream; common in soils)

Microcystaceae
Microcystis incerta

Nostocaceae
Anabaena catenula (by lights, alien?)
Cylindrospermum catenatum (by lights, alien?)
Pseudanabaena caterata

Oscillatoriaceae
Oscillatoria agardhii (by lights, alien?;also in Minnesota hyporheic)
Oscillatoria amoena (by lights, alien?)

Oscillatoria angustissima
Oscillatoria tenuis (OR/by lights, alien?)
Plectonema notatum (OR/by lights, alien?)

Scytonemataceae
Hydrocoryne undetermined species (by lights, alien?)

Scytonemataceae
Tolypothrix lanata (OR/by lights, alien?)

GREEN ALGAE (at least 7 species mostly near lights in cave, most species worldwide)

Borodinellaceae
Chlorosphaera undetermined species (alien? by lights)
Chlorosphaeropsis undetermined species (alien? by lights)

Chlorococcaceae
Chlorococcum humicola (also near lights in Lehman Caves in Nevada)

Mesotaeniaceae
Mesotaenium undetermined species (alien? by lights)

Palmellaceae
Palmella undetermined species (alien? by lights)
Sphaerocystis undetermined species (alien? by lights)

Prasiolaceae
Hormidium undetermined species (alien? by lights)

DIATOMS (at least 22 species, mostly near lights in cave, many species across North America)

Achnanthaceae
Achnanthes lanceolata (also in Montana & Nevada caves & in Minnesota sediment running water)
Achnanthes montana

Cymbellaceae
Cymbella minuta var. *silesiaca* (also in a Montana cave)

Diatomaceae diatoms
Cymatopleura undetermined species
Fragilaria construens (also in a Montana cave/by lights, alien?)

Naviculaceae
Diploneis undetermined species (also found in a New Mexico cave)
Melosira (also in Utah caves (assoc. with siliceous coralloids)/by lights, alien?) (may be a protist)

Navicula brekkaensis
Navicula contenta var. *biceps*
Navicula cryptocephala var. *veneta* (also in a Montana & Utah cave & in the hyporheic in Minnesota)
Navicula gallica var. *Montana* (also in a Montana cave)

Navicula insociabilis
Navicula minima var. *minima* (also in a Montana cave)
Navicula pelliculosa

Navicula perpusilla (also in a Montana cave & on surface in Southeast and Middle Atlantic states)
Navicula pupula var. *rectangularis* (also in a Montana cave)
Navicula secura
Pinnularia undetermined species (by lights, alien?; Minnesota hyporheic; benthic in Devil’s Hole, Nevada)

Nitzschiaceae
Hantzschia amphioxys var. *erassaw* (also in Montana and Utah caves/by lights, alien?)
Nitzschia linearis (also in Montana and Utah caves/by lights, alien?)
Nitzschia paleacea Grun. (also in Montana cave and as phytoplankton in Devil’s Hole, Nevada)

Raphidineae
Amphora coffeaiformis var. *perpusilla* (by lights, alien?)

FUNGI & **SLIME MOLDS** (at least 53 species, most species worldwide)

Anamorphic Ascomycetes fungi
Aphanocladium album (Preus) W. Gams (1971) (in Neotoma woodrat feces in Oregon Caves & in wall frass of undetermined taxa)

Family Corticiaceae
Haplotrichum ellipsosporum (Hol.-Jech.) Hol.-Jech (in wall frass of unknown taxa)

Family Clavicipitaceae fungi, Tribe Balansieae (or as family), Class Hyphomycetes
Acremonium undetermined species (in moonmilk in Oregon Caves)
Acremonium strictum (cosmopolitan aboveground/ in West Virginia & Oregon Caves)

Family Dematiaceae
Cladosporium - Order Moniliales, Dematiaceae fungi, Subfamily Didymosporae (or uncertain family placement; species in Virginia, West Virginia caves and in New Mexico and Texas bat guano)

Cladosporium cladosprioides (Fresen.) G.A. de Vries, 1952 (WV, in moonmilk and frass of unknown taxa)
Cladosporium sphaerospermum Penz. (from dead moth)

Gliomastix undetermined species (cave slime)
Monodictys levis (Wiltschire) S. Hughes (tree root debris in OR Caves, OR)

Stachybotrys chartarum (in *Neotoma* woodrat feces)
Ulocladium atrium (soil)

Family Dipodascaceae
Galactomyces geotrichum (woodrat nest and compacted trail)

Family Gymnoascaceae
Gymnoascus reessii. (in cave slime and *Neotoma* woodrat feces in Oregon Caves)

Family Helotiaceae fungi in Order Leotiales (also put in Leotiaceae)
Ascocoryne cyclichnium (Tul.) Korf (1971) on surface of large Douglas Fir root in Oregon Caves)

Family Hypocreaceae
Fusarium merismoides Corda, 1838 (OR Caves in OR; common in temperate & tropical soils, esp. in slightly acid to alkaline soils)

Fusarium solani (lint on flowstone; other species in Indiana, Nevada, New Mexico, Michigan, West Virgina and Virginia caves)

Family Mortierellaceae
Mortierella bainieri Costantin, 1889 (OR Caves, OR; common in many types of soils)
Mortierella exigua Linneman, 1941 (OR Caves, OR; mainly in forests on calcareous soils)

Mortierella gamsii Milko, 1974 (OR Caves, OR; mainly in hardwood forests on calcareous and black soils)
Mortierella hyalina (Harz) W. Gams, 1970 (OR Caves, OR; mainly in forests & cultivated soils)
Mortierella minutissima van Tiegh. (OR Caves, OR; in many types of soils)

Family Laboulbeniaceae
Lasiobolidium helicoideum (in *Neotoma* woodrat feces)

Family Lycoperdaceae
Lycoperdon pyriforme (on dead roots in cave)

Family Moniliaceae

Monacrosporium gephyrophagum (in wall frass of unknown taxa)
Paecilomyces (in cave slime, undetermined species also in New Mexico, Virginia and West Virginia caves)

Penicillium Link ex E.M. Fries, 1832 - Moniliaceae fungi in Class Hypomycetes (or put in Trichocomaceae, Order Eurotiales)

Penicillium aurantiogriseum Dierckx, 1901 (cave soil in OR (OR Caves); common in many types of soils, incl. Eurasian cave soils)

Penicillium citrinum Thom, 1910 (OR (OR Caves) in *Neotoma* woodrat feces ; common in many types of soils)

Penicillium chrysogenum (cave slime, also in Texas caves)
Penicillium echinulatum (cave slime)
Penicillium expansum Link (OR (OR Caves); common in many types of soils, around roots and in polluted areas)

Penicillium glabrumi (moonmilk)
Penicillium griseofulvum Dierckx, 1901 (OR (OR Caves); infrequent in many types of soils)
Penicillium jensenii K. M. Zalewski, 1938 (OR (OR Caves); common in many types of soils, incl. Eurasian cave soils)

Penicillium lanosum Westling, 1911 (OR (OR Caves); common in many types of soils, incl. Eurasian cave soils)

Penicillium miczynskii Zaleski (OR (OR Caves); common in soil and reported from air samples)
Penicillium olivicolor Pitt (OR (OR Caves); recovered from soil, household dust and air; in soil in birch stands)

Penicillium puberulum Bainier, 1907 (OR (OR Caves); reported from soils, air & cultivated plants)
Penicillium variabile (on large Douglas Fir root)
Penicillium waksmanii Zaleski (OR (OR Caves); common in many types of soils)

Trichoderma asperillum Samuels, Lieckfeldt & Nirenberg (OR Caves, OR; in soils)
Trichoderma viride (in moonmilk, also known from Texas, Virginia, West Virginia caves)
Verticillium lamellicola (in moonmilk)

Family Mucoraceae
Mucor hiemalis Wehmeyer forma *luteus* (Linnem.) Schipper, 1973 (OR Caves, OR; in many types of soils)
Mucor mucedo (Linnaeus) Fresenius (OR Caves, OR; in feces & forest soils)
Mucor plumbeus Bonorden, 1864 (OR Caves, OR; in many types of soils)

Family Pilobolaceae
Pilobolus umbonatus (in *Neotoma* woodrat feces)
Protrichia metallica (slime mold on large Douglas Fir root)

Spiniger meineckellus (in moonmilk)
Sporidesmium pedunculatum (on large Douglas Fir root)

Polypoaceae
Heterobasidium annosum (twilight zone)

Pyrenophoraceae fungi in Order Pleosporales
Cochliobolus spicifer R. Nelson (in soil)

Pythiaceae
Pythium torulosum Coker & P. Patterson (OR (OR Caves); infrequent in neutral pH soils & on roots)

Family Trichocomaceae fungi in Order Eurotiales
Emericella quadrilineata (wall frass of unknown taxa)

Family Tuberculariaceae fungi, Order Tuberculairiales, Class Hyphomycetes
Epicoccum nigrum (also in caves in Michigan, Texas and West Virginia)

ANTS (2 species in Family Formicidae in Hymenoptera (wasps, bees and ants))

Subfamily Formicinae, Tribe Lasiini
Lasius palitarsis (trogloxene or accidental in Oregon Caves, twilight trogloxene in Washington; in ground nests in southern Canada and northern US; 17 species in US or Canada, genus endemic to North America)

Subfamily Myrmicinae, Tribe Leptochoracini
Leptothorax nevadensis (trogloxene in Oregon Caves, accidental in Washington; on ground and in nests in Oregon, Washington and California; 6 species in US or Canada, genus endemic to

North America)

BEETLES (Coleoptera) (11 species)
Family Carabidae (carabid beetles)
Subfamily Trechinae, Tribe Broscini

Broscodera insignis (one subgenera in Himalayans, one Nearctic; 1 species in western US; surface nests in southeastern Alaska, south to Oregon, east to Wyoming, resting deep in loose rocks especially near streams, under stones on barren slopes or edges of snowfields; troglophile in Washington caves & Oregon Caves, disjunct genus in China area and in North America)

Subfamily Carabinae
Tribe Carabini

Carabus nemoralis (may be first record of live species in cave; 715 species in Eurasia and US and southern Canada (13 species) on ground or in litter and 2,000 years before present in Alberta cave; a diverse genera migrating from western North America as climates cool & dry)

Tribe Cychrini
Scaphinotus marginatus (species on ground or in litter in Alberta, Alaska, British Columbia, south or west to California, Idaho, Montana, WY/ troglophile or trogloxene in Alaska, British Columbia, Oregon, Washington; 49 species in genus in US with the greatest diversities in the Appalachians and the Pacific Northwest, Canada; 7 cave species in West & 1 or 2 in East)

Family Leiodidae (often subsumed into Staphylinidae)
Subfamily Catopocerinae, Tribe Catopocerini
Catopocerus undescribed species (known only from Oregon Caves but also likely deep in soil)

Catops (124 species in Palearctic, nAfrica, seAsia, Nearctic; 10 species in North America)

Catops basilaris (A common and widespread North American species; 6 species undescribed, genus across NA, south to Mexico; at least 2 other trogloxene species in West and one troglophile in East

Subfamily Cholevinae, Tribe Cholevini, Subtribe Catopina
Catoptrichus frankenhaeuseri (the only species in the genus/ aboveground from Alaska south to Oregon, west to Idaho in forest litter, mostly active in cooler, wetter months; probably carrion scavengers; troglophile? in British Columbia, Oregon and Washington)

Ptomaphagus undescr. species (epigean in upper elevation forest litter in wCA; twilight trogloxene in summer and fall in Oregon Caves)

Subfamily Coloninae (endemic NA genus of 42 species in 5 subgenera in forest litter)
Colon (*Tricolon*) *pacificum* Peck & Stephan (previously only known from coastal southern British Columbia to Montana, disjunct trogloxene or troglophile in Oregon Caves, only record of genus in North American caves)

Colon aeadeagosum (trogloxene in Oregon Caves, common and widespread species in western forests from Alberta and British Columbia to California)

Family Scarabaeidae (scarabs or scarab beetles), Subfamily Aphodiinae, Tribe Aphodiini
Aphodius (at least 5 species in woodrat nests in US or Canada; one troglophile? guanophile in Nova Scotia & one species in entrance pit in Alberta cave; nearly global genus of about 900 species; 200 species in US, Canada)

Family Staphylinidae (rove beetles)
Subfamily Aleocharinae, Tribe Aleocharini, Subtribe Aleocharina

Aleochara (undetermined species in Oregon Caves; 53 species in US or Canada, generally distributed; adults mainly predators of fly eggs, larvae, and pupae at dung, carrion or rotting fungi, seaweed, or cacti; larvae ectoparasitoides of fly pupae; 5 Eastern cave species, 2 Western cave species, 2 cave species in both East and West, genus in Eurasia)

Subfamily Staphylininae, Tribe Staphylinini, Subtribe Quediina

Quedius spelaeus (nearly global genus of >800 species; 91 (4 alien from Europe) species in US or Canada; most in forest leaf & log litter and mosses, but some under bark of decaying logs, in nests & galleries of mammals, in caves, or in wet habitats; 3 cave species in East, 3 in West and

3 (including *Q.s.*) in both East and West)

BRISTLETAILS (Microcoryphia) (jumping bristletails) (2 species)

Machilidae (microcoryphians) – These primitive insects never had wings.

1 *Neomachilis* undetermined species (trogloxene undetermined species in Oregon Caves and in Hawaii; 1 described species in continental US or Canada & one in Hawaii)

Campodeidae (dipluran bristletails)

Metriocampa undetermined species? (troglobite or troglophile undetermined as to species; up to 5 undetermined species in West; 1 undescribed species in East, 1 in West; 9 species in US or Canada, genus is disjunct, being mainly in Japan and in North America)

BUGS (Order Homoptera) (1 species)

Family Ortheziidae (root scales)

Arctorthezia occidentalis

(scale insect aboveground in New Mexico and non-native in Hawaii; troglophile root feeder in Mount St. Helens caves (Washington) & Oregon Caves; endemic genus of 3 species in US or Canada)

CENTIPEDE (1 species)

Order Geophilida (trogloxene or (less likely) troglophile in Oregon Caves)

HARVESTMEN (Order Phalangida) (scavengers & predators on mostly dead arthropods) (5 species)

Family Sclerosomatidae, Subfamily Leiobuniane

Leiobunum (twilight and dark zone trogloxene common on surface vegetation; 7 trogloxenes in East; 4 in West, disjunct genus centered in southern North America (especially Appalachians and Central America) and in southeastern Asia)

Nelima paessleri (mostly a twilight trogloxene that hibernates in caves throughout Northwest, genus in Eurasia)

Family Sabaconidae

Sabacon occidentalis (in surface litter and as trogloxene or troglophile from British Columbia to northern California, genus in Europe, North America and southeastern Asia)

Sabacon siskiyou (in California surface litter and as a troglophile in the Oregon Caves; two troglophile species in Midwest & Appalachians & two troglophiles or trogloxenes in West; the enlarged pincer-like feeding appendages near mouth are covered with glandular bristles & are used to "punch" mainly springtails and gnats which then become stuck in the bristles, genus disjunct ' between East and West)

Taracus silvestrii (Oregon Caves type locality and only known location – troglobite; the greatly enlarged pincer-like feeding appendages near mouth) of this genus helps reach into the aperture of a snail's shell; genus also in Eurasia, in the US only in the Pacific Northwest and the Sierras)

CADDISFLIES (Order Trichoptera) (2 species)

(From Cretaceous or possibly Jurassic (ancestral form to both Trichoptera & Lepidoptera?).

Family Hydropsychidae ((common) Net-Spinning Caddisflies) (trogloxene in Oregon Caves)

Family Lepidostomatidae (bizarre caddisflies)

Subfamily Lepidostomatinae (69 species in US or Canada, genus in Eurasia and tropical America)

Lepidostoma astaneum

(twilight trogloxene; 2 twilight trogloxene species in West and one in East; at least one species in karstic springs in East & one hyporheic species in gravels beneath streams)

CRICKETS (3 species)

Raphidophoridae (camel crickets) (or put in Gryllacridade, one of most primitive families of crickets)

Subfamily Ceuthophilinae, Tribe Ceuthophilini

Styracosceles oregonensis (trogloxene, iridescent gold stripe in juveniles, small size; 4 species in US or Canada, closely related to *Ceuthophilus*: 89 species in US or Canada; 33 trogloxene species in East, 24 in West; 8 to 9 undescribed species, genus endemic to North America)

Tribe Pristoceuthophilini

Pristoceuthophilus, (trogloxene + 5 other trogloxene & and 3 probable troglophile species; genus of 12 species endemic to Pacific Northwest, at least 6 species undescribed;

Subfamily Tropidischiinae

Tropidischia xanthostoma – no stripe, medium size (British Columbia to CA on surface, especially coastal/ yellow camel cricket/Trogloxene in Oregon Caves, British Columbia, Washington; troglophile or trogloxene in California (Trinity, Santa Cruz & Tulare Cos.; genus of one species endemic to Pacific Northwest)

FLEAS (1 species)

Family Ceratophyllidae

Ceratophyllus ciliatus (parasite in hair of Caves' *Neotoma c.* woodrats; 18 species in US/ Canada; at least 3 Western species on woodrats & on cliff swallows, genus also in Eurasia)

FLIES (31 species)

Family Calliphoridae (blow flies)

Eucalliphora latifrons (trogloxene or accidental)

Subfamily Calliphorinae, Tribe Calliphorini

Calliphora lilaea (surface areas from Alaska to Ontario, south to Northern Mexico and east to Colorado; trogloxene in Oregon Caves/ adults lay eggs in feces, carcasses or decaying plant matter; 16 species in US or Canada; genus also in Eurasia)

Family Chironomidae (midges)

(some cave species come from the rocky margins of rivers, lakes, and seashores)

Subfamily Orthocladiinae

Hydrobaenus undetermined species (same or other species as troglophile or trogloxene in Washington; one larvae species in East in brackish Water; 14 species in US or Canada; genus also in Eurasia)

Subfamily Orthocladiinae

Metriocnemis undetermined species (trogloxene in Oregon Caves; undetermined accidental? species in Washington and Alaskan caves; 1 undescribed species in Nova Scotia cave; 16 species in US or Canada ; genus also in Eurasia)

Family Heleomyzidae (heleomyzid flies) (> 500 species in 65 genera),

Subfamily Heleomyzinae,

Tribe Heleomyzini

*Acantholeria moscowa? (*trogloxene or accidental ; 3 US/Canada species; another species as trogloxene or accidental in Northwest Territories

Heleomyza serrata (aboveground in Europe, most of North America; troglophile or trogloxene in Indiana, Maryland, Oregon, southern Ontario, Washington, Wisconsin; trogloxene in Nova Scotia; 13 species in US or Canada; one other Eastern troglophile or trogloxene; undetermined troglophile in Pennsylvania, genus also in Eurasia)

Tribe Oecotheini

Aecothea specus (Alaska to Ontario, south to Georgia, California/ Troglophile or Trogloxene in Alberta, Alaska, Alabama, California, Georgia, Iowa, Kentucky, Manitoba, Missouri, Ohio, southern Ontario, Oregon, Washington, Wisconsin; Trogloxene in Arkansas, Illinois, Indiana, Kentucky, Missouri, North Carolina, Oklahoma, South Carolina, Tennessee;

trogloxene or accidental in California; troglophile or trogloxene in Colorado, Tennessee; 2 species in US or Canada; hang on ceiling absorbing water; larvae absent from caves; genus endemic to North America)

Subfamily Heleomyzinae
Tribe Heleomyzini
Amoebaleria flavotestacea (circumboreal, south to California and North Carolina; trogloxene

or accidental in Oregon Caves; accidental in Washington; 15 species in US or Canada; 2 troglophile species in Southeast & 1 in New Mexico; 2 trogloxene species in Northeast; genus also in northern Europe)

Family Anthomyiidae,
Subfamily Anthomyiinae, Tribe Anthomyiini
Anthomyia? (Oregon Caves has only known cave species, a trogloxene; 3 species on surface in US or Canada, genus also in Eurasia)

Family Muscidae (Muscid flies) (2 species as accidentals or trogloxenes in Oregon Caves)

Family Phoridae (coffin flies)
Subfamily Metopininae, Tribe Metopinini.
Megaselia inornata (aboveground in northern US/ troglophile or twilight trogloxene in OR; twilight troglophile? in Washington; 187 species in US or Canada; 1 possible troglobite, 8 or 9 troglophiles & 1 trogloxene in East; one widespread troglophile or trogloxene; genus also in Eurasia, southern Africa & Neotropics)

Subfamily Phorinae
Triphleba laticosta (troglophile or trogloxene in Oregon Caves, widespread aboveground in US and Canada; genus also in Eurasia)

Triphleba probably undescribed species (ORCA endemic) (22 species in US or Canada; 1 species is twilight troglophile? in Washington and accidental? in Missouri

Family Psychodidae (moth flies)
Subfamily Psychodinae

Psychoda satchelli
(aboveground in Europe, US, Canada/ trogloxene in southern Ontario & Washington; 2 trogloxene species in Northeast, 2 troglophile species in Southeast; undetermined species generally trogloxene in north and troglophiles in south; some species found on rotting plants or feces; genus in Eurasia and Neotropic)

Family Sciaridae (small fungus gnats)
Lycoriella (mushroom flies) (undetermined species include 1 twilight trogloxene in Illinois and Missouri, 2 in British Columbia, 1 in Utah (Uinta Mts.), 1 troglophile & 3 twilight trogloxenes in Washington; one species on porcupine dung in 2 Nova Scotia caves; 1 undescribed trogloxene or troglophile in Georgia; 14 species in US or Canada; genus in Australia, Eurasia

Family Sphaeroceridae (guano flies)
Subfamily Limosininae
Leptocera - Probable undescribed species in Oregon Caves; 48 species in US or Canada; genus in Eurasia, Australasia, seAsia)

Pseudocollinella sciapidis (aboveground in Washington and Idaho; trogloxene or accidental in Oregon Caves; one accidental in Washington caves; 14 species in US or Canada, genus also in Eurasia)

Family Tipulidae (Crane Flies)
Subfamily Limoniinae

Tribe Eriopterini
Chionea macnabeana (16 species in US or Canada; genus also in Eurasia)

Tribe Limoniini

Limonia undetermined species (twilight trogloxenes in Oregon Caves, California, Kentucky,

Washington and West Virginia; 2 trogloxene in West, 7 trogloxenes in East. 1 or 2 troglophiles & 1 accidental or trogloxene in Washington; 111 species in US or Canada, genus also in Eurasia, Pacific, Australia, Neotropics)

Tribe Pediciini (11 species in US or Canada)

Pedicia undetermined species (twilight or dark zone trogloxenes in Oregon Caves, Alaska, Illinois, Iowa, Missouri, and Washington, genus in Australia, Eurasia)

Family Tipulidae, Subfamily Tipulinae, Tribe Tipulini

Tipula undetermined species in Oregon Caves (2 trogloxenes or troglophiles in California, trogloxene in California, Oregon and Arizona; twilight trogloxene in Texas & undetermined species in California, Missouri, New Mexico, Colorado, Tennessee, Texas, Utah and Washington; 3 twilight trogloxenes & 1 trogloxene & 2 hyporheic (under streams &/or rivers) in East; 323 species in US or Canada, at least one endemic in Klamath/Siskiyou region; genus also in Eurasia)

Family Trichoceridae (winter crane flies)

Diazosma hirtipenis (trogloxene in Oregon Caves & California; aboveground from British Columbia to southern California, east to Nebraska and New York, only species in genus endemic to North America)

Trichocera columbiana (twilight trogloxene in Oregon Caves, trogloxene in California and Washington, aboveground from Alaska to California;

2 *Trichocera* undetermined trogloxene or troglophile species in Oregon Caves (2 trogloxenes in East, 1 trogloxene or troglophile; 1 troglophile on porcupine dung; 1 trogloxene or troglophile in Washington; 2-5 undetermined trogloxenes in British Columbia, Georgia, Tennessee, Illinois, Missouri; 27 known species in US or Canada, most species in Eurasia)

Mycetophilidae (Fungus Gnats)

Subfamily Bolitophilinae

Bolitophila (undetermined trogloxene species in Oregon Caves, southern Ontario and Nova Scotia; genus also in Eurasia)

Subfamily Mycetophilinae

Tribe Mycetophilini

1 *Mycetophila*(undetermined species (trogloxene or troglophile in Oregon Caves, California, undetermined trogloxenes in Washington, Utah and northern Arizona; 5 known trogloxene species in East & one in California; genus also in Eurasia, Australasia & Neotropics & from Early Oligocene in Colorado)

Tribe Exechiini

Exechiopsis undetermined species (4 trogloxenes in East, 1 (*E. nugax*) in West; undetermined trogloxenes in Arkansas, British Columbia, California, Oregon Caves, North Carolina, Ontario, Utah, undetermined trogloxene or troglophile in Oklahoma; 4 known species in US or Canada; genus also in Eurasia)

Subfamily Sciophilinae

Tribe Gnortistini

Boletina undetermined species (trogloxenes or troglophiles in Oregon Caves, Washington; twilight trogloxene in Nova Scotia; genus also in Eurasia)

Speolepta leptogaster (trogloxene in California, New Hampshire, Ontario, and Washington, mostly twilight trogloxene in Oregon Caves; aboveground in Europe and northern North America; two undescribed twilight trogloxene or troglophile in Vancouver Island caves in British Columbia; genus also in Eurasia)

GRYLLOBLATIDS (2 species)

Grylloblattidae

Grylloblatta 2 undescribed sp. (1 ORCA endemic troglophile or trogloxene & one more widespread species; 10 to 17 species in US or Canada, most trogloxenes; up to 7 undescribed species, only 1 species known from eastern Asia; may be surviving members of the Protorthoptera making them most closely related to crickets; probably more extensive on surface during Pleistocene as they feed on cold-deadened invertebrates)

MOTHS (4 species)

Geometridae (Measuringworm or Inchworm Moths)

Subfamily Larentiinae, Tribe Eupitheciini

Eupithecia (Accidental or undertermined species; 157 species in US or Canada)

Subfamily Ennominae, Tribe Bistonini

1 *Phigalia*? undetermined species (accidental or trogloxene)

Subfamily Catocalinae (once in Hypeninae) (1 species in US & Canada)

Scoliopterix libatrix (aboveground in most of North America, Europe and Russia/ twilight Trogloxene; cave or herald moth; scalloped owlet/ trogloxene in most states and provinces with many caves; only species in genus in North America; genus also in Eurasia).

Subfamily Larentiinae, Tribe Hydriomenini

Triphosa haesitata (aboveground most of North America except northern Alaska and northern Canada/ tissue moth/ twilight trogloxene in British Columbia, California, Manitoba, Nova Scotia, Ontario, Nevada, Oregon, Quebec, Washington; Caterpillars feed on buckthorns, cascara (*Rhamnus* sp.), barberry, hawthorn; 4 species in US or Canada; genus also in Eurasia)

MILLIPEDES (Class Diplopoda) (7 species)

Caseyidae

Speoseya undescribed sp. (troglobite endemic in River Styx; one other species endemic troglobite or troglophile in six caves in Sierras; genus endemic to Pacific Northwest)

Nearctodesmidae

Kepolydesmus anderisus (trogloxene or troglophile in Oregon, Washington; troglophile? in Washington; 1 species or subspecies in genus endemic to Pacific Northwest Idaho, Washington, Oregon)

Nearctodesmus cerasinus (aboveground in Douglas Co., OR, south to Humboldt Co., CA & disjunct in Mendocino Co., CA/ Trogloxene in OR (Josephine Co.) & British Columbia; genus endemic to North America)

Nearctodesmus insulanus (aboveground in coastal regions of British Columbia, Washington, OR, accidental in cave or caves in Vancouver Is., British Columbia; troglophile or trogloxene in Oregon Caves)

Nearctodesmus cochlearius. (near cave entrance; 3 species Pacific Coast region from British Columbia to San Francisco Bay, California third species (*N. salix*) accidental in cave in Mendocino Co., California)

Family Conotylidae

Taiyutyla (endemic undescribed species in Oregon Caves; 14 species in the Northwest)

Family Xystodesmidae

Harpaphe haydeniana subspecies *haydeniana (*yellow-spotted millipede; fairy train/ twilight trogloxene and occasional dark zone trogloxene in Oregon Caves, accidental or twilight trogloxene in one Washington Cave; produces toxic hydrocyanic acid (cherry like smell) unless nerve cord cut by beetle predator, mimicked by and/or mimic of Panassius butterfly larvae; Pacific Northwest endemic genus of three species endemic from British Columbia to northern California)

MITES (Order Aari) (13 species)

Family Anoetidae? (microbe feeders)

Undetermined genus

Family Erythraeidae

1 *Leptus* undetermined species (parasites of harvestmen; another undetermined species in NM caves)

Family Camisiidae (moss mites)
Camisia (undetermined trogloxene in Cave and undetermined twilight troglophile in Washington; genus also in Canadian Rockies, Eurasia, New Zealand and Neotropics)

Family Ceratozetidae
1 *Ceratozetes* undetermined species (twilight trogloxene species in Oregon Caves, Iowa, Kentucky, South Dakota & Missouri? caves; some species eat detritus or are associated with cricket guano, genus also in New Zealand, Eurasia, Neotropics)

Familiy Damaeidae
1 *Caenobelba* undetermined species
1 *Paradamaeus?* undetermined species

Family Histiostomatidae
Histiostoma (worldwide genus that eats fly larvae & hitchhikes on adult flies)

Myianoetus
(troglophile of worldwide genus that eats fly larvae & hitchhikes on adult flies)

Family Ixodidae
Ixodes (Ixodiopsis) angustus (ectoparasite on ID, WA *Neotoma occidentalis*; TX *Neotoma micropus*; ID, MT *Neotoma cinerea occidentalis* & OR *N. cinerea* woodrats)

Family Laelapidae
Haemogamasus ambulans
(Circumpolar epigean/ trogloxene in Oregon Caves, parasite in Washington/ carrier of Haemorrhagic fever virus/ ectoparasite on Maine *Myotis lucifugus* bats & California *Neotoma fuscipes,* Utah *N. cinerea* & *N. lepida*? woodrats)

Haemogamasus reidi (epigean in VA, OR/ Trogloxene in Oregon Caves; parasite in Washington; ectoparasite on Oregon *Myotis californicus* bats, OR *Neotoma cinerea* & *N. fuscipes &* IN *Neotoma floridana* woodrats)

Family Liodidae
Platyliodes (undetermined trogloxene or troglophile species in Oregon Caves; genus in Eurasia)

Family Parasitidae
1 *Gamasodes* undetermined species
(troglophile – Oregon Caves individuals may eats fly larvae & hitchhike on adult flies associated with deer mouse nests; another or the same undetermined species in Washington caves hitches rides on bats; genus in Eurasia)

Family Prothoplophoridae
Prothoplophora (accidental or trogloxene, only cave record of this genus in North American caves is in Oregon Caves; genus also known from Eurasia)

Family Pygmephoridae
(troglophile of undetermined genus, three genera are largely fungi eaters or ectoparasites on woodrats or bats)

Family Rhagidiidae
Undetermined genus

Family Trombidiidae
Undetermined genus (larvae are parasitic)

Family Zerconidae
Undetermined genus in Oregon Caves

MOLLUSKS (2 species)
Family Arionidae
Banana slug (*Ariolimax* (*A.*) *columbianus*) (endemic to Pacific Northwest, trogloxene in Oregon Caves, twilight trogloxene in California, Washington)

Family Xanthonychidae

Monadenia undescribed species (“*M. rothii*” Frest, 1999) (trogloxene & accidental in Oregon Caves; other species are troglophiles; genus endemic to North America)

PSEUDOSCORPIONS (Arachnid of Order Pseudoscorpiones) (1 species)

Family Chthoniidae

Pseudotyrannochthonius gracilis (undescribed subspecies in Oregon Caves; only other cave record of genus is *P. utahensis* as troglophile, troglophile or accidental in Washington; disjunct genus also in Australia)

SPIDERS (Order Arachnida) (8 species)

Family Hahniidae

Calymmaria emertoni (funnel web spider; moderately common trogloxene in twilight zone, found on The surface in Oregon and Washington; southernmost extent near Oregon Caves; genus endemic to North America)

Family Amaurobiidae

Callobius undetermined species (trogloxene or troglophile; 25 species mostly in surface litter in US or Canada; 4 species in caves in West, 1 in East; genus also in Eurasia)

Family Linyphiidae, Subfamily Linyphiinae

Arcuphantes potteri (troglophile in twilight & dark zones and in surface litter in California, Oregon, Washington; 7 species in US or Canada, mostly in Pacific Northwest; genus endemic to Pacific Northwest)

Bathyphantes diasosnemus

(probably from Cave’s entrance area; twilight and dark zone troglophile or trogloxene in Washington, Oregon; troglophile in northern California; in surface litter in Pacific Northwest; 19 species in US or Canada; 4 cave species in West & 4 in East)

Family Pimoidae

Pimoa altioculata (may be disjunct and the southernmost record in Oregon Caves; perhaps most common twilight spider in Pacific Northwest; genus also in Eurasia)

Family Nesticidae

Nesticus silvestrii (type locality in Oregon Caves; trogloxene common in lava tubes in northern California and Washington and in forest litter in British Columbia; genus also in Eurasian caves)

Family Tetragnathidae

Tetragnatha versicolor (common surface species genus also in Africa, Australia, Neotropics, eastern Asia)

Family Theridiidae (Comb-footed spiders)

SLUGS (1 species)

Family Arionidae slugs

Subfamily Ariolimacinae

Ariolimax (Ariolimax) columbianus (3 species in genus in US or Canada) (Pacific banana slug; Pacific bananaslug; banana slug/ epigean from Alaska to northern California/ trogloxene in Oregon Caves, twilight trogloxene in California and Oregon/ genus endemic to Pacific Northwest)

Subfamily Anadeninae - *Prophysaon coeruleum* (pale gray taildroppers) (3 species in genus in US or Canada, genus disjunct between eastern Asia and Pacific Northwest)

SPRINGTAILS (Collembola) (14 species) (cave species tend to have reduced, pointed hairs at the ends of the elongated, slender legs, both for increased tactile information; since the Eocene extinction at the genera leave is absent, a unique feature among hexapods)

Family Entomobryidae, Subfamily Entomobryinae, Tribe Entomobryini.

Entomobrya caerulescnes (7 trogloxenes (1 non-native), 3 troglophile in West, 4 trogloxene (2 non-native), 1 troglophile in Hawaii, 2 trogloxene (1 non-native), 1 troglophile (Texas) in East; genus also in Eurasia)

1 *Sinella* undetermined species (2 Troglophile, 10 troglobites (4 undescribed), 1 troglophile, 1 trogloxene in East, 2 troglobite (1 undescribed), 2 trogloxene. 3 troglophiles in West, 1 trogloxene & 4 troglobites in Hawaii; genus also in Eurasia)

Tomocerus (Tomocerina) curtus Christiansen, 1964 (in forest litter or on plants in Colorado and New Mexico; troglophile? in Oregon Caves and in cave in Siskiyou Co., California; caves in Iowa, Colorado, New Mexico, Northern Mexico; 10 cave species in West; 6 in East, range from trogloxenes to troglobites; genus also in Eurasia)

Tomocerus (Plutomurus) brevimucronatus (type locality) (in forest litter or on plants in California, Oregon, Washington; troglophile in Mariposa, Mendocino, Santa Clara, Santa Cruz, Siskiyou & Trinity Counties, California, New Mexico?, British Columbia),

Tomocerus californicus (troglophile in caves in Santa Clara, Mendocino, Santa Cruz & Shasta Counties, California; in forest litter or on plants in California and Oregon)

Tomocerus vulgaris (in forest litter or on plants in most of northern Eurasia and North America; trogloxene in Plumas & Tuolumne Cos., California and in Indiana, Pennsylvania, Washington and Wisconsin)

Family Hypogastruridae, Subfamily Morulininae
Microgastrura minutissima (in surface litter in California, Florida and Lousiana; Oregon Caves has only known cave record; genus also in Eurasia & Neotropics)

Family Isotomidae, Subfamily Isotominae
1 *Isotoma* undetermined species (3 described cave species in West & 10 in East, mostly trogloxenes and some troglophiles; genus also in Eurasia)

Family Onychiuridae, Subfamily Onychiurinae
Onychiurus oregonensis (troglophile type locality in Oregon Caves, also known from one cave in Trinity County, California; 25 troglobite, troglophile & trogloxene species in caves in US or Canada; genus also in Eurasia)

Onychiurus undescribed? species (near *Onychiurus pseudofimetarius*; troglophile in Oregon Caves)

Family Paduridae (water springtails) (only aquatic family of springtails)

Family Sminthuridae, Subfamily Dicyrtominae
Arrhopalites hirtus Troglophile in British Columbia, southeastern Alaska, Iowa, Illinois, Kentucky, Maryland, southern Ohio; trogloxene in Virginia, Washington, Wisconsin, Nova Scotia/ hairy cave springtail/ in soils in Alaska, Illinois, Oregon, California and Quebec; genus also in Eurasia)

Arrhopalites undescribed species (ORCA endemic; major cave genus with 30 cave species, mostly troglobites, some troglophiles and rarely trogloxene species mostly in East)

Ptenothrix (undetermined trogloxene or troglophile species in Oregon Caves & in British Columbia; 3 trogloxene or troglophile species each in East and West; genus also in Eurasia)

WORMS (Annelida) (1 species)
Oligochaete worms – Groundwater species dropped into cave via dome pits)

VERTEBRATES

Amphibians **(5 species)**

Family Dicamptodontidae
Pacific Giant Salamander (*Dicamptodon tenebrosus*) (wet areas of Pacific Northwest; twilight trogloxene in northern Califorina and trogloxene & undetermined Recent subfossil in Oregon Caves; genus endemic to Pacific Northwest, family disjunct in China)

Family Plethodontidae
black salamander (*Aneides* cf. *ferreus*) (Recent subfossil in Oregon Caves; genus largely centered & disjunct in Appalachians and Pacific Northwest)

Woodland salamanders - *Plethodon* undetermined species and likely <10,000 years in age subfossil

in Oregon Caves, the genus largely centered & disjunct in Appalachians and Pacific Northwest)

Salamandridae (newts, salamanders)
newt, red-bellied (*Taricha granulosa*) (twilight trogloxene or accidental in Oregon Caves, Alaska & Washington)

hylid frog (undetermined Recent subfossil in Oregon Caves, the only Hylidae presently at caves is the Pacific treefrog (*Pseudoacris* (*Hyla*) *regilla*)

Birds **(2 species)**
Grouse, blue (*Dendragapus gilli*) (unmodified bones in Oregon Caves, extinct subspecies in cave in Shasta County, California)

Wren, winter (*Troglodytes troglodytes*) (twilight trogloxene in Oregon Caves and in Washington)

Mammals (most genera also in Eurasia) (30 species)

Aplodontia (*Aplodontia rufa*) (genus endemic to Pacific Northwest; trogloxene and Recent or Ice Age fossil in Oregon Caves, Ice Age fossil in 4 caves in northern California, 1 outside of present range)

Bats
Western big-eared or Townsend's big eared bat (*Corynorhinus townsendii* ssp. *pallescens or townsendii)* (now in most of West/ Trogloxene in Oregon Caves and in caves in southern Arizona, Colorado, New Mexico, western Oklahoma and Utah

Big brown bat (*Eptesicus fuscus*) (trogloxene in most US cave states except most or all of Alaska)

Silver-haired bat (*Lasionycteris noctivagans*) (roosts in trees in most of northern US (except southeastern Alaska); infrequent trogloxene in Colorado, Kentucky, Minnesota, Nevada, Virginia, West Virginia) (only reported once in the Caves)

California myotis (*M. californicus*) (from southern Alaska to Guatemala, west to Texas; trogloxene in California, Colorado, Nevada, Oregon, Texas and Washington)

Western small-footed bat (*Myotis ciliolabrum*) (rare trogloxene in California, Colorado, Montana, Nevada, Oregon, Ontario, Quebec and Washington)

Long-eared myotis (*Myotis evotis*) (trogloxene in California, Colorado, Montana, Nevada, Oregon & Washington)

Little brown myotis (*Myotis lucifugus*) (trogloxene in most cave states of US and cave provinces of Canada

Fringed myotis or fringed-tailed bat (*Myotis thysanodes*) (most of western US, trogloxene in Arizona, California, Colorado, Oregon, Texas and Washington)

Yuma myotis (*Myotis yumanensis*) (trogloxene in California, Colorado, Oregon, Texas, Washington)

Bears – Black (Ursus americanus) had dens and Recent (1820 BP) subfossil in Oregon Caves & grizzly (*U. arctos*) bones extend to Pleistocene (>50,000 BP) in Oregon Caves)

Chipmunks (*Tamias*) (Recent (1820 BP) subfossil in Oregon Caves

Deer, black-tailed (*Odocoileus hemionus*) (Recent (1820 BP) subfossil in Oregon Caves)

Elk (*Cervus elaphus*) (Recent (1820 BP) subfossil in Oregon Caves)

Gopher, pocket (*Thomomys*) (Recent (1820 BP) subfossil in Oregon Caves)

Humans (*Homo sapiens)* (trogloxene in thousands of caves in all states in US & all provinces in Canada)

Jaguar (northernmost and one of most complete jaguar fossils in world; 14 cave fossil sites in US)

Jumping mice (*Zapus*) & deer or white footed (*Peromyscus maniculatus*) mice both recent (1820 years before present) subfossil in Oregon Caves)

White-footed mice (*P. maniculatus*) is a trogloxene in Oregon Caves, California, Missouri, Nevada, Pennsylvania & Washington)

Rabbits – *Sylvilagus nuttallii* occurs as Recent (1820 BP) subfossil in Oregon Caves & presently lives only the east of the Oregon Caves area)

Ringtails (*Bassariscus astutus*) (twilight (largely) trogloxene in Arizona, New Mexico, Texas, California and Oregon Caves)

Shrew-mole or vagrant shrew (*Neurotrichus gibbsii*) (1 extant species in US & Canada) (on surface from southwestern British Columbia to northwestern California/ Trogloxene in Oregon Caves; the shrew mole, vagrant shrew (*S. vagrans/ornatus*)), *S. trowbridgii* & *S. bendiri/sonomae* are Recent (1820 BP) subfossils in Oregon Caves)

Skunk, western spotted (*Spilogale gracilis*) (accidental in Oregon Caves, genus is Recent (1820 BP) subfossil in Oregon Caves)

Squirrels, flying (*Glaucomys*) (Recent (1820 BP) subfossil in Oregon Caves

Voles (*Aborimus (Phenacomys) longicaudus (= Clethrionomys l., Microtus l.*) (Recent (1820 BP) subfossils in Oregon Caves)

Woodrats, bushy-tailed (*Neotoma cinerea*) (trogloxene in most of Pacific Northwest states & provinces, Recent (1820 BP) subfossil in Oregon Caves)

Reptiles (5 species)

Alligator lizard (*Gerrhonotus*) (Recent (approx. 1820 years BP) fossil or subfossil in Oregon Caves; genus endemic to Western North America)

Boa, rubber (*Charina bottae*) (Recent (1820 BP) subfossil in caves; Boidae family disjunct with Africa)

Garter snake, western terrestrial (*Thamnophis elegans*) (accidental or rare twilight trogloxene in Oregon Caves - the Tribe Natricini found as a Recent (1820 BP) subfossil in Oregon Caves is likely this species or genus)

Lizard (*Sceloporus*) (Recent (1820 BP) subfossil in Oregon Caves; only the western fence lizard (*E. occidentalis*) is presently at the Oregon Caves)

Skink (Eumeces) (Recent (1820 BP) subfossil in Oregon Caves is most likely the western skink (*E. skiltonianus*)

Collecting: A reference collection can be maintained as long as it is part of the park collections. Otherwise, photographs and drawings are needed, especially in visual searches so that only the minimum number of individuals needed for identification of an unknown species need to be collected. Extensive consumptive sampling of the small populations usually found in the subsurface can significantly affect populations. It is not always practical to maintain voucher collections at parks. Cooperative agreements shall be developed with local universities or museums that meet curatorial standards for voucher and type specimen care.

Because small and moderately sized caves appear to have high extinction/extirpation rates, a collection of individuals of the same species and with very uniform morphologies may suggest the need for genetic testing. Some cave species have undergone recent near-extinctions or migration into caves in low numbers. Species near their range limits also tend to speciate. The result may be low genetic diversity for many species and a low ability to cope with human-caused changes.

Mammals: Small terrestrial mammals can be captured using Sherman traps. Trap treadles shall be standardized to respond to the weight of the smallest species to be sampled. More than one trap shall be placed at each sample point. Where caves permit, trap grids shall be large (e.g., 10-12 hectares); spacing between trap clusters can be "adjusted" by sampling different points on different days, with 30 meter spacing sample each point every other day by rotating traps as they are checked. Variation due to trap placement (a meter or less may make a difference even when traps are "selectively" placed at the most propitious areas around a selected point) can be accounted for by measuring simple variables at each trap) Distances between subsequent recaptures can be used to weight estimates if the actual area sample cannot be determined. If catch/effort indices are used (instead of estimated numbers) corrections shall be made for "sprung" traps (American Society of Mammalogists, 1987; Halvorson, 1984; Fellers and Arnold, 1988).

Other sampling techniques include track boards (for medium sized mammals), pellet counts, and nest/den surveys. Scat shape, size, composition, and fungus content can reveal the identity of many species and the age of the scat. Scat can now be analyzed genetically. The extent of darkened scent trails and the thickness and decomposition state of amberat can help in determining past and present use by woodrats in particular. Telemetry does not work well in most subsurfaces. Where justified, implanted microchips shall be used in better estimating subsurface populations of mammals, herps, or birds as the microchips are now small enough not to greatly impact the health or reproduction of most individuals.

Bats should not be handled more than is absolutely necessary for needed research. Only qualified researchers who understand NPS policies and mandates regarding protection of natural resources should do such handling. Humans should avoid interaction with hibernating bats. Managers should carefully consider research requests to avoid stressing the bats.

Bats require inventory and monitoring methods different from other small mammals or from birds (Krzanowski, 1971; Kunz, 1988; Thomas and LaVal (1988)). Transmitters and tags with extremely low damage rates have been developed. Harp traps have less impact on bats than mist nests used to monitor birds. As a result of computer software consisting of call libraries, Anabat or similar recorders can identify the ultrasonic feeding calls of all bat species known from the Pacific Northwest. However, Oregon Caves should also continue with capture and release studies because bats in the Cave do not make species-specific calls and the entrance and exit points of the major of the Cave’s bats appear to have changed recently.

Photomonitoring of roost sites and guano piles can be done when bats are not using a cave. The decomposition stage of guano piles will indicate activity history and can range from distinct pellets, to what looks like dark soil (as appears to be the case in the Caves), to the localized presence of phosphate minerals or mineraloids such as brushite, carbonate-fluorapatite, carbonate-hydroxylapatite, crandallite, guanine, hydroxy(l)apatite, monetite, phosphammite, and whitlockite. Such deposits sometimes can be paired with overhead roosts sites which can display dark staining, claw scratches, dome enlargement, and atmospheric corrosion. Abundant mold and macro-invertebrates indicate rather fresh guano. A synthetic (non-cotton) netting like bridal veiling shall be cleaned off each time before a deposit forms which "cements" the sheet to the guano pile (Buecher and Sidner, 1995:314).

Bat surveys can be hazardous unless precautions are taken against bat bites. Hazards from bat guano and/or large concentrations of bats are not present at ORCA.

Bats and birds can be easily injured in mist nets. Nets composed of vertical nylon filaments may cause less injury (Cross, 1986). If visual counts can be adequately correlated with ultrasonic bat counter recordings, then the latter can be set up all night to automatically record the number of bats entering and exiting cave openings to the surface. Dense bat migrations may require computer analysis of videos or the use of infrared mapping on cave walls, as has been used at Carlsbad Caverns (Fletcher, 1985). Assessing population change is best done with a combination of methods, such as combining band recovery with census estimates (Stevenson and Tuttle, 1981; Willig and Selcer, 1989).

At least several bat species can be disturbed by lights and talking and, to a lesser extent, by heat generated by lights or a passing tour and by high frequency noise from fluorescent light ballasts. When correlated with temperature and humidity changes, how often bat move around near tours compared to further away can indicate how many disturbances are occurring.

Arthropods: While invertebrates constitute about 70% of described species worldwide, the percentage in caves is likely to be over 97%. One estimate is that nearly half of the insect and arachnid species in North America remain to be described (Schaefer and Kosztarab, 1991). Because of the difficulty of sampling and the lack of subsurface biologists, the percentage of undescribed cave and soil species is likely to be even higher. Because of opportunistic migrations, semi-permeable dispersal barriers, rapid speciation, etc. even adjacent caves with similar biological habitats may have very different groups of animals. Several small caves may well have a greater total biodiversity than one large cave although this does not appear to be the case at the Monument.

The focus of inventories should be on those arthropods that are most likely to yield narrow endemics and undescribed species which have living taxonomists willing to identify or describe them. According to a review of Pacific West (Roth 2004) and known Monument species (see appendix A), this should include millipedes, grylloblattids, and flies and leioid, staphylinid, and carabid beetles. All of these are terrestrial species. Due to numerous connections between groundwater areas and low levels of organics, species are likely to be fewer in groundwater and have broader geographic ranges. Therefore, sampling of terrestrial species should be more important than sampling groundwater species whether in the cave or in non-cave areas of the Monument.

Sampling is partly covered by Southwood (1978). Sampling in order to develop a species list should include a mix of methods because this is most likely to sample the most species. Plastic cups 16 oz. or smaller can be baited with Limburger cheese, rolled oats, feces, rotted meat, etc. Sticky traps and baited traps can attract large numbers of individuals and species, especially those low on the food chain and those species that are not cave-adapted. Preservatives such as ethylene glycol shall be used only if past studies indicate that populations will not be significantly affected. Antifreeze with green dye should not be used as it may affect water flow dye tracing. Visual searches and passive traps are more likely to proportionally sample predators and troglobites. Passive traps should have funnel shaped inserts to prevent escape and normally should not be left in a cave for more than 24 hours. Except for species living in stream gravel or sand or those that drop into the Caves from domepits, wells usually have to be drilled in order to sample groundwater species.

For each species, only a few individuals need to be collected for proper identification by taxonomists. This allows for variation in morphology, the inadvertent collection of non-adults, and for the collection of both sexes. Some species can only be identified from one sex or with a particular instar. If the species has not been previously described, a series of instars may be needed. Only a single specimen of each species may need to be collected during the first part of an inventory.

The most efficient technique to sample invertebrates, especially the very small species (<5mm) is to extract them from the organic matter and soil in which they live. These usually are endogean, species who live in the soil and occur sporadically in caves. Sampling of includes Evans (1986) for crustacean zooplankton; Fellers and Drost (1991) for mollusks and arthropods, Hawkes (1979), Metcalfe (1989), and Miller and Payne (1988) for aquatic invertebrates; Ishida (1990) for copepods; Mangum (1986) for macroinvertebrates.

The flotation method of separating invertebrates from other materials consists of skimming invertebrates off the surface of water (most other materials will sink). The Berlese method uses hot and bright lights to drive animals (usually those in soils or organic materials) into collecting jars. The advantage of flotation over Berlese is you do not need a large sample and it is much more efficient than Berlese (Walter, D.E., Kethley, J., and J. C. Moore, 1987; Kethley, 1991). However, flotation won't work for the guano of insectivorous vertebrates because most of this material floats. If at all possible, organic material shall be returned to the site of collection after extraction.

Protists and Rotifers: Little sampling has been done on protozoa in caves or elsewhere (Carlough, 1989). This is largely because identification is time-consuming, cave-adapted protozoa are likely to be nonexistent or very few in number, and, unlike fungi and bacteria, are not very indicative of substrate conditions. Consequently, there are no plans to do a protist inventory in the Cave. Evans (1986) presents sampling methods for rotifers in waters often found in the subsurface. The most likely place to find a number of rotifers is in the gravels of that part of Cave Creek outside of the cave.

Flatworms (Turbullaria): Planaria often appear to be restricted to single cave systems and the same could be true for other tiny animals with low dispersal abilities. However, no taxonomists in the United States are currently working with their identification. Consequently no sampling will be done on flatworms except for visual searches at some of the Monument’s springs.

Bacteria and Archaea: Because of the importance of microbes in terms of food bases and biodiversity, management should pay special attention to preventing disturbances to microbial systems. This can be accomplished by adhering to minimum impact techniques. This should include packing out all trash, catching food crumbs when eating, and carrying feces and urine out of the cave. More common microbes can rapidly displace those adapted to low-nutrient environments if nutrient availability increases. High amounts of organics can even cause bacteria cells to burst, especially those adapted to low organic or non-organic food sources. Hair, skin, and surface microbes shed by human visitors have the potential to disrupt these environments for extended periods. Cave passages being studied by microbiologists may require access restrictions. Water shall be especially safeguarded. Studies have shown some of the most significant damage in caves occurs in pools where a change in water quality affects microbial communities.

Sampling for chemotrophic microbes should concentrate on the pyrite in the Exit Tunnel. This is because chemotrophs derive their metabolic energy from chemical reduction or oxidation of inorganic substances, such as sulphur or iron minerals. Speleothems near entrances and moderate airflow often have bacteria because they are sites for colonization by airborne microbes, incoming dissolved organics, and/or their subsequent concentration by evaporation. These and other wall species may be rare or absent elsewhere in the Cave. Natural wallrock bacteria can occur in areas where aerial organic particulates and seasonal condensation coincide.

Chemoorganotrophs get their food by oxidizing organic compounds. Chemoorganotrophs such as *Leptothrix* often are slow-growing native bacteria found in unpolluted waters and can be easily extirpated by human activity. Bacterial studies in Oregon Caves and its fairly high organic input indicate that the more elongated and unusual bacteria that survive in very low nutrient habitats probably do not occur in abundance in Oregon Caves. However, the subsurface other than caves have not been sampled at the Monument except for some soil microfungi. Although it is of a low priority for research at the Monument, different soils and geologic formations should be sampled at various depths as both depth and geologic formations likely are influencing the distribution and biodiversity of microbes (Balkwill et al. 1989).

Though microbial sampling should focus on potential hazards to humans, including those that involve Hantavirus, plague, rabies, tetanus, ticks, and tularemia, none of these safety hazards appear to be present in Oregon Caves. Sampling will likely record a minority of the species present. Incubation for at least 48 hours in a subsurface may enhance the number of species that will grow on a given enrichment.

Fungi: Low pH in areas that are rich in organics favor fungal growth. Microbial sampling requires sterile techniques to insure that what is cultured actually came from the subsurface. Most fungi exist in deep subsurface zones only in spore form, but occasionally actively growing fungi are found on recently introduced organics or in areas where spores have been introduced by cavers. Sterile rayon tipped swabs with a Stewart transport media culture tube can be used. These swabs can be inserted into soil or rubbed gently across other surfaces to sample fungal spores. Another technique is to aseptically expose petri dishes filled with potato dextrose agar to culture airborne fungal spores. Care shall be taken not to contaminate the media with spores brought in by the samplers; filter masks shall be used. Identifying fungal hazards is important and can include cryptococcosis, histoplasmosis, mycormycosis, and valley fever. The type of cave habitats in the Northwest and fungi sampling at Oregon Caves indicate that, so far, none of the species causing such diseases are present in the Cave. DNA studies on fungal differences between compacted trail areas and non-compacted areas are currently hampered by the lack of fingerprinting databases for most fungi.

Habitats: The condition, extent, and location of each major habitat should be inventoried, especially Entrance, Twilight, and Dark Zones. The Twilight Zone can contain threshold species found nowhere else in the area. The Dark Zone can be further divided into diurnally variable temperature/relative humidity, seasonally variable and relatively constant zones. Inventory systems used for forests may be helpful in determining habitat relationships (Dedon and Harret, 1982).

The focus in the Dark Zone shall be on humid and organically rich areas, such those with bat roosts, flood debris, thin ceilings, or lint. Visual inspection of habitats should include organic material (leaf litter, wood, guano, feces, carcasses, roots, etc.) as well as different substrates (soil, under rocks, cracks, crevices, flowstone, pools). As most invertebrates are less than 10 mm long, a magnifier such as the OptiVisor can help one spot the smaller species.

Cave streams can be sampled with a combination of visual searches for macroinvertebrates, plankton netting for pelagic species, and pumping/filtration for benthic (bottom dwelling) species. Mammoth Cave plans on sampling selected cave streams every seven years, a compromise between the need for data points and minimal researcher impact on the resource.

Abiotic factors to be measured include air and substrate temperature, pH and depth of pools, relative humidity, water and air flow, light intensity, and vertical heterogeneity. For example, the timing and intensity of floods is important in both mortality of individuals and the replenishing of organics. Temperature conditions are important for cold-dependent (cryophilic) species such as grylloblatids. In other cases, mineralogy and sediment relief, chemistry, moisture, stratification, and the volume of the habitat are important.

Mapping hydrologic contacts may be important in locating genetic interchange that may only occur when flood events connect two normally separate drainage basins. Such interchange may in part be why aquatic subsurface species show less endemism than terrestrial cave species. Mapping helps delineate the effect of abiotic (non-biologic) factors on biology by locating habitat fragmentation, surface land use, etc.

Ecological type: More advanced inventories should include distributions in time and space of troglobitic, endemic, rare, indicator, non-native, heroic (charismatic), keystone, disjunct (separate from main range), hazardous, human-impacted, dominant, disturbance-dependent, social, extirpated (locally extinct), widespread, range-limited, and otherwise important species. Troglobitic species are those only known from caves. Most important are those troglobites that show cave-adapted features. Heroic or charismatic species are those which people generally like, especially large furry herbivores with large, vertical heads. Keystone species are those important in sustaining the populations of other species. Extirpated species are those which are not extinct but which no longer occur in a specific area. Also included shall be proportional representation of different physiognomic types (e.g., bacteria, invertebrate, and vertebrate).

Guilds: Working with guilds rather than individual species can help delineate the most important ecosystem processes. A guild is the main lifestyle of a species, such as whether it is a herbivore, carnivore, or detritus feeder (Block, Brennan, and Gutierrez, 1987). These include bandits, batellites (inclunding guanophiles), detritivores (both guanobias and scavengers), fungivores, heterotrophs, parasites (including hyperparasites), phoretics, predators, and xylophages. Bandits are marauding cavernicolous predators and scavengers who plunder the resources of communities which inhabit guano, but who live mainly in other cave microhabitats. They have not been studied at ORCA due to the low amounts of guano. Batellites are species that are dependent on bats and include mostly parasites both internal and external. Although a list of likely batellites has been compiled, these species have not been inventoried at ORCA because it is unlikely that any of the species involved are rare or endemic. A guanophile is ultimately dependent during at least part of its life cycle on guano. A xylophage is an animal that consumes wood either to digest lifeforms on the wood and/or to digest the wood with the help of mutualistic protozoans and bacteria.

Determination of guilds is important because the number of guilds is much smaller than the total number of species and therefore more manageable in terms of data analysis. Documenting functional roles of species also is important is determining which species are most at risk from human-caused change. A subdivision of guilds describes interrelationships with other animals and includes commensalism, mutualism, parasitism, phoretics, predators, and symbionts. Inquilism is a type of mutualism in which one organism lives inside another. A phoretic appears to be parasitic but is simply on another animal for the ride. It is neither commensual nor mutualistic.

A few examples of the importance of inventorying ecological types can be given:

Predators at the top of the food chain are vulnerable to biomagnification of pollutants while long lived species, common in subsurfaces, are at risk from bioaccumulation of pollutants.

Troglobitic species often have reduced waxy cuticles, slimmer and more transparent bodies, and extended appendages compared to their more surface-adapted relatives. This makes increased absorption of some pollutants or heat from artificial lights more likely.

Indicator species such as isopods or fish can be used to establish indices of biological quality (such as pristine or exemplary) or integrity (Crumby, et.al., 1990; Dallinger, Berger and Birkel, 1992; Hawkes, 1979; Karr, 1991; Metcalfe, 1989). Other indices include stability, persistance (Connell and Sousa, 1983), resilience (Kelly and Harwell, 1990), migration rates, sensitivity to pollutants, etc. Invertebrate groups with short generation times, high biodiversity, and rapid population growth can help detect biologic change. Invertebrates have been used to look at the effects of dissolved oxygen, heavy metal, and turbidity levels. When correlated with water quality, the ratio between surface species and interstitial and cave species can be used as an index of pollution. Interstitial species are tiny soil or groundwater species that move between the grains of sediment or through conduits in carbonates.

Guanophile (guano lovers) distribution can record both past and present bat activity. They often are the first arthropods affected by humans in caves because humans so easily disturb so many bat colonies. Cave species most at risk from long-term extirpation are poor colonizers, like most mammals and endemic cave arthropods. Most interstitial fauna, bacteria, and fungi tend to be rapid colonizers and therefore they have not been studied as much as the macroinvertebrate troglobites and troglophiles.

Social species can have critical threshold populations below which maternity roosts, mating swarms, predator avoidance systems, and so on fail and all individuals may die or move elsewhere.

Timing of sampling should ideally cover two years so as to better differentiate seasonal versus longer-term or "random" changes. Major controls on populations include changes in organic input and relative humidity that in turn are largely dependent on outside rainfall and temperature change. Hawaiian lava tube troglobites, for example, have a diminished ability to withstand desiccation and this is likely to be the case with Oregon Caves as well. Caves with strong seasonal airflow tend to have migrations of cave-adapted species away from entrances with inflowing air and into more humid areas such as small cracks.

Populations of most importance are those comprising species types listed above as well as those of type localities and those that change greatly. Capture, marking, release, and recapture methods in random stratified sampling of appropriate habitat are the best way to establish population distribution and change. Unfortunately most cave species are too small for this method to be appropriate. Visual searches using quadrants and mouth aspirators are much quicker but produce more limited data.

Parameters such as age, stage, size-class structure permit projections of future conditions of recruitment, mortality, and productivity. Interspecies comparisons using this type of data can help map out the effects of competition, parasitism, predator-prey relationships, habitat size and quality, and human impacts on community composition. Such data can provide early warnings of pending problems. The caveat is that even the fairly simple ecosystems found in most caves are not as orderly as was once thought and therefore require considerable data before consistent patterns, if any, can be discerned. Dawson (1981) reviews the usefulness of absolute and relative sampling measures of abundance.

Because of the small size and low-food habitats of most subsurface species, measures of biomass and productivity are helpful in identifying potential energy bottlenecks, nutrient pools, limiting resources, and other critical controls on populations. The effect of depth from the surface is important, especially if the main food source is dissolved organics from diffuse flow. In this case, depth may have a peninsular effect (Milne, 1985), meaning that gene flow continues to maintain a single species. Because of fewer naturally occurring organics, deeper parts of a cave are more likely to be affected by human-introduced organics than those areas closer to the surface.

Stress: Gauging the type, intensity, duration, and periodicity of various types of stress on park species is important in determining which stresses are natural and which are anthropogenic. Human impacts may be detected by mobile animals vacating a cave, a drop in evenness (numbers of individuals relative to numbers of other species) or biodiversity (especially troglobitic and keystone species), and an increase in filter feeders (tubificid worms, rotifers), sewage bacteria, non-natives, or predator/prey ratios. Evenness reflects the variations in species relative abundances, and is independent of the species count, or richness. Essentially it is a measure of community organization (Odum, 1985).

Subtle, chronic stresses are often reflected in reduced growth and reproductive rates (Odum, 1985). Population variability and an increase in the r-selected/K-selected ratio have been widely correlated with population stress and instability normally not present in the Caves. K-selected species are those, like humans, that have low numbers of offspring, fairly stable populations, and live long lives, while r-selected species can rapidly reproduce to take advantage of increased food sources. The strategy of the many K-selected cave-adapted species appears to be a “waiting” strategy in which species with long lives can take advantage of rare influxes of food into caves.

Habitats previously filled by K-selected species are subdivided by perturbation or stress. This opens up space that is then saturated by non-cave adapted species. Original influx of pioneer and mid-success ional species temporarily inflates both diversity and species richness. As disturbance affects compound, the number of species that can coexist with the disturbance decreases. Frequent, high-energy stress of long duration can erode subsurface communities completely (Freedman, 1989).

In species-poor habitats, as are most subsurface habitats, the introduction of non-native species may result in rapid loss of native species and a high success rate of non-native introductions. Non-native worms in the Cave may be reducing the organic content of cave sediment, rendering the sediment less valuable to cave species. A number of non-native plants have been show to cause changes in soil structure that allow more non-natives to move in. Migration into most subsurfaces is slow and, as a result, vacant habitats are likely to exist that can be filled by non-natives.

Although biodiversity often is thought to be species specific, all levels from genetic to community/ecosystem diversity shall be considered. The number of species coexisting within a uniform habitat is termed alpha diversity and is often the only one considered by subsurface managers. As habitats change along microclimate or organic richness gradients, new species are found as other species drop out, and this species turnover rate is termed beta diversity. It likely is high in Oregon Caves as strong gradients exist, such as changes in temperature, relative humidity, and organic content.

Theta diversity also can be high in caves. It is the rate at which additional species are encountered as geographic replacements within a habitat type in different localities. As caves are degraded and fragmentation "progresses," it is first the theta rarities (local endemics) that become endangered and are lost. This happens first in regions with the richest cave biotas, as in the Monument’s bioregion. Comparing karstic basin, region, national, and global diversity can help identify diversity not yet adequately protected.

To identify which changes at Oregon Caves actually signal trouble, managers must know the normal cycle for its communities, especially in the most pristine areas of an already impacted cave. For example, in some simple food webs found in subsurfaces, population densities may oscillate as they return to equilibrium. Population-growth rates are the single most important variable in predicting whether a population will remain viable in the future. The lower the growth rate, the more slowly average persistence time increases with population size. If subsurface populations consist of a hundred individuals or less, fluctuations in terms of unbalanced sex ratios, uneven annual population growth or food availability, can cause the loss of that population. This likely is not the situation in Oregon Caves since it lacks the relatively large individuals, such as cave fish or salamanders that usually have the lowest populations of all cave-adapted species.

Knowing about natural variability can help detect whether there will be resonance from the match between intrinsic/human effects, thus increasing population oscillations to the point of extirpation.

Because of strong seasonality in food resources, even populations in more complex food webs dependent on guano or flood debris can fluctuate widely. Frequent and long term sampling is usually needed to map out such complex dynamics. However, this is unlikely for Oregon Caves except possibly during deglaciations when water and organic input likely was higher at least for groundwater species. Biodiversity is also strongly dependent on sample size (Kaesler and Herricks, 1977; Loehle, 1990).

Overall, heavy human visitation in a cave may have only a slightly negative effect, if any, on both cave adapted arthropods and entire community groupings (Carlson, 193:33). However, individuals species may decrease (as in a troglobitic dipluran, (Crawford and Seenger, 1988) and many troglobites may become less common near trails (Crawford, 1994; Northrup, 1992). This could most likely occur in heavily visited caves where rapid changes in airflow or food sources cause migrations of arthropods subject to trampling. Biodiversity and populations levels in Hawaiian caves are inversely proportional to the level of visitation and human disturbance (Howart, 1983:57).

Based on size and variability of populations, a percent of disturbance that those populations can tolerate without being significantly impacted can be estimated. That percent can be drawn as a volume around major trails, underneath sewer lines and/or by altered entrance areas associated with that particular habitat. Sampling can then be done on and far from that volume's surface. Similarities in capture rates between same-habitat sites far and near the trail could then indicate whether or not human-impacts are having significant impacts on subsurface arthropods. Populations with very restricted habitats or with very uneven distributions may have to be sampled by age classes or some other factor, in order to understand the effect of human impacts. This shall be done with non-lethal passive traps so as not to compound monitoring goals or to impair populations with low numbers of individuals.

Organics: Dissolved organics and a soil survey help determine the relative effects and ratios of human-caused and natural organics in a subsurface energy budget. PO_4, NO_3, NH_4, NHO_3, NH_3, toxic metals (chromium and copper), and dissolved oxygen concentrations can be inventoried at drip and stream sites if water quality degradation or nutrient bottlenecks are suspected. A soil survey can be combined with dye injections and analysis of water that has flowed through a soil profile.

Organics not native to subsurfaces can include non-native plants, lint, skin flakes and oils, trail asphalt, wood or epoxy, and more airborne particles from entrance changes. All may cause subsurface animals adapted to food poor environments to be outcompeted by surface adapted, opportunistic animals. Cave-adapted macroinvertebrates tend to avoid foot traffic vibrations and an increase in light, noise, and heat caused by public tours. The effects on resident populations of removing human-caused organic debris should be monitored. Important ecological parameters to measure include decomposition rates and the ratio of living/dead organic matter. Biotic distributions in subsurfaces are often determined by the state of decomposition of organic matter.

Decreased organic input into subsurfaces can cause as much impact as too much organics. Because soil organic input in a subsurface may only be a few percent of what occurs on the surface, food is the limiting resource for many species, including troglobitic ones. A decrease in the predator/prey ratio can indicate that soil organic input is decreasing, such as normally happens in the conversion of a surface forest to a grassland or parking lot. Increased discharge from these or other human impacts can flush organics out of a cave instead of depositing them.

Cave pools with human-caused organics can be monitored by measuring dissolved oxygen, especially during times of heavy organic input and/or lack of convective overturn in spring and fall. Biological oxygen demand (BOD) of pool bacteria is an easy way to detect overall changes in bacterial activity caused by foot traffic, lint, lights, etc. (Bratvold, 1995). Bacterial populations in pools may peak when the amoung of water entering the pools equals drainage/evaporation rates and decline during overflow and low flow times (Bratvold, 1994). To determine limiting factors, measurements can be made concurrently of nitrates, amino acids, short chain organic acids, nitrate, nitrite, ammonia, and soluble reactive phosphate.

Inventory of the percent coverage of visual cave slime and slippery biofilms can help identify trail impacts, airflow changes, and changes in water quality, especially the amount of dissolved organics (Bratvold, 1994).

Mitigation: Efforts to mitigate the impacts of human-caused increases in organics in the Cave include tarps, settling "ponds" and/or raising curbs to trap lint, reducing total wattage and the % of lighted areas. All such efforts need to be monitored to evaluate their effectiveness. Control over the number and timing of visitors on a trail is crucial to evaluating human impacts.

Plants: A three year inventory of percent coverage of non-native plants in the cave determined the frequency of hypochlorite spraying that was the minimal needed to prevent human-caused carbonate solution and/or substantial increases in biota attracted to the non-natives. Estimating coverage by non-natives shall be done with strong headlamps; blue-green algae can grow in less than a foot-candle, what appears totally dark to people temporarily blinded by trail lights. The amounts of hydrogen peroxide used shall be monitored thereafter and coverage estimated again if lighting or hydrogen peroxide usage changes substantially. Two lights located away from the trail can be randomly placed to help differentiate the effects of lights and hydrogen peroxide spraying from other trail impacts. Mitigation should include spraying only during periods of high airflow and the use of less hot or bright lightbulbs. The pH of adjacent water bodies has been measured and changes appear to be minor.

Cultural: It is critical to inventory the exact location and description of artifacts that can be moved. In most cases, unless the possibility of vandalism or theft is high, most cultural artifacts and their contextual data can best be preserved in situ.

Archeological: Normally perishable artifacts such as those made of wood or cloth can appear quite fresh and well preserved in caves and may even be thrown out during cave restoration unless prior inventories have been done.

Dating by thermoluminesence relies on a fairly uniform buildup of electron traps that is reduced to zero when the artifact was heated as in some pottery and stone tools. The specimen to be dated is heated once more and the intensity of light given off by the release of trapped electrons is measured. One must also know the background radiation that stimulated the filling of the traps and the sensitivity to radiation of the material itself. Racemization dating is based on the chemical change in amino acids, where a light emitting amino acid over time is converted to a mixture of two substances which possess no emissions.

Markings: Modern graffiti may be difficult to distinguish from historic graffiti (more than 50 years old) or even prehistoric rock art unless a good inventory exists that precisely locates all markings. Graffiti not promptly removed or obscured induces further graffiti. A well-done inventory insures that only graffiti vandalism is promptly removed, not historical or archeological graffiti. All graffiti dated to less than 50 years ago may be removed unless there is a likelihood that a particular graffiti may become historically significant over time and is not being documented. However, letter styles and other criteria shall be used to help establish the age of "new" historic writings or rock art because of the ease in which historic or archeological items can be overlooked in past inventories.

No application (such as chalk) shall be used in making rock art and writings more legible for photographic documentation, etc. Aluminum oxide may be used on non-porous pictographs if it can be shown that such a coating on an adjacent non-pictograph rock surface can be completely removed after the time required for documentation. The high porosity of many carbonates makes this unlikely.

Ethnography: As a focus of fertility and creation and as gateways to the lower world in many Native American worldviews, caves often serve as critical markers of the cultural geography of many societies. Associations may be with groups far from their cultural boundaries as drawn by anthropologists. Any main cultural inventory of subsurfaces should include consultations with extant native peoples, at least within an anthropologically defined region, and perusal of the ethnographic literature on culturally extinct groups. It is, of course, up to the native people as to what information they are willing to share. An ongoing ethnographic survey for ORCA may reveal if there are any remembered or current cultural affiliations with the Monument. However, a comprehensive ethnography should include data on all people associated with a subsurface, including researchers, cavers, tour guides, etc. Visitor surveys are helpful in recording and predicting human behavior and its impact on subsurfaces.

Geology: Dating of bedrock gives the maximum time for cave development and can determine the significance of park resources. For example, the dating of the fossil radiolarians in the chert within the marble or argillite beds will tell whether or not the black graphite lines are near the Permian/Triassic boundary. If they are, then such bedrock features will likely be nationally or internationally significant. Dating of cave features, coupled with location and speleothem ring inventories, help to delineate the prehistoric timing and frequency of both solutional and depositional processes.

Unstable uranium atoms decay at characteristic rates to various different daughter products. Uranium 234/238 dating has had limited success in caves. The daughter product most favored for dating is Thorium-230 and the preferred materials for dating are freshwater-deposited speleothems. Since uranium is soluble in the water that deposits these limestones, whereas thorium is not, a newly forming stalactite will contain uranium but no thorium. As time passes, uranium will decay to thorium and the thorium/uranium ratio will increase and can be dated. Dense flowstone or dripstone with original depositional layers intact and abrupt termination of that deposition are less likely to be contaminated with newer uranium than are wet, porous speleothems, bones, teeth, shells, etc. The same holds true for isotopes of carbon in carbon 14 dating.

Flowstone and dripstone often fluoresces with a black light shining on it. Phosphorescence is luminescence in which a stimulated substance emits light after the external stimulus ends. Electrons move to higher energy levels and then slowly fall back to their former orbits, emitting characteristic wavelengths of light. How much glow there is from the flowstone depends mostly on the amount of fulvic acid in the calcite. The thinnest lines, visible only under a microscope, may record changes in calcite deposition during individual days and so are far better than tree rings in reconstructing past climates. The lines are hundreds of times more detailed, correlated with the two main climate factors (temperature and precipitation), and up to ten times as old (up to half a million years).

The thickness of the line apparently records how much rain fell and/or (in the case of Oregon Cave) the water film thickness (29% of growth variability in the Cave). The UV brightness tells the temperature. Speleothem studies indicate that changes in the solar constant in a cycle of 11,500 years produces climate change equal to that caused by the orbital variations thought to be responsible for glacials/ interglacials. Luminescence records with resolution of several years can be correlated with the sunspot numbers (higher incoming solar infrared and soil temperatures) and the atmospheric production of carbon 14. Records with a resolution of 100 years or less can be correlated with global climatic signals. Cycles of solar activity and insolation with periods of 1, 2, 11-22, 55, 95, 180, 300, 400, 600, 900, 1200, 2300, 3350, 5000 and 16,900 can be detected by luminescence studies of speleothems (Shopov et al. 1998). Organic rates of deposition in annual flowstone layers can be correlated with O^{16}/O^{18} ratios.

Other radiation damage methods utilized to determine age include electron spin resonance, measuring the absorption of microwave radiation by unpaired electrons—that is, those having very little stability—in radiation-damaged minerals and glasses when they are exposed to a strong magnetic field. The results provide estimates of the amount of damage to electrons, a type of damage that occurs at a known rate in some settings.

In thermoluminescence, radiation damage displaces electrons from a parent atom, and the displaced electrons become trapped in the atoms' crystal lattice. When the mineral is heated, the electrons return to their stable configuration, releasing excess energy as light. To estimate the amount of original radiation damage, the luminescence is measured on a glow curve. This method is mostly used in archeology to date glasses, ceramics, bone, and flints. One variation of the method relies on zeroing the past doses of quartz grain in sediments by sunlight, an effect known as bleaching, and is known as Optically Stimulated Luminescence (OSL). A second variant looks at radiation traps at the infrared end of the spectrum and is called IRSL. The technique can be used on single grains and it has the advantage that those grains that have been zeroed by sunlight can be distinguished and separated out from those within the same sample that have not been sufficiently bleached by sunlight. These techniques can be used to determine not only the age but if an artifact was made in a cave or not.

During radioactive decay, the fission fragments leave a trail of damage called "fission tracks" in a mineral. The longer the decay, the greater the density of tracks, so counting the tracks can give an estimate of the duration of decay since the last heating event.

Color of formations and other cave surfaces can be marred from smoke (torches, candles and/or carbide lamps), lint, skin oils and flakes, non-native plants, and dust from cave trails and the outside. Changes in soils from fire suppression, trail compaction, depth from the surface, atmospheric CO2 increases affecting plant growth and patterns, acid rain, and how fast water reaches part of a cave may alter organic acids that color cave formations.

Cleaned formations can be isolated from touching by changes in trail design. If the formation does not returns to a dingy color it is more likely to be a result of lint, dust, or mud/asphalt droplets produced by trail traffic as opposed to the effects of touching. Color charts can help quantify changes, such as how fast restored formations return to their original color.

Erosion: Erosion and/or chemical changes can result from human actions. This includes 1) freezing, dehydration and dissolving of formations, 2) touching and walking, 3) acids produced by lint and living or decaying non-native plants, 4) salts from hands, 5) electrical changes, and 6) increased or concentrated water discharge.

Only a few examples can be given. Salts can cause significant corrosion of handrail steel unless it is stainless. Large amounts of aluminum gels have formed on electrical fixtures and upon drying have spread further into the Cave. Temperature changes in summer and precipitation events in winter have been implicated in ceiling rock fall in marble caves. Especially hazardous are unconsolidated sediments, as in boulder or piping caves or where glacial deposition, entrance enlargements, or re-solution of cemented rubble piles has caused instability.

Rock stress recorders could be installed to monitor glacial surges and movement in joints. The recorders can document past geologic activity at specific sites, but they cannot predict where rock falls would occur. Rock fall and exfoliation (cracked plates of rock) is most common in cave passages rapidly enlarged, with loose sediment or near entrances. Exfoliation can occur naturally deep in a cave as a result of low Pleistocene temperatures but that is not likely to be a safety concern. Such exfoliation normally will show calcite deposition and/or corrosion at its edges whereas human-caused exfoliation usually has sharp edges. Precise surface leveling, drilling, logs of drilling resistance, and deeply set telescopic bench marks and strain gauges can access the risk of increased ground surface instability as a result of either human or natural processes.

Exploration: Planned surface development and adjacent land use necessitate knowing where a karst system extends. Techniques that can detect changes in rock porosity and stratigraphy include gravimetric, acoustic, magnetic, telluric, resistivity, spontaneous potential, cone pentrometer, ground penetrating radar, and seismic (Roth, 1995). Simultaneous vertical and horizontal resistivity monitoring has been used to trace an injected electrolyte solution to confirm predicted flow paths and flow rates. However, most methods usually fail to delineate cave-size voids. Closely spaced drilling is the only reliable method but is likely to damage any cave encountered.

The best way to locate caves is on foot and with an understanding of how local caves formed. Aerial photography using infrared or snowmelt areas can map where cave air is reaching the surface..

Cave Formations: High on inventory priorities, especially in newly discovered caves or cave passages, shall be any feature most at risk from human impacts, including those:

1) Currently biological in origin (calcitic moonmilk, rust stalactites, manganese/iron crusts),

2) Most sensitive to temperature (fine-grained, wet calcite) or relative humidity changes,

3) Most easily destroyed by physical impacts, especially those on the floor or low ceilings (conulites, moonmilk, broomstick and sand stalagmites, bottlebrushes, filiform helictites, vermiculations, mud cracks, hoodoos, spitzkarren, , and thin ribs, rims, and rimstone),

4) Removable items (cave pearls, sparkly sediments),

5) Features easily overlooked (speleogens from atmospheric corrosion, etc.), and

6) Rarities (quartz boxwork, flexible and subaqueous flowstone, calcite-covered vermiculations, lizard skin popcorn).

Mineralogy: Simple field techniques can inventory mineral groups into broad distributions. Once this is done, critical samples can be x-rayed, etc. for more definitive determination. In the field, only small, detached minerals shall be tested and then put back. Calcite and aragonite fizz if 10% hydrochloric acid is added and can be scratched by a penny. Dolomite will fizz if powdered. Non-porous aragonite will sink in bromoform but calcite will float. Gypsum can be scratched by a fingernail, will not fizz, and dissolves in hot hydrochloric acid. Quartz will scratch glass and often is translucent.

Various minerals, when correlated with other features, are important in determining past cave enlargement and alteration. Sulfuric reactions may be associated with celestite, sulfur, endellite, secondary chert, cave clouds, folia, ramiform caves, and extensive atmospheric corrosion fill. Mixing zones may have spongework, high salts, and honeycomb erosion. Hydrothermal action is associated with sulfur minerals, barite, fluorite, logomites, metacinnabar, cupolas, and high geothermal gradients, although only a sulfur mineral (pyrite) appears present in Oregon Caves. Drought may be evidence by corbelled or broomstick stalagmites and efflorescences (gypsum, natron, halite, gypsum, iron/manganese crusts). Gypsum occurs seasonally in Oregon Caves while iron/manganese crusts may have resulted from a drier climate than what presently occurs.

Aside from breakage, staining, or removal, most human impacts on cave minerals are subtle, such as the transformation of calcite into aragonite from cave lights, the exposure and subsequent production of sulfuric aside from pyrite, and the gradual hardening of moonmilk from increased water flow or changes in temperature. Transformation impacts may be detected by an inventory of pseudomorphs, those minerals that have been altered but which still retain their original crystal form.

Sediments: Cave sediments can be dated paleomagnetically and can help identify prehistoric soils, surface and subsurface weathering and erosion rates, paleo-water flow direction, speed, and volume. Sediments can preserve fragile prints thousands of years old as well as serving as a source for ancient mud glyphs, etc. For inventory methods, see Irving and Bjornn (1985) and Stone (1986).

Cosmogenic nuclide dating (jokingly called “suntan dating”), derives its name from cosmic rays. Quartz is composed of silicon and oxygen atoms. When neutrons and muons from these rays hit silicon nuclei in rocks, one proton and a neutron may be knocked loose to produce an unstable radioactive isotope of aluminum (^{26}Al with a mean half-life of 700,000 years). If an oxygen nucleus is hit, four protons and two neutrons may be lost, creating a radioactive isotope of beryllium (^{10}Be, half-life of 2.2 myrs). ^{26}Al is produced six times faster than ^{10}Be. When quartz grains enter a cave, the inherited radioactive isotopes decay at different known rates and therefore changes in this ratio yield the time that both isotopes were no longer being produced, that is, no longer exposed to the sun. Because the aluminum isotope decays faster than that of the beryllium, the ratio decreases over time and has been used used to date sediment burial over the past 5 million years, much longer than thorium-uranium or radiocarbon methods. Cosmogenic nuclide dating is more complex than other dating because new radioactive elements are constantly being produced while a rock is exposed to cosmic rays. The aluminum and beryllium isotope concentrations are so small that only a very sensitive technique called accelerator mass spectrometry (AMS) can be used. Uncertainties in determining burial dating therefore commonly exceed 100,000 thousand years (Granger & Fabel 2002).

Sediments most critical for inventory and monintoring are those that are dry and in the path of walking humans. Lint deposition concentrates where air is moving upward, downward, through small, rough passages, or into large rooms. In fairly uniform and dry caves, the distribution of lint from the center of the trail can be measured by removing lint and then measuring a five-year accumulation.

Because of the lack of biological or weather changes, cave sediment compaction from foot traffic appears relatively permanent. Compacted sediments can concentrate runoff and subsequent erosion. They often have decreased particle size and will dry up faster during dry periods and thus increase dust being kicked up and deposited off the trail. This can increase radon hazards and, in extreme cases, directly decrease visibility in the cave and or indirectly by creating condensation fogs. Habitat for soil fauna may be lost as well. A rough estimate of the surface area of trail compaction can be had by measuring the depth of heel prints or the amount of pooling in a transverse perpendicular to a trail. Proper placement of both paved and unpaved trails can minimize the total area of compaction.

Paleontological resources are the only direct evidence of past life and as such are the basis for understanding the history of life on Earth and are an integral part of our planet's biodiversity. These resources are preserved as fossils which are any remains, trace or imprint of a plant or animal that has been preserved by natural processes in the earth's crust.

Fossils are associated with subsurfaces primarily in two ways. They may be an intrinsic part of the rocks especially marine sediments such as limestone or dolomite, in which the cave is formed or they may be intrusive, having secondarily accumulated in cave passageways. Both fossil types occur in Oregon Caves. With regard to the second association of fossils with caves, caves often provide the only means of preservation of fossils in a region, especially places that do not act as areas of sediment accumulation. This is especially true of mountainous areas such as the Monument that do not have many areas of sedimentation, such as a lake. As with other areas, the remains preserved in these caves may provide information on the presence of species, both plant and animal, and the past ecology of the area that might not otherwise be available.

In some caves with sediments in passageways or rooms, tracks may be preserved, as is the case with Oregon Caves. All caution shall be taken to ensure that traffic through these areas does not disturb or destroy the tracks. Tracks often will be in the same part of the cave floor that cavers would normally traverse.

Collection and removal of fossil material from subsurfaces should follow as closely all procedures outlined in NPS-77 for other fossil material with proper collection and documentation.

Given the special circumstances that exist in subsurface environments, there are times when removal of fossil resources is paramount for their long term protection and care. As noted on page 157 of NPS-77, protection may also include, where necessary, the salvage collection of threatened specimens that are scientifically significant. In a subsurface environment some of the circumstances that may threaten a specimen include:

1. Caves often have narrow passageways that permit only limited room to maneuver. Because of the limited nature of these passageways, the remains of animals are often found in the only available route for movement through the cave. Fossils in this position are susceptible to damage by cavers walking or crawling through this passageway. The limited light available and inexperience in recognizing paleo-resources also enhances the possibility of damage to the specimen. In such circumstances administrative closure of the passage and/or proper collection of the fossils and removal from the passageway are imperative for their survival.

2. Fossil material often occurs loose on the surface of passageways. When noticed as to its nature often this material is picked up and moved to the side in order to "protect" it thus removing if from its original context. Small specimens may be moved numerous times, separated from related specimens, and eventually may be lost or stolen. Improper handling can also result in breakage to the specimen. Specimens such as this are particularly vulnerable and shall be properly collected, mapped, documented and placed in the park collections.

3. Fossils often accumulate in cave passages due to the action of water. Active streams in caves or streams that are seasonally active may uncover fossil material or bury material. Stream passages that are seasonally active have the potential to remove specimens or transport them to other portions of the cave system. Although a specimen could remain in a particular stream for long periods of time, an unusually wet year or higher than usual runoff into the cave may result in the loss of the specimen. Proper collection and documentation of the specimen shall be considered.

Sediments that accumulate in caves may include the remains of small vertebrates or invertebrates, both of which may be important for understanding the local ecology. These remains may include animals living in the cave, for example, bats, or may be the remains of prey brought in by predators such as owls. Deep sequences of sediments may preserve a significant portion of time that documents ecological changes in the vicinity of the cave. Recovery of these small vertebrate and invertebrate remains may require the removal of bulk sediment samples for processing. Screening can help sort out bones that are somewhat larger than the silty sediments in which they commonly occur.

Given soil acidity, thin soils, and rapid erosion in the Monument, there is limited potential for fossils to be found in subsurface areas other than caves. In all circumstances, though, the collection, removal and documentation of important specimens shall be conducted under the auspices of a professional paleontologist, working in conjunction with the park's cave natural resources specialist.

<u>Temperature</u> changes result largely from airflow and, to a lesser extent, from water flow changes. Increased temperatures in subsurface water could reduce oxygen levels and spread diseases among macroinvertebrates. Compared to surface cousins, some aquatic troglobites have increased sensitivity to temperature fluctuations. Higher air temperatures near lights can alter calcite to aragonite. If sufficient organics are present, Ph and oxygen levels would decrease and calcite solution would increase.

An increase in the precipitation ratio of a common isotope of oxygen with 8 neutrons to a rarer isotope with 10 neutrons increases during warm climates because the lighter molecule evaporates more easily from warm ocean water and becomes part of precipitation. Assuming there is no further evaporation in the cave, as appears to be the case in Oregon Caves (Vacco 2003), prehistoric temperatures can then be determined by the ratio of oxygen isotopes in flowstone. Paleotemperatures can be corroborated with the amount of deuterium in fluid inclusions (Gentry et al. 2002) as well as comparison with temperatures values inferred from pollen, marine, and ice core records.

Drilled bedrock in deep subsurfaces also can record long term temperature fluctuations. Paleotemperatures are important in understanding how and where current global climate change is affecting cave temperatures and therefore should be included in a study of such change.

<u>Vandalism</u>: An inventory should include a count of broken formations, regrowth measurements, classifications of breakage, and a photo and video documentation of a cave's formations and artifacts (Benson, 1983; Frantz, 1990).

Broken formations can be marked with whatever material will adhere to wet speleothems, not wash off, and not introduce significant amounts of material foreign to the Caves. A broken formation count shall be conducted every two years after the initial one is completed. Only after two to three surveys is there a fairly accurate and complete baseline. Surveys shall be done with headlamps since having tour lights on will most likely result in only partial coverage. A minimum size of broken formations is chosen, below which the breakage is not counted. Small, broken formations, such as popcorn, will be inventoried in groups. The diameter of the groups to be counted will vary from cave to cave but usually averages a few inches.

Vistas are measured using a system of fixed photopoints and/or videopoints established at selected sites within the Cave. Each site is marked with an unobtrusive identification tag and inventoried as to the nearest survey point. Distance and orientation to the nearest survey point and azimuth and declination to which the camera is pointing, exposure information, and height of the camera from the ground will be recorded. Phototransects shall be repeated every two to ten years, depending of the parameters measured, visitation levels, or documented resource degradation.

Even with this information, a slide from a previous inventory will have to be taken in order to position and frame the camera accurately. These photos and videos provide comparative qualitative and quantitative data for any resources visible within the photograph. ASA 25 speed color slide film and a 50mm fixed lens and the same flash unit will be used. The adequate f-stop will be established and two identical shots taken of each photopoint every five years. Alternating negative and positive transparencies and then combining them would indicate that nothing has been added or taken away from an area if the combined transparencies are totally black.

Water: Wherever water-borne pollutants constitute a threat to subsurface resources, a watershed approach is usually best. Useful data sets include synoptic and flood pulse water quality sampling, correlative biomonitoring of these same waters, and acquisition of land use and demographic data for each drainage basin. Synoptic refers to sampling at a fixed calendar date and time regardless of conditions. Information is needed from surface headwaters, cave waters, resurgences, and base-level streams wherever applicable. Even data from larger nearby watersheds, especially those that incorporate the Monument’s drainage offers useful comparisons and suggestions on what data collection to focus on. Design of a water quality program is covered by Flora (1984), Land Manager's (1991), Sanders, et. al., (1983), Smillie (1982), and Stednick, (1991), and US EPA (1986). Chemical methods are reviewed by US EPA (1983). The use of fixed stations versus intensive surveys is covered by Van Belle and Hughes (1983).

Subsurface aquatic systems are especially vulnerable to alteration by people and include indices of change relatively easy to measure. Ions, turbidity, pH, temperature, discharge, and other parameters likely to be altered by human activity shall be monitored periodically where feasible to quantitatively measure any change. The growth of cave features can be affected by temperature, evaporation, aerial deposition, pollution, flow routes and flow through times. Because karst conduit waters show great variability in quality and discharge over time, more than one yearly cycle needs to be inventoried. Mammoth Cave uses an "on five year-off two year" schedule of synoptic sampling.

Of critical importance is the solubility index. This index measures to what extent the water is dissolving or precipitating minerals. In the Cave and in many other areas, this often is a delicate balance and may shift depending on seasonal, climatic, and waterflow changes. Temperature, pH, and major ions (calcium, magnesium, and sometimes sulfate, chloride, sodium, and iron) should be inventoried in order to calculate the solubility index.

Once subsurface waters have been grouped by their ion content, pollution, etc. a relatively easy and inexpensive method can be used to monitor future changes, such as the measurement of both pH and TDS. If any major deviation of a particular water "signature" occurs, such as the pH/TDS graph point of one type of subsurface water occurring in the point cluster of another water type, then a full analysis of major ions, total organic carbon, and long-chain hydrocarbons shall be done to determine where the source of the change. If long-chain hydrocarbons are detected, the more impacting polyaromatic hydrocarbons shall be searched for. Biodiversity can also be used to measure pollution intensity (Verma, Sharma, and Goel, 1987).

Water temperature is a low-cost method of monitoring transport times and locating contaminants. A water temperature close to that of input sites would indicate rapid transfer and flow rates, a common result of human impacts on the surface.

If the original size of entrances cannot be determined, inventorying water and pool speleothem levels of pools both near and distant from cave entrances may help determine prehistoric relative humidity and water levels and the size of entrances at that time. Adjacent evaporimeters and analysis of the specific conductance of pool water and associated drips can help determine evaporation rates.

Diffuse seepage usually occurs along bedding planes, as dry season inflow from sediments, and in proto-caves. Conduit flow occurs in cave streams, in vadose shafts, and through vertical joints, normal faults, etc. There is no sharp division and flow rates along the same path can change to either type depending on the season and rate of water flow. However, the more the water table follows surface contours the more likely water moves by diffuse (slow) seepage.

Flow rates can be determined by dye tracing, dissolved ion concentrations, and matching peaks in surface precipitation with peaks in speleothem drip rates. Location of flow can be determined by cave exploration and by more indirect methods for non-cave areas.

Waterflow creates an electric current whose potential gradient is proportional to the driving pressure. The voltage distribution on the surface corresponds to the horizontal component of the underlying waterflow. Mapping the natural-potential field so generated can map waterflow. A positive natural potential may indicate downward waterflow. A negative may indicate upward evaporation. Contour lines of increasing magnitude may indicate the direction of horizontal waterflow (Lange, 1993). Simultaneous vertical and horizontal resistivity monitoring has been used to trace an injected electrolyte solution to confirm predicted flow paths and flow rates (Fish et al., 1987).

Tracing studies need to be carefully designed in diffuse flow regimes as traces of dyes can contaminate or invalidate future studies for several decades. Only dechlorinated water shall be used both in diluting the dye and in "chasing" it if a dry site is used for injection. Charcoal packets placed throughout the cave can serve as passive detectors, providing a non-quantitative indicator of the areal extent of dye movement. Mammoth Cave has developed continuous flow quantitative dye detectors.

Helium, fluorescein, rhodamine WT, Tinopal CBS-X (a fluorescent brightener), and lycopodium spores in that order probably have the least impact on subsurfaces especially if they are below 100 parts per billion. All mixing and calibration equipment shall be separate from the area used to test for dyes. The lab shall be checked with UV light after every use and kept clean. Incandescent lighting reduces photodegradation of most dyes although all diluted dyes should be stored in complete darkness.

The sharpness of the drip rates and dissolved ion peaks is partly determined by how faster water flows through rock cracks. Sharpness and short-lived events can only be discerned by continuous measurement, such as with the use of dataloggers and tilt buckets. Because of great variation in individual drip rates, area coverage using plastic tarps can be used. They shall be changed as needed to prevent bacterial buildup.

Paleoflow directions can be determined by the orientation of bones, flat pebbles and cave scallops. Paleoflooding can be estimated from the extent and number of bevels and atmospheric corrosion rills.

Concentration of flow from buildings and parking lots can excavate infilled caves and cause land subsidence. Concentration of flow into a small dam and off of the main parking lot of the Monument, as well as cut and fill development in the 1920s, likely contributed to slope failures in the 1950s, 1960s, and 1990s.

The natural range of water tables, drainage basins, inputs, probable flow routes, and discharges should be established. Establishing water budgets can help in each basin in determining components of the water yield, the runoff from a drainage basin. Precipitation, known karstic flow and now evapo-transpiration can be directly measured or at least modeled so that interstitial leakage, unknown karstic flow, and/or residence times can be calculated. Aerial photographs can be studied to locate lineaments (straight lines) that might indicate the fastest flow rates. The Monument now has Lidar (laser) data that may show such features as well as correlations with bedrock geology, soil zones, and vegetation patterns and how all of these may affect the subsurface.

Human-caused changes in waterflow rates, timing, duration, and levels can cause erosion, reduction of habitat from siltation and relative humidity changes, reduced organic input from floods, etc. A combination of quantitative dye tracing with flood pulse water quality sampling can identify point and nonpoint pollution sources and discern their individual contribution to the overall contaminant load. No dye tracing has show substantial contaminants in the Cave's subsurface but this does not mean that none will occur in the future. As subsurface basin divides in karstic terrain typically do not correspond to surface divides, locating the divides is important in influencing local or regional land use.

Once the natural range and comparisons with more pristine caves/above surface areas has been determined, more effective mitigation can begin. Prescribed fires, manual cutting of brush, or soil catchment devices above caves can restore waterflow amounts and timing lost as a result of fire suppression (Agee 1991), forest conversions, or soil erosion. Any major mitigation effort should be monitored for its own effect on the subsurface.

Flood pulses can be the primary flow mechanisms that transfer pesticides, coliform bacteria, suspended solids, and naturally occurring heavy metals. Heavy metals can be absorbed onto organics or clay particles especially during times of high turbidity and contaminate stream sediments for decades (Martin and Coughtrey, 1982). Particulate matter can also transport organic contaminants as well. An increase in turbidity (cloudiness) can predict an approaching flood pulse.

Chloride is an inexpensive test which may indicate the presence of oil field brines, road salts, urination, algae spraying, sweat on handrails, or other sources. Ratios of chloride to other ions such as potassium and sodium can help pinpoint the type of pollutant. For example, if high chlorides and sulfates are found without high bacterial counts then oil field brine contamination is suspected. A topical survey would then be initiated with expanded parameters such as bromide and additional sites temporarily added to identify the source(s). High sulfates and low chlorides may indicate natural dissolution of sulfate minerals if the mass flux is relatively constant, and high chlorides with low sulfates may indicate contamination by road salt or sweaty hands. Chloride concentrations taken both in rainfall and in the subsurface can give rough measures of evapo-transpiration.

Nitrate-nitrogen values can be a useful predictor of human-caused additions of nitrates to water. A high nitrogen-nitrate concentration indicates a high nutrient load, which, depending on other parameters such as bacterial counts, may be from septic waste or fertilizer sources. Dissolved nitrogen should have priority in monitoring as it is more important than nitrogen-rich particulates both in biological uptake and reactivity with other ions. The same is true for most if not all limiting nutrients.

Fecal streptococci bacterial test results are used in ratio with fecal coliform to differentiate between human or animal pollution of the water. A fecal coliform/fecal streptococci ratio (FC/FS) of 4.0 or greater indicates pollution derived from human wastes, and a value of .7 or less indicates pollution from livestock or other animal wastes. A FC/FS between 2 and 4 suggests the predominance of human wastes in mixed pollution, and a ratio between .7 and 1.0 indicates primarily animals waste in mixed pollution (Olsen, 1993). A high concentration of orthophosphates also indicates contamination from concentrated human or other animal wastes, as in leakage of effluent from pig or chicken holding ponds.

DNA and protein analysis can be used to address a large number of resource concerns, such as the relationship of one organism to another, whether gene flow is occurring, whether a species has reached a genetic bottleneck and therefore is vulnerable to extinction, whether a species is a species complex, etc. Generally, the more detailed the questions, such as the time of divergence of two populations or whether a population constitutes a separate species, the more costly the procedures.

If a sample indicated that human wastes may be present, microbial source tracking, such as developed by Dr. Mansour Samadpour from the University of Washington, would be used to determine the origin of bacterial organisms such as fecal coliform and E. coli. However, DNA studies need not only be used in identifying species. For example, small cave species with high DNA variability suggests that they may perceive the environmental patchiness as coarse grained and therefore differentiate genetically side by side because there is such a high density of different habitats (Sbordoni et al. 1994). Management therefore must be especially careful that human impacts does not destroy or blur such differences in habitats.

DNA and microscopes are not always needed to determine major microbial groups, especially in caves where single bacterial groups may be dominant in any one area. Sight and smell can give clues to such groups. Flammable, odorless gases usually result from bacteria and archaea that give off methane. Sulfurous smells indicate bacteria that use sulfur. A salty smell with pink crusts indicate halophilic (salt loving) bacteria. Thick, smelly cave crusts are often from fermenting bacteria and, in the absence of sulfur, is often a sign of human-cause contamination. Black crusts of iron and manganese involved bacteria that oxide these elements. “Caver’s perfume “ is a sweet smell associated with actinomycetes bacteria in caves and soils.

VII. **REVISIONS TO PLAN**

Changes in this plan may be approved by the Regional Director upon recommendation by the Superintendent. The only exceptions to this procedure are: (1) grammatical corrections, (2) page numbering corrections, (3) deletion, correction or addition of sections in the appendices, (4) correction of the table of contents, and (5) addition of new computer file names. Offices maintaining copies of the plan will be promptly notified of any change. Revised pages will be dated in the lower right-hand corner of the page. Changes requiring the Regional Director's approval will be submitted with a new cover sheet for signature and dates, which will replace the existing cover sheet upon approval.

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GLOSSARY Notes: Words outlined in bold are defined elsewhere in the glossary.

accreted **terrane** – a very large mass of rock at least several kilometers across which has been **tectonically** emplaced by **faulting** or **crustal** plate movement onto a large rock mass such as a continent.

Accretionary wedge – Highly distorted sediments and rocks squeezed up against buoyant rock (usually a continent) by **subduction** but which are not **subducted** completely because the material is too lightweight to be dragged down completely.

Acid dew – Also called condensation-corrosion. - Warm, moist air rising in a cave from the **geothermal** or other temperature gradients condenses on colder surfaces and, by absorbing CO2, dissolves ceilings, walls, and cave formations. Common in large vertical caves, hydrothermal caves, caves with sulfuric acid, near entrances, where warm and cold air masses mix (fogs) and where warm surface streams enter caves.

Adaption – adjustment of organisms to their environment that involves development of new or better functioning structures or other improvements.

aerial **fuels:** All live and dead vegetation in the forest canopy or above surface fuels, including tree branches, twigs and cones, snags, moss, and high brush

Aerosol sinter - a hardened crust or coating of calcareous dust.

agency - Any federal, state, or county government organization participating with jurisdictional responsibilities.

allogenic or allochthonous stream or drainage - Surface drainage coming off of non-karst, as in the case of Oregon Caves.

alluvial corrosion - Where greater intensity of solution is caused by water moving through sediments rich in CO2, thus increasing the ability of the water to dissolve carbonates, as in the case between the Rimstone Room and the Ghost Room and in the Wedding Cake Room.

alluvium - Any sediment deposited by stream, ocean, or river. Pebbles are usually rounded, unlike angular **colluvium**

alpine **karst** - Formed in areas of high altitude and relief. Similar to arctic karst but may have more kotlic sinks, etc. from greater snowfall.

apron - A smooth bulging mass of **flowstone** covering sloping projections from walls of caves (as in Paradise Lost) or limestone cliffs.

aspect - direction toward which a slope faces.

backflooding or back-flooding - Temporarily rising water level in a cave caused by downstream passage being too small to pass an abnormally high discharge. Creates bevels, clastic deposits, dead end passages, genetic flow, and possibly rills.

Baldacchino **canopy** - One formed when downward growing flowstone meets a water surface.

basalt – a dark-colored fine-grained extruded volcanic rock, rich in iron and magnesium, that is chiefly composed of the minerals plagioclase and pyroxene.

bedding plane – in **sedimentary** or stratified rocks, the division planes which separate the individual layers, beds, or strata. Cracks within them are normally created by the release of pressure when adjacent rocks are eroded.

bedrock – Primary in-situ rock as opposed to secondary deposits like **speleothems**, **talus**, etc bell **canopy** – a variety of canopy which is shaped like a bell or mushroom and which forms where flowstone builds up laterally as well as vertically.

bevel – Horizontal **channel** indentation more than 3" high in walls. Develop where **vadose** standing water with an open air surface absorbs carbon dioxide and therefor corrodes faster than water further below.

bladed **popcorn** – Cave popcorn that has arranged in the same orientation and which appear as dull blades.

blow-up - A sudden increase in **fire intensity** or **rate of spread** strong enough to prevent direct control or to upset control plans. Blow-ups are often accompanied by violent convection and may have other characteristics of a **fire storm**. (See **Flare-up**)

boxwork – minerals which originally formed as blades or plates along cleavage or fracture planes and then the intervening material dissolved leaving the intersecting blades or plates as a network projecting from the floor, wall, or ceiling.

braided stream - One with interlacing networks of channels separated by branch islands or bars. Often the result of a stream with a high sediment load. Oregon Caves most resembles three-dimensional braided surface streams and tend to form under conditions of high **hydraulic head,** short cave evolution times and short expanses of soluble rocks, conditions often present in temperate mountains.

breakdown - 1. Angular cave **detritus** > 10 cm. wide fallen into a cave room. Includes. block (ceiling, wall), chip, chockstone, congelifract, loose, rafted, room, and slab (ceiling, wall).

breakthrough - The great increase in erosional rates from the change from laminar to turbulent flow. Breakthrough time is how long it takes for a conduit to enlarge enough to begin turbulent flow. 10,000 to several million yrs. depending largely on length, hydraulic gradient, and initial width of cracks. It probably was fast in Oregon Caves, from 10,000 to several hundred thousand years.

breccia - a sedimentary rock formed of angular fragments of older rock and cemented together by minerals or by a fine-grained matrix. A meta-breccia is one that is metamorphosed.

calcite – calcium carbonate, $CaCO_3$. Major mineral component of limestone and marble.

calcareous - Containing calcium carbonate (CaCO3).

canopy – 1. The heights in a forest with the most leaves. A multi-storied canopy has different elevations where leaves are concentrated. 2. a subtype of flowstone where material projects laterally away from a cave wall or other speleothem. The overhanging flowstone could have formed on sediment now removed (some fill may be imbedded underneath), by meeting a water or ice surface (baldacchino canopy).

carbon dioxide - CO2, a gas usually from double to fivefold (500 to 1,500 ppm) in caves compared to the surface. Concentrations can also increase during a fire although the production of carbon monoxide during some fires is much more of a hazard.

carbonate - 1. Mineral with the anionic structure of CO3-2. Incl. **calcite**.

capacity, carrying - Limit of human activities beyond which the system irreversibly changes

Categorical exclusion (CE) - an action with no measurable environmental impact which is described in one of the categorical exclusion lists in section 3.3 or 3.4 and for which no exceptional circumstances (section 3.5) exist. NPS also uses the acronym “CX” to denote a categorical exclusion.

cave – 1. a natural subterranean cavity, fissure, or tube which is person-sized or larger and which extends past the twilight zone.

cave bacon – a variety of thin, translucent drapery with parallel color banding.

cave breathing - Periodic microscale and mesoscale wind changes that most often occur in constricted passages. Some occur from surface atmospherics, from waterfalls in a cave, or possibly from wind blowing across entrances or from gravity acoustic waves (55-70sec.) of auroral type originating in the ionosphere or by the jet stream (6-30 minutes) (Lewis, 1981).

ghost, cave - **Speleogen** caused by aqueous or condensation corrosion of speleothem. Usually opaque, chalky if by condensation corrosion (Watson's Grotto), more translucent (just before Ghost Room) if by renewed aggression from dripping or flowing water.

cave crust – See crust

cave popcorn – a nodular variety of subaerial coralloid.

cement - Precipitated material that holds adjacent grains together. Cement changes a sediment into a rock during lithification.

CFR – Code of Federal Regulations.

channel, (solution) - 1. Incised **karren** slots > 50 cm. wide. Narrower ones are **rills** or microrills. Incl. **anastomoses,** canyon, ceiling, chute, **meander, and notch (bevel)**.

chert – Hard, very dense or compact **sedimentary** silicate of quartz crystals < 30 microns wide.

chimney - 1. A narrow, rounded, vertical or sub-vertical shaft or small **domepit** in the roof of a cave, generally smaller than an aven or dome pit and traversible by chimneying. A blind chimney does not reach the surface.

clastic - Pertaining to a rock or sediment mostly made up of clasts (rock fragments) that have been moved some distance for their place of origin.

clay - **Sediment** composed of particles of any composition (often a crystalline fragment of a clay mineral) < 1/256 mm or .00016 inches. Particles above this size generally do not form colloids. Clay smears and doesn't feel gritty in hand or on teeth.

colluvium - Any mixed **sediment** of soil material, cave **fill** and/or rock fragments deposited by rainwash, sheetwash, or creep

concretion - Concentric-layered rounded rock that is chemically precipitated in **sedimentary** bedrock. Often flattened in the same orientation as adjacent bedding planes due to faster water flow in that direction and subsequent faster precipitation and growth.

conduit - 1. Tubular voids >10mm in diameter or 100mm -10m. Smaller voids are sub-conduits. Sometimes the term only refers to karst conduits or is restricted to water-filled voids. 2. A subterranean stream course filled or once filled completely with water and under water pressure. Usually circular or elliptical in cross-section with the longest dimension parallel to bedding, as is often the case in Oregon Caves.

congelifract - Talus split off by frost action. A type of **felsenmeer**.

conglomerate - **Sedimentary** rock of rounded, waterworn fragments of rock or pebbles, cemented by another mineral. Cemented cave **fill** cannot be pulled apart with fingers.

contact - The junction of two different geologic **formations** or units, as in **bedding planes,** and the meeting of igneous and sedimentary rocks, or layered sediments. Most contacts in or adjacent to carbonate deposits are often preferentially penetrated by groundwater.

contact spring - Gravity spring where water flows to the land surface from permeable strata over less permeable or impermeable strata that prevent or retard downward moving water, as appears to be the case with the River Styx.

contain a fire – A fuel break around the fire has been completed. This break may include natural barriers or manually and/or mechanically constructed line.

coralloid – a **speleothem** type which is nodular, globular, botryoidal, or coral-like in shape and which forms from thin films of water. Cave **popcorn** is a rounded, microcrystalline coralloid that forms above the water saturated zone. Subaqueous coralloids form underwater but are not common in Oregon Caves.

corrosion - Erosion where rocks and soil are removed or worn away by natural chemical processes.

corrosion **bevel** - Corrosion notch or **bevel** extending several meters into the rock. Creates a flat roof regardless of geologic structure. Assoc. with the **foot caves** of karst **towers** abutting alluvial floodplains or, as in Oregon Caves, at the base of cliffs.

corrosion notch - 1. Any substantial indentation in cave walls or cliffs. Incl. waterline notches, corrosion bevels, vadose wall notch, paragenetic wall notch. 1. Bevel in cave walls tapering off very steeply below a past or present waterline.

crust – the outermost shell of the earth above the mantle.

crust, (cave) - Flowstone (mostly) or other speleothem usually < a few cm. thick. In general, rougher, flakier, and more brittle, porous and granular than a coating.

crystal - A substance with a regularly repeating atomic pattern often expressed by plane faces, as in minerals. Recrystallization into larger crystals is common in wet speleothems.

cultural resources - Aspects of a cultural system that arevalued by or significantly representative of a culture or that contain significant information about a culture. A cultural resource may be a tangible entity or a cultural practice. Tangible cultural resources are categorized as districts, sites, buildings, structures, and objects for the National Register of Historic Places, and as archeological resources, cultural landscapes, structures, museum objects, and ethnographic resources for NPS management purposes.

cumulative actions - Actions that, when viewed with other actions in the past, the present, or the reasonably foreseeable future regardless of who has undertaken or will undertake them, have an additive impact on the resource the proposal would affect.

cumulative impact - The impacts of cumulative actions.

curing - Drying and browning of herbaceous vegetation or slash.

detritus - Sediment of loose rock/minerals eroded off by mechanical means.

diffuse flow - Slow circulation of groundwater in **karst** aquifers where all, or almost all, openings in the **karstified** rock intercommunicate, are full of water in the saturation zone and are not big or permeable enough to allow conduit flow. Being replaced by term “slow flow.” Probably occurs in Oregon Caves only in very narrow vertical and bedding plane cracks.

dike - A tabular intrusion structure that cuts across the bedding or foliation of the surrounding bedrock. Dikes with positive relief from differential solution are **petromorphs**.

direct effect - An impact that occurs as a result of the proposed action or alternative in the same place and at the same time as the action.

directional popcorn - Points in direction of airflow.

DO – Director's Order, a segment of NPS policies and regulations.

dog(-)tooth spar - Sharp-tipped scalenohedral **calcite** crystals. Forms in Oregon Caves cave **velvet** in high humidity.

domepit – in a cave, a rounded vertical passage or high chamber, characterized by vertical solution grooves on its walls and usually by showering water.

drapery – Often called cave drapery. Curtainlike, linear **flowstone** from water droplets running down walls or ceilings. Often wavy or folded. May have a web-like attachment to **stalactites**.

dripstone - **Speleothems** deposited by dripping water. They usually result from **mineral** deposition due to loss of carbon dioxide or water (evaporation) but they include frozen deposits like ice but not volcanic frozen deposits like lavacicles.

DOI – Department of the Interior

EA – See environmental assessment.

efflorescence - A whitish fluffy or crystalline **crust** on rock or soil where surface or wicked water is evaporated and solutions crystallized.

EIS – See environmental impact statement

El Nino - As a weather cycle characterized by unusually warm ocean temperatures in the Equatorial Pacific, compared to La Nina, is characterized by unusually cold ocean temperatures in the Equatorial Pacific.

environmental assessment (EA) - A brief NEPA document that is prepared to (a) help determine whether the impact of a proposed action or alternatives could be significant; (b) aid NPS in compliance with NEPA by evaluating a proposal that will have no significant impacts, but that may have measurable adverse impacts; or (c) evaluate a proposal that either is not described on the list of categorically excluded actions, or is on the list but exceptional circumstances apply. EAs are concise, analytical documents prepared with public participation that determine if an Environmental Impact Statement (EIS) is needed for a particular project or action. If an EA determines an EIS is not needed, the EA becomes the document allowing agency compliance with NEPA requirements.

environmental impact statement (EIS) - A detailed NEPA document that is prepared when a proposed action or alternatives have the potential for significant impact on the human environment. Prepared with public participation, they assist decision makers by providing information, analysis and an array of action alternatives, allowing managers to see the probable effects of decisions on the environment. Generally, EIS's are written for large-scale actions or geographical areas.

environmental screening process - The analysis that precedes a determination of the appropriate level of NEPA documentation. The minimum requirements of the environmental screening process are a site visit, consultation with any agency that has jurisdiction by law or special expertise, and the completion of a screening checklist. The process shall be complete for all NPS actions that have the potential for environmental impact and are not described in section 3.3.

environmentally preferred alternative - Of the action alternatives analyzed, the one that would best promote the policies in NEPA section 101. This is usually selected by the IDT members. CEQ encourages agencies to identify an environmentally preferable alternative in the draft EIS or EA, but only requires that it be named in the ROD.

escape route **-** A preplanned and understood route firefighters take to move to a safety zone or other low-risk area, such as an already burned area, previously constructed safety area, a meadow that won't burn, natural rocky area that is large enough to take refuge without being burned. When escape routes deviate from a defined physical path, they shall be clearly marked (flagged).

epiphreatic **-** Adj. for water moving through intermittently or seasonally saturated or floodwater zones above the phreatic zone.

erosion – the group of processes whereby earthy or rock material is loosened or dissolved and removed from any part of the earth's surface. It includes the processes of weathering, solution, corrosion, and transportation.

erratic speleothem **-** 1. Syn: eccentric. 2. Where forces of crystal growth, airflow, or capillarity dominate over gravity-driven vertical growth.

etchpits **-** Small, usually circular, holes one mm. to several cm. wide. **Pitting** commonly assoc. with atmospheric corrosion if on bedrock and with splashing corrosion if on flowstone. Incl. **drop dent** and **solution pit**.

exfoliation **- Erosion** of broken or peeled-off scales, lamellae, as concentric sheets from bare rock surfaces. Exfoliation **detritus** from frost action forms **felsenmeer**.

extirpated species – Those species which are not extinct but which no longer occur in a specific area.

facetten **-** Inclined walls with a slope of about 45 degrees. Standing **phreatic** water features formed by slowly moving cells of density-driven currents. A 1-3 mm layer of relatively denser water forms above rock surfaces and flows downward at about .5 cm./s to create flow cells.

fault – a break in the earth's crust along which movement has taken place. conjugate joints or faults are two sets formed as a result of the same stress, especially shear pairs.

fault breccia **-** A **tectonic** breccia of angular fragments from the crushing, shattering, or shearing of rocks during **faulting**, from friction between the walls of the fault, or from distributive ruptures assoc. with a major fault.

fault gouge **-** Materials generally composed of clay sized particles along a **fault**. Usually the result of movement along fault surfaces but may result from hydrothermal alteration because faults enhance movement of such fluids.

faller **-** A person who fells trees. Also called a sawyer or cutter.

FCRPA – See Federal Caves Resources Protection Act

See Federal Caves Resources Protection Act (FCRPA) – Law that exempts cave managers from revealing cave locations via FOIA requests and which calls for protection, inventory and monitoring of caves but does not specify associated protocols, etc.

felsenmeer **- Detritus** rubble produced by frost shattering.

flowstone – **Speleothem** or non-cave chemical sedimentary deposit formed by flowing or seeping water as hard coatings or cascades.

flowstone welt **-** Apparently from junction of different waterflows, commonly where stalagmites and stalactites join into columns.

foot caves – Those that form at the base of cliffs because of concentrations of acidic soils and vegetation there.

formation – 1. stratigraphically, the primary unit in lithostratigraphy consisting of a succession of strata useful for mapping or description generally possessing distinctive lithologic features. 2. speleographically, secondary deposits in a cave forming stalactites, stalagmites, etc., best prefixed with cave so as to avoid confusion.

General Management Plan - Also referred to as the GMP, it is the document that has gone through the NEPA document as an EIS and which outlines management actions for a National Park Service area for a 20 year period.

geothermal gradient - The rate of increase of temperature in the Earth with depth. High gradient areas are more likely to have caves of **hydrothermal** or lava tube origin.

GMP – See General Management Plan

gour - Includes **rimstone** dam and **microgour**. Syn.: rimstone pools.

gradient - The change in **hydraulic head** over a given distance with groundwater flow usually occurring in the direction of decreasing hydraulic head.

graphite – **Mineral** of native carbon, black to steel-gray, very soft. Its weakness probably helped cause faulting along bedding planes.

granite – a coarse-grained intruded rock that has a high percentage of **quartz** and potassium **feldspar**.

granitic – rocks that have similar compositions to granite, such as monzonite

half(-)**tube** - 1. Trace of a **ceiling channel** or **tube**. Most form during incipient speleogenesis.

helictite – a spleothem type which is twisted and worm-like, and which grows via a small capillary canal at its center.

heroic or charismatic species – Those which people generally like, especially large furry herbivores with large, vertical heads.

humic substance - Certain organics, usually acids such as fulvic and humic, derived from soil. Provide most color for speleothems. May be transported into speleothems as ligands binding calcium ions

hydraulic gradient – the difference in the free standing water level between one place and another. 1. The change in static head per unit of distance in a given direction. If not specified, the direction generally is understood to be that of the maximum rate of decrease in head. 2. The slope of the water table or potentiometric surface in an aquifer.

hydrothermal water - Subsurface water at least 4-6o C. hotter than mean annual temperature on the surface.

hyporheic – That area of sediment under running water such as in streams and rivers.
igneous – Rock that was once molten.

imbricated - Angle of flat pebbles, a **sediment** structure, like shingles on a roof, point downstream.

impact – Human actions that affect the environment.

impact topics - Specific natural, cultural, or socioeconomic resources that would be affected by the proposed action or alternatives (including no action). The magnitude, duration, and timing of the effect to each of these resources is evaluated in the impact section of an **EA** or an **EIS**.

indirect **impact** - Reasonably foreseeable impacts that occur removed in time or space from the proposed action. These are "downstream" impacts, future impacts, or the impacts of reasonably expected connected actions (e.g., growth of an area after a highway to it is complete).

inception horizon **-** That part of a bedrock sequence that passively or actively favors the localized inception of dissolutional activity. It is a geologic unit most susceptible to **speleogenesis**, especially to the earliest cave-forming processes. It is critical to the origin of many if not most nontectonic caves.

incised **flowstone -** Micro**karren** composed of dendritic meander **karren** or micro**rills** from flowing water re-solution.

infiltration **-** Discharge yield or downward entry of water through **sediment** or permeable rock.

initiation **-** The phase of speleogenesis that includes the initiation phase (which includes inception phase of laminar flow) and up to or the start of turbulent flow in the gestation phase.

invasion vadose **- Vadose** cave or cave passages created by new streams invading rock already drained during previous cave development. Incl. vertical shafts.

island arc – curved chain of islands, generally convex toward the open ocean, margined by a deep submarine trench and enclosing a deep sea basin.

JHA – See job hazard analysis**.**

job hazard analysis (JHA) **-** This analysis of a project is completed by staff to identify hazards to employees and the public. It identifies hazards, corrective actions and the required safety equipment to ensure public and employee safety.

joint – Generally more or less vertical or transverse to bedding, .parallel sets of **apertures**, cracks, fractures, or partings in bedrock with no sign of offset on either side of crack. Preeminent **structural** control on cave formation. Rectangular (often from tensional (pull-apart)forces) and 60/120 degrees (often from compressional or shearing forces) systems are most common.

K-selection – Refers to species that tend to have specialized habitats, long individual lifespans, few offspring, and prolonged parental care

karren **-** 1. Karstic solution grooves from a few mm. to about 10 or a few meters in width and which are separated by ridges. Larger features of this form are **karst**. 2. All small bedrock **corrosion** features in soluble rocks.

karst – a type of topography that is formed on limestone, gypsum, and other rocks by dissolution, and that is characterized by sinkholes, caves, and underground drainage. Surface karst is exokarst and subsurface is endokarst.

keyhole or keyhole passage **-** A small **passage** or opening in a cave; in cross section, rounded at the top, constricted in the middle and rectangular or flared out below. Usually the result of initial solution of water filled **conduits** at the rounded top and subsequent erosion of a slot by streams with an air surface.

keystone species – Those species who are important in sustaining the populations of other species.

La Nina **-** La Niña is a weather cycle characterized by unusually cold ocean temperatures in the Equatorial Pacific, compared to El Nino, which is characterized by unusually warm ocean temperatures in the Equatorial Pacific. During a La Niña year, winter temperatures are cooler than normal in the Northwest.

limestone – a sedimentary rock composed primarily of calcite.

litter **-** Top layer of the forest, scrubland, or grassland floor, directly above the fermentation layer, composed of loose debris of dead sticks, branches, twigs, and recently fallen leaves or needles, little altered in structure by decomposition.

lizard skin **popcorn** or **flowstone -** Bumpy (coralloidal) flowstone in which bumps are elongated in the direction of splashing, dripping or airflow that produces atmospheric corrosion and/or calcite deposition.

loess – Non-stratified silt, clay, and dust, originating as glacial sediment, but re-deposited by wind. Uniform, porous, slightly solidified, often highly calcareous aeolian dust (mainly silt) from desert basins or glaciofluvial sediments from newly glaciated areas. Grains usually are angular and so fit together enough so that vertical cliffs may develop, as in the case near the first Paradasie Lost platform, although this is not loess as it is loess redeposited by water.

long term - Impacts that last longer than one year.

losing stream **-** A stream or reach of a stream in which water flows from the stream bed into the ground. In karst terranes, losing streams may slowly sink into fractures (the case at Oregon Caves) or quickly disappear down a bedrock ponor.

luminescence **-** Emission of light by a substance that received a different wavelength energy externally. Dripstone and flowstone often give a bluish to greenish white light if excited by strobe lamps and UV. Calcite incl. calcium salts of fulvic acid (bright blue-green). Most from calcium salts of fulvic (lighter, brighter) and humic (darker, weaker, longer wavelengths) acids and lesser amounts of low-molecular weight organic esthers.

major – Impact would have a substantial, highly noticeable influence on the resource on a regional scale.

major federal action **-** Actions that have a large federal presence and that have the potential for significant impacts to the human environment. They include adopting policy, implementing rules or regulations; adopting plans, programs, or projects; ongoing activities; issuing permits; or financing projects completed by another entity.

manganese oxides **-** Ore minerals that can't be identified ID in field; **FMO** if charcoal-black, clay size, and has no odor. Often have some **iron oxides, calcite, quartz** and, less commonly, the mineral romanchite.

mantle – The layer of the earth below the crust, usually starts around 8-15 miles under oceans and 20 to 45 under continents.

marble – a metamorphic rock, mainly of calcium carbonate, that was derived from limestone. Usually coarser grained than limestone and of lower porosity, averaging less than 1%

maze cave - A complex pattern of repeatedly connected passages. Usually has or had less directed waterflow than branchwork or single-conduit caves.

meander - 1. Overdeveloped or self-exaggerated bend in a stream course or other channel either on the surface or underground, caused by more erosion on the outside than on the inside of a bend through natural wash of the flow. Commonly originate in caves as half-tubes along bedding-planes during protocave development.

meander niche **-** A crescent-shaped **alcove** on the wall of a cave; formed by stream erosion, as after the first River Styx bridge. Syn.: conical wall niche.

meandering runnel **-** Wavy or winding rain rill. Solutioning may or may not be from dripping water.

memo to file **-** A memo to the planning record or statutory compliance file that NPS offices may complete when (a) NEPA has already been completed in site specific detail for a proposal, usually as part of a document of larger scope, or

(b) a time interval has passed since the NEPA document was approved, but
information in that document is still accurate.

metamorphism – alteration of rocks in the earth's crust due to heat and pressure (the rock does not truly melt, if it did we would call it igneous).

microgours - Parallel and/or convoluted **flowstone** or **sediment** ridges less than 1/2" high. Usually on steep slopes.

microkarren **-** **Karren** from 1mm to 3mm. across and up to several cm. deep, usually with parallel runnels, or, less often, convergent or randomly intersecting **runnels**. Most common in areas of slow solution, as in deserts and periglacial areas. Probably due to overflow and concensation corrosion.

mid-ocean ridge – great median arch or swell of the sea bottom extending the length of an ocean basin and roughly paralleling the continental margins; one in the Atlantic is several hundred miles wide, very irregular topographically, and rises at some places to form islands.

minor – Impact to the resource is perceptible and measurable, but is localized. Minor impacts would not result in impairment of that particular Park resource.

mitigated EA - An EA that has been rewritten to incorporate mitigation into a proposal or to change a proposal to reduce impacts to below significance.

mitigation **-** A modification of the proposal or alternative that lessens the intensity of its impact on a particular resource.

mixed corrosion **-** Solution of carbonates from the mixing of two **saturated** waters that differ in CO2 partial pressure, as in domes, joint intersections, etc.

moderate – Impact is clearly detectable and could have appreciable effect on the resource.

Monument – Oregon Caves National Monument

moonmilk – a speleothem type consisting of white, finely crystalline clay which feels like powder when dry and cream cheese when moist. From Swiss dialect moonmilch, elf's or gnome's milk, as antibiotic activity was ascribed to magical little people. May result in Oregon Caves from **organic** activity such as from bacterium actinomycetes, and less often or likely, fungi or algae.

mutual aid agreement **-** Written agreement between agencies and/or jurisdictions in which they agree to assist one another upon request, by furnishing personnel and equipment.

mylonite - Compact, chertlike with streaking/banding from fault micro**breccia**tion.

NAAQS - National Ambient Air Quality Standards

National Environment Policy Act (NEPA**)** - NEPA is the basic national law for protection of the environment, passed by Congress in 1969. It sets policy and procedures for environmental protection, and authorizes Environmental Impact Statements and Environmental Assessments to be used as analytical tools to help federal managers make decisions.

National Historic Preservation Act of 1966 (NHPA) – An act of the US Congress that establishes guidelines and regulations associated with historic features and features that have the potential to be officially listed as historical.

negligible – The impact to the resource is barely perceptible, not measurable and confined to a small area. Negligible impacts would not result in impairment of that particular Park resource.'

neoteny – Refers to species with delayed sexual maturity, such as in humans.

NEPA process - The objective analysis of a proposed action to determine the degree of its environmental and interrelated social and economic impacts on the human environment, alternatives and mitigation that reduce that impact, and the full and candid presentation of the analysis to, and involvement of, the interested and affected public.

NHPA - National Historic Preservation Act

nodule - A small, irregularly rounded knot, mass, or lump of a mineral or mineral aggregate, normally having a warty or knobby surface and no internal structure, and usually exhibiting a contrasting composition from the enclosing sediment or rock matrix in which it is embedded. Most nodules appear to be secondary structures in sedimentary rocks; they are primarily the result of postdepositional replacement of the rock and are commonly elongated parallel to the bedding and show distortion of surrounding sedimentary layers, as is the case in Oregon Caves.

non-native - Those species and population sizes that would not be present in a particular area without the impact of past or present human activities.

normal fault - Where the hanging wall appears to have moved downward relative to the footwall. Usually from extensional tectonics and therefore more likely to develop into caves than can reverse faults.

notch, solution - Curved **bevel** incuts from decimeters in cross-section and meters in length. Usually occur where humic soils abut very steep or vertical carbonates, especially limestone. May enlarge into foot caves.

notice of intent - The notice submitted to the *Federal Register* that an **EIS** will be prepared. It describes the proposed action and alternatives, identifies a contact person in *NPS*, and gives time, place, and descriptive details of the agency's proposed scoping process.

notices of availability - Separate notices submitted to the *Federal Register* that the draft EIS and the final EIS are ready for distribution.

NPS – Acronym for National Park Service

ophiolite – A regular sequence of rocks formed during the formation of ocean crust, usually either in mid-ocean ridges or in back-arc basins. The deepest to shallowest rocks range from peridotites (depleted **mantle**), to **serpentine**, to sheeted dikes, to pillow basalts, to chert, to (in some cases) limestone.

organic - Material presently or once part of life forms and viruses or compounds normally produced by life forms but not necessarily derived from them (as in organics in meteorites).

Organic act – The law passed by Congress and signed by the President that established the national park system and gave it its primary mandates in managing the lands entrusted to it.

palette, (cave) - 1. A more or less flat protruding sheet of crystalline carbonate **petromorph** , usually a vein, that is spared during solution of the rock on each side of it.

paragenesis - **Phreatic** enlargement upward due to sediment armoring of floor.

paraphreatic - Adj. for a cave passage with an air surface under relatively low flow but which becomes completely water filled under high flow and/or when the downstream drainage is temporarily impeded.

partings - **Bedding** plane **apertures** between beds. Probably the third most important zone of weakness for cave enlargement in general but the most important one in Oregon Caves..

patina - A colored film or thin outer layer **crust** produced on the surface of a rock or other material by weathering after long exposure.

pendulous flowstone – Often with a droopy look, likely the result of clays, moonmilk, etc.

prevention **–**NPS term for activities directed at reducing human impacts before they happen.

pendant, (rock) - Vertical (90 to 45 degrees) **petromorph** often surrounded by anastomoses and projecting from a ceiling. Vertical section is >3 times longer than thickest dimension.

permafrost - Ground that is perennially below the freezing point of water.

petromorph - 1. A **speleogen** jutting out from bedrock because of differential solution.

phosphorescence **- Luminescence** in which the stimulated substance emits light after the external stimulus ends. Cave carbonate often displays green (sometimes blue) phosphorescence unless much iron, clays or organics occur.

phreatic – the major subsurface zone of water saturation.

phreatic loop - Where water dissolves passages around a blockage , common in dipping limestone with widely spaced bedding-related fissures, as is the case at Oregon Caves.

piracy, subterranean (stream) - Capture of a surface stream perched on soluble rocks and its diversion underground to an adjacent entrenched stream.

pitting - Rounded **cavities** up to ten cm. across. Often from splashing water on flowstone and atmospheric corrosion (deeper, more vertical pits) or other solution on bedrock.

pluton – a large mass of intruded rock below the earth’s surface.

pocket - 1. **Cavity**, less common on floor, or walls of a cave, shaped like a round-bottomed kettle, unrelated to pitting, joints, bedding, or potholes. Either length or width is less than six inches.

pothole - 1. Small, rounded cavity in floor flowstone or bedrock irrespective of origin.

powder, cave - A cave **fill speleothem** with crystals 10-50 microns. Over 100 minerals worldwide. Often caused by dehydration, less often by redox reactions and strong acid aggression. Differs from moonmilk in mode of formation and lack of plasticity.

preferred alternative - The alternative an NPS decision-maker has identified as preferred at the draft EIS stage. It may be the same as the initial proposal or proposed action, or it may be different. It is identified to show the public which alternative is likely to be selected to help focus its comments.

pressure, hydrostatic - The pressure exerted by the weight of water at any given point in a body of water at rest.

pressure solution – solution occurring preferentially at the contact surfaces of grains (crystals) where the external pressure exceeds the hydraulic pressure of the interstitial fluid. It results in enlargement of the contact surfaces and thereby reduces pore space and tightly welds the rock.

programmatic documents - Broader scope EAs or EISs that describe the impacts of proposed policy changes, programs, or plans.

proposal - The stage at which NPS has a goal and is actively preparing to make a decision on one or more alternative means of accomplishing that goal. The goal can be a project, plan, policy, program, and so forth. NEPA begins when the effects can be meaningfully evaluated.

pyrite - Pale-bronze or brass-yellow **sulfide**, FeS_2, often in the form of cubes. Assocaited with organics in carbonates or thin noncarbonate beds such as shales or coal. Oxidation with or without bacterial mediation releases sulfuric acid.

quartz - A **silicate**, Si02, the most common mineral after feldspar and commonly forms sandstones.

rate of spread - The relative activity of a fire in extending its horizontal dimensions. It is expressed as a rate of increase of the total perimeter of the fire, as rate of forward spread of the fire front, or as rate of increase in area, depending on the intended use of the information. Usually it is expressed in chains or acres per hour for a specific period in the fire's history.

record of decision (ROD) - The document that is prepared to substantiate a decision based on an EIS. It includes a statement of the decision made, a detailed discussion of decision rationale, and the reasons for not adopting all mitigation measures analyzed, if applicable.

relict - 1. A type of species belonging to ancient groups whose fortunes have waned through geological time.

resource management plan (**RMP**) - A document prepared by field office staff with public participation and approved by field office managers that provides general guidance and direction for land management activities at a field office.

resources - The natural or cultural resources of an area, such as timber, crass, watershed values, recreation values, and wildlife habitat.

reverse fault - Hanging wall appears to have moved upward relative to the footwall. Usually from compressional tectonics and therefore less likely to form open conduits for cave development than normal faults.

rhythmites - Varve-like **sediment structure**. Common in caves in glaciated areas. Represents deposition from pondings beneath or along the flanks of glaciers. Whether each couplet is a annual (true **varve**) is unknown. The ones in Oregon Caves probably represent slight variations in slackwater deposition, with larger grain layers forming first.

rill - Small **karren** grooves up to 50 cm. wide on surface exposures of limestone and less commonly in caves. Most common in arid and semi-arid areas. Can form in vertical shafts, from bedding or joint inflow after flooding, from point source or sheetflow, from enlarging of joints or glacial striations, and from condensation-corrosion above cave floods.

rillenkarren - Downslope parallel Hortonian **rill**s about 1-4 (2-3) cm. (avg. 2cm) wide, no space between and with sharp intergroove crests or ridges no more than 1 cm. high and cut by subaerial solution. Meanders are greater at the lower angles. Planar solution surfaces (ausgleichflache) develop further downslope where runoff depth prevents raindrop erosion.

rimstone dams – a speloethem type consisting of a barrier of material which obstructs a cave stream or pool.

RMP - resource management plan

rockshelter or rock shelter - Grotto, large embayment, or relict or corrasion cave (Def.#1) in which all traversible parts is reached by sunlight, esp. a shallow cave or other traversible cavity under an overhanging rock ledge.

ROD – See record of decision

rootsicles – roots of trees or plants which become calicified when they grow down into a cave passage.

quartz – crystalline silica. An important common rock-forming mineral.

scallops – a mosaic of small shallow intersecting hollows formed on the surface of soluble rock by turbulent dissolution. They are steeper on the upstream side, and smaller sizes are formed by faster-flowing water.

scarp, solution - **Karst** cliff at least ten meters long and two meters high formed by more active solution of lower area or by corrosional undercutting of the base of the cliff, as is likely the case at the Exit Tunnel. Larger than **solution notch**.

scoping - Internal **NPS** decision-making on issues, alternatives, mitigation measures, the analysis boundary, appropriate level of documentation, lead and cooperating agency roles, available references and guidance, defining purpose and need, and so forth. External scoping is the early involvement of the interested and affected public.

serpentine – A mineral group the erodes into soils toxic to or too dry to most plant life.

short term - Impacts that last one year or less.

significantly - A subjective interpretation of the intensity of impact, in several contexts, of the proposed action or alternatives.

sedimentary - Rocks, such as most cave **bedrock**, speleothems, or cemented sediments, formed at normal temperatures at earth's surface.

shelfstone, (cave) - A horizontally projecting speleothem ledge attached to the edge of a past or present pool. Top of shelfstone may be highest water level while bottom may be the lowest water level.

sill – A layer crosscutting earlier features and usually igneous.

show cave - Commercial cave with human-made alterations such as stairs, lights, paved walkways, etc., for public access and usually for guided tours.

significant impact – Those human-caused actions that impairs the biological or geological integrity of an area, such as the extinction of a species or major and/or permanent changes in populations, etc.

silicate - Rock, **mineral**, or **sediment** with SiO4 atomic units. <u>Incl</u>. feldspar, quartz, and chert.

sink(hole) - 1, American term for a circular, 2' wide to larger size **karst** depression. Grades into shafts if > six feet deep and sides are more or less vertical. Locally higher solution rates caused by water flow convergence result in sinks. The formation of one sink favors the formation of others. Most common along lineaments in temperate areas.

slickenside - Polished and smoothly striated surface from friction along **fault**s.

solifluction - The slow viscous downslope flow of unsorted and saturated surficial sediment especially in areas underlain by frozen ground. Can clog **sinks** and other access to caves and concentrate flow in other access points.

solubility - The total amount of solutes that will remain indefinitely in a solution maintained at a constant temperature and pressure in contact with the solid crystals from which the solutes were derived.

spar - Loosely applied to any transparent or translucent **crystalline** mineral, especially calcite. Microspar, crystals 5-20 microns wide cause cave velvet.

speleogen – A cave shape at least partly dissolved by water solutions. Defined in **FCRPA** as "relief features on the walls, ceiling, and floor of any cave or lava tube which are part of the surrounding bedrock, including but not limited to **anastomoses**, **scallops**, **meander** niches, and rock **pendants** in solution caves ..”

speleogenesis - The process of cave formation and destruction, including all changes between the start and end of an underground drainage system. The initiation phase includes the inception phase of laminar flow and up to or the start of turbulent flow in the gestation phase.

speleothem – a secondary mineral deposit formed in caves by the action of water.

spitzkarren - Pinnacle karren grooves about .5 meters apart, separated by rows of sharp-crested pyramidal, spearlike, or steeplelike peaks (needles). Common on surface but rare in caves. From turbulence of high-gradient passages (subaqueuous) and possibly in cave from mixing of air masses and resulting acud dew (subaerial).

splash patches - Condensation corrosion areas (often elliptical) resulting from the concentration of falling condensation droplets in particular areas. Areas may be fairly smooth or, if falling from great heights or with water still able to dissolve a lot of calcite, may show extensive cusp-shaped pitting.

splitkarren - Karren depressions elongated one cm. to several meters along minor joints, veins, **stylolites**, or micro-fractures. Length to maximum width ratios < 3:1. Features taper sharply with depth and appear to be splitting the rock. Closed splitkarren terminate on the host fissure while open splitkarren can end in more solutionally widened karren such as rills or grikes. May begin as microfissures.

spongework - Irregular network of randomly shaped solution voids from a few cm. to >1 m. wide. Likely phreatic and formed under slow flow and dissolution close to calcite saturation. May result from epiphreatic floodwaters otherwise known for forming maze caves or in the waters of meltwater channels in decaying snowpatches. Larger and more isolated hollows are pockets. The larger spongework is termed boneyard.

stalactite – a cylindrical or conical dripstone deposit of minerals, generally calcite or aragonite, hanging from the roof of a cavern.

stalagmite – columns or ridges of carbonate of lime rising from a limestone cave floor, and formed by water charged with carbonate of lime dripping from the stalactites above.

stylolites – A feature in which solution usually of carbonates results in usually jagged lines of insoluble residues due to differential rates of solution.

subduction – plate collision boundary where one plate is sinking beneath another.

sulfide - Ore mineral linkage of sulfur with metal or semimetal.

symbiosis – The growth together of different species in a close relationship such as mutualism or parasitism.

syncline - Downfold of bedding with a troughlike form and the youngest strata in the center.

talus - Rocky **detritus** of any size or shape (usually coarse and angular) derived from and lying at the base of a cliff or very steep, rocky slope. Also, the outward slopping and accumulated heap or mass of such loose broken rock, considered as a unit, and formed chiefly by gravitational falling, rolling, or sliding.

tectonics – Large scale movement of parts of the earth relative to each other.

terrane – a large group of rocks bounded by fault surfaces that has been displaced from its point of origin and has distinctive rock types and fossils by which it is recognized.

tiering - The use of broader, programmatic NEPA documents to discuss
and analyze cumulative regional impacts and define policy direction, and the incorporation by

reference of this material in subsequent narrower NEPA documents to avoid duplication and focus on issues “ripe for decision” in each case.

transgression - The spread of the sea over level areas due to sea level rise or **tectonic** downwarping.

troglobite – an organism that must live its entire life underground.

troglophile – any organism that completes its life cycle in a cave but that also occurs in certain environments outside the cave.

trogloxene – any organism that regularly or accidentally enters a cave but that must return to the surface to maintain its existence.

tube - 1. A generally smooth-surfaced **phreatic** passage of (nearly) elliptic cross section. Range from just human-size to over 15 meters; larger ones rarely are of uniform section. May be straight or winding. Increased solution along bedding planes in horizontally bedded rock tends to result in more flattened elliptical cross sections and in more vertically elongated cross sections in areas of vertical joints, faults, etc.

turbulent flow - Flow in which physical (in contrast to only molecular) mixing of a fluid occurs. It begins in a dissolutional subconduit as its diameter increases to the point where differences between flow velocity at the bounding wall (slowed by friction and adhesion) and the maximum velocity of the tube’s center are sufficient to cause eddies within the flowing water.

underfit stream - Where a stream is presently too small to have created the enclosing valley or cave passage. Often caused by higher Pleistocene flows or where the opening of lower levels in caves causes **piracy**

uplift – elevation of any extensive part of the earth’s surface relative to some other parts.

USDA – United States Department of the Interior

vadose – above the water table, the area where water and air mix.

vermiculation - Thin, irregular, discontinuous **sediment** usually of clay, sometimes of silt, but may be composed of hydrated iron and aluminum oxides, and soot. From flocculation/soil-like aggregation of sediment from drying, liquid films. Most common in Oregon Caves where floodwaters filled the room with water muddy from glacial silt Leopard-skin vermiculations can evolve into intersecting straight lines in densely fractured areas. The more diffuse and slimy and less dendritic ones can form from human-caused lint and algae.

water table – the surface between the zone of saturation and the zone of aeration; the surface of a body of unconfined ground water at which the pressure is equal to that of the atmosphere. The contact between the vadose and phreatic zone. Water tables often are complex in carbonate areas, especially where subsurface conduits and subconduits have recently developed; water filled conduits can overlie dry ones. Further increases in permeability can result in a better defined and relatively flat water table.

welt - 1. Linear **speleothem** in which water moves through medial cracks under capillary pressure and deposits carbonates, usually calcite. A flat analog of an helictite.

wind, cave. Thermic airflow results from different weights of air columns at different temperatures and operates in caves with two or more entrances at different elevations, as is the case with Oregon Caves.