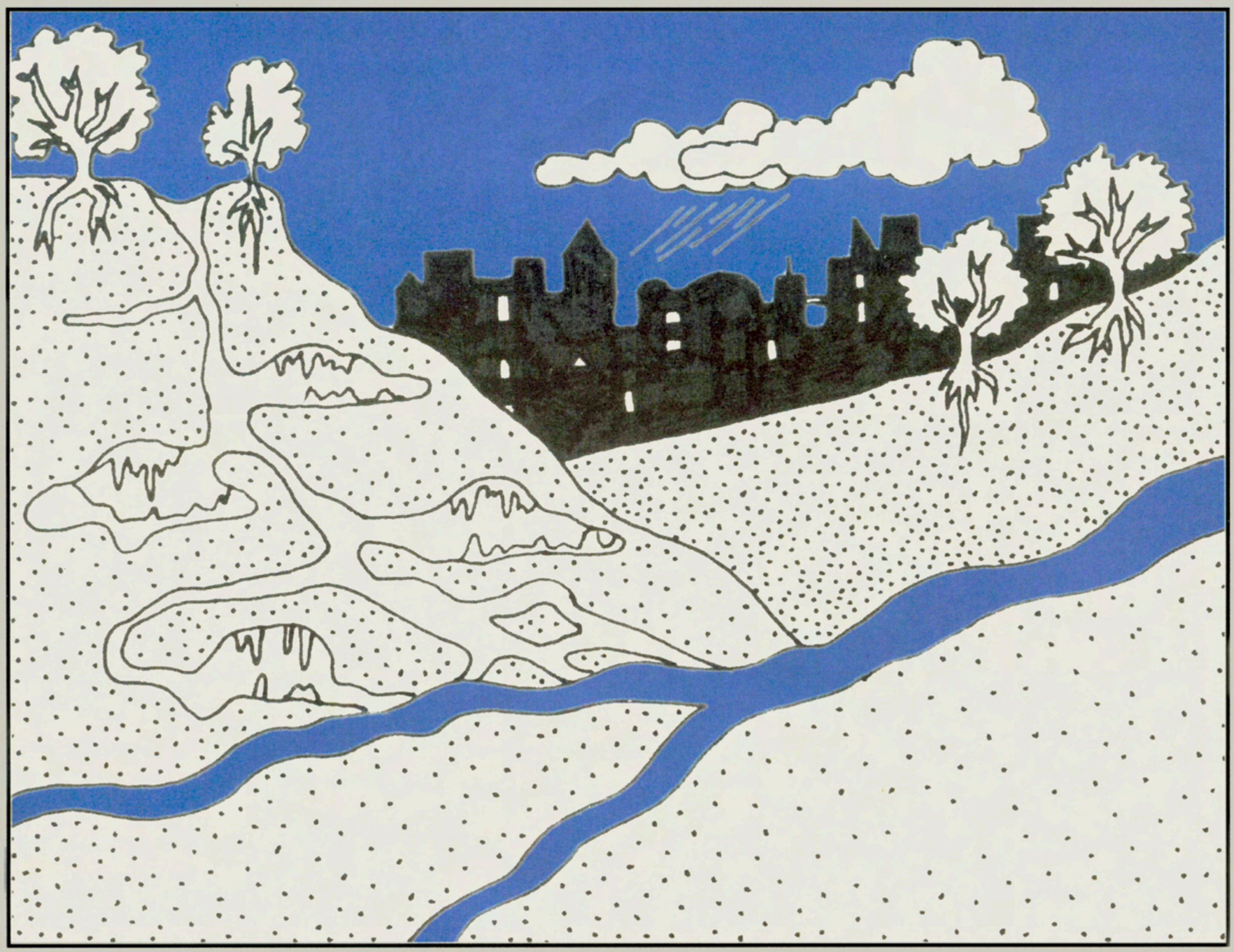
14th National Cave & Karst Management Symposium



Living With Caves & Karst

Proceedings

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Welcome

Welcome to Chattanooga, Tennessee, and the 14th National Cave and Karst Management Symposium hosted by the Southeastern Cave Conservancy. This is the last symposium of the millennium. In anticipation of both old and new management issues that face professionals in the next century, we have brought to together this year an impressive variety of knowledge and expertise in the business of studying, managing, and conserving the cave resource.

The limestones surrounding Chattanooga have excellent positive and negative examples of management issues affecting caves and karst. We invite you to take advantage of the variety of topics this year and to participate in the workshops and field trips. The symposium offers you a tremendous opportunity to learn about caves, cave management, and cave conservation. Equally important is the opportunity to meet new people and network with individuals and organizations sharing the same interests.

Please take the time to meet the members of the Southeastern Cave Conservancy and the members of the symposium staff. Our enthusiasm will be evident. If there is anything that we may do to make your stay more comfortable, or help you in any way, please let us know. Again, thank you for coming and have a great time this week.

Mark Wolinsky, Chairman
Geary Schindel. Co-Chairman

Greetings

On behalf of the Southeastern Cave Conservancy, welcome to Chattanooga and the 1999 National Cave and Karst Management Symposium. Many members of the Conservancy have worked long and hard to prepare for your arrival and to ensure that you have a memorable and rewarding experience this week. We are pleased to be your hosts, and will be glad to do whatever we can to assist during your stay. If there is anything you need, please don't hesitate to ask one of the symposium staff or Conservancy members.

The region around Chattanooga is commonly and affectionately known to local cavers as "TAG" — the acronym for Tennessee, Alabama, and Georgia, whose state borders meet at a common point a few miles west of the city. There are more than 12,000 known caves in this region, and most of them are located within a 100-mile radius of that point, as are cities including Huntsville, Chattanooga, Nashville, Knoxville, Birmingham, and Atlanta. This not only accounts for the region's popularity among cavers, but also illustrates the challenges facing all of us who care about caves, their contents, and their inhabitants. How will we work with cities, industry, politicians, and residents to ensure that their growth and development activities consider the facts of life in one of North America's major karst regions?

Caves are everywhere here. They are in back yards, pastures, parking lots, and on the side of the road. They are under city buildings, schools, houses, roads, and freeways. Everyone knows they are there, but few know much about them. Therein lies our mission, I think. We must work to raise awareness of the value and significance of caves and karst to ensure that growth, opportunity, and development do not come at the expense of fragile ecosystems, historic sites, and underground wilderness.

By hosting this Symposium, the Southeastern Cave Conservancy hopes to promote better understanding of and appreciation for cave and karst management, conservation, protection, and research. We thank you for joining us and for your participation, and we welcome you to the place we love — the place where we live — TAG.

Bill Putnam, Chairman,
Southeastern Cave Conservancy, Inc.

Theme

The theme of this symposium is “Living with Caves and Karst.” Many cities in the Tennessee Valley Region will pass into the next millennium with enormous planning problems in a karst region that has seen accelerated rates of residential, commercial, and industrial development. In increasing numbers, municipalities are forced to consider the effects of karst and its fast-moving groundwater in their planning and development. Similar situations exist in many other karst regions across North America.

In this symposium we will highlight impacts and threats to caves and karst in metropolitan areas, consider implications of caves and karst for land use planning and development, and examine strategies and techniques for conservation and management of caves and karst resources in that environment. The primary impacts on karst resources in the region result from timber harvesting, septic tank degradation, petroleum pipeline ruptures, non-point-source pollution, and industrial discharge. Rapid population growth and residential development in the cave-rich area are also issues. Increases in recreational caving, timber harvesting, and residential development are creating widespread pressure on cave fauna and associated habitat. Similar concerns apply to the many caves containing significant cultural and scientific resources. By focusing on these issues, we hope to foster a better understanding of the challenges of responsible development and growth in karst regions.

Description of a Protocol for Monitoring the Population Status of the Tumbling Creek Cavesnail (Hydrobiidaie: Antrobia culveri)

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Poster Session

The Tumbling Creek Cavesnail was described in 1971 based on specimens recovered from Tumbling Creek Cave (in Taney County, Missouri). It appears the number of *Antrobia culveri* in Tumbling Creek Cave has decreased substantially in the last 20 years but no quantitative data support this impression. A stratified sampling scheme was developed to monitor the population of this snail, which is endemic to Tumbling Creek Cave. Permanent markers divide an accessible stretch of Tumbling Creek Cave into seven variable-length sections of alternating "favorable" and "marginal" habitat. Favorable habitat is characterized as riffle habitat with gravel to large rocks and medium to fast stream flow. Marginal habitat is characterized as large pool (deeper than 0.6 meter) and minimal flow, or riffle habitat with a solid rock bottom. A PVC frame (0.09 meter square) is used as a sampling square. Rocks within a square are examined and the number of snails observed is recorded. The number of plots in each section constitutes approximately 3% or 1% of substrate area (for favorable and marginal habitats, respectively) within that section. Comparisons (between habitats, seasons, or years) can be made.

Planning for the Impact of Convention Caving

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Abstract

Annual NSS National Conventions are attracting larger attendance and it is estimated that 50% to 75% of cavers attending expect to go underground at least once during the five-day event. Often convention sites are chosen for the facilities with little attention being paid to the capacity of the caves in the area. Convention organizers may put pressure on cave managers to relax visitation limits in order to accommodate the increased demand. Those that do so may later regret their hospitable gestures when the caves are degraded.

Should cave managers and cavers be allowed or encouraged to voice their concerns about the potential impact of a proposed convention on caves in the area? What would be the best way to evaluate the impact of a proposed convention? What are the pros and cons of limiting convention caving? What is the responsibility of the NSS in making these decisions? These questions will be discussed in relation to past and future planned conventions.

Here Today, Gone Tomorrow? Initiating Steps for Preserving West Virginia's Cave and Karst Terrain

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Abstract

Nationwide, caves and karst terrains face serious threats from a multitude of social and economic forces such as construction activities. At the same time many have felt a strong need for greater education and outreach efforts regarding karst regions for protecting these rare and fragile environments from being obliterated. In a manner similar to other cave and karst bearing regions, West Virginia continues to recognize challenges and evolve feasible solutions for protecting its caves and karst resources. Moreover, any such forward-looking strategies must involve a proactive, rather than a reactive stance in planning. However, until recently, there was lack of a formalized, concerted, viable group dedicated to the mission of preserving the state's karst regions. This presentation offers an overview of the West Virginia Cave Conservancy, a federally-recognized, 501(c)(3) status organization presently working with communities in West Virginia to pursue its preservation and management missions. The Conservancy is doing this by working to purchase or lease caves (such as Rapps Cave, a significant archaeological site that was recently leased to the West Virginia Cave Conservancy). The Conservancy also works with cave owners to create management plans that will allow access to such areas while protecting the landowners. This presentation outlines the stages involved in the evolution of the West Virginia Cave Conservancy as a recent organization and emphasizes specific cave and karst-related goals and objectives that are central to its mission.

Introduction

West Virginia is having problems similar to those of many other states in reference to its caves. They are becoming more difficult to protect and harder to gain access to. Out of over 3,800 caves in West Virginia, only 107 are owned or managed by cavers or groups of cavers. This may seem like a high number of caves owned by cavers, but in comparison to the number of caves in the state, it is a small percentage. This paper will introduce the West Virginia Cave Conservancy, a federally-recognized, 501(c)(3) status organization that is working to protect the cave and karst features in West Virginia, describing the history, projects, fundraising, and future goals of the organization.

History

The West Virginia Cave Conservancy was created with a four-part mission statement. First was to protect the cave and karst resources in the state through education and resource management. Second was to promote the study of caves and karst. Third was to provide maximum possible access to these resources. Finally, the West Virginia Cave Conservancy would offer a full range of management resources.

Many people recognized the need for a cave conservancy. There were organizations like the West Virginia Association for Cave Studies and the Cave Conservancy of the Virginias that already existed, but the major inhibitor of buying or managing property was the question of who would be responsible. Not until George Sively, the previous owner of Organ Cave, passed away in 1994 did this thought begin to take the form of an organization. In 1995, at the NSS National Convention in Blacksburg, Virginia, the President of the NSS set up an ad hoc committee on Organ Cave. This committee was to stay informed on the Organ Cave situation and work toward the formation of a non-profit organization that would buy the cave if and when it would be offered for sale. Bob Handley was named as chairman of this committee. Handley spoke to Cliff Lindsay, who was already managing McClungs Cave, along with Ed Swepston and Dave Cowan, about forming an organization that would serve to protect the cave.

Contact was maintained with the heirs, although no progress was made toward the purchase of the cave. Lindsay and Handley, with the help of Swepston, worked up a charter for the Greenbrier Cave Conservancy in the spring of 1997, and it was chartered in July of that year. Shortly after the Greenbrier Cave Conservancy was chartered, Mark Wolinsky of the Southeastern Cave Conservancy called Lindsay about access to McClungs Cave. The conversation continued and discussion about the two conservancies took place. Wolinsky suggested that the Greenbrier Cave Conservancy should expand the scope of its efforts. After further discussions, Handley, Lindsay, and Swepston formed the West Virginia Cave Conservancy, which was chartered in December of 1997. At the first meeting, the following were asked to join as directors: Lonnie Burns, Tim Brown, Dave and Sandy Cowan, Ray Garton, and Tina Hall. Bill Jones was later asked to be a director, followed later by J.C. Fisher and Jeff Bray in 1998, filling the 12-member Board of Directors.

In the spring of 1998, there was an opportunity to purchase the property containing the original entrance to Maxwelton Sink Cave in Greenbrier County, now closed due to debris burying the cave during a dying hurricane in the early 1970s. This opportunity came about on short notice and forced the organization, in its infancy, to react quickly. There were only two weeks for preparation before the land was to be sold at auction. Cowan and Lindsay did a survey of the land that was thought to be necessary to gain access to the cave, also feeling that the new landowners may feel more comfortable selling if they knew the West Virginia Cave Conservancy was serious. The new owners were encountered after the auction, and negotiations are still taking place. This situation did give the Conservancy some quick attention in the caving community through fundraising in preparation for the purchase of the land. This brought the organization into the eyes of the caving community.

Projects

In November of 1998, there was an announcement about an auction that included two entrances to Greenville Saltpeter Cave in Monroe County. This popular cave has four entrances, two of which are already owned by The Institute for Earth Education, an organization that shares the conservancy's thoughts on preservation of the cave. The West Virginia Cave Conservancy had a very short period of time in which to respond, and once again had to act quickly to be ready for the auction. It was decided that the Conservancy would work together with the Institute for Earth Education to purchase the cave. We also decided that because the location of one of the entrances was so close to property already owned by the Institute for Earth Education, we would introduce the idea of an underground easement to the auctioneer. The thought was that this could be used to connect a majority of the cave to property owned by the Institute. This idea of an underground easement was introduced and eventually used in the purchase of Organ Cave by the new owners. These were the first two times that an underground easement was used in a purchase involving a cave in West Virginia. The Institute for Earth Education was able to purchase the two entrances and the underground easement at auction with the help of the West Virginia Cave Conservancy.

The West Virginia Cave Conservancy also helps the Southeastern Cave Conservancy, Inc. manage Lobelia Saltpeter Cave in Pocahontas County. This cave and property was offered to the SCCI while the West Virginia Cave Conservancy was still forming. When the SCCI heard that a group had formed in West Virginia, they offered to work together on the management of the cave. The first project on this property was to clean it up since there had recently been a fire on the property. The West Virginia Cave Conservancy worked with the state in a special program, called "West Virginia Make It Shine" month, and was able to remove the garbage from the site at no charge. Artifacts were also found in the cave and these were sent to nearby Droop Mountain Battlefield State Park for protection in fear that they would be vandalized at their current location in the easily-accessible cave.

Most recently, Rapps Cave in Greenbrier County, a known archaeological site, was purchased by some landowners who were interested in conservation. The West Virginia Cave Conservancy worked with these new landowners to create a lease agreement that would allow for a professional archaeological dig. The West Virginia Cave Conservancy asked for a grant from the Cave Conservancy of the Virginias and received $16,000 to contract archaeologists for the dig. The dig begins in April of 2000. Although the cave is not open to the public at this time, any that are interested in helping with the archaeological process are encouraged to contact the conservancy.

Fundraising

The fundraising practices of the West Virginia Cave Conservancy have been varied. Many different levels of membership are available, including a charter membership for the first year of the organization. The National Speleological Society National Conventions have also been sources of funds by making brochures available through a number of vendors. At the Old Timers' Reunion which is held Labor Day Weekend each year, the West Virginia Cave Conservancy has been very noticeable since Old Timer's takes place in West Virginia. The goal here seems to be to create a fundraiser that is different and unique and which people will remember from year to year. In 1998, a small crane was constructed with a "pit" of buttons, all reading "Dig the Max," in reference to the hopeful purchase of Maxwelton Sink Cave. The patrons used a little crane to dig buttons from the pit. Each button cost ten dollars and some of the buttons had winning numbers on the backs, which corresponded to prizes donated by vendors. In 1999, we had a rubber duck race in the Tygart Valley River. The ducks were donated by the city of Ronceverte, and were sold for five dollars. Each duck had a number and the first 20 ducks to cross the finish line won prizes. The West Virginia Cave Conservancy also plans an annual banquet. This fundraiser takes place in Lewisburg and is a time for members to meet and talk to each other and the directors. Members and benefactors are also recognized for their support.

Future Goals

The West Virginia Cave Conservancy plans to continue its negotiating for Maxwelton Sink Cave, but also has other plans for the future. There are currently negotiations under way for the purchase of Bone Cave in Greenbrier County. The West Virginia Cave Conservancy is also working on a management plan with the owner of Haynes Cave in Monroe County. There has also been some positive response concerning opening negotiations for some of the lesser-known entrances to Organ Cave. The West Virginia Cave Conservancy also plans to spread to more parts of West Virginia.

Conclusion

While only in its first two years, the West Virginia Cave Conservancy has accomplished a great deal toward preserving the cave and karst features of West Virginia. As the organization grows, its goals will be met and it will be instrumental in protecting more caves in the state, as well as raising the percentage of caves owned by cavers from three percent to a much higher percentage. It also looks toward the future to educate citizens so that caves and the life inside them may not be as endangered in the future.

Acknowledgements

I greatly appreciate the efforts of all the board members of the West Virginia Cave Conservancy, especially Bob Handley, Cliff Lindsay, and Dave Cowan for helping in various ways with this paper. I also thank Dr Parvinder S. Sethi at Radford University for his help with preparations for the presentation of this paper at the 14^{th} National Cave and Karst Management Symposium. I also want to thank Yvonne Droms for her comments on this paper.

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A Karst Resource Inventory of the George Washington and Jefferson National Forests

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Abstract

The George Washington and Jefferson National Forests stretch across nearly 1.8 million acres in the western Virginia and eastern West Virginia portions of the Appalachian Mountains. The mountainous forestlands are fringed, and occasionally dissected, by linear bands of karst topography formed in carbonate rock of Cambrian through Mississippian age. The Virginia Speleological Survey has documented approximately 90 caves and an untold number of springs, sinkholes, and sinking streams on the Forest. The exact location, dimensions, and natural heritage value of many of these caves and karst features is not currently known by the Forest, nor actively managed to protect karst resources.

The development of a new management plan, and a grant from the Fish and Wildlife Foundation, were the catalysts that allowed the Forest Ecology Group to focus on the collection of specific information about some of the Forest's most sensitive aquatic habitats and groundwater recharge zones. Through the cooperative efforts of the Department of Conservation and Recreation's Virginia Karst Project (Natural Heritage Program) and the Karst Waters Institute, Inc., a special team of conservation-minded cavers was assembled, trained, and permitted to make observations about the aquatic (and terrestrial) habitats in targeted Forest caves. The Karst Resource Inventory Team, as the group is known, is also responsible for collecting voucher specimens of stygobitic fauna, where needed, from cave stream, epikarst, and phreatic habitats. The team will intensively gather data on the aquatic fauna of the Forest's karst for the next year, and will develop a final report on their findings with the assistance of Dr Dan Fong at American University.

Because the George Washington and Jefferson National Forest is located in a region of such high biodiversity and endemism, the Karst Resource Inventory Team has elevated expectations for the discovery of several species new to science, as well as new locations for known species. The habitat descriptions and maps generated by the Team are invaluable to the future planning process, and will be used by Forest staff to prioritize karst areas for protection from the impacts of logging and excessive recreational use.

Introduction

The George Washington and Jefferson National Forests (hereinafter referred to as the Forest) include nearly 1.8 million acres of the central and southern Appalachians in western Virginia and eastern West Virginia. For more than ten years, the U.S. Forest Service and the Virginia Department of Conservation and Recreation have cooperated in a series of on-going projects to inventory the natural heritage resources of the Forest. The natural heritage values of the Forest include the habitats of rare plant and animal species, significant natural communities, and the geologic and hydrologic features that support this biological diversity. The objective of the work has been to facilitate ecological management and monitoring strategies that preserve the integrity and viability of the Forest's most salient natural heritage resources.

Based on the results of regional and site-specific inventories, the Department of Conservation and Recreation produced a list of sites with exceptional levels of biodiversity that are proposed as candidates for Special Interest Area, Research Natural Area, or other conservation land management status (Erdle *et al*., 1996; Rawinski *et al*., 1996; Wilson, 2000). Past ecological surveys focused on targeted species and the collection of detailed vegetation and habitat information about natural communities. The current project was designed to focus on the role of the Forest as the topographic and geologic "source water area" for the watershed that sustains life beyond the Forest boundary. Specifically, this project addressed the groundwater catchment areas that are the most vulnerable to potential degradation from surrounding land use activities. Most often there are karst areas that occur along the edges of the Forest boundary. This cave fauna inventory project was initiated to augment previous inventories of the Forest's plant and wetland communities on carbonate terranes. The project was facilitated by the generous assistance of the Karst Waters Institute, the Cave Conservancy of the Virginias, and the dedicated cadre of cavers known as the Karst Resource Inventory Team.

Karst Resources of the Forest

The Forest extends across three physiographic provinces in western Virginia—from the crest of the Blue Ridge Mountains, through parts of the Valley and Ridge, and westward to the Appalachian Plateau. Much of the land is extremely mountainous, with peaks in excess of 4,000 feet (1,219 meters) in the northern section and 5,500 feet (1,676 meters) in the southern section. The mountains are typically fringed by linear bands of karst that make up less than 0.5% of the total land area of the Forest. The karst and carbonate rock areas occur at elevations ranging from around 600 feet (183 meters) to 3,700 feet (1,128 meters)(Fleming, 1999).

Average annual precipitation varies widely across the Forest, and ranges from approximately 36 inches (91 centimeters) to 50 inches (127 centimeters)(van der Leeden, 1993). Given the density of springs and caves located along the edge of the Forest, runoff and karst infiltration must constitute a substantial component of groundwater recharge both within the Forest and on adjacent lands. Forest lands overlie the headwaters areas for six of Virginia's major drainage basins, including the Big Sandy, Upper Tennessee, New, Roanoke, James, and Shenandoah-Potomac. Bedrock ranges in age from PreCambrian through Pennsylvanian, with cave-producing carbonate units occurring throughout the Cambro-Ordovician, Silurian, Devonian, and Missippian strata. Karst lands include some of the most productive sites for potential timber harvests, yet the variety of microclimates occurring in these terranes also results in exceptional ecosystem diversity that should be appropriately protected and managed by the Forest (Fleming, 1999).

Distinctive Forest Community Types on Karst

Most karst land in the Forest is mantled with sandy, acidic material derived from upgradient slopes of varying combinations of sandstone, shale, quartzite, and/or gneiss. Carbonate bedrock is exposed where soils are thin and rocky, and the substrate is rich in available calcium and magnesium. In 1997 and 1998, Department of Conservation and Recreation—Department of Natural History ecologists sampled the mineral soils and substrates of rare plant community types associated with carbonate rocks in the Forest. Sample sites were selected based on several criteria, including consistency with the Department of Conservation and Recreation—Department of Natural History 's table of limestone and dolomite indicator species. Thirty-four sample plots were classified according to topographic position, slope shape and aspect, drainage, soil/substrate characteristics, and plant associations. The following calcium-loving (calciphilic) plant communities were identified from this analysis (Fleming, 1999).

Rich Cove/Mesic Slope Forests occur in cool, sheltered locations on north- to east-facing slopes. Stands are also to be found on low carbonate ridges and rich flood plain terraces. Globally, this plant community type is cited as being among the biologically-richest systems in the world (Fleming, 1999). The typical mixed canopy of a Rich Cove/Mesic Slope Forest might be composed of *Acer saccharum* var. *saccharum* (sugar maple), *Acer nigrum* (black maple), *Tilia americana* (basswood), *Liriodendron tulipifera* (tulip poplar), *Fraxinus Americana* (white ash), *Aesculus flava* (yellow buckeye), *Ulmus rubra* (slippery elm), *Quercus rubra* (northern red oak), and *Carya Cordiformis* (bitternut hickory). The understory vegetation may include *Asimina triloba* (pawpaw), *Lindera benzoin* (spicebush), *Magnolia tripetala* (umbrella magnolia), *Cornus alternifolia* (alternate-leaved dogwood), and *Staphylea trifolia* (bladdernut), in addition to nutrient-loving herbaceous plants, such as *Trillium* spp.(trilliums), *Caulophyllum thalictroides* (blue cohosh), *Laportea canadensis* (wood nettle), *Hydrophyllum* spp.(waterleaf), and the fern species (Fleming, 1999).

Montane Seepage Wetlands occur along toe slopes and stream headwaters where groundwater discharges in the form of seeps and springs. These areas are perennially or ephemerally saturated, rarely completely flooded, and occur under both acidic and calcareous conditions. Seepage wetland communities, including bogs and calcareous fens, are rare in Virginia, and contain habitat-restricted species of plants and animals that are priorities for protection (Fleming, 1999). Montane Seepage Swamps often occur in association with slow, diffuse groundwater flows rather than the relatively fast-moving, conduit flow networks normally associated with cave systems.

Karst areas with south to west facing slopes are generally warmer, and may support Dry-Mesic and Dry Calcareous Forests on thin, rocky soils. These forests can occur where narrow bands of pure Mississippian-age limestone outcrop at higher elevations, and include populations of significant plants of global or state rarity. Some of these communities are relatively pristine due to the rugged terrain and elevations at which they occur. In these steep, rocky habitats, trees are often stunted, which diminishes the potential for future timber harvests. *Quercus muhlenbergii* (chinkapin oak) is the characteristic tree of this community type (Fleming, 1999).

Rare Calcareous Barrens and Outcrops occur on steep, dry, limestone and dolomite cliffs in the Forest where the sparse canopy allows light-demanding and lithophilic (rock-loving) plants to flourish. This community is typified by growths of shrubs and prairie-like grasslands in xeric upland openings, surrounded by *Juniperus virginia* var. *virginia* (eastern red cedar), chinkapin oak, white ash, *Fraxinus quadrangulata* (blue ash), *Frangula caroliniana* (Carolina buckthorn), *Philadelphus hirsutus* (hairy mockorange), *Rhus aromatica* var. *aromatica* (fragrant sumac), *Celtus tenuifolia* (Georgia hackberry), *Rhamnus lanceolata* ssp. *lanceolata* (lance-leaved buckthorn), and *Thuja occidentalis* (American arborvitae) (Fleming, 1999).

Cave and Karst Water Resources

The carbonate rock units with which these important plant communities are associated also contain caves of various dimensions and significance. Unpublished information from the Virginia Speleological Survey contains reports of approximately 90 caves within the Forest boundary, although the exact locations, dimensions, and natural heritage value of many of these caves are not currently known (Lucas, 1999; Kastning and Kastning, 1993). Hundreds of other caves occur along the perimeter of the Forest and on adjacent private land that could be potentially impacted by Forest management. This is particularly important where springs and surface streams originate on Forest lands, sink into the subsurface and contribute to cave streams, springs, wetlands, and public and private drinking water sources.

In addition to the more than 25 species of rare calcium-loving plants that are currently being monitored on carbonate strata in the Forest, the ecological community includes land snails and threatened species of freshwater mussels that rely on available calcium and magnesium for shell formation (Fleming, 1999; Koch, 1998). The diverse troglophilic and obligate cave fauna of the Forest includes salamander, bat, and many invertebrate species (Fleming, 1999). More than 80 species of stygobytes (aquatic cave fauna) have been identified in Virginia. In all, more than 90% of the cave-dwelling species are endemic to the central and southern Appalachians. This high level of endemism and biodiversity places the Appalachian region among the most important karst areas in the world for biological value (Culver, 1999).

Because the karst areas have been identified as a high priority for conservation, the Forest Ecology Group determined that a detailed inventory of the natural heritage value of the caves was essential for updating the Forest

Management Plan and to protect karst resources both within and outside the Forest boundary. The current project with Department of Conservation and Recreation, the Karst Waters Institute, and the Karst Resource Inventory Team was initiated to begin the inventory process by focusing on the aquatic cave fauna of the Forest.

Conducting the Cave Inventory

With funding from the National Fish and Wildlife Foundation and Cave Conservancy of the Virginias, the Forest entered into a cooperative agreement with Department of Conservation and Recreation—Department of Natural History and Karst Waters Institute to conduct the inventory in multiple phases. The first phase focused on the documentation and identification of stygobitic fauna associated with cave environments. In 1999, a Forest intern compiled the available information on known caves in the Forest (Lucas, 1999; Kastning and Kastning, 1992; Holsinger, 1975; Douglas, 1964). That information was used to assign a preliminary priority ranking to each cave, based on the age and detail of the record and the presence or absence of water. With 90 caves to inventory, the rankings were designed to highlight the caves which had not been visited, or which required more detailed descriptions.

The Department of Conservation and Recreation invited experienced cavers from around the region to form the Karst Resource Inventory Team, a special group of trained volunteers to focus on the Forest inventory project. The team collectively received the required permits to sample cave fauna in the Forest from the Department of Game and Inland Fisheries and the Virginia Cave Board. As Department of Conservation and Recreation volunteers, they signed agreements that required professional behavior while representing the state, and were covered by the Commonwealth's risk management insurance during work activities and related travel.

Grant funds covered the expense of a weekend training session for approximately 30 volunteers. The combined classroom and field training was provided by Drs David Culver, Dan Fong, and Horton Hobbs of the Karst Waters Institute, and Kevin Simon. Sessions addressed habitat types and food supplies, the major taxonomic groups in caves, relative distribution of known species, and sample collection and preservation techniques. Instruction on the collection of field data included a trip to a local stream for benthic sampling, and visits to two caves with different types of aquatic habitats. The Team was geographically divided into four subgroups that covered the twelve Ranger Districts in the Forest. The groups generally worked in the areas they were most familiar with or lived near.

Team 1 included members of the Mountain Empire and Powell Mountain Grottos, and took responsibility for the Clinch Ranger District in the furthest southwest portions of Virginia. Team 2 included members of the New River Valley and VPI Student Grottos, who covered the Mount Rogers National Recreation Area, as well as the New Castle, Wythe, and Blacksburg Ranger Districts. Team 3 consisted of Blue Ridge Grotto and NSS Virginia Region members who worked in the Glenwood, James River, and Warm Springs Ranger Districts. Team 4 included members of the TriState and Front Royal Grottos, who surveyed the Lee, Dry River, Pedlar, and Deerfield Ranger Districts in the northern part of the Forest. Each team was responsible for the inventory of 20 to 25 medium- to high-priority caves over the course of the project. Since much of the cave information was old and/or inaccurate, teams were informed that steep ridge-walking exercises and lost driving time were to be expected.

Team members documented important observations in the caves, including signs of pack rat, raccoon, and bobcat usage, historical and archaeological evidence, bat numbers and descriptions, and occurrences of troglobitic and terrestrial fauna such as cave crickets, millipedes, beetles, collembola, harvestmen, mites, spiders, salamanders, and crayfish. The teams are permitted to collect voucher specimens of stygobites, when present. They also provide detailed descriptions of cave streams, pools, and flowstone habitats (substrate, estimated flow, and the like). Collection sites were marked on cave maps when they were available. In some cases, teams surveyed caves or provided sketches in adequate detail to allow the sample sites to be revisited. Other information that was collected included ambient weather conditions, observed vandalism, encounters with adjacent landowners or Forest users, mileage and working hours, accidents, and so on. Samples are preserved in ethanol or isopropyl alcohol, properly labeled, and shipped to Dr Dan Fong at American University for subsequent identification and cataloging.

During 1999, a record drought affected access to and the availability of water in many caves, and resulted in reduced sample recovery. Where water was low or absent, Team members still noted interesting observations of troglobitic species and planned return visits to a percentage of the caves when more normal precipitation resumed. In some cases, Team members continued to survey caves to produce maps for conservation management purposes and to correct erroneous location records. A final project report will be prepared for the National Fish and Wildlife Foundation and Forest in September 2000. The Karst Resource Inventory Team has already planned a fall meeting to finalize the first year of the project and to plan future activities to supplement the initial cave inventory.

Threats and Management Challenges

Through these inventory projects, the Forest Ecology Group is documenting the occurrence of exemplary ecological communities and species with special habitat requirements to improve ecosystem management and conservation planning practices. The portions of the Forest underlain by carbonate rock make up a relatively minor fraction of the total land area, yet present several resource management challenges. First, due to the fact that conventional hydrologic models for forestry operations do not account for surface water losses to groundwater, impacts resulting from timber harvests on karst are not adequately addressed in pre-harvest plans (Waring and Schlesinger, 1985; Brown, 1991). Second, over-visitation of caves in remote areas of the Forest, as well as those located in popular recreational areas and near private property, may conflict with conservation management principles. Third, water supplies in the Forest serve as invaluable and sometimes irreplaceable drinking water sources for rural areas.

Large-scale timber harvests and road construction on steep slopes in karst catchments pose significant potential threats to cave communities in the Forest. Soil loss from roads in the southern Appalachians can exceed 5,000 ton/ha/year on slopes of 20% or more (Waring and Schlesinger, 1985). Heavy equipment also creates excessive soil compaction, decreases infiltration, and increases runoff and erosion rates. Drainage alterations and road construction in or across the beds of sinking streams have created sedimentation impacts to caves, subsurface streams, and groundwater resources (Brown, 1991, 1999). Disposal of logging debris and slash in and around cave entrances and sinkholes can alter the natural nutrient flow associated with caves and prevent access by raccoons, bobcats, and other wildlife. Effective buffer zones are difficult to design around karst features, given the variety of habitats and foraging areas required by cave fauna, and the inherent permeability of the epikarst. The epikarst consists of the densely fractured and solution-enhanced zone of bedrock between the soil interface and the “water table.” Hydrologically, the epikarst is characterized by vadose percolation, but can locally function in a water storage and transport role (Field, 1999).

Erosion from unauthorized ATV and hiking trails impact surrounding forest and plant communities, and provide opportunities for the introduction of invasive weeds (Wilson, 2000). Designated hiking trails are usually stable and well maintained, but the steep, undesignated trails leading to cave entrances create erosion and safety hazards. Such trails may actually increase cave visitation by the curious and unprepared novice. As problems with these trails are documented, recommendations for improved control, abandonment, posting, and/or repair of certain cave access trails should be considered and implemented.

The financial and environmental cost to gate all Forest caves would be prohibitive and counter-productive because gates can impede the natural nutrient transport and air flow of caves, and affect the use of caves by wildlife. In timber harvest areas, gates would not provide any protection from alterations in surface and subsurface hydrology, drying, or excessive sedimentation. Properly designed, constructed, and maintained gates have been successfully employed to eliminate over-visitation, vandalism, and disturbance of dwindling bat populations in the Forest, such as the federally endangered Indiana bat (*Myotis sodalis*). As part of this project, old or unmaintained gates will be noted and targeted for removal or replacement with secure bat-friendly gates with animal access portals, as needed.

With the recent federal emphasis on watershed and Source Water Protection (USEPA,1997), watershed groups and state drinking water programs are focussing more attention on the catchment areas in the national forests and other large expanses of public land that serve as important source areas for aquifer recharge. This is especially important in the mountainous regions with karst valley footslopes and floors. Furthermore, the Forest owns many large springs that have been historically used as public and community drinking water supplies (Brown and Ruark, 1997). Many of these springs continue to sustain consistent flows even during the prolonged drought of the late 1990s, and serve as important groundwater reservoirs for both rural domestic consumption and surface stream base flow. The Forest has Special Use Agreements with small community water systems for the use of some wells and springs, while public access to others is relatively uncontrolled. Some of these springs are resurgences for karst systems, and provide convenient monitoring points for water quality and for cave invertebrates during periods of high flow. The protection of these large springs, as well as the smaller, biologically-significant seeps and fens, should be a conservation priority for the Forest.

Control and Use of the Data

The information collected during this project will be jointly controlled through confidential data-sharing agreements between the Virginia Speleological Survey, Department of Conservation and Recreation, and the Forest. Sensitive natural heritage resource information that could encourage removal or destruction of rare species is exempt from the Freedom of Information Act in Virginia, and will not be released to the public. The data will be used by Department of Conservation and Recreation and the Forest to develop specific management strategies for the protection of karst resources, and will serve as the cornerstone for achieving "significant" status for these caves under the Federal Cave Resources Protection Act.

The Federal Cave Resources Protection Act provides legal protection for caves on federal land that are designated as significant based on biological, cultural, geologic/mineralogic/paleontologic, hydrologic, recreational or scenic, and educational/scientific values.

The final report will be submitted as a supplement to previous reports summarizing the biologic and geologic importance of certain karst areas of the Forest (Kastning and Kastning, 1992; Erdle *et al*., 1996; Smith *et al*., 1997; Fleming, 1999; Wilson, 2000). Each of these reports recommends special U.S. Forest Service conservation designations, such as Research Natural Areas and Special Interest Areas, that would set these sites aside for additional monitoring, research, and educational purposes and to preserve their current condition from over-use or disturbance.

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Hubbards Cave Revisited: Adaptive Cave Resource Management on a Private Nature Preserve

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Abstract

Hubbards Cave Preserve, located in Warren County, Tennessee, was purchased by The Nature Conservancy in the mid 1980s to protect a significant endangered bat hibernaculum. Historic censuses indicate that over a quarter-million gray bats (*Myotis grisescens*) and several thousand Indiana bats (*Myotis sodalis*), both federally endangered, once utilized Hubbards Cave as a winter roost. Soon after purchasing the preserve, The Nature Conservancy, the American Cave Conservation Association, and other partners built an airflow cave gate over the main sink's south entrance to prevent human disturbance of the bat colonies. Since this initial gate project, however, declining bat populations, rampant vandalism by trespassers, and the discovery of irreplaceable cultural and archaeological resources inside Hubbards Cave have caused The Nature Conservancy to re-address its access management and biological monitoring of the entire property. In 1998 and 1999, airflow gates with newly adapted designs were constructed over the remaining two sinkhole entrances, and the south gate was retrofitted with a box opening to enhance the flight path of emerging bats. The Nature Conservancy and the National Speleological Society also joined forces to begin the development of an access and monitoring policy.

Introduction and Background

When the U.S. Fish and Wildlife Service and Bat Conservation International conducted a winter bat survey of Hubbards Cave Preserve in early 1998, it ended a three-year lull in population censusing at The Nature Conservancy's finest cave preserve in Tennessee. Although both the federally endangered gray bat (*Myotis grisescens*) and Indiana bat (*Myotis sodalis*) thrived in this hibernaculum as recently as the late 1980s, a series of management situations at the preserve had caused concern about the bats' safety during hibernation. The 1998 survey team estimated just under 100,000 grays and no Indianas.

One hundred thousand bats seems like a lot, and it is—but in the 1960s and 1970s, Dr Merlin Tuttle from Bat Conservation International counted over a quarter-million grays and several thousand Indianas and heralded Hubbards Cave as one of the Southeast's most significant endangered bat hibernaculae. By the 1980s, that count had dipped to 150,000 grays; by 1991, less than 90,000 grays and a paltry ten Indianas made the record. And in 1998, the gray bats held steady at just under 100,000, and the Indiana bats were gone.

The purchase of Hubbards Cave and the surrounding 50 acres in the mid 1980s signaled the beginning of The Nature Conservancy's most challenging stewardship scenario in Tennessee. A multi-ton, steel airflow gate was erected over the cave's south entrance soon after the preserve's acquisition, but the gate did nothing to safeguard the two entrances across the sinkhole or the mountain land around the cave mouth. By 1994, the sinkhole and cave walls were spattered with graffiti, black spray paint marred the Conservancy's endangered bat sign, and trespassing all-terrain vehicle users had beaten paths across the hilly terrain. Finally, in 1997, vandals burned a Civil War-era ladder inside the west passage, an especially atrocious offense that galvanized a massive effort to take back responsible control of the cave's access and resources.

Today, after 15 years of Conservancy ownership, Hubbards Cave Preserve boasts airflow gates over all three of its main sink entrances. Each gate embodies a separate design that was chosen to satisfy different management objectives.

Cave Gate Design Methodology and Results

The construction of Hubbards Cave's first gate in 1986 did not transpire without debate. Critics voiced concerns that the gate's full design would create a flight path obstacle for the bats. To research this possibility, the U.S. Fish and Wildlife Service observed the bat flight several times in the mid 1980s. Results indicated that the gate's full front (*i.e.*, vertical and horizontal bars reaching from ground level to the top of the mouth) was working properly and presented no problems for the bats using it. This older cave gate design is representative of the first models used for conservation, with vertical support beams spaced on four-foot centers.

In spite of the U.S. Fish and Wildlife Service's reassurance, the population of bats using the main sink's three entrances decreased from approximately 260,00 individuals to 88,000 between Dr Tuttle's original count and the late 1980s. Some bats also exhibited a behavioral change by choosing new roost sites not protected by the south gate, thereby creating concerns that the structure was somehow causing the population decline. Vandalism and raccoon predation were also increasing at the preserve so the relative importance of factors contributing to the bats' downward spiral was unclear.

One year after the Civil War ladder's destruction, Hubbards Cave's second gate was constructed over the west entrance. This small gate exemplified the new cupola design (Figure 1) that sought to protect the west passages' cultural and archeological artifacts while still accommodating the endangered bats that swarm in the west entrance before hibernation. However, the construction of the second gate also left one remaining entrance, the north passage,

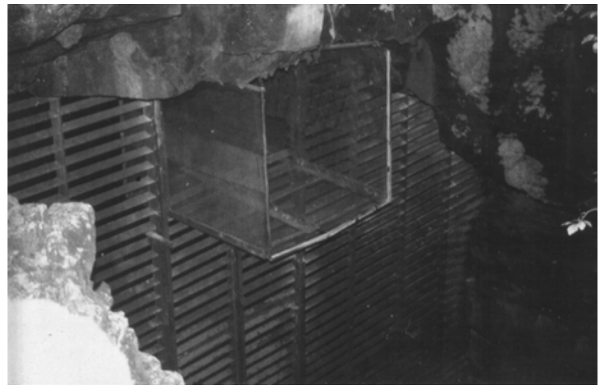

Figure 1

undefended against vandals and trespassers. Plans were immediately underway to build the third and final gate in 1999 in order to safeguard all of Hubbards Cave's winter bat roosts and human artifacts.

The north entrance gating project utilized yet another style of bat gate. This type has an open top to permit bats easier access to the north passage with less navigation between steel bars, but a shield extends off the front and back which makes it extremely difficult to violate (Figure 1).

The 1999 gate project also revisited the preserve's original south gate in an effort to stabilize the older structure while alleviating lingering concerns that the gate was inhibiting bat flight. The modifications of the south gate included reattachment of the column tops to the roof of the cave and the installation of a shielded, eight-foot by eight-foot window in the gate's top center (Figure 2).

Figure 2

In October of 1999, bats were observed with night vision equipment over several weeks of swarming activity prior to hibernation. Video was recorded at the south, west, and north entrances to gauge the animals' reactions to the three different cave gate designs. These observations revealed the following:

- At the south gate, the bats used the main part of the structure as often and as well as they used the modified, eight-foot by eight-foot opening.
- Bats using the north gate used the main part of the gate as well as the open space over the top.
- Bats easily used the west gate in spite of its size. Several bats were observed flying through both sides of the cupola as well as out the top cap.
- The south gate does not influence the temperature at the hibernation site.

Conclusion

Fifteen years and three gate styles later, it may finally be concluded that the original south gate did not cause the endangered bat population decline. Increases in human traffic, vandalism, and raccoon predation are the likely causes.

Hubbards Cave Preserve has become a success story that illustrates the power of partnerships in effecting conservation and adaptive land management. The preserve is now monitored by a local caver, a critical contact for educating neighbors about the endangered bats. Historians and archaeologists, all interested in preserving the cave's cultural resources, donate their time performing artifact surveys to document the extensive, prehistoric human use of Hubbards Cave. These same people are contributing to the preserve's new management plan in a cooperative effort to manage Hubbards Cave for a variety of resources, including recreation. Even simple actions like an annual trash clean-up bring dozens of volunteers to task, more so than at any other Conservancy preserve in Tennessee. With protected entrances and high levels of support and volunteerism, the Conservancy anticipates future bat counts in which Dr Tuttle's quarter-million tally for gray bats becomes a reality once again.

Acknowledgements

Special thanks go to American Cave Conservation Association, Bat Conservation International, Wallace Research Foundation, U.S. Fish and Wildlife Service, Tennessee Wildlife Resources Agency, Southeastern Cave Conservancy, Inc., National Speleological Society, and the dozen grottos that volunteer tirelessly at Hubbards Cave Preserve.

Using a Geographic Information System for Alabama Cave Shrimp Habitat Protection

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Abstract

The endangered Alabama Cave Shrimp (*Palaemonias alabamae*) is known to live in only two cave systems, both in Madison County, Alabama. The shrimp was last seen in the type locale (Shelta Cave) in the early 1970s. This population was presumed to be exterminated by decreasing water quality caused by the use of pesticides in the developing neighborhoods within the watershed. This study focuses on the Hering Cave population because of increasing pressure from development, logging, rural solid waste disposal practices, and agriculture. A Geographic Information System (GIS) model of the Hering Cave watershed integrates data from topographic maps, digital elevation maps, thermography, dye traces, and field studies. The GIS facilitates hydrological and contamination modeling of the area and permits assessment of the hydrological impacts of development and logging. It can also be used to assist modeling impacts of projected development in the watershed.

Surface Disturbance Threats to Karst Faunas in Tasmania, Australia

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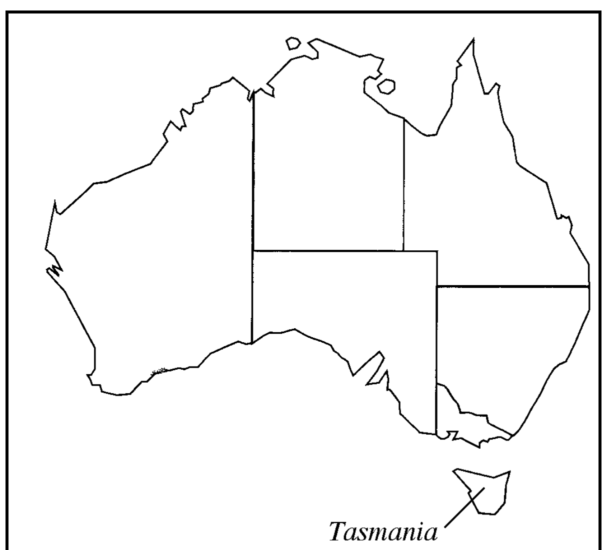
Abstract

Tasmania is the island state of Australia, approximately 160 kilometers (100 miles) south of the Australian mainland. The total karst area in Tasmania is around 3,500 square kilometers (1,345 square miles) representing about 5% of the total Tasmanian land surface of 68,332 square kilometers (26,215 square miles). Some 4,000 caves are reportedly known, mostly found within the 135 documented karst areas; the karst bio-space within these areas contains a diverse array of invertebrates species, aquatic and terrestrial. A number of caves and karst areas in Tasmania have been degraded by land surface disturbance due to mining, road-making, and forestry activity, particularly where the ground-breaking impacts of forestry activity including deforestation occur in upstream catchments. Impacts from surface disturbances have affected karst bio-space ecosystems and food chains leading to disruption of species communities due to a decline in species numbers, species diversity, and actual presence of individual species. The effects of forestry practices including road making and deforestation have lead to increased sediment load and turbidity in cave streams, plus less predictability of stream flow, including a substantial increase in flooding events. Road-making and inefficient conduit of road runoff waters have introduced sediment loads into caves in many parts of Tasmania, impacting on cave faunas. Mining is also threatening several karst areas of Tasmania. In the World Heritage Area Ida Bay karst of southern Tasmania, the limestone quarrying that had impacted on two cave systems, Exit Cave and Bradley-Chesterman Cave, is now being ameliorated by a site rehabilitation of the former Benders Quarry site.

Introduction (and land area comparisons)



Tasmania is the small island State of Australia, lying approximately 160 kilometers (100 miles) south of the Australian continent, separated from the mainland by the Bass Strait. Australia itself is an island—in fact the world's largest island. Size-wise, Australia (including Tasmania) has a land area of 7,686,850 square kilometers (2,971,081 square miles), very similar in size to the 2,960,207-square-mile USA landmass between Canada and Mexico, (excluding Alaska and Hawaii). Despite its large area size, Australia has a small population, around 19 million, roughly as many people as the City of London in England. Some 98-99% of the Australian population lives on the coastal fringe. USA is situated between the latitudes 25°N and 48°N; Australia is situated closer to the equator: between the latitudes 10°S and 43°S, with the island state of Tasmania at this southern end.

[A few more land area comparisons: Tasmania is a little larger than West Virginia (24,807 square miles); about two-thirds the size of Virginia (39,598 square miles), Kentucky (39,732 square miles) and Tennessee (41,220 square miles); and half the size of Alabama (50,750 square miles) and Georgia (57,919 square miles).]

Caves and Karst in Tasmania

Tasmania is located between latitudes 40 and 43 degrees south; it lies within the cool Temperate Zone and has a weather regime controlled by the influence of westerly winds. Due to topographic influences, the weather pattern in Tasmania has created a moist to wet environment in the mountainous southwestern, western, and Central Plateau areas and a dry central lowland and east coast.

There are approximately 4,000 caves known in Tasmania. Most caves are known from the 135 documented karst areas plus a lesser number of caves from the 40 plus non-karst (pseudokarst and parakarst) areas (Clarke, 1999). Although many of these karst areas are quite small, the total karst area in Tasmania approximates 3,500 square kilometers (1,345 square miles),that is, about 5% of the total Tasmanian land surface of 68,332 square kilometers (26,215 square miles).

In northern and northwestern Tasmania, some karst lies beneath improved pastureland; in western and southwestern Tasmania there is a considerable area of karst underneath either buttongrass sedgeland or alpine vegetation. The actual area of forested karst in Tasmania—predominantly wet or dry, eucalypt dominant, broad-leafed sclerophyl forest and/or myrtle and sassafras dominant rainforest—is probably about 1,800 to 1,900 square kilometers, representing less than 60 percent of the total karst area. There are additional karst areas downstream from forested catchments; some of the catchment forests are being actively logged at present.

Karst areas and cave faunas in Tasmania continue to be threatened by inappropriate forest practices, particularly in karst catchments, along with the effects of road making and mining. The sum-total of these various impacts, either directly below the carbonate rock karst surface or downstream from catchments where groundbreaking disturbances occur, all potentially threaten the faunal component of the karst bio-space.

Threatened Cave Fauna Habitats in the Karst Bio-Space

Karst bio-space is a convenient term to describe the total habitat space for aquatic and terrestrial species in carbonate rock karst areas. The karst bio-space is represented as the sum-total of the actual or potential habitats and microhabitats of all living species in karst (Clarke, 1997b, 1997c). This bio-space can be described in dimensional terms as micro-caverns (millimeter), meso-caverns (1 to 15 to 20 millimeters) and macro-caverns (1.5 to 2.0 centimeters) (Clarke, 1997c). Although most of our cave fauna records relate to species known or collected from caves (the macro-cavern component of the bio-space), in many karsts, the saturated (below water table) and unsaturated meso-caverns probably represent the major habitat space component for invertebrate cavernicoles in the karst bio-space. The spatial component of these meso-cavern-sized spaces includes the numerous interstitial voids in cave streambed or streamside substrates as well as the small solution tubes, cracks, and fissures that drain surface waters from the carbonate rock surface mantles, soils, and surface litters.

In Tasmania, there is evidence to show that ground-breaking activity associated with timber plantations, timber harvesting, or mining activity have significantly impacted on karst processes and the habitats of cavernicolous invertebrates (Clarke, 1997a; Eberhard, 1990, 1992b; Kiernan, 1984). The most threatened species are the aquatic species living in the meso-caverns and macro-caverns of the saturated epikarst and endokarst and flooded (phreatic) regions. In some disturbed areas, the hypogean cave faunas in the twilight and transition zones of caves have been replaced by an "invasion" of opportunistic exotic species such as flatworms, snails, and fresh-water crayfish from epigean habitats (Clarke, 1989; Eberhard, 1990). Although the most threatened faunas are the aquatic species, particularly obligate species, any disturbance to the karst bio-space ecosystem and food chain, will ultimately affect terrestrial species.

Nature of the Threat to Karst Bio-Space and Faunas

Soil mantles on carbonate rock are generally thin, clayey residual soils. The mobilized grits from clays in disturbed soil profiles can lead to blockages in solution-widened meso-cavern cracks or fissures in the karst bedrock, impeding further karst solution processes and impacting on the karst bio-space. Ground breaking activity in karst catchments usually leads to an increase of sediment influx into streams from surface runoff. Similarly, forest removal or changed vegetation regimes in karst catchments generally lead to altered stream flow conditions. For example, flooding in stream caves often occurs as a result of the increased water yield following forest removal in catchments (see Figure showing high water levels in Gunns Plains Cave). The effect of flooding is heightened where Radiata pine plantations are harvested along with the marked increase in sediment yield and silt loss compared to harvesting of native forests (Clarke, 1989, 1997a). Needle-leafed pine trees have increased evapo-transpiration rates compared to broad-leafed native forests in Tasmania. The growth of pine trees on karst significantly reduces the water intake of carbonate rock surfaces leading to "drying-out" of caves (Clarke, 1997a) and potential desiccation of invertebrate cavernicoles.

Gunns Plains Cave flooding

Aquatic cavernicoles including stygobionts in hypogean (underground) habitats of karst areas will be threatened by the same impacts that affect aquatic species in surface habitats (Clarke, 1997a). The stygobionts from Tasmanian karst areas are mainly represented by species of crustacean groups: copepods, ostracods, bathynellid syncarids, anaspidacean syncarids, phreatoicidean isopods, janirid isopods and crangonyctoid amphipods, plus two other groups: hydrobiid gastropods and paludicolan flatworms (Clarke, 1997a). The effects on cave faunas will be more marked because of the limited mobility of some species to avoid impacts, for example the minute aquatic snails (Eberhard, 1992a, 1992b) or the narrow habitat range due to restricted hydrological system limits imposed by the individual subterranean karst, together with the naturally low nutrient input levels.

Terrestrial cavernicoles in hypogean habitats of karst areas will be directly and indirectly impacted by effects on aquatic species and alterations to stream hydrology that promote sediment deposition, affect moisture input levels, or interfere with natural air current movements. Terrestrial cave faunas will also be directly impacted by disturbances to the epigean karst surface that modify bio-space humidity due to reduced percolation flow or introduce toxic pollutants (including sedimentation) and similarly modify other natural meteorological conditions related to air volumes and air flow (Clarke, 1997a, 1997b).

Ground Breaking Disturbance Impacts of Forestry, Particularly Deforestation

A number of caves and karst areas in Tasmania have been degraded by land surface disturbance in upstream catchments. Turbid floodwaters have been observed emerging from cave effluxes in the Gunns Plains karst in northern Tasmania and in the Weld River karst of southern Tasmania. Both these karsts are situated downstream from logging operations in forested catchments. Some of the cave communities in stream caves in the Gunns Plains karst area contain very few aquatic species and the terrestrial species in these sites appear to be mainly accidental epigean species and trogloxenes. Similar impacts have been reported in sections of the Mole Creek karst as a result of poor management in forested areas, particularly on private landholdings (Kiernan, 1984, 1989).

Forest practices commonly include road making and snigging tracks; quarrying of stone for road emplacement, fill for low-lying areas, or as road gravels; timber harvesting, clearing, windrowing, and burning; plus the development and maintenance of plantations. Most of these forestry practices will lead to significant impacts on cavernicolous faunas. There will be direct effects on aquatic invertebrates and indirect effects on terrestrial species either in those karst areas underneath forest activity or karst downstream from catchments that are being logged or developed for plantation forests. The cave fauna of karst bio-space will be directly impacted by surfaces disturbances in karst (Clarke, 1997b, 1997c) particularly ground breaking activity and the destruction of surface litter or mulch by forestry practices including fire (Holland, 1994).

Problems of Road Making and Logging with Suggested Solutions

Road making in karst catchments of Crown lands and private lands should follow strict guidelines, such as those in the Tasmanian Forest Practices Code (Forestry Commission, 1993). Roads should be constructed in a manner that avoids sediment input to streams. Ideally, where possible, roads in karst catchments should follow ridgelines; if not on ridgelines, roads should run parallel to and at least 100 metres distant from major watercourses and incorporate sufficient sized drainage channels and sediment traps or settling pits to prevent sediment-laden waters reaching watercourses. If sediment overload is likely to be a problem, filtering mechanisms (such as tea-tree brush or pea-straw bales) should be deployed. Karst catchments should only be partially logged in any given season and logging coupe sizes should be minimal to reduce runoff and altered flow regimes in streams draining into karst areas that are known or likely to contain cave fauna communities.

Where sealed roads traverse across karst, there is a necessity for appropriately designed ducting, conduits, or open table drains (with a sealed base) to convey water off the karst. Where runoff water has to drain into karst from roads or roadside guttering, the runoff water should be transferred via settling ponds or sediment traps as mentioned above.

Threats from Mining

In the Ida Bay karst of southern Tasmania, limestone quarrying has impacted on two cave systems which have related hydrological drainage during periods of high recharge: Exit Cave and Bradley-Chesterman Cave (Clarke, 1989, 1991; Houshold 1995; Kiernan 1993). While the nearby Benders Quarry was operating upstream from Bradley-Chesterman Cave, there was an almost constant smell of petroleum products in the cave streamway, along with an absence of cavernicolous aquatic species (Clarke 1989; Eberhard, 1990, 1997). During the time when the quarry was working there was frequent turbidity in Eastern Passage, one of the major side passages in Exit Cave. Subsequent investigations indicated that the headwaters of Eastern Passage drained from Benders Quarry and the turbidity was due to flocculation of an accumulated bedload of semi-compacted clays derived from the mobilization of the clayey palaeokarst fills in the former Benders Quarry (Clarke, 1991; Houshold, 1992; Kiernan, 1993). Baseline studies in *Exit Cave* indicated reduced population densities of aquatic snails and less diversity in aquatic species in the passages draining to Exit Cave from the quarry (Eberhard, 1990, 1992b, 1997). The minute pinhead-sized hydrobiid snails are known to be a good indicator of water quality (Eberhard, 1992a; Barmuta, 1998); the sparse numbers of hydrobiids in the cave passage leading from Benders Quarry were quite apparent when compared to population numbers and densities in other passages in Exit Cave.

In other parts of Exit Cave, upstream from, or not connected to the side passages draining the quarry, the species diversity was unaffected. For example, four aquatic obligates (all believed to be stygobites) were observed in a short (meter long) stream section of Western Passage: anaspidean syncarids, crangonyctoid amphipods, paludicolan flatworms and minute 1-millimeter sized hydrobiid gastropods (Clarke, 1997a). Benders Quarry was closed in 1992 and since the extensive quarry rehabilitation began in 1993-1994, population densities of hydrobiid snails in Eastern Passage have been slowly increasing. Similarly, recent observations in Bradley-Chesterman Cave indicate that a number of previously unseen cavernicolous species are now appearing in the cave streamway.

Another limestone-quarrying proposal is currently being considered in an area of glaciated polygonal karst at Mt. Cripps in northwest Tasmania—a karst area also covered by a pristine, unlogged myrtle dominant rainforest. Caves in this Mt. Cripps karst area contain many significant invertebrate species, including endemic species known only from single caves in this karst area. At time of writing, the objections to the exploration license for this quarry proposal are still before the Mining Tribunal court in Tasmania.

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About the Author

Arthur Clarke: active as a speleologist on both local (Tasmania) and national (Australian) scene with a background in geology, karst geomorphology, and invertebrate zoology (biospeleology). Actively involved with management aspects in the re-development of the Hastings Caves tourist complex in southern Tasmania. Currently in full time post graduate studies studying for a Masters Degree at School of Zoology, University of Tasmania, (Sandy Bay, Tasmania, Australia) looking at factors affecting the biodiversity and distribution of invertebrate species in cave ecosystems in two adjoining karst areas of southern Tasmania: in Cambrian Dolomite and Ordovician Limestone.

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Protection of the Edwards Aquifer Recharge Zone through the Sensitive Land Acquisition Program

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Abstract

The Edwards Aquifer is the sole source of drinking water for over a million people in South Texas. Our responsibility to protect this precious resource is becoming increasingly important, especially with a rapid rate of residential and commercial development occurring within the boundaries of the Edwards Aquifer Recharge Zone.

The San Antonio Water System initiated a Sensitive Land Acquisition Program in the fall of 1997 specifically for the purpose of protecting and preserving the quality and quantity of water entering into the Recharge Zone. The Land Acquisition Program is a unique and innovative program established to protect lands that are predisposed to geologic sensitivity and contamination. The main objectives of the Land Acquisition Program is to protect water quality through the preservation and protection of point recharge features, such as caves, solution cavities, and sink holes in the Edwards region. Other methods of protection for San Antonio's sole-source aquifer include the establishment of conservation easements and fee simple acquisition of sensitive lands thus achieving the goal of reducing the detrimental impact of certain land use practices on the recharge zone.

To date the Land Acquisition Program has played a role in the preservation of 6,471 acres of recharge zone and approximately 13,700 acres are currently under negotiation. The success of the Land Acquisition Program is a direct result of the partnerships that have been established with non-profit agencies such as The Trust for Public Lands, The Nature Conservancy of Texas, and The Bexar Land Trust. These agencies share a common goal of preservation of open space, protection of water quality, and the protection of species habitat associated with the Edwards Aquifer.

Assessing Risk and Identifying Resources for Search, Rescue, and Medical Emergencies

A tool for land managers who have neither jurisdiction nor personnel to conduct or manage an emergency operation.

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Abstract

A presentation designed for karst managers who lack jurisdiction for conducting searches and rescue operations or managing medical emergencies or who have jurisdiction but lack personnel to conduct search and rescue operations or respond to medical emergencies.

No land manager should wait until an actual emergency incident to be introduced to his or her local search and rescue teams or local medical responders. This presentation provides an overview of the steps land managers can take to identify appropriate response resources, make sure their organization is part of the command structure for the incident, and ensure the event is run in accord with their needs.

Introduction

Land managers fall into two broad categories when it comes to planning for emergency incidents:

- Those with jurisdiction to provide emergency assistance and the personnel to provide part or all of the response; and
- Those who lack either the legal jurisdiction to conduct or manage an emergency operation, or who do not have personnel trained in emergency operations.

Jurisdiction, for the purpose of this paper, means the authority or legal power to manage some, or all, of the incident. Those land managers with jurisdiction and with personnel to handle some portion of the emergency operation, are usually governmental entities—city, county, state, or federal. These managers frequently have a duty to provide an emergency response. And, the public visiting these properties often expects a response or assistance from individuals wearing the uniform of these land management agencies.

Land managers without jurisdiction are usually from the private sector encompassing not-for-profits, trusts, foundations, and individuals. They face a different set of challenges than do managers with jurisdiction and a duty to respond.

All land managers have the potential for an emergency incident requiring outside resources and responders. Unfortunately, from the land manager's viewpoint, not all such incidents end on a positive note. The incident may create adverse publicity for the land manager, decisions may be made by responding emergency personnel that are not in accord with the land manager's policies and practices, land and water resources may be negatively impacted, and sensitive flora and fauna may be destroyed or damaged.

These negative outcomes are especially common for land managers with no jurisdiction for managing or conducting an emergency operation on their property or for those who may have some jurisdiction but have no personnel to provide that response.

To ensure a more positive outcome from the land manager's point of view, it is important to plan ahead for emergencies requiring outside responders. The day of the emergency is not the time to learn how to manage an emergency incident, meet responding personnel, and describe your organization's policies to the responders, press, and family members. Indeed, the chances are excellent that the event will be well under way, and responders already on scene, before you are aware that the emergency exists.

A good plan should:

- be designed around the basic types of emergencies
- assess the risks to individuals the land manager's property presents
- assess the risks to the property that the response to the emergency presents
- determine how to handle publicity
- identify potential responders, and
- contain ways to mitigate the effects of the response

Four Types of Emergencies

There are four basic types of emergencies that usually require outside responders:

- medical emergencies
- searches for lost individuals
- rescues of ill or injured individuals
- natural disasters such as fires and floods
-

Occasionally an incident may incorporate portions of all four. In addition to these emergency events other types of situations may arise–such as plane crashes. But the planning for the four major events should provide sufficient guidelines for handling these other types of disaster situations.

Medical Emergencies

Medical emergencies can occur anywhere. There is little difference between what can happen to an individual at home, at the mall, or on managed land. Common medical emergencies include:

- heart attack
- stroke
- choking
- difficulty breathing
- rapid onset illness, such as a reaction to an insect sting or a snake bite
- illness due to a chronic condition such as diabetes

Responders to medical emergencies bring to the ill or injured subject the highest level of pre-hospital care immediately available. The EMS (emergency medical services) system of pre-hospital care encompasses "First Responders," and Emergency Medical Technicians (EMTs). For most communities, this usually means an ambulance service that provides, at a minimum, basic life support. But care can and does vary from one state to another, and even within counties in a state.

The least that the landowner should expect from an organized rescue service (county, city, or private) is that personnel have received "First Responder" training. This means that the individuals are trained to provide initial care for patients suffering injury or sudden illness and trained to help EMTs at the emergency scene. Some services provide advanced life suppport and others have advanced life suppport personnel who are also trained in wilderness response protocols. Frequently, these emergency medical responders are backed up by a helicopter transport program staffed by paramedics and nurses and operated out of a hospital with a large trauma or critical care facility.

"First Responder" training is fairly standardized. Classes are based on guidelines originally developed as a 40-hour course by the U.S. Department of Transportation. Unfortunately for the land manager, when it comes to other EMS training, each state has its own definitions of what constitutes basic and advanced life support. It is not unusual for some of the skills considered advanced in one state to be considered part of the basic life support skills in another.

Individuals injured on your property will receive the same standard of emergency medical care that the community surrounding your property receives. The chief difference in an EMS response to an individual on land management property and one at the mall, or at home, is one of access to the individual.

Searches for Lost Persons

Searches usually involve a person, or persons, reported overdue or presumed lost. On some occasions they may involve an object, such as a weapon used in a crime.

The lost or overdue person(s) may range in age from very young children (sometimes just barely able to walk) to adults. The individual may have a chronic medical condition, be physically or mentally handicapped, be mentally ill, or have a debilitating disease such as Alzheimer's. A search should always be treated as an emergency.

A land manager may become involved in a search directly or indirectly. The person may have become lost while on the manager's property and is reported lost by the land manger. Or, the overdue or lost individual is presumed to have wandered onto the management area from adjacent property. Either way, the effect on the land and its managers is the same.

Jurisdiction for search is not uniform in the United States. In western states, search is frequently the responsibility of law enforcement agencies, such as the sheriff or the state police. In eastern states the jurisdictional lines may cross, and several agencies may have, or may believe they have, the responsibility for search. And responsibility for search may also vary from county to county within a state—a problem for land managers whose properties encompass more than one county. Often in the east, when a dispatch center, such as a 911 facility, receives a call about an overdue or missing person the center will dispatch a law enforcement officer. If the law enforcement officer determines that there is no foul play, the officer may request the services of the fire department to actually conduct the search. Law enforcement may then leave the scene, and all responsibility for search then falls to the fire department.

Most land managers consider search to be an above-ground activity. But those with caves, or non-operative mines, must consider and plan for searches below ground. Searches can also take place in water and present additional difficulties. Most searches that occur in water are for the bodies of individuals presumed drowned.

Rescues of Ill or Injured Individuals

Be aware that the term rescue can be interpreted in two ways. In many areas, when a group is identified as a rescue squad, their main functions are automobile crash extrications and back-up medical assistance for an ambulance-based service. Their training and equipment is focused solely on medical support and the use of vehicle extrication tools.

The other meaning of rescue involves assistance to the ill or injured in remote, or difficult to access, wild land areas. The rescue operation brings the highest level of medical care, immediately available, directly to an injured or ill individual and evacuates that individual from the point where they were injured or taken ill. Because this type of rescue frequently involves a location where normal EMS access is difficult, this means that frequently the ambulance crew is not going to provide initial care to the injured or ill person. Instead, the rescuers will provide this initial care and transport the person to the waiting ambulance-based personnel.

Like search, rescues can take place above or below ground. Like search, rescue above ground can involve the use of motorized vehicles and aircraft. Radios can be used to keep track of the rescuers and receive updates on the injured or ill person(s). Expect rescues underground to take longer. Specialized communications must be set up and evacuation becomes an exercise in logistics and manpower.

It is not always clear who has jurisdiction for rescue. Again, in the western states, this usually lies with law enforcement. In the eastern states the situation is even more confusing than it is for search.

Some states only allow rescue services to be performed by a governmental agency such as a fire department, or through a state-certified rescue program. Other states allow any group wishing to provide rescue services to incorporate, raise money, and hold themselves out as a rescue organization within their county. In some states this has resulted in several rescue organizations competing for victims (and funding) with other county rescue groups. There are no current standards for what constitutes appropriate rescue training for the wilderness environment.

Always be aware that a medical emergency, or a lost individual, may include a rescue component.

Natural Disasters Such as Fires and Floods

Fires and floods present their own set of problems. Some wild land managers may prefer for the area to burn, rather than allow the fire to be suppressed. When heavy trucks and brush crews enter an area they can often do more damage to the environment than the fire presents. In addition, some types of vegetation require fire to re-propagate. Response to fires varies from area to area. Many states have agencies devoted to forestry. One of their responsibilities is the suppression and management of various types of wild land fires. But it is not unusual for county or city fire departments to also engage in this activity.

Floods present a hazard to individuals that may be hiking, camping, or using the property for day trips or events. Flooding can also be a factor in cave rescue. Responders for flood events will vary from county to county. Special training is needed for responding to victims trapped in rapidly moving water.

Planning for Ensuring a More Positive Outcome

It is impossible to control a large event once it has begun. Begin, instead, by assuming that one or more of these emergencies will occur and create a written plan to address your concerns. Creating a plan requires initiative on the part of the land manager. To be good, a plan does not have to be complex. But it does need to be comprehensive. The plan should:

- Assess the risks to individuals the land manager's property presents
- Assess the risks to the property that the response to the emergency presents
- Determine how to handle publicity
- Identify potential responders, and
- Contain ways to mitigate the effects of the response

Assess the Risks to Individuals That Your Property Presents

All properties present some risk to visitors. The risk might simply be in terms of lack of easy access for medical personnel when dealing with a medical emergency such as a heart attack. Or the risk might be more direct, such as falling from a height, or drowning. Note the places on the property where such risk exists. The point is not necessarily to minimize the risk, but to know it exists. Once a risk is identified, the land manager will be able to give adequate directions to the responders involving that location, be aware of the types of response necessary for an event at that location, and be prepared to provide input before and during the management of the emergency.

When assessing risk it is important to discuss these factors with the land manager's attorney. For some organizations, acknowledging that the property presents any risk at all will outweigh all other factors such as environmental degradation or unfavorable publicity.

It will be necessary to physically visit the property and its features to do an accurate assessment of the risks that it presents. Record locations or directions to these risk features as well as basic information about the feature (height, depth, and so on). Consider access to these locations, and the types of skills responders would need to have to handle an emergency at the location. Begin by noting the obvious:

- **Falls from heights**. Are there heights, such as cliff faces, water falls, or boulders, that present an opportunity for a view, or are a site for such sports as rappelling or rock climbing?
- **Confusing points on trails**. If there are trails on the property are there any points where an individual can be easily misled? Is signage misleading, confusing, or difficult to read?
- **Poisonous plants or insects**. Are there common or unusual poisonous plants or insects on the property? Do any require unique anti-toxins not normally available to EMS personnel or from the local hospital?
- **Water hazards**. Are there bodies of still or moving water that can become points of danger for the unwary? What is the water depth, or the rate of water movement? Is this seasonal?
- **Other**. Are there features to the property, such as old mines, tunnels, wells, buildings, or slide areas that are unique and present some danger? What are they? Are they year round or seasonal?

Assess the Risks to Your Property That These Emergencies Present

All emergency incidents affect the organization and its property. The amount of impact is dependent upon the size of the event, the urgency of the mission, and the duration of the event. Those things with the most impact include:

- **People**. A small emergency, such as a response for a heart attack, will bring at least two medical people to the scene. A larger incident, such as a search or a rescue, may bring dozens, or even hundreds, of people to the scene. When people are present for any length of time they bring all of their physical needs with them. They need to be fed, watered, and toileted. People generate waste as well. When they are located in one area in large numbers their mere physical presence will impact the land. When they walk, or are transported, that too can change the environment.
- **Equipment**. People will bring equipment with them. In a minor medical emergency this will be the medical kit and the ambulance stretcher. In a rescue, this may mean a large amount of material that must be located at one or more sites convenient to the rescue operations. Equipment must some-

times be transported to a rescue site. This could involve additional environmental impact.

- **Vehicles**. People and equipment are transported to the scene in vehicles. In the case of a volunteer organization (even if it is run as part of a governmental unit) this may mean a large number of personal vehicles. Often, response protocols dictate that a fire truck be sent to certain types of medical emergencies. Fire trucks are very large, heavy, and require significant amounts of space in which to be turned. Other rescue vehicles that are used for transport of personnel may also be large and heavy and will impact the land. All vehicles will probably remain on scene until the emergency is resolved. This means that they will be parked in a location that may or may not be of the land manager's choosing.
- **Command**. This refers to the individual(s) managing the incident. Most incidents can be resolved with a very small number of individuals in these command roles—one or two at most. But a large search or rescue may involve many more individuals. Sometimes, where jurisdiction is not clear, there may be several entities who take the command role—possibly operating at cross purposes.
- **Operations**. This term refers to the tactical side of the emergency incident. It includes conducting the search, performing all of the tasks necessary for a rescue, and handling the medical needs of the patients and/or the responders. This can be one of the most damaging portions of the event as far as land use and the impact on flora and fauna is concerned. To haul someone up a cliff involves a good deal of repetitive movement in a small space. This can produce unwanted environmental damage. Large groups of untrained searchers moving through the woods can also be damaging. Occasionally fences must be cut to provide access for personnel or equipment. Gates are sometimes forcibly opened.
- **Publicity**. The longer an event runs, the more chance there will be that it will become the focus of the written and visual media. In addition, each responding agency may have protocols that involve publicity that are not in accord with that of the land manager.

Determine How to Handle Publicity

Plan ahead and determine who in the case of a medical emergency, a search, or a rescue, will speak for the land management organization. Make sure that everyone in the organization is aware of this decision and is willing to abide by it. Choose a second individual to serve as a back up, or to act as relief during an incident of long duration.

Have written information available beforehand that describes the land management organization and its purpose.

Decide in advance what information about the property is to be disseminated (such as locations, or information about relics, flora, or fauna). Spend some time determining how the organization wants to handle situations that include life-threatening injuries to a visitor or possibly even death.

If the organization wants the media present, then there should be some criteria for triggering that decision. Before the event, identify specific individuals within the print and visual media and establish a working relationship with them. Those are the individuals to call during an emergency incident. Coordinate press activities with those of the other responders. Frequently their press needs may be at odds with those of the land managers

Identify Potential Responders

911 Centers

Begin by determining who dispatches the responders. Emergency 911 dispatching is usually county based, but not all 911 programs are created equal. In some communities 911 is a centralized service where all dispatchers for all emergency services (fire, sheriff, police, medical, emergency management) are all located within the same facilitiy, and have simultaneous access to the same computer screens and data. It is also possible to have a 911 Call Center, but to have several major emergency providers, such as the sheriff, choose to operate their own dispatch service.

In other communities 911 reaches a single dispatcher, or emergency service provider (frequently the sheriff's office) or agency, who then routes the caller to the responder the dispatcher believes is appropriate. Other dispatchers are not co-located and may not have access to the same sets of data. If the caller is routed incorrectly there may or may not be a quick way to return the caller to the original dispatcher for re-routing.

Emergency 911 centers serve as a dispatch center. They usually work with written protocols. The 911 center does not create these protocols (how many trucks to send; which fire station goes to which address), the responding agencies do.

After determining how the local 911 center works, give them a name and telephone number so they can reach a representative of the land management agency. Then ask them for a list of all agencies they dispatch, and the types of calls for which each responder is responsible. If 911 does not dispatch all emergency responders, find out who is not included and add them to the list. Then meet with each responding organization.

Meet with Each Responding Organization

Meet with each potential responding organization. Remember, there may be more than one organization that believes they have jurisdiction over your emergency. Meet with everyone that feels they have some authority to exercise over your situation. This includes the ambulance service, the fire department, all organizations responsible for search or rescue, law enforcement (sheriff and police), game rangers and natural resources law enforcement personnel, and the coroner.

Begin each meeting by explaining how each responder can reach a representative of the organization. This has to be easy for the responder. No responder, or dispatch center, has the time to place a dozen telephone calls in order to reach the land manager.

At each meeting discuss the risks that your property contains. Explain any environmental concerns, laws, or requirements on your property that will directly affect the responders. Explain your desires regarding participation in command decisions or operations. And ask questions:

- Do they have personnel with the ability to access your risk areas?
- What type of training do the responders have specific to the risks that you have identified on your property?
- What equipment specific to your risks will they bring to the incident?
- How many people and vehicles do they anticipate sending?
- Have they ever conducted an operation of this type before?
- Who do they use as a back up should the event be of long duration, or require additional skilled responders?
- Do they use the Incident Command System as their on-scene management structure?
- What are their protocols for radio traffic?
- Who in that organization is authorized to speak to the press?
- Is the press routinely notified of certain types of events?
- How will they work with you to meet your needs?

Based on their answers the land manager may want to enter into a discussion (at this meeting, or at another) about areas of concern. Some elements may be negotiable, others may not.

Ways to Mitigate the Effects of the Response

Adequate pre-planning can mitigate many of the effects of a large operation. However, there is always a balance that must be maintained between the protection of sensitive areas and the potential loss of the life of the rescue subject or of the rescuers themselves. The most effective way to achieve this balance is by learning what is required for the most common tasks involved in a medical, search, or rescue-related emergency.

A good plan will address those aspects of the emergency that create the highest impact on selected land features. Plan ahead for vehicle parking and the staging of personnel. Pre-plan low impact routes for emergency responders to use to reach high-risk areas. If the event is of long duration, make sure plans exist for handling a large number of people within a small area.

If over-lapping jurisdictions are identified as a problem, insist that the Incident Command System be followed, and take advantage of its Unified Command function. This allows all those with jurisdiction, or with a major stake in the event, to have an incident commander present at the scene, responsible for developing the operational plan and responsible for choosing the operations chief. It also requires all command positions to be co-located. Preplanning for this will help both the land manager and the responding organizations.

Conclusion

This paper has presented an overview of a planning process for land managers to address emergency incidents. Unfortunately, as with any overview, it is impossible to cover all situations and contingencies and to provide the detail necessary for the development of such a plan. Creating a good plan takes a significant amount of time and energy—and sometimes money. This paper can only serve as a starting point in the development of such a plan.

Conducting and Managing Search and Rescue Operations

Mitigating Risk for Land Managers with Jurisdictional Responsibilities.

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Abstract

A presentation designed for karst managers with jurisdictional responsibilities for search and rescue and the personnel to conduct some or all of the operation.

The focus is on organizing and training personnel to provide an initial response to these events, initiating and conducting the initial response, and developing a planning and training manual to govern that response. The presentation is based on the experiences of the Cave and Cliff Division of Walker County Fire and Rescue.

Introduction

All land managers have the potential for an emergency incident on their property. Such incidents can include medical emergencies, searches for lost individuals, rescues of ill or injured individuals, and natural disasters such as fires and floods. Occasionally an incident may incorporate portions of all four. In addition to these emergency events, other types of situations may arise, such as plane crashes, that dictate an emergency response.

Not all land managers have the jurisdictional authority to respond to such incidents. Broadly speaking, this means the authority or legal power to manage some, or all, of the incident. Not all land managers have the personnel to respond. However, some land management organizations have the jurisdictional responsibility for an emergency incident, and personnel to handle some, or all, of the response to such an incident. Those land managers with jurisdiction and with personnel to handle some portion of the emergency operation, are usually governmental entities—city, county, state, or federal—although some private entities exist that have enough personnel capable of managing an emergency operation.

These land management organizations frequently have a legal duty to provide an emergency response. And, the public visiting these properties often expects a response or assistance from individuals wearing the uniform of these land management agencies. This expectation includes an immediate initial response, a comprehensive follow-up to the initial response, and the ability of the land manager to command the situation.

Failure to plan for, and meet, these expectations, can put the land management organization, its flora and fauna, and its visitors, at risk. Improper response can result in:

- Further injury to individual,
- Failure to address the needs of the individual
- Unwanted damage to the land, its flora, and fauna
- Injury to the responders

To mitigate these risks requires appropriate resources, both equipment and personnel. Of these two, the most difficult to address is personnel. Equipment is usually designed to meet certain standards and can be measured and compared. However, in the field of search, rescue, and emergency response, there are no nationally recognized standards for training, personal equipment, or level of experience.

There are, however, some ways to mitigate the risk that this current lack of standards imposes. The keys to mitigation are to:

- Identify risks to individuals or groups that the property presents
- Identify appropriate responses to each of the identified risks
- Identify appropriate resources for response to each type of incident
- Provide training to personnel
- Organize the response, and
- Use an appropriate command structure

Identify Risks

A risk is basically anything that can cause, or contribute to, creating an unplanned-for event. Risks include:

- **Falls from heights**. Are there heights, such as cliff faces, waterfalls, or boulders, that present an opportunity for a view, or are a site for such sports as rappelling or rock climbing?
- **Confusing points on trails**. If there are trails on the property are there any points where an individual can be easily misled? Is signage misleading, confusing, or difficult to read?
- **Poisonous plants or insects**. Are there common or unusual poisonous plants or insects on the property? Do any require unique anti-toxins not normally available to EMS personnel or from the local hospital?
- **Water hazards**. Are there bodies of still or moving water that can become points of danger for the unwary? What is the water depth, or the rate of water movement? Is this seasonal?
- **Other**. Are there features to the property such as old mines, tunnels, wells, buildings, slide areas, that are unique and present some danger? What are they? Are they year round, or seasonal?

Identify Appropriate Responses

Once the existing risks are identified, decide what type of response might be necessary and determine if personnel on-site can handle that emergency without assistance. The land manager may determine there are certain emergencies personnel on site are not adequately trained or equipped to handle.

For example, personnel on site may be trained to handle a medical emergency should it arise in the parking lot, but may not be trained to manage one that is wilderness based. If a swift water hazard is present, staff may not be trained and certified in swift-water rescue. If there is a cave on the property, staff may have the training in the high angle and patient evacuation techniques necessary, but may not be familiar with their use in the underground environment.

Identify Appropriate Resources

In Walker County, Georgia, the Department of Natural Resources has jurisdiction over several of the state's finest cave and wild land resources. However, they do not have sufficient personnel on site to provide an initial response to a complex incident, nor do they have the depth of personnel state wide to handle a long or difficult search or rescue on their properties in Walker County. Instead, they rely on one of the divisions of the county fire department to provide personnel and technical expertise for these types of operations.

But sometimes these two groups are not sufficient to provide follow-up. In those instances the fire department must call on additional groups with similar training and expertise to provide assistance.

This situation is not unique. Many land managers with paid personnel may have insufficient trained personnel to handle:

- An incident of long duration
- A incident that is technically complicated
- An incident that involves a large number of subjects, or even
- The initial response.

Nearly all land managers have to rely on both their own staff and additional personnel to manage many emergency operations.

Staffing, for emergency incidents, usually involves personnel that are:

- Paid
- Volunteer, or a
- Combination of paid and volunteer.

These individuals can either be under the direct control of the land manager, or come from other organizations or agencies. In the example of Walker County, Georgia, above, the Department of Natural Resources has paid staff, and the fire department is an all-volunteer organization.

Using the information from the risk assessment, and the types of response necessary to address those risks, determine what type of additional resources might be needed. Look at both the source of those resources and the training those resources have. Based on that information:

- Develop a tentative list of resources for emergency situations,
- Determine the level of training of those resources identified, and
- Meet, or talk, with each resource identified as appropriate to your needs to discuss protocols for emergency operations.

Although these activities appear in this list in serial order, some of them may need to be managed simultaneously.

Identification of appropriate resources is more than compiling a list of possible responders. It is also important to understand what the resource means when they describe a service that they can provide.

The term "rescue" can be interpreted in two ways. In many areas, when a group is identified as a rescue squad, their main functions are automobile crash extrications and back-up medical assistance for an ambulance-based service. Their training and equipment are focused solely on medical support and the use of vehicle extrication tools.

The other meaning of "rescue" involves assistance to and evacuation of the ill or injured in remote or difficult to access wild land areas.

Develop a List of Resources for Emergency Situations

There are four types of resources commonly available. They represent paid, volunteer, or a combination of both:

- Individuals within your own land management organization
- Local agencies
- Mutual aid
- State level resources

Individuals Within Your Own Land Management Organization

The first line of response should be land management staff. There may be individuals within your own land management organization, without a daily, job-related responsibility for emergency response, who have received search, rescue, emergency medicine, or command training. This is usually as a result of a personal interest, or because they are involved with a volunteer fire department or search and rescue group. Their training can encompass anything from:

- Medical–First Responder, EMT, Wilderness First Responder or Wilderness EMT
- Management—managing the lost person incident, the Incident Command System
- Technical—high angle rescue, confined space, hazardous materials, cave rescue, swift water rescue, agricultural or farm rescue

Local Agencies

Next come the local agencies with a duty to respond to emergency situations. These agencies may be paid, volunteer, or a combination of both. These include responses to wildland fires, structural fires, lost persons, medical situations, and injured or trapped individuals. Wildland fire response is often the responsibility of the state forestry commission. The local fire department may be responsible for a variety of responses such as structural fire suppression, some limited wildland activity, automobile extrication, and search and rescue (in either the wilderness or urban environment). Other agencies, such as sheriff's offices and rescue squads not affiliated with fire departments, may also have responsibility for search and rescue missions.

A quick way to develop a list of potential resources is to determine who dispatches the responders. This is most frequently a 911 call center. However, not all 911 centers dispatch all emergency services within a district. It is possible to have a 911 call center, yet have several major emergency providers, such as the sheriff, choose to operate their own dispatch service. Ask the 911 center for a list of all agencies they dispatch, and the types of calls for which each responder is responsible. If 911 does not dispatch all emergency responders, find out who is not included and add them to the list.

Working with the parent agency and the 911 center identify the units (hall, station, division) that would normally be dispatched first and second to the various types of emergencies at the property.

For example, in case of a fire on the area, it is necessary to know and work (within the chain of command) with the fire stations that are dispatched first, and with the stations that protocol dictates come next.

Mutual Aid

Many local agencies have written mutual aid agreements with responders from other counties and cities. There are also mutual aid responses based on tradition, rather than written agreements. Again, the 911 call center will have some information on mutual aid responders. But, it will be helpful to verify this information with each local emergency response resource.

State Level Resources

This includes responders that can be accessed through state or federal agencies. In some states, search is the responsibility of the state level law enforcement agency. Responders are frequently paid employees of the agency.

State level resources may also include volunteer services, usually incorporated as not-for-profits, that are willing to travel and provide their services state wide. Search dog units frequently operate in this manner

Level of Training

Once resources have been tentatively identified, the next thing to ascertain is their level of training in the areas of expertise necessary to the land management organization. This is much easier said than done, because there are no national standards for search and rescue groups, either at the individual or at the team level.

As a rule of thumb look for participation by some or all of the group members in:

- National or regional training programs operated by not-for-profits
- Certification programs from nationally known private training firms
- Associations or societies whose mission is the same as the group

Good training can be provided at the local level within the group. However, such training may tend to become in-bred and may often fail to keep up with new equipment and techniques.

Another good way to determine level of training is to ask for copies of the textbooks or manuals the group uses as a basis for their training program. The group may also have developed its own training manual.

Also ascertain how often they train in the specialty area in which you are interested. A volunteer fire department may train every Monday evening, but they may only train once a year, for a few hours, in the specialty you need.

Meet with Each Resource

It is obvious that to develop sufficient information on training levels, some conversation with the resource must take place. Follow up on this initiative and either meet with, or hold further conversations with, these potential resources.

Three things should emerge from these meetings:

- Information on equipment that the resource can make available
- Information covering special protocols the land manager needs the resource to follow, and
- Information on any special needs that the resource has in responding to the land management organization's emergency incidents

Provide Training

It should not be assumed that the resources identified, whether individuals or groups, have ever trained or worked together. Nor should it be assumed that, although there may be mission overlap (both the fire department and the sheriff's office believe they have responsibility for search), that all groups have equal, or even the same type, of training for the mission. In addition, land management staff may require training to meet the risks that the property represents.

Most land manager's do not want to become training agencies. They have neither the resources nor the personnel. However, if they want to ensure a positive outcome for emergency events involving a range of resources, it is important to make sure that two issues are addressed:

- Training for land management agencies own staff

- Shared training opportunities with additional responders

Generally speaking, training needs to be provided on three levels. The first is awareness. Resources should be able to identify the nature of the incident, the types of skills required to resolve the situation, be able to determine if they (as responders) have the necessary skills, and be able to determine who to call to resolve the incident if they do not have the skills. The next level is operational. Resources need the skills to actually resolve the situation under supervision. The third level is technician, which means the individual has the expertise to execute the skill and direct others. When looking at training, be sure to provide training only for the level needed.

Training for Land Management Staff

The organization needs to adopt some suitable methods and techniques for addressing their risk response needs. There are three ways to do this:

- Write a land management organization specific training manual
- Adopt one or more techniques and procedures described in standard rescue publications, or
- Create some combination of the above

Once suitable methods and techniques for meeting risk needs are determined, then schedule routine training and stick to the methods chosen.

Shared Training Opportunities

If the land manager wants some control over the outcome of the emergency incident, it is important to consider the training needs of the potential resources. It is important for outside responders to become familiar with the land management staff and with the terrain in which they will be working. Also, the land manager, as a sponsor of training opportunities, can provide a neutral ground for various types of responders to work and train together, sometimes for the first time.

Organizing The Response

Take the initiative in planning for and organizing the response. An emergency incident is not the time to discuss techniques, methods, or organizational needs. Plan ahead.

Emergency responses do impact property. Before such a situation arises, discuss with the identified responders any special needs and requirements that the land management organization may have in respect to endangered or sensitive fora and fauna. If there are some trails that provide access to the property that present fewer environmental concerns than others, let the responders know which ones those are. If parking is an issue, plan ahead, and determine how that will be addressed. If a site with sensitive plant life presents a high level of risk for a fall, and the only way to extricate the subject is by working in the sensitive area, determine what level of damage the property manager is willing to accept, or try to develop alternatives. Put as many of these expectations in writing as possible.

If the county in which the property is located has a centralized dispatch system for emergency responders, take advantage of this. If resources outside the normal dispatch area are identified, add them to the call list for the dispatch center. This speeds up response time.

Be consistent in the nature of your expectations. Do not allow access by a route one day, and then deny it on another, without adequate notice and justification. Require that all emergency operations be performed professionally, meeting the requirements of the training the organization has identified. Again, put information in writing.

Brief responders before the incident, and debrief them afterwards. All responses can be improved and the information for that improvement comes from practice, and from the debriefings conducted after every incident.

Use an Appropriate Command Structure

When faced with working with multiple responders—such as fire departments, rescue squads, law enforcement, or emergency management agencies—insist that all responders use the Incident Command System for on site emergency management.

All organizations and agencies have a management structure under which they operate on a daily basis. Within that management structure is usually a chain of command which does not vary. However, managing search and rescue or other risk-based incidents frequently requires flexibility not found in the daily management structure of an organization.

There is a different management structure that most public safety agencies across the United States use at the scene of an emergency incident, whether it is a large incident (100 or more responders) or a small one (one or two responders). This on-scene management system is called the Incident Command System.

The Incident Command system:

- Is organized around the management of the five basic tasks of functions that need to be accomplished in managing any incident–command, planning, operations, logistics, and finance
- Allows the incident's organization to reflect only what is required to meet planned tactical objectives
- Defines a span of control
- Provides common terminology
- Provides for integrated communications
- Provides a systematic plan for resource management
- Defines needed incident facilities, and
- Provides for an action plan–either written or unwritten

The incident command system has many strengths, one of the greatest being the "Unified Command" function. It must always be kept in mind that each governmental agency and each responder–be it law enforcement, fire department, or emergency medical personnel–may only provide operational support within very specific guidelines dictated by their state constitutions, state legislation, state rules and regulations, and local laws, ordinances, and policies. Neither may governmental jurisdictions and agencies abdicate their legal authority or responsibility to others. The unified command function of the Incident Command System provides a mechanism where no agency yields its authority or jurisdiction, nor may they be made to perform or provide services outside their legal scope of activity.

Briefly, under the unified command function:

- Each agency with jurisdiction chooses and appoints its own commander for the incident. Obviously, there can be many Incident Commanders.
- There is only one command post, and all of the Incident Commanders are co-located at that post
- The commanders develop a set of objectives for the incident that all can agree to support.
- Once all of the commanders agree to the objectives, they then develop a single action plan. This is where the rubber meets the road. All commanders lay on the table what resources–in terms of people, equipment, and money–they can bring to the situation. All commanders also define the limitations under which they must operate.
- All incident commanders agree to the plan
- The incident commanders then select one individual, the operations chief, to implement the plan

Unfortunately, not all agencies are familiar with the unified command function of the Incident Command System. This is true even though the information is available in a number of standard publications that are commonly used by fire departments and rescue squads. This may be one area where joint training will yield benefits for all involved.

In Conclusion

The keys to mitigation all require initiative on the part of the land manager. And even taking the initiative is no reassurance that all events will occur in the manner planned and agreed upon. But by planning ahead, meeting with responders, making the needs or the land management organization know, and providing training opportunities, it is possible to resolve many incidents to the satisfaction of all involved.

Recent Projects and Problems of the Michigan Karst Conservancy

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Abstract

Michigan Karst Conservancy was founded in 1983, bought their first property in 1987 (480-acre Fiborn Karst Preserve) and their second in 1990 (28-acre Stevens Twin Sinks Preserve). An additional 2.5 acres including the Bruski Sink was donated to add to the latter in 1997. A Landowner Liaison Program is attempting now to encourage future acquisitions. Most regular activities are concerned with management of the current preserves, with the development of interpretive trails, informative displays, research projects (geological and historical), and community outreach. In 1996 Michigan Karst Conservancy joined with the Northeast Michigan Karst Aquifer Protection Plan (a "319" project under the federal Clean Water Act), to conduct trash cleanouts, fencing, and diversion of flow and sediments at the Stevens Preserve, and in 1997 established an MOU with the Hiawatha National Forest to conduct a karst feature survey on a portion of the Niagaran Escarpment in Michigan's Upper Peninsula, and for the littoral caves in sandstone around Grand Island. Information about Michigan Karst Conservancy projects is on their web site at http://www.caves.org/conservancy/mkc/

Significant problems Michigan Karst Conservancy is trying to address are cultivating new, dedicated, volunteers to grow into the organization, to eventually replace the founders and early members that now form most of the board and active participants, to increase our outreach activities with communities in which our Preserves are located, and to find volunteers to assist in Preserve acquisition and management.

The Michigan Karst Conservancy was one of the early cave and karst conservancies founded on the "land trust" model—a private, non-profit organization, dedicated to the protection of caves and karst by means of direct purchase or by otherwise controlling land use with easements or leases. Our history and activities were described in a presentation at the 1995 National Cave Management Symposium, at a time when there were only a few conservancies actively seeking ownership of cave or karst preserves. (See "The Michigan Karst Conservancy: a Land Trust Approach to Cave Management," in the Proceeding of the 1995 Symposium.) In the four years since then the cave and karst conservancy movement has been growing rapidly, to the point where it is difficult to keep track of the new conservancies and their variety of purposes, organization, and activities. The best source of information about this is now being maintained by the Conservancies Committee of the National Speleological Society, accessible at http://www.caves.org/preserves/. This account will be about recent activities of the Michigan Karst Conservancy, as being of potential value to other cave and karst conservancies that are being founded or as they choose their programs.

Landowners Liaison Program

Michigan Karst Conservancy owns just two preserves, as we did in 1995—the Fiborn Karst Preserve and the Stevens Twin Sinks Preserve. While Michigan is not a state with many caves, the Michigan Karst Conservancy board some years ago adopted a priority list of ten cave and karst sites for which we would try to acquire titles or easements. The Landowner Liaison program sends letters to the owners of these sites approximately annually to keep them informed about the Conservancy, and also to send them information about karst and caves and land use issues (especially groundwater protection) related to these features. It is hoped, of course, that when they might want to sell their land that they will keep the Michigan Karst Conservancy in mind. We would much prefer a donation of land, but karst areas in Michigan are rural farming (or forested) areas and the equity of landowners is primarily in their land. Seldom is there a great tax advantage for these landowners to donate.

Preserve Management Activities

It is our purpose to keep our karst preserves as natural as possible while providing educational opportunities for the public. The following are the activities we have conducted at our two preserves:

Fiborn Karst Preserve is a 480-acre site containing Michigan's most significant (currently known) limestone caves. It is located on the Niagaran Escarpment between a higher ancient post-glacial bog and an alluvial lowland. An abandoned 80-acre quarry, and parts of the now ghost town of Fiborn Quarry (1907-1939), are also on the land. One weekend a month, from spring to fall, is devoted to trail maintenance and other management work at the Preserve. We also offer public tours of the Hendrie River Water Cave. An annual Geology and Hydrology Field Trip was begun in 1997, which has been quite popular. A Neighbors Get-Together is scheduled in August, attended by Michigan Karst Conservancy members, former residents of the old town of Fiborn Quarry (1907-1939), and current residents from the surrounding communities. Besides being enjoyable social events, these help maintain our association with many people with an interest in, or whose lives have been associated with, the Fiborn Quarry area.

Modest scientific efforts also continue on the Preserve, such as studies of its small-mammal population (including bats), hosting a field trip from a Natural Areas Association Conference, providing assistance for a project surveying endangered or threatened dragonfly populations in the Upper Peninsula of Michigan, and most recently the start of a Fiborn Karst Origins Project, to attempt to document the chronology and causes of the development of this very rare (for Michigan), apparently post-glacial, karst area and its caves. The most extensive project has been the Fiborn History Project, devoted primarily to the industrial and personal histories of Fiborn Quarry itself and their relation to and effects upon the caves, which is now documented at the Michigan Karst Conservancy web site (http://www.caves.org/conservancy/mkc/), on an outdoor exhibit of six large panels with photographs and text at the Emma Kalnbach Pavilion (Emma was the last teacher at the Fiborn Quarry school, and a member of Michigan Karst Conservancy prior to her death in 1995), and in a paper presented at this symposium (M. Warner, "Site History as an Asset in Preserve Management").

The primary management problem at the Fiborn Karst Preserve is to control unauthorized visits to Hendrie River Water Cave, which are potential sources of damage to the cave and surroundings and of accidents to very poorly equipped and informed people. The area is remote and cannot be regularly patrolled, so catching trespassers is very difficult. The trespass problem has even resulted in our discovering a new but well-worn trail to the cave, created by trespassers in 1999.

Stevens Twin Sinks Preserve consists of about 30 acres near Alpena in northeast Michigan on which are three deep (up to 30 meters) and impressive sinkholes, which resulted from collapse into large cavities dissolved out of evaporites situated below limestones, at depths of about 300 meters. The sinkholes are deep enough that a different plant community, more representative of areas to the north in Canada, has developed on the sinkhole floors, due to the delayed spring and the early fall microclimates.

The Preserve land was purchased with two ("twin") sinkholes, and the adjacent Bruski Sinkhole was donated to the Michigan Karst Conservancy in 1996. An interpretive trail has been laid out, but a lack of volunteers to help develop the trail and its interpretive material has slowed making this Preserve more accessible to the public. It may also be fairly said that there is less interest in this Preserve by many active members the Conservancy that are more interested in the caves at Fiborn. Consequently more effort has been devoted to developing a locally-based Preserve Committee, although this has recently floundered as initial local enthusiasm waned.

In 1993 a Northeast Michigan Karst Aquifer Protection Project was established with the nearby Presque Isle County Conservation District, with funding from the EPA "319 Project" (non-point source water pollution), under the Clean Water Act. The purpose has been to divert, treat, or mitigate groundwater pollution that has been occurring due primarily to farm operation runoff into sinkholes. Michigan Karst Conservancy has become a participant in this project, with runoff diversion channels and filter areas being constructed in 1998 to prevent the erosion and transport of sediment into the sinkholes from adjacent farmland. In 1999 the project has been extended to begin the cleanout of a century or more of trash deposition into Bruski Sinkhole (located conveniently at the intersection of two country roads), and the fencing of the sinkhole to deter further dumping. The 319 Project pays 75% of the cost of these improvements: the 25% Michigan Karst Conservancy share has been covered by a grant from the Northeast Michigan Community Foundation, credits for the labor of volunteers and for the donation of the use of a large crane (and operator) for the cleanout, and by a donation from the Michigan Interlakes Grotto of the National Speleological Society.

Assisting Other Agencies

The cooperative 319 Project with a county agency has just been described. Michigan Karst Conservancy was also recently a participant with several state agencies in developing a management plan for an area known as Simmons Woods in the Upper Peninsula. This was a 10,000-plus acre site fronting on Lake Michigan which The Nature Conservancy bought from a steel company that had held the land because it is underlain by the Engadine Dolomite (a potential steel making flux rock), and transferred to the Michigan Department of Natural Resources. The Nature Conservancy was interested primarily in the plant communities that are associated with the beaches, but the whole area is a thinly mantled karst with forests, fields, and lakes, as well as much bare karst pavement. A cave with an entrance adjacent to the property presumably continues into Simmons Woods, although its course has not been determined.

An even larger project was begun in 1997 with the establishment of a Memorandum of Understanding between Hiawatha National Forest and Michigan Karst Conservancy, for us to coordinate a Hiawatha Forest Karst Survey Project. While two volunteer survey teams were immediately created and given areas of the Forest to survey for karst features and endangered or threatened plants, in this case volunteerism faltered and these first teams have not gotten into the field. We are attempting to reinvigorate this project, although it does face some impediments, in that what cavers call “ridge walking” is here more like “swamp slogging,” and with no as-yet known caves in the Forest, the attraction to cavers is somewhat minimal.

However an offshoot of the Hiawatha Forest Karst Survey Project arose in 1998 when the Forest Service widened a road on Grand Island, a National Recreation Area in Lake Superior, and altered some sandstone overhangs (related to the impressive features of the nearby Pictured Rocks National Seashore). A flurry of local activism arose, which led Michigan Karst Conservancy to get involved when we pointed out the existence of the Federal Cave Resource Protection Act, which applies also to “recesses”—even in sandstone. A reconnaissance trip was conducted to the island that year, and in 1999 the Michigan Interlakes Grotto took on a survey of the littoral (“sea”) caves around the island as a project on behalf of the National Forest, conducting their own reconnaissance of part of the shoreline in 1999 (described at http://www.caves.org/grotto/mig/).

Future Directions

This report of Michigan Karst Conservancy activities may well be the last one at a National Cave and Karst Management Symposium, as our activities become dwarfed by other land trust cave conservancies elsewhere, such as the magnificent efforts of the new Southeastern Cave Conservancy, reported upon at this symposium. However, regardless of size, all cave and karst conservancies will at some point be struggling with some of the same issues Michigan Karst Conservancy faces. These include:

Aging of the founders: almost all cave and karst conservancies in the USA today are still being managed primarily by their founders. It is a serious challenge for them to develop the “new blood” leadership that will have the enthusiasm of those that came before. This can be particularly difficult for Michigan Karst Conservancy, not having a large number of caves in the state to help recruit interested cavers, while also not having a very prominent extent of public interest in karst, needed to recruit from citizens not specifically interested in caves.

Shift from participant to institutional boards: people who follow the evolution of non-profit charitable corporations observe a general pattern. The earliest boards consist of active participants in the group’s activities, although they often mostly do not have particular knowledge or skills in business, law, finances, corporate management, public relations and fundraising - the skills most essential to maintaining an effective organization. In time, though, most such corporations move their active participants from their boards to be executives or staff, and acquire on their boards individuals with the supportive professional and resource skills that are needed. This has been recognized for a long time by the Land Trust Alliance (association of land trusts, http://www.lta.org) to be a difficult transition, which is however made easier by the extent to which a participant board engages in introspection and board development activities.

Developing citizen volunteers*:* even the best board and officers will not make a charitable non-profit function effectively if they do not have volunteers to carry out the tasks of the organization. Often, the board and officers *are* the volunteers! But there is a much larger group of publicly spirited citizens in any community who will volunteer for causes if they are convinced they are worthwhile. Cave conservancies have little experience in cultivating and leading such citizen volunteers. Few have a "volunteer development function" within their organization, as does The Nature Conservancy.

It is immensely satisfying to be in at the beginning of a worthwhile effort. The problem we all face in this new era of cave and karst conservancies is to provide for the continuation of our dreams *in perpetuity* - a time scale about which few people think when they are up to their ears in the challenges of the day. Michigan Karst Conservancy took one step toward *in perpetuity* in 1995 by placing part of our Endowment Fund with the Community Foundation of Northeast Michigan. In this arrangement, the principle of the investment is transferred *in perpetuity* to the Community Foundation, but a donation is matched by the State with a tax credit, in addition to having federal tax deductibility. The effect is that, while the principle cannot be recovered, the return to Michigan Karst Conservancy from the net donation can currently approach 23% per annum.

There are a lot of resources available to cave and karst conservancies, especially joining with other types of conservancies and their national organization, the Land Trust Alliance, or local consortiums of "land trusts, " provided in Michigan by an annual Michigan Land Trust Conference. The problem is to seek out and draw upon those resources, while not losing our enthusiasm for the very specific knowledge and goals of cave and karst protection.

Historic Preservation at Hubbards Cave: Inventory and Management of Cultural Resources

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Abstract

Following the destruction of historic material by vandals in 1997, a group of conservation-minded cavers, guided by professionals, undertook to identify, inventory, and suggest management strategies for the cultural resources of Hubbards Cave, Tennessee. With the permission of the Nature Conservancy, owner of the site, the Hubbards Cave History Project team assessed the damage to the cave's historic resources, evaluated the threat to remaining resources, and performed short-term preservation efforts. While previous efforts to protect the historic resources of the site relied upon education, through on site signage, the efficacy of this approach was thrown into doubt. The team recommended passive entrance control, using gates, for the historically important (and unprotected) West and North Passages. These recommendations fit in well with the Nature Conservancy's own plans for biological preservation at the site, which is a critically important bat cave. Over the following two summers gates were erected which protected both resources.

The Hubbards Cave History Project began a detailed inventory of the historic resources on site, with the goal of recording primary information for future researchers. As a supplement, we also created an archive by compiling written information on the cave. Historic structures, such as ladders, steps, bridges, and saltpeter vat remains, were described, sketched, and photographed, as were other artifacts and features. Ambitiously, the team began a long-term effort to document the numerous names, dates, and other wall markings in the cave. During the first year of work, we discovered evidence of Pre-Columbian usage of the cave and turned to Professor Jan Simek and the University of Tennessee Cave Archaeology Research Group. A parallel archaeological study of the prehistory of the site soon commenced. In 1999, a third project began, a re-survey of the cave system by regional cavers, to aid both the history and archaeology projects. These three complementary projects co-exist remarkably well, and this bodes well for the future study of this significant cave.

Hubbards Cave, located on the Cumberland Plateau escarpment in Warren County, Tennessee, is one of the most historically significant caves in the state. The cave contains a wealth of important material culture resources, representing four major themes in the environmental history of caves: pre-Columbian usage before Anglo-American settlement, saltpeter mining in the 19th century, use of the cave environment as a social and recreational space in the late 19th and early 20th centuries, and the rise of cave conservation in the last 50 years. A large, mostly dry cave, the site has well-preserved artifacts which are unique and irreplaceable. Yet these resources have suffered both gradual and catastrophic damage over the years, resulting in a diminished resource for a site with tremendous research and educational potential.

Early speleologists in Tennessee, such as Tom Barr and Larry Matthews, studied Hubbards Cave, recognized the historical significance of the saltpeter mining artifacts, and published pleas for the conservation of cave resources, including historic resources, in their writings. Yet damage to the site increased after 1960, as the cave, already well-known locally, became known to a wider public. Matthews, for example, in 1971 noted and photographed a wheelbarrow used by saltpeter miners to transport cave earth, yet the artifact was no longer present in 1977 when I first visited the cave.

Early attempts at on-site historic preservation focused upon education of visitors through signage. Nashville cavers, led by Joel Buckner, placed a conservation sign inside the cave at a unique, lashed, three-sectioned Civil War era ladder in the late 1970s, explaining the importance of the artifact and asking visitors to leave it unused and undisturbed. In the mid-1980s, after the Nature Conservancy bought the cave to protect its critically important bat colony and habitat, additional signs were placed at the cave entrance urging visitors to cooperate in the conservation of the biological and historical resources of the cave. These signs also pointed out that the features of the cave were protected under Tennessee law. At about the same time a new, small, wooden ladder was placed in the cave next to an historic peg and hole ladder so that visitors would not use the 19th century artifact. While the Nature Conservancy erected a large gate to protect endangered bat roosts in the South Passage of the cave, unmonitored access to the historically important West and North Passages continued. Unfortunately, the strategy of preservation through education proved inadequate, at least in this specific situation, for while most visitors to the site understood and respected the importance of the cave, a small number of vandals could and did inflict great harm to the cave's cultural resources.

In the summer of 1997, Nashville caver Thany Mann visited Hubbards Cave and was shocked to find that vandals had destroyed, by burning in place, the three-piece, splint- lashed Civil War era ladder. This unique artifact had been admired by several generations of cave explorers and had considerable research and educational value. On a more basic level, it was part of our common human heritage and a link with the irretrievable past. Though we have suffered similar losses before, we are all poorer from this loss. Thany noted what he thought might be new damage to other cultural resources as well. After exiting the cave, he notified the Nature Conservancy and other interested parties of his discovery.

Spurred on by Thany's report, Gabby Call of the Tennessee Nature Conservancy and Rob Robbins of the National Speleological Society organized a trip on September 13, 1997, to assess the overall situation at the cave and perform a variety of conservation tasks. I talked to Rob beforehand and offered to lead a team to assess the damage to the cave's historical resources while other teams engaged in biological research, removed recent trash, installed new conservation/cave law signs, constructed a second modern bypass ladder, and so on. This trip was the beginnings of the Hubbards Cave History Project, which is now in its third year.

One major problem in analyzing damage to the cultural resources of Hubbards Cave was the lack of an adequate baseline for comparison. In fact, little was known, and less documented, concerning the historical resources of the cave. We knew it contained historic ladders, some evidence of saltpeter mining, and some historic signatures, but that was about it. So on the first work trip into the cave, I decided to thoroughly inventoried the cave's resources while at the same time assessing the recent damage. Little did I know what I was getting into. Luckily for me, from that first trip forward I had the full support and help of a group of historically-minded conservationists and cavers, including Lynn and Brian Roebuck, Rob Robbins, April Hannah, Tim Curtis, and others.

On September 13, 1997, the Hubbards Cave History Project began, first by describing, sketching, and photographing the artifacts and historic wall markings in the entrance room. We then did the same for the short North Passage. We immediately made significant discoveries, ranging from the previously unknown presence at the cave of Shelah Waters, a well-known 19th century Tennessee cave explorer, to evidence of exploration and gypsum mining by pre-Columbian cultures. We took some emergency preservation actions by marking off cane torch fragments in the North Passage while we took two small samples for further study.

Later, we began the inventory of the extensive West Passage, focusing at first on the historic built structures, which included bridges, ladders, paths, shoring timbers, and stone-stair steps. In addition, we assessed the recent damage to some of the resources, which, in addition to the destruction of the three-sectioned ladder, included minor damage to the peg and hole ladder, much spray paint over historic graffiti, and the unearthing of three previously buried saltpeter troughs in the entrance room. We placed signs at each artifact cluster as a short-term measure, but two things were clear: the resource was both larger and more significant than previously suspected and it was still very vulnerable.

In our initial report to the Nature Conservancy, we submitted a preliminary artifact inventory, accompanied by illustrations and photographs and keyed to an existing, though only marginally useful, map of the cave. We also documented the names, dates, and wall markings in the North Passage. Most significantly, we analyzed the nature of the threat to the cave, which was primarily vandalism from unregulated trips, and recommended several management strategies for historic preservation on site. These were, first, that although most of the cave was very conducive to long term preservation due to its stable, low-humidity environment, the three saltpeter troughs recently unearthed at the entrance were threatened by exposure and should be re-interred. Secondly, unsupervised visitation should cease, though educational and research trips should be allowed in the appropriate season. Thirdly, since active enforcement of access limitation was impractical due to the cave's location, passive entrance control, that is a gate, for the West Passage would protect the majority of the currently vulnerable resources. There was some concern that gating the West Passage would divert all the unauthorized traffic into the seldom-visited North Passage. And lastly, removing of the modern ladder into the entrance room and posting additional signs were practical steps that might help protect the cave entrance without damaging its aesthetic value. These ideas for historic preservation fit in well with the Nature Conservancy's own plans for biological conservation at the site and, over the next two years, many of these ideas were implemented.

We began the 1998 work season at the end of April by beginning the inventory of cultural resources in the already protected South Passage. Again, artifacts and historic wall markings were described, illustrated by drawings, and photographed. And again additional historical discoveries were made, including a probable moonshine cooker, which adds another dimension to the history of the cave. The contrast between sections of the cave was great, as the South Passage, gated in 1985, contained none of the graffiti from the last 15 years that so mars the West Passage. Hubbards Cave History Project team member April Hannah prepared a nicely done second report for the Nature Conservancy on the cultural resources in the South Passage.

In June 1998, members of the Hubbards Cave History Project aided the Nature Conservancy in gating the West Passage of the cave. From our point of view the gate was highly desirable for preservation of historic material in the West Passage. There would be no more burning of artifacts or spray painting over historic wall markings. Thanks to the Nature Conservancy, the bleeding had finally stopped. During the gating work, we did also manage to find time to examine one previously un-inspected passage and document a few more historic inscriptions.

On July 11, 1998, we returned to Hubbards Cave for a productive historic inventory and preservation trip. We had previously consulted with Dr Jan Simek, head of the University of Tennessee Cave Archaeology Research Team, about our work at the cave. Based on our conversations, we decided to re-inter the three saltpeter troughs as soon as possible. Brian Roebuck and Marbry Hardin led a team that efficiently and carefully laid the artifacts back into one of the original beds and reburied them. This will stabilize the extremes of temperature and humidity that cause rapid decomposition of wooden artifacts on the entrance floor. Also on July 11 we began the enormous task of recording the names, dates, and wall markings in the extensive West Passage, which will number in the thousands when completely inventoried. Additional trips on September 7, 1998, and August 14, 1999, have continued this major effort, which remains far from complete. The signature record at Hubbards is one of the most extensive in the state, rivaling that of caves such as Big Bone Cave. We systematically and carefully scrutinized the cave walls, trying to untangle the jumble of faint, sometimes superimposed, lines, smudges, and torch marks which, remarkably, contain meaning to the trained eye. Since wall markings contain three types of information, conveyed respectively by content, style, and media, we noted aspects of all three while performing our inventories. For example, the inscription "Absalom Brown 1809" would be recorded on paper and film, which is the content, but we would also indicate the style, an older orthography with ruled lines, and the media, a wall etching. Not willing to hastily or arbitrarily judge which marks were historically important, we decided at the beginning of the Project to record the information *in toto* as a primary document for future researchers. The very large number of historic names in the cave will, when recorded and analyzed, give insights into of the social history of the cave and surrounding communities, as well as provide information on the cave's past as an extractive industrial site. They contain great genealogical and local history value as well.

By 1999, the activities of the Hubbards Cave History Project had clearly broadened. While short term or emergency historic preservation had been our original goal, along with assessing damage to resources, those tasks were now complete. We had also completed our inventory of built structures in the cave. Now, long-term preservation was foremost in our minds, along with the continuing creation of a primary document to allow scholars to "read" the walls of the cave. We formalized our launch of a Hubbards Cave archive, maintained by Rob Robbins. The archive was created by collecting the many scattered references to the cave in the historical literature and holding them in a central location for research purposes. We also began participating in two other newer projects at Hubbards Cave, which in part stemmed out of our efforts.

In July and August of 1999, the Nature Conservancy built a massive bat-friendly gate on the last remaining unprotected section leading off from the entrance, the North Passage. The Hubbards Cave History Project personnel again assisted. This protection, described by Gabby Call and Roy Powers in a paper elsewhere in this volume, was none too soon. Upon arriving at the site, for instance, Brian Roebuck and I had to replace an artifact of undetermined age in its proper provenance, as unauthorized visitors had carried a primitive cedar tree "ladder" out of the North Passage and used it at the entrance sinkhole. Project personnel, especially Lynn Roebuck, were on site to find, collect, and preserve any cultural materials displaced when the footings of the gate were installed. The new gate on the North Passage, like the 1998 gate on the West Passage, demonstrates the compatibility of biological and historic preservation, for structures built primarily for bat and bat habitat protection also securely protect important cultural resources. While we continued our historic inventory in 1999, we also participated in interdisciplinary trips with two other projects working on site. I had notified Jan Simek about our work and discoveries at Hubbards Cave in the fall of 1997. Jan agreed to date, using C 14 assay, the two cane-torch samples we had collected from the North Passage. The early dates obtained, c. 2730 BP and 2260 BP, led to a joint site visit by the University of Tennessee Cave Archaeology Research Team and the Hubbards Cave History Project, whereupon additional discoveries were made, confirming and extending some of our earlier finds. Soon Dr Simek proposed a major archaeological study of the site, to be conducted by Erin Pritchard, one of his graduate students, under his direction. We have since conducted three additional joint field trips, one in 1998 and two in 1999, between the Hubbards Cave History Project and the University of Tennessee Cave Archaeology Research Team. This cooperation has been beneficial for both groups, as each has learned from the other's expertise. This cooperation has now extended to other caves and other projects as well.

One problem facing both the History Project and the Cave Archaeology Research Team was the lack of a detailed map of the cave. There had been at least three maps made of parts of the cave, the first dating back to the early 1940s, but even the most recent one, by Bill Deane in the mid 1970s, omitted significant passages and showed very little detail for others. After seeking permission from the Nature Conservancy, the two existing projects, History and Archaeology, recommended that a third project be created, whose purpose was to provide an accurate, detailed map of the cave for scholarly work and management planning. Soon, Marbry Hardin, a well-known Tennessee Cave surveyor and project leader, organized a multi-grotto survey effort, which began its work in the 1999 field season. Members of the History Project have participated in every survey trip to ensure close communications between the complementary projects. The 1999 field season ended with three active and cooperative research, survey, and inventory projects in place. All three eagerly await the beginning of next year's fieldwork.

In conclusion, the important historic resources at Hubbards Cave have been protected from the most immediate threat by piggybacking historic preservation onto the biological preservation strategies that the Nature Conservancy has successfully adopted. In this case, there has been no conflict between the different goals of biological protection, historic research, and preservation of cultural resources. Instead, there has been complimentary work, supported by different teams for their own reasons, which protects the diverse and important resources more securely while allowing significant research to continue in the appropriate season.

For the Hubbards Cave History Project, the work at the cave is continuing. While many of the passages have now been inventoried, several others have not. We have over a thousand names, dates, and wall markings recorded already, but many more remain to be documented. We are well on our way toward creating a usable primary document, based on cultural features in the cave, which will be of great value for future scholars. Someday an important history of the cave will be written which will rely heavily on our work at the site and our documents archive. We have a solid, well-trained team of enthusiastic cavers in place, and team members have already applied their new expertise to the study of other caves across the region, making other significant discoveries in last year or two.

Several years ago, Bill Halliday suggested, with considerable foresight, that the National Speleological Society create a policy for Historic Preservation in caves. While this has been slow in coming, recent field work across the cave regions of the U.S., including our own little project at Hubbards Cave, suggests that, perhaps finally, the idea of preserving the past in American caves has come of age. I do a cringe a little though, when I hear my team members suggest that we "do Big Bone Cave next."

About the Author

Joseph C. Douglas is an American historian, trained at Middle Tennessee State University (B.A. 1986, M.A. 1991) and the University of Houston (currently ABD). His specialization includes both environmental and public history, with an emphasis on the history of caves. He is the recipient of the 1998 Peter Hauer Spelean History Award from the National Speleological Society and is a frequent contributor to The Journal of Spelean History. He is an Instructor of History at Volunteer State Community College in Gallatin, Tennessee.

Threats to Surface and Karst Groundwater of Mammoth Cave National Park from The Arthur Oil Field, Kentucky

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Abstract

In the early 1990s, a small oil boom began in Edmonson County, Kentucky. Oil production continues and a number of wells have been drilled on properties adjacent to the southwestern edge of Mammoth Cave National Park. Besides being the world's longest cave, Mammoth Cave is one of the premier "reference" caves for understanding cave and karst systems. In January of 1997, a well fitting ruptured, spilling over 2,000 liters of crude oil that flowed on the surface into the park. Only a quick and coordinated effort prevented the oil from sinking into, and contaminating, the primary karst aquifer. This spill highlighted the potential threat posed by these wells, and demonstrated the need for a better understanding of the karst hydrogeology of this region of the park, to better prepare for future threats associated the numerous oil wells and other petroleum facilities.

In order to prepare for potential threats in the area, scientists and students of Western Kentucky University and the National Park Service are cooperating in the development of a geographic information system (GIS) data base which depicts the hydrogeology, oil well location data, karst features, access roads, and, in particular, surface and subsurface flow routes adjacent to these oil facilities. This database will then be distributed to the various agencies, organizations, and emergency response personnel, including a summary map for use in the field during emergency responses and to better plan and coordinate future efforts.

Temperature Data Logging in Missouri Bat Caves

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Abstract

We present our preliminary results of digitally logged temperatures in Missouri bat caves that are inhabited by the Indiana bat, *Myotis sodalis*, and the gray bat, *Myotis grisescens*. Both species are endangered. Eight Indiana bat hibernacula, including one mine, were monitored since the fall of 1998. Four of these included gray bats. The temperatures in some of the hibernacula declined quickly and deeply in reponse to cold fronts, while the more horizontal caves were more thermally stable. Relative humidities also dropped quickly during cold fronts. Some caves provide a variety of microclimates for different bat usages. This study is partially included in a national study of Priority I Indiana bat caves. Conclusions are only tentative at this time.

Introduction

The endangered Indiana bat, *Myotis sodalis*, and the endangered gray bat, *Myotis grisescens*, utilize particular caves in Missouri. Gray bats use various caves at different times of the year, while Indiana bats use caves for mating in the fall and for hibernation. Maternity roosts for gray bats typically are warm traps with high dome rooms. Hibernacula typically are caves or mines that have below-average temperatures. The mean annual temperature of the Missouri Ozarks (based on weather records we analyzed from Waynesville, Missouri) is about 13°C (55-56°F). Many Missouri caves reflect this mean annual temperature.

Since 1980 Richard Clawson used a digital thermometer to take spot measurements of ambient and rock temperatures during winter surveys of hibernating bats. A general idea of preferred hibernation temperatures developed, but we could not record the full range of temperatures until the advent of miniature data loggers.

In 1997 Missouri Department of Conservation's Mark McGimsey and Ken Lister installed Onset XT data loggers in three gray bat caves. Elliott joined that effort in 1998 and concluded it in 1999. Those data will be presented in a separate paper.

In Missouri regular censusing of Indiana bat caves began in 1975 and censusing of gray bat caves began in the late 1970s (LaVal and LaVal 1980, Missouri Department of Conservation 1992). Since 1980 Richard Clawson has led these surveys for the Missouri Department of Conservation. William R. Elliott joined the effort in 1998. Since 1979, Missouri's Indiana bats, as measured at five major hibernacula, have declined about 89%, from 210,000 to 23,000. Indiana bats have declined in most other states, except in Indiana, where recent surveys have shown a slight increase (Dunlap, 1999). Gray bats have declined less dramatically and now appear to be stable at their major maternity caves that are protected.

The drastic loss of so many Indiana bats calls for testing many hypotheses about their environment. In this study we are primarily concerned with two questions: Are Indiana bat hibernacula becoming too warm? Are they too variable in temperature? We shall focus on the 1998-1999 temperature data recorded in selected Missouri caves and a mine. This is part of a wider study of Indiana bat hibernacula by partners with Bat Conservation International. Preliminary results of Priority I caves will be released in a report by Merlin Tuttle of Bat Conservation International. These first results yielded some valuable information but no firm conclusions can be drawn at this time.

Materials and Methods

We used a new model of data logger sold by the Onset Computer Corporation, the Hobo® H8 Pro, with two channels for temperature and relative humidity (Figure 1). These data loggers are weatherproof, have an advertised accuracy of 0.2°C and 3% relative humidity, and a memory capacity of 64K (enough for more than a year of sampling).

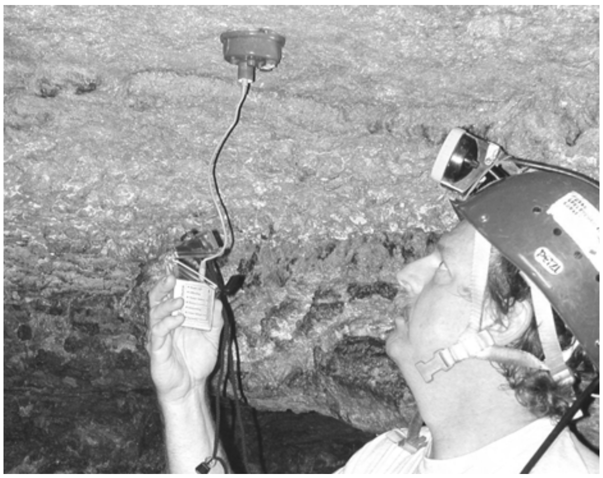

Figure 1. William R. Elliott uses an Onset Hobo® Data Shuttle to offload temperature and humidity data from the Hobo® H8 Pro data logger. The shuttle can hold data from up to seven data loggers.

The logger's 3.6-V lithium battery was rated for three years, but we had problems with resistance building up in some of the batteries, which caused some data loggers to stop early or not run at all. Onset notified its clients about this problem, and we replaced some of the faulty batteries after the first year, but we lost potential data from two out of 20 loggers because of the battery problem. The battery can be removed, briefly shorted with a paper clip or a pocketknife, then replaced. However, the problem can recur. Onset provided a different make of battery to remedy the problem, but one of our two failures was with the new battery. Some loggers would not relaunch with the one-year-old batteries, even after shorting them. The only other problem we noted was an anomalously high temperature spike on one occasion at one outdoor logger (81°C on February 21, 1999), which we ignored.

We deployed the loggers between July and October, 1998, and we retrieved data in August and September, 1999. At most sites we mounted an outdoor data logger on a tree near the cave entrance, and placed a plastic weather cover over the logger. Inside the cave, following Bat Conservation International guidelines, we usually mounted the data loggers on the ceiling at bat roosts with screw anchors installed with portable drills and hand tools. Each logger in the cave had a thin disc of clay between it and the ceiling, which kept the metal back of the logger in close contact with the rock. This arrangement allowed the logger to equilibrate more with the rock temperature instead of the air temperature. This was desirable since these bats are thought to select rock temperature over air temperature. The clay also allowed us to insert the probe of a digital thermometer behind the logger and take readings as a check. We also inserted a patch of clay into a hole or crack near the logger as a second check. On our return to retrieve data these check points were within a few tenths of a degree C of each other and what the logger registered. Ambient air readings were also taken.

Relative humidity often was at saturation in our study caves, and often exceeded the 95% limit that most electronic relative humidity sensors have. In our results the relative humidity often ranged up to a recorded value of 105% (which is impossible), but the overall pattern of humidity change throughout the year and in relation to weather events is still of interest. The relative humidity usually drops dramatically with strong cold fronts, then creeps up again.

Although deployed over a period of three months, the loggers were all set for a three-hour sampling interval on the same schedule, and their clocks were synchronized within one minute. Data were retrieved from the loggers using a small Hobo® Shuttle data transporter, which can store data from up to seven loggers. Data were then uploaded to a computer and analyzed using BoxCar® Pro 3.51 software from Onset. This program instantly graphs each data set. We merged data into approximately year-long data sets of several loggers, and we graphed the data using the Microsoft Excel 97® spreadsheet program.

We obtained weather data from 1975 through 1998 (as daily minimum and maximum temperatures) for several Missouri cities from the Department of Soil and Atmospheric Sciences, University of Missouri–Columbia. The data set from Waynesville, Pulaski County, Missouri, was the most complete and is geographically close to most of our study sites. We examined the secular trend of annual means, extreme lows, and extreme highs using Excel®.

Our study sites in Missouri were Great Scott Cave and Scotia Hollow Cave, Washington County; Bat Cave, Shannon County; Pilot Knob Mine, Iron County; Onyx Cave, Crawford County; and Brooks Cave, Great Spirit Cave, and Ryden Cave, Pulaski County.

Results

To save space we shall present graphs for three types of thermal situations that we see in our data: a site that appears too warm, a site that appears too variable, and a site that appears optimal for hibernation.

Figure 2 depicts the data from Great Scott Cave, Washington County, Missouri. This horizontal resurgence cave has two downstream entrances. We positioned one data logger on a tree and its temperature curve is shown as "outside." We placed four loggers on the cave ceiling at different points ranging from 30 meters to 150 meters inside. A fifth logger at 200 meters from the entrance did not run.

Station #1 in Great Scott is the usual winter roost for Indiana bats, but during colder periods they move farther into the cave to higher, warmer ceilings above the stream. #1 shows that temperature becomes less variable farther into the cave, as expected. However, the baseline temperature in the cave's interior is about 12°C, which may be too warm for a good Indiana bat hibernaculum. Station #1 experienced quite variable temperatures between 1 and 10°C from December, 1998, through March, 1999. During the winter the other roosts varied between 7 and 12°C.

Figure 3 depicts the temperature curve for Bat Cave, Shannon County. This cave has a large, funnel-shaped entrance on the side of a ridge above a river, and acts as a cold-trap. A data logger was placed on a low ceiling where the bats usually hibernate. Another logger was placed on a 12-meter-high ceiling where the bats sometimes move during cold periods; however, this logger did not run and had to be replaced. The graph shows that the lower ceiling temperatures, though in the desireable range much of the time, were quite variable, even dipping to -8°C (18°F) in early January, 1999. The response to cold fronts was nearly instantaneous (within the same three-hour sampling period).

Figure 4 is the temperature curve for Pilot Knob Mine, Iron County. This abandoned iron mine, excavated in rhyolite, is located near the top of a prominent hill and is well-ventilated by upper and lower entrances. The mine is a near-perfect cold-air trap. When approaching the

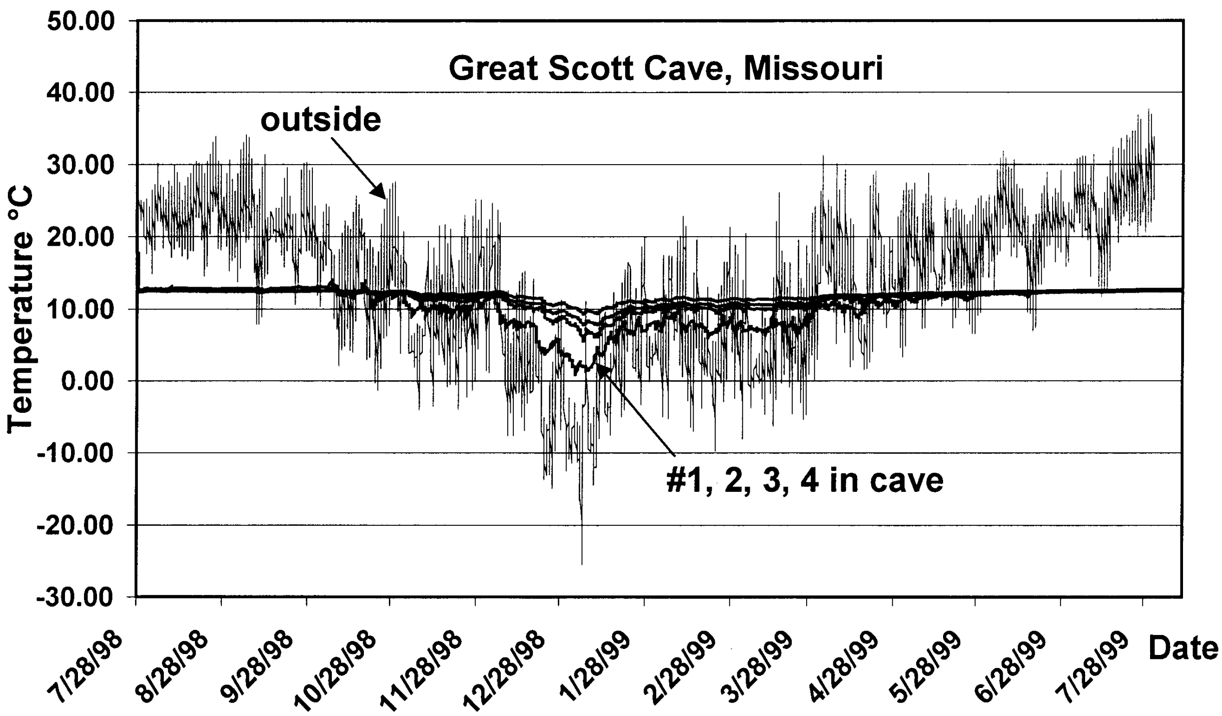

Figure 2. Temperature data from Great Scott Cave, Washington County, Missouri.

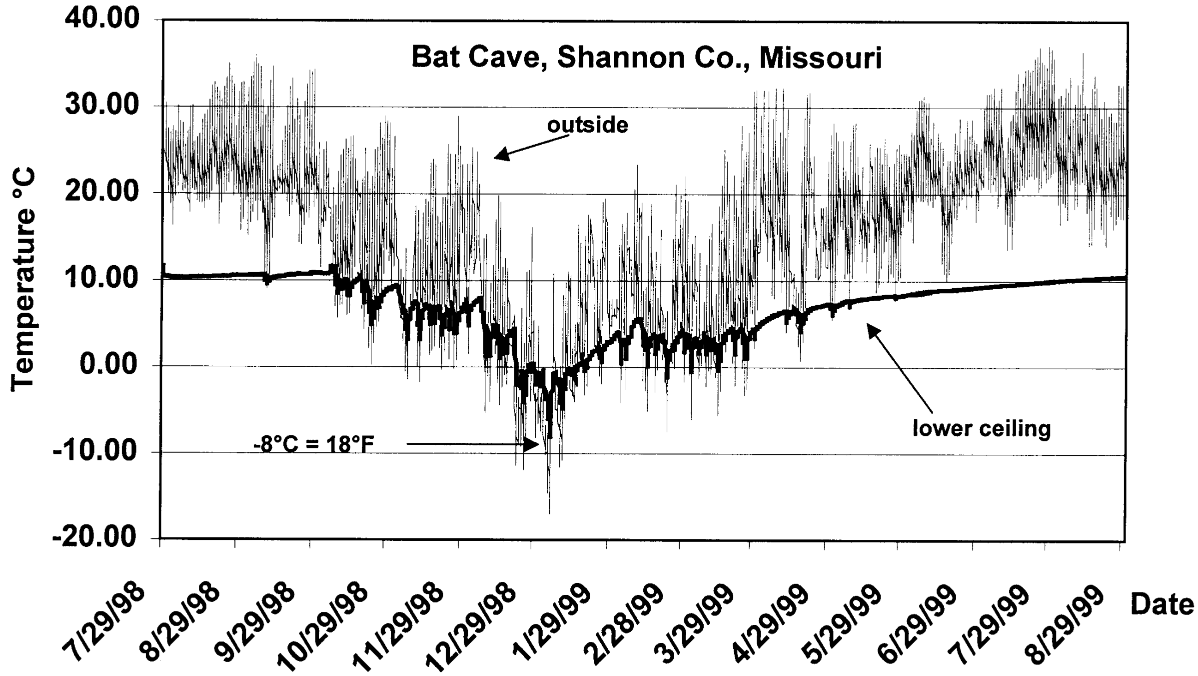

Figure 3. Temperature data from Bat Cave, Shannon County, Missouri.

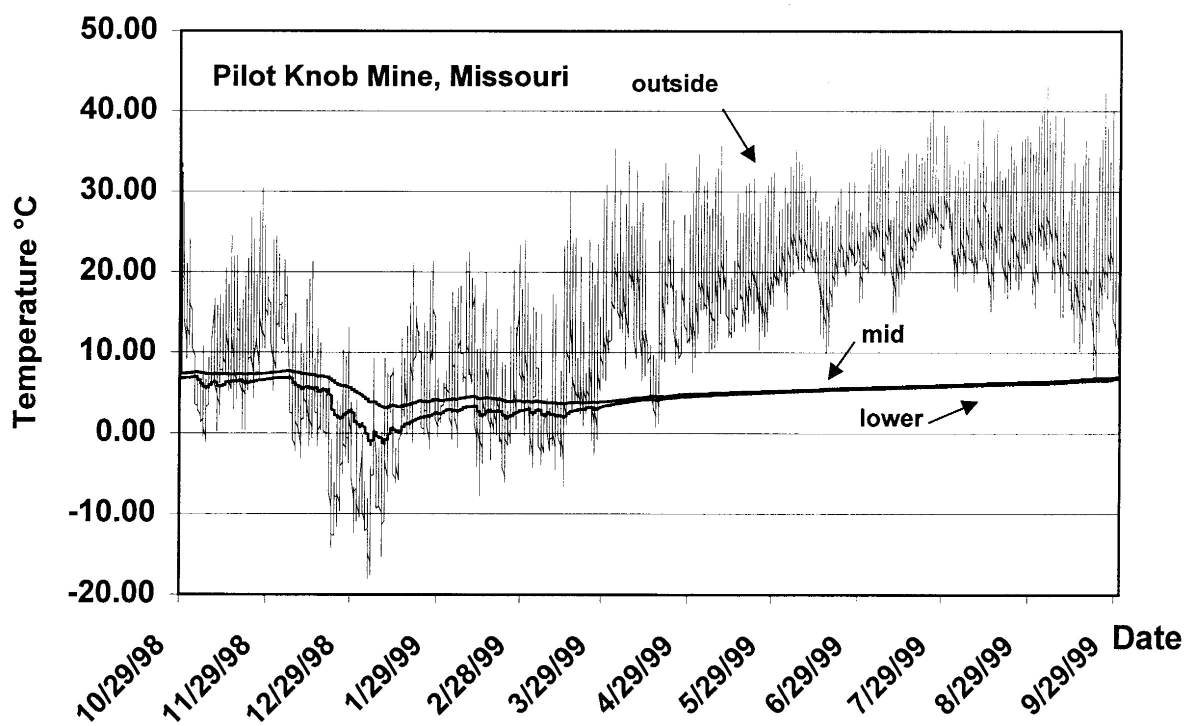

Figure 4. Temperature data from Pilot Knob Mine, Iron County, Missouri.

main, lower entrance of the mine, one usually meets an outflow of chilled air. The outdoor logger was located away from this effect. Two loggers were placed inside, one at about 100 meters inside and about 30 meters below the level of the entrance, and the other about 25 meters farther in and 10 meters lower, at the end of the accessible part of the mine. We did not attempt to enter the lowest levels of the mine, which are below dangerously steep, loose, rubble slopes. The loggers were placed on the floor below Indiana bat clusters because we had no portable drill at the time. Upon our return in October, 1999, we mounted the loggers on the ceiling about three meters above the floor. There should be some minor differences in temperatures from floor to ceiling, but not enough to change the overall thermal picture of the mine.

Figure 4 shows that Pilot Knob Mine is almost ideal for Indiana bat hibernation. Even in the summer the baseline temperature is about 8°C (46°F). During the winter the loggers registered -1 to 5°C. It seems likely that the lower, inaccessible areas of the mine may have slightly lower, but similar temperatures. The structure of the mine offers the bats many alternate roost sites at slightly different, but fairly stable temperatures.

Discussion

Great Scott Cave once housed up to 85,700 Indiana bats in 1983, but the census steadily declined to 9,100 in 1999. The main stream entrance is five meters wide and three meters high, and the secondary entrance, located two meters to the right of the main entrance, is about one meter in diameter. The tubular passage from the smaller entrance joins the main passage about 20 meters inside. A rebar bat gate was installed on the main entrance in 1978, at which time the smaller entrance was closed with a masonry wall. In 1991 the main gate was replaced with a more modern airflow, angle iron gate, but the wall remained in the smaller entrance. Observations of bats and temperatures over the years led us and Merlin Tuttle of Bat Conservation International to suspect that the masonry wall could be inhibiting air exchange, thus causing the front part of the cave to become warmer. In August 1999, Missouri Department of Conservation replaced the masonry wall with a bat gate. We will continue to monitor temperatures in the cave to see if the hibernaculum cools to a more optimal temperature. We cannot say at this time that warm temperatures caused the decline of Indiana bats in Great Scott Cave, but it is a concern.

Bat Cave held up to 76,700 Indiana bats in 1979, but they declined to 6,175 in 1993 and then to a few hundred in 1999. The cave also harbors gray bats. Clawson observed a die-off of about 35,000 Indiana bats in this cave in the winter of 1980. He observed many carcasses on the floor from the previous winter, presumably frozen to death by a severe cold front. We cannot be certain that a freeze caused the die-off, as the cave entrance was not fenced until 1986 and was vulnerable to an act of vandalism, but there was no evidence of such an act. Our 1998-1999 temperature graph varied from about 12° to -8°C, which could easily freeze bats. The shape of the temperature curve indicates much variation. We would classify Bat Cave, Shannon County, as a "risky cave" for bats because it is too responsive to cold fronts. However, it probably is a good hibernaculum most of the time. Since the severest cold fronts are unpredictable, it also would be risky to remedy the situation by trying to control cold air infiltration into the cave in some simple way.

It is not known when Indiana bats first occupied Pilot Knob Mine, but a colony of 80,000 was established by 1962 (Myers 1964). LaVal and LaVal (1980) estimated 139,000 Indiana bats by comparing the exit rate they observed with the exit rate of bats at Great Scott Cave. No reliable census has been made because much of the interior of the mine is not safely accessible. However, harp trapping at the entrance during the fall over the years indicates that this is still a healthy population. The mine temperature is optimal, and the site enjoys a high degree of protection from the U.S. Fish and Wildlife Service, so disturbance of the bats is almost nonexistent.

Most other caves showed temperature graphs intermediate between Pilot Knob Mine and Great Scott Cave. We observed the following variation: Brooks Cave 5 to 10°C, Scotia Hollow Cave 4 to 12°C, Onyx Cave 5 to 12°C, and Ryden Cave 7 to 12°C. Great Spirit Cave was the most variable at 0 to 21°C. All of these caves have had Indiana bat declines, so we cannot necessarily consider temperature as the one factor causing the decline.

From 1975 to 1999 the mean annual temperature (calculated from daily highs and lows) at Waynesville, Missouri, was 12.9°C (55.3°F). The standard deviation was 1.4°C and the range was 11.7 to 14.4°C (53 to 58°F). There appears to be no significant change in mean annual temperature since 1975. However, in examining extreme lows in January, we found that there may be a warming trend since 1975 from about -21 to -18°C (-7 to 0°F). We believe that extreme low temperatures from severe cold fronts are important in influencing hibernaculum temperatures, perhaps more important than mean annual temperatures. Severe cold fronts are usually associated with strong winds and barometric pressure drops, which cause more cold air invasion into caves than weaker fronts. However, we cannot predict how much influence such a slight increase in January lows would have on the hibernacula we have studied.

A number of factors are known or suspected to affect Indiana bat populations. Disturbance during hibernation was one of the first of these factors to be recognized and still is a threat at unprotected sites. Improperly designed cave gates have been implicated in some population declines, but all such gates have been removed or replaced. Loss or reduction of roosting or foraging habitat during the non-hibernation seasons has been postulated, but no instances of habitat-caused population loss have been documented to date.

In view of these other possible stresses on Indiana bats, we cannot conclude at this time that temperature shifts in hibernacula are primarily responsible for the loss of Indiana bats in Missouri. However, we plan to continue monitoring these sites for a few more years. Additional information may help us to resolve these questions.

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A Strategy for Improved Karst Management in the Tongass National Forest, Alaska

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Abstract

Fifty years of industrial timber harvest in the Tongass National Forest, Alaska, have heavily impacted the region's karst and cave resources. Regional scale timber harvest on karst appears likely to continue in the Tongass for at least another decade. Current USDA Forest Service karst management practices in the Tongass have become outdated in light of new ideas and new information gathered within the last few years. Over the last decade, cavers of the Tongass Cave Project and Glacier Grotto have undertaken numerous cave exploration and inventory projects throughout the Tongass, often with USDA Forest Service support. The cooperative projects have improved the understanding of karst systems in the Tongass and the effects of timber harvest on those systems. USDA Forest Service karst management strategies currently in place were designed when the understanding of the effects of surface management practices on deep cave resources were poorly understood and without benefit of the wealth of information available today. By incorporating new data and concepts into an improved karst management strategy the USDA Forest Service could better protect fragile cave resources while avoiding possible future violations of the Federal Cave Resources Protection Act of 1988. New management strategies will need to be resource specific, focus on the deep cave environment as well as the epikarst zone, and develop balanced protective measures for entire karst hydrologic systems rather than just individual karst features.

Cave Management in the United States: An Overview of Significant Trends and Accomplishments

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ABSTRACT

More than 20 percent of the United States is underlain by karst topography, the type of soluble rock landscape where caves can form. Only a small percentage of the more than 40,000 known caves in America's karst lands are owned or managed by the U.S. Government. Most American caves are privately owned, including more than a hundred commercial show caves. In recent years, the American show cave industry, government, and private-sector groups have made substantial progress in cave management in large part by reducing the gap between public understanding of caves and karst areas and what is known by scientists and cave managers. Notable successes and improvements have come largely as a result of widespread educational efforts and the growth of public-private partnerships. This paper will provide an overview of these and other significant cave management trends that are occurring throughout the United States.

Introduction

Approximately 20 percent of the United States is in karst, the type of soluble rock landscape where caves can form. Currently there are more than 40,000 caves known in America's karst areas. The U.S. Government owns a small percentage of these, less than 5%. The remaining caves are privately owned, including more than a hundred major privately owned or state operated show caves, and an additional hundred marginal show cave operations. Private ownership and management of caves in the U.S. has always been significant.

Private-public sector partnerships are playing an increasingly important role in cave management and conservation efforts in the U.S. Twenty-five years ago, few people in the United States had heard the word "karst" and most of those living in karst areas did not understand the relationship between land use and natural resources such as caves, springs, sinkholes, and other karst features. For the most part, show caves focused on entertainment. Cavers focused on caving, and government ignored caves (unless they could sell an admission). The American show cave industry, the federal government, and the private nonprofit sector have only recently begun to embrace efforts to improve public understanding caves and support for land stewardship of cave areas. Although there is still a large gap between public understanding of caves and karst areas and what is known by scientists and cave managers, the notable successes and improvements in cave management in recent years have come largely as a result of widespread educational efforts.

In this paper I will examine the important events in the evolution of U.S. cave management including:

- increased public awareness and support for conservation issues fueled by high profile environmental news events, such as the destruction and subsequent restoration of Hidden River Cave;
- an increasing emphasis on education and stewardship by show cave operators;
- volunteerism and private sector partnerships with government cave managers;
- development of new cave protection laws and regulations; and

- The growth of private nonprofit organizations and land trusts in acquiring and preserving significant caves

Increased Public Awareness and Support for Conservation in the U.S.

Cave explorers and show cave operators share a love and interest in caves which most of the public doesn't quite comprehend. Despite our best educational efforts, most Americans still have considerably more empathy for issues that affect the more familiar ecosystems on the surface. Fortunately caves have benefited from the American public's overwhelming support for conservation of natural resources, and especially for the protection of groundwater quality.

This trend can be traced to the Post World War II prosperity in the United States which created a huge middle class of people who were relatively well educated and financially able to concern themselves with issues well beyond basic survival needs. This relative prosperity coincided with a growing public awareness of the environmental problems generated by unchecked industrialization and pesticide use in agriculture.

In 1962, Rachel Carson published a book entitled *Silent Spring* which is often credited with awakening public opinion about the threats posed by water contamination from toxic chemicals dumped into the nation's lakes and waterways. High profile incidents such as the burning of the Cuyahoga River in Cleveland, Ohio; the meltdown of a nuclear reactor at Three Mile Island; a toxic waste site at Love Canal, New York; and the decimation of the American bald eagle population by DDT and similar insecticides fueled news media and public interest in conservation.

These events, and others, spawned new federal regulations, numerous environmental advocacy groups, and a whole generation of pro-conservation Americans. Although not as well known, cave systems had their share of horror stories.

After World War II, U.S. caving grew in popularity and, as post war cave explorers grew older, they began to notice a significant increase in cave vandalism. Before long, National Speleological Society grottos began organizing the first cave cleanups and restoration projects. Government officials began recognizing the existence of significant caves, in part because they were getting pressure from caving groups to visit caves they didn't even know existed. Communities dependent upon cave springs for water began discovering that the water flowing through karst areas and into their water taps was frequently contaminated.

The American Cave Conservation Association soon realized that broad public support for conservation of caves could be developed by tapping into the public's growing concern for water quality issues. The ACCA moved its headquarters from Richmond, Virginia, to Horse Cave, Kentucky, in 1987 to undertake what would be one of the decade's most remarkable cave conservation achievements.

The Destruction and Restoration of Horse Cave

One of the most dramatic examples of the problems affecting caves occurred at Horse Cave, Kentucky. Horse Cave is a small town of 2,500 people located in south-central, Kentucky, about 15 miles from Mammoth Cave National Park. Horse Cave was once the first of more than a dozen show caves that tourists could visit on their drive south from Louisville, Kentucky, to Nashville, Tennessee.

An impressive 50-foot-wide entrance opens directly beside the town's Main Street. The owner of the Cave, Dr G.A. Thomas and his son Harry maintained a hydroelectric generator and water pumping system in the cave which provided both water and electricity to the town before the end of the 19th Century. By the 1930s, a substantial village had grown around the entrance to Horse Cave.

As the City of Horse Cave grew over it, the cave, which was later renamed Hidden River Cave, began to suffer from groundwater contamination almost immediately. A common practice was injection of sewage waste into sinkholes or even directly into cave passages through straight pipes. In 1943 a creamery moved into the town of Horse Cave and began dumping waste products, such as whey, into sinkholes upstream from Hidden River Cave. Public tours into Hidden River Cave closed the same year as the odor of raw sewage emanating from the cave entrance made visitation impossible.

Over the next 50 years, Hidden River Cave continued to be polluted by sewage from the creamery, a metal-plating plant, and the town's domestic waste treatment plant, which was injecting partially treated waste into a sinkhole. In 1987, the nonprofit American Cave Conservation Association moved its headquarters to Horse Cave and joined with local citizens to promote improvements to the waste management facilities. A new sewage plant and a 10-mile conveyance line to take treated sewage out of the sinkhole plain area were built in

1989. This stopped the primary sewage discharges into the cave.

Once the sewage problem was solved, the ACCA worked in partnership with the City of Horse Cave to purchase the cave and surrounding lands and develop the American Cave and Karst Center at the site. The Center, now called the American Cave Museum, has been open since 1993 and annually gets more than 16,000 visitors. The City owns the museum and the cave and the ACCA operates the attraction on behalf of the City. Under ACCA's leadership the Museum has developed substantial educational exhibits, teaching materials and programs; and has been influential in getting other caves in the U.S. to develop more educational tours.

Show Caves as Educators and Land Stewards

Historically, private show caves primarily focused on entertaining their cave visitors. If the cave did not have an interesting history, then the management often produced a new history (fakelore). Mythological interpretive stories may have been entertaining but they contributed little to public understanding of caves.

The government approach wasn't much better. For years, cave interpretation by federal agencies, such as the National Park Service, focused on "nature is nice and interesting." The change that was needed was to make the information relevant to visitor's lives. Today, U.S. show caves frequently provide interpretive exhibits on cave geology and other topics, and feature tours that emphasize science and educational content.

Much of the groundwork for this interest in science and education was laid by pioneers such as Tom Aley at the Ozark Underground Lab and Dr James F. Quinlan at Mammoth Cave National Park. These scientists/educators began making the public aware in the 1970s of the crucial environmental connections between caves and the surface areas around caves. Their work made caves relevant to people other than cave explorers.

Dr Quinlan's research demonstrated that the hydrologic watersheds which affected Mammoth Cave extended well beyond the national park's official boundary. He generated tremendous media interest in the pollution problems facing the south-central Kentucky karst, and was an advocate of practical groundwater monitoring techniques in karst areas.

The educational programs and the consulting services provided by the Ozark Underground Laboratory (operated by Tom Aley) influenced a new generation of cave managers nationwide and numerous school children in Missouri. Instead of focusing on entertainment, the programs at the Ozark Underground Laboratory utilized the cave as a science learning lab. Students who visited the site learned how pollutants dumped in sinkholes miles away could impact the water quality and endangered cave animals living in Tumbling Creek Cave, and how this was but an example of common conditions in karst areas.

As public awareness and interest in cave conservation spread, the show cave industry began discovering the value of integrating science education with the entertainment aspects of their businesses. A National Caves Association meeting in Horse Cave in 1988, for example, was themed "conservation is good business."

This theme has since become the business motto for Fantastic Caverns, a privately operated show cave in Missouri. Fantastic Caverns has profited immensely from this philosophy. They provide educational programs to approximately 15,000 school children annually. The students return and bring their parents.

In the opinion of this author, Fantastic Caverns does perhaps the best job of any show cave in America of providing interactive interpretive exhibits and demonstrations on their tour. The cave has a saltpeter manufacturing demonstration, an audio-visual presentation (inside the cave), an artificial palaeontological dig, and biological study areas. A special Discovery Tour goes off the main trail to explore the geologic, hydrologic, and biological aspects of the cave.

Other U.S. show caves are also beginning to offer educational programming that goes well beyond simply "showing" the cave. At Hidden River Cave, students can participate in water testing activities, play a land use management game, construct models of sinkholes, and tour educational exhibits at the American Cave Museum in the cave's entrance. Several years ago, the American Cave Conservation Association developed an educational curriculum in partnership with the National Caves Association. A number of caves have utilized ACCA's "Learning To Live With Caves and Karst" Curricula or are modifying it to meet their own needs.

Communication and technology sharing has also improved among Show Cave operators, cave managers, and scientists. During the 1980s a government sponsored series of Cave Management Symposia espoused topics such as developing thematic interpretive talks, reducing the levels of cave lighting to control algal growth, cleaning the algae growth regularly to protect the surfaces of formations from damage. One private cave went so far as to put in drainpipes beneath cave walkways to collect the wastewater runoff from the trails. Volunteer restoration projects and workshops to remove debris and repair broken formations have become annual events at national parks and several privately owned caves.

When the American Cave Conservation Association began looking for trail construction ideas for restoring the flood-prone historic tour at Hidden River Cave they were influenced by a fiberglass walkway that had recently been constructed in Appalachian Caverns, Tennessee. This led the ACCA to developing a boardwalk made of recycled plastic. This material has worked well in wet cave environments, does not release toxic materials, and is now being used in several other caves, including Mammoth Cave. Treated lumber, in contrast, releases copper, chromium, and arsenic.

Volunteerism and Public/Private Partnerships

In the 1970s, resource managers with various federal agencies had a problem. They could not effectively manage caves on government land because cave explorers were tight lipped about disclosing cave locations. Cavers soon recognized that secrecy alone could not prevent damage to caves, especially not the damage from land use activities and groundwater contamination, however they feared that public disclosure of cave locations would lead to more serious vandalism of caves.

To overcome this secrecy, federal land management agencies, such as the U.S. Forest Service, National Park Service, and Bureau of Land Management began sponsoring symposia and seminars to encourage private partnerships with researchers, conservation groups, and cavers. This led to more trust between cave explorers and resource managers, helped create new organizations such as the American Cave Conservation Association, and led to exploration and conservation partnerships between federal agencies and organizations such as the Cave Research Foundation and the National Speleological Society.

Currently, the trend towards private/public partnerships in cave management is still growing. Government owned caves at national and state parks are beginning to rely on private contributions and volunteer labor to accomplish goals that are beyond their budgeted appropriations. At Mammoth Cave National Park, for instance, contributions from private corporations have helped build trails and restore historic entrance conditions. Volunteers groups annually provide manpower at Mammoth Cave to improve trails and remove old trail debris that had accumulated over the years. Volunteers also provide significant manpower at Carlsbad Caverns to conduct restoration work and to remove hundreds of pounds of lint that accumulates on cave formations from visitors' clothing.

Nonprofit organizations such as the American Cave Conservation Association, National Speleological Society, The Nature Conservancy, and Bat Conservation International have been working for decades to protect caves by acquiring land, sponsoring restoration projects, and constructing cave gates to control access.

Much of this work has been accomplished through partnerships with the federal government. Nonprofit groups have supplied the volunteer labor. Federal agencies, such as the U.S. Fish and Wildlife Service and the U.S. Forest Service have provided funding to purchase steel and other gating supplies.

The design and construction of cave gates has improved significantly over the past decade. Early gates were often constructed with no thought given to the effect the gate might have on animal life occupying the cave. Frequently, early gates were constructed which left little room for bats to fly in and out safely while avoiding predation. In some cases, gates were constructed which destroyed entire bat populations by making it impossible for the bats to enter or exit the cave.

With the help of the U.S. Fish and Wildlife Service, the American Cave Conservation Association developed a style of cave gate that does not seem to adversely affect most species of bats. The placement and construction of new ACCA bat gates takes into consideration the potential for altering airflow and consequently humidity and temperature conditions; provision of adequate spacing between bars for bats to move in and out of the cave; and reduction of flood problems, such as blockage of the entrance by debris piling up against the gate. In cooperation with various federal agencies, Bat Conservation International, and The Nature Conservancy, the ACCA has been involved in construction of more than 150 new gates on caves and mine openings in the United States over the past 20 years.

New Laws and Regulations

Spurred by nonprofit groups and increasing public support, a flood of new laws and regulations in the U.S. has been created to protect caves and cave resources. During the 1970s, the federal government passed laws protecting archaeological sites and endangered species. In the 1980s and 1990s, the nation's environmental movement brought new regulations to protect drinking water, such as the Clean Water Act, and, through the Environmental Protection Agency, began providing significant levels of funding for enforcement of these laws, education about point source and non-point source pollution, and clean up of toxic waste sites.

Several cities in karst areas, such as San Antonio, Texas; Lexington, Kentucky; and Springfield, Missouri, have adopted sinkhole ordinances to help control land use that occurs in surrounding karst areas. In 1988, as a response to strong support from cavers through the U.S., the Federal Cave Resources Protection Act was passed by Congress. This law protected cave resources on lands owned by public agencies such as the U.S. Forest Service and Bureau of Land Management, but was not designed to protect caves that were privately owned.

Caving groups also pushed for state laws to protect caves from acts of vandalism. Currently, 22 U.S. states have laws protecting cave resources. Many of these laws are weak and have rarely been tested in the courts. The highest profile cave vandalism case in recent years involved three individuals who broke into a cave at Mammoth Cave National Park in 1995 and mined more than 800 pounds of cave formations. The individuals were caught and sentenced to jail terms. The sentencing was stiffer than usual because a national park was involved.

Unfortunately, privately owned caves are frequently vandalized with little or no consequences to the perpetrators. This is primarily a reflection of the value that the U.S. places on individual property rights. Private cave owners in the U.S. do not want government involvement in the management of their caves. Consequently, groups like the American Cave Conservation Association have focused on education and providing assistance to help property owners protect their caves, and, hopefully, increase their desire to do so.

The Growth of Nonprofit Groups and Land Conservancies

As public support for conservation has grown and matured over the past half century, so has the affluence of conservation organizations, including caving groups. Land conservancies are among the most successful of modern conservation organizations in the U.S. They avoid the controversy of advocacy, which often entails going against business interests. Instead, most conservancies focus on raising money to purchase and protect land. Usually, a nonprofit Conservancy can provide a landowner with tax benefits in return for an easement in perpetuity or donation of land to a Conservancy. The Nature Conservancy is now the largest private cave owner in the United States with at least 113 Conservancy preserves in the United States centered around cave ecosystems.

Numerous other caves have been acquired or protected by archaeological conservancies, statewide conservancies, and various local cave conservancies. Members of the National Speleological Society have purchased and managed caves through the efforts of groups such as the Butler Cave Conservation Society, Indiana Karst Conservancy, Perkins Cave Conservation and Management Society, Texas Cave Management Association, and Greater Cincinnati Grotto. The Society also manages nine cave preserves. The Cave Conservancy of the Virginias and the Richmond Area Speleological Society have provided funding support for cave acquisitions and educational projects. The Southeastern Cave Conservancy has become one of the fastest growing conservancies and has acquired more than a dozen caves over the past decade. The American Cave Conservation Association now manages Hidden River Cave and provides substantial technical support services for those interested in managing and conserving caves.

Conclusion

Cave conservation in the United States is evolving rapidly and has primarily originated from citizens rather than the government. High profile environmental disasters helped create a pro-environmental public in the 1970s. This has led to the creation of numerous nonprofit groups and conservancies which are becoming involved in cave management, and a stronger focus on science and education among show cave operators.

The most significant trend in the U.S. is the growth and expansion of partnerships between government and private organizations in purchasing and managing significant caves, conducting scientific research, and educating the public. Perhaps the most important change in cave management philosophy has been towards a science based interpretative style, which makes information about caves and the karst landscapes meaningful and relevant to the cave visitor.

Walkway Development and Construction Relative to Reducing Visitor Impact in the Historic Section of Mammoth Cave

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Abstract

In 1996 Mammoth Cave National Park began several projects directed toward reducing visitor impact in the Historic Section of Mammoth Cave. One of the most significant components of the program was the development and construction of a prototype walkway that would be more compatible with the cave environment. The primary goals were to eliminate the mining of cave sediments for trail construction, to control the migration of potentially harmful lint introduced by visitors, eliminate dust created by soil based trails, and reduce the opportunity for graffiti and vandalism.

While implemented as a resource management project, the walkway obviously involved conditions which had far reaching impacts not only for the cave, but park operations as well. Beginning with the planning and design process, through the construction, and continuing on with future upkeep, numerous details had to be incorporated. These factors included materials, engineering, tour logistics, visitor experience, safety, environmental and archaeological compliance, and sustainability to name just a few. The actual building of the walkway introduced further challenges, the most extraordinary being the constraints of a major construction project in a cave environment.

Ultimately two different designs were carried out, a 550-foot-long boardwalk built with a combination of cypress lumber and recycled materials, and an 800-foot walkway constructed from hexagonal paving blocks and recycled plastic lumber. Throughout the process and having over a year's worth of hindsight and feedback from the new designs, a vast amount of experience has been gained from these prototype walkways which can be built upon for future work at Mammoth Cave National Park.

Introduction

Even with the longest cave system in world, it is impossible to provide access to large numbers of visitors without impacting the fragile cave environment and its associated resources. In 1998 alone over 445,000 (Interpretation, 1999) people toured Mammoth Cave, and whether they were aware of it or not, directly or indirectly each one of them left some sort of physical reminder that they were there. Although most of these impacts seem small on an individual level they become magnified over time with the ever-increasing number of total visitors. Fortunately, some of these impacts can be reduced and managed with proper trail design. With that goal in mind the Science and Resources Management Division at Mammoth

Cave National Park set out to develop and construct a prototype walkway along selected passages within the Historic Section of Mammoth Cave. In 1996, a three-year effort to restore the Natural Entrance ecotone of Mammoth Cave (Olson, 1996) was funded through the Natural Resources Preservation Program. A portion of the funding was targeted toward the reduction of visitor impacts through prototype trail design and construction.

In developing the new walkways four primary resource impacts were to be addressed:

Sediment mining - When the original trail network was constructed in Mammoth Cave most of it was completed using rocks and soil from within the cave. These soil-based trails still make up the larger part of the network. The trails were built over the natural breakdown floor, using crushed and smaller breakdown as a sub-base with a sediment layer on top as the tread surface. While full-scale construction of this type of trail had not occurred in some time, up until 1997 sediments were still being mined to patch and maintain the existing trail. (Mining was discontinued primarily for safety reasons associated with the pits.)

The obvious impact from mining sediments is the aesthetic damage that it does to the section of cave where material is excavated. However, irreversible harm is also done to the resources associated with those sediments. Lost or severely damaged are potential habitats for cave biota, the geologic record within the sediments, archaeological and historical artifacts and their inherent record, as well as paleontological resources

Dust - Cold, dry air pouring into the cave in winter dries out the soil-based trails. As large tour groups pass (as many as 125 people per tour, clouds of dust disperse and settle throughout the passage. Over time a thick patina of dust is deposited on the cave features. Changing cave atmospheric conditions create other problems that, while not having a direct impact on the resources, create rough walking surfaces. In some areas cold, dry air breaks up the surface and in other locations dripping condensation leads to pitting and slick spots.

Lint and other foreign matter – Visitors introduce a wealth of minute particles into the cave environment when they enter. This includes lint, skin cells, hair, dust, and any other of a host of foreign materials that are inadvertently sloughed-off as people move through the cave (Jablonsky *et al.*, 1994). While these objects are small in size their cumulative weight can be measured in pounds and they fuse into grotesque layers and mats of crud. Most significantly, this "crud" can potentially harbor microscopic organisms that are detrimental to both the natural and cultural features within the cave.

Graffiti and vandalism – Many of the cave walls and features are within relatively easy reach of visitors. For those with bad intentions it provides ample opportunity to leave their mark, break something off, or pocket a "souvenir."

With these four primary impacts in mind the baseline was set for a new walkway. The park had to get out of the sediment mining business. The dust problems further eliminated soil-based or similar treads. Lint and other particulates had to be managed through containment and collection, which could be accomplished through lint curbs. Graffiti and vandalism needed to be reduced by limiting the accessibility to vulnerable areas via a more defined trail, which restricted the opportunities for mischief. While these were the fundamental components necessary from a resource management perspective, much more would need to be considered in the planning and design process. A new walkway had implications for a wide range of park operations.

Planning and Design

Under the Natural Resources Preservation Program ecotone restoration project three heavily impacted areas were selected for building new trails:

- **Houchins Narrows**, the entrance passage into Historic Mammoth.
- The **Rotunda**, the first large room that visitors encounter and one of the main sites for the War of 1812 saltpeter works.
- A segment of **Broadway**, a passage extending east from the Rotunda 650 feet through Methodist Church.

Some options for a new walkway had to be considered in order to submit a budget with the funding proposal in 1996. The proposal called for "a low profile, recycled plastic boardwalk trail with lint curbs, aisle lights, and electrical outlets" (Olson, 1996) to be constructed in all three areas. Other possibilities were also looked at including concrete. Intense planning and design began in January 1997, with a walk-through of the affected passages. Representatives from every park division were involved to obtain input with respect to the design and how it should reflect the needs of their operation.

For interpretation and guiding visitors through the cave a primary concern was maintaining a substantial trail width. Current records show that nearly a quarter of a million people pass through the areas in question each year (Interpretation, 1999). The tours are large (125+) and frequent, particularly in the summer. Groups are often required to pass in opposite directions and during peak periods the problems are magnified by the logistics of a self-guided tour. Interpreters also needed sizeable areas where they can gather groups for talks. Furthermore, the walkway could not significantly detract from the visitor experience. Finer details such as light angles and view points were also considered.

With regard to safety, providing a safe, level walking surface was only the tip of the iceberg. Sloped areas had to be minimized particularly in consideration for future mobility impaired access. Aisle lighting had to be incorporated due to the addition of lint curbs, which would potentially block illumination from the main passage lights. Handrails were necessary along slopes and elevated sections, or where sensitive resources were located.

From a maintenance standpoint, sustainability was critical. The new structures had to be cost and labor efficient over the long term. With funds and personnel at a premium, the resources would not be available to do intensive upkeep. If repairs were necessary they would have to be accomplished with relative ease, particularly in light of the severe limitations of conducting work in a cave. Also considered was the potential for reversibility. Obviously, the park wanted the maximum lifetime out of its new walkway but if for whatever reason it needed to be replaced, dismantling and removal with minimal impact to cave resources had to be designed in.

Design options had to consider the logistics of handling materials in the cave and what type of equipment could be used. Cave access anywhere is generally limited, but fortunately the Historic Entrance has an adequate service road leading to it. However, the entrance traverse involves a long, steep incline with steps. Once inside the cave operating space was not a factor, but the construction areas were as much as 1,500 feet in from the entrance. To conduct work, many types of equipment were immediately eliminated because of the harmful gases emitted by standard combustion engines.

Walkway materials had to be durable enough to withstand the rigors of the cave environment and heavy tour traffic. At the same time they could not introduce any harmful impacts to the cave. The required attributes included:

- Resistance to corrosion and decay associated with cave environments.
- Resistance to the continuous wear and tear presented by millions of visitors.
- No potential for chemical leaching.
- No potential to alter the habitat for cave biological communities.
- No safety hazards to visitors.

Other resource impacts had to be factored in also. From a natural resources perspective, aside from paleontological materials, new trail construction was not really an issue, as the area that would be impacted had been previously disturbed during construction of the original trail. Cultural resources, on the other hand, were another matter. When the old trail was constructed it was built directly on top of artifacts dating back thousands of years, ranging from the Late Archaic (2000 BC) to the War of 1812. These materials would undoubtedly be encountered when excavation of postholes began. Avoiding them or mitigating any impact was paramount. To ensure compliance, detailed archaeological investigations began in the summer of 1997 and continued as necessary throughout the actual construction.

To complete the design work a civil engineer was brought on board in February 1997 as a Conservation Associate, hired through the Student Conservation Association. The design process was a prolonged and demanding venture for both the project's engineer (Scott Henrickson) and manager (John Fry). While the broad concepts were agreed upon with relative ease, resolving the details often required vast amounts of time. Each option seemed to have its own set of positive and negative characteristics, often without a clear picture of which outweighed the other. Moreover, in some instances one factor or operation had to be compensated for at the expense of another. New issues were encountered that had no precedents that could be drawn upon for answers. One example was whether the lint curb presented a tripping hazard, and if so how could it be mitigated.

Throughout 1997 and 1998 numerous presentations were conducted with the park management team for review and approval of the designs. Smaller-scale meetings were also held throughout the construction process to handle last-minute changes. Ultimately two different designs were selected: in Broadway a boardwalk built with a combination of cypress lumber and recycled materials and in the Rotunda and Houchins Narrows a walkway constructed from hexagonal paving blocks (pavers) and recycled plastic lumber.

The two designs would have several features in common. All of the new walkways were built directly over the existing trail. With respect to reversibility, if the trails were removed today, the only lasting impact would be from shallow postholes, which can easily be mitigated. Both designs would incorporate 15-inch-high lint curbs to contain lint and other particles. Electrical outlets were added for vacuuming up the "crud," as well as providing service for maintenance and interpretive activities. Aisle lighting was also provided to illuminate the walking surface. Beyond that the two designs differed drastically while still supporting the same basic goals and requirements.

Broadway Boardwalk

A boardwalk was chosen for the Broadway passage for two primary reasons. First, slopes along the passage's existing trail were relatively steep, particularly as it descended into Methodist Church. A raised boardwalk provided a gentler grade over the main segment and steps were built for the Methodist Church hill. Secondly, the shallow base provided by the existing trail did not permit deep footers that would be needed for the support posts of an at-grade paver walkway. While footers were necessary for the boardwalk, the comprehensive integrity of the structure allowed for shallower excavations.

The original 1996 proposal for the project called for the new walkway to be constructed through Methodist Church. However, this plan was abandoned early in the process due to apprehension about how any design would affect the appearance and interpretation of Methodist Church. Therefore, the boardwalk ends with a short paver landing at the base of the steps leading into the Church.

Also, in the original proposal the walkway was to be constructed from recycled plastic lumber. Unfortunately, under current technology, most of the recycled plastic lumber that is available on the market is not acceptable for use as structural members. One product, Trimax, can be utilized for structural purposes due to recycled fiberglass that is added to the mix specifically for strength. However, Trimax and recycled plastic in general proved too costly for using it in the entire boardwalk. The cost is $3.16 per board-foot for Trimax and $3.04 per board-foot for standard recycled plastic lumber. (Note: all prices cited in this document are based on quotes and final bids received from various suppliers between 1997 and 1999.) In addition, fiberglass can cause allergic reactions, which eliminated Trimax in concern for the health and safety of visitors.

Nonetheless, recycled materials were not completely out of the picture. Trex, a composite material of %50 recycled plastic and %50 recycled waste wood, was selected for the decking material. At $1.26 per board-foot the lumber was affordable and was considered to provide better skid-resistance than recycled plastic.

Cypress lumber was selected for the primary structural members of the boardwalk because of its strength and resistance to decay. Although treated lumber would have been more cost efficient, the introduction of chemically treated materials into the cave environment was not seen as an option. Cypress provided a viable alternative at $0.82 per board-foot. It was also used for the lint curbs as well as the top and intermediate handrails, which had been incorporated into the boardwalk design because of the inherent elevation and drop-offs.

Houchins Narrows and Rotunda Paver Walkway

Because of the low ceilings in Houchins Narrows, a boardwalk concept was eliminated, as the substructure would reduce the clearance by at least 10 to 12 inches. As for the Rotunda, an existing deep trail base and reasonable grades removed the limitations that would have made a boardwalk design necessary. For these two areas a design based on concrete hexagonal paving blocks was selected over concrete based on several advantages.

First, the pavers are more easily repaired if needed. A damaged paver could simply be replaced with another paver, whereas concrete patching requires considerable more materials and effort. Ultimately, such patches never blend in and the trail acquires a run-down appearance, which should not happen with the pavers. Second, concrete becomes polished over time and presents a slipping hazard. Pavers are specifically designed to maintain a skid-resistant surface even if wear should occur. Third, while in itself not easy, a paver walkway can be more easily reversed (removed) than concrete. Finally, and in hindsight, the archaeological resources buried beneath the various layers of trails are more accessible should future investigations occur.

In addition to the paving blocks themselves, the paver walkways required a four-inch subbase of compacted, dense grade stone (3/8-inch diameter down to screenings and fines) and a coarse sand setting bed that the blocks lie on. In the Mammoth Cave design, the walkway materials were held in place by edge restraints mounted to support posts set in concrete footers. The edge restraints and lint curb for this project were built using standard recycled lumber and tied into Trimax support posts. (All of the plastic materials were dark gray in color.) Where needed, new, stainless steel railings were erected and the restraints and curbs were mounted directly to them.

Construction

Broadway Boardwalk

During the design process, construction was split into two phases. Phase I was to be the paver walkway from the entrance gate down Houchins Narrows and through the Rotunda, completed during the winter months of 1997 and 1998. Phase II would be accomplished the following winter and take care of the boardwalk construction in Broadway. However, plans changed in late August of 1997 when the preliminary archaeological report was completed. The investigations showed that artifacts in the Houchins Narrows section were extremely vulnerable and the walkway designs were not adequate in avoiding serious impact. Time was needed for alterations. In the interim, approval had been obtained to move forward with the Broadway boardwalk. The two phases were switched with the target dates for construction closing in. Work had to take place between December 1 and March 15 in order to avoid major conflicts with peak visitation periods.

Because of the switch, many of the details for the boardwalk had to be sorted out and acted on quickly. The focus had been on the paver walkway, for which significant materials had already been ordered.

The type and sources for lumber was one of the decisions to be made. Once cypress was selected, kiln-dried stocks were not readily available and wouldn't be until well into construction. Therefore, green cypress had to be used, which had the potential for supporting fungi. While growth did occur, the wood was cleaned as it came into the cave. In addition, the Broadway passage is extremely dry and should inhibit anything further. (Periodic observations are being made to look for new growth.)

Construction in the Broadway section began on November 24, 1997, with an in-house crew hired by the park. Park personnel were employed for both the boardwalk and paver walkway construction rather than contractors. With its own staff the park could be extremely flexible in making changes and fine tuning the work and final product. Time crunches could also be more easily addressed. In addition, park personnel are also more aware of the sensitivities related to working in a national park. The boardwalk crew consisted of a carpenter, two carpentry workers, an electrician, and two maintenance workers.

The most labor intensive task of the Broadway operation was moving over 3,000 pieces of lumber and hundreds of bags of concrete into the cave; not to mention countless other pieces of materials and equipment required for the job. At least two hours each day was dedicated to manually carrying supplies down the entrance steps and hauling them to the worksite on carts.

Tours continued in the Historic Section until after the holidays. During this period construction focused on excavating footers and setting the main support posts. Once tours were shifted to other locations the full structure began to develop with the addition of support beams and joists throughout the length of the boardwalk. Once all of the primary members were in place the crew went back through and laid the Trex decking, followed by the lint curbs and handrails. Throughout the process electrical service (in PVC conduit) was tied directly to the boardwalk and the aisle lights were mounted in the lint curb.

In early March, just two weeks ahead of the 15th deadline and despite the hard work of the crew, it became obvious that the boardwalk was in danger of not being completed on time. The long steps into Methodist Church, which incorporated the complexity of a slight turn with multiple flights and landings, had not even been started. At that point virtually the entire Facilities Management Division of the park was called in to help, along with periodic assistance from other divisions. Working in shifts to take advantage of the large numbers and limited electrical power, the boardwalk was completed on time. Tours returned to the Historic Section on March 15, 1998.

The Broadway boardwalk runs 550 feet from the Rotunda to the landing at Methodist Church. The deck of the finished boardwalk ranges from one to four feet above the existing grade. It is eight feet wide with two expanded areas where tours can congregate for talks. The ideal width would have been ten feet, however the configuration of the old trail base was not adequate to support that width.

The most problematic issues with the boardwalk have been associated with the lighting configuration. The first problem is at Methodist Church and the steps leading into it. All of the fluorescent aisle lights for the new walkways are louvered at 45 degrees so they only cast light onto the walking surface. On the steps, lights are mounted into each riser. Unfortunately, when groups are down at the base of the steps (anywhere in Methodist Church) and look back toward the steps the louver angle is negated. The resulting glare is somewhat overwhelming. This scenario was not anticipated during construction and the park continues to search for a remedy to the problem.

A second lighting difficulty became apparent on the main stretch of the boardwalk. Here the lights were mounted on the lint curb every eight feet, alternating from side to side. This arrangement proved to be too bright and ultimately bulbs were pulled such that there is now a light alternating every 24 feet.

Another problem area is the noticeable rumble that rises from the boardwalk as hundreds of feet move along the passage. This problem was looked at during the design phase and was not seen as a limiting factor. However, future designers should evaluate soundproofing measures and incorporate them if at all possible.

Houchins Narrows and Rotunda Paver Walkway

Taking advantage of the time provided by switching the order of construction, the plans for the paver walkway in Houchins Narrows and the Rotunda were adjusted to avoid any impacts to cultural artifacts. Project approval was obtained and construction was set for the winter of 1998-99. The time crunch for the paver walkway was not as critical as tours would be minimally impacted by construction and would not have to be shut down in the Historic Section. Nonetheless, a target date of April 1 was set to avoid larger scheduling conflicts.

Having experienced the rigors of transporting large volumes of material into the cave, project personnel knew that getting 6,000 pavers in, along with tons of sand and gravel, would be a monumental task. Fortunately, at one time the park headquarters building and visitor center were climate controlled with cave air brought up via a shaft adjoining Houchins Narrows. This heating and cooling method had been abandoned (due to radon concerns) and the shaft was closed off at the top and bottom. However, the shaft provided direct vertical access to the Narrows from a point immediately off of the Historic Entrance service road. Furthermore, when reopened at the bottom, the 75-foot-deep shaft was found to be wide enough to handle the three-foot by four-foot pallets the pavers were loaded on.

With this stroke of good fortune a contractor was hired to lower (by crane) all of the pavers and other assorted materials into the cave and haul them to the worksite. An equally vital element added by the contractor was an electric cart, which they lowered into the cave and used to move the pavers. This "cave friendly" cart was subsequently rented by the park to handle materials throughout the duration of the project. Ultimately, even though approximately 700 pieces of recycled plastic lumber had to be carried down the entrance steps by hand, the shaft and cart would save a phenomenal number of hours of backbreaking labor.

Once again the walkway project employed park personnel to do the actual construction. The crew consisted of a carpentry worker, two welders, an electrician, two equipment operators, and three maintenance workers, with additional help from the park hydrologist (Joe Meiman), who was detailed to the crew for an extended period. For this phase the project manager (Fry) handled the construction as a member of the crew, directing day-to-day operations and providing labor support.

Work began with the lowering of the pavers during a four-day operation in mid-December 1998. Construction then started in the Rotunda with posthole excavation and assembly of the outer structures of the walkway including support posts, edge restraints, and lint curbs. Work was also taking place on the surface, as over 400 feet of stainless steel handrail was being built in the park's welding shop. The prefabricated sections were subsequently hauled into the cave, mounted in place, and welded together. As the development of the various support features progressed, the electrical service and lighting was incorporated.

Once these structures were in place, the operation continued on into Houchins Narrows. The crew also started to move dense-grade gravel into the cave for the walkway's sub-base. Again the shaft and cart proved invaluable. A plastic PVC pipe was erected in the shaft with feeding and dispersal hoppers at the top and bottom respectively. The material was loaded on the surface with a front-end loader, dropped into the cart at the bottom, and hauled directly to where needed (as much as a ton at a time). The sand setting bed material was handled the same way.

Initially, a six-inch pipe was used but because it was too narrow and had a slight curve from top to bottom, it continuously became clogged. It was replaced with a properly aligned, 12-inch pipe and no further problems were encountered. In the end approximately 150 tons of gravel and 50 tons of sand would be transported in.

By mid-February work had progressed to the point where gravel could be laid continuously. Once leveled, the material was compacted (per specifications) with a compactor powered by a propane engine. On March 1, the initial layer of sand was screeded out and the first paver was laid in the Rotunda.

To work with gravity in setting the pavers, the walkway had to be laid from the low end in the Rotunda out to the high end at the entrance area of Houchins Narrows. Logistics also required all of the material to be stockpiled in or just off of the Rotunda. Once in place, the pavers could not be driven over with the heavy electric cart and hard labor once again came into play as carts were used to move the blocks forward along the advancing walkway. Nonetheless, work progressed rapidly and the last paver was laid in Houchins Narrows on March 31, 1999.

Unfortunately, upon completion of the walkway over 700 pavers were left over and still on-site in the cave. This was the combined result of last minute reductions in trail width, the efficient cutting and fitting of pavers during construction, and miscalculation by the project manager. Also during construction, the overall length had been reduced near the entrance because of headroom problems and sensitive archaeological artifacts in that area. In the end, the remaining pavers were hauled to the shaft and hoisted out.

The completed paver walkway extends through approximately 770 feet of the cave, covering nearly 8,000 square feet. It is ten feet wide through Houchins Narrows and most of the Rotunda, where some areas were reduced to eight feet due to the restraints of the existing trail footprint. There are expanded gathering areas around the Rotunda for interpretation and self-guided waysides.

Results

With respect to primary goals, the new walkways have been successful to this point. Hardened trail surfaces have been constructed without mining or otherwise exploiting the cave's resources. Without soil for a tread, dust is no longer a problem although dirt is tracked onto the new surfaces from the remaining soil-based segments. Within weeks of their completion lint and other materials had visibly accumulated at the base of the lint curbs where it will not disperse throughout the passage and is easily collected. Furthermore, with the channelized flow gained through the lint curbs and railings, potential violators are less likely to damage cave walls or other resources.

With respect to the extended goals the results have been largely positive. Other than fine-tuning some problems inherent to the new designs and the periodic vacuuming of lint, maintenance requirements have been nonexistent. After two full seasons with the boardwalk and one with the walkway, tour logistics and interpretation have continued as before with no noticeable changes. Neither design has led to any safety problems. In fact, with a consistent and predictable surface, visitors can now look around at the cave as they walk instead of watching their feet.

The word of mouth review of the new walkways has been mixed. The primary reaction is how the boardwalk and paver walkway have affected the appearance of the cave for staff and returning visitors. Mammoth Cave is steeped in tradition and part of that tradition has always been subtle, natural-looking dirt paths. Raised boardwalks, paving stones, stainless steel, and lint curbs run counter to what had become part of their cave experience. The before and after contrast can prove to be a shock and for many "old-timers" the new structures now dominate that section of the cave, detracting from their experience. The only remedy is time as the prototypes become ingrained into the tradition and visitor experience of Mammoth Cave.

Lessons Learned

Design and construction of the prototype walkways in the Historic Section of Mammoth Cave was a learning experience in every sense. It was the first trail construction in the park to be centered on resource management issues. Many of the materials used were new to the park. Overall it was probably some of the largest scale work to take place in the cave in quite some time. Ultimately, the lessons learned by the personnel connected to the project can be applied not only at Mammoth Cave, but also in other caves and parks where new designs are in the works.

The first and foremost concern throughout the life of the project was a universal problem, time. Although on paper the work spanned three years, in reality the project had to go from zero to completion in less than 2.5 years. Funding procedures and the restraints of peak visitation periods led to the condensed time frame. Planning and design, management review, compliance, and construction of two distinct phases had to be completed in that period. Deadlines sometimes became an unfortunate factor in the decision process, an example being the use of green lumber for the boardwalk.

In the future, to avoid such pitfalls in prototype development, it may be beneficial to split the design process and the construction into two distinct projects and funding proposals. The design process would follow the scenario below and take place over approximately one year:

1. Thoroughly establish all of the walkway's requirements and goals.
2. Research plans, materials, and methods.
3. Research and mitigate compliance issues.
4. Develop multiple design options with complete cost/benefit analysis for each, i.e. choosing by advantage.
5. Present designs for management review.
6. Fine-tune designs and obtain final approval.
7. Prepare construction plans and procedures as well as personnel requirements.
8. Complete detailed funding package.
9. Submit construction proposal.

With this agenda a design engineer, focused on this one mission, could develop a solid package with only one major deadline.

Regardless of the timing scenario, one critical stage that planners need to be prepared for is the management review. The best recommendations are to have a firm cost/benefit analysis developed for each design, be prepared with potential alternatives within a specific design, and be ready for anything. Superficial or casual remarks can potentially send the design process off on tangents that are unnecessary and time consuming. Establish what is important and obtain clear direction from the managers with respect to their views and intentions.

In future plan development, before selecting one specific segment, designers should review the entire trail network using a holistic approach. In establishing priorities, factors such as resource threats, trail conditions, and visitor related concerns must be balanced against construction logistics. Within Mammoth Cave the targeted areas were the most heavily impacted passages in the Historic Section and desperately needed attention. However, other sites may find that the benefits of addressing problems deeper in the cave take priority over moderately impacted areas that are more directly accessible (and may be made less accessible by new trail designs).

The final bit of advice is to use in-house crews whenever possible. Given the dual headaches of conducting a major construction project in a cave and the limited time constraints, flexibility is essential. Designs may need last minute changes, work hours may be adjusted, tours may need to be compensated for, and a hundred other things may arise which cannot easily be overcome by either the contractor or the tight requirements of a contract. Furthermore, most personnel hired by the park have at least some experience working in the park and the cave environment. They are familiar with the problems and concerns and can adjust to where the job is done correctly and efficiently with minimal impact.

For now the Science and Resources Management Division is out of the walkway construction business. Nonetheless, a baseline has been established for developing a structure that provides a quality visitor experience while at the same time minimizes impacts to the cave's vulnerable resources. Working from this model, the park's Facilities Management Division is moving forward with plans to extend the paver walkway down Audubon Avenue from the Rotunda to Little Bat Avenue. Construction begins in January 2000.

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Evolving Geographic Information Systems Capabilities for Management of Cave and Karst Resources

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Abstract

Geographic Information Systems (GIS) software and the increasing power of desktop computers have created powerful tools for the management of cave and karst resources. This includes tools for:
1) the bookkeeping of large, complex spatial data sets,
2) analysis and quantitative modeling of karst processes, and
3) visualization of both spatially and temporally complex data.

Over the last four years, the advent of Environmental Systems Research Institute's (ESRI) ArcView package has made Geographic Information Systems more accessible to users in the karst science and management community. More recently, the ArcView extensions, 3D Analyst, Spatial Analyst, and CaveTools, have added particular utility for karst applications. Using these tools, we are developing methods to manage karst resources more effectively as well as moving toward a deeper understanding of karst systems' fundamental behavior and organization.

On the western boundary of Mammoth Cave National Park, potential threats to water quality from oil drilling adjacent to the park are being cataloged for emergency response teams using Geographic Information Systems. Regional water quality impacts to the aquatic ecosystem within the Mammoth Cave Karst Aquifer are also being studied through land use inventories within the aquifer's 350-square-kilometer recharge area. The long-term goal of this "bookkeeping" project is to develop numerical models relating land use changes to potential water quality impacts. Other research is working toward understanding the basic organization of karst flow networks utilizing cave survey data and ArcView's three-dimensional analytical capabilities applying morphometric concepts that have been developed for traditional surface flow networks.

"Have Cave, Will Travel"

The Use of Portable Cave Exhibits in Environments Education

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Abstract

A traveling cave exhibit can be used very effectively to help get across the messages of cave resource conservation and ethics. The Bureau of Land Management Carlsbad Field Office designed and constructed such a cave for use as an environmental education exhibit. It was constructed of one-inch PVC pipe covered with chicken wire and burlap and sprayed with industrial grade polyurethane. The exhibit has been used several times across the United States and has held up quite well. It contains bilingual interactive interpretive signs, a running stream and plunge pool, bat roosts, interpretive video, an interactive cave restoration station, and is wired for sound and lights.

Challenge

As part of the 1997 Boy Scouts of America (BSA) National Jamboree the Bureau of Land Management requested a cave as one of their exhibits on the "BSA Adventure Trail." I was contacted to design and produce the exhibit. I wanted to produce an exhibit that would convey the sights, sounds, and feel of being in a real cave and combine that with the elements of cave resource education, conservation, and safety.

Design

The most efficient design was an S-shaped structure with two common interior walls. The entrance is at one end of the S and the exit at the other. This design creates three parallel passages. Each passage has a different theme. Both ends have crawlway and wheelchair-accessable entry and exit. The wheelchair access is through a light-tight removable door. The entrance passage contains a running stream and plunge pool and the interpretive signs tell about cave and karst geology. The interior passage has speleothems and a bat roost. The interpretive signs discuss bat myths and bat truths. The exit passage has a restoration section and interpretive signs that convey messages on cave conservation and safety.

Construction

After several unsuccessful initial construction concepts I finally decided to construct it out of one inch PVC pipe as a frame, covered with one inch chicken wire, then covered with burlap. Then I sprayed the entire structure with structural polyurethane foam. The speleothems were constructed in the same manner. First the outline of the exhibit was drawn out on the floor of the BLM warehouse. It measured 20 by 28 feet and averaged a 6½-foot ceiling height. The PVC pipe was laid out, fitted together with couplers, and glued. Where the pipe was arched to make the roof, a hot air gun was used to relieve the stress on the PVC.

The structure was wired to incorporate lighting sconces and electrical outlets for sound and video capability. The wiring was installed in electrical PVC conduit with all outlets a minimum of eighteen inches above ground height and equipped with ground fault circuit interrupters to meet electrical codes. The lighting is indirect and uses 4-watt night lights.

Once the frame and wiring were complete, 1 by 12 pine boards were mounted in the areas where the interpretive signs were to be installed. This would give the signs something to be screwed into and would hold them securely. The frame was then covered with one-inch chicken wire, and burlap was applied to the chicken wire using hog rings. The next operation was to contract the spraying of the polyurethane. Two 55-gallon drums of urethane and catalyst were used to cover the structure. It was sprayed on hot, using a direct displacement pump. The inside was sprayed first. By the time the outside was ready to be sprayed the structure was sturdy enough to walk on.

After the outside was sprayed the structure was coated with a heavy weather resistant latex paint. The inside was painted with a light grey base coat then highlighted with spray paint in just the right cave colors. The structure was then cut into eight pieces so it could be loaded into a truck and transported. Removable polyurethane speleothems were then added.

Bells and Whistles

To add realism to the exhibit, enhance its interpretive value, and increase its fun-factor, several special effects were added.

Interpretive Signs: Twelve interactive interpretive signs are used in the exhibit. All the signs are in English and Spanish. One part of the message is on the front of the sign, then the sign can be opened up for the rest of the message inside. Interpretive signs cover cave geology, karst hydrology, cave biology, cave climatology, bat myths and truths, cave conservation, and safety.

Stream and Plunge Pool: The right side of the entrance passage has a live stream which comes out of the wall and flows down a trough to the end of the passage, turns the corner and disappears into a plunge pool. The plunge pool is about 18 inches deep with a submersible water pump in the bottom. A hidden 3/8-inch tube returns the water to the spring source.

Bat Roost: Rounding the corner you enter the bat roost area. The bats are made of cast resin and are actual size and anatomically correct. There are clusters of Mexican free-tails, and individual Big Brown Bats and *Myotis Velifer*. Under the bats are guano piles. Bat squeak and flutter sounds are heard from a specially produced compact disc. The CD player is hidden under a rock ledge that is accessible from the outside. The bat sounds play on a repeating track. A 13-inch TV-VCR plays a three-minute continual loop video about bats and bat conservation. Four interpretive signs cover bat myths and truths.

Speleothems: The middle passage also contains a number of speleothems that can be removed when the exhibit is transported. Stalactites, stalagmites, sodastraws, and columns grace the hallway. They are affixed using velcro and made fast with spray polyurethane foam.

Climate Control: The cave is given a further touch of reality by the addition of refrigerated air. An air-conditioner is placed outside the exhibit and refrigerated air is fed into the cave through an air duct. This reduces the noise level of the air-conditioner and fans. The refrigerated air gives the entire cave cool realism and also adds positive air pressure inside the cave which creates a cool breeze blowing out of the entrance and exit crawlways.

Restoration Station: Rounding the corner you face a wall of graffiti. On the floor is a limestone block, which also has spray paint on it, and several nylon bristle scrub brushes. This is the visitors' opportunity to get first hand experience of how difficult it is to remove spray paint from cave walls. The interpretive signs give a Leave No Trace message and points on cave conservation and safety.

The exit passage is filled with the echoing sounds of dripping water. The specially produced sound track comes in from a CD player hidden behind a false rock.

Transportation and Assembly: The pieces of the structure can be craftily loaded into a 24-foot Ryder truck, with only one piece left over. The last piece can be transported on a 16-foot flat-bed trailer. Once on location the pieces can be placed together and drawn tight using binding cinches. The joints are then filled with spray foam and allowed to dry over night. The foam can then be spray painted to match the interior of the cave. Then the speleothems are added. When the cinch straps are removed the structure is sturdy enough to walk on. There are electrical outlets on the outside of the exhibit that can be plugged in and provide current to the entire display. It is easiest to assemble the exhibit with five or six people but it has been done with two. Complete assembly takes from four to six hours. Disassembly is best done with a keyhole saw to cut the foam joints apart. A reciprocal saw may also be used but there is a greater possibility of cutting into the structure of the exhibit.

Availability: The exhibit has been on display at Fort Hill, Virginia, for the two-week BSA National Jamboree. Nearly 4,000 scouts visited the exhibit during that time. It has also been on display in Phoenix, Arizona; Bishop, California; Tucson, Arizona; and Carlsbad, New Mexico. It is available on request through the Bureau of Land Management Carlsbad Field Office. Contact Jim Goodbar at (505) 234-5929, james_goodbar@blm.gov 620 E Greene St, Carlsbad, New Mexico 88220.

Interagency Cooperation at the Highest Level: A Review of the Draft Interagency Agreement for Cave and Karst Resources Management in the Federal Government

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Abstract

The purpose of this agreement is to achieve more effective and efficient management of caves through cooperative action by Department of the Interior, Bureau of Land Management, U.S. Fish and Wildlife Service, U.S. Geological Survey, National Park Service, and the Department of Agriculture, USDA Forest Service. The agreement identifies areas of mutual concern and establishes avenues for cooperation in the management, research, protection and conservation of cave resources.

For several years a number of the Federal agencies have been working together on cave resources management without the benefit of a national agreement. There have been local agreements addressing the cooperative management of cave resources but no formal agreement at the national level. A draft agreement is now circulating in the Washington Offices of the Bureau of Land Management, U.S. Fish and Wildlife, U.S. Geological Survey, the National Park Service, and the USDA Forest Service. The purpose of this agreement is to achieve more effective and efficient management of caves through cooperative action. The agreement identifies areas of mutual concern and establishes avenues for cooperation in the management, research, protection, and conservation of cave resources. With a national agreement, the cooperating agencies should find it easier and quicker to pull together national level resources for projects of mutual concern. Basically, it should cut through some red tape.

Cooperative action is needed based on the following mutual situations:

- The passage of the Federal Cave Resources Protection Act of 1988 require federal agencies to secure, protect, and preserve significant caves on Federal lands. Further, the Federal Cave Resources Protection Act urges agencies to foster increased cooperation and exchange of information.
- A large number and diversity of caves and karst lands are managed by the four agencies.
- The Bureau of Land Management, U.S. Fish and Wildlife Service, National Park Service, and the USDA Forest Service have similar visitor use patterns in the caves they manage and recognize the need for consistent management of cave and karst resources.
- Increasing visitor and land use pressures are expected to continue and are accelerating the deterioration of cave and karst environments such as the disruption of biological, archeological, paleontological, cultural, recreational, and other speleological values.
- Similar issues associated with safety and resource protection being faced by the agencies could be more effectively solved through interagency collaboration and coordination.
- Combined capabilities are more effective than individual agency efforts.
- The Endangered Species Act of 1973, as amended (16 U.S.C. 661667e) and the Fish and Wildlife Coordination Act, as amended (16 U.S.C. 15311543) are administered by the U.S. Fish and Wildlife Service. The U.S. Fish and Wildlife Service and all other Federal agencies must insure that activities they carry out related to the management of their cave resources meet the requirements of this legislation. Effective fulfillment of these re-

sponsibilities will be facilitated by this cooperative effort. Fulfillment of U.S. Fish and Wildlife Service obligations under the National Wildlife Refuge Administration Act of 1966, as amended by the National Wildlife Refuge System Improvement Act of 1997 (16 U.S.C. 668dd668ee) will be facilitated by the knowledge and experience that will be provided through this Agreement.
- The U.S. Geological Survey has the capability to support the research needs of the scientific programs involved with cave and karst resources management.

All agencies involved in this agreement will agree to cooperate in the following aspects of cave and karst management and resource protection:

- **Environmental Education**—Agencies will cooperate in the development and production of mutually beneficial environmental education materials such as brochures, pamphlets, programs, videos, and the Leave No Trace program.
- **Training**—Agencies will cooperate in the development, offering, and teaching of training courses and seminars related to cave and karst resources management and other aspects of speleology including biology, geology, hydrology, mineralology, paleontology, and cave search and rescue and the cooperative hosting of the National Cave Management Symposiums.
- **Information Pooling and Transfer**—Agencies will share information concerning cave and karst resources management, current issues, problems, and solutions.
- **Research**—Agencies will, when appropriate, develop and coordinate research needs and projects.
- **Regional Agreements**—Agencies will enter into additional regional and local agreements for specific programmatic involvement and cooperation.
- **Publications**—Publications (including distribution to the world wide web) documenting cooperative efforts may be prepared by any agency, or jointly, provided that all parties involved have an opportunity to review manuscripts prior to publication. To the extent possible, decisions involving authorship and review of reports will be addressed during the preparation work plans or work agreements. Should differences of viewpoint occur, an effort will be made to reconcile them. However, this shall not prohibit any agency from publishing the data provided it assumes sole responsibility and gives appropriate credit to the other agency(ies). All parties agree that sharing credit is mutually beneficial, and will make every effort to assure that appropriate credit, including the use of official agency visual identifiers, is given for work performed under this agreement.
- **Freedom of Information Act**—Agencies will share information resulting from significant issues arising from Freedom of Information Act requests.

Once the Interagency Cave and Karst Resources Management Agreement has been signed it should facilitate other states and regions to develop their own, more specific, agreements.

New Advances in the Study and Management of Arkansas Caves

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Abstract

Research in Arkansas cave ecosystem ecology is being performed at several scales: population dynamics of Ozark cavefish, trophic dynamics of cave stream foodwebs, an ecoregional comparison of cave biodiversity, and a state-wide assemblage of a cave database. Monitoring and research efforts have focused on Cave Springs Cave, Arkansas, which is a recovery cave for the Ozark cavefish and a site where extensive disturbance has occurred. Research in this cave complex includes the use of occular surveys of the cavefish population, organic matter budgets, water quality monitoring, epifluorescence microscopy, and stable isotope assays. Habitat stressors include: a 15-year trend of increasing organic pollution, the presence of heavy metals and semi-volatile organic compounds, and continuous violations of state water quality regulations. Water quality monitoring over the last three years indicates that heavy metals may be concentrated in the sediments and bioaccumulating in the foodweb. The historic application of sewage sludge in the cave spring's recharge zone is implicated as a pollutant source. Concentrations of nitrate, ortho-phosphate, total phosphate, total coliforms, and several dissolved metals were all highly correlated to discharge and concentrations were highest during storm flows. Yet occular surveys indicate the Ozark cavefish population is recovering and present in densities higher than any published record. Furthermore, preliminary results of stable isotope assays indicate that traditional organic matter sources (e.g. guano, DOM) are dominant in the foodweb. At the state level, a biological survey of caves has begun and is focused on updating the status of rare and endangered stygobitic species. Concurrent physical, chemical, and geological data collection will be used to interpret the distribution of these species of concern. In particular, factors such as cave ownership, public use, water quality, proximity to faults, and abundance of organic matter inputs will be statistically compared to the abundance and diversity of cave fauna. Finally, a database (with restricted access) is being assembled to unify multiple-agency management efforts.

Research in Arkansas cave ecosystems is being performed at several scales: population dynamics of Ozark cavefish; trophic dynamics of cave stream foodwebs; an ecoregional comparison of cave biodiversity, and a state-wide assembly of cave databases and cave managers.

Ozark cavefish recovery efforts have focused on Cave Springs Cave, Arkansas, which is home to the largest population of *Amblyopsis rosae* and is a site where extensive disturbance has occurred. Monitoring and research efforts, funded by the Arkansas Natural Heritage Commission and the Cave Conservancy Foundation, include annual visual surveys of the cavefish population, the construction of an organic matter budget, baseflow and stormflow water quality monitoring, the determination of microbial population dynamics using epifluorescence microscopy, and foodweb analyses using stable isotope assays. Several habitat stressors have been identified, and include a 15-year trend of increasing organic pollution, the presence of heavy metals and semi-volatile organic compounds (pthalates), and continuous violations of state water quality regulations (see Brown *et al.*, 1998; Graening and Brown, 1999). A significant increase in nitrate, specific conductance, and dissolved metals (aluminum, barium, copper, iron, and lead) has been detected over 15 years of water quality sampling. Water quality monitoring from 1997 to 1999 reveals that total coliform densities continually exceed Arkansas State Water Quality Standards (Regulation 2), occasionally by a factor of 1,000. Significant amounts of nitrate are also present (with a yearly average of over 5 mg NO_3-N/L), and phosphate concentrations occasionally exceed Regulation 2 standards. Furthermore, beryllium, copper, lead, selenium, and zinc are present in concentrations in the cave water that exceed the Regulation 2 standards for chronic, and sometimes acute, toxicity to aquatic life. Sediment and tissue analyses indicate that heavy metals are concentrated in the sediments and bioaccumulating in the food web. The historic application of sewage sludge in the cave spring's recharge zone is implicated as a pollutant source. Concentrations of nitrate, ortho-phosphate, total phosphate, total coliforms, and several dissolved metals were all highly correlated to discharge. A recharge zone analysis was begun using a Geographical Information System, and will aid management and conservation practices. In spite of these disturbances, visual surveys indicate the Ozark cavefish population is recovering and is present in densities higher than any published record (166 individuals). Furthermore, preliminary results of stable isotope assays indicate that traditional organic matter sources (especially bat guano) remain dominant in the foodweb, despite significant loading of animal and/or septic waste.

At the state level, a biological inventory of caves has begun, and is focused on updating the status of rare and endangered cave species. This study is a cooperative effort between the Arkansas Game and Fish Commission, the Arkansas Natural Heritage Commission, the University of Arkansas, the USDA Forest Service, and the U.S. Fish and Wildlife Service. Concurrent physical, chemical, and geological data acquisition will be used in conjunction with a Geographical Information System to assess habitat quality and interpret the distribution of these species of concern. In particular, factors such as cave ownership, public use, water quality, proximity to faults, and the quantity and type of organic matter inputs will be statistically compared to the abundance and diversity of cave fauna. Hypotheses pertaining to the colonization and migration of stygobites through karst conduits will be tested. Preliminary results of the state-wide survey indicate that *Amblyopsis rosae's* status is stable, if not improving, and that the range of the cave crayfishes, *Cambarus aculabrum* and *C. setosus*, may be greater than previously recorded. Furthermore, one of the populations of *C. aculabrum* has apparently recovered from a minimum of two individuals, and is now equal to the maximum published for that cave (nine individuals).

At the regional level (the Springfield and Salem Plateaus), researchers, NSS grottos, The Nature Conservancy, and federal and state (Arkansas and Oklahoma) land managers are now meeting regularly to discuss mutual needs and to share resources. Cooperative products include new surveillance and gating techniques, the assemblage of a cave resource database (with restricted access), cave clean-ups, increased funding for research and recovery actions, and educational/public outreach programs. Such a collaboration is timely because the Ozarks are experiencing rapid growth and land-use changes, which will undoubtedly affect cave ecosystems. The goal of this consortium might be summarized as the attempt to guide these land uses and growing economies towards practices that preserve cave ecosystems and conserve the groundwater resource.

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These publications are available online at: http://biology.uark.edu/bisc.html

The Role of Research and Education in Cave and Karst Management

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Abstract

To effectively manage and protect karst resources, we must first understand them. This requires not only an inventory of the resource elements, but also an understanding of how these elements are related and how they behave. Changing management strategies for the Mammoth Cave System by the National Park Service, for example, illustrate this concept. For years exploration and survey of the cave were actively discouraged. Eventually, efforts by Cave Research Foundation with the support of the National Park Service revealed that the Park's most important resource was indeed the longest known cave in the world. Even then, more years passed before resource managers appreciated the importance of land use beyond the boundaries of the national park, where most of the cave's major rivers were shown by dye tracing to originate.

A multifaceted program of research is underway in the south central Kentucky karst by Western Kentucky University, Mammoth Cave National Park, and the Cave Research Foundation to investigate a wide range of basic and applied questions. These include fundamental questions about cave, landscape, and aquifer development, including cave enlargement rates and processes, cave stream network organization, and carbon dioxide transport. Applied investigations are evaluating threats to the cave and aquifer from agricultural, urban, and transportation land use, working to develop effective strategies that strike a balance between competing economic and ecological needs. There are also less parochial questions: rivers within the cave system are part of a global network of research sites evaluating the impact of karst geochemical processes on the global carbon cycle and thus the potential for global climate change.

Site Conservation Planning for Caves and Karst Features

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Abstract

The Nature Conservancy has embarked on a major planning effort to ensure that projects designed on paper will translated into on-the-ground conservation action. Site conservation planning is a problem-solving and decision-making framework for defining site boundaries and deciding how to effectively conserve the conservation targets at a site. Site conservation planning has eight interactive components including: defining targets, identifying and engaging partners, assembling information, analyzing stresses to system, developing strategies, turning strategies into actions, determining feasibility, and measuring progress. Site conservation planning can be particularly challenging when dealing with caves and karst features. Targets may be illusive or unknown; the stresses to the systems may be difficult to define.

Several example sites are explored to demonstrate how site conservation planning can be used and is important for conserving karst sites. In some cases, protection of cave entrances may have little value in the overall conservation of the cave system. In some examples, the entire watershed the cave system is located in may be critical to the cave's conservation, in other cases only the ground directly above the cave is important. Can conservation strategies be implemented and goals realized and are actions having the intended affect? These are important questions that need to be scrutinized before just the cave entrance is purchased, gated, and considered "protected." The time put into a site conservation plan is dependent upon the complexity and importance of the site. However, even a day or two of going through this process will improve the effectiveness of your conservation actions.

Introduction

The Nature Conservancy, the largest private manager of natural reserves in the world, has embarked on a major planning effort to ensure that projects designed on paper will translated into on-the-ground conservation actions. The Nature Conservancy has termed its planning effort "Site Conservation Planning." Site conservation planning is a problem-solving and decision-making framework for defining site boundaries and deciding how to effectively conserve the conservation targets on a site (The Nature Conservancy, 1998). Familiarization with this planning technique can be helpful for managers of karst sites and can help ensure effectiveness of karst conservation actions.

Overview of Site Conservation Planning

Site Conservation Planning has seven major queries that are asked of a site to assist in organizing, analyzing, and processing information vital to management of the preserve. The seven queries include:

- What are the conservation targets and long-term goals for those targets?
- What ecological and biological attributes sustain the targets over the long term?
- What are the characteristics of the human communities at the site?
- What current and potential activities interfere with the maintenance of ecological processes that sustain the targets?

- Who are the organized groups and influential individuals at the site, what are their interests, what impacts might we have on them, and how might they help or hinder achieving site goals?
- What can we do to prevent or mitigate threatening activities, and how can we influence important stakeholders to make decisions that are favorable to the site?
- What are the areas at the site where we need to act?

Site Conservation Planning can be an important method to determine the feasibility of a project. A potential project may have a fatal conservation flaw, a bad site, or strategies or goals that are unrealistic. By going through the site conservation process, the flaws should become obvious and the feasibility of a project can be determined. Thus this planning process can identify those projects that are the most feasible, thereby saving scarce resource dollars.

In considering a Site Conservation Plan in a karst setting, perhaps the most important questions to answer are questions number one and two, which can be summarized as: what are the targets and how can these targets be sustained and managed? These can be difficult to ascertain in a cave setting, as the targets may be illusive or unknown, and the stresses to the systems may be difficult to define. Several cave examples will now be explored to examine the value of the planning process and to demonstrate the biological knowledge necessary to succeed in the planning process.

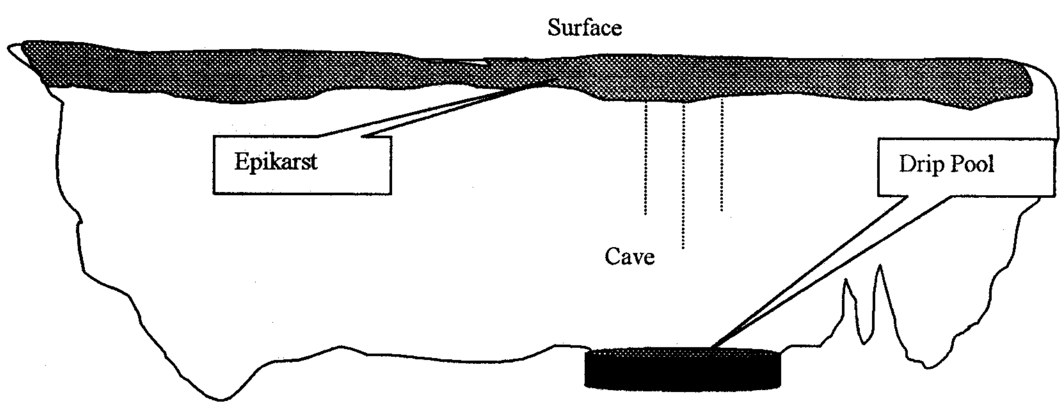
Specific Karst Examples

In examining the ecology of an area, it is often useful to describe its vegetation in terms of its community make-up, such as a beech-maple forest. The areas surrounding a cave entrance and inside a cave can also be thought of as community types Dr David Culver from American University in Washington, DC, has classified cave communities based on the way in which water and nutrients move through the cave system (Culver, 1991). Water and nutrients are the keys that sustain the unique life found in the cave, and it is important to determine how these elements enter and exit the cave.

Drip pools found in caves can be classified as one type of cave community. Often these drip pools contain endemic species. In many cases these species' true home is the epikarst found above the cave, but from time to time these species fall or "drip" from the epikarst into drip pools in the cave proper. In this example of a cave community, nutrients (and contaminants) and water move into the cave from the surface, through the epikarst.

A "threats assessment table" can then be constructed to determine: (1) what are the

Cave Drip Pool/Epikarstic Community



More Important: Protect area directly above cave, and epikarstic waters.

Less Important: Watershed or entrance to cave.

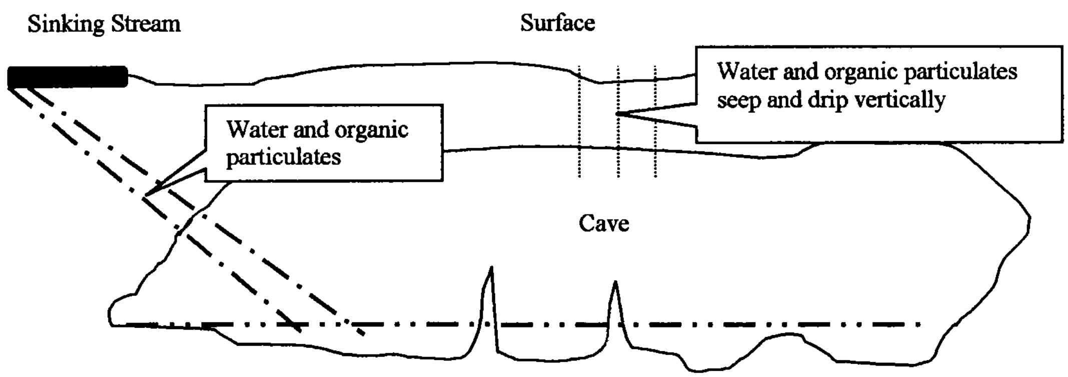
Priority System in Community: Soil column directly above cave, and drip pools in cave.

stresses to this drip pool community; and (2) what are the sources of these stresses. This table can assist in identifying actions that would need to be accomplished in order to protect the drip pool community. In the following table L = perceived Low Threat, M = perceived Medium Threat, H = perceived High Threat. Each threat level can be given a numerical value (L = 1, M = 2, H = 3), so that each stress can be averaged and prioritized.

Threats Assessment Table

	STRESS					
		Alteration of Water Flow	Alteration of Organic Matter (+ or -)	Degradation of Water Quality	Physical Destruction of Cave Habitat	
	Overall Rank					
SOURCE						
Poor Silvacultural Logging Practices		M	M	M		
Roads		H	M	M	H	
Residential Development		H	L	M		
Quarrying		M	L	L	H	
Recreational Caving			L	L	M	
Poor Agricultural Practices		L	M	M		

Cave Stream Community



More Important: Protection of watershed and area directly above cave. Requires surface and upstream protection. Delineation of subsurface karst basin needed to fully protect this cave community type.

Less Important: Entrance to cave.

Priority System in Community: Stream in cave.

In this community, the most important conservation target is the soil and surface directly above the cave. Having a good map of the cave and how it relates to the surface will be important for planning. Because the animals found in this community are transitory in nature, inventory and monitoring should be done more often than with other cave communities. Fauna distribution is very patchy in this community. Sampling of the epikarstic water should be attempted. Recreational caving such as crawling through, or stepping in, drip pools can have catastrophic effects on this community. Any change in water flow through the soil, or in water quality in the soil, will affect the drip pools. Note that large purchases of land in the cave watershed, or even controlling the entrance, may not be critical for *this particular community type.* However, if activies such as recreational caving are determined to be a major source of stress, then control of the cave entrance may be important to control access.

Another type of cave community is driven by nutrients and water coming directly from surface flow. In this cave stream community, the targets of concern may include cave fish, crayfish, salamanders, and other species dependent on the stream to bring water and nutrients into the cave.

Again, a threats assessment table can be created to organize and analyze the threats to the cave system. Information about the specific cave and its location will be important in determining the stresses and sources of these stresses, and will not be the same for every situation.

Threats Assessment Table

	STRESS					
		Alteration of Water Flow	Alteration of Organic Matter + or -	Degradation of Water Quality	Physical Destruction of Cave Habitat	
	Overall Rank					
SOURCE						
Poor Silvacultural Logging Practices		M	H	M		
Roads		H	M	M	H	
Residential Development		M	+ Septic H	M		
Quarrying		H	L	L	H	
Poor Agricultural Practices		L	H	H		

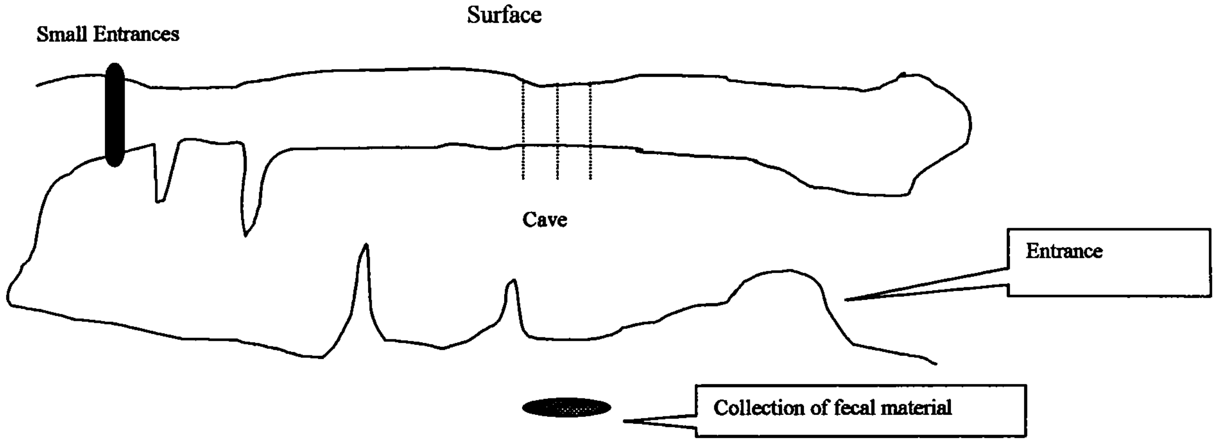
An increase in nutrients can cause an invasion of non-cave species, because cave-adapted species are usually adapted only to low nutrient levels. Logging and farming practices can cause increases in nutrients, thus allowing colonization by non-cave organisms. However, development, especially paving large areas, can cause a decrease in the nutrients reaching the cave system, which may cause the die-off of the indigenous cave organisms.

Degradation of water quality could include: decreases in dissolved oxygen; siltation; and pollution by metals, sewerage, or other industrial contaminants. This differs from alteration of organic matter within the cave. Degradation of water quality introduces toxics into the cave system.

If a cave stream community becomes a conservation priority, much more planning, analysis of the entire watershed, and money may be needed to protect the waters flowing into the cave. The actual entrance to the cave may play little or no importance to preserving the stream community.

A third example demonstrates how a cave entrance may be of importance in karst protection. In some cave systems, the major way that nutrients are introduced into the cave is by animals, such as bats, woodrats, and raccoons, or smaller species such as spiders and crickets. Their input of dung and food matter may play the major ecological role in the cave. This type of cave community, known as a transitory organic matter community, is dependent on animal imputs of nutrients.This community is quite different from those which use water flow or drip to introduce organics. In the transitory organic matter community, the cave entrance may be of critical concern.

Transitory Organic Matter Community



More Important: Protection of foraging areas around cave entrances, and entrances.

Less Important: Watershed

Priority System in Community: Animal movements through entrances which bring food inputs (fecal material and other organics) into cave.

Threats Assessment Table

	STRESS					
		Woodrat Decline	Alteration of Organic Matter (destruction of entrance area buffer forest)	Bat Decline	Physical Destruction of Cave Habitat	
	Overall Rank					
SOURCE						
Poor Silvicultural Logging Practices		M	H	M		
Roads		H	M	M	H	
Residential Development		H	L	M		
Quarrying		L	L	L	H	
Poor Cave Gate Construction		L	H	H	L	

	STRESS					
		Woodrat Decline	Alteration of Organic Matter (destruction of entrance area buffer forest)	Bat Decline	Physical Destruction of Cave Habitat	
	Overall Rank					
SOURCE						
Increased Raccoon Populations						
Poor Agricultural Practices		L	L	H		

In this community, the most important process is the flow of nutrients into the cave throught the cave entrance. Bats, woodrats, and cave crickets are three main transporters of nutrients into the cave. All three of these species need an undisturbed foraging area outside the entrance in which to feed. Woodrats and crickets are most impacted by logging or construction near the entrance. Bats are most impacted by an improperly installed bat gate.Thus, the conservation action for this cave community may include purchase of a larger buffer area around the cave entrance. Purchase of lands in the cave watershed may have little impact on this non-waterflow dependent community, unless the land is directly around the entrances.

Each of these threats tables can then be converted into a more visual model. Figure 1 displays a visual threat assessment for the Transitory Organic Matter Cave Community.

This more visual model may be of assistance in organizing how stresses and sources of stresses interact with the cave community. Once conservation threats are organized in this manner, specific actions can then be taken to alleviate the sources of stress. Success can be measured by how well the sources of stresses are eliminated.

Discussion

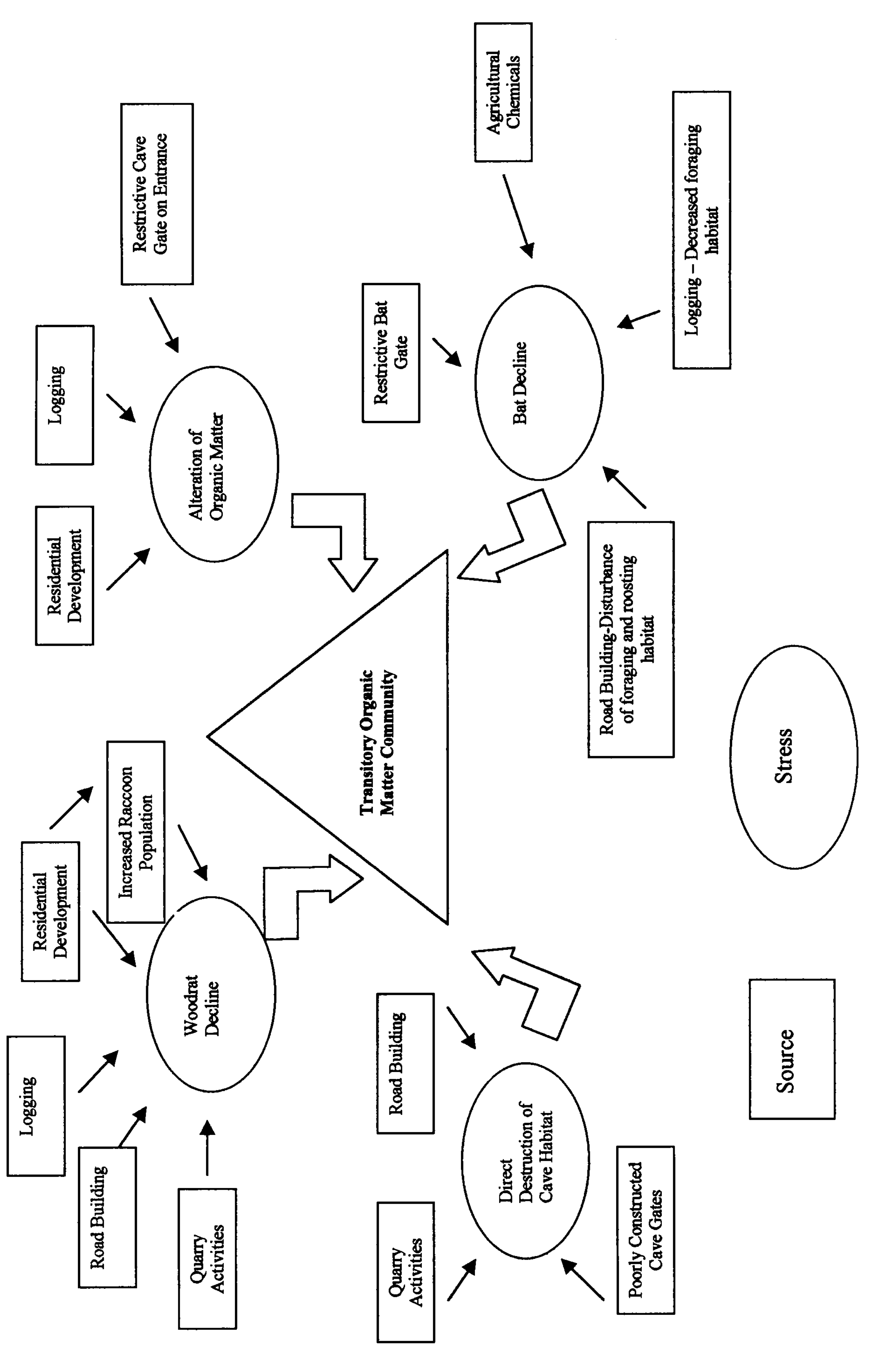
For effective cave conservation, identifying the intended targets to be protected is the first and most important step. The actions taken may be different depending on what targets are picked. Financial resources may be wasted if intended targets are not accurately identified.

In the drip pool community, the targets depend on the epikarst and soil directly above the cave. The entrance and surrounding land and watershed may play little role in the conservation of species living in the drip pool However, the area directly above the cave may be of critical importance. Logging, housing developments, and agriculture may have little impact to this cave; however, structures built over the cave or activites directly above the cave may have a major impact. Large amounts of financial resources may be spent on protecting the watershed when in fact only the land directly above the cave needs to be protected.

Other cave communities may need a much greater amount of research and/or finanical resources. A cave stream community may need dye tracing research to define the boundary of the watershed. Then a plan for protecting the watershed will need to be synthesized. This watershed protection may employ many protection tools, including outreach and education, registry, easements, and fee ownership.

Often, more than one cave community may be found within a cave. For example, organisms found in a drip pool may be protected by just protecting the area directly above a cave. A well meaning cave manager may gate the entrance of the cave to help protect the elements in the drip pool. However, there may be other communites in the cave that could be harmed by blocking the entrance. If there is a transitory organic matter community, dependent upon animals bringing organics into the cave system, blocking the entrance may have critical effects on that community. Therefore, careful identification of all communities within the cave system is of critical importance, so that actions taken to protect the community do not inadvertaintly cause harm to another.

Figure 1. Visual Threat Assessment for Transitory Organic Matter Cave Community



Summary

Site Conservation Planning can be a useful tool for planning and implementing conservation at a cave site. These are the steps that can be helpful in undertaking cave conservation:

- Identify the conservation targets in the cave system. These targets may be specific species or actual cave communities.
- When the targets are species, try to place the targets into a cave community type. Determining how water and nutrients move through the cave can be helpful in defining the cave community.
- Define the known and/or perceived threats and stresses to the cave community and its inhabitants.
- Define the sources of the stresses.
- Prioritize the degree of threat that each stress and stress source has on the community.
- Create specific action plans that will reduce the sources of the stress.
- Reassess the actions on a regular basis to determine how well the sources of stress are being reduced or eliminated.

By using these steps, cave land trusts and cave managers can more effectively plan conservation measures that will have direct positive impact on their sites, insure that money is spent judiciously, and be able to measure their success by tracking how well actions reduce sources of stress. One-solution-fits-all does not work in cave conservation, and spending time planning and researching the specific site will greatly increase the likelihood of ultimate success.

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History and Current Status of the Hart's-Tongue Fern in the South

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Abstract

Long considered one of the rarest ferns in North America, the Hart's Tongue was listed by the U.S. Fish and Wildlife Service in 1989 as both endangered and threatened. The fern was found growing in Tennessee in 1849 and growing in Alabama in 1978. The Tennessee populations seem to be gone and one of the two populations in Alabama appears healthy. Both Alabama locations are protected in that the pits are closed by the landowners and vertical rope skills are required to access the ferns.

Hart's-Tongue fern, *Phyllitis Scolopendrium, Asplenium scolopendrium* var. Americanum

Hart's tongue fern is one of the 26 species of ferns listed as endangered by the U.S. Fish and Wildlife Service. Two of the ferns on this list are also listed as threatened, the hart's tongue fern and the Alabama streak sorus fern. Both of these ferns are found in Alabama. The streak sorus only grows on a short stretch of the Sispy River in Bankhead National Forest.

Long known as one of the rarest ferns in North America, the hart's tongue has been reported from New Brunswick, Ontario, New York, Michigan, Tennessee, and Alabama.

The Hart's Tongue was first found in central New York in 1805-1807 and about 92% of the existing plants (3,500) still grow there.

In 1849 it was reported in Roan County, Tennessee, southwest of Knoxville, growing in a cave entrance. However by 1900 the entire population was gone, probably collected.

In 1878 it was found growing in a limestone sink in Marion County near South Pittsburg, there were hundreds there.

In 1898 it was reported as 200 plants there.

In 1900 the count was 110 plants.

In 1911 the count was down to 58.

Between 1911 and 1929 the south slope of the sink caved in.

In 1929 there were only six plants left and spores from plants in Ontario, Canada, were scattered in the sink.

In 1933 the count was five plants.

In 1935 the count was 26 plants with four mature plants and the other 21 theorized to be from the 1929 spores.

In 1981, when Dr A. Murrary Evans inventoried the plants there were, 17.

In 1998 when I first checked the location there were only three plants, one on the north wall which appeared to be a tiny mature plant, probably the European version, and one on the east side of the sink and one on the north side of the sink, both of these last two had only two leaves each and the fronds were only about an inch to inch and a half long.

At the time the sink was grown over with vegetation and the light level measured at the two smallest plants was only three to four foot candles.

On June 15 1998 there was a major event of Hall/Torosion on the vegetation over hanging the 40 foot sink and the light levels are now 12 to 150 foot candles for the plants which is in line with the light levels at the two known Alabama locations.

In September 1999 I visited the location and found that the east side plant was no longer there and the small plant on the south side looked the same as when I first saw it.(two fronds and 1 to 1.5 inches long.)

The plant on the north wall still appears to be a mature plant with five fronds from about three to four inches long. (Figure 1)

Figure 1

The soil chemistry has been checked and compares to the chemistry of the soil from the Alabama locations. The light levels have been adjusted. It's unknown why the existing plants don't thrive, the environment is very similar to the Alabama location where the fern is growing very well.

This location is on privately owned land and is a 40-foot pit which requires vertical rope work to access the ferns growing on a ledge about 30 feet down. A stream from a spring falls into the west side.

In October 1978 John Short reported the hart's tongue in a sink in Jackson County, Alabama. There were 20 plants with 8 adult plants.

In 1997, when I visited the Jackson County location, there were only two mature plants left. At this time we installed a U.S. Fish and Wildlife Service data logger by the plants to record light level, soil moisture, air temperature, and soil temperature. (Figure 2)

Figure 2

Periodic visits are still being made to this site to offload data from the data logger. The plants generate plenty of spores, which are released in the fall each year, but no new plants occur. In August 1998 I placed several plant starter trays in the vicinity of the two plants to capture spores.

In September 1999 I took the contents of two of the trays and introduced them to the soil around the plants and brought the other two trays home to observe.

This location is in Wheeler Wildlife Refuge and is protected. There is no on-site control but a permit is required to visit the location and it is closed from September to May to protect the grey bats. This location is at the bottom of a 50-foot sink and a handline is needed to access the ferns. This is the only southern location without an in-flowing stream.

In 1979 the hart's tongue was discovered in a sink in Morgan County, Alabama. In May 1980 John Short visited the location and recorded 53 plants with 20 adult plants and others from sporelings to almost adults. In 1997 there was a major rain and the stream into the pit washed away lots of soil from the ledge and left only 20 plants. By 1998 the fern had recovered so there were 150+ plants growing on the ledge. In 1998 a data logger was installed to monitor the environment. In September 1999 I counted 50+ plants with about one half of them mature plants. I have also had plant starter trays around the ferns for over a year. (Figure 3)

Figure 3

This location is privately owned and the landowner has closed the pit to everyone but allows us to access the data logger. This is an 80-foot pit with the ferns growing on a ledge 30 feet down and vertical rope skills are required to access the ferns. There is an inflowing stream.

In summary there are three locations for the hart's tongue in the south, the Marion County, Tennessee, location where the fern is barely hanging on and appears to be the European version; The Jackson County, Alabama, location with only two mature plants left that generate plenty of spores each year but no new plants occur; and the Morgan County, Alabama, location with a very healthy population that has shown it can recover after a disaster.

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Living with Pseudokarst

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Abstract

Urbanization is rapidly increasing in some sparsely inhabited "substandard" subdivisions on Hawaiian pseudokarst. Because of conduit flow of groundwater in lava tubes and lava tube caves, an increasing threat of contamination and pollution exists. Yet conduit flow of water in such pseudokarsts is omitted from conceptual diagrams and models of local hydrology and dye tracing is an alien concept.

The extent of the problem in Hawaii is unknown. In Terceira (Azores, Portugal) much of the water supply of a sizeable town is obtained from conduit flow through a lava tube cave; municipal water works have been constructed in the cave. A "boiling" freshwater spring in the harbor of Hilo, Hawaii, is among several phenomena suggesting similar flow. Some Hawaiian lava tube caves contain still-water clay deposits; others have sorted to unsorted heterogenous streamfill. Thus, both steady state and flood pulse flow must be considered.

Kaumana Cave is suggested as a model site for study. It contains garbage dumps including automotive wastes and pesticide containers in an area that periodically floods to the ceiling. The resurgence of its floodwaters is unknown, and input and output through various feeder cracks is highly dependent on volume of rainfall. A piping conduit may exist beneath the cave.

Introduction

Public health aspects of groundwater flow in karstic conduits are a common topic at national cave and karst management symposia. Recent investigations in Hawaii and elsewhere indicate that conduit groundwater flow in volcanic pseudokarsts is a cause for similar concern. This is contrary to conventional wisdom, that is, that the flow of lava tube caves is flowing lava, not flowing water (Halliday, accepted for publication). Even a notably authoritative recent overview of groundwater tracer dyes merely commented that "dye transport has apparently occurred both through fractures and through paleosoil zones (in basaltic lava flows)" (Aley, 1997).

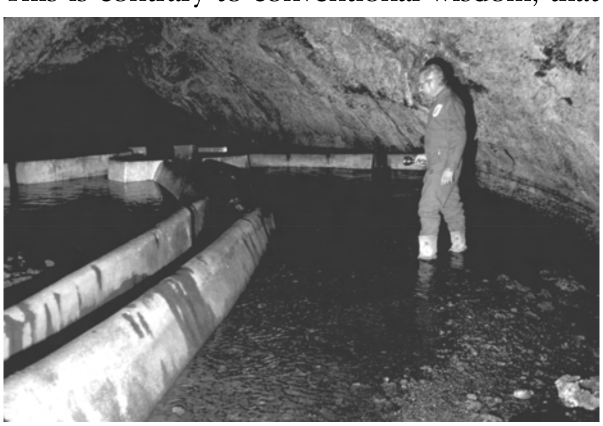

Figure 1. Municipal waterworks in a lava tube cave on Terceira, Azores. Photo by author.

This mindset has been universal, however. Long ago, the noted geologist James A. Dana noted the essential nature of volcanic pseudokarst, with water "to be found only in caves" (Dana, 1849). Decades ago on the island of Terceira (Azores, Portugal), municipal waterworks were constructed in a lava tube stream cave which drains a small caldera (Figure 1). In Mauritius, "Womens' Washing Cave" is at the downslope end of a pseudokarstic window. In both Utah and Hawaii, local ranchers have dammed streams in lava tube caves for domestic and livestock use.

Stream Downcutting Into Lava Tube Caves

Only a moment's reflection is needed to recognize that ordinary stream downcutting across the course of a lava tube cave will channel streamflow into the cave it intersects. Further, that the tubular downslope pattern characteristic of lava tube caves may be even more conductive to conduit flow of water than that of karstic caves.

In volcanic pseudokarsts, surface streams tend to sink into cracks before they have an opportunity to cut down into lava tube caves but increasing numbers of examples of downcutting piracy into lava tube caves now are on record. Perhaps the most spectacular is in the headwaters of the Rogue River, Oregon, USA (Figure 2). In Hawaii, the upper level of well-known Turtle Cave (Kau District, Hawaii County) is truncated by downcutting by a stream which crossed it diagonally. Its lower level contains extensively sorted deposits of a typical turbulent stream.

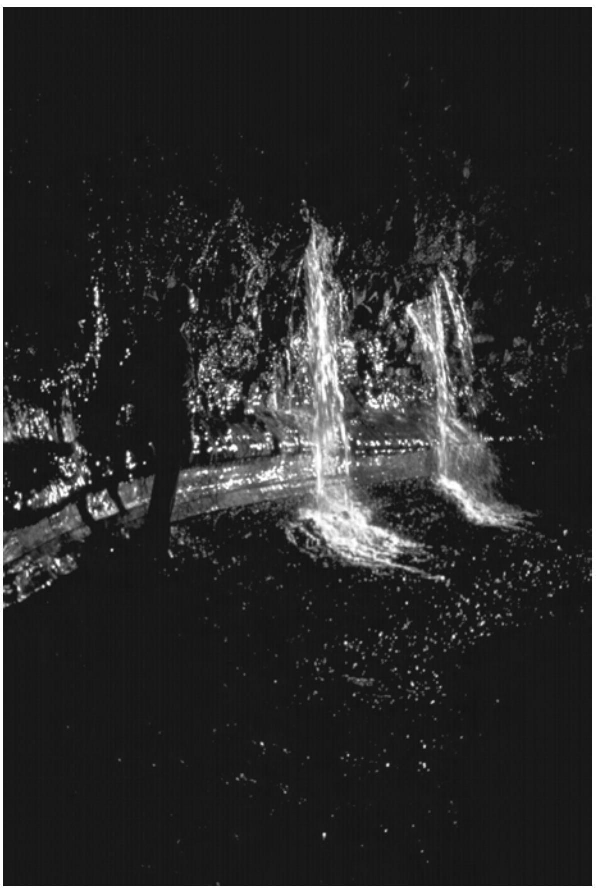

Figure 2. Piracy by downcutting of the Rogue River into a lava tube cave, Oregon, USA. Photo by author.

Downslope Lava Tube Swallets

Numerous other lava tube caves in Hawaii, Korea, and elsewhere contain sorted or unsorted stream or pond deposits resulting from surface water naturally channeled into a preexisting cave entrance. Some of these have been incised subsequently by downcutting within the cave. Near Hilo, Hawaii, Pukamaui is a lava tube cave opening on the bank of the Wailuku River on the northeast edge of a very large pseudokarstic complex. Until it was walled up, this cave periodically captured much of the water supply of Hilo (Stearns and Macdonald, 1946). The lower kilometer of Ape Cave, Mount Saint Helens, Washington, USA, contains two successive tephra "mudflow" deposits from an eruption about 1,800 years before present; each is about one meter thick. Nearby, some smaller caves carry snow runoff. A few served as conduits for tephra "mudflows" after the 1980 eruptions and at least one "mud resurgence" was observed.

Hawaiian Pseudokarsts and Their Significance

More than 9,000 square kilometers of "the Big Island" of Hawaii consists of a complex of volcanic pseudokarsts. One consists largely of the Ailaau Flow Field of Kilauea Volcano, mostly 300 to 500 years old. It contains Kazumura Cave (the world's longest known lava tube cave) and many others. In this large pseudokarst, a total of about 100 kilometers of cave passages has been mapped to date, with much remaining. It is generally considered the world's leading area for the study of lava tube caves. Other speleoiferous pseudokarsts exist on Mauna Loa and other volcanos throughout Hawaii. On the islands of Mau and Oahu, tunnels drilled to tap perched bodies of water incidentally intersected lava tube caves with running streams at considerable depth.

The Ailaau Flow Field Pseudokarst is close to the city of Hilo, and is the location of increasingly populated "substandard" subdivisions, which lack city water, sewers, and other normal infrastructure. Some wells exist, but most homes depend on rooftop water catchment. Many homes lack even septic tank disposal, with pipes conducting raw sewage directly into cracks and lava tube caves. An even denser population with a more fully developed infrastructure lives atop a narrow tongue of pseudokarst funneling downslope into the city of Hilo from the northeast side of Mauna Loa volcano.

The most recent flow here (containing Kaumana and some smaller caves) was in 1881. Nearby caves in older flows are know to extend down to sea level in Hilo. So do other caves in the town of Kailua-Kona on the other side of the island.

Figure 3. Garbage dump in Kaumana Cave, Hawaii. Photo by author.

Unlawful Disposal in Hawaiian Lava Tube Caves

Large dumps of unlawful waste exist in Kazumura Cave, Kaumana Cave, Lower Uilani Cave, and others throughout Hawaii. Automobile wastes are especially conspicuous, but partially emptied pesticide cans and medical wastes also have been identified. The garbage dumps in Kaumana Cave are especially troubling. Multiple dumpsites containing pesticide cans and medical wastes are present in a section which floods to the ceiling, and floodwaters have distributed some of the waste downflow. Further, raw sewage has been reported in a remoter section of the cave beneath Kaumana Village (an up-slope suburb of Hilo), as in several other "Big Island" lava tube caves. During extreme flood pulses, groundwater bursts from the lower entrance of this cave and invades a subdivision built atop what was once the lower 500 meters of the cave. At other times, the resurgence of its floodwaters is unknown.

Basic Hydrogeology of Hawaii Island Pseudokarsts

Several recent investigations indicate that the volcanic pseudokarst of Hawaii diverge considerably from the traditional Ghyben-Herzberg freshwater lens concept (Izuka and Gingerich, 1998; Fischer *et al.*, 1966; George Wilkins, quoted in Hastings, 1989; Smith, 1999; Doty, 1980 *et al.*). Where no conduit exists, the porosity of various volcanic beds results in considerable compliance with this model. Several types of impervious structures, however, form local barriers to groundwater flow, both horizontally and vertically. Especially important horizontal barriers are dense, unfractured expanses of pahoehoe basalt with effects somewhat comparable to those of chert, shale, and sandstone layers in limestones. As for vertical or steeply tilted barriers, more or less impermeable dikes trap discrete bodies of meteoric water on the flanks of various volcanos. All these structures are unrelated to conduit flow unless piping has occurred long the upper surface of dense pahoehoe basalt. The islands are tectonically and isostatically active, however. Cracks up to one or two meters wide are locally very important in directing and expediting underground flow at velocities approaching those of conduit flow. Comparatively small tectonic cracks serve as feeders and drains for streams in lava tubes.

Further complexity in groundwater flow on the Big Island is evidenced by two major confined aquifers of considerable thickness. Both conduct large volumes of rainfall from points high on Mauna Loa volcano. They extend downslope beneath Hilo and some of its southern suburbs to deep, ill-defined submarine resurgences. The lowermost was discovered only recently, at a depth of nearly 300 meters. When it was intersected by a test well, hydrostatic pressure caused an artesian flow of 10,000 liters/minute (Smith, 1999). The degree of missing of groundwater carried in lava tube conduits with these deep aquifers is unknown.

Basal springs of Hawaii Island especially diverge from the simple Ghyben-Herzberg lens model. Instead of diffuse resurgence at sea level, bubbling springs are numerous (Stearns and Macdonald, 1946). Many discrete freshwater plumes extend seaward atop the ocean, as far as 400 meters (Fischer *et al.*, 1966). Some comparatively small plumes are approximately aligned with Kaumana Cave, but much larger resurgences exist about one kilometer farther south, in the Waiakea Pond-Wailoa Stream complex. This complex discharges approximately 500 million liters/day into one section of Hilo Bay—a first magnitude spring. In its outer channel is a large upwelling "boil" of water, which appears to emerge from the mouth of a conduit of some type. Also impressive is Ninole Springs at Punaluu, downslope from a speleoliferous pseudokarst of Mauna Loa volcano. This spring complex is estimated to have a discharge of 60 to 75 million liters/day (Martin and Pierce, 1919). Here, the largest springs emerge from lava tubes (Stearns and Clark, 1930; Stearns and Macdonald, 1946). At sea level, discharges downslope from the Ailaau pseudokarst, volumetric estimates are more difficult, but large volumes clearly resurge here also. It is surprising that conceptual diagrams and models of regional hydrogeology omit lava tube and other conduit forms of groundwater flow. References to dye tracing here apparently are nonexistent.

Hydrology of Kaumana Cave

Kaumana Cave is an extensive, largely unitary lava tube cave located on a moderate slope in the upland suburbs of Hilo. About 2,200 meters have been mapped to date. An additional 500-meter section is known to have been destroyed by subdivision construction downslope from Edita Street. Considerably more cave exists upslope from the mapped section, partly underlying Kaumana Village. Raw sewage has been reported entering this section of the cave. Much as in the case of dendritic karstic cave systems, still farther upslope is a recharge area, typical in the ohia rainforest at this elevation (Doty, 1980). In the upper end of the mapped section, floatable debris is stuck to the ceiling, indicating extensive flooding of this part of the cave. In a roomier area just downslope from this area, running water often is heard just beneath the apparent floor of the cave. A piping cave like Christmas Canyon Cave, Mount Saint Helens, Washington may exist here.

During heavy rainfall (10 to 12 centimeter/day for three days) several small waterfalls jet out into the cave passage two to three meters above the floor. They are located a few hundred feet downslope from the section which floods completely. They spurt into the cave through cracks in its accreted lining, and appear to emerge from a perched aquifer incised by the lava flow containing the cave. They form a shallow stream which flows downslope for about 300 meters, passing beneath the main entrance sink through a lower level passage formed by a secondary ceiling. Its flow is augmented by smaller insurgences through other cracks, near floor level. Loss into other cracks diminishes its volume and, except during maximum flood pulses, it finally disappears into the cave's floor. Similar augmentation and loss through tectonic cracks have been observed and photographed in Mauritius and in Utah. Except for the maximum flood pulses mentioned above, resurgences of this stream are unknown.

Figure 4. Waterfalls, Kaumana Cave, Hawaii. Photo by author.

Significance of Conduit Flow in Hawaiian Lava Tube Caves

In the drier parts of Hawaii Island, conduit flow in lava tube caves some day may provide significant municipal or agricultural supplies of water. Deep confined acquifers, however, currently appear more promising for these. The present focus, therefore, is on public health aspects of conduit flow—just as in the case of similar flow in karsts.

It thus is obvious that unlawful disposal sites and raw sewage are potential threats to ground water quality in parts of Hawaii Island. Also it is obvious that these threats will increase with increasing population density in certain pseudokarstic areas unless present practices are altered drastically. But it is not certain that these practices are actually causing unacceptable harm to Big Island residents. Nor is it certain that even today's uncontrolled population growth will inevitably impact groundwater quality to an unacceptable level. The dilution fact in the Ailaau pseudokarst and the Mauna Loa deep aquifers is enormous. Admittedly, Hilo Bay is polluted, and swimming is discouraged. Where swimming is common in other freshwater plumes such as Ninole Springs, there are anecdotal reports of a high incidence of otitis externa and its complications. But the incidence of leptospirosis actually seems to be lower from well water than from rooftop catchment. Perhaps it is fortunate, however, that the apparent drainage of the Aillaau pseudokarst is to a section of coast unsuitable for swimming and lacking in wells.

Management of Conduit Flow in Big Island Pseudokarsts

The usual laws for the protection of groundwater exist in Hawaii, but the General Plan for Hawaii County (1990) does not include protection of groundwater (nor caves) and these laws are generally unenforced.

The Hawaii Chapter of the National Speleological Society has proposed two approaches to this problem. On one hand, it has proposed a series of new provisions in the 2000-2009 General Plan. These new sections would provide a priority for protection of caves, pseudokarst, and groundwater, with zero tolerance of raw sewage and toxic and hazardous wastes. Further, it has proposed a conference to bring together human resources in the relevant fields to clarify actual threats to public health and to recommend solutions.

In September 1999 the Commission on Volcanic Caves of the International Union of Speleology commended the Hawaii Chapter for its leadership in this important area.

Conclusions

Conduit flow of water in some volcanic pseudokarsts differs only quantitatively from that in karstic terrains and has the same public health implications. Studies of types long established in karstic terrain need to be implemented in large areas of Hawaii. Both steady state and flood pulse flow must be considered. Titles of symposia on management of caves and karst should be expanded to include this additional area of concern.

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Cave Restoration and Conservation: Topics, Methods, and Discussion

Val Hildreth-Werker and Jim C. Werker
National Speleological Society

Abstract

From prevention of cave damage to formation repair, we will cover low-impact strategies and proven techniques for cave conservation and restoration. An interactive format for discussing methods and concerns will begin with a five-minute slide show to summarize issues and stimulate discourse. Ample time will be allowed for questions and open discussion. Topics will include cave-safe materials, trail marking, erasing footprints, cave-safe graffiti removal, Leave No Trace ethics, new techniques in speleothem cleaning, gypsum cleaning, formation repair, and preserving microbes. We will emphasize ethics used in various parts of the country for different cave systems. We are actively identifying methods to lessen caver impact, preserve natural features, avoid contamination, and minimize disturbance of cave biota. Jim and Val are editing work for a book, *On Cave Conservation and Restoration*, to be published by the NSS in 2000. Pre-publication order information will be available during the symposium.

Cave Softly . . . and Leave No Trace

Val Hildreth-Werker and Jim C. Werker
NSS Resource Protection and Preservation
The Guadalupe Ranger District of the Lincoln National Forest

Poster Session

The Guadalupe caves of southeastern New Mexico are featured in this museum-quality display. For the joint Forest Service/NSS project, we coordinated educational conservation add-on pieces for the existing Guadalupe exhibit. Visitor impacts and restoration efforts in undeveloped caves are illustrated. Emphasizing the ethic of cave softly . . . and leave no trace, the caption on each conservation board describes an aspect of destruction along with the restoration efforts required to repair or remediate the damage.

Formation Repair Techniques

Val Hildreth-Werker and Jim C. Werker
National Speleological Society

Poster Session

An automated slide show will give updated information on methods and materials for cave-safe formation repair. Proven techniques for repairing and reconstructing stalagmites, stalactites, draperies, rimstone dams, gypsum crust, soda straws, helictites, and the like will be presented. Technical information on epoxies and stainless steel pins is included. Information packets will be available on request.

Hot-Spots of Biodiversity and Management Issues for North American Cave-Adapted Fauna

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Abstract

Although many more species remain known but undescribed from caves and associated habitats in the contiguous United States, 973 species and subspecies formally have been described from these habitats (all data from published records and statewide lists of subterranean faunas) and compose the largest known subterranean fauna of any country in the world. Of this total, 673 are terrestrial (troglobites) and 300 are aquatic (stygobites). Arachnids, crustaceans, and insects dominate the biodiversity, with each contributing between 22% and 30% of the total species diversity. Approximately 20% of the land area of the 48 contiguous states is underlain by cave-bearing rocks and nearly 45,000 caves are known from 1,128 counties in 48 states, yet less than 17% of U.S. counties (513 of 3,112) have even one troglobite or stygobite. Troglobitic species are concentrated in northeast Alabama (particularly Jackson County) with other clusters in Kentucky, Texas, Virginia, and West Virginia. Only 23 counties account for over 50% of the terrestrial species and subspecies. Stygobitic species are concentrated in south central Texas (Hays County) with other agglomerations in Florida, Oklahoma, Texas, Virginia, and West Virginia. Only 18 counties account for over 50% of the aquatic species and subspecies. Over 60% of the entire obligate subterranean fauna are county endemics and about 300 of these also are single site endemics; less than 4% of these have federal status. This fauna is extremely vulnerable and their protection requires habitat preservation, including protection of the associated surface habitat.

Faunal Inventory of Georgia Caves

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Abstract

Georgia contains nearly 500 caves, mostly found in the northwestern and southwestern corners of the state. The faunal composition of most caves in the state is largely unknown. Charged with the protection, conservation, and management of all nongame wildlife in the state, the Georgia Department of Natural Resources' Nongame-Endangered Wildlife Program recently initiated a faunal inventory of these caves in hopes that a better understanding of their biota will help to properly guide conservation and management measures. Inventory methods consist mainly of hand collecting and baiting. Most invertebrate specimens are sent to appropriate experts for identification. Thus far, 25 caves have been surveyed. Despite only a modest number of sampled caves to date, many interesting finds have been made including the discovery of several undescribed species. We plan to present an overview of the project and elaborate on the early discoveries.

Misconceptions About Caves and Karst: Common Problems and Educational Solutions

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Abstract

Processes that have formed caves and karst and continue to operate in karst terranes are complex and not easily visualized by the public at large. This has resulted in several common and pervasive misconceptions about the intrinsic nature of karst. Unfortunately these misconceptions are all too often embraced by influential individuals, in both the public and private sectors, who have the authority and mandate to address and alleviate environmental and engineering problems occurring in karst terranes. An essential step in effective environmental management of karst regions is through education, whereby misconceptions are debunked and replaced with sound, clearly presented explanations of karst processes that address the origin of karstic landforms and networks of groundwater flow and that illuminate the interaction between natural processes and human activity. Eliminating misconceptions and teaching well established, modern concepts in a clear and concise manner could considerably reduce environmental problems in this fragile landscape.

Some common misconceptions about karst are: (1) Bedrock is solid, without voids; (2) Water enters sinkholes because they are there, rather than water creates sinkholes; (3) Pollutants put into the ground in karst remain where they are placed; (4) Water from karst springs is pure; (5) All sinkholes form catastrophically; (6) Karst is always well expressed on the surface; (7) Caves form by erosion; (8) Caves are as old as the rocks they are in; (9) Groundwater flow in karst is simple and direct; and (10) A lack of known caves suggests little or no development of karst. Each of these flawed views can be easily rectified through timely education.

Introduction

Karst terranes are inherently very sensitive to environmental stresses and far surpass many other landscapes and geologic settings in this regard. Environmental problems in regions of karst are increasing in both aerial extent and intensity, especially in localities where land use is rapidly changing as relatively undisturbed land is undergoing economic development. This is particularly evident in areas experiencing urbanization, an inevitable result of population growth and concomitant increases in residential, commercial, industrial, and agricultural activity. Progressive degradation of natural environments proceeds as increasing numbers of buildings, parking lots, and other structures are built and as various transportation and utility corridors are extended. The impact of this activity on karst is often severe

(Kastning, 1989, 1995, 1996). Environmental problems in karst typically include (1) instability and collapse of the ground surface, (2) erosion or sedimentation of sinkholes, (3) flooding of sinkholes, (4) contamination of groundwater, and (5) destruction or alteration of spelean environments. Because human activity in karst terranes may easily impact the subsurface in various ways, caves are particularly at risk. Problems include disruption of ecosystems or damage to the contents of caves, such as aesthetic deposits of minerals or archaeological and historic materials. The reader may readily find information on environmental impacts on caves and karst in various sources (Aley, 1972; Aley and others, 1972; Dougherty, 1983; Kastning and Kastning 1991, 1993; LeGrand, 1973; Slifer and Erchul, 1989; White, 1988; Zokaites, 1997).

Examples of environmental problems in karst are well documented in the literature, including proceedings volumes of the 13 preceding National Cave Management Symposia and proceedings of numerous geotechnical conferences on this subject (Kastning, 1994). As a means of alleviating environmental stress in karst lands, a trend in recent years is to produce informative booklets, brochures, maps, and posters on karst for distribution to schools, libraries, museums, and similar institutions (Hubbard, 1989; Kastning and Kastning, 1990, 1992, 1995; Zokaites, 1997). These are also being provided to landowners and governmental officials in communities underlain by soluble rock.

There is a pervasive lack of understanding among people living in karst regions about the intrinsic nature of this type of terrane and the characteristic processes that have formed it and continue to operate. Unfortunately, this unfamiliarity also extends to many individuals who have the authority and mandate to address and alleviate environmental and engineering problems that arise from changes in land use. Even more disconcerting than this large information gap is the prevalence of wrong information about caves and karst that is assumed by the public or is promulgated through spoken or written contact or through lay and media publications (newspapers, magazines, brochures, advertisements, and the like).

A Working Definition of Karst

Although the term "karst" is being used more and more by the press and is appearing in publications and documents from time to time, the meaning of the term is not always an easy one to convey to a lay person. The definition is somewhat convoluted and, when stated, usually needs to be embellished with examples. Specific wordings defining karst have been published in various speleological and geological lexicons (*see* listing of karst glossaries in Kastning, 1994). The glossary of karst terminology compiled by Monroe (1970) is recommended for those who desire a fairly complete guide to the many karst terms used by specialists.

An essential first step in effective management of karst terrane is to define karst. In very simple terms, the following working, one-sentence definition has been found to suffice: *Karst is a landscape that is principally formed by the dissolving of bedrock.* For clarity, it is useful to add that karst is characterized by sinkholes, caves, dry valleys (little or no surficial drainage), sinking streams, springs and seeps, solution valleys, and various forms that are sculpted on the bedrock surface (collectively known as *karren*). Hydrologically, groundwater in karst terranes flows efficiently through openings in the bedrock that have been enlarged by the dissolution process. Surface water is rapidly conveyed underground at zones of *recharge* (typically where water enters sinkholes, soil, and vertical fractures in the bedrock) and then passes through a network of conduits (fractures, partings between beds of rock, and caves). The water eventually emerges at the surface in zones of *discharge* (springs, seeps, and wells). Karst forms in rocks that are soluble to various degrees when in contact with slightly acidic natural water. Commonly, the rocks that are most easily dissolved, and hence become karsted, are carbonate units, such as limestone and dolostone (sedimentary) and marble (metamorphic), and sulfate units such as gypsum (sedimentary). Nearly all rocks may be dissolved to some degree. Only minor solutional features develop in materials with very low solubility in water, such as granite, gneiss, and other silicate materials. In most cases, these features are insignificant in terms of hydrologic and environmental impact. Most significant areas of karst in the United States are found within outcrops of limestone, dolostone, marble, and gypsum.

The study of karst is a relatively new science that draws largely on the principles of geology and physical geography. A thorough professional understanding of the processes that occur both at the surface and in the underground and an appreciation for the total hydrologic system necessitates a familiarity with scientific karst studies. The level and scope of modern karst studies are demonstrated by the recent proliferation of textbooks on the subject (*see* *listing in* Kastning, 1994). Recent texts on karst and caves include those of Ford and Williams (1989), White (1988), and Klimchouk and others (2000). Additionally, the number of scientific journal articles and graduate theses on karst is expanding at a phenomenal rate.

Misconceptions About Karst

There are many common misconceptions regarding caves and karst. Over the years we have addressed several that have been particularly troublesome in the regions and local communities where we have worked on environmental problems. Moreover, misconceptions are innocently conveyed to visitors on tours at some show caves, although this problem is lessening as owners and managers of these attractions are themselves becoming more aware of the processes of karst and speleogenesis. We have previously addressed four of the most common misconceptions (Kastning and Kastning, 1994, 1997). In this paper we revisit these and include six others. The misconceptions discussed here are among the most prevalent and many of these are potentially troublesome in cave and karst management.

Misconception No. 1: Bedrock is solid, without voids. Rocks are viewed as strong, unyielding, and relatively inert materials that provide a stable foundation at the surface of the earth. This may be true of crystalline materials such as igneous and metamorphic rocks and hard, dense, insoluble sedimentary rocks. However, soluble rocks (such as limestone, dolostone, marble, and gypsum) may easily have been hollowed through dissolution by acidic groundwater. Pore spaces and fractures (representing primary and secondary porosity, respectively) may be enlarged in this way, resulting in conduits that become interconnected into extensive, well-integrated flow networks (Figure 1). Cavities excavated in this manner may vary greatly in size and extent, with some attaining large dimensions. Dissolutionally enlarged openings, in turn, may cause structural instability of the bedrock and provide avenues for rapid circulation of groundwater. *The presence of karst features on the surface is nearly always indicative of subsurficial openings and integrated groundwater flow paths.*

Misconception No. 2: Water enters sinkholes because they are there, rather than water creates sinkholes. Most people recognize that water enters sinkholes. After all, if a sinkhole is a closed depression on the surface, it will collect water from precipitation and run-

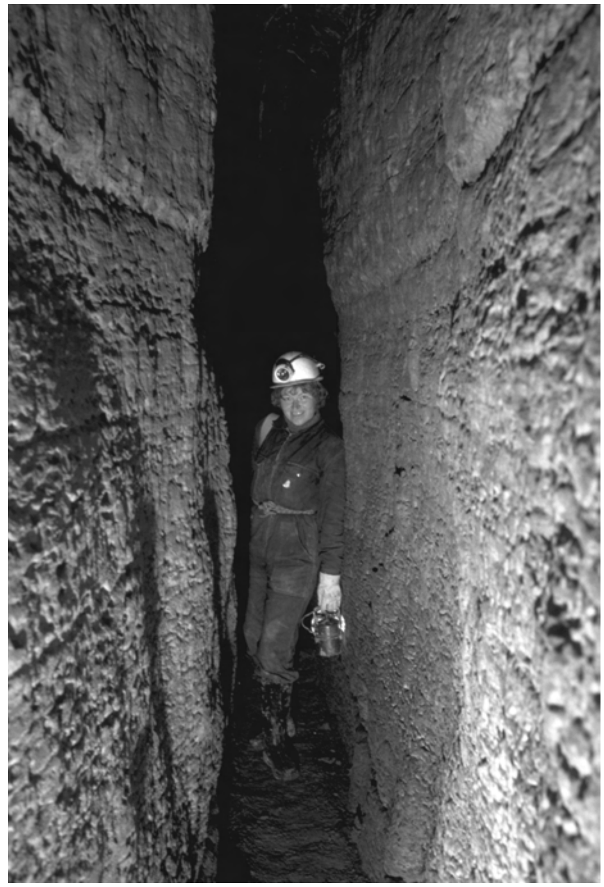

Figure 1. Cave passage in Mystery Cave, Mystery Cave State Park, Fillmore County, Minnesota. This passage has developed along one of many parallel joints. Note the prevalence of pore spaces and bedding-plane partings on the walls of this passage. The pores represent much of the porosity present at the time of deposition of the sediments (primary porosity). The joints were tectonically produced at a much later date and are part of the secondary porosity available to groundwater flow. Even later, groundwater flowing through both types of openings (primary and secondary) have dissolved the bedrock on the walls of the joints, enlarging the width of the joint and thereby allowing for more space for groundwater flow (tertiary porosity).

off. This water has nowhere to go except into the ground. Sinkholes are all too often viewed as pre-existing funnels that happen to channel and concentrate water that impinges on them. However, the relationship between surficial waters and sinkholes is generally the converse (Kastning, 1999): *sinkholes form and enlarge at places where surficial water can easily enter the ground, such as along enlarged fractures in soluble bedrock.* Infiltrating water has

Figure 2. Sinkhole and vertical-shaft entrance to Purgatory Pit, Rutland County, Vermont. This entrance consists of a series of offset shafts in marble that have formed along joint planes. The sinkhole-shaft complex formed in response to recharge entering fractures that extend downward from the surface. Even though many sinkholes presently receive surficial water from precipitation, most were created as water slowly percolated downward along enlarging openings.

formed the sinkholes, rather than pre-existing sinkholes merely providing convenient sites for recharge (Figure 2). Of course, once established, sinkholes may then concentrate water flow and continue to enlarge.

Misconception No. 3: Pollutants put into the ground in karst remain where they are placed. When compared with most other types of rock (sandstone, shale, and crystalline rocks, such as granite, gneiss, and the like), carbonate rocks and gypsum are highly porous and permeable. *Karsted rocks will not naturally filter contaminants to any appreciable extent.* Moreover, contaminants are easily and very rapidly transmitted to points of discharge, principally springs and wells. The residence time of chemical ingredients in karstic groundwater is relatively short in comparison to that in other rock terranes. Water issuing from the subsurface through springs and wells may easily be contaminated by toxic substances that are introduced in recharge zones. Waste placed in sinkhole dumps or "solid" landfill wastes will leach from these deposits and migrate with the groundwater (Figure 3). One of the most effective attention getters when explaining this phenomenon and its consequences to the public is to comment on how leachate from dead farm animals placed in sinkholes may appear in tap water in nearby homes. In karst, what goes into the ground may soon come out of the ground with little chemical change.

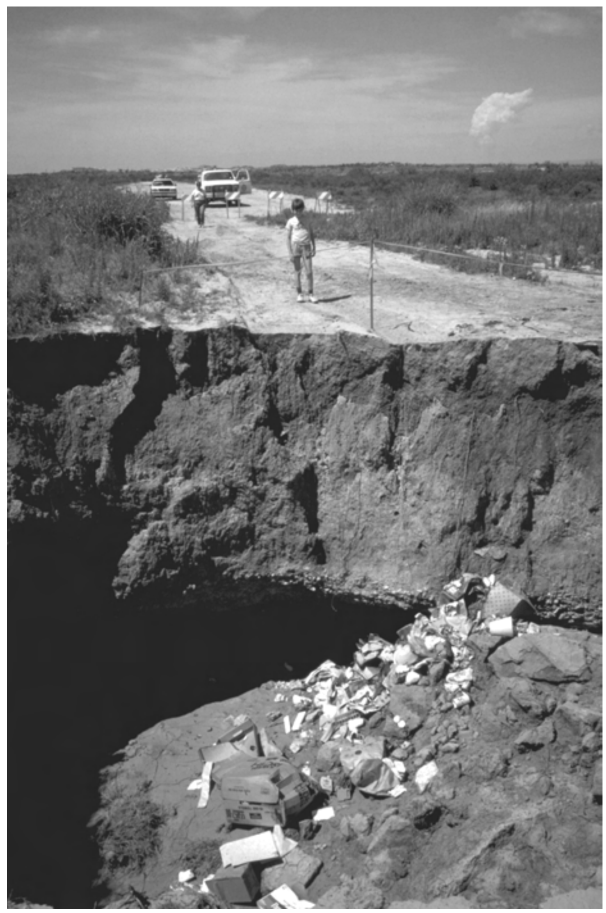

Figure 3. Household trash dumped into a sinkhole in gypsite terrane, near Carlsbad, Eddy County, New Mexico. This sinkhole formed just three days before this photograph was taken. In that short time, an individual found this sinkhole and disposed of trash. Chemical contaminants in trash are quickly transmitted into underlying aquifers and to local water supplies such as springs and wells.

Figure 4. Entrance to Donaldsons Cave, Spring Mill State Park, Lawrence County, Indiana. This a moderately large karst spring. Many springs in karst are used as water supplies. Despite public opinion that spring water is inherently pure, water issuing from karst springs has moved quickly through the aquifer, with little or no chemical change or filtration.

Misconception No. 4: Water from karst springs is pure. There is a general belief that water issuing from natural springs has been naturally purified and is thereby healthy to drink and use (Figure 4). This is exemplified by the popularity of bottled spring water. There are hundreds of brands of bottled spring water being sold in the United States today. Additionally, many people, including those living in karst areas, routinely obtain "potable" water from springs, assuming that water emanating from the ground must be clean. The fallacy that spring waters are inherently pure is obvious from the explanation in Misconception 3 above. *Groundwater in karst moves rapidly from points of recharge to points of discharge, with relatively little chemical change.*

Misconception No. 5: All sinkholes form catastrophically. Most people living on well developed karst may be able to recognize a sinkhole and be able to describe a sinkhole based on its geometric form and know that water enters the ground through sinkholes. *However,* most consider sinkholes to have formed through sudden collapse of the ground into pre-existing voids (caves) in the subsurface. In fact, one of the chief concerns of landowners who have sinkholes on their property (especially where they are close to buildings) is that the land may collapse catastrophically, perhaps taking a building with it. Careful inventory and analysis of sinkholes in a particular area, however, would most likely show that relatively few have formed by outright collapse. Instead, *most sinkholes form gradually, keeping pace with dissolutional removal of bedrock in the subsurface.* This type of sinkhole, commonly referred to as a solution-subsidence sinkhole, is characterized by a bowl shape with gentle slopes (Figure 5). Conversely, solution-collapse sinkholes, formed by catastrophic failure of the bedrock in will typically have steep (often vertical) walls with exposed bedrock.

Figure 5. Typical sinkhole on the Pennyroyal Plain, east of Mammoth Cave National Park, Barren County, Kentucky. Most sinkholes form as bowl-shaped depressions with gently sloping sides and little exposed bedrock. Termed "solution subsidence sinkholes," these form gradually as dissolution slowly modifies the upper surface of the bedrock above fractures through which dissolved material is carried into the subsurface. These sinkholes are unlikely to result in sudden collapse. Most observed sudden collapses result as soil particles are slowly plucked and moved downward by percolating groundwater (a process termed piping or suffosion) followed by catastrophic collapse of the thinning roof of the developing cavity.

Misconception No. 6: Karst is always well expressed on the surface. All too often land is considered to be non-karsted even though it is underlain by soluble rock. Typically the basis for this conclusion is that there are no obvious karst features on the surface, especially well-defined sinkholes. In the course of our personal geotechnical investigations, the authors have seen several cases where large sections of land have been designated as non-karstic simply because surficial depressions appear to be absent (Kastning, 1995, 1996). Yet, we found that some depressions may exist that are very subtle and have little topographic relief. They would certainly not show up on topographic maps that have a 20-foot or greater contour interval (Hubbard, 1991). For example, a thicker than typical soil layer (such as in valleys at the base of steep mountains) might "hide" or mute karstic features. Moreover, some of these lands exhibit other, less obvious karst features, such as dry valleys (Figure 6) and springs or seeps. *In some cases, there may be little or no surficial expression of karst even though well established, karsted, groundwater-flow networks may exist in the subsurface.*

Figure 6. Dry streambed, Schoharie County, New York. Karst is not always well expressed on the surface. One clue that a terrane is karstic is that surficial stream channels have little or no flow. Small stream channels in karst are often dry except immediately following significant precipitation.

Misconception No. 7: Caves form by erosion. Nearly every caver or karst scientist who has visited a number of show caves has heard an explanation of how that particular cave had been "carved" by a swiftly running underground stream. Everyone is familiar with the erosive power of surficial streams, so it seems natural to extend this process to the subsurface. Besides, it gives the impression of the awesome power of nature. Yet, careful measurement of flow in cave conduits through timed dye-tracing studies, along with analysis of dissolution scallops in the bedrock walls and floors of caves (Figure 7), shows that water traveling through even the largest conduits is generally too slow for significant erosional removal or rock. *Most caves form through dissolution of the bedrock by slowly circulating groundwater.*

Misconception No. 8: Caves are as old as the rocks they are in. Again, this is a common mistake that one hears time and again on tours in show caves. It is an easy mistake to make, after all the bedrock is usually very old, often in the range of hundreds of millions of years. It is awe-inspiring to think that the cave you are visiting is that old. However, *caves are relatively young landforms, formed in rock that is typically ancient.* The age of most caves in karst regions is not older than one or two million years (Figure 8). This has been determined through use of radioisotopes and paleomagnetism in cave sediments and through correlation of caves with the known surficial erosional history of the region.

Figure 7. The Sump in McFails Cave, Schoharie County, New York. Scallops visible above the water level indicate the slow velocity of flow present under phreatic conditions when the passage was enlarging by dissolution of the bedrock. Scalloping is not a product of erosional excavation.

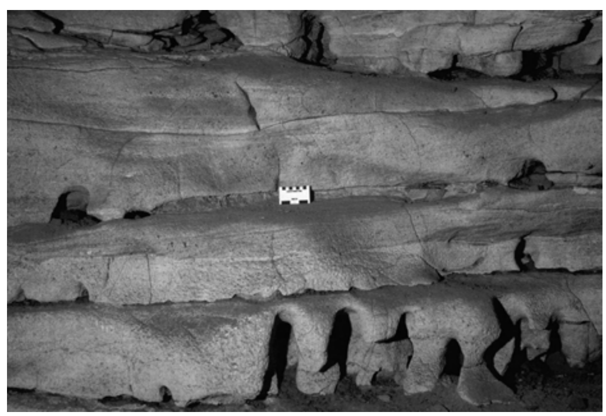

Figure 8. Bedding-plane anastomoses in Wyandotte Cave, Crawford County, Indiana. These small openings are typically characteristic of early stages of excavation of cave passages within favorable beds of soluble rock. Clearly, even these immature openings are considerably younger than the sedimentary rocks that surround them. Certainly mature caves are even younger, typically having formed during the last million or so years.

Misconception No. 9: Groundwater flow in karst is simple and direct. It is a simple matter to note where water may enter the ground in karst regions, namely through sinkholes or where streams disappear into swallet holes or cave entrances. Similarly, it is easy to identify discharge points such as springs or seeps. It follows then that, in many cases, observers would assume that water would likely take a relatively direct route from the observed points of recharge to points of discharge. This route is often conceived as the shortest route between two points. Whereas the inferred route may be the correct one, it is inadvisable to make that conclusion in karst. There are many documented cases, based on well designed dye-tracing studies, where water takes a devious path and emerges at a distant point and not at the nearest spring (Figure 9). Paths of groundwater flow in karst also may converge or diverge in the subsurface, resulting in fewer or more possible routes. Additionally, conduit flow systems are flashy in character and respond in unpredictable ways to storm events or other rapid changes in surface-water conditions. For example, overflow pathways to springs may be used only during flood events. Therefore, *networks of groundwater flow in karst are usually complex, and flow paths and discharge points may be difficult to predict.*

Figure 9. Big Spring, Ozark National Scenic River, Carter County, Missouri. This spring is the largest in the United States in terms of discharge. Tracer dyes injected at many recharge points, up to tens of miles distant, have been detected at this spring, indicating an extensive and complex contributing groundwater drainage basin. Flowpaths of groundwater in karst may be indirect and complex. Dye tracing is the only reliable way of determining such flowpaths.

Misconception No. 10: A lack of known caves suggests little or no development of karst. Not all areas of karst have known caves. The absence of known caves is often used as a reason to classify a terrane as non-karstic, especially if the surface is also devoid of obvious karstic landforms (see Misconception No. 6, above). However, there are many examples of karst terranes where recharge zones and discharge zones are easily identified and mapped (Figure 10). Timed dye-tracing studies may show that groundwater travels at velocities commensurate with conduit flow, proving that these particular terranes are karstic in the subsurface, even though few or no enterable caves are known. There are many documented situations where caves were eventually found in terranes thought to have a low potential for the discovery of caves. Furthermore, conduits do

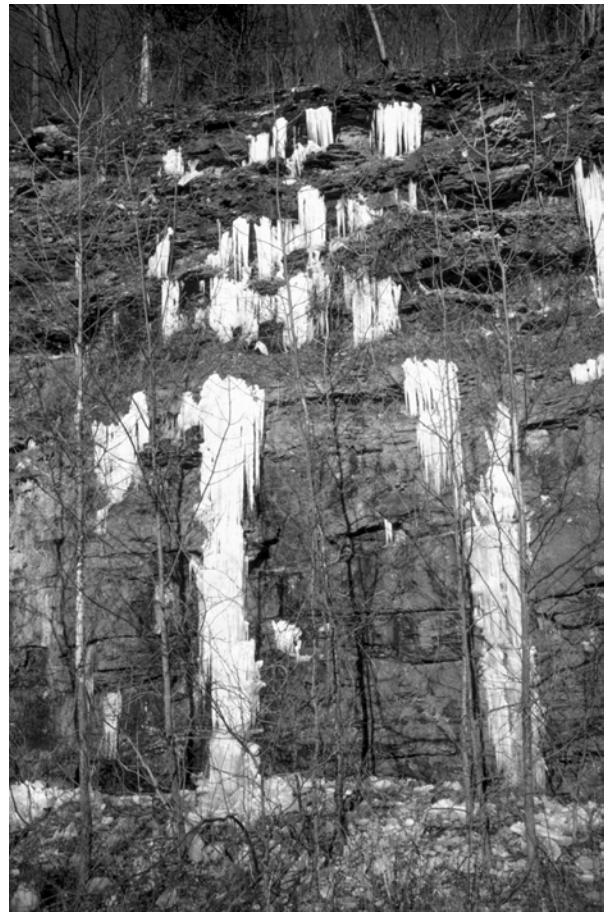

Figure 10. Seepage from bedding-plane partings along a wall of an abandoned quarry, Radford, Virginia. Groundwater flow is highlighted in this example by freezing of discharging water in winter. Many karst areas have significant flow along partings and fractures, yet enterable caves may not present or yet discovered. Nonetheless, groundwater discharge may be considerable along numerous small conduits. The absence of known caves does not in itself indicate the absence of karst.

not need to be large enough for human exploration in order for well-integrated flow systems to exist. *Groundwater in karst may easily flow in openings too small to be termed "caves," yet this flow may be hydrogeologically significant.*

Conclusions

Through no fault of their own, many people living in karst regions (and many who make crucial environmental and management decisions related to those areas) are misinformed about the geomorphic and hydrogeologic processes that operate in karst and form caves. Misconceptions about caves and karst, including the ten enumerated above, are relatively easy to debunk and clarify through education. The speleological community has an obligation to do what it can to protect cave and karst resources. It has the data and knowledge that is required to manage karstlands properly. Educational outreach to the population at large and to those whose mandate it is to properly manage and protect the environment goes a long way toward encouraging responsible behavior and decision making. Explanations should be clear and concise, keeping in mind that members of the lay public may be learning about karst for the first time. Graphical aids, such as maps, drawings, and photographs, go a long way in making the points necessary. Progress is being made in this regard and should continue.

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Recent Conservation Successes at U.S. Bat Caves

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Abstract

Bat Conservation International has been involved with cave conservation and management since our founding. Site restoration and protection of important bat caves has been recently increased through development of our North American Bat Conservation Partnership, which facilitates research and conservation at the field level. Cooperative projects with the National Park Service, USDA Forest Service, The Nature Conservancy, various state agencies, and other organizations have helped protect some of the most important bat caves across the United States. Direct assistance comes from scientific assessment of sites; training of field biologists and managers, such as through our Bat Conservation and Management and Cave Gating workshops; and direct financial support, such as from our Conservation Fund grants. A variety of recent case studies will be discussed, showing how these cooperative projects have benefited vulnerable bat colonies. Recent findings from important current and former Indiana bat hibernacula will also be covered.

The examples mentioned in this presentation illustrate the grass-roots application of the North American Strategic Plan for Bats, modeled after the highly successful Partners in Flight and currently in development. Materials on the Indiana Bat Hibernacula Monitoring Project, the Conservation Fund grants, and the continent-wide Strategic Plan will be available.

The National Cave and Karst Research Institute—An Update

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Abstract

The Geologic Resources Division of the National Park Service is providing a steering committee chairman for the remainder of the fiscal year for start-up of the National Cave and Karst Research Institute. This role has been added to the current duties of the Science and Technical Services Branch's National Cave Management Coordinator. Among several tasks before the first meeting of the Institute Steering Committee was to:

- refine the stated mission, goals, and objectives of the Institute,
- develop a draft position description for an interim institute director,
- draft recommendations for alternatives for the structure of the Institute, and
- participate in finalizing the organizational model.

The first meeting resulted in a draft of the institute director's position description, a refined mission statement, and a set of recommendations for the start up of the Institute. A summary of the recommendations from the steering committee members is that the Institute, in order to foster sound science, will:

- create a Chief of Science on staff,
- appoint a science advisory board,
- function as a central clearinghouse for research on federal lands,
- keep no cave locations or sensitive information,
- support issue-driven science supporting resource management,
- not support research projects that are not locally approved,
- be interdisciplinary and include all aspects of speleology, and
- require all research to promote sustainability in karst systems and resources.

The Nature Conservancy's Planning for Subterranean Invertebrates of the Interior Low Plateaus

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Abstract

The Nature Conservancy is developing a series of large-scale conservation plans based on eco-regional boundaries for the entire U.S. These plans are designed to identify the best remaining occurrences of globally rare species and communities within and among ecological regions. During the planning process for the Interior Low Plateaus Ecological Region, subterranean invertebrates became a primary focus. Since in some cases these animals are poorly known they presented particular challenges for conservation planning.

To address the lack of centralized knowledge regarding the distribution of subterranean organisms a systematic approach was developed wherein the Interior Low Plateaus was subdivided into faunal units based in part on endemism. Nine major subdivisions were created, three containing additional subunits. For most of these faunal areas a comprehensive subterranean species inventory does not exist. For others, for example the Mammoth Cave fauna of Kentucky, Blue River fauna of Indiana, and Huntsville fauna of Alabama, the fauna is better known. Where the fauna was generally well documented, three sites for each globally rare invertebrate were identified for conservation. For poorly known areas, general guidelines were put forth to conserve a set of subterranean communities representative of the area in hope of securing protection for fauna that is not yet well known. In the end, sites containing over 300 species of globally rare cave invertebrates were recommended for conservation status.

The Nature Conservancy is developing a series of large-scale conservation plans based on ecoregional boundaries for the entire U.S. These plans are designed to identify the best remaining occurrences of globally rare species and communities within and among ecological regions. During the planning process for the Interior Low Plateaus Ecological Region, subterranean invertebrates became a primary focus. The Interior Low Plateaus includes northern Alabama, central Tennessee and Kentucky, southern Indiana, southern Illinois and the southwestern corner of Ohio. Dozens of troglobitic species have been described from this region, which includes well known caves like Cumberland Caverns (Tennessee), Mammoth Cave (Kentucky) and Wyandotte Cave (Indiana). In some cases these animals are poorly known, with the possibility of hundreds of species remaining undescribed. Thus, the subterranean invertebrates of the Interior Low Plateaus presented particular challenges for conservation planning.

To address the lack of centralized knowledge regarding the distribution of subterranean organisms a systematic approach was developed wherein the Interior Low Plateaus was subdivided into faunal units based in part on endemism. The following list includes nine major faunas, of which four contain smaller faunal subunits. This analysis is based on the zoogeographic works of Barr (1968), Peck (1989), Peck & Lewis (1978), and Lewis (1983).

In each area examples are given of endemic troglobites. The examples were taken from the works of Barr (1959, 1960, 1962a, 1962b, 1979, 1980; & Peck 1966), Causey (1959), Cooper, *et al.* (1974, 1997), Christiansen & Bellinger (1998), Ferguson (1981), Hobbs, Jr. *et al.*(1972, 1977), Hoffman (1956; & Lewis 1997), Lewis, (1982a, 1982b, & Bowman 1981), Loomis (1939, 1943), Malcolm & Chamberlin (1961), Muchmore (1965, 1976, 194, 1995, 1996), Peck (1973, 1974, 1984), and Shear (1973).

(1) <u>Pennyroyal Fauna</u> - Pennyroyal Plateau of central and western Kentucky, as well as the extensions north of the Ohio River in Illinois (Shawnee Hills) and Indiana (Mitchell Plain); the Muscatatuck region included in the Bluegrass by Barr (1968) is switched into the Pennyroyal section here due to the Muscatatuck's faunal affinities with the Mitchell Plain.

Bedford Fauna - Indiana, Monroe County south to central Orange County
Endemic: *Pseudanophthalmus leonae, Apochthonius indianae, Arrhopalites bimus*

Blue River Fauna - south central Indiana, including Harrison, Crawford, Washington, and southern Orange County
Endemic: *Pseudanophthalmus eremita, Pseudotremia indianae, Rheocyclops indiana*

Muscatatuck Fauna - southeastern Indiana, Clark to Decatur counties
Endemic: *Pseudanophthalmus barri, Pseudotremia nefanda, Hesperochernes holsingeri*

Breckinridge Fauna - Kentucky from the Hart County Ridge north to the Ohio River at Meade County
Endemic: *Pseudanophthalmus cnephosus, Pseudotremia amphiorax*

Mammoth Cave Fauna - Kentucky from Hart County Ridge south to north-central Tennessee, west to Warren County, Kentucky
Endemic: *Palaemonias ganteri, Antriadesmus fragilis, Pseudanophthalmus striatus*

Hopkinsville Fauna - Warren County, Kentucky, west to the Ohio River, dips into northwest Tennessee
Endemic: *Pseudanophthalmus loganensis, Litocampa jonesi*

Hardin Fauna - southern Illinois east of Hicks Dome fault area, Hardin, eastern Pope, and Saline Counties
Endemic: *Pseudanophthalmus illinoisensis, Pseudotremia* undescribed species

Shawnee Hills Fauna - southern Illinois west of Hicks Dome fault area, Pope, Johnson, Union, and Jackson counties
Endemic: unknown

(2) <u>Central Lowland Fauna</u> - glaciated areas of the Central Lowland Province included here in the Interior Low Plateaus ecoregion, with karst buried under till; subterranean fauna of this area primarily phreatobitic in nature as caves are unavailable as habitats.

Illinois Basin Fauna – central Illinois
Endemic: *Caecidotea beattyi*

Scottsburg Lowland Fauna – south-central Indiana
Endemic: *Caecidotea teresae*

(3) <u>Bluegrass Fauna</u> - north-central Kentucky (Lexington region)
Endemic: *Caecidotea barri, Pseudanopthalmus horni*

(4) <u>Cumberland Plateau (Edge) Fauna</u> - Huntsville, Alabama north through Tennessee to Adams County, Ohio)

Adams Fauna - southeastern Ohio, physiographic extension of western escarpment of Cumberland Plateau
Endemic: *Caecidotea filicispeluncae, Pseudanophthalmus ohioensis*

Carter Fauna - northeast Kentucky in Carter County
Endemic: *Pseudotremia carterensis, Pseudanophthalmus krameri*

Powell Fauna - eastcentral Kentucky in Powell, Jackson, Lee & Estill counties
Endemic: *Pseudanophthalmus exiguus*

Rockcastle Fauna - east central Kentucky south to north east/central Tennessee
Endemic: *Pseudotremia unca, Nelsonites jonesi, Kleptochthonius erebicus*

Caney Fork Fauna - eastern Highland Rim/edge of Cumberland Plateau in Tennessee
Endemic: *Orconectes incomptus, Antriadesmus mollis, Nelsonites walteri*

Huntsville Fauna (east) - southern terminus of edge of the Cumberland Plateau in

Huntsville, Alabama area and adjacent Tennessee

Endemic: *Palaemonias alabamae, Tetracion jonesi, Pseudanophthalmus intermedius*

Huntsville Fauna (west) - transition zone between terminus of Cumberland edge and southern Highland Rim

Endemic: *Procambarus pecki, Batrisodes jonesi, Speoplathyrhinus poulsoni*

(5) Cumberland Saddle Fauna - southcentral Kentucky between eastern and western sinkhole plains

Greensburg Fauna - Greensburg area including parts of Adair, Metcalfe, Green & Hart counties

Endemic: *Pseudotremia merops, Pseudanophthalmus darlingtoni*

Tompkinsville Fauna Tompkinsville area including parts of Barren, Metcalfe, Cumberland, Monroe counties

Endemic: *Pseudanophthalmus cerberus*

(6) Central Basin Fauna - Nashville Basin area of northcentral Tennessee

Endemic: *Pseudanophthalmus insularis, Ptomaphagus barri*

(7) Western Tennessee River Valley Fauna - western Highland Rim/western valley of Tennessee

Endemic: *Pseudanophthalmus occidentalis*

(8) Western Coal Field - western Kentucky and adjacent part of southern Indiana, not karst. No known subterranean fauna in this area

(9) Western Illinois Sinkhole Plain - extension of Ozark Salem Plateau into Illinois, Monroe & Saint Clair Counties

Endemic: *Gammarus acherondytes, Mundochthonius cavernicolus*

For most of these faunal areas a comprehensive subterranean species inventory does not exist. For others, for example, the Mammoth Cave fauna of Kentucky, Blue River fauna of Indiana, and Huntsville fauna of Alabama, the fauna is better known. Where the fauna was generally well documented, three sites for each globally rare invertebrate were identified for conservation consideration where possible. For poorly known areas, general guidelines were put forth to conserve a set of subterranean communities representative of the area in hope of securing protection for fauna that is not yet well known. In the end sites containing over 300 species of globally rare cave invertebrates were recommended for conservation status. It is hoped that this identification of caves and other karst features based solely on the presence of globally rare species can provide a reasonable and cost-effective approach for conserving not only globally-rare subterranean animals but other species that share the same habitats as well.

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A Tale of Two Cities: Conservation Focused Cave Bioinventories by The Nature Conservancy in the Karst Areas of Louisville and Saint Louis

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Abstract

In 1995 The Nature Conservancy (TNC) of Indiana initiated a three year bioinventory of caves in the Blue River basin of southern Indiana. The character of the area, located about 25 miles from Louisville, Kentucky, is changing from rural to suburban. The bioinventory surveyed about 200 caves, from which a list of over 100 globally rare invertebrate species was produced, many of which were endemic to the area. In 1998-1999 a bioinventory was conducted in a similar karst area in western Illinois, just south of St. Louis, Missouri. The bioinventory surveyed nearly 70 sites and resulted in a list of about 35 globally rare species.

Rather than discussing the caves or fauna, the focal point herein is the way in which the results of these bioinventories were managed to further conservation management goals. TNC practices conservation as a data-driven process. To this end all troglobites collected were identified to the species level, given a global rank of rarity, and annotated to justify the rank. Common names were coined to further communication with non-zoologists. Many undescribed species were found and funding was arranged to encourage taxonomists to publish descriptions.. The caves surveyed were rank-ordered by the number of significant species present to prepare "shopping lists". TNC and state heritage programs are proceeding in securing these caves through acquisitions, conservation easements, and donations of property.

In 1995 The Nature Conservancy of Indiana initiated a three-year biological inventory of caves in the Blue River basin of southern Indiana. This karst area contains over 1,000 caves, including the Binkley Cave System, which, at over 20 miles of surveyed passageway, is the most extensive cave known in Indiana. The character of the area, located about 25 miles from Louisville, Kentucky, is changing from rural to suburban. During the course of the inventory nearly 200 caves in Harrison, Crawford, Washington and Orange Counties were surveyed for subterranean invertebrates (Lewis, 1998).

In 1998-1999 another cave bioinventory was conducted in a similar karst area in western Illinois, just south of Saint Louis, Missouri. The area, although geographically smaller than the Blue River karst, was very reminiscent of that found in Indiana. Hundreds of caves were known in this well-developed sinkhole plain, including Fogelpole Cave, the largest cave in Illinois at 14 miles in length. The bioinventory surveyed nearly 70 sites (Lewis, Moss, & Tecic, 1999).

A much greater faunal diversity was found in the caves of the Blue River area as compared to the fauna of the western Illinois karst. In the Indiana area were found 56 troglobites and more than 100 globally rare invertebrate species, many of which were endemic to the area. The Illinois area produced about 25 troglobites and 41 species of global rarity. Part of the reason for the larger numbers found in the Indiana karst was the larger geographic area surveyed there when compared to the relatively small region inventoried in Illinois. However, a significant part of the reason is that the fauna is inherently more diverse in southern Indiana.

For example, the millipeds of the genus *Pseudotremia* are ubiquitous in caves of the Appalachians and Interior Low Plateaus. However, the genus is represented in Illinois by a single species in the southeastern tip of the state (Cave Spring Cave, Hardin County, Peck & Lewis, 1978). A total of seven species of *Pseudotremia* were found in caves of the Blue River area, as well as *Scoterpes sollmani*. Likewise, the carabid beetles of the genus *Pseudanophthalmus* have a nearly identical distribution, again extending only from the east only into Hardin County, Illinois. There are four troglobitic species of *Pseudanophthalmus* in the Blue River area, but none in western Illinois. The faunas of the two areas are summarized in Table 1.

This is not to say, however, that there are no interesting components to the fauna of western Illinois. To the contrary, the only troglobitic species of *Gammarus*, *G. acherondytes*, is endemic to the western Illinois karst. Likewise, the nearctodesmid milliped *Ergodesmus remingtoni* found in caves of western Illinois is the only representative of this family not occurring in the western part of North America.

One of the focal points herein is the way in which the results of these bioinventories were managed to further conservation management goals. The Nature Conservancy practices conservation as a data-driven process. To this end all troglobites collected were identified to the *species* level, given a preliminary global rank of rarity if one did not already exist, and annotated to justify the new rank. Common names were coined so the conservation of these species can become more meaningful to the public at large. Many undescribed species were found and funding was arranged to encourage taxonomists to publish descriptions.

The caves surveyed were then rank-ordered by the number of significant species present to prepare "conservation shopping lists." The Nature Conservancy and state heritage programs are now planning to conserve many of the most significant caves through acquisitions, conservation easements, and donations of property where possible. In other cases these "traditional" conservation methods are not entirely appropriate. There are instances were the threats to particular sites are not ameliorated through owning or managing a specific piece of ground containing a karst feature. Several sites in each area are in fact under some form of legal conservation status, but threats may still persist. Many times the threat to significant

Table 1

	Blue River Karst, Southcentral Indiana	Sinkhole Plain Karst, Southwestern Ill
Aquatic Fauna:		
snails:	*Fontigens cryptica*	*Fontigens antroecetes*
	Antroselates spiralis	
flatworms:	*Sphalloplana weingartneri*	*Sphalloplana hubrichti*
	Sphalloplana chandleri	
ostracods:	*Sagittocythere barri*	
	Pseudocandona marengoensis	
	Pseudocandona jeanneli	
copepods:	*Diacyclops jeanneli*	
	Megacyclops donnaldsoni	
	Cauloxenus stygius	
	Rheocyclops indiana	
amphipods:	*Crangonyx packardi*	*Gammarus acherondytes*
	Crangonyx undescribed sp. 1	*Bactrurus brachycaudus*

Table 1		
	Blue River Karst, Southcentral Indiana	**Sinkhole Plain Karst, Southwestern Ill**
	Crangonyx undescribed sp. 2	
	Stygobromus undescribed sp. 1	*Stygobromus subtilis*
	Stygobromus undescribed sp. 2	
isopods:	*Caecidotea stygia*	*Caecidotea packardi*
	Caecidotea jordani	*Caecidotea spatulata*
bathynellid:	bathynellid undescribed sp.	
crayfish:	*Orconectes inermis*	
Terrestrial fauna:		
isopods:	*Miktoniscus barri*	
spiders:	*Phanetta subterranea*	*Phanetta subterranea*
	Bathyphantes weyeri	*Porhomma cavernicola*
	Islandiana cavealis	
pseudoscorpions:	*Kleptochthonius packardi*	*Mundochthonius cavericola*
	Hesperochernes mirabilis	
mites:	*Veigaia bakeri*	
	Veigaia wyandottensis	
millipeds:	*Pseudotremia indianae*	*Ergodesmus remingtoni*
	Pseudotremia conservata	*Chaetaspis* undescribed sp.
	Pseudotremia purselli	
	Pseudotremia blacki	
	Pseudotremia cookorum	
	Pseudotremia burnsorum	
	Pseudotremia salisae	
	Scoterpes sollmani	
Springtails:	*Sinella cavernarum*	*Arrhopalites carolynae*
	Sinella alata	*Arrhopalites hirtus*
	Sinella undescribed sp.	*Oncopodura iowae*
	Pseudosinella fonsa	*Pseudosinella* undescribed sp.
	Arrhopalites lewisi	*Arrhopalites lewisi*
	Arrhopalites ater	*Arrhopalites ater*
	Arrhopalites undescribed sp. 1	*Arrhopalites* undescribed sp. 2
	Tomocerus missus	*Tomocerus missus*
	Onychiurus undescribed sp. 1	*Onychiurus* undescribed sp. 2
	Hypogastrura lucifuga	
	Isotoma undescribed sp.	

Table 1		
	Blue River Karst, Southcentral Indiana	**Sinkhole Plain Karst, Southwestern Ill**
Diplurans:	*Eumesocampa* undescribed sp. 1	*Eumesocampa* undescribed sp. 2
	Litocampa undescribed sp.	*Eumesocampa* undescribed sp. 3
		Haplocampa undescribed sp.
Beetles:		
	Pseudanophthalmus tenuis	
	Pseudanophthalmus eremita	
	Pseudanophthalmus stricticollis	
	Pseudanophthalmus youngi	
	Batrisodes undescribed sp.	
Flies:	*Spelobia tenebrarum*	*Spelobia tenebrarum*

sites originates elsewhere. Examples would include faulty septic tanks that leach into the site, aquifer drawdown or modification by nearby land users, improper disposal of toxic materials in sinkholes, agricultural or suburban runoff, and the like.

In these instances it may not be necessary to secure the site through acquisition but rather address the source of threat instead. This may include landowner education, assistance in implementing best management practices for forestry or agriculture, improvements in wastewater treatment, or better land use planning with sufficient tools for implementing compatible land use on larger scale.

Because the threats to karst communities can be so variable, it is necessary to thoroughly evaluate each conservation target site to assess the source and degree of threats, if any are present, and approach them accordingly. In every case, a site conservation plan should be created for each site to document its biological significance, identify threats, and include recommendations as to how The Nature Conservancy and its conservation allies should approach the conservation of each site. For the Blue River basin this would represent the creation of approximately 35 individual site conservation plans for sites evaluated during the bioinventory and found to include significant occurrences of globally-rare species or communities. For the western Illinois area approximately 15 sites were similarly identified and need well-crafted site conservation plans with conservation methods that are likely to be carried out in the foreseeable future. It seems feasible that if all of the significant subterranean sites in each area are sufficiently secured through what is likely to be a range of conservation approaches, then the fauna of these habitats has a reasonable chance of persisting into the future.

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Recent Projects of the Indiana Karst Conservancy, Inc.

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Abstract

The Indiana karst Conservancy had its beginnings in the mid 1980s. Since then we have been working with other agencies, landowners, cavers, and so on to work out questions concerning karst and karst features, including caves. For example, one project is the Hoosier National Forest/Indiana Karst Conservancy Karst Inventory Project, where we locate, inventory, and write management plans for all of the caves on the forest as well as provide input for their overall karst resource management strategies. This is an ongoing project, which has gone a long way to build mutual respect between the two organizations, and much has been accomplished. Just last year they presented us with the region's Honor Award for Environmental Protection. Other recent projects include those involving acquisitions, cleanups, nature park development, and the like. This presentation will cover the above and more on what we're all about.

Hoosier National Forest/Indiana Karst Conservancy Karst Inventory Project

This is an example of the Indiana karst Conservancy working with the federal government. The Hoosier National Forest/Indiana karst Conservancy Karst Inventory Project has been active since the late 1980s in a comprehensive endeavor responsible for locating, surveying, and inventorying caves and karst features for their archaeological, biological, geological, hydrological, paleontological, and recreational values and keeping records of findings for the subsequent writing of individual management plans for each cave located. It is a monumental task, to date 107 caves have been confirmed. It is comprises mainly volunteers from around the state with representatives from each individual grotto, survey, and conservancy serving on its board. Related responsibilities include the nomination of significant caves, special areas, and the like. Field work days are held on the third Saturday of each month with management meetings taking place once every other month. In December 1998 the Project was awarded the prestigious Eastern Region Honors Award by the Forest Service.

During the presentation, delegates will be introduced to the project and its philosophy as well as be shown a sample of the Hoosier National Forest's caves along with examples of each of the values listed below. Slides include a map of the karst areas in the state and on the Forest, a large gulf by the name of Wesley Chapel Gulf from the air as well as closer views including inside of its caves, examples of archaeological (historic signatures), biological (amphipods), geological (cave formations), hydrological (cave streams), paleontological (bear wallows and bones), and recreational (challenging traverses) discoveries, team members at work, ceremonial signing of the first completed management plan, and a group shot of those that attended the 1998 Eastern Region Honors Award presentation.

Leonard Springs Nature Park

This is an example of the Indiana karst Conservancy working with city government. Leonard Springs Nature Park is an 84.5-acre park with an emphasis on karst conservation and education. It is managed by the City of Bloomington in cooperation with the Indiana Karst Conservancy and contains three small caves, two large and impressive springs with their associated waterfalls, and various other secondary springs. The property was originally purchased in the early 1900s and dammed to serve as the city's third water source. Later, it became apparent that the reservoir was not able to hold as much water as anticipated for the growing population due to it being located in a karst area of the Mitchell Plateau. Water shortages ensued and Indiana University threatened to move out of town. Eventually, the city and Indiana University came to an agreement to build a subsequent reservoir in a non-karst area northeast of the city. Leonard Springs ceased being used as a reservoir in the mid 1940s. It remained abandoned until a transfer from the Utilities Department to the Parks and Recreation Department took place in 1998. Currently, the old reservoir and surrounding land are in the process of being reclaimed by nature after over a century of use by farmers, millers, and others.

Various grants were received and work began in the spring of 1999 to turn the once-abandoned property into a prosperous place for people to hike and appreciate the karst resource. A mile-long trail with a 100-stair steel walkway that brings one from the top of the reservoir to the bottom was designed and added in order to reduce erosion. Along the way, interpretive signs placed in strategic areas enhance the learning experience. Other signage includes rules of the park. In addition, together with various other local caving organizations such as the Bloomington Indiana Grotto and Eastern Indiana Grotto, numerous clean ups took place on the property and in its caves as they had been used as trash dumps by nearby residents.

During the presentation, delegates will be introduced to the park and its philosophy as well as be shown a sample of the caves and springs. Slides include a map of the park, introduction and interpretive signage, the trail, stairway, and an overlook used to view a shelter cave along the way, and volunteers active in the process of the cleaning up. Soon the city will start emphasizing educational programs being developed for the park and its visitors.

Indiana Department of Natural Resources Abandoned Mine Gates

This is an example of the Indiana karst Conservancy working with state government. As population in the state increased, it became more and more apparent that coal mines abandoned in the late 1800s through early 1900s needed to be secured. The mines and their various low tunnels had become unstable and prone to collapse. Local residents were concerned that their children could become trapped. Therefore, the Indiana Department of Natural Resources would simply bulldoze them shut.

However, bats had started using them as homes. Eventually, the Indiana Department of Natural Resources and Indiana karst Conservancy were introduced to each other and an agreement was reached whereas the Indiana karst Conservancy would build bat-friendly steel gates to secure the mine entrances so that the bats and other creatures could come and go yet keep children out. This agreement was to the mutual benefit of not only the Indiana Department of Natural Resources and Indiana karst Conservancy but also the bats and local residents.

Work began in the spring of 1999. The Indiana karst Conservancy along with an Department of Natural Resources representative would visit the mine locations and take measurements and photos of the entrances. Later, they would return with a host of volunteers to construct them, welding each one together individually on site. The gates were subsequently primed and gated. Monitoring of the gated mine entrances proved that bats were indeed using them. In 1999, six bat-friendly abandoned mine gates were constructed.

During the presentation, delegates will be introduced to a typical reconnaissance mission to a mine-gating site, be shown photos of a mine entrance being surveyed, volunteers building and welding the gates on site, and gates being primered and painted.

The Orangeville Rise

This is an example of the Indiana karst Conservancy working with a related non-profit organization. In the spring of 1999, the Indiana karst Conservancy acquired one of the largest, most picturesque springs in Indiana, the Orangeville Rise, from The Nature Conservancy. The nature Conservancy felt that the Indiana karst Conservancy would be a more appropriate steward of the property as it focus primarily on conserving karst features. The property consists of approximately three acres and drains several square miles of land to the north and east of the feature. It is part of the world-class karst region of the Lost River System and has been designated a National Natural Landmark. It is also a state-dedicated nature preserve and is considered a prime tourist attraction in the area.

During the presentation, delegates will be introduced to the Orangeville Rise by being shown slides of the spring, signage, and a photo of the signing of the transfer that took place between representatives of the Indiana karst Conservancy, Indiana Department of Natural Resources, and The Nature Conservancy.

In conclusion, the Indiana karst Conservancy is finding that there are many commonalities between the various agencies and individuals as to how karst is managed. Watersheds and properties also overlap in certain areas. They are now not only focusing on working with these agencies, but encouraging the agencies to work together with them for the preservation of our sensitive karst areas. It is a challenge but one that is well worth it.

About the Author

Kriste Lindberg has been an active member of the caving community since 1992. She was introduced to it while teaching nature classes, writing curriculum, and leading field trips for the Chicago Academy of Sciences. Currently, she has been with the Indiana Karst Conservancy for five years, starting as a member in 1994, becoming a director in 1996, and subsequently President in 1999. Throughout this time, she has been collaborating with local, county, state, and federal governments as well as individuals throughout Indiana in the pursuit of maintaining the quality of the state's underground resources. Projects she is part of include the Hoosier National Forest Karst Inventory Project, various cave survey and management teams, Indiana Department of Natural Resources abandoned mine gatings, land acquisition, and most recently the expansion of the Indiana Karst Conservancy's education and outreach efforts (she has earned a BGS degree focusing on the earth and social sciences and an MSED). She is currently employed as the Park Manager of Leonard Springs Nature Park for the City of Bloomington and has been an integral part of the parks development since it began to be developed in the spring of 1999.

Delineation of Karst Groundwater Divides by In-Cave Dye Tracing, Mammoth Cave Karst Aquifer, Kentucky

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Abstract

Karst groundwater basin divides are currently depicted as two-dimensional lines on maps, but they are better considered as complex, three-dimensional surfaces within the subsurface. Dye traces are necessary to map out these surfaces and to locate conduits inaccessible to cave surveyors, and are indispensable for understanding the geometry of the complex networks of flow paths through the aquifer.

A key reason why the Mammoth Cave System is the world's longest known cave is that its passages extend over several major groundwater basins. The divides between these basins define the drainage system geometry and precise location of them is critical for understanding and protecting the cave and its remarkable aquatic ecosystem. In 1999 we initiated a long-term program of dye tracing within the Mammoth Cave System to more precisely locate the divides and to understand their increasingly apparent complexities. This involves both underground injection and surface injections aimed at underground dye receptors. In addition to identifying the divides, well-designed traces can also connect previously fragmented stream segments.

A trace from a first order cave stream in the Candlelight River area, intended to pin down the divide between the Pike and Echo River Basins, emerged at Floating Mill Hollow Spring, unexpectedly crossing a previously established drainage line. A second trace from Outward Bound, the easternmost known stream in the cave, went to Ghengis River within the Pike Spring Basin. Dye receptors are in place at Bögli Shafts for a surface injection at Floating Mill Hollow, which will have to wait for the end of this summer's severe drought.

An Instrument and Method for Measurement of Dust Fall in Caves

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Abstract

Dust fall in show caves causes a slow degradation of the aesthetic values that attract visitors to the caves. Some material falls directly to the pathway to be trodden underfoot and re-entrained in the air, while finer material, when released to the air is widely advected through the caves where it settles on all surfaces. Strategies to control dust have examined pathway design, reducing dust material brought into the cave and maintenance activities to remove deposited material.

An essential part of an investigation of methods to reduce dustfall is a means to measure the dustfall with sufficient sensitivity and precision to be able to evaluate quite short term changes in the rate of dust fall. An instrument is described which has been used in a variety of experiments measuring dustfall in Australia and UK. The method of using the instrument and considerations useful for designing observation programs are discussed. The instrument is sensitive enough to measure a dust film of 3 micrograms per square centimetre, about half the threshold of perception of critical observers. The sensitivity of the measurements allows short experimental programs to compare alternate strategies of dust management. A total of 10,000 visitors could be sufficient for a trial comparing alternate management methods.

Introduction

Current world's best practice in show cave management involves the construction of pathways that are specially designed to immobilize the particulate material dropped by visitors, so that it can be collected and removed from the cave. If material is not immobilized it may be re-entrained by the subsequent visitors walking on it and may spread onto the area adjacent to the pathway where cleaning may be very difficult.[1]

Recent research[2] [3] has shown some new aspects of the dust distribution processes. The dust released by cave visitors can be considered as having two components. The first component is of particles large enough to fall straight to the floor, where management strategies involving the pathway can be applied. The second component is of particles small enough to be swept into the plume of warm air rising from the visitors,[3] [4] see Figure 1. Table 1 shows the settling properties of airborne particles and it can be seen how the particles are able to stay suspended in the air for times that range from seconds to days.[5]

That this airborne dust is a major problem was shown by the spectacular visual improvement at Jenolan Caves, Australia, when steam and water cleaning were used to restore caves which had for years been used for cave tours.[6] [7]

Measurements in eastern Australia, Western Australia, and England have shown a remarkably constant rate of deposition of airborne particulate material from show cave visitors.[8] The rate of release is in the order of one microgram of dust per person per second, and although this seems quite a small quantity, with one million visitors a year visiting a cave for one hour, over a period of ten years this amounts to 36 kilograms of dust. This quantity excludes the much greater mass of coarse particles that fall directly on to the pathways, this is dust that remains suspended in the air for hours and deposits on every surface within hundreds of feet of the pathways.

Although a relatively small amount of work has been done on dust analysis in caves,[9] [10] [11] [12] there is a considerable literature of work done in similar situations in museums, industrial sites, and homes. It is reasonable to assume that the dust fall in caves is composed of fine mineral dust, smoke, organic material shed by the humans, natural organic material of plant origin including pollens and spores, and textile degradation particles.

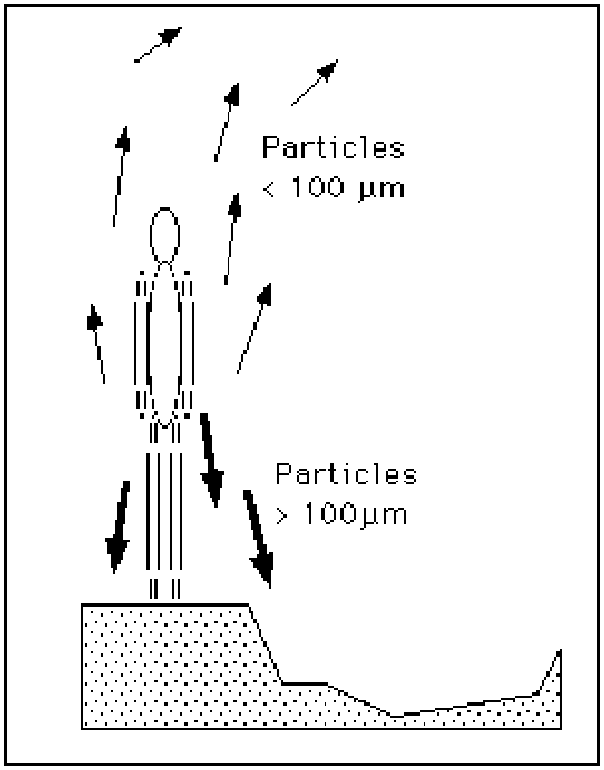

Figure 1 - Differentiation of dust by particle size as it is released from the subject.

Measurements by the author ([3] and unpublished measurements) have shown that the particle size distribution in caves during cave tours is remarkably similar to that indoors and out of doors in both urban and rural situations. The particle size range of interest is between 0.1 and 100m (Figure 2).[8] As air movement in caves is often quite slow, the usual fate of the suspended particles is to be deposited throughout the cave.

Figure 2 shows the measurements of dust sampled from the air in Jenolan Caves with an APS Aerodynamic Particle Sizer. The size categories are based on the surface area of the particles. Other parameters such as number or mass for the size categories would give different histograms with different maxima.[3] Surface area is used as a measure of particle size distribution because it is the property that is linearly related to the visual effect of the particles when they deposit on a solid surface.

The rate of visual degradation by dust fall of the cave is imperceptibly slow so a cave manager may be unaware that damage is occurring. Ten years is the time scale for serious degradation of a cave to occur, but over ten years human memory and perception tend to be unreliable. This is one reason why it is necessary to find a method to measure the visual degradation of the cave before serious damage is done.

The management methods already applied to many caves—the building of railings and paths, have already greatly contributed to the protection of the caves from dust when compared with unmanaged caves. The impact of just one visitor to a show cave produces an impact that is usually several orders of magnitude less damaging to the cave than the visit of one caver to a wild cave. This, in most tour caves, may be only due to the elimination of getting mud on clothes. Once on clothing mud dries and is rapidly launched into the air as dust.

This reduction of impact is at the expense of considerable cave development, which, although it is a form of cave damage, should be

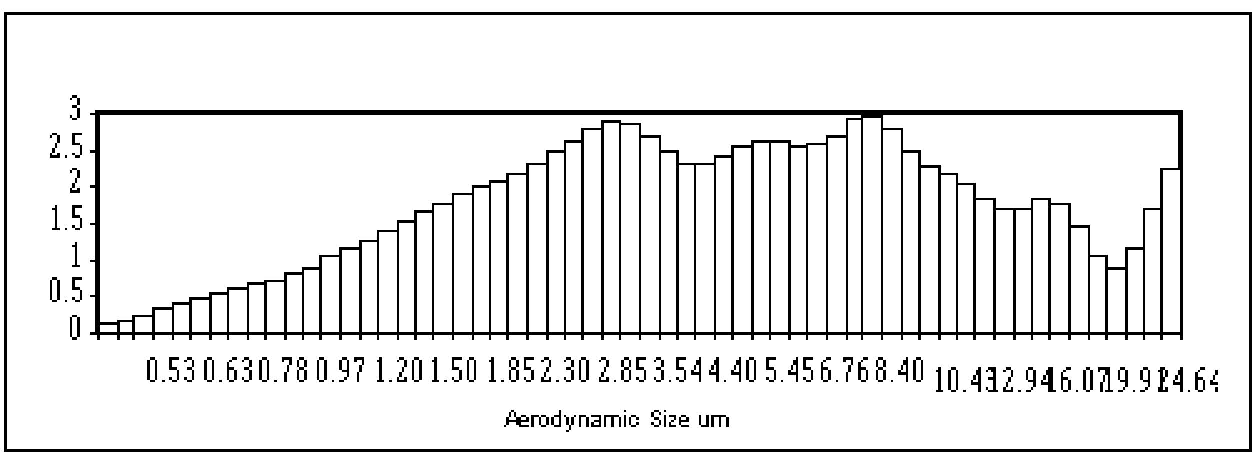

Figure 2 - Distribution of aerodynamic size of dust particles sampled in a show cave, this graph shows relative particle surface area per category per cc of air sampled

Particle Diameter (µm)	Settling Velocity (m/s)	Brownian Displacement in 10s (mm.rms)	Time to settle one meter
0.01	6.95×10^{-8}	1	166.5 days
0.1	8.65×10^{-7}	0.12	13.38 days
1	3.48×10^{-5}	2.3×10^{-3}	7.98 hours
10	3.06×10^{-3}	7.0×10^{-3}	326.8 sec
100	2.61×10^{-1}	2.2×10^{-3}	3.83 sec

Table 1 Physical behaviour of aerosol particles. Data from Baron and Willeke (1993)

a one-off activity that will greatly reduce all future impacts.

The method described here presents a consistent measure of the optical absorption of the dust film as a direct indicator of the visual degradation by the dust film of the cave. The method has been developed to allow comparisons of dustfall between different sites and times and to give an absolute measurement of the problem suitable for the evaluation of dust management techniques and to aid the incremental development of better cave management practices.

Dust Management Strategies

There would seem to be two main strategies to deal with the deposition of airborne dust. The first is to prevent the dust getting into the caves the second is to remove it from the caves.

1. Reduction of dust entering caves.

The dust is transported into caves via two main routes; direct transport into the cave in the air exchanged from the surface[12] and dust carried in by visitors.[8]

The air that enters the cave may be part of a natural circulation that is part of the cave's original microclimate or be due to man-made changes that could or should be reversed. Either way management of the areas outside the cave may achieve a reduction in the dust concentration in air entering the cave. Dust in parking areas, bare earth and gravel paths, and poorly vegetated land areas can all contribute to the ambient dust levels outside the cave and all can be improved by alternative management methods. The dust levels outside caves that are of concern are much less than is easily visible. Any management of the airflow into a cave may need to be balanced with respect of the needs for fresh air for the visitors and the need to maintain an appropriate microclimate.

The dust that is carried in by the visitors can be controlled by a number of methods, either to reduce the dust on the clothing or to reduce the quantity released in the cave. Some of the dust released in the cave will fall directly to the floor, it is important that this dust is not trampled and raised into the air to have a second chance to be spread through the cave.

Possible dust control strategies might include:

- Mats to clean the shoes before visitors enter the caves
- Air curtains to dust down visitors at the entrance
- Air jets to brush dust off visitors as they pass through the entrance.
- Mats or carpet on the flooring to absorb and immobilise dust until it can be cleaned up and removed from the cave.
- Frequent cleaning of pathways to remove dust.
- Reduction of the tduration of the tour, distance walked or amount of exercise in the cave, as each of these parameters are associated with more dust release.
- Issuing covering clothing to reduce dust release.

Some of these strategies may be more applicable in a particular situation than others. In most caves the cost and efficiency of the strategy will be important and there is much scope for new ideas to be tried.

2. Removal of dust from the caves.

There seems to be little prospect of removing dust from the air in caves as the aerodynamic size of the particles makes their movement relative to the air quite slow. Filtering, electrostatic precipitation, and such methods only work if all the air in the cave is cycled through engineering hardware. Such installations are used in museums and industrial clean rooms, but in caves would be expensive and difficult to make aesthetically and ecologically acceptable. So if the dust has gained entry to the cave the only option is to remove the dust from the cave surfaces.

The removal of dust from the caves has been done at Jenolan[6] [7] originally by the use of steam but now by water sprays. To enable routine cleaning it proved necessary to harden the cave by the installation of redesigned concrete paths, drains, and sumps to collect the contaminated washing water. The use of washing becomes very difficult when earth and mud formations are present. When washing is unsuitable because of mud or fine porous speleothems the only remediation now used is to pick up the fibrous material leaving the majority of the particulate material covering the surface.

Method

The Physical Measurement Process

To determine whether new management methods have made an improvement to dust control, trials should be conducted to evaluate the methods. To run trials a reliable sensitive method of dust measurement is required. This method has been investigated for some years.[3]

Glass Petri dishes, with an identification number engraved on them, as a surrogate surface, are placed in an array of sites considered to be representative of the cave being managed. The exposure of the dishes is relatively unimportant, even when sheltered by a covering surface 28mm above the dish the dust deposition was only reduced by 50%.[3]

The dust particles collect on the glass dish by two main processes, molecular diffusion and collision for the smaller particles and gravitation for the larger particles, both processes applying to some extent to all particles.

The smaller particles will deposit on all surfaces, the larger particles preferentially deposit on horizontal surfaces.

At suitable intervals of time the dust film on each dish is measured with the optical densitometer. The optical processes in the measurement depend on the interaction of the dust with the light beam. Solid matter reacts to light in a number of ways and except for very specific conditions will always absorb, reflect, refract, or diffract incident light.

This interaction is greatest when the index of refraction of the particles is most dissimilar from the surrounding medium. For this reason the dishes are dried by gentle warming on the hand for about a minute before measurement to remove any water that may be between the particles. At high humidity there is often a water film that reduces the light interaction by matching the indices of refraction between the particles and other particles and the glass.

The optical densitometer is designed to make a robust measurement of the proportional area of obscuration on the surface of the dish. By collimating the light source and detector, any light that is absorbed, diffracted, refracted, or reflected by the dust film from the light beam is lost to the detector. The collimation of the beam greatly reduces the sensitivity of the measurement to particle colour, giving a measure of the covering power of the film.

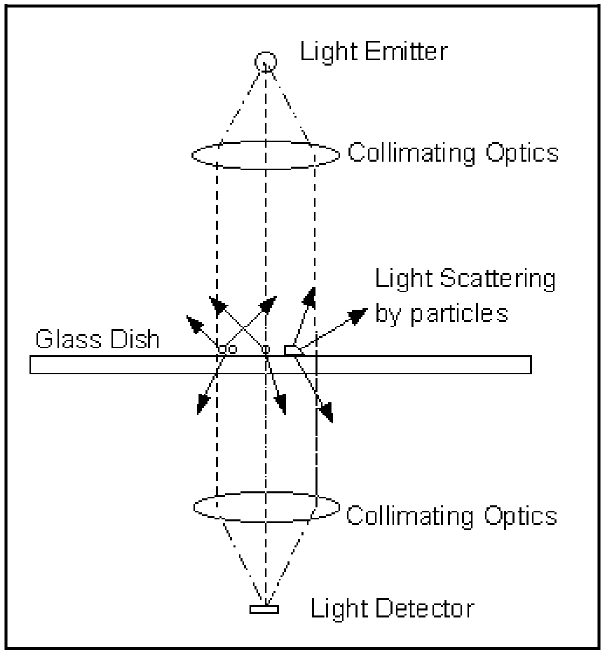

Figure 3. Optical system of the dust film measuring instrument.

To make the instrument insensitive to ambient light, a coded modulation of the light beam is analysed by the detector so that incident light is not detected. The instrument is self calibrating, only linearity of the measurement system is required to get full accuracy.

This is very important in a cave where lenses tend to fog or get smeared. A paper tissue may be frequently wiped over the optical surfaces without loss of precision.

The sequence of operation of the instrument is to:

(a) With a paper tissue polish the new dish until it is thought to be clean.

(b) Place it on the instrument and adjust the scaling control to get a meter reading of 1,000 units.

(c) Remove the dish, and if it was a perfect dish a number of about 1,084 should be shown, as the light lost by reflection from the two surfaces, top and bottom, of the glass remove about 8.4% of the light from the beam.

If the reading is much higher than 1,084 then the polishing process may be inadequate and should be repeated. When the dish is satisfactorily clean, record the value of the instrument after the dish is removed as a zero value for that dish.

When a dish has been exposed to dust fall for a suitable time and the dust film on the dish is to be determined, set the instrument to the value near 1,084 that the dish had when clean, dry the dish by warming, clean the underside of the dish with a paper tissue, then place the dish on the instrument.

The reading will then be some value less than 1,000, depending on the density of the dust film.

A value of 990 will show that 1% of the light has been blocked by the dust film.

The response of the instrument becomes non-linear with respect to the quantity of dust on the dish as the film gets thicker.

A formula converts the measurement to linear units, the formula is simple to use in a spreadsheet program or a PC executable program is available to convert the data.

$$Q = 1000 * LOG_e(1000/R)$$

where Q is the quantity of dust in units of opacity

R is the reading from the instrument of the dish with dust.

Discussion

The unit of measurement , the Q unit, is the quantity of dust needed to cover 0.1% of the surface. (i.e. reduce the transmission of light by one part in a thousand). This is a practical unit of measurement but the mass of dust needed to reach this level depends on the nature of the dust, mainly the diameter of the dust particles.

Carey[13] and Hancock, Esmen & Furber[14] examined the level of dust coverage that produced perceptions of dustiness under indoor conditions. 0.2% to 0.45% coverage (Effective Area of Coverage or EAC) was perceptible, while 0.4% to 0.7% was perceived as "dusty" or "dirty." These levels of dust were for black dust on a white background, the visual effect may be less when there is not a large color contrast between the dust and the substrate. The effects of dust in caves have more than a visual effect, the biological and mineralogical pollution of the surface effects subsequent growth of speleothems as well as the microbiological and biological communities.

Measurements in caves by the author have shown values that indicate an Effective Area of Coverage as high as 30% in deposits that had accumulated over a year. The relationship between mass of dust deposited in the cave and the density of the film measured in the dish in a tour cave was 30 milligrams of dust per square meter of cave surface gave a measurement of an Effective Area of Coverage of 1%. This was a density on the dish of only 3g/cm2. The instrument will resolve 0.3g/cm2.

The use of the Petri dishes to sample the dustfall allows other methods of analysis to be used in conjunction with the optical measurement.

Sampling the dry deposition of particles has been reviewed by Nicholson,[15] but although previous workers have used Petri dishes for sampling dustfall, the use of the dishes does not seem to have been previously used in an integrated sampling and measurement system for dust fall.

The problem of dust that has fallen being dislodged from the dish does not seem to exist as the high humidity of the cave ensures that strong forces of adhesion come into play when the dust contacts the dish.

The sampling schedule and processing of results using this method means that useful management feedback can be obtained from only 10 to 20 hours of work a year, a quite practical amount of time to devote to management practice evaluation.

So far only one instrument has been built, but it is available to continue the task of developing a robust, effective technology of impact minimization in tour caves. The next stage in this work is for a cave manager to take part in a demonstration project to be mounted in a tour cave to continue the process of method development and to demonstrate the achievable levels of reduction of impact. More participating cave managers and more instruments should quickly follow if significant success is achieved.

Conclusion

The management of dust in show caves may be effected by varying management practices so that there is less dust deposited in the caves. To determine the incremental improvement of each improvement of management, a robust objective measurement of the rate of dust deposition is needed. Fortunately sampling problems do not seem to be of major concern so that a modest measurement program using optical measurement of dust deposited on a suitable substrate will be able to identify the most effective and economic methods of dust reduction. Dust-free parking areas and paths, vegetated moist soils instead of bare earth, dust and mud absorbent path coverings near the cave entrance, even air curtains and air jets to dust the visitors as they walk through may be feasible.

Control of conditions outside the caves may be a major method of dust reduction, for both dust advected directly into the caves and for dust carried into the cave in textile materials worn by visitors.

The optical method described here is robust and very sensitive and should match the requirements of many cave managers.

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Urbanism and Cave Conservation In Central Texas

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Abstract

Cave management issues can be costly and may represent a serious burden to landowners. Cave conservation and cave invertebrate species protection may involve safety concerns, cost and time considerations, profitability, and unfortunately lack of concern. Conservation can be encouraged and incorporated into a project from the beginning to prevent unexpected delays or enormous costs involved in re-planning the design or long negotiations with agencies that may be involved. We can learn from the experiences of those who have gone before us and encourage land owners to think ahead in the process of developing land. Examples of Section 10 (a) permitting for cave-adapted invertebrates in Central Texas and examples of cave management plans with ideas for promoting cave conservation areas as an educational tool or community project will be discussed.

Caves present educational opportunities, and conservation easements can be used as part of a community or educational facility to teach children and adults about the importance of conservation and how they can incorporate conservation into their daily lives. Greenbelts or cave conservation areas are the perfect locations for educational stations where people can read about the extra effort that has been put into planning the development. If the developer shows that they are committed to the long-term health of the environment, they are showing that they are committed to a higher standard of living. A development can increase its appeal, save money, and prevent unnecessary delays by demonstrating that it cares about the over health of community and by helping the resident keep the environment and the community healthy.

Americans sense that something is wrong with the places where we live and work. . . As though the whole thing had been designed by some diabolical force bent on making human beings miserable. And naturally, this experience can make us feel glum about the nature and future of our civilization. From James Howard Kuntsler, "Home from Nowhere," *The Atlantic Monthly*, Vol. 278, September 1996.

Forward

Karst terrains provide a challenge in urbanizing areas, both from an engineering and environmental protection standpoint. Karst terrains and associated voids within limestone can offer engineering difficulties related to ground competency, construction techniques, foundation and roadbed instability, ground water seepage, and septic disposal. Karst terrain is often environmentally sensitive, providing a rapid infiltration or recharge to an aquifer, and frequently supporting rare and endemic flora and fauna. These regions are susceptible to impacts from urban development, which can include contaminated runoff with high sediment loads, hydrocarbons, fertilizers, and pesticides. Additionally, impervious cover can significantly alter water, air, and nutrient infiltration characteristics of aquifers and subterranean ecosystems. Environmental significance and sensitivity of karst regions have only been recently realized in the past couple of decades. Efforts to minimize the impacts of urbanization on karst terrains have had little impetus prior to the past decade. Much of the recent attention to these regions has been fostered by federal listing of many cave-dwelling or spring-dwelling organisms as threatened or endangered.

In Central Texas, a large karst region known generally as Edwards limestone provides recharge to the Edwards Aquifer and supports a high degree of biological endemism in subterranean cave systems. Seven species of troglobitic invertebrates and a host of aquatic salamanders, fish, plants, and invertebrates associated with Edwards limestone spring outlets have been placed on the federal endangered species list. A larger number of other karst- or aquifer-related species are being considered for listing and many others are endemic to the area. Sprawling urban development is occurring around Austin, San Antonio, and smaller communities over and near Edwards Limestone. The result has been intensive clashes between development and environmental protection interests with resulting lawsuits, increasing regulatory requirements, and increased development costs. Local, state, and federal agencies in the urbanizing areas are requiring cave conservation and aquifer recharge protection.

Introduction

Unexpected delays, extra costs to redesign site plans, and extended negotiations with regulatory agencies may be avoided if conservation plans are incorporated into a site plan from the beginning of a proposed development. Landowners may plan ahead for cave conservation to save valuable time and money. This strategy includes: planning ahead for conservation, using cave preserves as amenities or educational features, protecting caves, and promoting a higher standard of living through the use of common areas and green space.

This paper examines several land planning strategies designed to incorporate sensitive area conservation while gaining benefits from these green spaces, for the enjoyment and education of the public. Several examples of land development conflicts and successes with karst conservation are explored.

New Urbanism

Traditional communities strike a balance with natural elements that provides a unique identity as well as physical limits on development. Caves, springs, local weather, vegetation, views, harbors, and topographic features define the individuality of a memorable place or neighborhood (Katz *et al*., 1994). In contrast, current communities are defined by our total reliance on automobiles, ozone action days, paved parking lots, traffic jams, contaminated soil, degraded natural habitats, pollution, and crime that destroy our view of our neighborhood and home. Understanding the natural beauty of a place can be expressed in the design of a community, striking a balance between the natural and manmade environment.

New urbanism is a city planning technique that revives the 1920s notion that people and the environment should be part of city designs (Kuntsler, 1996). New urbanism offers an alternative to the sameness of the suburban landscape. In order to achieve new urbanism goals of walkability and increased social interaction, a community is designed with high density development concentrated in the less sensitive areas, with lots of open green space in between (Katz *et al*., 1994).

An example of new urbanism planning is found in Austin, Texas. The Hyde Park neighborhood in Austin, Texas, is known as a Traditional Neighborhood District, a term used to describe a neotraditional approach that embodies the preWorld War II neighborhood plan that is considered an effective tool to control sprawl (Wagner, 1997). As shown in Figure 1, a Traditional Neighborhood District has specific characteristics that result in a compact, mixeduse, pedestrian-oriented community (COA, 1997). The Traditional Neighborhood District includes formal and informal open spaces that encourage community activity, identity, and civic pride. Greenbelts and preserve areas are an important element of Traditional Neighborhood Districts and may be used to protect endangered species and sensitive environmental features such as caves or other natural features. By creating nature trails and preserves, a community becomes more walkable. Accessible trails increase the chance for community interaction. This design also reduces the environmental impact by decreasing the amount of land used for development.

New urbanism and traditional neighborhood design may effectively incorporate cave management plans while simultaneously preventing possible governmental violations or accidents. Cave management plans are used to develop conservation zones and to define boundaries of environmentally sensitive areas. Preplanning for cave conservation can reduce bureaucratic negotiations by anticipating the protection needs for a planned community.

Cave Management in Central Texas

In central Texas, federally protected species and aquifer protection define the need for cave

"Open Space: Formal and informal open space is located throughout a TND. The design of the neighborhood gives priority to open space. These spaces enhance community activity, identity and civic pride. The neighborhood plan creates a hierarchy of useful open spaces: a formal square in the Neighborhood Center, parks and playgrounds throughout the neighborhood, and streets that promote walking and encourage informal meetings." (COA, 1992)

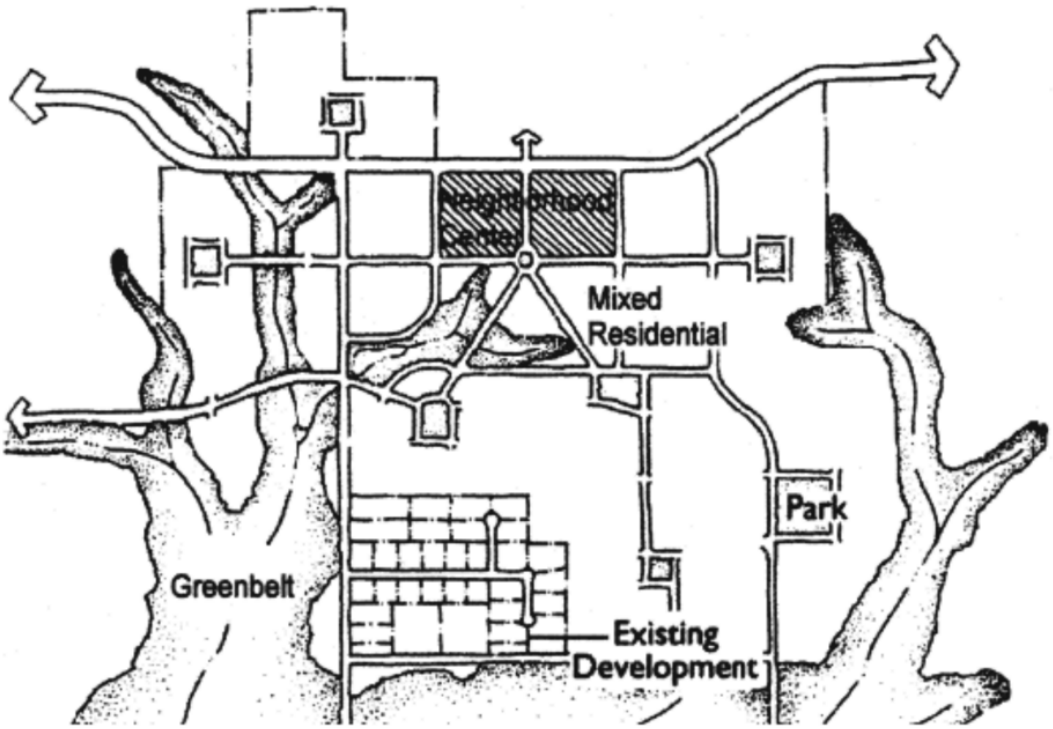


FIGURE 1
OPEN SPACE PLAN

conservation. Caves are distributed throughout the world and are protected for many reasons including: habitat of endangered flora and fauna; rare minerals or unique formations; important sites for hydrogeologists, paleontologists, climatologists, and geomorphologists; historic and prehistoric cultural resource values; recreation; and aquifer recharge protection (IUCN, 1996). Following are three examples of cave conservation in central Texas, including Lakeline Mall which resulted in an unusual amount of delays and exorbitantly high consultation fees due to negotiations with U.S. Fish and Wildlife Service relating to cave conservation efforts. Buttercup Creek and Village at Western Oaks also experienced delays and extra costs. However, these were not as significant as those experienced by the Lakeline Mall project. Buttercup Creek and Village at Western Oaks projects are examples of alternative designs that incorporate many of the philosophies of New Urbanism.

Lakeline Mall Legacy, Austin, Texas

Lakeline Mall, a 116.0acre site in northwest Austin, was purchased by Simon Property Group in 1986. The Austin area was at an apex of a growth boom in the 1980s causing rapid urbanization and development over an environmentally sensitive karst region known as the Jollyville Plateau. Caves were found on the proposed mall property, but they were not considered significant to recharge of the local aquifer because they were found within an isolated remnant of Edwards Limestone no longer hydrogeologically connected to the Edwards Aquifer. Because of the perceived insignificance of the caves, plans for development and the development approval process continued. However, federally listed caveadapted invertebrates were found in late 1989.

The U.S. Fish and Wildlife Service notified Simon Property Group of the presence of the listed species and indicated that continued development of the mall could result in an illegal "taking" of a federally protected species. The "take" of a federally listed, threatened, or endangered species is prohibited under Section 9 of the Endangered Species Act of 1973. A "take" is defined as the killing or harassment of a protected species or the alteration of an essential habitat used by a protected species.

In early 1990, Simon Property Group initiated a long and arduous incidental permitting process. To gain the right to develop about 62.0 acres of land within the range of the protected invertebrates, Simon Property Group ultimately agreed to purchase 234.0 acres of land for a preserve, provide funds for managing those preserves, contribute funds to the regional Section 10(a) permitting process, and fund a 10year cave research program. The cost of this undertaking was very high, both in dollars and time. Finally, in 1992, Simon Property Group was issued the first 10(a) permit in the Albuquerque Region of the Fish and Wildlife Service, a full two years after the discovery of Lakeline Cave, and about six years after purchase of the property. More delays and financial losses followed the 10(a) permit due to loss of financing and economic decline, among other problems. The whole process resulted in five years of delay and a cost of several million dollars that was amplified by the unexpected discovery of federally protected species and failure to plan ahead for cave conservation. However, the mall finally opened for business in late 1996.

Buttercup Creek, Cedar Park, Texas

Buttercup Creek includes a preserve system that avoids impacts to known populations of federally protected cave-adapted invertebrates via a Section 10(a) Permit. Figure 2 shows the overall Buttercup Creek design. Figure 3 shows a photograph of one of the cave preserves. Although Buttercup Creek experienced delays and added costs, these were not as significant as those experienced at Lakeline Mall because of significant forethought with regard to cave conservation.

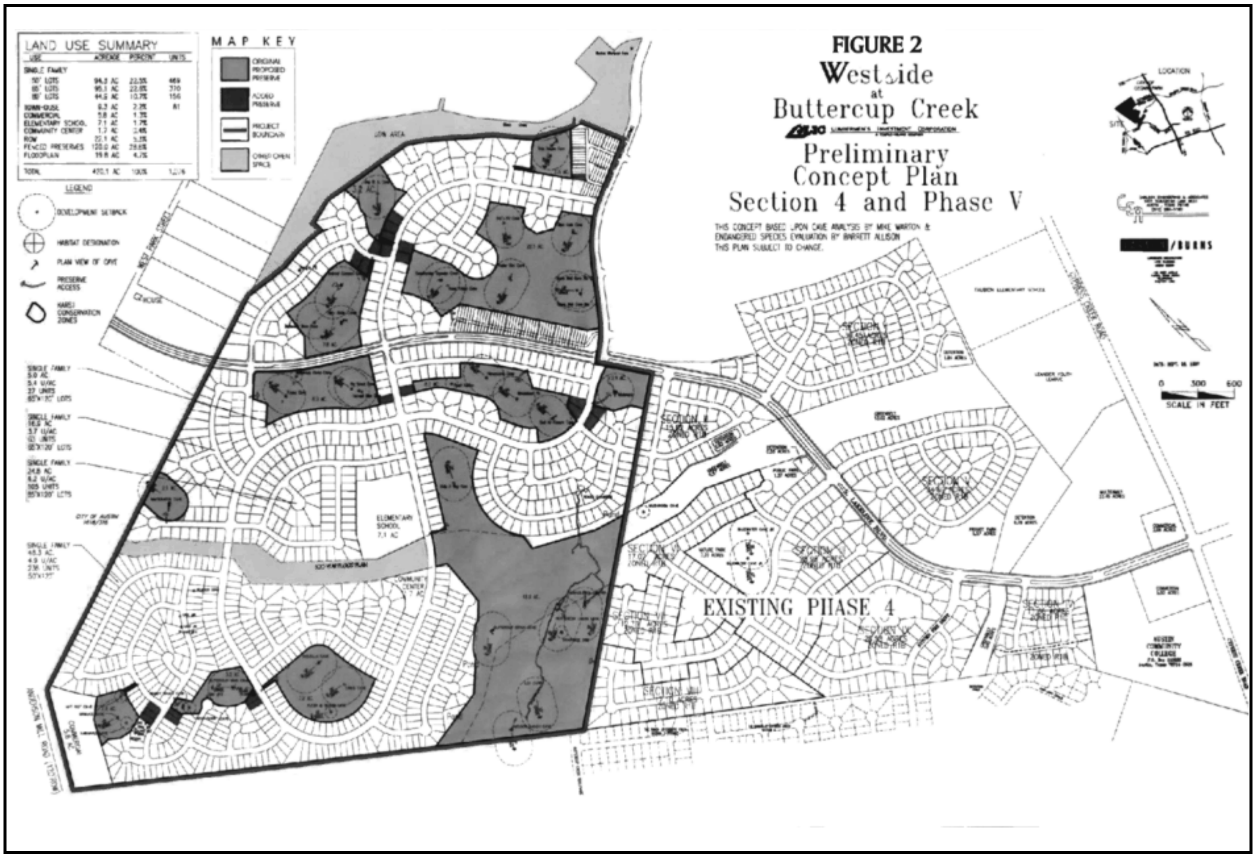
Buttercup Creek includes at least 12 separate cave preserve areas (totaling 132.7 acres). The preserve shape and size are based on catchment areas, topography, and subsurface extent of each cave. Additional floodplain greenbelts, totaling 33.4 acres, provide open connections between several of the cave conservation zones. The Buttercup Creek Habitat Conservation Plan focuses on complete avoidance of a take of a listed species or species of concern to the extent that is reasonable. The Plan includes the continuation of responsible development practices and karst conservation measures that are a regular practice of this developer, Lumberman's Investment Corporation. The Plan also includes plans to minimize and mitigate any potential indirect impacts on any caves or protected species. By distributing educational material, Lumberman's Investment Corporation encourages residents to help keep Buttercup Creek an environmentally aware and aesthetically pleasing place to live.

The preserve system is based on longterm monitoring and extensive geologic and hydrogeologic studies. Cave conservation zones are deeded to the City of Cedar Park for conservation management. All significant cave entrances with protected species or species of concern are gated and fenced to prevent unauthorized access or entry. Only restricted recreational use (hike or bike trails or picnic areas) is allowed except within sensitive conservation zones. No public use or access is allowed in the more sensitive zones. Urban runoff is diverted or naturally treated near cave conservation zones. Additional sandy loam soil cover is placed in yards and landscaped areas adjacent to cave conservation zones for enhanced retention and absorption of fertilizers, pesticides, and other common constituents.

A plan provided to all contractors handles issues such as construction period erosion and siltation management; additional measures and protocols for storage, use, and spill containment; and countermeasures for constructionrelated chemical and petroleum products. Natural vegetative buffers are maintained along the floodplain of Buttercup Creek. Surface water or non-point source drainage flows from streets and parking areas are diverted to treatment systems or are discharged downgradient of the cave conservation areas. Impervious cover is limited to about 30% or less.

Village at Western Oaks, Austin, Texas

The Village at Western Oaks subdivision is located over the environmentally sensitive Ed-



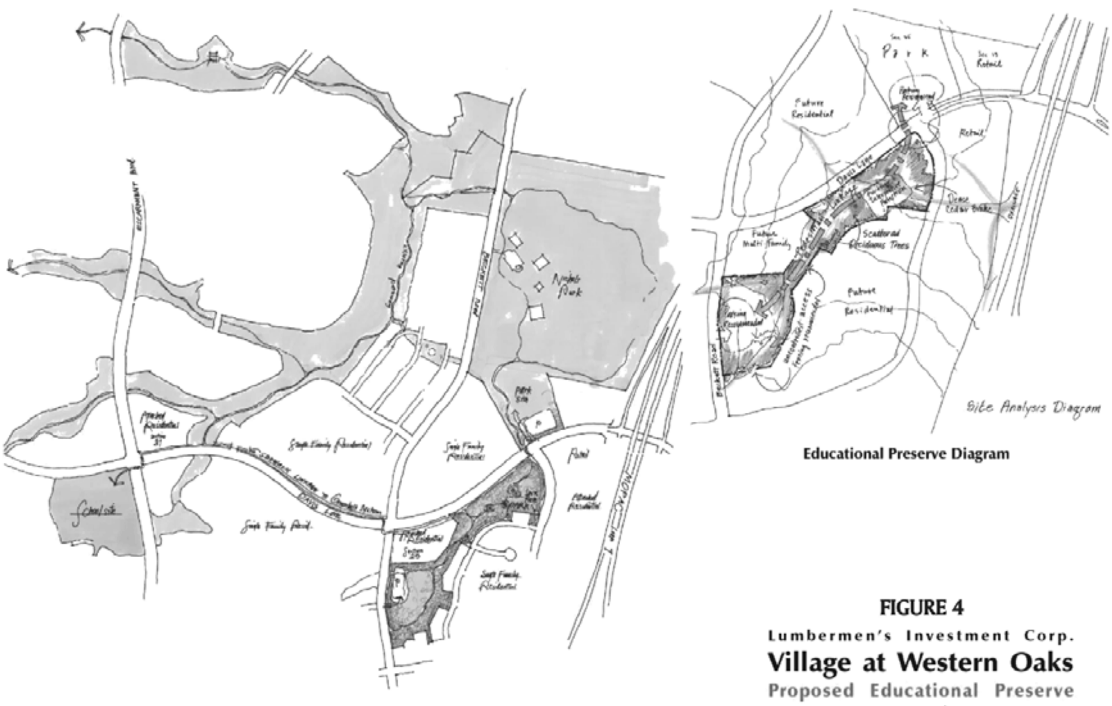
wards Aquifer Recharge Zone. Prior to development, Lumberman's Investment Corporation identified areas critical for aquifer protection, such as creeks, drainage areas, and point recharge features. Those features are protected within a generous greenbelt and park area. Lumberman's Investment Corporation put a significant amount of effort into Village at Western Oaks preserve system to avoid impacts to caves and the Edwards Aquifer. Figure 4 shows the Village at Western Oaks Open Space Plan. Village at Western Oaks experienced few delays related to cave conservation. Preplanning eliminated the need for time-consuming negotiations with state and local governments.

Lumberman's Investment Corporation also practices prudent environmental conservation in the design and implementation of landscaping, pest management, and water conservation throughout maintained public areas of the subdivision. These practices include the use of native and xeric landscaping, minimal use of lawn chemicals, and water conservation measures including rain cutoffs for automatic sprinklers and lowevaporation loss irrigation systems. Vegetation buffers and wet ponds filter surface water runoff before it reaches caves.

When completed, Village at Western Oaks will include an educational cave preserve with four caves, an information kiosk, hiking trail, and interpretive nature signs (Figure 5). These areas will provide a common green area where neighbors can meet and interact. These parks are within walking distance of most residences, creating a more walkable environment.

The shared goals of cave management practices for Buttercup Creek and Village at Western Oaks subdivisions included cave gating and fencing, limited accessibility, and routine inspections. Recreational use (hiking trails or picnic areas) is permitted over less sensitive areas. Vegetation and habitat management plans define conservation practices for property managers. Integrated pest management plans to reduce chemical and fertilizer uses are common to these projects. Lumberman's Investment Corporation distributes educational materials to residents and homeowners to teach them about the benefits of reducing harmful constituents in yard runoff; proper storage, use, and disposal of household products; and use of native landscaping or xeriscaping to reduce the need for water and chemicals. Homeowners take a role in protecting surface water runoff that gives them an opportunity to protect nearby caves and their aquifer, while maintaining a successful lawn or garden.

FIGURE 3
BUTTERCUP CREEK CAVE PRESERVE



Educational Preserve Diagram

Village at Western Oaks Open Space System

FIGURE 4
Lumbermen's Investment Corp.
Village at Western Oaks
Proposed Educational Preserve
BOSSE & COMPTON

Options For Development Near Caves With Protected Species

Regional Habitat Conservation Plan Participation

Regional habitat conservation plans are regional permits that set aside land to ensure the overall survival of protected species while ensuring continued economic growth. Habitat conservation plans reduce the costs incurred by landowners by limiting the need for consultation and costly permitting. Habitat conservation plans promote a regional conservation view that is generally more effective than piecemeal conservation efforts.

The Balcones Canyonlands Conservation Plan is an example of a regional habitat conservation plan (Section 10(a) permit). The Plan was developed in Travis County, Texas, to allow landowners to participate in the county-wide conservation of endangered species, while allowing them to use land that may have otherwise been undevelopable. The Plan was developed to balance economic growth and the preservation of habitats by setting aside 30,000 acres of protected habitat. Developers participate in this plan by paying fees ranging from $55 to $3,000 per acre. Participation is voluntary and is an alternative to an individual Section 10(a) permit that may take many years to complete and can be very costly.

Individual Section 10(a) Permit

A Section 10(a) permit from the U.S. Fish and Wildlife Service is required for development if all avenues for conservation have been explored and it is possible that development of the site will directly or indirectly affect a cave with federally protected species. Individual permits are often time-consuming and costly. Permits usually require mitigation or a donation of additional undeveloped land with similar species or characteristics. Individual cave management plans are usually required.

Individual Cave Management Plans

Development without impact to a cave with protected species can eliminate or reduce the need for negotiations or permits. Usually, this type of action requires a cave management

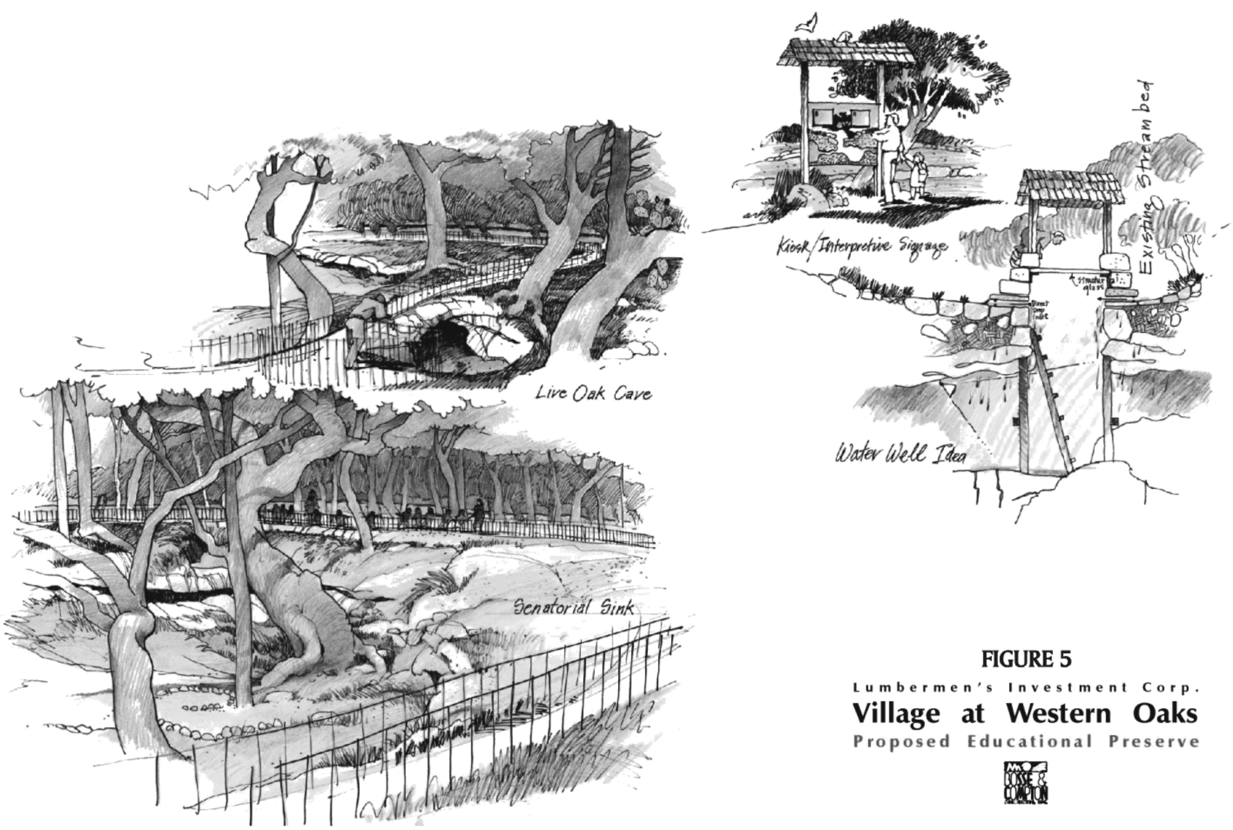


FIGURE 5
Lumbermen's Investment Corp.
Village at Western Oaks
Proposed Educational Preserve

plan. Cave management plans are used as guides to prevent possible endangered species violations and provide conservation, while incorporating setbacks into development plans from the very beginning. Section10(a) permits usually require cave management plans as well.

A landowner may elect to dedicate the conservation zone and cave to a public management entity. In Texas, cave management may be contracted out to such organizations as the Texas Cave Management Association, the Texas Cave Conservancy, or another approved management entity such as the Southeastern Cave Conservancy.

Management of a cave is ultimately the responsibility of the property owner. The environmental consultant establishes guidelines that include cave gating and fencing to protect cave contents and control cave access. Educational materials are prominently displayed so that schoolchildren, consumers, or residents know that considerations have been made to protect caves, cave species, or an aquifer.

Conclusion

Prudent environmental conservation in the design of landscaping, pest management, and water conservation throughout common areas is not only practical, but imperative for livable communities. Positive practices include mixed-use design, centralized commerce, generous parks or greenbelts, accessible public transportation, native and xeric plants, rain cutoffs for automatic sprinklers, lowevaporationloss irrigation systems, integrated pest management plans, and educational programs for new residents. Greenbelts or cave conservation areas should include educational kiosks where people can read about the extra effort put into planning the environmentally aware community. A balanced environment can support a strong economy by providing centralized commerce, attractive neighborhoods, communal green space, transportation options, and opportunities for community involvement.

Green plans are longterm environmental strategies that ensure a higher quality of life for present and future generations. There is no standard green plan; each community can adapt the basic principles of green planning to its own needs and conditions (RRI, 1999). Guidelines include: reduced lawn size, corner stores, narrow streets, eliminating culdesacs, setting limits on developed areas, increasing parks and green space, hiding the garage, mixed housing types, planting trees curbside, leaving as many existing trees as possible, planning for mass transit, linking the neighborhood to work, creating town centers, shrinking parking lots, using smaller outdoor lamps, and providing green space at the edges or center of communities (Nelessen, 1994).

A vibrant, balanced community environment can support a strong economy by providing centralized commerce, attractive neighborhoods, communal green space, transportation options, and opportunities for community involvement. Lower crime rates and higher qualities of life are found where greenbelts or parklands are within walking distance (RRI, 1999). Caring for the longterm health of the environment is a commitment to a higher standard of living. If land developers show that they are committed to the longterm health of the environment, they are showing commitment to a higher standard of living. This is the most effective form of advertising. Developers can increase the appeal of a community, save money, and prevent unnecessary delays by planning ahead for cave conservation and helping residents keep the environment and the community healthy.

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About the Authors

Lee Sherrod, author of the forward, is a cofounder of Horizon Environmental Services, Inc. and specializes in terrestrial and wetland ecology, endangered species, and environmental assessments. He has more than 18 years of experience in the technical applications of these fields and the regulatory aspects of project compliance procedures. He is a recognized expert in wetlands issues and is certified as a "Professional Wetland Scientist" (No. 000155) by the Society of Wetland Scientists Certification Program, Inc. He has directed hundreds of wetland assessment and permitting assistance projects throughout the southern United States that have included jurisdictional wetland delineation; aerial photographic interpretation and mapping; habitat creation, enhancement and reclamation; and shoreline stabilization and mitigation planning. Mr Sherrod has been qualified as an expert witness in federal court regarding wetlands and endangered species issues and has been regularly invited to give presentations and lectures on these issues at conferences and universities. He has been a longstanding steering committee member of a state organization comprising scientists and regulators to further endangered species research and conservation efforts. He has successfully represented private applicants in Section 10(a)(1)(B) permits (Endangered Species Act incidental take of endangered species) issued in the Albuquerque Region of the U.S. Fish and Wildlife Service. He is Habitat Evaluation Procedure certified and has participated in many Habitat Evaluation Procedure analyses, performing the computer analysis for many of these studies. He brings an enormous amount of practical experience and expertise to any project to simplify environmental assessment and regulatory permitting assistance, particularly as related to wetlands and endangered species.

Kristin Miller, author of this paper, is a Registered Professional Geologist (Mississippi Registration #0523) and Environmental Specialist. Ms Miller has more than eight years experience in consulting and seven years experience at the Texas Natural Resource Conservation Commission and Texas Water Development Board. Ms Miller has performed more than 250 geological assessments to complete Water Pollution Abatement Plans within the Edwards Aquifer Recharge Zone for review by the the Texas Natural Resource Conservation Commission. Ms Miller specializes in geologic assessments, cave studies, karst investigations, cave management plans, biological sampling, integrated pest management, endangered species habitat assessments, population surveys, project management, Phase I Environmental Site Assessments, and environmental permitting assistance. She is a member of the Geological Society of America, Austin Geological Society, and University of Texas Grotto. Ms Miller has been caving since 1982, where she began as a tour guide and part-time volunteer, surveying Inner Space Caverns in Georgetown, Texas. She is authorized to conduct biological sampling and is listed on Horizon's Scientific Collection Permits. Ms Miller is an ASTM-trained Environmental Site Assessment Professional and provides due diligence investigations regarding the potential for hazardous substance liabilities. She provides technical, biological, and geological support and on-site investigations for FERC documentation and Environmental Impact Statements throughout Texas and Louisiana.

The Management of Logsdon, Hardin, and Swirl Canyon Caves—A Cooperative Effort Between the Nashville Grotto and the Southeastern Cave Conservancy, Inc.

William Overton
NSS 40961
1999 Chairman,
Cave Property Management Committee
Nashville Grotto

Abstract

During the early 1990s, Dr William R. Halliday donated approximately 40 acres of land in Hart County, Kentucky, to the Nashville Grotto of the National Speleological Society. The property contained Logsdon Cave and was designated by the grotto as the William R. Halliday Cave and Karst Preserve. The grotto then formed a subcommittee to manage the property.

From 1997 to 1998, changes in property ownership of two caves in Davidson County, Tennessee, presented an opportunity for the Southeastern Cave Conservancy, Inc. to lease and the Nashville Grotto manage Hardin and Swirl Canyon Caves. Hardin Cave is a popular three-mile-long cave in the western part of the county and has been the scene of many parties. Swirl Canyon Cave had been closed to caving for many years and is the second longest cave in the county. The area near both caves is actively being developed as Nashville continues to grow. The property owners were approached and agreed to lease their properties to the Southeastern Cave Conservancy, Inc. The caves were gated at the request of the owners. The Nashville Grotto also leased Logsdon Cave to the Southeastern Cave Conservancy, Inc. and is now managing all three caves for the Conservancy. The caves are open to scientific, educational, and recreational caving on a permit basis.

What would you do if someone gave you a cave?

A cooperative effort between the Nashville Grotto, the Southeast Cave Conservancy, and private landowners began with a generous gift in 1992 from Dr William Halliday. Thirty-eight acres of land with a multi-drop vertical cave on it soon became a reason of concern for the members of the Nashville Grotto. With the open pit entrance and an old wooden ladder extending several feet above the pit entrance, grotto members soon realized the great liability of owning a cave.

After just a few trips to the cave site, it was obvious attention to safety was going to be of utmost importance to the members of the Nashville Grotto. The very nature of the cave, small passages, tight winding crawlways, and numerous vertical shafts and open air pits, would make this cave attractive to hard-core vertical cavers. Bolts had to be set as exploration continued deeper into the cave. The concerns of the grotto turned from excitement of owning a deep vertical cave to liability issues.

A rescue would be almost impossible if an accident ever occurred in Logsdon Cave. The logistics of a rescue would be beyond imagination. What would the liability of the Nashville Grotto be? It was apparent we needed a user agreement to ensure only qualified cavers would be allowed into the cave. The Logsdon Committee was established and the beginning of the Nashville Grotto Cave Property Management was begun. Members to the committee were elected, but the job was only starting.

The first user agreements were difficult to write. No one realized just how difficult a task this was going to be. Just how could the committee protect the grotto and allow guests to explore cave? After two years and multiple attempts, we produced a 38-page document covering everything from requiring a Nashville

Grotto guide to trash removal. It was just too much for anyone to want to go to our cave. In 1996 it was decided the committee could use a little help and options were looked into. A new organization to the caving community had been heard of and the Logsdon Committee checked out the actions of the Southeastern Cave Conservancy Inc.

The Southeastern Cave Conservancy had purchased half a dozen caves, leased almost as many, was raising money to acquire more, and was obviously doing something right. What was it they were doing that the Nashville Grotto wasn't? After all, we owned the land outright and only needed to manage it. That is much easier than it sounds. Investigation by the Logsdon Committee found the Conservancy had the ability to put liability insurance on the caves they owned and leased. That was the final deciding factor that convinced the Logsdon Committee to lease the property the Nashville Grotto owned to the Conservancy, with the provision the Nashville Grotto would remain the managing party and have the right to make the final decisions about their property. The next months were spent working out details and answering concerns of both the Conservancy and the Nashville Grotto. Questions like how would the access to the cave be established? Just how would we determine who would enter the cave? Logsdon Cave was on property located near the very large Fisher Ridge Cave system and many cavers had hopes of connecting the two. With big air movement coming from the entrance of Logsdon Cave, digs were always going on. The number of request for trips to Logsdon Cave was growing.

The Logsdon Committee had a user agreement they had set up as a plan for their property and, with a few minor changes, the Logsdon Committee decided to use this as the base document and fine tune it for Logsdon Cave's own needs. Once access plans were established the cave almost ran itself.

Swirl Canyon

Shortly after the plans were instated for Logsdon Cave, a committee member heard about an unhappy cave owner in the Nashville area. Charles Donan owned a parcel of land with the second longest cave in Davidson County. Students from a near by high school would cut classes and hang out at the cave. The neighbors had complained to him and he wanted to close the cave. He didn't care about being hassled with people wanting to visit his cave.

Mr Donan was approached with a plan to lease his cave to the Southeastern Cave Conservancy, Inc. He was surprised such an organization even existed and was delighted to turn over his headaches to someone else. The agreement was to clean up the sink and build a gate to stop the high school students from entering the cave. We had to maintain the property and keep it free from trash and cut the grass to have an access road and a parking area.

Now that we had another cave to manage we needed funds to build a gate. We decided to hold a fundraiser. The Nashville Grotto was the sponsor of the SERA Cave Carnival in 1998 and they agreed a percentage of the SERA profits would be used to buy materials for a gate at Swirl Canyon Cave. The labor was to be from volunteers and a gate was to be.

In March of 1998 a small group of grotto members went to Swirl Canyon and inspected the entrance to determine the best location for a gate and try to determine a cost of materials for the gate. A board member from the Conservancy, Geary Schindel, contacted local contractor and avid caver, Bill Overton, to engineer and design a gate. The task proved to be difficult to do in such an odd entrance. Due to the fact the stream entrance fills with run off during heavy rains and the cave entrance sumps, a typical gate wouldn't be feasible. A riser of several feet would be required to allow water to enter the cave while keeping the door of the gate free from debris being washed in during times of high water.

A seven-foot horizontal circular design was drawn up with a three-foot vertical wall at the narrowest section of the sink. This was incorporated to keep the gate above the high water marks. The door to the gate was designed to swing into the cave and transform into a set of steps allowing easy access from the raised platform into the cave.

The gate was built in late September 1998 with the help of six volunteers. Large numbers are not always required but a larger compliment of help will make the construction of any project of this size go faster. The gate was constructed of four-inch angle iron a quarter of an inch thick. In most cases thicker steel is used but the short lengths did not require such heavy metal for strength. Thinner metal was used in an attempt to keep cost down. Since steel is sold by the pound several hundred dollars were saved. spacing between the bars of 5¾ inches was used to allow for bats that might enter the cave. No bat colonies live in Swirl Canyon due to the flooding waters when it rains. The crossbars were attached to the vertical walls using three-quarter-inch hardened rolled steel cut into one foot pins. Six-inch-deep holes were drilled into the rock walls using a rotary hammer drill and the pins were driven into the holes. Removal of the pins is almost impossible.

The crossbars were welded first, then the top bars forming the frame for the door, and last the crossbars that made up the actual gate. The door was built on site and installed using a simple hinge system and conventional locking unit. Swirl Canyon Cave is not a well known cave and it was felt attempts to defeat the gate would be minimal.

The door turned out to be heavier than first thought so the use of a counter balance was incorporated to help make the task of closing the door easier. A foot plate was installed on the counter balance to allow one person to apply a downward force on the lever to raise the door up while a second person put the lock in place. The use of a simple lever turned the almost impossible task of locking the gate into a most pleasant one, requiring only a few seconds of time and almost no effort. A pin was welded to the side of one of the cross bars to hook on a chain attached to the door, keeping the door from swinging into a neutral position and restricting the entrance of the cave when the gate is open.

The crossbars on the door were turned perpendicular to the gate to create the steps of the ladder. Care was given to build a door with a large enough dimensions to allow a rescue skidder through in the event a rescue had to be preformed in the cave.

The Swirl Canyon Cave gate was built in two very long days of 15 hours each. The designing of the Swirl Canyon Cave gate took weeks and the planning and preparation for the gate took several months. The seven volunteers who did the actual work worked wonders. In over a year of operation the Swirl Canyon Cave gate has not been violated.

Hardins Cave

Hardins or Junkyard Cave is a totally different situation from the other caves we manage. Hardins Cave is the longest cave in Davidson County at just over three miles. Hardins or Junkyard Cave was placed on the Tennessee Superfund clean up in the early nineties.

The former owner of the property had allowed the storage of hundreds of 55-gallon drums on the property. The state demanded a cleanup be preformed before the land could have any improvements or even be sold. The Tennessee Department of Transportation constructed a new highway through the middle of the old junkyard site and divided the cave entrance from the area where the drums were stored, helping keep the cave safe from any contaminants. The site was cleaned and finally removed from the Superfund list and placed for sale. Thanks largely to the devoted efforts of a few the Nashville Grotto members, Hardins Cave is the only Tennessee Superfund site to ever be cleaned and removed from the Superfund list. The quality of the air and water in the cave today is well with in the tolerances established by the Environmental Protection Agency making this a truly unique cave location.

When Nashville businessman, Barry Walker, heard of the property being for sale, he purchased it for a development he planed to build and another friendship was formed. Barry Walker has developed several unique sites in and around Nashville including the revamping of an old automobile factory, the Marathon Motorcar Company.

Barry was approached by members of the Nashville Grotto and was ask what he planed to do with the cave on his property. At this point he didn't even know about the existence of the cave and wanted to see his newly purchased cave. On his first trip to the cave several members of the Nashville Grotto and Barry found a pair of bats tied together with a piece of string and left to die. Barry was shocked at the sight of this act of cruelty and almost immediately agreed to lease the cave with the provisions this kind of act would never happen again in his cave. He also requested the word "Junkyard" be dropped from the name. Once again the wheels were in motion and another cave would soon become the property of the Southeastern Cave Conservancy, Inc. and the Nashville Grotto would become the managers. A contract was drawn and, after both parties had agreed, a signing ceremony was held at the February 1999 winter business meeting of the Southeastern Cave Conservancy. During the process of working out the details, the Nashville Grotto as an act of good faith and as a vote of confidence, engineered and constructed the gate on Hardins Cave.

This gate would prove to offer a completely different set of concerns and problems. Hardins Cave is the longest cave in Davidson County and at over three miles is not a small cave by anyone's standards. The cave is also well known by locals and has always had a large number of visitors yearly. With such a well known cave and party location, vandalism was our largest concern. And if that wasn't enough after the new highway was built the cave entrance is only 150 feet from the road and in plain site of the traffic on Highway 12.

The area near the entrance has been used as a dumpsite for people and had a wide collection of debris ranging from a water collection tank to used tires and everything in between. In all, seven truckloads of trash were removed just to get the entrance area cleaned. The cave itself has had numerous cleanup trips to remove the bulk of the trash, with trips still being held today. The cave, though not completely clean, is much better than when the Conservancy and Nashville Grotto took control on February 13, 1999.

Publicity wasn't a problem as Hardins Cave has been on the local news several times. With three rescues preformed at Hardins Cave in the 1990s, the local papers and television stations are very familiar with the cave. The local newspaper and one of the local television stations came the day of the gating for an interview. Both ran favorable stories about the gating actives of the Nashville Grotto and how it would make the cave a safer place for everyone involved. The power of positive publicity can never be underestimated.

The construction of the Hardins Cave gate was held on December 5, 1998, a rainy day that produced a fast-flowing creek into the normally dry entrance crawl. Again Bill Overton was contacted to design and engineer the gate. The gate was constructed about 60 feet inside the entrance of the cave. This was the first usable location in the cave for a sturdy gate. With the fear that locals might try to use force to remove any gate built, we felt the distance would assist in keeping the gate from harm. The gate was built in a narrow section of the cave approximately six feet wide and ten feet tall.

The team of volunteers consisted of members of three Tennessee grottos, Nashville Grotto, Cumberland Valley Grotto, and Central Basin Grotto. Volunteers had come from as far as Alpine, Tennessee, about 180 miles away. A work site was set up, steel unloaded, and the gate was started. Placement of the base of the gate was done and a framework of steel rose from the six-inch angle iron. Three-foot pins were driven into the floor of the cave below the threshold of the gate. Later 1,100 pounds of concrete would be poured and six drain holes would be placed. The work went steadily for ten hours and the Hardins Cave gate was built in one day. The door of the gate was built off site due to the concerns of security for this cave.

The door was built at a steel fabrication facility owned by one of the oldest and largest locksmiths in Nashville. West End Lock Company donated time materials and years of knowledge to assist the Grotto in producing one of the most secure and solid gate doors I have ever seen. With such a well known cave and one that has been actively used for so many years, closing off this cave could prove to be difficult if not down right impossible. That is why the services of West End Lock Company were enlisted.

A chain is only as strong as its weakest link. In most cave gates the lock proves to be the weakest link. In the Hardins Cave gate special attention was given to the locking mechanism. For the Hardins Cave lock a high security Medeco controlled keyway, drill resistance, pick resistance, bi-axle, interchangeable core mortise cylinder lock was recommended. When absolute key duplication controls are necessary, nothing less will do.

A special deadbolt locking mechanism was used as well, one that is almost impervious to cutting by a torch or saws and is extremely difficult to damage by ordinary means.

The combination of these two items wrapped in a ½-inch-thick steel housing resulted in an almost bombproof lock. What does this all mean? In most cave gates the gate itself is usually strong enough to withstand any assault, but the lock? Well most locks only require a local hardware store to duplicate the key and the entire gate has been compromised. The locking system used on the Hardins Cave gate has a very special key. A key that can only be duplicated at one place in the entire United States. No other hardware store, K Mart, or for that matter locksmith shop has a blank to cut the key. Without a photo ID and your name on a signature card to compare to, no one gets a copy of the key cut, and I mean no one. Plus the controlled keyway makes the distribution of the keys for Hardins Cave up to the managing committee and only the committee. In the event a key is lost or stolen, the core can be changed, on site, in a matter of a few minutes. This allows the lock to be maintained with less effort in less time and more often. With a special key called a change key or site key anyone can remove and replace the interchangeable core with a new one. The managers of Hardins cave have three such cores, two for general lock maintenance, and one in the unlikely event a key is lost or stolen.

It should be mentioned that if not for the generosity of many businesses throughout the Nashville area the construction of these gates and the completion of these projects would not have been possible. The use of a portable generator/welder from Haileys Harbor Shipping Company. the use of a 20-foot flatbed trailer large enough to haul the steel from Mid Atlantic Products, the use of a steel fabrication shop for building the gate doors and lock from West End Lock Company, and the use of the many tools, lights, and cords required for the construction of the gates from The Overton Group.

Also the volunteer efforts of the grotto members constructing these gates brought both gates in under the estimates cost by almost 30 percent. The leftover funds have been used to manage the properties without using funds from the grotto.

Management of Properties

In 1998, with the acquisition of so many caves and surrounding property, the Nashville Grotto felt the need to change the Logsdon Committee name to one that described better the duties of the committee. They decided to name the committee the "Cave Property Management Committee" and add two more members, bringing the total to seven. With the new name came new duties. Now there were three cave properties to manage, all with different requirements. Hardins Cave would have much more requests for visitation and would need tighter controls. Swirl Canyon is lesser known and has had very few requests for access while Logsdon Cave only sees vertical cavers and only a few each year. With the caves spread over such a wide area, maintaining open communications with every property was difficult. A phone line was set up and a voice mailbox was developed as the main means of access to the cave properties. This number is posted at all three cave locations.

With the voice mail a single person can be reached by anyone wishing to gain access to any of the caves. The voice mailbox also allows the Nashville Grotto and the Cave Property Management Committee to stay in contact without posting a private individual's phone number, this keeps the members from being harassed by an irate local who has been denied access to the cave. The voice mail was set up to page a pager whenever a message is left so a committee member will know almost immediately when a request is made for access. The pager is left with different people depending on the schedule of the committee. Along with voice mail, an e-mail account was set up as well. With today's fast pace and the time constraints of individual committee members these two means of access have proven to be most adequate.

Meetings are held on a quarterly basis and are kept upbeat, productive, and entertaining with interesting locations, concise agendas, and meticulous records, all kept available to any grotto member in good standing. While outings don't always have to be at caves, most are designed to promote cave conservation and management. The Southeastern Cave Conservancy, Inc. and the Nashville Grotto are currently working on other cave properties in and around the Nashville area and hopes are high by both parties to keep this friendship active for may years to come.

Trips to the caves include educational trips for the Tennessee State Parks; recreational trips like a birthday party, home schooling, local church groups, or the Boy Scouts of America; numerous NSS members visit our caves; and even rangers at a local state park use our caves as a model for how a cave should be properly managed. Scientific trips for local research are currently being conducted at two of our caves, and even a detailed, grade 5 map is being drawn for Swirl Canyon Cave.

Now the caves are running smoothly and most trips to the properties are to do general maintenance. The time has come for the volunteers to enjoy the fruits of their labors. Trips to cave properties include trash removal, gate maintenance, graffiti removal, and the general requirements any landowner has to perform: cutting the grass, removing fallen trees, and the never ending task of hauling off others peoples trash. We have even taken on the task of documenting the return of the natural inhabitants, the bats.

In conclusion, the cooperative efforts of the Southeastern Cave Conservancy, Inc.; the Nashville Grotto; and most of all the landowners of Swirl Canyon Cave, Hardins Cave, and Logsdon Cave have taken the dreams of a few people and turned them into a reality of successful cave management, working to secure the future of caves in middle Tennessee and southern Kentucky.

So, what would you do if someone gave you a cave?

You would conserve it.

Pigeon Mountain
Thirty Years of Noninterference

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Abstract

Cave Management by noninterference has been the policy of the Georgia Department of Natural Resources for the last 30 years on the Pigeon Mountain Area. As a state-owned wildlife management area, multiple use is encouraged as long as it does not conflict with the primary purpose of the site. Caving is just one of the many activities on the area. Pigeon Mountain is part of the Cumberland Plateau and caves occur in abundance. Ellisons Cave, the deepest in the Eastern U.S., draws cavers to its deep vertical shafts while Pettyjohns Cave with its multi-level muddy passages draws 10,000 visitors per year. Cave use data from a simple registration process has been in place since 1980 and shows remarkable trends. Management problems have been minimal and partnerships with cave groups have proven to be beneficial.

"We are the government and we are here to help." Cave Management and noninterference means that only the most minimal intrusion into the recreational cavers' experience is allowed. Cave locations are not disclosed, no cave maps are displayed, and there are no signs directing visitors to the caves. Bureaucratic rules must be extremely simple and only user monitoring takes place.

Pigeon Mountain located in northwest Georgia is a projection of the Cumberland Plateau and over 40 known caves occur in this site. The Georgia Department of Natural Resources, Wildlife Resources Division, began purchasing this land in 1970 and currently owns over 14,000 acres. The area is managed as a wildlife management area with its goal of wildlife enhancement and the protection of scenic, geologic, and biotic resources. Multiple use is allowed as long as it does not conflict with the primary purpose of the area. The area is not a park, there are no developed facilities, and access is permitted 24 hours per day year round. Staff consists of one ranger. Approximately 100,000 people visit the area each year with caving as one of the categories of users.

The two caves that receive almost all of the use are Ellisons and Pettyjohns Caves. Ellisons Cave is the deepest cave in the Eastern United States at 1,067 feet total depth. Numerous vertical shafts are attractive to the experienced vertical caver. Fantastic Pit at 586 feet is the deepest, followed by Incredible Pit at 440 feet. The cave is 12 miles long and multiple entrances actually allow a "through the mountain" trip. The cavers can enter on the east side of the mountain and exit on the west. The cave was known to early settlers but exploration past the first thousand feet of known cave began in 1969. The walk to the entrance is a one-mile hike with an elevation gain of over 800 feet. Pettyjohns Cave is 100 yards from a gravel road. Known since a publication in 1837, Pettyjohns has one entrance and it is the highest point in a system of 240 feet of depth with a length of 6.5 miles. Pettyjohns is known for its wonderful brown mud and its jungle gym climbing passages. Places like the pancake squeeze, tobacco road, the echo room, Z bends, and the waterfall entice cavers into the far reaches of Pettyjohns.

Cave management by the Department of Natural Resources simply did not exist prior to 1977. The Georgia Cave Protection Law (OCGA 12-4-143) was enacted in 1977 providing legal protection to Georgia's caves. Pigeon Mountain was a remote place with little public use,a small network of jeep roads, and no cave related problems. That all changed on March 3, 1979, when a professor and several college students were trapped by high water in Anderson Spring Cave. The resultant rescue effort and media event prompted a new look at cave management by the Department of Natural Resources. Being primarily wildlife professionals, several cave organizations and cave experts were consulted for formation of a cave management plan. Several options were explored ranging from no access with cave gates to simply do nothing and see. Supervisor Collins and Area Manager Rogers decided to begin a simple caver registration program similar to their hunter registration system. This system, which began in 1981, consisted of simply filling out a card and depositing it in a box located near the cave entrance or trailhead. This system went unchanged until the form was revised in October of 1994 to actually make the process easier for the visitor.

These cards can provide valuable information to the cave manager. Besides the usual name and hometown a few other pieces of information are asked. A blank for NSS yes or no indicates affiliation. Cave rescue is a complex problem and the overdue caver is a common problem. A phone number, vehicle description, planned itinerary, and planned exit time are extremely valuable information to have when dealing with an overdue caver. The perforated checkout stub can be matched by number to the cave card and show that the party has actually left the cave. With the vehicle description, the parking lot can be checked for the missing party. This simple system can prevent endless cave searches or simplify them immensely. Cards are collected monthly and tabulated. A total number of visitors, a total number of trips, percentage of trips indicating yes on NSS, are the only data currently evaluated.

What do the cards show us? Pettyjohns Cave has only 15% of trips indicating NSS affiliation. Yet Ellisons Cave shows the inverse with 73% indicating yes. Visitation trends and totals are most interesting. (These indicate actual card counts. Standard trail registration percentage is 60% when the observer is undetected. If caver numbers are enlarged by 40% the visitation reaches staggering proportions for a wild cave. In data collected by very visible volunteers at the Pettyjohns site a 74% registration rate was observed so the 60% figure is reasonable.

What cave management problems to these numbers divulge? At Pettyjohns actual polishing of the entrance has occurred. The surface looks like a polished grave stone. If each visitor leaves the cave with an average of one pound of mud smeared on his body the average yearly mud removal can be calculated in tons. At Pettyjohns the typical caver has a flashlight and no other equipment. In fact not everyone entering the cave has a light. Observations show that about 85% of the people entering the cave have a light, only 10% have a helmet. With their unfamiliarity with the technology of caving, these cavers are also unaware of the conservation needs of caves. Litter, graffiti, and alcohol use are common though illegal. One benefit of all of these people is an expansion of the food base for cave creatures. These problems are addressed by education efforts at the sign-in kiosk. NSS brochures are kept available. Clean up trips by cave clubs pick up litter and scrub the walls. A unique approach is to place a gasoline generator near the entrance and run heavy duty wire over a thousand feet into the cave to power a disk grinder with a wire brush attachment. The Southeastern Cave Conservancy, Inc. spent a total of 31 weekend days in an educational program in 1993 and 1994 that introduced cavers to responsible caving.

Ellisons Cave is protected by the technology required to explore its depths. Prior to 1993 long ropes were routinely left hanging or stashed in Ellisons. Knowledge of the "courtesy ropes" became widespread in the caving community. This practice was then prohibited, this limits trips now to people willing to drag a 600-foot rope up the mountain and into the cave.

It would seem that with all of the people going into Pettyjohns and the extreme nature of Ellisons that cave rescue would be an everyday occurrence. The truth is that rescue is rare. In Ellisons there have only been five rescue events since 1969. That is one every six years. Three were injuries, one was a search, and one was a body recovery. In this system the injury rate is one accident per 1,760 users. In contrast, the NOLS caving program shows one evacuation per 411 user days. Pettyjohns cave with its huge numbers of unprepared cavers should be a cave rescue nightmare but it is not. Since the cave card program began in 1981 there have been four rescues and no deaths. Three were falls requiring evacuation and one was assistance with a dislocated arm. This results in an injury rate of one per 9,629 users or once every 4.7 years.

In conclusion, 30 years of cave use on Pigeon Mountain has shown that a noninterference policy works. As a result a tremendous amount of recreational caving opportunity has been provided, the cave resource has not suffered unduly, safety has not been compromised, and taxpayer money has been wisely spent. Partnerships with cave organizations and cave experts has been the key to making this system work. The Department of Natural Resources would

especially like to acknowledge the help of the following:
Walker County Fire-Rescue Cave and Cliff Division
The National Speleological Society
The Southeastern Cave Conservancy, Incorporated
The Dogwood City Grotto of the NSS
The Chattanooga Grotto of the NSS
The Pigeon Mountain Grotto of the NSS
The Lost Mountain Grotto of the NSS
The Georgia Speleological Survey of the NSS

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CAVE USER REGISTRATION FORM
Pettyjohn's Cave

No. 1000

Fill out this form completely, do not leave spaces blank without explanation.

TOTAL NUMBER CAVERS THIS CARD ☐

NAME OF ALL CAVERS THIS GROUP____________________

HOMETOWN__________ NSS: _____ YES _____ NO

PHONE NUMBER ( ) __________

ENTRY DATE: ________ ENTRY TIME: ______ A.M. ______ P.M.

PLANNED FINAL EXIT TIME (and date if NOT same as entry date) ______ A.M. ______ P.M.

PLANNED ITINERARY WHILE IN CAVE (PLACES, ROUTES, SCHEDULES): __________

IMPORTANT __________
VEHICLE LICENSE NUMBER MAKE MODEL COLOR
(over)

Check Out Form - Pettyjohn's Cave
Please Deposit checkout form in box.

Final Exit Time: _____ A.M. _____ P.M.

ACCIDENT REPORT (List names of person(s) injured, type of injury, and location of accident):

No. 1000

Remarks: __________

IN CASE OF EMERGENCY CALL 911

IN CASE OF EMERGENCY NOTIFY:

____
Name and Telephone Number

____
Address

BY SIGNING THIS REGISTRATION THE USER CERTIFIES THAT:

He/She has read, and understands and agrees to comply with the rules and regulations and requirements for use of Pettyjohn's Cave.

He/She is aware of the hazards invovled in cave use, including serious injury or death.

He/She accepts reponsibility for the safety of self, and, if acting as the leader of a group, the individuals in the group; and relieves the State and its employees of any liability or responsibility of any kind as provided in the Cave Protection Act of 1977. (GA. Laws 1977, p.833, as amended).

He/She agrees to return to the cave Check Point Location and deposit a Pettyjohn's Cave User Checkout Form as soon as possible after exit from the cave.

Date:__________ Signed: ____________________

PIGEON MOUNTAIN CAVE USER REGISTRATION FORM

Fill in the form completely, do not leave spaces blank without explanation. For additional space use back of form.

NAME OF USER: ______________________________

ADDRESS: ______________________________

____

NAME OF CAVE(S) TO BE ENTERED: ______________________________

____

ENTRY DATE: ______________ PLANNED ENTRY TIME: ______ a.m. ______ p.m.

PLANNED FINAL EXIT TIME (and date if NOT same as entrydate) ______ a.m. ______ p.m.

PLANNED ITINERARY WHILE IN CAVE(S) (places, route(s), schedule(s), include entry/exit times for each cave if more than one cave is to be entered): ______________________________

____

____

____

VEHICLE PARKING AREA USED: ______________________________

____

VEHICLE LICENSE NUMBER MAKE MODEL COLOR

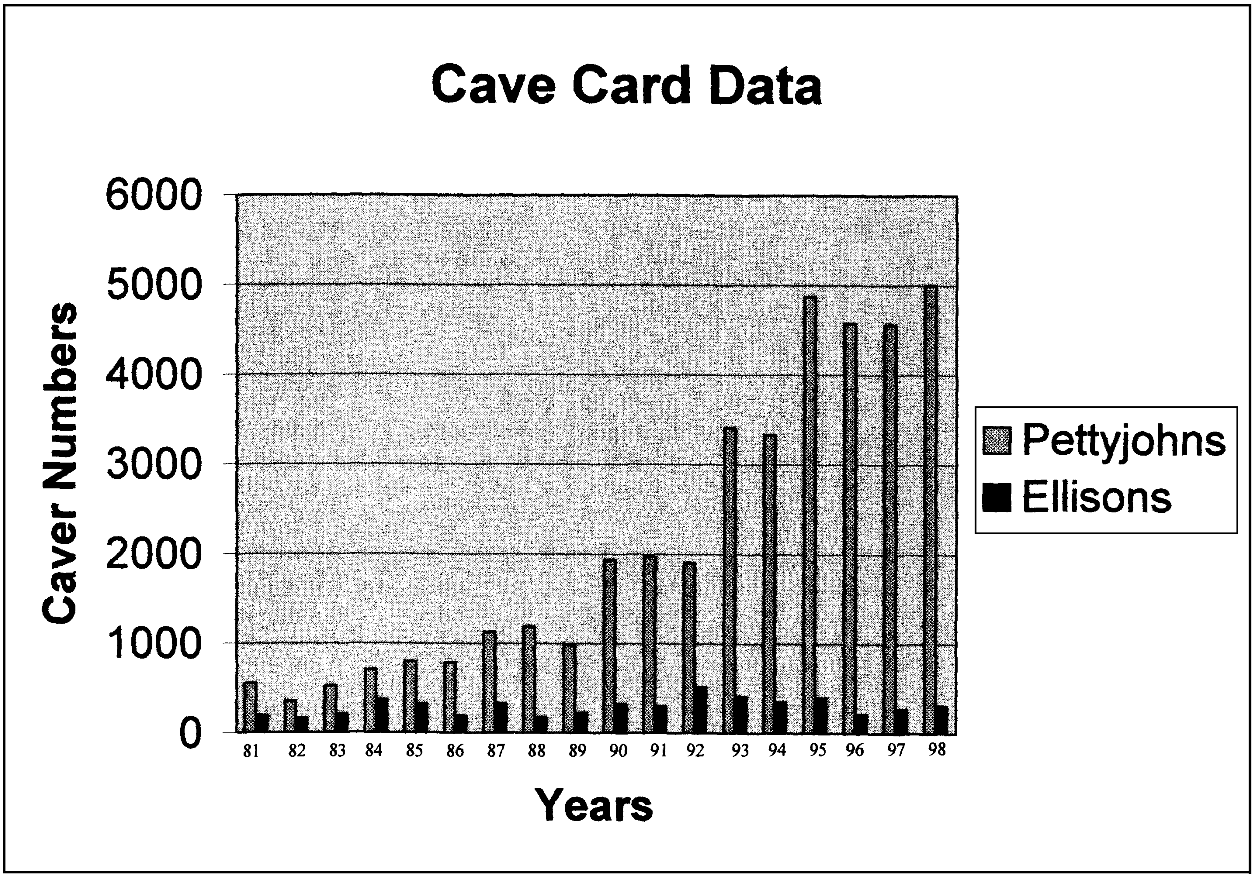
(OVER)

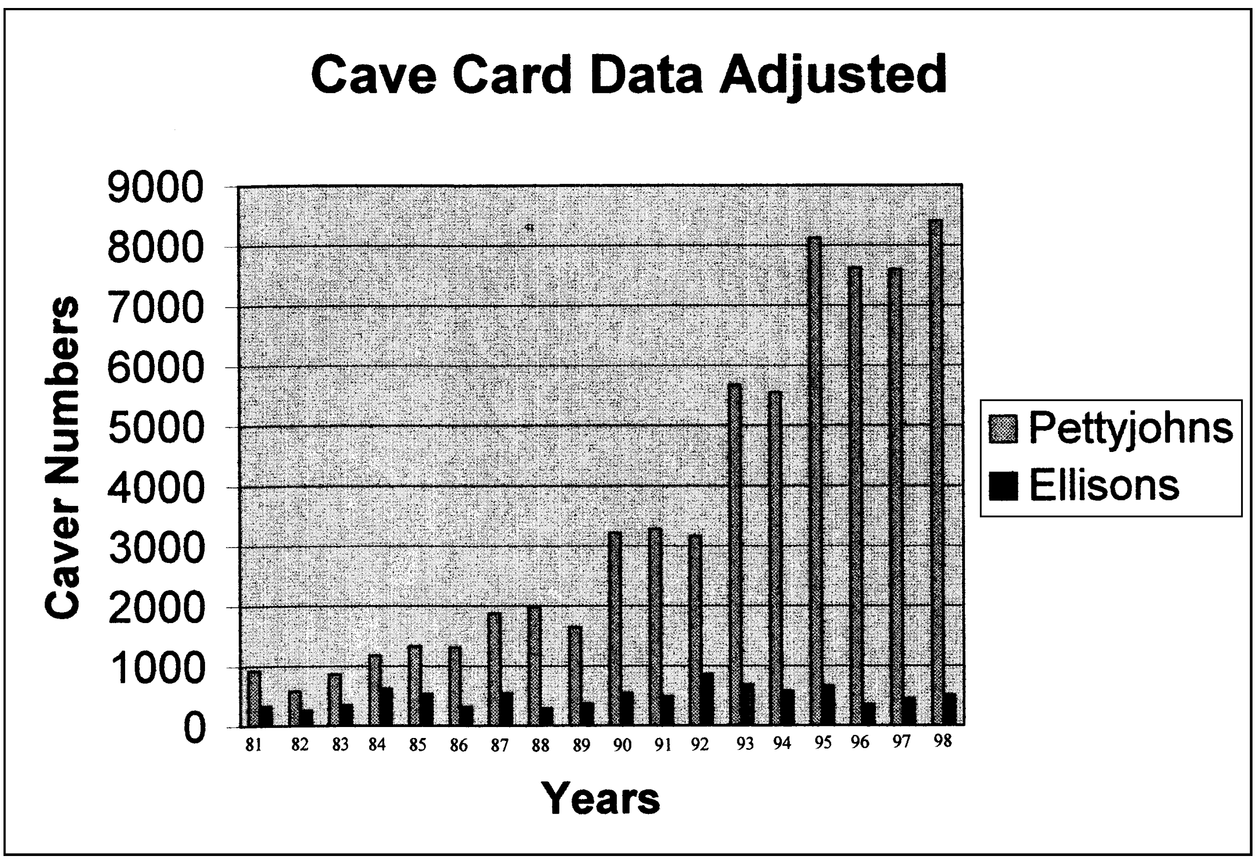
Pigeon Mountain WMA
Visitor Use Estimates
2001

User Activity	User Numbers
Cave Exploring	12,500
Rock Climbing	22,000
Bicycling	4,500
Horse Back Riding	4,700
Hiking, Day Trips	14,000
Hiking, Overnight	2,500
Motor Travel	40,000
Camping	10,000
Hunting	4,500
Wildflower Viewing	4,500
Bird-Wildlife Watching	1,500
Butterfly Study	200
Hang Gliding, Parasailing	250
Hossil Hunting	200
Fishing	300
Swimming	500
Civil War Site Tours	250
Astronomy	150
unspecified	1,000
TOTAL	123,550

Pigeon Mountain
Visitor Use Estimates
1998

User Activity	User Numbers
Cave Exploring	12,500
Rock Climbing	11,000
Bicycling	4,000
Horse Back Riding	4,500
Hiking, Day Trips	14,000
Hiking, Overnight	2,500
Motor Travel	35,000
Camping	7,000
Hunting	4,500
Wildflower Viewing	2,000
Bird-Wildlife Watching	1,500
Butterfly Study	200
Hang Gliding	250
Fossil Hunting, Geology	200
Fishing	200
Swimming	500
unspecified	1,000
TOTAL	100,850


Cave Card Data
Caver Numbers
6000
5000
4000
3000
2000
1000
0
81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Years
Pettyjohns
Ellisons


Cave Card Data Adjusted
Caver Numbers
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98
Years
Pettyjohns
Ellisons

Successful Cave Management Strategies at Carlsbad Caverns National Park

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Abstract

Carlsbad Caverns National Park contains 87 known caves of which Lechuguilla Cave and Carlsbad Cavern are the two largest. In the last ten years, there have been a number of successful management strategies implemented to protect cave resources while allowing a range of access availability. Carlsbad Cavern has been impacted from its early days of discovery in the late 1800s to the present and is the focus of a number of projects to restore impacted areas, remove lint from visitor trail areas and to survey and inventory cave features. A commitment from management for personnel and funding allows the park to manage over 200 volunteers throughout the year to work on cave projects. The development of survey standards and guidelines for those entering caves of the park have been successful in reaching our goals of protecting cave features while allowing access.

Management strategies have not been limited to inside the park, but also working with outside agencies and neighbors to protect cave resources. Oil and gas drilling operations adjacent to the park on our northern boundary has been a prime example of cooperation between agencies to protect cave resources.

For continued protection of cave resources for the future, strategies include removal or mitigation of manmade structures located over Carlsbad Cavern, developing better trail cleaning methods and other maintenance related activities in Carlsbad Cavern, and the replacement of the culvert and locking mechanism for Lechuguilla Cave.

Carlsbad Caverns National Park contains some of the most spectacular yet fragile caves in the world. There are numerous recent examples of successful cave management strategies that have provided education for visitors and better protection for cave resources. Without the approval and support of the upper management of the park, few, if any, of the examples listed would have been possible. In addition, without the support of hundreds of volunteers, our programs would have been smaller in scope and less successful.

Limited And Varied Access

Carlsbad Caverns National Park has a range of options for visitors to experience caves of the park. These options help protect park caves and their features while allowing access to the visiting public. Most visitors come to experience spectacular Carlsbad Cavern with its paved trails and electric lights. For the more adventuresome, guided tours into three off-trail areas in Carlsbad Cavern and two other park caves, Spider Cave and Slaughter Canyon Cave, are offered. For those with experience and proper gear, there are eight other caves available to visit on your own. These caves range in difficulty from an easy walk-in cave to a cave with a vertical entrance pitch of 300 feet. One last cave is available for the experienced vertical caver as a guided trip. This cave has a 180-foot entrance drop. The rest of the caves of the park are not available for recreational caving, but are open to approved scientific research.

Supporting Conservation, Restoration, and Lint Removal

Caves of the park are extremely fragile. Every day we learn more about how fragile these places really are. Any time anyone enters a cave of the park, there will be some impact. How that person travels through the cave will determine the extent of that impact. Resources found in caves of the park are essentially nonrenewable. This means that once lost, these resources will never come back. With this in mind, we know that settlers discovered Carlsbad Cavern as early as the 1880s. The oldest known signature in the cave is dated 1898. This means that Carlsbad Cavern has seen more than 100 years of people marveling at its wonders. Unfortunately, for most of that time the extreme fragility of the cave was not understood. This has resulted in a tremendous amount of impact to the cave, much of which can never be recovered or restored. Causing impacts have not been limited to the visitor, but the building of the trails, the placement of the lights and electrical system, and the many trips off the paved trails to maintain the infrastructure have all taken its toll. Over the years, even an unimagined substance such as lint has changed Carlsbad Cavern forever.

Despite the negative impacts that have occurred, Carlsbad Cavern is still one of the world's great wonders and awes the unsuspecting visitor. Management has taken an active role in trying to conserve the cave features that are left, restore the areas that can be restored, and literally clean the cave of the lint that has accumulated over the past 100 years.

Conservation: One of the more recent innovative ways to conserve cave features has been the placement of double-lined flagged trails throughout all major trade routes in all caves of the park. Though initially perceived as visually ugly, the protection of floor features these flagged trails provide are well worth it. By keeping all traffic to a confined trail, the vast majority of continuing impacts have been stopped almost immediately. Once everyone has gotten used to the visual aspects of the flagged trails, it becomes hard to imagination not using them. The park uses fluorescent orange surveyor's flagging tape to mark trails and a striped red and white tape to indicate more delicate or hazardous areas where caution may be needed to avoid impacting delicate features.

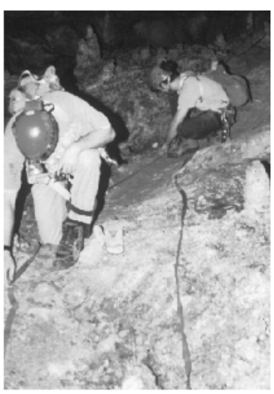

Figure 1 Delineating both sides of all major trails with surveyor's flagging tape provides those moving through the cave with easy-to-see trails that prevents them from walking in areas that are more delicate. (NPS Photo)

Other conservation projects have included replacing wooden bridges that cross deep pools or pits and replacing or removing rusting metal ladders that were used to provide easy access to areas throughout Carlsbad Cavern. It is thought that a number of these structures were placed in the cave in the 1940s or 1950s. Wooden bridges that had been used to span pools have become rotten over time and contaminated the pools. Most ladders that were placed in the cave were composed of galvanized steel, which over the past 40 years have severely corroded in places.

Restoration: Though many of the impacts can not be restored, many can be. Over the last ten years, hundreds of volunteers have spent literally thousands of hours cleaning flowstone, restoring floors, and removing elevator blast debris. Their efforts, though small considering what still needs to be done, have helped return the cave to a semblance of what it was like when the first explorers entered Carlsbad Cavern.

Some restoration efforts in the cave have involved the removal of structures such as metal ladders and metal walkways. Placed in a different time, all structures throughout the cave are being evaluated to determine their structural integrity as well as their purpose and need.

Lint: Over the years since the discovery of Carlsbad Cavern, the cave walls had slowly gotten darker and darker. Since it was a slow process, no one really noticed. No one noticed until some speleothems had turned black with dust and lint covering them. The lint even began forming its own stalactites, known affectionately now as lintcicles. Then onto the scene came Pat Jablonsky. She was ready to tackle this daunting task of cleaning the lint found along the three miles of paved

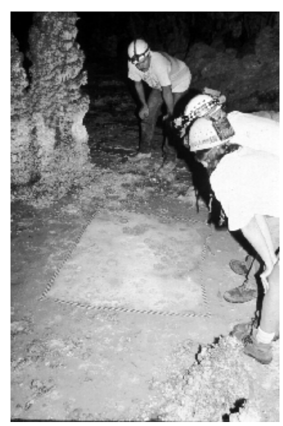

Figure 2. Volunteers observe a cleaned test spot along the visitor trail in an area of Lower Cave known as the Rookery. (Photo Richard Walk)

trails in Carlsbad Cavern. Her "Lint Camps" have cleaned literally pounds and pounds of lint from the cave. As an ongoing project, Pat and her "Lint Pickers" have returned some of the sparkle to areas long covered in dust and lint.

Development of Survey Standards

It is important to know where cave passages and rooms are in relation to each other as well as what is found in those places. Accurate, readable surveys of the caves can provide cave managers with a lot of this information. The modern survey of Carlsbad Cavern and other caves in the park began in mid-1960s and has continued to the present. Unfortunately over the years, the quality of notes, sketches, and survey data varied widely. In order to standardize the information being collected during survey trips, a set of survey standards were developed in 1992 that spells out what information is required from survey teams and the quality of those notes and sketches. Also implemented at this time was a guideline of only allowing designated sketchers to sketch the passage features and write down the notes as instrument readings are taken. The goal of the sketcher is to produce a quality sketch that accurately depicts the passage that has been surveyed and to record all necessary notes, numbers, and other information pertaining to the passage. The sketcher is also in charge of the survey team and needs to make sure all necessary information is collected and guidelines are followed. All notes and sketches are turned in to the park after each survey trip and a critique is prepared for each sketcher.

For the park, this has meant providing the personnel to oversee this activity, but the results have been a survey where the quality of notes and sketches are much better than in the past.

Development of Guidelines for Entering Caves

By the early 1990s, literally hundreds of volunteers, employees, and scientists were utilizing the caves of the park for various appropriate reasons. Though everyone knew that the caves of the park were fragile, there was very little guidance from the park as to how to minimize impacts while traveling and working in the caves. Written guidelines were developed for entering Lechuguilla Cave, Carlsbad Cavern, and the other caves of the park. These guidelines are part of the park's Cave and Karst Management Plan. Developed by park staff and numerous caver volunteers, these guidelines are designed to protect park caves. Our goal is to allow limited access to the caves or cave areas for various appropriate reasons while emphasizing the delicate nature of the caves and the need to minimize our impacts upon those caves. By stating exactly what is expected of those entering the caves, these written guidelines also help avoid confusion and miscommunications between the cave managers and those working in the caves. A primary result from the development of these guidelines has been a raising of conscientious among cave users concerning the fragility of the resources and better protection of the caves and their resources.

Working With a Number of Groups and Individuals

An important aspect of successful cave management strategies has been the use of volunteers to accomplish much of the physical exploration and survey of new passages and the conservation and restoration of known cave areas. It has been valuable to work with a number of different caving groups and individuals. This allows a larger pool of talented volunteers to be used and creates an atmosphere of fairness, which can be lacking when only one group is allowed to work in park caves. Maintaining a working relationship with a number of groups and individuals does require more staff time then if working with only one group, but can be very beneficial and rewarding.

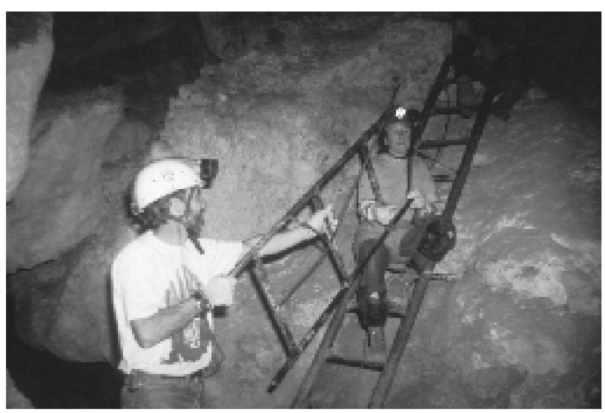

Figure 3. Deemed to be a safely hazard and unnecessary, the metal ladder and a number of other metal structures leading into the New Mexico Room were removed by volunteers from the Pajarito Grotto. (Photo David Jagnow)

Basing Management Decisions on Good Science

The management of caves and other natural resources is not an easy task. Without correct, non-political answers to a complicated and intertwined set of factors, management decisions may have tremendous repercussions for natural resources, including fragile ecosystems. The critical need for good, scientific research is even more pronounced when those resources are non-renewable, such as are found in many caves. The following are two examples at Carlsbad Caverns National Park where scientific studies are helping to make reasonable management decisions which in turn will protect cave resources better for the future.

Development Concept Plan for Carlsbad Cavern Area: The area immediately adjacent to Carlsbad Cavern has been altered significantly since the early 1900s. Over the years a number of structures have been placed directly on top of the cave without any real knowledge of the effects these structures may have on the cave itself. In 1995, a study was initiated to investigate the (1) infiltration routes and pathways into the cave, (2) contaminant levels that already exist and potential sources for those contaminants and (3) a description of worst-case scenarios for major disasters and how they may affect the cave. This scientific study provides the backbone for a major effort to remove a number of non-essential structures and to mitigate impacts from others that must remain in place for now. This study will help ensure that Carlsbad Cavern remains a viable, protected resource for centuries to come.

Microbes and Lechuguilla Cave: From the time of the breakthrough in Lechuguilla Cave in May 1986 through the early 1990s, microbes were not even thought of in relationship to the cave much less considered in its management. That all changed when in 1993, Dr Larry Mallory from the University of Massachusetts applied for a research permit to culture and study native microbes from the cave. As these studies progressed, more research microbiologists became interested in the apparently unique organisms that Lechuguilla, and probably most other caves, may harbor. Various studies have shown that unique microbes are found in many locales throughout the cave including pools and other water sources, corrosion residues that are found on floors, walls, and ceilings in numerous areas, and the large deposits of native sulfur found in several places in the cave. The extent and the uniqueness of the microbes found in the cave has had a direct bearing on how Lechuguilla Cave has been managed in recent years. Scientific studies have shown us that the cave and its resources are even more fragile than ever considered. In response to these studies, we have changed our guidelines for entering the cave to help preserve these fragile ecosystems. Because of these studies and discoveries we can better protect a resource that until recently, we never even knew we had.

Working With Agencies and Neighbors

Maintaining good working relationships with agencies and neighbors make good sense. Occasionally issues may arise from outside the boundaries of the park that can directly or indirectly affect caves of the park. Oil and gas drilling operations adjacent to the northern boundary of the park have been the most threatening issue to arise in recent years. Working with the Bureau of Land Management, various caving organizations and individuals and, ultimately with the U.S. Congress, the National Park Service was able to stop the drilling activities and to create a cave protection zone north of the park.

Summary

Carlsbad Caverns National Park has made great strives in successfully implementing strategies to protect cave resources while providing education and interpretation to a visiting public. The conservation and protection of cave resources has become a priority for management officials and as a result the cave resources have greatly benefited from this support. The use of volunteers has been critical in the successful implementation of many of our management strategies. Everyone who has contributed to these efforts can be proud of the work they have done. We certainly are. The hope is that visitors to the park in the far future will still be able to enjoy the same spectacular cave resources that we see today.

Land Use and Water Quality Threats to the Mammoth Cave Karst Aquifer, Kentucky

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Alan Glennon
Chris Groves
Michael Anderson
Center for Cave and Karst Studies
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Joe Meiman
Division of Science and Resource Management
Mammoth Cave National Park
Mammoth Cave, Kentucky

Abstract

Threats to the health of karst ecosystems, including the Mammoth Cave Karst Aquifer, come from a variety of agricultural, urban, and transportation land use practices. For the Mammoth Cave Karst Aquifer, the U.S. Fish and Wildlife Service has funded the Center for Cave and Karst Studies to:

- classify land use,
- perform a dye-trace investigation to determine if the hydrologic network of the eastern end of the Mammoth Cave System extends into a fourth major drainage basin,
- develop a GIS (Geographic Information System) as a data storage and retrieval tool, and
- investigate potential protection strategies for these areas.

Anderson Level III land use classification at 1:24,000 scale was conducted for 375 square kilometers comprising the Turnhole Bend Basin, Echo River Basin, Pike Spring Basin, Mile 205.7 Spring Basin, Suds Basin, and intermediate drainage areas. Within the Mammoth Cave Karst Aquifer:

182 square kilometers is Forestland
171 square kilometers is Agricultural
19 square kilometers is Urban and Built-up
2,000 square kilometers is Water
1 square kilometer is Barren land.

Suds and Mile 205.7 Spring Basins were included in the study area because they were potential outlets for the dye trace. The results from the dye trace in the northeast portion of Mammoth Cave are pending, but an intermediate receptor within the Pike Basin has already shown positive. A dye trace near Candlelight River conducted within this study emerged at Floating Mill Hollow Spring, thus identifying a new spring basin that communicates with known passages in the Mammoth Cave System. ArcView GIS was used to catalog and analyze the results of the land use classification.

Cave Acquisition and Management Experiences of the Southeastern Cave Conservancy

Bill Putnam
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putnam@scci.org

Abstract

The Southeastern Cave Conservancy was incorporated in 1991, and has since become one of the most active cave acquisition and conservation organizations in the U.S. With more than 27 caves on 15 preserves in six states, the SCCi draws on a large volunteer base for assistance with cave acquisition and management. Partnerships with caver groups, conservation organizations, and government agencies have been critical to the success of the conservancy. The organization's history demonstrates the effectiveness of private, grass-roots cave conservation efforts.

When a group of cavers got together in my living room nine years ago to discuss starting a cave conservancy, I knew we had a great idea. I just didn't know whether anyone else would agree. The idea that cavers could come together to buy and manage caves seemed reasonable, but we all knew that it would take huge sums of money and a vast amount of volunteer labor. Would the caving community really support the idea? We could not be sure, but we felt that perhaps the time was right.

The SCCi was the brainchild of Jeff and Alexis Harris. Long-time activists in the Georgia caving community, Jeff and Alexis called together a group of cavers in 1990 to discuss forming a cave conservancy. I volunteered my house as a centrally located site for the first meeting. About 20 people showed up and a lively discussion ensued. A series of planning meetings followed, culminating in the incorporation of the non-profit Southeastern Cave Conservancy, Inc. in May of 1991. We received the coveted IRS 501(c)(3) designation (which makes contributions tax-deductible for the donors) in November of that year, and we were in business.

At the time, we all thought that we would be relying mainly on donations of caves, and perhaps leases or conservation easements, for most acquisitions. We thought we could raise the money to actually *buy* a cave once in a while as long as it wasn't too expensive. I doubt that any one thought that in nine years the SCCi would raise more than $300,000, and own and manage more than 25 caves and 700 acres in six states. I am sure that none of us dreamed that our little conservancy would be able to take on a $200,000 debt load and expect to pay it all off just to buy some caves.

But that's where we are today. And it's all because of the support we have received from the caving community. Ordinary cavers, by donating their time, energy, and money to the SCCi, have made it possible for cavers to actually own and manage a large number of southeastern caves, to re-open closed caves, and to forever protect endangered species and fragile cave environments.

The SCCi was lucky in many ways during its development. We had good advice and guidance from many people and organizations, which allowed us to sail smoothly through incorporation and to obtain the critical tax-exempt charitable organization status that makes donations tax deductible. We modeled ourselves on The Nature Conservancy and sought their advice in developing our bylaws and our acquisition guidelines. We received logistical as well as financial support from Pigeon Mountain Industries, our loyal corporate sponsor. Ask anyone who has been involved in the incorporation of a non-profit organization about the difficulties of getting started, and especially of becoming a 501(c)(3)—you'll hear plenty of horror stories. We managed to get through it all in just a few months at a cost of only a couple of hundred dollars. I remember folks passing the hat at a planning meeting to get the filing fees. We owe a great debt to the folks who made that happen.

We also got a very lucky break right off the mark when Dogwood City Grotto member

Chuck Henson offered to donate Howards Waterfall Cave to the brand new, barely organized SCCi. Chuck had to have a lot of confidence in us to do that, and I know it gave us a big boost. Other cave conservancies have taken years to acquire their first cave, and Chuck handed us our first one on a silver platter. I believe it set the stage for the good things that followed. Howards is a wonderful cave, one of Georgia's longest and most popular, and it would be hard to overstate the value and importance of Chuck's donation to the Conservancy.

We had a lot of discussions about what to tackle for our first big acquisition project. Many in the group had a great love for and attachment to Fox Mountain in Rising Fawn, Georgia. More than ten caves, including Cemetery Pit, Rustys Cave, and Hurricane Cave are located there on 332 acres owned by the heirs of Dr D. S. Middleton. Several of the caves are among the longest and deepest in the state. Local cavers Jeff and Alexis Harris and Steve and Kaycee Logan had tried to buy part of the property several years earlier, only to be stymied by a problem with the title. No bank would make a loan against the property without a clear title. The owners had the property listed for sale, and we all worried that a change of ownership would close the caves, or worse—result in development or logging of the land around the caves.

As we were considering whether our new conservancy could raise the money to buy more than 300 acres, we received word that Neversink, the crown jewel of TAG (Tennessee-Alabama-Georgia) pits, was up for sale. After much discussion and soul searching, we concluded that we would have a much better chance of raising money to buy the well-known and much-loved Neversink. The fact that it was only 86 acres instead of 332 was also a deciding factor. I know it was hard for some, particularly Jeff and Alexis, to see Fox Mountain go to the back burner, but we all knew that Neversink would draw more attention and support and would be a great catalyst for the growth of the conservancy.

Of course, we never anticipated that it would take almost three years before Neversink became ours. We plunged into negotiations, with no money in the bank and no experience in buying land other than that of those of us who had bought homes. I won't go into all the details, trials, and tribulations, but I doubt that we will ever have a harder time getting a cave than we had with Neversink. It was sold right out from under us twice—the second time we had even shaken hands and exchanged money. Some folks chided us, wanting to know why we couldn't close the deal. The bottom line is that you can't force someone to sell you something if they don't want or need to (unless you're the government). Many people began to question whether the Southeastern Cave Conservancy, Inc. was really viable.

We had a nice boost in the middle of the Neversink doldrums, when Cavers Inc. decided to give Glove Pit to the SCCi. Cavers Inc. was formed by a group of Huntsville cavers well before the SCCi, and had acquired the cave from a developer concerned with liability. It was a pioneering effort in the southeast, and that made it very significant to us that the founders of Cavers Inc. felt the SCCi was working well enough and was worthy enough of their trust for them to donate their cave. We owe Bill Varnedoe, Carl Craig, and the other founders of Cavers Inc. our thanks.

Soon after the donation of Glove Pit, everything finally came together for us at Neversink. Capitalizing on the groundwork laid by Steve Davis, Kris Green, and Linda Tucker, the SCCi's master deal maker, Mark Wolinsky, was able to work out a deal with the cave's owner which satisfied concerns about water rights, boundary locations, and access. It was a good thing that he did, because Kris, who was the SCCi Chairman at the time, had been vigorously collecting donations and pledges to pay for the cave for some time. He had quite a large chunk of the money lined up, and we'd have looked pretty bad if we'd failed. Kris never doubted, though. He used to get so mad at me for asking: "How we gonna pay for this sucker?"

"I don't want to hear it!" he'd say. Well, ol' Kris was right, as usual, and we didn't have to give the money back, thank goodness.

I would have to say that it was Neversink that finally put the Southeastern Cave Conservancy, Inc. on the map. That pit is visited and admired by cavers from all over the country. When folks realized that the SCCi was really committed enough to take on a $50,000 purchase, they took a new look. Many liked what they saw, and pitched in to help pay for the purchase. More than 400 cavers bought a $40 "Piece of the Pit" to help pay for the acquisition. Many grottos around the country sent donations, in some cases emptying their treasury to help. Over $30,000 was raised before the closing, and the remaining $20,000 (financed by a loan from a true hero among cavers) was raised and repaid in just six months after the purchase. Faith was restored, and enthusiasm (and membership) reached a new high.

But like the car-chasing dog that finally caught one, we were left with the question: what do we do now? Well, the obvious thing was to bring out the Fox Mountain project and have a go at that. If we can buy 40 acres, why not go for 300? But it was not to be—at least, not yet. Before we could really get started we received word that Kennamer Cave might be available. When we checked into it, we found that not only was it available, the owner was ready to sell immediately. After the long struggle to get Neversink, the Kennamer purchase seemed like a runaway train—it was fast and furious, and was concluded in just three months. For $36,500, in January of 1997 the SCCi acquired 100 acres containing the entrances to Kennamer and Little Kennamer caves. Maybe they won't all be as hard as Neversink after all, we thought.

Suddenly we were in debt again. Well, it worked once, so we figured it was good for another try. Let's divide the cave up and sell it off (in honorary ownership, or course) piece by piece. You have to sell the cave in order to buy it. It has a sort of twisted logic to it, don't you think? The "Buy a Piece of Kennamer" program, a shameless copy of the earlier and wildly successful "Buy a Piece of The Pit" program which financed Neversink, was launched and was soon well on its way to paying for the Kennamer purchase. We were able to raise more than half the money in advance, and only had to borrow $16,000 this time, with the generous backing of the Richmond Area Speleological Society. By January of 1998 we had raised enough capital to repay the loan in full.

Meanwhile, back at the ranch, another back burner project caught fire. We'd been talking with the owners of Surprise Pit and the Fern Sink entrance to Fern cave for almost a year. The cave had been temporarily closed after a couple of back-to-back rescues, and we were trying to get them to lease it to the SCCi. The owners would get the benefits of our liability insurance, and the cavers would regain access to Alabama's deepest pit. After almost a year of friendly discussion, we arrived at an acceptable 99-year lease agreement and the deal was done. In March of 1997 the SCCi entered into the first of many cave leases. The SCCi's Fern Cave preserve is managed jointly with the surrounding Wheeler National Wildlife Refuge, which contains the rest of the entrances to the Fern Cave System, Alabama's longest.

Soon after, we were able to adapt the Fern Cave lease for use in two other acquisitions in Tennessee. Gourdneck Cave is an active stream cave, which serves as the only reliable water supply for its owner. As part of the lease, the SCCi agreed to maintain the water lines in the cave, which is also home to a wide variety of aquatic cave life, including the blind Tennessee cave salamander. South Pittsburg Pit is a 160-foot open-air shaft with more than 2,500 feet of passage at the bottom. The pit was closed several years ago following the rescue of some inexperienced cavers. In April of 1997 the SCCi signed long-term leases on both caves.

We have since used the lease again as the basis for an agreement with the Nashville Grotto, leasing the grotto's William Halliday Cave Preserve in Kentucky, which contains Logsdon Cave. Logsdon is a difficult multi-drop cave, which may one day connect to the Fisher Ridge cave system. It is the SCCi's first project outside the TAG states. The lease allows the grotto to participate in the SCCi's insurance policy, while the SCCi provides support and delegates management authority back to the Nashville Grotto. I expect that the SCCi will be doing many more leases in the future as cave owners recognize the benefits of this arrangement.

Early in 1997 we received yet another unexpected opportunity. The owners of Fricks Cave in Walker County, Georgia, were planning to sell their farm and retire. Fricks is home to an estimated 10,000 federally listed endangered gray bats. It houses the largest known concentration of the bats in Georgia, as well as Georgia's only confirmed population of Tennessee cave salamanders. Naturally, we were quick to look into the details. It turned out that the Georgia Department of Natural Resources and The Nature Conservancy were also very interested in seeing the cave protected, but were unable to make arrangements to purchase the cave in time for the rapidly approaching auction. With the blessings and assistance of both, the SCCi went to the auction and was able to buy 34 acres including all three entrances to the cave. The $105,000 price tag sent some conservancy members into shock, but we received generous loan financing through The Nature Conservancy of Georgia. Once again, many cavers, grottos, and sponsors are stepping up to help pay for the acquisition.

And then, finally, after simmering on the back burner for six years, the Fox Mountain property was ready for the main course. In a surprising turn of events, Mark Wolinsky emerged from the first face-to-face meeting with the owners with an agreement to purchase the entire 332-acre property at an affordable price of $89,640 complete with owner financing and generous terms. Once again, fortune smiled on the cavers, and the purchase was completed in September of 1997. While Cemetery Pit, Hurricane Cave, Rustys Cave, and the other smaller caves on the property have always been open to cavers, isn't it wonderful to know that they are ours to love, enjoy, and protect now and forever?

Just when I thought the Southeastern Cave Conservancy, Inc.'s plate was completely full, another great property came to our attention. The owners of Horse Skull Cave and Jacks Hole, near Bridgeport, Alabama, were reportedly interested in leasing or selling the caves to the SCCi. We met with one of the owners, Bill Kampmeier, and found him to be very enthusiastic about the idea of a cave preserve. After discussing the options, we settled on a purchase of 40 acres surrounding the two caves. Horse Skull Cave is an interesting horizontal cave with more than 2,500 feet of passage. Jacks Hole is a 90-foot pit with about 200 feet of passage at the bottom. The $16,500 purchase was completed in January of 1998, with a five-year owner-financed mortgage.

As for future plans, we have many other acquisition projects underway. We are negotiating for Tennessee's Tiftonia Pit and Airplane Cave, and have submitted a proposal to acquire Alabama's Anderson Cave and a 50-acre tract that includes several smaller caves. Anderson Cave is another gray bat cave and access will have to be limited to protect the bats. We are also working with the State of Tennessee and the owner of the Woodard Sink entrance to Dunbar Cave to arrange the cleanup and acquisition of the sink entrance. We are also pursuing several other possible acquisitions, including Anvil Cave, Walnut Cave, and Coon Creek Cave in Alabama, Junkyard Cave in Tennessee, and several other caves in Tennessee, Georgia, and Florida.

Along the way we have made valuable contacts with a number of organizations interested in caves and the endangered species which sometimes use them. The Nature Conservancy of Georgia has been a strong ally, providing financial and logistical support for the Fricks Cave purchase as well as valuable advice and contacts. The Nature Conservancy of Alabama and the Alabama Natural Heritage Program have also been helpful, and we appreciate the assistance of Jim Godwin, one of their zoologists, in surveying a number of our preserves. We have implemented a Memorandum of Understanding with the Nature Conservancy of Tennessee that has some wonderful possibilities. We have worked with the Georgia Department of Natural Resources in supporting the study of the gray bats in Fricks Cave, and helped support the second season of research at that site. We also appreciate the support we have received from Bat Conservation International and the U.S. Fish and Wildlife Service.

In 1997 I was pleased to see the Southeastern Cave Conservancy, Inc. become an institutional member of the National Speleological Society. We have always valued our relationship with the NSS and its southeastern grottos. All of our directors and most of our 400 members are NSS members. Several of the directors are NSS Fellows and some are Life Members. Much of our early support came from the Dogwood City Grotto, Huntsville Grotto, Birmingham Grotto, and Chattanooga Grotto. We have always felt that the SCCi and the NSS serve complimentary roles and share the same goals when it comes to cave conservation. I am sure that the two organizations will develop even closer ties in the future. All of our property management and access plans encourage membership in the NSS, as well as in the SCCi. We deeply appreciate the support we have received from the Society and its members and grottos, as well as the generous access to conventions, meetings, information, and publications that the Society has provided.

1998 was a year of consolidation for the conservancy. We worked hard to raise money and pay off out mortgages on the Fricks, Fox Mountain, and Horse Skull Preserves. As a result, we did not seek acquisitions as aggressively as in previous years. In spite of this, we acquired four new caves—two by donation and two by lease. Long-time caver Marsall Fausold donated the historic Lobelia Saltpeter Cave and 30 acres of land in West Virginia. The cave is a little far from our usual stomping grounds, and is managed for SCCi by the West Virginia Cave Conservancy, which was formed later that year. We also received the donation of Jennings Cave from the Florida Speleological Society. The FSS acquired the cave in a tax sale, put up the money for the purchase, and donated the cave to SCCi. They now serve as the management team for the preserve. With help from the Nashville Grotto of the NSS, we obtained leases on two caves near Nashville, Tennessee. Swirl Canyon Cave and Hardins Cave are gated and managed for SCCi by the grotto's Cave Management Committee.

So there you have it—the SCCi in a nutshell. In one year the Conservancy's holdings grew from 37 acres to over 700, and the number of caves under SCCi ownership or management went from four to over 25. This phenomenal progress was possible only because of the tremendous support of cavers throughout the southeast and across the country. Their contributions and efforts are the life blood of the Southeastern Cave Conservancy. I truly believe that we are receiving this support because of our aggressive acquisitions and our demonstrated commitment to cave ownership by cavers.

These accounts also demonstrate the many partnerships that we have developed to acquire and manage caves. Working with so many different groups is sometimes complex and demanding, but it is the only way we can distribute the workload out to the people who have the knowledge, resources, and proximity to the caves to effectively manage them. Our all-volunteer organization manages an ambitious program of cave acquisition, fundraising, and cave management with no paid staff and no office. We run an organization with an annual budget ranging from $80,000 to $118,000 and more than 95 cents of every dollar goes to cave acquisition and management. The tiny remainder is spent on newsletters, member services, and administrative expenses like liability insurance.

I was going over the membership list with our Treasurer, Buddy Lane, a while back and we noticed that over 30% of the current SCCi members live outside the TAG states. We have members in California, New York, and even Canada. I think this shows the broad appeal of the SCCi to cavers, and that's important. The SCCi cannot continue to grow and prosper without the strong support of the caving community. It needs you and every other caver. The same is true for the other cave conservancies in Indiana, Missouri, Texas, and the northeast.

We frequently receive cards, letters, and email from donors and new members expressing their amazement and excitement at our success and the pace of our acquisitions. I, too, am amazed at the way the SCCi is racking up the acquisitions. Sometimes, though, I wonder if we're really going to be able to keep this up—especially the fundraising part. After all, we're already committed to paying off $210,000 in acquisitions over the next five years. To borrow a phrase from the movie "Field of Dreams," our philosophy seems to be "Buy it, and they will give." Our Acquisitions Chairman, Mark Wolinsky, puts it another way, saying "We have sailed to the New World and burned our boats." As the person who signs on the dotted line for these massive loans and purchases, I can tell you that it takes a lot of faith in your fellow cavers.

Most cave conservancies depend on donations of land or conservation easements for their acquisitions. Some hold only leases or conservation easements and own no actual property. They get their caves cheap, but they don't get many caves and their protection may not be very secure. The SCCi is unique among cave conservancies in that we aggressively try to buy property at fair market value. What we can't buy, we try to lease.

This approach is obviously working for us, but it is extremely capital-intensive compared to the methods traditionally used to acquire caves or other conservation property. Leases are good, but it's not hard to terminate a lease, so the protection isn't very secure. Conservation easements have a lot of promise, but they are complicated and time-consuming to implement. There are also significant risks related to costs of enforcement when ownership of easement-protected property changes hands. In the end, it comes down to private ownership of land—one of the fundamental principles of our society. The best way to protect something is to own it, don't you think? And sure, we'll take a donated cave any time we can get one, but that's just it—you can't get them very often. If you are serious about owning caves, and I mean *lots* of caves, there is no alternative to going out there and buying them. It's the American Way.

Many of the people who write want to know what else they can do to help besides donating money. There are countless things that we need help with on a regular basis, such as organizing work days and cave cleanups on our properties, designing brochures and artwork, building signs and information kiosks, and working the SCCi booth at caving events. But the bottom line is that it takes cold, hard, cash to buy land and caves. Some folks don't like that part. "Money, money, money," they say. "That's all you care about." But like it or not, you can't become the owner of very many caves without it. Give money, help raise money, or do both—that's what it takes.

Our targeted fund raising programs are very popular and have been crucial to our Neversink and Kennamer purchases. But they take a lot of work to administer, cost a significant amount for shirts, certificates, stickers, and the like., and bring in money only at irregular intervals (mainly at conventions like SERA and TAG). We can't plan in advance when we don't know how much we will raise, and it's difficult to prioritize acquisitions without that kind of long range planning and budgeting. We started our credit-card-based Sustaining Contribution program to address that problem, and to ensure a steady cash flow to cover monthly and quarterly mortgage payments. That program is now generating over $2,500 per month and covering about ⅔ of our regular loan payments. Hopefully, the donors will keep their support coming as the current loans are retired and new purchases are made.

It takes a combination of regular sustained giving and targeted fundraising to make a continuing acquisition program work. Naturally, we are busting our butts to get all the outside grants that we can from conservation and wildlife organizations, philanthropic foundations, corporate sponsors, and so forth. But they don't make up the bulk of the money, cavers do.

I don't want to seem chauvinistic here. The Southeastern Cave Conservancy is certainly not the only successful cave conservancy around. But I have spent some time looking into the activities and operation of most of the other cave conservancies in America, and it is obvious that many have potential beyond their current circumstances. What does it take to make the quantum leap forward? Vision. Passion. Confidence. Maybe a dash of bravado. Be bold and take risks. When we see someone step up and make a commitment, we are drawn to follow. Join your local cave conservancy. Pick a special cave in your area and come up with a proposal to buy it. Believe in your heart that your fellow cavers will back you up—they will! It's working for the SCCi and it can work for you. We'll be glad to help anyone who asks. There is nothing preventing cavers from owning, managing, and protecting caves all across America.

Consider for a moment the amount of money required to pay for the SCCi acquisitions described above. The total cost of these properties is well over $200,000. We can not raise that much money in a single year, no matter how many "Piece of the Cave" packages we try to sell. We have to finance these acquisitions with loans or owner financing, which means making monthly payments. Can't we all spare a few dollars a month to buy and preserve caves? Just 200 people giving $5.00 per month on a credit card can generate enough cash to cover the payments on $200,000 in mortgage loans. For only $5.00 per month you can finance the acquisition of hundreds of acres of cave lands. That's what I call leverage! It's working for the SCCi, and it can work for you.

And that's what it's all about: Buying Caves for the Future.

Underground Radio Use in Cave Rescue Operations

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Abstract

Since 1997, the Walker County, Georgia, cave rescue team has been experimenting with low frequency underground radios for use in cave rescue communication systems. Using 185kHz single sideband radios with loop antennas, we have conducted tests in several caves in the Southeastern US. In the last year, improvements in equipment and operating procedures have increased the working range of these radios from 200 meters to almost 1,000 meters through the rock, with depth up to 250 meters. Our objective has been to develop a lightweight, mobile, underground radio communications system for use in long and deep cave systems where field phones are difficult to deploy and use. Further, we hope that such a radio system will allow an initial response team to establish communications with the surface immediately upon arrival at an accident site, providing more timely information for planning and decision making. Use of the radios in the March 1999 Ellisons Cave operation demonstrated their effectiveness as both a supplement and an alternative to wireline phone systems.

Introduction

In early 1996 Walker County Emergency Management Agency in Georgia, USA, obtained three CB Transverter cave radios made by Ian Drummond for use in cave rescues, primarily at Ellisons Cave. Deep pits and long distances have created difficulties for field-phone communications in previous incidents. The cave has entrances on opposite flanks of Pigeon Mountain, one connecting via Fantastic Pit (free-hanging, 156 meters), the other via Incredible Pit (free-hanging, 134 meters). The two pits are 1,300 meters apart, separated by winding horizontal passages that cross under the center of the mountain with typical overburden exceeding 400 meters. An accident under the center of the mountain would require field telephones to be run through more than two kilometers of passage and down pits totaling more than 215 meters in depth.

Early Tests

In the initial tests, one radio was deployed on the surface directly above Fantastic Pit and another was taken into the cave. Both radios were equipped with the one-meter-square loop antenna. As supplied, the radios were able to provide communication in the passages above Fantastic Pit and from the top of the pit to the surface 70 meters above. They could not, however, provide a link from the bottom of the pit to the entrance (335 meters horizontally, 216 meters depth), nor into the extensive horizontal passages running under the ridge of the mountain. Contact from the bottom of Fantastic Pit to the surface directly above (240 meters) was barely possible, though not of sufficient quality or reliability for rescue use. Atmospheric noise was a significant problem for the surface radio.

The rescue group wished to extend the range of the radios and through a dialogue between Bill Putnam and Ian Drummond decided to experiment with two parameters: operating procedures and antenna size. Both these methods are relatively cheap to implement compared to methods such as increasing power to 20 or even 100 watts.

The basic concept of the operating procedure was to position the surface antenna to minimize atmospheric noise, then rotate the underground antenna to maximize the received signal. This was moderately effective until we decided to try moving the surface radio into the cave entrance passage to shield it. About 30 meters into the cave the overburden has risen to approximately 20 to 30 meters. With hindsight it is possible to calculate the attenuation of the ground which turns out to be about 17dB (a factor of 7.4). The beneficial effect of this natural shielding was immediately apparent when we made our first transmission from the new location. With no other changes, we were able to achieve full communication from the entrance station to the bottom of Fantastic Pit, 400 meters straight through the limestone.

In considering the effect of antenna size, increasing the area of an antenna while keeping the wire size and number of turns constant will always increase the antenna efficiency and hence the distance that the transmitter can be from a given receiver. The effect on reception depends on whether the receiver is limited by atmospheric noise or by the electronic noise floor of the receiver. If the radio is atmospheric noise limited, increasing the antenna size will increase both signal and noise levels without changing the signal to noise ratio. However, if the receiver is noise floor limited, a larger antenna will increase the signal without increasing the noise, and hence increase the distance the receiver can hear a given transmitter. At Ellisons the deep underground radio was noise floor limited. Hence a bigger antenna would increase the distance it could hear the surface radio as well as the distance it could transmit to the surface. A two-meter-square, two-turn loop was constructed for use deep underground.

Specifications

The specifications of the cave radios were as follows:

- Operating frequency and mode: 185 kHz, choice of lower or upper sideband.
- Two watts of RF power was supplied to a one-meter-square antenna with three turns of 16 AWG (0.129 cm diameter) wire.

New Techniques and Equipment

The ideas and equipment were tested by Bill Putnam, Kris Green, Eddie Foust, and Buddy Lane in Ellisons Cave in September 1998. One radio was located about 30 meters inside the main entrance. Another was placed at the top of the first pit (40 meters deep), about 275 meters in from the entrance. Both of these radios used the one-meter-square loop. The third radio, equipped with the new two-meter loop as well as the original one-meter loop, was taken to Fantastic Pit and beyond.

When the radios were tested from the top of Fantastic Pit prior to the descent, the improvement over the previous trial was quite dramatic. At the bottom of the pit, the two-meter antenna provided excellent quality voice communication with both stations in the upper cave. The one-meter loop also gave acceptable performance (though with about half the signal strength), even though the distance to the entrance station was more than twice the distance to the surface location used in the earlier attempt. After extensive testing the underground party was able to proceed to a point 670 meters horizontally and 243 meters below the entrance and still maintain two-way voice communication. This is a major increase in the performance of the system at reasonable cost.

What is more, the party was not over. The entrance radio, shielded by the overburden, was now noise floor limited and could use a loop larger than one-meter to extend the two-way range. Who knows how large the deep underground loop could be before atmospheric noise becomes a factor in limiting its performance? And finally, we have been using only two watts output power, while the antennas have been constructed to handle up to 20 watts. Boosting the power is expensive compared to enlarging the antenna, but we can consider it when we reach the practical limits of antenna size.

We also decided to try coaxial extension cables for the entrance station antenna so that we may position the loop within the cave and the operator outside at the entrance with other rescue personnel. This will allow the radio and operator to be protected from adverse cave environments and still take advantage of natural noise shielding while providing for centralized communications at the entrance during rescue operations. Feed line loss is almost negligible at 185 Khz, so noise pick-up will be the determining factor on cable length and type.

This technique was tested in November 1998 by Bill Putnam and Diane Cousineau at Ellisons Cave. We used a 30-meter coaxial cable (50 ohm, commonly used for computer networking) to place the antenna about 25 meters inside the cave with the base unit and operator located just outside the cave entrance. Communication between the entrance and the Warm Up Pit area was easily achieved, with no noticeable adverse effects from the use of the extension. We feel comfortable that extensions up to 100 meters should be useable without loss of signal.

Further Tests

On January 6, 1999, Bill Putnam, Diane Cousineau, Jeff Adams, Eddie Foust, Geri Foust, Kris Green, and Damon Keyes returned to Ellisons cave for additional testing. The team was now equipped with two-meter loop antennas for all radios, as well as a four-meter antenna for the deep station. We also carried a 30-meter coaxial extension cable for use with the entrance radio antenna.

Fixed stations were set up at the cave entrance and at the top of Fantastic Pit, and the third radio (the "deep station") was taken down the 178-meter pit and through the lower levels of the cave. The entrance station was about 70 meters inside the cave entrance to take advantage of the natural shielding and warmer in-cave temperature. Both fixed stations in the upper cave used the new two-meter loop antennas. The deep team carried both two-meter and four-meter loops.

Using the two-meter loops on all stations, working range was extended to about 670 meters through the rock, a 22% increase from the previous figure of 550 meters. Using the four-meter loop at the bottom station, we worked a maximum range of 850 meters. At that distance the two-meter loop did not work and the four-meter loop was marginal. I believe that the four-meter loop would have been OK at 800 meters. That represents a 44% increase from the earlier trip. Surface noise was a problem at the entrance station, even though it was 50 to 75 meters into the cave. That may have been due to stormy weather to the west.

We tried the two-meter loop at all stations. It worked fine out to the North Pole (550 meters), but was not as good as we had hoped at the Gnome Creamery (670 meters from the Entrance station, 610 meters from the Fantastic Pit station). We could reach the entrance with it, which we could not do last time, and the bottom crew could hear them faintly but clearly, but the entrance station could only copy about 50% of our transmission due to background noise. The Fantastic Pit station could copy 100%—they were about 60 meters closer and had better shielding from the background noise. I believe that the extra shielding rather than the shorter distance was the key. The four-meter loop gave much better results, with 100% copy from bottom to entrance, but it was still faint. It was solid for contact with the Fantastic Pit station.

At the final station, the W90 Junction (850 meters from the Entrance station, 790 meters from the Fantastic Pit station), the two-meter loop barely reached the Fantastic Pit station with about 30% copy. The four-meter loop reached both the Entrance and Fantastic Pit stations with 100% copy, but was very faint. The Entrance station had a lot of trouble understanding us due to the faint signal and high background noise.

Based on this, I believe that the maximum working range of the current radios using two-meter loop antennas is about 670 meters if both stations are well shielded from background noise. Using the four-meter loop for the bottom station increases the working range to about 800 meters, an increase of about 18% over the two-meter loop. It will be necessary to test the radios in other caves and other regions to before we can be confident that these figures are generally applicable.

We also made a number of tests and observations about antenna orientation, which confirmed our previous observations. Laying the antennas flat on the ground reduces the range dramatically. In that configuration the radios barely reach from the Entrance to the bottom of Fantastic Pit. The best performance is always obtained by holding the antenna in a vertical plane and rotating it about a vertical axis so that both antennas are in the same azimuth plane. This technique requires that all antennas be used underground for shielding from surface noise.

The four-meter loop was difficult to deploy and use underground. We did not have a frame for it, but used a combination of "clothesline" and poles made from the two-meter frame to raise and orient the loop. Raising it was not too difficult, but changing the orientation was. We hung the antenna from a five-millimeter accessory cord "clothesline" strung across the passage at the proper orientation. The top corners of the loop were secured to the line using electrical tape. We then joined the PVC segments of the two-meter loop frame to make two 2.8-meter poles, which we used to hoist the line until it was about four meters off the floor. The bottom corners were secured to handy rocks with bungee cords. This method would work OK as long as you have two, four-meter poles, 15 meters of cord, and places to tie it off in the right orientation. The proper orientation can be determined from a map of the cave showing the station locations.

As a practical note for any future operations in Ellisons, placing a radio at the top of the Warm Up Pit should give adequate shielding and allow communication with locations in the bottom cave out to and beyond the mid-point between Fantastic Pit and Incredible Pit. If atmospheric conditions are quiet, a station at the Entrance can also reach the mid-point of the cave. The two-meter loops are adequate, but the four-meter loop does give clearer communication at the extreme range. It is possible to use the two-meter loop to determine the desired orientation and then erect the four-meter loop to match.

March 1999 Rescue Operation

On March 10, 1999, the cave radios were put to the test in an actual mission when the Walker County cave rescue team was called to Ellisons cave for a caver stranded on rope in 134-meter Incredible Pit. The radios were used to provide essential communications for command and control of the operation. Unfortunately, the team arrived to find the stranded caver already dead, probably from hypothermia and/or harness hang syndrome, so the operation was a recovery rather than a rescue.

One radio was deployed on the surface at the Incident Command location at the top of the mountain about 75 vertical meters above the Stairstep Entrance to the cave. A second radio was set up in the Waterfall Room at the bottom of the entrance pit. That one was about 45 meters below the entrance and about 120 meters below the Incident Command station. The third radio was taken down to the top of Incredible Pit, about 75 meters below the entrance and about 150 meters below the Incident Command location. The two underground radios were sent in with the initial response team and deployed immediately upon arrival at the designated locations.

From the Waterfall Room to Incredible Pit was 152 meters at bearing 80 degrees and down 45 meters. From the Waterfall Room to Incident Command was 230 meters at bearing 160 degrees, and up 120 meters. From the top of Incredible Pit to the Incident Command station was about 260 meters at bearing 195, and up 150 meters.

The antenna at the Incident Command station on the surface was initially deployed flat on the ground to minimize background noise. Later it was found that it worked better in a vertical orientation for communication with the Waterfall Room station. Background noise prevented communication with the Incredible Pit station except for occasional faint reception during lulls in the noise. The noise was not too bad until the sun rose, caused varying difficulties through the day, and subsided somewhat after sunset.

The Waterfall Room station was able to communicate clearly with both of the other stations, and was used as a relay throughout the operation. Its antenna was initially deployed horizontally to match the surface station, but we soon found that the vertical orientation worked better. When the Incredible Pit station came on the air, we found an orientation that allowed communication with both stations without moving the antenna. It was vertical, and oriented at approximately 80 degrees. At that time the other two stations both had their antennas in the horizontal orientation. The Waterfall Room antenna remained in its vertical orientation for the rest of the operation. Some background noise (probably distant lightning) was heard late in the operation (Wednesday evening) but it did not cause a problem.

Wired field telephones (U.S. military surplus) were also deployed as far as the second pit, 100 meters beyond the Waterfall Room, but they failed mid-way through the operation. Hand-held VHF radios were used at the entrance pit and at the second pit to communicate up and down the drops. The cave radios were the primary communication channel for command and control, and provided excellent service until the very end of the operation, when batteries began to fail after over 15 hours of use.

The almost 90-degree angular separation between the Incident Command station and the other two stations helps explain why the Incident Command and Incredible Pit stations could not communicate directly. Had we oriented the antennas better, we might have been able to gain direct communication. We did not use a map to try this. The Incredible Pit antenna could not have been oriented along a 195-degree azimuth because of the passage size and shape (narrow canyon running along bearing 80 degrees).

The Next Generation

We have two projects underway to improve the efficiency and range of the radios. The first is the development of a combined transceiver/transverter unit, combining a 20-meter amateur radio transceiver with the 185 khz transverter. By integrating the two components, we can decrease overall package size and decrease power consumption. The current system uses a citizen's band radio to drive the transverter, and most of the 5-watt output of the CB is wasted. The ½-watt output of the 20-meter ham transceiver is better matched to the transverter's input power requirement, so less power is wasted.

The second project is the development of an in-line booster amplifier capable of output at 2, 6, or 20 watts. This external amplifier is coupled in-line between the transverter and the loop antenna and is user-selectable for low, medium, and high power transmission. Our antennas are already designed for 20 watts, so no modifications will be required to take advantage of the higher power level. We hope that by boosting the power to 20 watts we can achieve through-the-rock communication of more than 1,000 meters.

Summary

We are satisfied that the concepts of shielding the surface radio in a cave entrance, and using an asymmetric antenna configuration can significantly increase the range of cave radio systems at relatively low cost and low operational complexity. Our experiences in the March 1999 Ellisons Cave operation demonstrated effective use of the cave radio systems in actual mission conditions. The radios provided critical communications with rapid deployment, and functioned as intended while conventional wireline phones failed. We hope that further development and testing will increase the working range to more than 1,600 meters through the rock, allowing wireless voice communication to the bottom of the deepest caves in North America.

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Exotic Species in North American Caves

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Abstract

Exotic species are important threats to endemic fauna in epigean habitats. However, the threat of exotic species to endemic cave fauna has not been the focus of traditional cave management. Several invasive exotic troglophiles are capable of invading cave habitats and might even competitively exclude troglobitic species. Cave resource managers and biospeleologists need to pay attention to several groups with particularly invasive species including ants, centipedes, earthworms, isopods, millipedes, mites, and spiders. In some situations even exotic troglobites and other unlikely invaders are a potential problem.

Current cave faunal records documenting populations of native species in conjunction with exotic species are important in monitoring the progress of invasive species. For example, states like South Carolina have no records of cave millipedes before the introduction of *Oxidus gracilis*, which is now the only millipede known in South Carolina caves. While some exotic species can not be controlled, others may be controlled with new management practices. For example red imported fire ants can forage in caves and decimate endemic troglobite populations. Properly timed fire ant insecticides can be applied, but management must take into consideration the foraging behavior of cave-dwelling crickets and harvestmen. Land management may also influence fire ant foraging in caves.

Other exotic species include the earthworm, *Dendrodrilus rubidus*. *Dendrodrilus rubidus* is the most common earthworm found in many cave surveys and might exclude native species. Native earthworms sometimes use caves as a refuge, and are no longer present in epigean habitats. With the invasion of *Dendrodrilus rubidus* and other exotic species, the native cave fauna may go extinct.

The purpose of this paper is to present the threat of exotic cavernicoles and to suggest studying their impact on cave ecosystems. As world commerce and travel increase so too does the introduction of exotic animals and plants. Exotic species are continuously introduced to the United States by accident or for purposes like biological control, landscaping, agriculture, or the pet industry (Malakoff, 1999). Most species do not survive but others kill or exclude endemic species, sometimes driving them to extinction. According to Enserink (1999), habitat destruction is being replaced by exotic species introductions as the most significant threat to global biodiversity. The U.S. federal government only recently acknowledged the threat of exotic species and stopped federal agencies from actively spreading them (Kaiser 1999). State and private industry will probably take longer to follow.

Not all exotic species compete with their endemic counterparts. Instead some transmit or harbor pathogens. An example is the "brown dog tick," *Rhipicephalus sanguineus,* a vector for several canine and human diseases, which were introduced with the tick from the Old World (Cooney and Hays, 1972). Exotic bat parasites can also import or transmit diseases. For example *Cimex lectularius*, the exotic human bed bug, also feeds on vespertilionid bats and probably transmits *Trypanosoma cruzi* and other bat trypanosomes (Paterson and Woo, 1984). In what seems to be an unlikely relationship several aquatic insects and snails are intermediate hosts for bat helminths (Chen, 1964). With the constant influx of exotic species into aquatic habitats, these parasites can be introduced into bat populations.

Caves historically have been expounded as nutrient-poor low-energy systems (Culver 1982). The low-ecosystem productivity probably acts as a mitigating factor in controlling exotic cavernicoles. Exotic species have invaded North American caves. When all invertebrate species (excluding mollusks) from cave surveys in Alabama, Florida, Illinois, Georgia, South Carolina, and Tennessee were counted, 11%, were exotic (Peck, 1970; Holsinger and Peck, 1971; Lewis and Peck, 1978; Peck, 1989, 1995; Reeves, 1999). When individual orders of cavernicoles were examined, some trends were evident. For example, 42% of the terrestrial isopods in caves of Alabama and Georgia are exotic species (Peck, 1989; Holsinger and Peck, 1971). Most exotic isopods are larger than the endemic troglobitic *Miktoniscus* spp. European isopods, including the troglophiles *Cylisticus convexus* and *Porcelio laevis*, are now more common than the native species in some epigean habitats. Both species have symbiotic fungi and nematodes (Lichtwardt, 1986, Reeves unpublished data). In natural situations, symbiotic fungi do not harm their hosts and probably help in nutrient absorption (Lichtwardt, 1986). Symbionts sometimes kill new host species or become parasitic when they are introduced. There are reports of several symbiotic fungi killing their hosts or occluding their guts (Coluzzi, 1966; Sweeney, 1981; Lichtwardt, 1986).

Millipedes are a second group of cavernicoles with a large percentage of exotic species. In Georgia, 50% of the cavernicoles in the orders Julida and Polydesmida are exotic species (Holsinger and Peck, 1971; Reeves, 1999). In Howards Waterfall Cave, both exotic millipedes and endemic troglobites occur sympatricaly and both groups are infected by fungi and nematodes (Reeves, 1999). The most common exotic millipede in many Georgian caves is *Oxidus gracilis* (Reeves, 1999). *Oxidus gracilis* sometimes forms aggregations and releases a noxious compound when disturbed. Hundreds of aggregating *O. gracilis* can move into caves. These millipedes both compete with native species and harbor potential diseases. The ecological effects of these exotic millipedes have not been determined.

Annelids, specifically earthworms, are the third most common exotic cavernicoles. Unlike isopods or millipedes, earthworms are often overlooked by cave biologists. Exotic earthworms have replaced many of the endemic species in epigean habitats (Reynolds, 1998). Caves might represent a refugium for endemic species but in most caves this is not true (McAlpine and Reynolds, 1977; Reeves and Reynolds, 1999). Earthworms are capable of changing the physical and biological components of cave soils. For example, Dendrodrilus rubidus and Aporrectodea spp. can preferentially feed on guano or organic debris with high microbial or fungal activity (Doube and Brown, 1998). Earthworms and their smaller relatives, enchytraeids, can consume and change the soil microbial community once they are established in a cave. Earthworms also transport nematodes and other potential earthworm pathogens.

Not all exotic species that harm cavernicoles live in caves. The red imported fire ant, *Solenopsis invicta*, forages in caves. In Texas, *S. invicta* has had devastating effects on most ground-dwelling wildlife (Allen *et al*, 1994). These ants will forage more than 20 meters from their nests, and colonies are now present in all southern states. The projected range extension of *S. invicta* could make it an important exotic species when managing caves and karst in the United States. *Solenopsis invicta* is common in disturbed areas like high-traffic cave entrances.

Exotic cave species are not limited to caves in the United Sates. Tropical caves are not as well studied as in the United States, but good records exist for some systems. For example, Chilibrillo Cave, Panama, was surveyed by Peck (1971) and among the endemic species collected in the survey were several exotic cavernicoles. These exotic species included a snail (*Subulina octona*), a millipede (*Chrondrodesmus kelaarti*), and possibly the collembolan (*Cyphoderus similis*), which is also known from Africa, California, and Iowa (Peck ,1971).

Exotic species in caves have not attracted attention compared to those in epigean habitats. Some studies have made the distinction between exotic species and endemics (Howarth, 1973), but further research is needed to determine the real significance of exotic species in cave ecosystems. Ecological studies are needed to assess the influences of exotic species on the cave ecosystem. Hundreds of exotic millipedes, earthworms, or isopods probably impact the cave ecosystem. The relationships between native cavernicoles and exotic species have not been well documented. Until the influences of these exotic species are understood, no management practices can be recommended. Simple lists of what species are troglobitic, troglophilic, trogloxenic, and accidental will not suffice to predict the ecosystem-level effect of exotic species, their relative abundance, or parasite-vectoring capacity.

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The Caver's Resource Workshop

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Abstract

In 1997 and 1998, Rob Robbins and the Southport Chronic Cavers developed a prototype for a Caver's Resource Workshop, the first of which was held at Fall Creek Falls State Park in Tennessee in March, 1998. The workshop was a response to a perceived need to help cavers become aware of, and be able to work with, various professionals and agencies involved in the study and management of caves. After extensive planning, the workshop was attended by more than fifty persons and produced positive results. This model can be usefully emulated in other sections of the country to further exchanges of information and cooperation between cavers and resource professionals and agencies.

History

During the fall of 1997, Rob Robbins was involved in the cleanup of Hubbards Cave in Warren County, Tennessee. This specific cave contains not only a biological significant population of the gray bat (*Myotis grisescens*) but also some very significant historical artifacts.

Having been a caver off and on for many years and with very little organized caving, Rob was unaware of the scope of the contents of caves and how to go about protecting their contents as outlined in the National Speleological Society's Conservation Policy that follows:

NSS Conservation Policy

The National Speleological Society believes: That caves have unique scientific, recreational, and scenic values; That these values are endangered by both carelessness and intentional vandalism; That these values, once gone, can not be recovered; and That the responsibility for protecting caves must be assumed by those who study and enjoy them.

Accordingly, the intention of the Society is to work for the preservation of caves with a realistic policy supported by effective programs for: the encouragement of self-discipline among cavers; education and research concerning the causes and prevention of cave damage; and special projects, including cooperation with other groups similarly dedicated to the conservation of natural areas. Specifically:

All contents of a cave—formations, life, and loose deposits—are significant for its enjoyment and interpretation. Therefore, caving parties should leave a cave as they find it. They should provide means for the removal of waste; limit marking to a few small and removable signs as are needed for surveys; and, especially, exercise extreme care not to accidentally break or soil formations, disturb life forms, or unnecessarily increase the number of disfiguring paths through an area.

Scientific collection is professional, selective, and minimal. The collecting of mineral or biological material for display purposes, including previously broken or dead specimens, is never justified as it encourages others to collect and destroys the interest of the cave.

The Society encourages projects such as: establishing cave preserves; placing entrance gates where appropriate; opposing the sale of speleothems, supporting effective protective measures; cleaning and restoring over-used caves; cooperating with private cave owners by providing knowledge about their cave and assisting them in protecting their cave and property from damage during cave visits; and encouraging commercial cave owners to make use of their opportunity to aid the public in understanding caves and the importance of their conservation.

Where there is reason to believe that publication of cave locations will lead to vandalism before adequate protection can be established, the Society will oppose publication.

It is the duty of every Society member to take personal responsibility for spreading a consciousness of the cave conservation problem to each potential user of caves. Without this, the beauty and value of our caves will not long remain with us.

The Plan

It was at a bat flight count in late September 1997 that a talk with Geary Schindel, then of the Nashville Grotto, brought to light the concept of a workshop where cavers and scientist could get together sharing information. We hoped that the scientists from many fields would enlighten cavers as to their particular interest in caves, enlisting the cavers' aid. It would become a two-way street where the cavers would learn what to look for and whom to contact and the scientist would gain more help in the way of eyes in the various caves.

The first thoughts were to keep it reasonably priced and centrally located to better benefit the majority of the cavers in the area. Accommodations were also taken in account for those having to travel. To keep the price reasonable, the only payment for the speakers was that lunch would be provided for them.

The Preparation

As soon as a date, time, and location were ascertained, the Southport Chronic Cavers set out to contact numerous scientists and organizations they thought might be interested in participating. It was astounding the replies received. "Why hasn't this been thought of before?" to "I'd be more than pleased to participate. What do I need to bring?" More speakers than time were invited to participate. As it ended up, there were 18 speakers with each being allotted only 20 minutes as we only had the conference room at Fall Creek Falls State Park near Pikeville, Tennessee, for just the one day.

Each speaker was requested to submit a brief biography and outline of his presentation. Audio-visual equipment was to be supplied by Fall Creek Falls State Park. The brief biographies and outlines were used to prepare a handout booklet containing all the pertinent information.

The Presentation

On Saturday, March 14, 1998 the first ever Cavers' Resource Workshop was under way in a conference room at Fall Creek Falls State Park. The following speakers put on a program for the cavers that was second to none. Ground was broken for an unheard of cooperation between those in attendance and the presenters. There were many slide presentations and handouts along with question and answer periods.

The Workshop was broken into four sections:

Government and Cave Preseration

Bob Hatcher - TWRA/Endangered Species Coordinator

Bob Currie - USFWS/Federal Endangered Species Act

David Withers - Natural Heritage/Zoologist

T. Hill Henry - TVA/Zoologist

Humans and the Cave Environment

Dr. Jan Simek - UT/Knoxville/Anthropologist

Nick Fielder - State of Tennessee/Archaeologist

Joe Douglas - VSCC/Historian

Cave Fauna

Dr Michael Harvey - Tennessee Tech/Biologist/bats

Dr Ronald Caldwell - Lincoln Memorial University/Biologist/Tennessee Cave Salamanders

Dr Thomas Barr - UK/Lexington Ret/Biologist/cave beetles

Non-governmental Organizatons , Cave Preservation, Research and Stewardship

Helen Galloway - The Cumberland Spelean Association

Geary Schindel - The Southeastern Cave Conservancy

Beth Guidera - The Tennessee Nature Conservancy

Stuart Carroll - Fall Creek Falls/Naturalist

At the end of the program, a standing ovation for the presenters was given to show appreciation for their participation. The total cost to the cavers attending was $8.00 plus the cost of their food and lodging should they have decided to spend the night.

Understanding the need for more trust and cooperation, a second Cavers' Resource Workshop is being scheduled for the spring of 2000.

Future Assistance

To set up such a program in your area is really quite simple. You can follow the above example, which also gives clues to the type speaker that may be of interest, or you can be more selective for the exact type of program you wish to put on.

Cave Gate Airflow Disturbance— A Qualitative Study

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Abstract

Cave gates have been used for many years to protect cave resources from damage and destruction by intruders. Such gates, if not designed properly, impose certain restrictions on the natural airflow in and out of the caves. Recently improvements have been made that help minimize their effect on the cave environment. Modern cave gates employ improved strength, ease of installation, and reduced airflow disturbance designs. New gates, when designed and installed properly, attempt to protect the caves without altering the delicate cave environment.

The materials and construction techniques for cave gates typically consist of steel pipe, angle iron, and steel bar sections. The components can be assembled in various ways to both protect the cave and minimize airflow disturbance into and out of the cave. To date no quantitative or qualitative study has been conducted on airflow disturbances caused by a typical cave gate. Little is known about how much effect various gate designs have on cave airflow at typical airflow velocities at a cave gate.

This paper describes a qualitative study of cave gate generated airflow disturbances. This study was performed in a water tunnel at the University of Tennessee Space Institute using half-scale cave gate sections. Flow velocities tested are representative of typical large cave gates in large cave passages with Reynolds numbers on the order of 100,000. Different flow visualization techniques have been used to observe the flow patterns and disturbances generated by different gates. Interpretation of the observed flow fields identifies differences between various gate designs.

Many years of cave gating experience in the United States has shown increasingly better ways of how, where, and when to install gates in sensitive cave locations. Although the exact reasons to gate caves varies, the methods involved must be sensitive to the cave environment and the caves' inhabitants. Early gate installations were focused on keeping out unwanted visitors without much thought going into what changes the gate itself could make to the cave. Besides discouraging the passage into and out of the cave for bats and other cave dwelling creatures early gates also changed air flow patterns enough to impact some cave environments severely. Cave gate builders[10] [12] [15] soon learned to build gates that were less restrictive to both bat flight and airflow. Many major improvements have been made in the last decade yet cave gate technology is still in its' infancy. Gate designers have met the challenges of design by creating tamper resistant, free flowing gates that bats tolerate well. These gates are constructed of inexpensive materials [1] [10] [12] and can easily be built by volunteer labor. Studies and observations have shown them where gates should be placed to minimize airflow disturbance and maximize the protection of the cave environment. To date however there have been no published studies of what effects a gate has on the air flowing through it in typical cave environments.[1-5] [12] [15] Much can be learned from the study of airflow through various gate designs to improve future gates. This paper investigates the flow quality of airflow through typical cave gate structures and will attempt to determine the impact that gates have on the amount of flow through them. Some of the important aerodynamic concepts needed to understand flow through gate structures is explained to allow readers to better appreciate the effects cave gates have on airflow.

Because gates must be positioned so that they do not adversely affect airflow through the cave system[12] [15] one of the most important aspects of cave gating is the location of the gate. Air flowing through a typical cave passage must flow over and around objects such as rocks, formations, and man-made structures like gates. Flowing air must turn corners, go through restrictions, and interact with rough solid surfaces. When fluid flow is constricted by any means (such as smaller area sections or objects that reduce the available flow area) several changes occur in the fluid flow. A scientist named Bernoulli[8] did fluid experiments through tubes fitted with reduced area sections. He noted that the fluid velocity increased while its pressure decreased through the reduced area sections. For frictionless incompressible fluids the Bernoulli Equation is $P + \frac{1}{2}\rho V^2$ = a constant where P is pressure, ρ is density, and V is velocity. This equation will not apply for very fast fluid flows where the velocity is over approximately one third of the speed of sound of the fluid. Slow moving airflow such as that in caves is considered to be incompressible and the Bernoulli equation applies well for this type of flow. Another important concept is that for frictionless incompressible flow the mass flow of fluid through a system is constant.[8] The equation for mass flow is ρAV where ρ is density, A is area, and V is velocity. A change in flow area A and/or density ρ requires that the velocity increase to keep mass flow constant. Using these equations it is apparent a cave gate will not reduce the amount of air travelling through the cave since the velocity of the air through the openings in and around the gate will simply increase to allow the same mass of air to pass through the cave passage as would without the reduced flow area induced by the gate. In real life fluid flows friction does exist between the fluid and solid objects. Some loss of flow can and does occur for all real fluid flows due to friction and other phenomena. Some of these shall be discussed in later sections of this paper.

In order to understand airflow through cave gates it is necessary to have a basic understanding of how to characterize fluid flows. An important parameter used to characterize fluid flow is called the Reynolds number. Reynolds number is defined as the flow velocity multiplied by a characteristic length (measured in the direction of the fluid flow) divided by the kinematic viscosity of the fluid flow.

$$R_e = \frac{VL}{v}$$

Reynolds number[7] [8] can be used to compare one fluid flow to another. It can also be used to determine the best model scale and fluid velocity combination to correctly simulate a fluid flow in a wind tunnel. For example a half size model would need to be tested at twice the fluid velocity to correctly simulate full size flow in the same fluid. Similarly using a test fluid with ten times the kinematic viscosity would require flow velocity only one tenth that of the real fluid to match the Reynolds number condition with a full size model. It can be shown that the typical Reynolds number for cave gate airflow is on the order of 100,000. This is based on a characteristic length for a cave gate section (in the direction of flow) of three inches and a velocity of 10 ft/sec. Large cave gates likely have average airflow velocities lower than 10 ft/sec. Velocity was experimentally determined in Hubbards Cave by the authors using smoke to observe the airflow through the north and south gates. It was found that the average typical summer day velocity through the cave gates at Hubbards was three to 4 ft/sec. This suggests that for many properly gated caves the flow of air is very slow through all but small constrictions in the passages. For this paper a Reynolds number of 100,000 was used to determine the flow velocity and model scale for testing in a water flow tunnel. A water tunnel was chosen due to the superior flow visualization capabilities it provides over that of wind tunnels using air or other gases. Dye is injected into the water flow to help observe the structure of the flow through the half scale cave gate models.

In real fluid flows friction[7] [8] is created by the interaction of the fluid with other objects. Objects in the path of a moving fluid create disturbances to smooth steady flow. In caves these objects can be walls, formations, holes, rocks, and even gates. Disturbances to smooth flow are under the general category of turbulence. The change from smooth flow to turbulent flow can be induced by many sources.

Surface roughness, protrusions, blunt objects, and even streamlined objects can cause fluid flow to become turbulent under various conditions. The friction and fluid turbulence created by objects in a flow create drag. Drag is measured as the force applied on an object by a fluid passing over and around it due to friction. Drag in any fluid flow can result in a loss of flow rate since some of the momentum of the flow is used to change the direction and circulation of the flow field. Under most conditions drag causes an area of lower pressure due to the momentum loss the fluid experiences. This phenomenon is usually called pressure drag. The pressure drag of individual objects can be determined in wind tunnels while measuring the pressure drop across the object as well as the drag forces it creates. A drag coefficient for any object can be experimentally determined for a range of Reynolds numbers and can be used to compare the efficiency of various objects with matching flow Reynolds numbers. Many times the fluid flow interaction between objects in flows creates drag that is higher than the combined drag of the individual objects. It is therefore important to model each object carefully and to study the combination of all objects in a flow when possible. The ideal case is to have a near full scale model of the object in question in a wind tunnel. Most of the time this is not practical and smaller sections or scale models must be tested in the space permitted by the wind tunnel. Since drag can and does lower the amount of flow through fluid conduits such as caves it is important to try to find what effect a cave gate type of structure will have on air flow in caves.

Cave gates are routinely constructed with vertical and horizontal members[12] that resemble the protective screens and grids used for foreign object protection in wind tunnels and engine inlets. These structures have been studied to obtain data for pressure drag and the associated pressure loss, turbulence, and structural loads. These data can then be used to increase the efficiency of the screens and grids to obtain maximum performance of the tunnels and inlets. Some relations are available to get a good idea of the magnitude of the drag effects in screen like structures subjected to fluid flow. Hoerner has generic equations for calculating the loss coefficient for such objects. He starts with the concept of solidity ratio which is simply a ratio of area covered by the object (cave gate for example) to the area of the original opening. A solidity ratio of 0.5 for example would mean that a cave gate would reduce the area available for airflow by half. This does not mean that the airflow is reduced to half that of the original airflow. The velocity will simply increase across the gate to allow most of the airflow to pass through as stated earlier per Bernoulli and mass flow equations. Some small quantity of airflow is lost due to the effects of pressure drag. Thus we can easily see that the more efficient a screen or cave gate structure is aerodynamically the less flow loss the flow path will experience. Hoerner quotes two useful equations[7] that describe the loss coefficient for both screens made from round rods and those made from sharp edged strips. These equations are for fluid flows with Reynolds numbers greater than 1,000 and thus are similar in scale factor to cave gate airflow. Since screens and cave gates have many differences in construction, interference between vertical and horizontal members, and cross sectional shape of members they can only be used to approximate the relative difference in loss coefficient between cave gate designs. Even with these limitations the following analysis proves useful to illustrate the pressure drop characteristics of these types of structures. The equations follow:

$$\zeta_{round} = (\delta / (1 - \delta))^2$$

The above equation is used for round rod screen or grid where δ is the solidity ratio for the screen or grid.

$$\zeta_{sharp} = (0.5 + \delta)^2 / (1 - \delta)^2$$

The second equation is used for sharp edged strip construction screens and grids where again δ is the solidity ratio for the screen or grid. Arbitrarily choosing a solidity ratio of 0.4 gives a loss coefficient for round screen equal to 0.444 whereas the sharp edge screen loss coefficient will equal 2.25 using the same solidity ratio. The definition of loss coefficient is given by the equation:

$$\zeta = \Delta P / 0.5 \rho V^2$$

Where ρ is the density and V is the velocity of the fluid. Using this equation the Pressure drop ΔP can be calculated for each loss coefficient using density for air at sea level of 0.00237 lb-sec/cu-ft and choosing a velocity of 10 ft/sec to simulate slightly faster cave gate airflow through the gate passages between members of the gate. For a loss coefficient of .444 the pressure drop is 0.053 lbs/sq-ft and similarly for a loss coefficient of 2.25 the pressure drop calculates to 0.226 lbs/sq-ft. Using a standard air pressure of 14.5 lbs./sq-in the percentage of pressure loss calculates to 0.009% and 0.010% respectively. Either of these pressure drops is so small at low velocity as to be insignificant. Of course using the above equation it can be determined that the pressure drop would rise with the square of the velocity. Figure 1 shows the Pressure Loss versus Velocity for several Loss Coefficients. From this figure it is obvious that larger Loss Coefficients produce larger pressure losses. Also the figure shows that pressure loss is very small for velocities less than 50 ft/sec. Mass flow of fluid through a screen or gate is affected in the same proportion as is pressure loss. To illustrate this consider the fluid flow downstream of a screen or cave gate where a small pressure loss has occurred and the temperature and density have stabilized with smooth steady flow conditions. Since mass flow is defined as density times flow area times velocity,

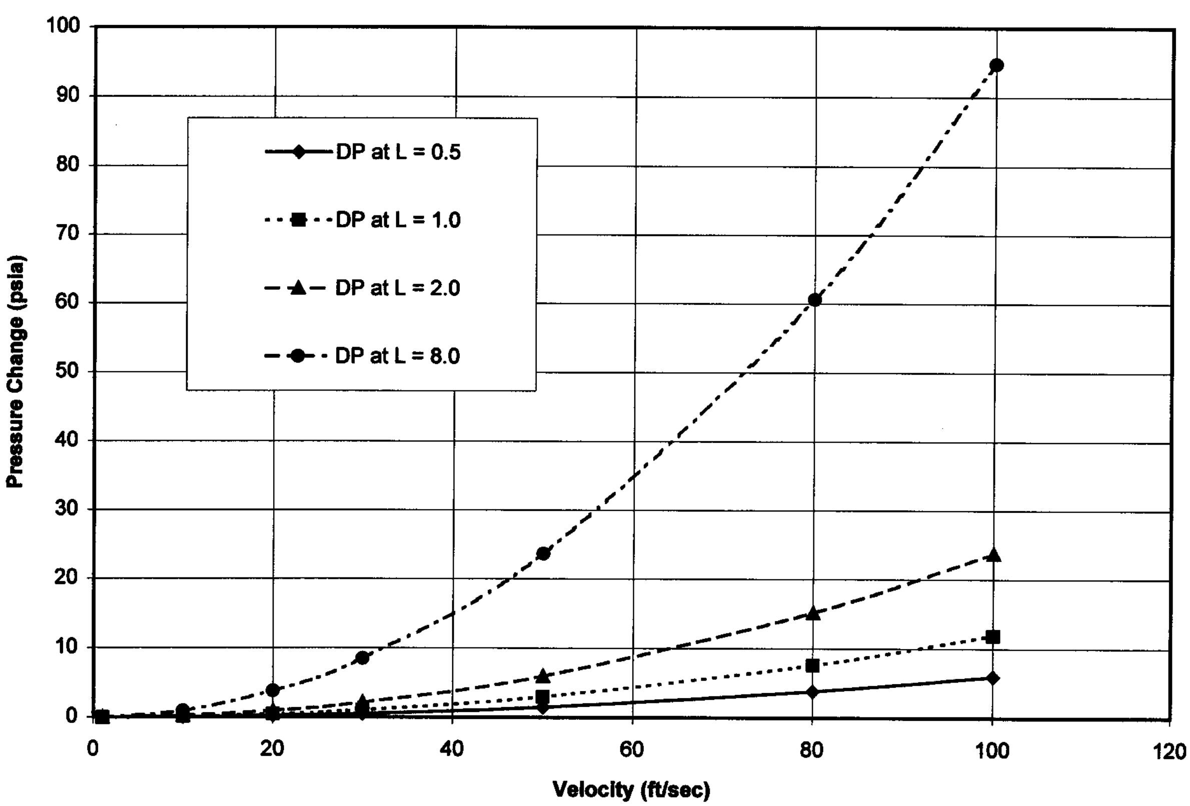
$$\dot{M} = \rho AV$$

and density is defined (for ideal gases) as pressure P divided by a constant R times temperature T,

$$\rho = \frac{P}{RT}$$

if we assume temperature is constant then density ρ varies directly with changes in pressure. So with area A and velocity V held constant (for a given flow path) the mass flow of that flow path will change proportionally to any change in the pressure. This means that for example a 1% loss in pressure will equate to a 1% loss in mass flow rate. Though the above loss coefficient equations are for screen or grid meshes having square flow paths and not for cave gates they do show that the pressure drop across structures such as these at Reynolds numbers representative of cave gate airflow is very small at the low flow velocities occurring near cave gates. Since cave gates have fewer vertical members than the square flow path of screen structures the interference effects to fluid flow between vertical and horizontal members should be less for gates than for screen struc-

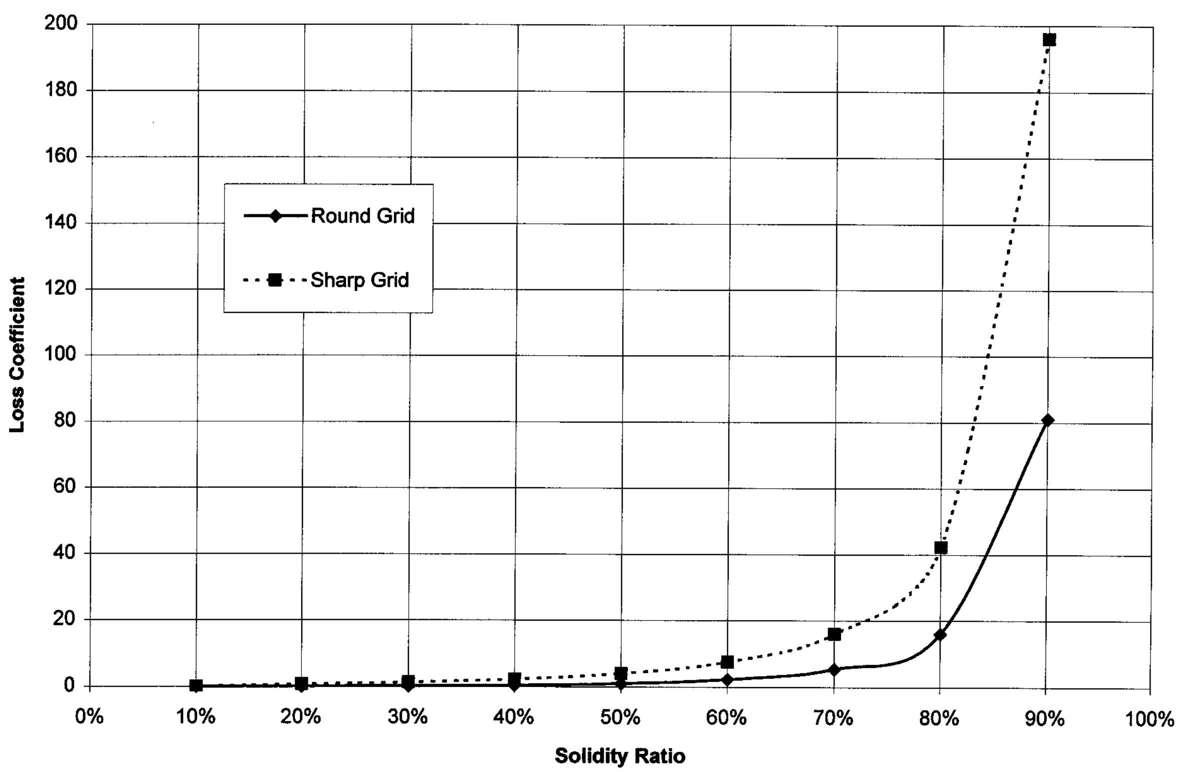
Figure 1
Pressure Change (DP) vs Velocity at Various Loss Coefficients (L)



tures. In other words it is likely that cave gates create less pressure drag than screens for similar cross section shapes at the same flow conditions. The solidity ratio is also an important parameter in determining the pressure drag of any gate or grid structure in a fluid flow. Figure 2 illustrates the effects of solidity ratio on the loss coefficient. For ratio of less than 0.6 the loss coefficient remains small but rapidly gets larger as it increases above this value. At a solidity ratio of 1.0 the loss coefficient goes to infinity (corresponding to zero flow through the gate). One other obvious conclusion is that in general round cross section structures are more efficient than sharp edged structures at Reynolds numbers of 100,000. Accordingly it is of interest to investigate the flow qualities of some of the typical cave gate design cross sections.

Some data exists for steel structural shape drag coefficients. Hoerner[7] has examples of round bar, square bar, and angle steel at various Reynolds numbers that can give us an idea of what representative values for drag coefficient are for these shapes. Rounded edges in general have less resistance to fluid flow than sharp edges. Thus round bar has a lower drag coefficient than do square and angle sections. Data on these shapes for air at a Reynolds number of 100,000 varies from a value of 1.2 for round bar to 2.0 for square bar shapes with angle somewhere in the middle. This shows that round bar creates less drag at Reynolds numbers of 100,000 than do the other shapes with sharp edges and corners. From an analysis of drag coefficient alone the logical conclusion is that round bar is a better material for efficient fluid flow in a cave gate. However, an interesting flow pattern can develop using round bar for Reynolds numbers between 10,000 and 100,000 that can affect drag as well as create vibrational modes that could possibly be undesirable. At these Reynolds numbers round bar shapes develop a pattern of vortices on the downstream side of the bar. These vortices (forming what is called a "vortex street") are periodically developed on opposite sides of the shape creating vibrations in the air that generate tones. This is sometimes evident in the plains states where wind makes phone wires "sing" between telephone poles. While there is no data to support any harm will come to cave species from sound vibrations emanating from gate vortices it is undesirable from the stand-

Figure 2
Solidity Ratio vs Loss Coefficient for Round and Sharp Edge Grids



point of causing change to the cave environment. This condition (known as the critical Reynolds number) will change when the Reynolds number rises between 300,000 and 400,000 at which point drag coefficient drops to approximately 0.3. The reduction of drag at these Reynolds numbers is due to a transition from turbulent boundary layer flow from laminar boundary layer flow.[9] The boundary layer of a flow is that which lies close to the surface of an object in a flow. This layer is responsible for all surface friction drag due to the shear forces in the fluid as it reacts with the object in the flow. In the case of round bars transition from laminar flow to turbulent flow allows the size of the flow wake trailing the bars to become smaller and thus the total drag to become smaller.[8] This loss of drag coefficient could be desirable for caves with higher flow velocities where Reynolds number is usually above the critical Reynolds number. Note that these data are based on wind tunnel tests of single round bar shapes and do not incorporate interference effects that vertical members, attachment hardware, and other components of a cave gate or grid type structure have upon fluid flows. Actual flow patterns can only be modeled in wind or water tunnels where these phenomena can be observed and measured. It should be noted however that it is very possible that round-bar cave gates with Reynolds numbers between 10,000 and 100,000 produce vortex streets with resultant tone generation.[7] Depending on the flow conditions the frequency of these tones may or may not be audible to humans. The tone frequency can be calculated using the equation for the Strouhal Number for round bar. At a Reynolds number of 100,000 the Strouhal Number for round bar is 0.2 and with the other flow parameters known the frequency of tone generation from vortex streets can be obtained.[7] The equation for Strouhal number is given as:

$$S = f\,h / V$$

where S is the Strouhal number, f is the frequency in Hertz, h is the diameter of the round bar in feet, and V is the velocity in ft/sec. For a velocity of 10 ft/sec the frequency for vortex streets is about 16 Hz. The strength of the tone is proportional to the energy of the fluid flow and thus low velocity flows will generate weaker tones.

In summary:

- Every cave gate will experience different air flows,
- The best location of a cave gate is where the airflow is very slow,
- Solidity ratio of cave gates must be kept to a minimum to reduce pressure loss,
- There is less than 1% pressure loss for low velocity airflow for typical cave gate materials at solidity ratios of 60% or less,
- To more completely understand the flow modeling of gates either analytically or experimentally is encouraged.

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Methods for Estimating Colony Size of Mexican Free-tailed Bats

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Poster Session

Carlsbad Cavern hosts a colony of several hundred thousand Mexican free-tailed bats (*Tadarida brasiliensis* mexicana). Colony sizes, population behavior, roost geography, repeatability of methods, and cost efficiency have all been problematic for obtaining accurate abundance estimates. Past methods have varied from gross ocular counts to complex calculations using video and still photography. No previous method has provided a measure of statistical precision nor has any method proven valuable as an index to trends. Investigators and managers need a variety of procedures from which to choose so that consistent and useable data can be obtained. The poster presents our progress in developing reflective infrared photography as a means of estimating colony size and assessing long-term trends in large colonies of Mexican free-tailed bats. Using still black/white infrared images taken from fixed photomonitoring stations in the roost, with photographs repeated on consecutive days, colony size is estimated from the area of cave ceiling covered by bats. For example, using a roost density of 2,153 bats per square meter and the mean area of ceiling covered with bats, we estimated there were 353,000 (+1- 22,000) resident bats roosting in Carlsbad Caverns in fall 1996. We believe that immigration and emigration contributed to increasing trends in area estimates during the spring monitoring and decreasing trends in fall estimates. With 1997-99 refinements, including monitoring flight noise, developing ceiling contour maps, and carefully timing additional photographic sessions, this method should provide valid estimates of annual population trends.

An Overview of the Balcones Fault Zone Portion of the Edwards Aquifer in South-Central Texas

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Abstract

The Balcones Fault Zone Portion of the Edwards Aquifer is located in south central Texas and includes portions of Kinney, Uvalde, Medina, Bexar, Comal, and Hays Countys. The Edwards Aquifer is the sole source of water for over 1.5 million people including the city of San Antonio. It is extensively used for crop irrigation and is the source of water for the two largest springs in the southwestern U.S.—Comal Springs and San Marcos Springs. Geologically, the aquifer occurs in the Cretaceous-aged Edwards Limestone, which is extensively faulted and fractured. Groundwater is contained in dissolutionally enlarged fractures and bedding plane parting.

Previous examination of the Edwards Aquifer revealed the presence of at least 44 unique species living within the aquifer, including the widemouthed blindcat and the toothless blindcat. However, little is known of the distribution and population of these species.

The Edwards Aquifer Authority has been mandated by the Texas Legislature to manage, conserve, preserve, and protect the Edwards Aquifer. Pursuant to this mandate, the Authority has undertaken a series of 17 inter-related "optimization" studies over the next eight years at a cost of more than $6 million. These studies are designed to obtain the necessary data to better manage the aquifer.

Delineation of the Recharge Area for a Karst Spring Serving a Small Community on the Cumberland Plateau Escarpment

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Abstract

To meet Wellhead Protection requirements of the Safe Drinking Water Act of 1993, all public water systems must delineate a zone of protection around their ground water source. The purpose of delineating Wellhead Protection Areas is to define the geographic limits most critical to the protection of a well or spring. Use of water tracer techniques is costly and can present potential use problems to water customers in highly karst springs with relatively small contributing drainage areas. The incorporated Town of Orme, Tennessee, is supplied by Orme Spring. Orme Spring emerges from the north side of a karst window in the Monteagle Limestone. Orme Spring Wellhead Protection Area was delineated using surface reconnaissance, cave exploration as well as a cave map superimposed on the topography, and altimetry collected over different seasons of the year. With a good degree of confidence, a delineation of the area contributing recharge to Orme Spring was determined without the cost and possible water use disruption of a tracer study.

The Wellhead Protection Program for Public Water Systems in the USA was developed in response to the 1986 Amendments to the Federal Safe Drinking Water Act. The State of Tennessee adopted and began implementing this program in 1994. The purpose of the program is to define the recharge zones for all Public Water Supply ground water sources and protect these areas by a variety of means, including land use planning and community awareness.

This paper focuses on the water source for a small town in Marion County, Tennessee—the Town of Orme. Orme currently has a population of 93 people. It was originally developed as a coal mining industrial town located at the head of Doran Cove, a valley incised into the Cumberland Plateau of Alabama and Tennessee (see Figure 1). No coal has been deep mined from this area in more than 40 years. Today the town consists of a generally low- and moderate-income population, with a preponderance of senior citizens. The municipal water source is a spring (Orme Spring) discharging into a large sinkhole above the town and the entire water system is gravity fed. During normal flows, a small portion of the spring water is captured in a spring box and routed through sand filters to a holding/disinfection tank, which feeds the distribution system. During extended periods of very dry weather, the majority of the spring's output is captured for the water system. During periods following heavy rains, the turbidity of the spring water becomes high, necessitating the filtration system, which has been in existence for more than 25 years, having been constructed and maintained by various Federal aid programs to Appalachian communities. Figure 2 is a photograph looking up the valley toward the town and the escarpment where the spring is located.

The Tennessee Division of Water Supply undertook to aid the Town of Orme in delineating

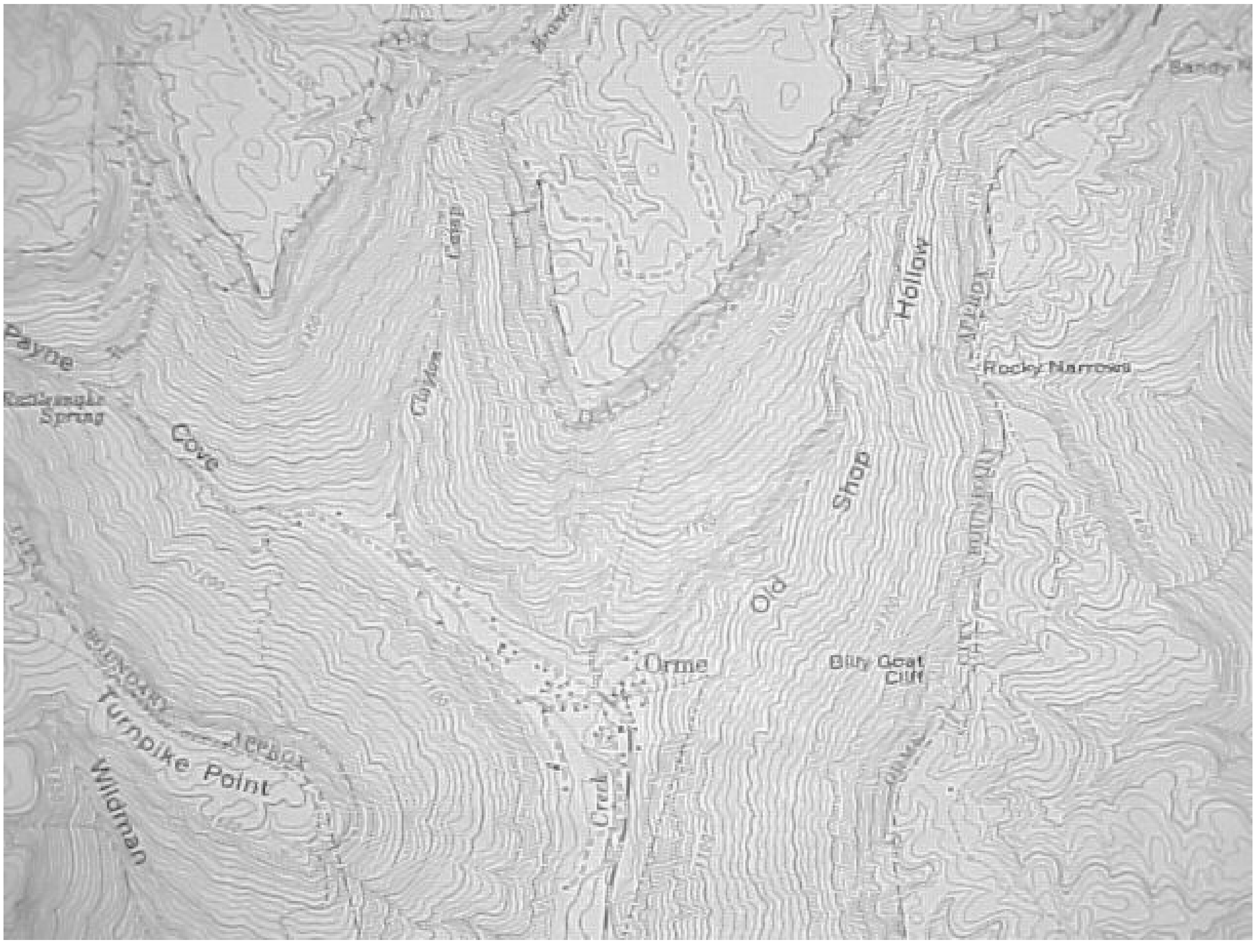

Figure 1: Topographic Map of the Orme, Tennessee, area.

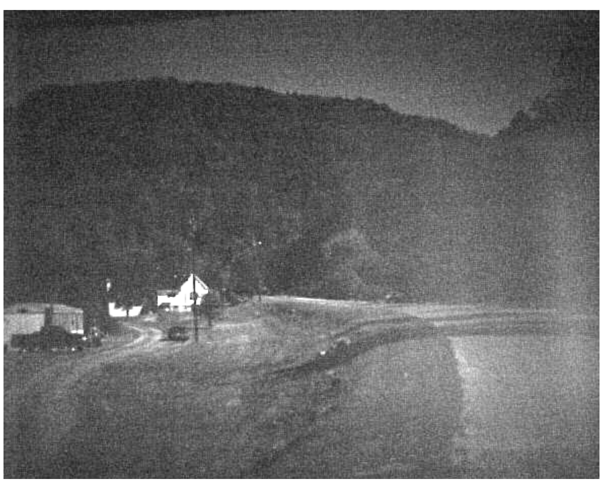

Figure 2: Doran Cove looking toward Orme and Orme Spring.

the recharge area for Orme Spring due to the financial circumstances of the municipality, even though the legal requirement for the determination is with the water supplier. Water tracer techniques using dyes or other materials were considered, but potential problems for the customers of the water system seemed probable from this because of the relatively small drainage area and the system's limited water storage capability. While not ruled out as a final resort, it was decided to develop the best picture possible of the flow patterns by surveying the locations and elevations of the various karst features.

The majority of the Town of Orme lies between 800 and 900 feet in elevation, while the Orme Spring issues at an elevation of 1,137 feet from the Monteagle Limestone and immediately plunges more than 50 feet into a sinkhole cave, also in the Monteagle (see Figure 3). Figure 4 is a diagram by Dr N.C. Crawford of the generalized geology and stream capture and resurgence patterns existing on the slope of the Cumberland Plateau. Figure 5 shows the karst and mining features identified up slope from Orme Spring in both the Clayton Camp Branch and Old Shop Hollow drainages, which flank Orme Spring on both the east and west, respectively.

Division of Water Supply personnel began the field investigation by walking the ridge of

Figure 3: Orme Spring, Showing Spring Box and Top of Waterfall.

the plateau above Orme Spring and the two drainage valleys noted above. Clayton Camp Branch did not have identifiable karst features of significant size and the stream did not appear to be losing any water. No obvious sinkholes were found on top of the plateau. In Old Shop Hollow, however, the stream was found to be sinking in at least two locations. A known and mapped stream cave, White Cricket Cave, also existed in this hollow, and a karst window was discovered near the valley floor below White Cricket Cave. White Cricket Cave is a significant stream cave formed at the contact between the Bangor Limestone and the Hartsell Shale. At the cave entrance, the stream falls over an impermeable layer in the Hartsell and flows underground a short distance to a karst window where it emerges and falls into the Monteagle Limestone. Approximately 160 vertical feet lower, the water emerges again and sinks in the karst window near the valley floor mentioned above. The elevation resolution of the topographic map was not sufficient to determine if the water from White Cricket Cave and the two karst windows might be above Orme Spring and, thus, a possible source to the spring.

Water quality and altimetry data were collected from the lower karst window and Orme Spring. No significant differences were found in the water quality data. However, the altimetry data showed an elevation of 1,107 feet for the insurgence point of the lower karst window, giving an elevation at least 30 feet below the elevation of the spring box at Orme Spring. Therefore, the water in the White Cricket Cave stream and the two karst windows does not contribute to Orme Spring. This discovery allowed a significant area on the east flank of Old Shop Hollow to be excluded from the Orme Spring Wellhead Protection Area. The splitting pattern for water in the upper reaches of Old Shop Hollow between Orme Spring and White Cricket Cave remained to be determined.

Seasonal observation of the discharge rates of Orme Spring, the White Cricket Cave stream, and the lower karst window, as well as both Clayton Camp Branch and Old Shop Hollow streams, added more information to determine the recharge area of Orme Spring. In the dry fall months Clayton Camp Branch had slightly less water than in the wet winter and spring months, while the uncaptured water at Orme Spring is just a trickle in the dry fall months but a raging waterfall in the wet season. This pattern supports the decision to exclude Clayton Camp Branch from the Wellhead ProtectionArea. During dry months White Cricket Cave and its two associated lower karst win-

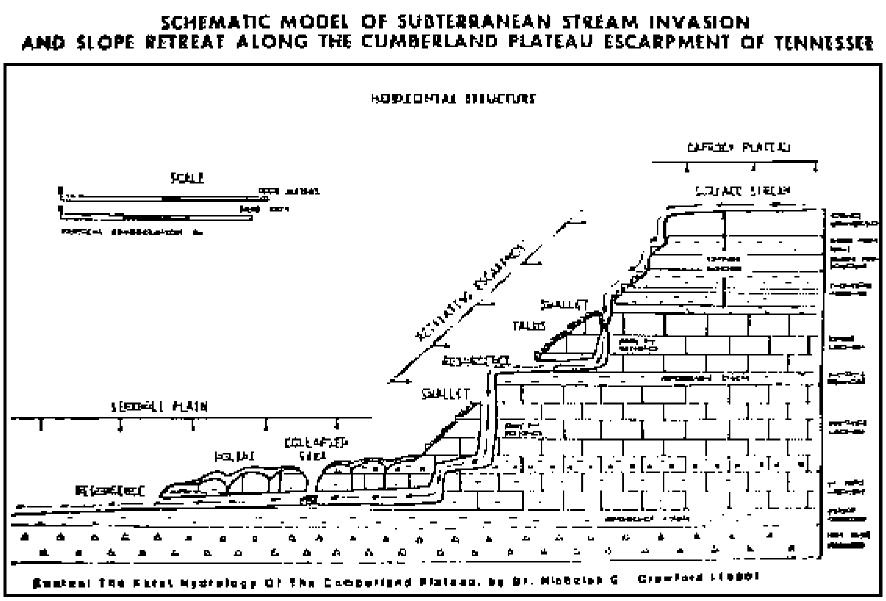

Figure 4: Schematic Model of Subterranean Stream Invasion and Slope Retreat along the Cumberland Plateau Escarpment of Tennessee. Source: The Karst Hydrology of the Cumberland Plateau, by Dr. Nicholas C. Crawford (1980)

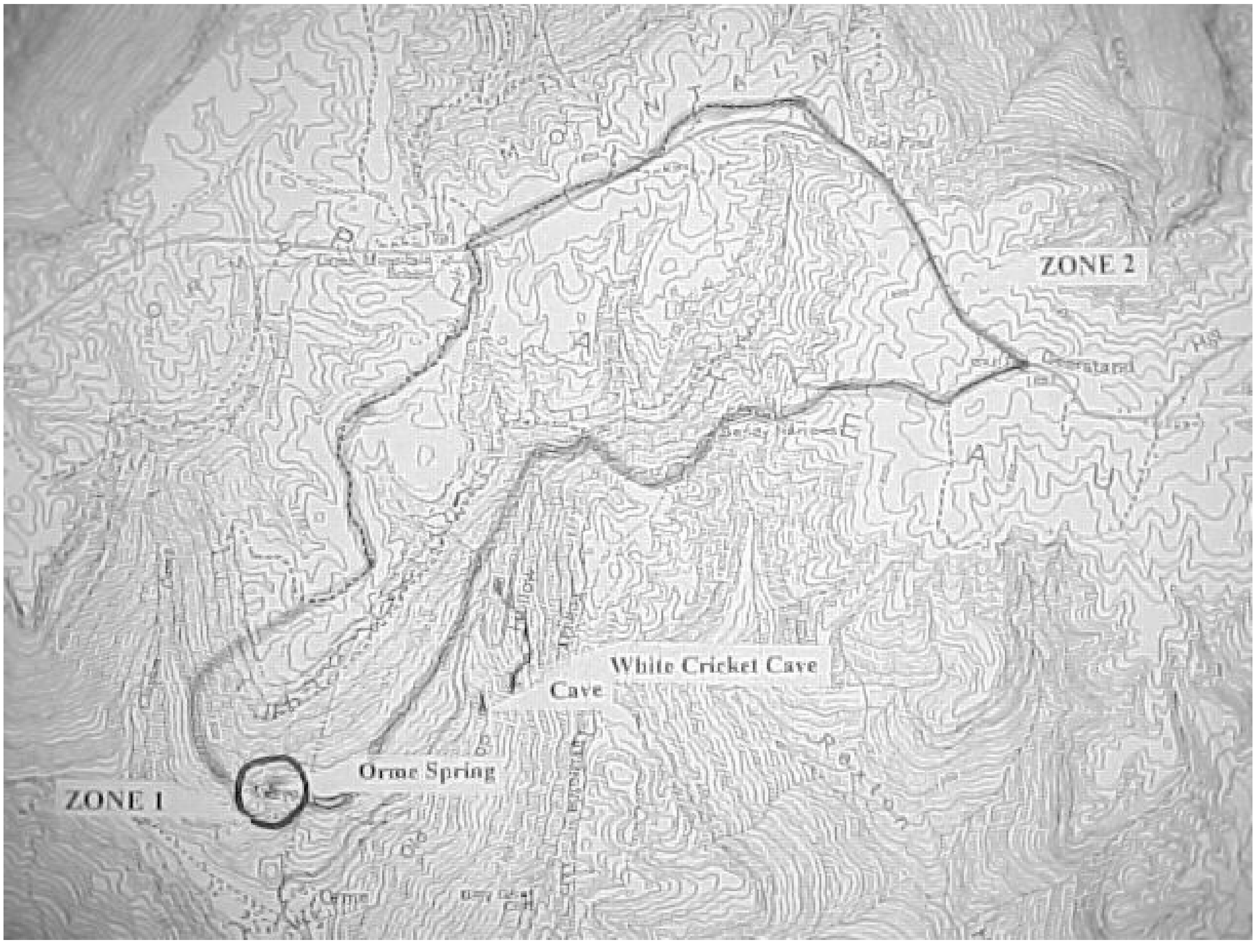

Figure 5: Wellhead Protection Area for Orme Spring, with Associated Karst Features.

dows have a much greater flow than Orme Spring, but in the wet months Orme Spring has a similar, or higher, discharge rate as the White Cricket Cave system. Because of this, the upper reaches of the Old Shop Hollow drainage must be feeding both the White Cricket and the Orme Spring karst systems, with White Cricket capturing most of the baseflow and the Orme Spring conduits taking progressively more of the flow as the upstream discharge increases. This mechanism explains the history of turbidity problems at Orme Spring following heavy rainfall events. All of the upper end of the Old Shop Hollow drainage was, therefore, included in the Orme Spring Wellhead Protection Area.

Figures 1 and 5 show a row of many deep mine portals above Orme Spring and Old Shop Hollow at the base of the plateau caprock. These are the openings to the extensive underground mining project of the Sewanee coal seam that once supported the economy of the Town of Orme. Now all are abandoned and several have discharges of mine water flowing down toward Old Shop Hollow and Orme Spring. Because of this, areas of the plateau in the vicinity of the mines were included in the recharge zone.

Figure 5 shows the final Wellhead Protection Zone as delineated by the above investigative process. This delineation was accomplished without the cost and possible water use disruptions of tracer studies and at no cost to the Town of Orme. The Division of Water Supply feels a good degree of confidence in the accuracy of this work and the delineated zone is now incorporated in the approved Wellhead Protection Plan for the Orme municipal water supply.

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Protecting Inaccessible and Un-accessible Caves

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Abstract

Cavers have done a lot toward protecting caves for which we have access, but what about protection of caves for which access does not exist? A brief discussion of this problem, along with suggestions for protection of these resources is covered. Discussion to include: land trusts, conservation easements, and watershed associations.

Aspects of Cave Management on Federal Lands

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Abstract

This paper includes a brief look into cave management on the federal level. Presentation of an ongoing research project to establish background information regarding various aspects of cave management will be discussed.

The Protection and Management of Prehistoric Cave Art in the Southeast

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Abstract

Knowledge of the existence of dark-zone cave art in the southeastern United States is relatively recent. Documentation and systematic study of this prehistoric medium is even more recent, stemming from the discovery and subsequent research in Mud Glyph Cave, Tennessee. It has now been 20 years since that discovery. There are currently over 30 documented such sites in the Southeast, and several new sites are discovered each year. Many of these dark-zone cave art sites are in imminent danger of destruction by vandals, looters, and graffiti artists. Even cavers can unintentionally damage this ancient art simply by their activities in caves. In this paper we discuss efforts at protecting and managing these fragile sites. Specifically, we focus on recent work in 1st Unnamed and 5th Unnamed Caves and Mud Glyph Cave, Tennessee and 18th Unnamed Cave, Alabama.

Introduction

Ancient art work from the southeast of North America found far below the surface of the earth, in the "dark zone" of caves beyond the reach of external light, is now known in nearly 30 caves. These works suggest what may be several newly recognized but widespread prehistoric art traditions. While the nature and scale of the Southeast's cave art is only now being fully assessed, these traditions are clearly more intensive and expansive than examples of dark zone prehistoric art sporadically recorded in other parts of North America (*e.g.* Bilbao 1997; Greer and Greer 1997). Spanning more than 3,500 years, southeastern cave art has great time depth and originated among Archaic period hunter-gatherers some 4,000 years ago (Simek *et al*. 1998). The fluorescence of this tradition, though, was during the late prehistoric Mississippian Period from AD1000 to AD1600, when complex chiefdoms based on maize agriculture characterized socio-political organizations in the region (Simek and Cressler n.d.).

The use of caves by prehistoric southeastern peoples has been recognized since the 19th century, when early archaeologists entered and explored Mammoth and Salts Caves in Kentucky (Watson 1969, 1974). Prehistoric art, while possibly present in these caverns, was not observed at that time. Archaeological attention was first drawn to the aesthetic use of caves with the discovery of Mud Glyph Cave, Tennessee, in the late 1970s (Faulkner *et al*. 1984; Faulkner 1986). Charles Faulkner of the University of Tennessee undertook the first archaeological study of a southeastern cave art site at Mud Glyph Cave. Over the next decade, more cave art sites were found through informal surveys stimulated by that discovery. Systematic regional surveys were initiated and the rate of discovery accelerated. Over the past two years, ten new cave art sites have been authenticated, bringing the present number to 31. A complex cave art tradition is now evident, one with great time depth and variation in content.

Unfortunately, these prehistoric wonders are in jeopardy. Looters, graffiti artists, and even cavers are taking a toll on this precious ancient art. Over the past five years, we have begun to try to protect this ancient and sacred artwork. Because of the costs often involved in protection, our efforts have been halting—sometimes successful, sometimes less so. Resources, legal issues, and caver cooperation have all contributed to our successes and failures. In this paper we describe and, in some senses, justify our recent efforts at protecting southeastern prehistoric cave art. We discuss some of the problems we face and some of the solutions we have applied. We touch on preservation efforts at several important sites, and we explain why we have taken the approaches we have taken in specific cases. Before we talk about what we have done to manage these cultural resources, however, a few examples of what can happen to these sites when they are unprotected are in order. Hopefully these will show why we have a rather immediate interest in the problem of art cave protection.

A Worst Case Scenario

In June of 1999, we visited 22nd Unnamed Cave in middle Tennessee, not far from 3rd Unnamed Cave where we have conducted extensive archaeological investigations over the past three years and which was the subject of an *American Antiquity* publication (Simek *et al.* 1998). Members of the Tennessee Cave Survey had alerted us to the fact the cave contained "more charcoal than they had ever seen in a cave," a characteristic often indicative of prehistoric dark-zone cave activity. Long known by local inhabitants as an archaeological site, 22nd Unnamed Cave's vestibule at one time contained extensive evidence of prehistoric human occupation. Given this, we decided to conduct a survey of both the vestibule and the dark zone. Before undertaking our study we determined Champion International, Inc. owned the property and we requested and were graciously granted a formal permit from Champion allowing us to work in the cave.

It was immediately apparent that pothunters have heavily looted the cave (Figure 1). Pits and trenches were evident everywhere and artifacts taken from the sediments were lying about on rock surfaces next to looters' holes. During our first visit, we made a general surface collection of cultural materials left behind by the looters. We also explored the cave's dark zone and discovered and identified two charcoal pictographs. Numerous cane torch stoke marks were also noted on the passage walls. Single pieces of cane charcoal were collected from the sediment surfaces just below the panels where

Figure 1. Interior of 22nd Unnamed Cave (Tennessee) showing extensive excavation by looters. The sediment has been reworked by artifact hunters, destroying the context of any archaeological materials.

the pictographs are located. Those samples yielded radiocarbon age determinations of 890 ± 50 BP (AD 1130) and 860 + 50 BP (AD 1160). These ages are statistically indistinguishable from each other and both are well within the prehistoric Mississippian Period in this area. Pottery sherds recovered from the vestibule indicate an Early to Middle Woodland Period presence about 2,500 to 1,500 years ago.

Although 22nd Unnamed Cave was badly looted and vandalized, we decided to conduct more intensive archaeological investigations there in September of 1999. We wanted to thoroughly document the pictographs and stoke marks. We also hoped to excavate several shovel test pits and clean previously exposed looters' pits to elucidate the stratigraphy in the cave vestibule. By extension, we hoped to get some understanding of the cave's occupational history. Unfortunately, absolutely no intact deposits could be found. We were unable to delineate any stratigraphy anywhere in the vestibule other than loose fill from reworked looters' pits. Two shovel test pits near the drip line of the cave yielded some cultural materials that appear to have come from undisturbed sediments. These materials were not, however, indicative of any prehistoric cultural period. Other artifacts collected were recovered from surface contexts where looters apparently left behind artifacts they did not consider valuable. In short, the occupational history of the prehistoric inhabitants of the cave has been completely destroyed by looting.

The dark zone of 22nd Unnamed Cave faired better than the vestibule. Prehistoric peoples traversed every dark zone passage, no matter how small or tight. Cane torch stoke marks and charcoal fragments remain intact and in place as evidence of their passing. In fact, in some crawl passages, the sediment floor is so heavily sooted with charcoal that it appears black. In addition to the pictographs and stoke marks on the walls, there are two distinct panels of human hand prints, smears really, produced by charcoal-sooted hands. Upon exiting some of the sooted belly crawl passages, our hands were covered with charcoal; when we tried to wipe them off on breakdown surfaces, the charcoal smears did not transfer to the rocks. Thus, the handprints must have been made when the charcoal was fresh, and they must be very old.

In sum, prehistoric peoples used and explored 22nd Unnamed Cave very extensively over a period of perhaps 2,000 years. The archaeology of this cave was surely rich and quite important at one time. Unfortunately, we can say very little today about prehistoric activities due to the extent of destruction by looting. This cave is one of the worst examples of looting we have seen, and it highlights the ongoing battle we fight to protect archaeological resources from destruction.

Danger to the Resource

There are numerous examples of unknowing damage to prehistoric art sites in the Southeast. In 1st Unnamed Cave, one of the first mud-glyph cave sites discovered in the ridge and valley of east Tennessee, graffiti artists had plied their craft since early in the 19th century (Simek *et al*. 1997). A fine mud veneer on the cave walls and ceilings made an excellent surface for historical dates, profanity, and signatures. The mud veneer is continually damp as a condition of its survival, and as pliable as the surface is, it saw frequent use even into the modern era. Unfortunately, underlying the historical and modern graffiti was a vast number of prehistoric mud glyphs, some quite elaborate and reflecting the religious symbolism of Mississippian "Southern Cult" iconography (Figure 2).

Figure 2. Mud glyph from 1st Unnamed Cave (Tennessee) defaced by recent graffiti.

Cavers, too, can inadvertently endanger prehistoric art in caves they visit. An example of this comes from 5th Unnamed Cave in middle Tennessee. Identified as a prehistoric burial cave in the 1980s and hidden with rocks and branches at that time, the cave was rediscovered by ridgewalkers in the early 1990s, who opened and began to explore it. Petroglyphs on the walls of the cave, relatively fresh when first observed, were rubbed by persons moving through the cave passages until they began to wear off of the walls. Once open, the cave was easy prey to looters, who dug out the human interments searching for associated artifacts. When we revisited the cave in 1997 to check on its condition, we found fragments of human bone scattered about the mouth of the pit with no remaining intact burial deposits to be found. Many remains, of little interest to artifact hunters, had been tossed into various areas of the cave.

In consultation with the local sheriff's office, the Tennessee State Archaeologist and the Tennessee Indian Commission, we recovered all the human remains we could find from 5th Unnamed Cave for reburial under Tennessee State Law TCA11-6. To be certain that the remains were those of prehistoric people, we radiocarbon dated a small fragment, obtaining a Woodland Period determination of 2,030 ± 50 BP (55 BC). We re-interred the human remains in a remote part of the cave, afterwards sealing the cave with large boulders winched down from above the site using heavy equipment., We were greatly aided in this effort by members of the Spencer Mountain Grotto of middle Tennessee.

Protecting Art Caves

Protecting cave sites is, therefore, of paramount concern to us in our present work of locating, surveying, and documenting prehistoric southeastern cave art. Our approach to protection has several facets. One is that we never use the common or registry name of a cave, even though nearly all the caves containing cave art have common or local names. Instead, we refer to cave art sites by numbers as Unnamed Caves; this nomenclature was developed in consultation with the Tennessee Cave Survey, who asked that we not rename caves (something that can and has created more confusion than discretion) but simply disguise the names. We never give cave locations. And we never confirm or deny the guesses made by archaeologists and cavers based on our publications and public presentations. On the other hand, we are always willing to address the subject of southeastern cave art to lay groups, professionals, and cave organizations. While discrete as to location, we believe that education is the best form of protection. Cavers have become our eyes and ears, discovering many of the known art caves and aiding us in our formal surveys.

Another aspect of our protection program is landowner relations. Most of the sites we are examining lie on private land, and there is no recourse to protection other than what landowners will allow. In nearly every case, landowners appreciate what their land holds and do their utmost to help protect them. The owners of 11th Unnamed Cave, for example, allowed the Nature Conservancy and The Archaeological Conservancy to gate a cave, which contains prehistoric artwork, on their property. The owners of 3rd Unnamed Cave actively protect their caves themselves, monitoring the cave openings and bringing authorities into situations where trespassing occurs. To date, none of the landowners we have encountered have even asked about exploitation or commercialization of the archaeological sites their land contains. Instead, they share our concern with preservation and protection.

In a few cases, especially those where art caves are greatly exposed or on public lands, we have had to close sites by constructing gates. The Tennessee Valley Authority (TVA) and The Tennessee Nature Conservancy have taken leads in this regard. So far, we have helped TVA construct two gates in art caves within their management areas. One of these was 1st Unnamed Cave, where a gate compatible with gray bat habitation was necessary. TVA personnel themselves built the structure and it has not been breeched in over two years. A second TVA site was gated in 1999. 18th Unnamed Cave had no biological import, so a simple, but heavy, gate was placed into its opening. In all cases where TVA has authority over land containing art caves, TVA police monitor the sites even after gating has been completed. Attempting to breech a TVA gate or to loot a site on TVA-managed property is a felony violation of the Federal Archaeological Resources Protection Act and penalties are severe. Thus, caves gated on TVA property are well-protected.

Gating art caves on private land has proved to be a more difficult problem because there is rarely the monitoring program in place that public lands enjoy. This is nowhere more evident than at Mud Glyph Cave. The first prehistoric art cave to be systematically studied, Mud Glyph Cave has been the most difficult to protect. Landowners were willing to have the cave protected but unable to contribute much in the way of resources or effort. When studies were finished in the cave in 1982, a series of gates, each one more substantial than its predecessor, was placed into the cave opening. Each one was breached easily by looters and curiosity seekers. During this time, the grid system used by Faulkner and his colleagues was damaged, and artifact hunters dug several small holes into the cave floor sediments. Fortunately, no damage was done to the prehistoric glyphs. Finally, a six-foot-long section of conduit pipe was driven into the cave opening and filled with concrete and rubble, effectively plugging the cave mouth permanently. There was no weak point, no access for anyone including archaeologists. Thus it remained for nearly 20 years.

There had always been questions concerning the effects of sealing Mud Glyph Cave. Were airflow or moisture regimes altered in such a way as to cause the mud banks bearing the glyphs to dry out? Had the protection itself damaged the art? Had catastrophic rainfall events led to flooding in the sealed cave and destruction of the glyph panels by erosion? The answers to these questions remained unknown as long as Mud Glyph Cave was closed.

In the past year, curiosity seekers dug around the plug into Mud Glyph Cave. While an unfortunate breach of cave security, we have had an opportunity to enter and observe the glyphs. This has allowed us to compare the state of the glyphs in 1999 with their condition in 1982. We present a few examples of these comparisons here. We note that the mud glyphs in Mud Glyph Cave were drawn with tools on hard-packed mud banks deposited by fluvial action (Faulkner 1986). This situation contrasts with some other mud glyph cave art sites we have reported in recent years (Cressler *et al*. 1999; Simek *et al*. 1997).

Figure 3 shows the largest mud glyph panel in the cave; it is also, perhaps, the most vulnerable to erosion, as witnessed by the columnar spalling of clay at the lower edge of the mud bank. Close comparison of the recent photograph (Figure 3b) with Bill Deane's 1982 photo (Figure 3a), however, shows that there has been virtually no change in the erosion front for 19 years. This lack of change characterizes all the panels we examined (Figure 4). Even on a very fine scale, such as for the small owl glyph shown in Figure 5, no new drying cracks have formed and no cracks have widened due to changing interior environmental conditions. Thus, despite 17 years of closure, the glyphs in

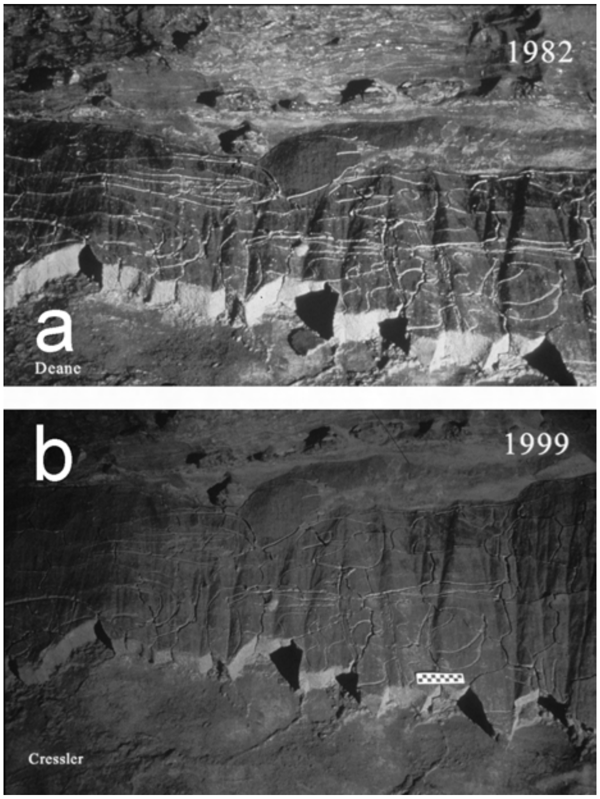

Figure 3. Mud glyph panel from Mud Glyph Cave (Tennessee). 3a: the panel in 1982; 3b: the same panel in 1999. Note the mud erosion front at the base of the bank; there is no change in the panel over 17 years. (Photos: a: Bill Deane, b: Alan Cressler)

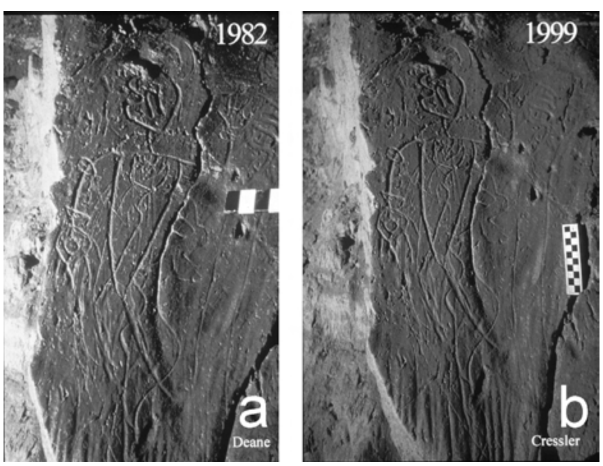

Figure 4. Individual mud glyph from Mud Glyph Cave (Tennessee) showing a warrior/ball player. 4a: the panel in 1982; 4b: the same panel in 1999. Again, note the erosion front at the left of the pictures and cracks that are present in the surface of the mud bank containing the glyph. No change in condition is evident over the 17 year period represented in these photographs.

Mud Glyph Cave seem to have suffered little due to drying, flooding, or microclimatic variation. This is good news indeed. We have already closed the entrance that compromised the plug, and have already built a very small gate in that new passage. In this way, we believe Mud Glyph Cave will remain secure yet be accessible for study. We hope to initiate long-term longitudinal studies of air flow, humidity variation, and biological activity in order to monitor the condition and assess the preservation of the ancient art. We are obviously quite excited about this prospect.

Summary and Conclusion

In sum, cave and karst managers, especially in the Southeast, should be aware of the potential for prehistoric artwork in the caves they oversee. This rare and precious archaeological record is only now coming to light, and it is more beautiful, and more enigmatic, than we previously realized. Spanning more than 3,500 years of prehistory, these artworks are quite varied in form and content. And they are vul-

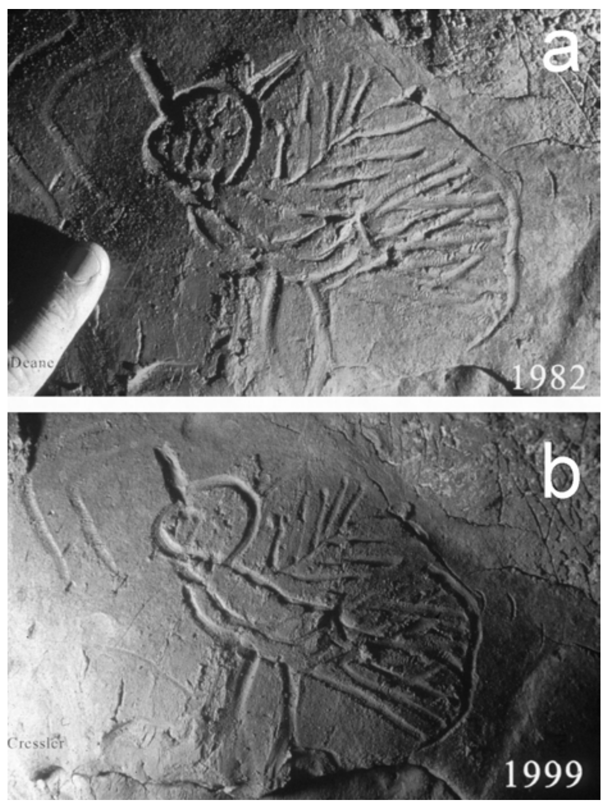

Figure 5. Small mud glyph from Mud Glyph Cave (Tennessee) showing an owl. 5a: the panel in 1982; 5b: the same panel in 1999. Details of the glyph, including line margins and fine cracks in the mud, have not changed since 1982. (Photos: a: Bill Deane,

nerable to damage both incidental and intentional. They therefore deserve our immediate and persistent consideration in all karst management planning.

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Landfill Gas Transport in Karst

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Abstract

The solid waste disposal practices of many localities over the past 40 years have resulted in a proliferation of old, closed landfills located in karst areas. Recent investigations indicate that landfill gas, created by the decomposition of waste, can potentially seep into voids within karst and migrate considerable distances off site. Adjacent property owner concerns have typically excluded off site investigations into the extent of landfill gas impacts. New, innovative gas monitoring techniques have enabled investigators to actively map and track the distribution and migration of landfill gas off site via temporary and non-invasive methods that respect adjacent property owner concerns. Characterizing the extent of off-site impact in karst has enabled investigators to identify primary gas transport mechanisms and flow paths existing within voids in the bedrock. Several case studies of investigations at closed landfill sites situated in karst areas of the Valley and Ridge geologic province of Tennessee and Virginia are presented to illustrate the potential for previously unseen off-site impacts resulting from the transport of landfill gas via the void network. At each case study site, investigators have been successful at remediating off-site gas impacts by accessing the bedrock voids and redirecting the flow to the surface with passive vents installed at the property line. The temporary off site gas monitoring networks installed at each case study site initially enabled investigators to track the gas migration to the bedrock voids. The temporary off-site gas monitoring networks presently provide the data necessary to demonstrate the effectiveness of the passive bedrock-void gas vents.

CKIS—GIS in Cave and Karst Management

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Abstract

A Cave and Karst Information System (CKIS) is a specialized type of geographic information system (GIS). Common tasks and issues are found in developing a CKIS when compared with other types of GISs, but developing a CKIS also presents a unique set of problems, issues, and considerations. ArcView GIS is a popular desktop GIS software product that includes tools, extensions, and customization capabilities that provide a robust framework for data management and visualization of cave survey data and inventories, as well as a substrate for both analytic and interpretive applications. Several prototypes have been implemented that have demonstrated the usefulness of cave and karst information systems and ArcView GIS. Preliminary work has yielded specialized code and techniques for visualization and data management. This work has also identified issues and shortcomings that future work will need to address.

In recent years the significance of karst and caves has achieved widespread recognition. As pointed out by the National Park Service's National Cave Management Coordinator, Ronal Kerbo, cave and karst systems are important for two major reasons:

Firstly, most of the nation's freshwater resources are groundwater. About 25% of the groundwater is located in cave and karst regions. The National Geographic Society notes that water resources are a critical concern as society enters the 21st century. The protection and management of these vital water resources are critical to public health and to sustainable economic development.

Secondly, caves are storehouses of information on natural resources, human history, and evolution. Many avenues of research can be pursued in caves. Recent studies indicate that caves contain valuable data that are relevant to global climate change, waste disposal, groundwater supply and contamination, petroleum recovery, and biomedical investigations. Caves also contain data that are pertinent to anthropological, archaeological, geological, paleontological, and mineralogical discoveries and resources.

None of the components of this interlocking set of resources can be wisely managed without understanding their systemic relationships with the many other components. Understanding, protecting, managing, and conserving such an extraordinarily rich and complex set of resources requires tools capable of integrating, manipulating, and querying the information used to describe their many facets.

In 1997, recognizing that Geographic Information Systems (GIS) technology was rapidly becoming one of the most effective approaches to cave and karst resource management, the Cave Research Foundation established a GIS Resource Development Program under the direction of Mike Yocum. The goal of the program is to assist Cave Research Foundation personnel, federal agency staff, and other researchers access and utilize spatial data, GIS applications, and other software tools for the purpose of cave and karst resource management. A longer-term goal is to use GIS to develop a collective knowledge and support base for cave conservation, protection and management.

The importance of cave and karst research was also recognized at leading GIS software vendor Environmental Systems Research Institute (ESRI), with the establishment of an ESRI Cave and Karst Conservation Program and an ESRI Cave and Karst Special Interest Group coordinated by Bernie Szukalski, an Environmental Systems Research Institute Product Manager.

The Cave Research Foundation GIS Resource Development Program is drawing together GIS expertise to assist in the development of Cave and Karst Information Systems (CKIS). Cave Research Foundation GIS personnel include individuals with broad and varied expertise, who can provide resources, support, assistance, services, and tools to aid researchers both understand and effectively manage caves and karst.

Critical requirements in the CKIS development process are a survey of currently used software and methods, an inventory of existing data and data formats, a user needs assessment, a knowledge of training needs, and the initiation of a core CKIS prototype that can be tested and elaborated to provide specific tools and applications suited to the varying needs of different users.

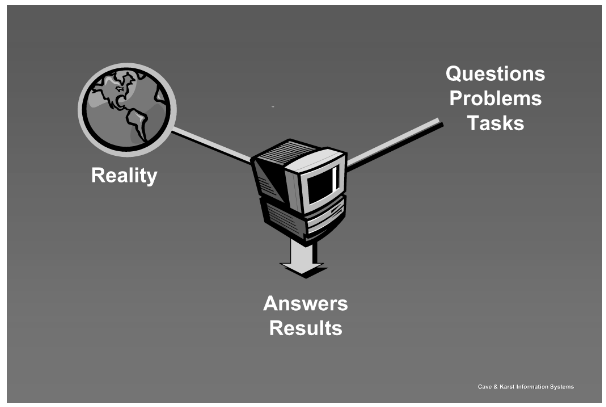
As a first step in developing a prototype CKIS, the Cave Research Foundation, in cooperation with the Kentucky Office of Geographic Information Systems, convened a CKIS Workshop in Frankfort, Kentucky on November 12 and 13, 1998.

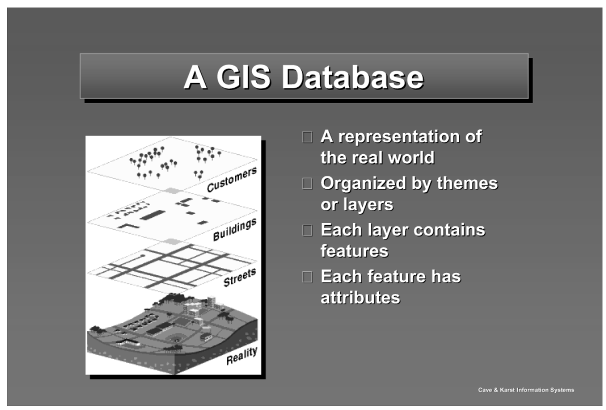
The workshop was devoted to discussing common GIS goals and problems, as well as individual needs of the agencies represented, which were: the Cave Research Foundation, the Center for Cave and Karst Studies, Ewers Water Consultants, Environmental Systems Research Institute, the Kentucky Division of Water, the Kentucky Geological Survey, the Kentucky Office of Geographic Information Systems, the National Park Service, and NCAD Corporation.

Meeting activities included a demonstration of some of the possible uses of ArcView GIS for managing, querying and analyzing data; discussions of methods participants currently use for managing cave and karst data; hardware; software, and data types and formats.

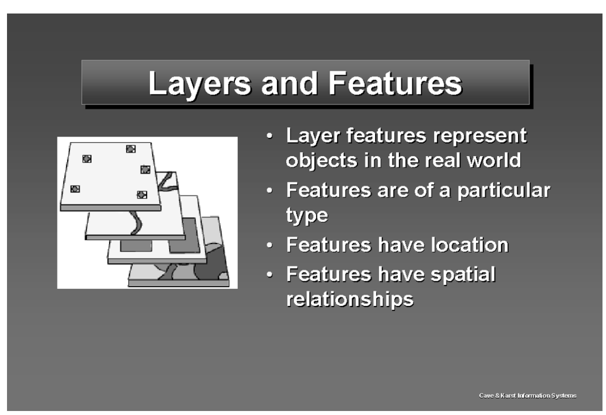
This meeting highlighted the need for both an introduction to GIS and to the potential uses of specialized GIS applications that focus on caves and karst.

What is GIS? GIS is a technology that incorporates various kinds of data and relates them to spatial data, enabling visualization of relationships among the various data sets. A GIS database is typically organized in various layers or themes that represent objects in the real world.

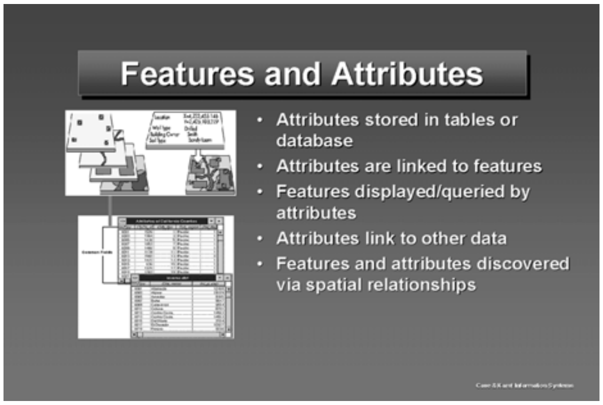




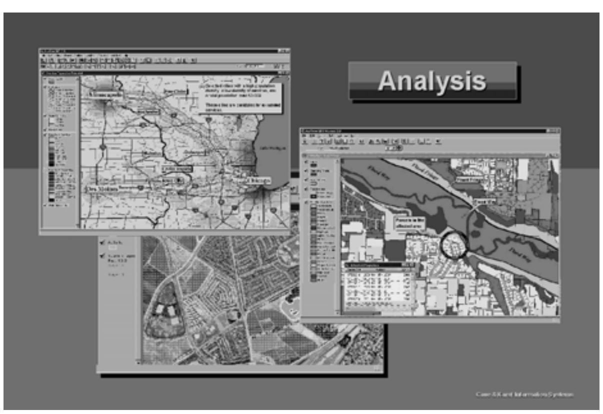
The range of data that is now routinely being integrated into GIS applications is enormous, as its usefulness is recognized in both government and private business. But regardless of the content, the data is organized in similar ways: layers or themes containing features that represent objects in the real world. The fea-



tures can be characterized by their attributes, which are stored in tables or databases linked to the features. The attributes can also be linked to other data. The features and their attributes can be displayed and queried by their attributes.

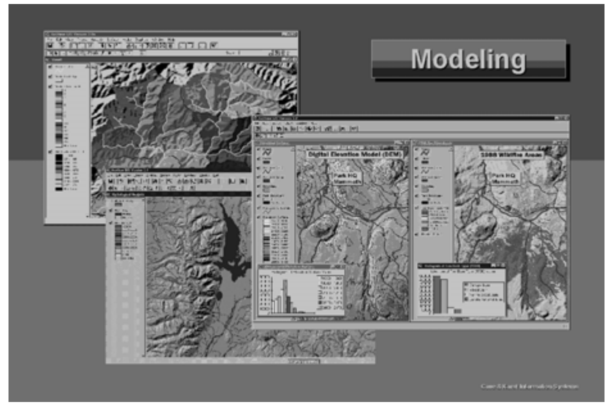


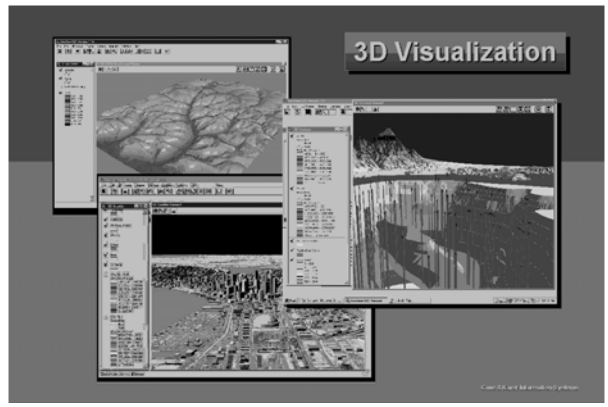
Using the tools provided by GIS software such as ArcView GIS and its extensions, data can be integrated, displayed, queried, and analyzed in many ways, depending upon the needs of the user.



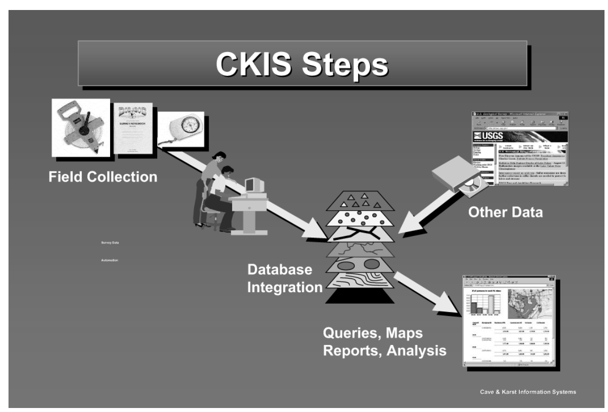
Data can also be used for modeling and visualization.

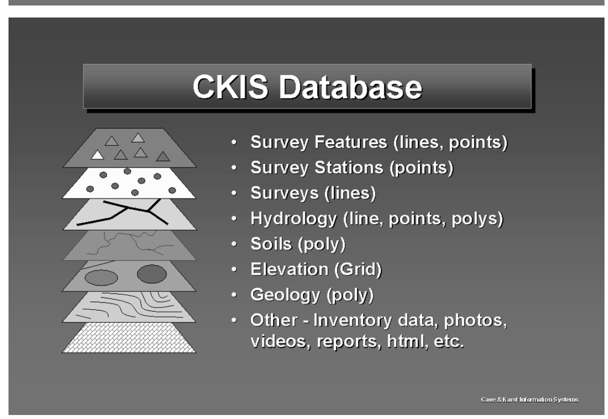
The first steps in building a cave and karst information system are to collect and integrate





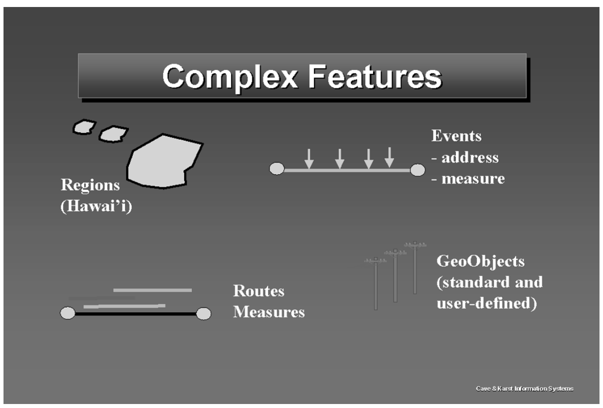
data. This begins with the collection of cave survey data in the field, adding other types of data as needed for the particular application.

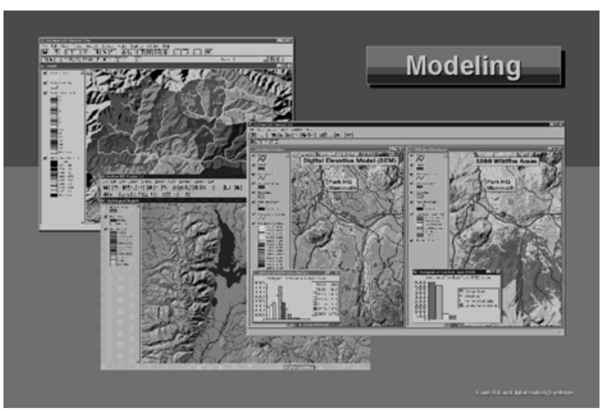




Data types can include such varied items as date, time, yes/no (presence or absence of data item), feature type (e.g., swallet), matrix, x-y coordinates, x-y-z coordinates, flow velocity, discharge rate, solute concentration, temperature, specific conductance, pH, stage (level), relative humidity, wind speed, wind direction, evaporation rates, number (e.g., of a species), air quality indicators, or microgravity readings. In addition to cave related data, the project may also include many types of surface data such as biological data for fire management or vegetation studies.

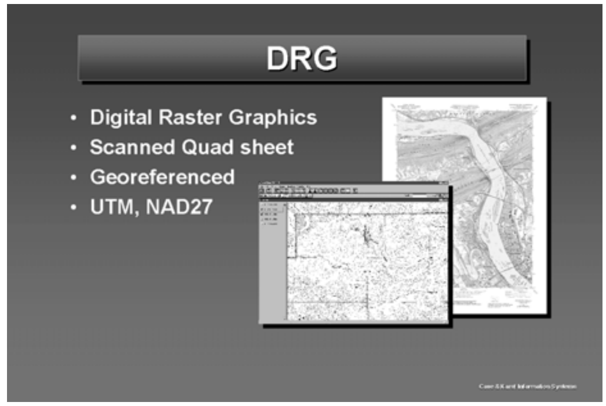
The format of the data included in the project may depend upon the nature of the output required for the final product. Are the features to be analyzed simple or complex? Does the project need raster or vector data?

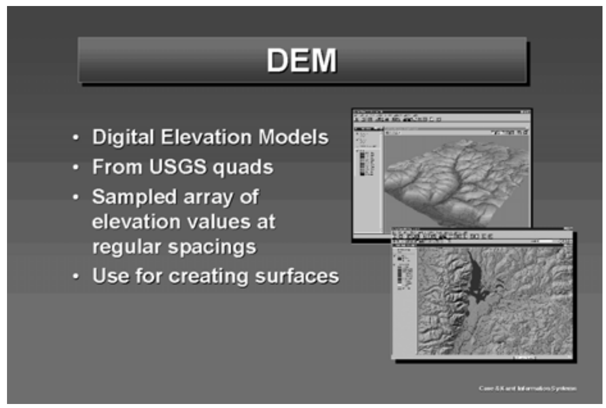


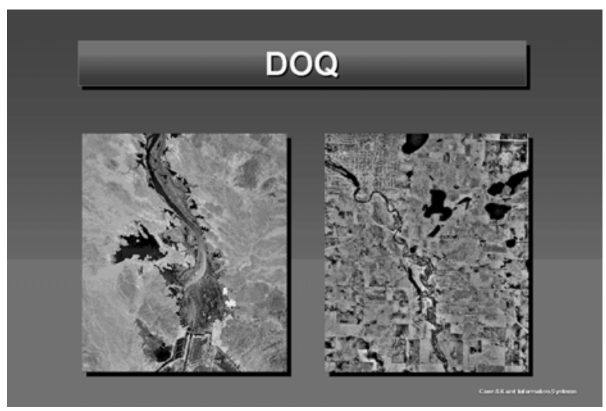


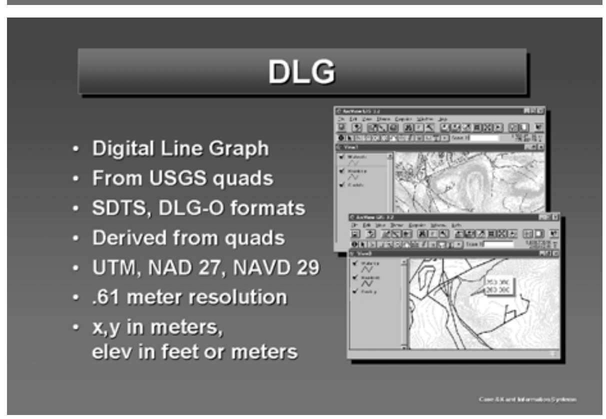
Of particular interest for cave and karst studies are the various types of surface data available from the U.S. Geological Survey. The formats are DRG, DEM, DOQQ, and DLG.

The DRG (Digital Raster Graphic) is simply a scanned and georeferenced topographic sheet. The DEM (Digital Elevation Model), a sampled array of elevation values at regular spacings, is a georeferenced raster format used for creating surfaces. The DOQQ (Digital Ortho Quarter Quadrangle) is a georeferenced aerial photograph. The DLG (Digital Line Graph) is derived from USGS topographic quads, and displays contour lines with their elevations as attributes.

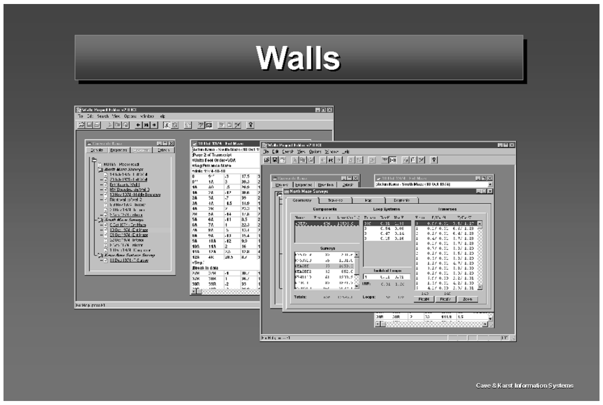


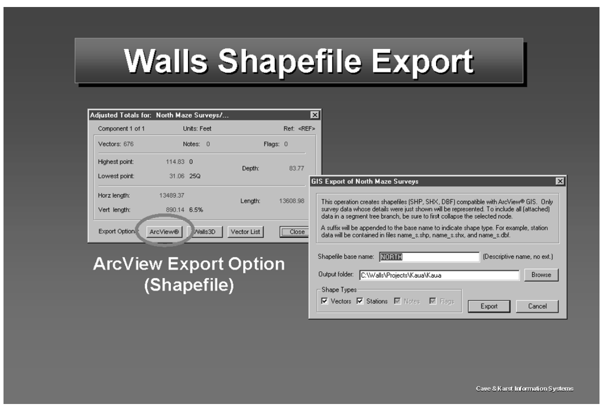




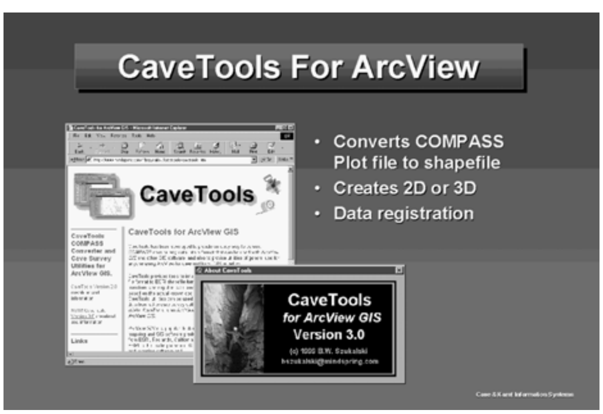


To integrate cave survey data into an ArcView GIS application it needs to be converted to a shapefile format. Currently there are two ways of doing this. Walls, by David McKenzie, exports shapefiles directly.

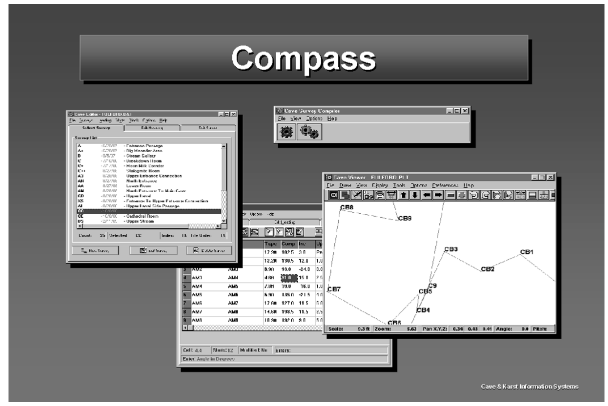


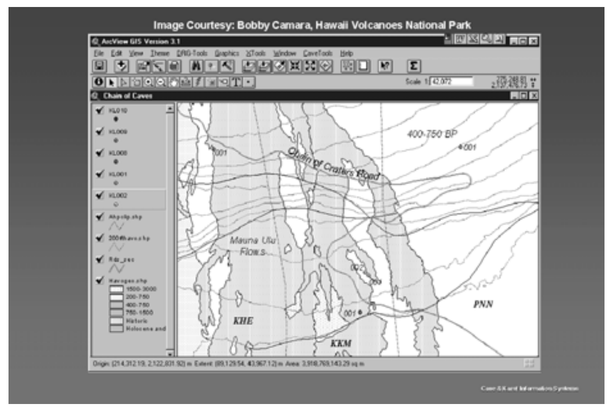


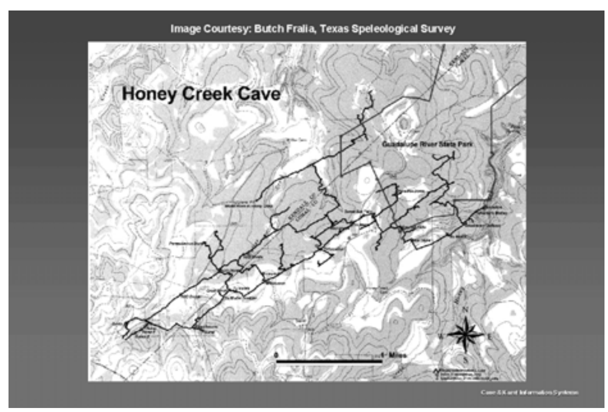
CaveTools, a free ArcView GIS extension, developed by Bernie Szukalski, converts the plot file output from Larry Fish's Compass program to shapefile format. CaveTools also allows registration of any station for which the real world coordinates are known, as well as an x, y or z shift of the shapefile.



Once the cave survey data has been converted to a GIS compatible format, integration with other data types can take place. The simplest display is simply cave survey data as a shapefile line plot, which can be either two- or three-dimensional. This can be overlaid on other data as shown below.

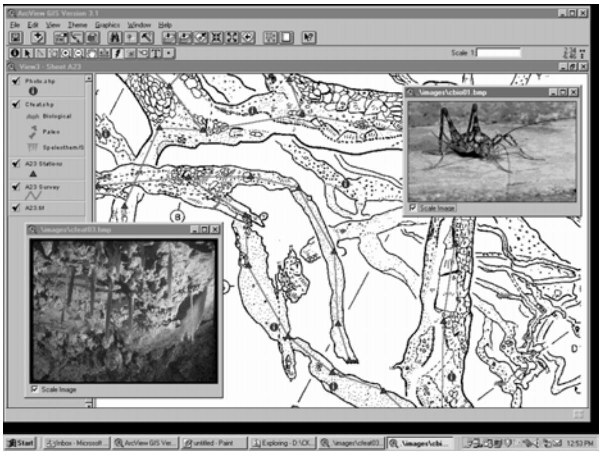


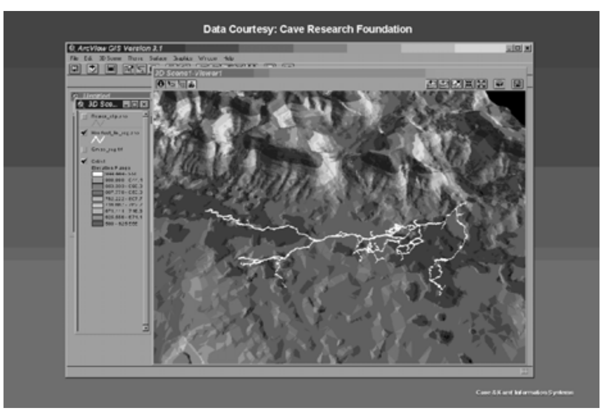


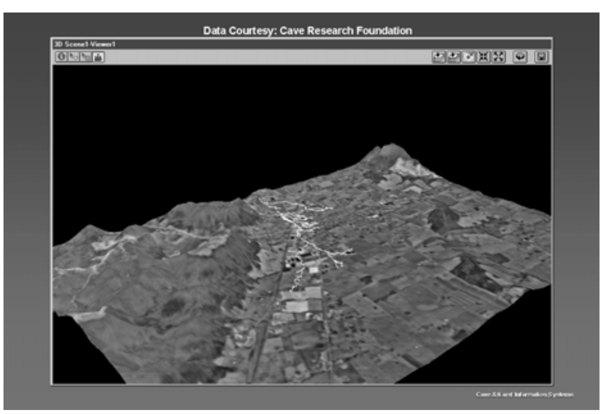


Uses and data types will vary with the needs of the project. GIS can incorporate not only tabular data, but also graphics files and even video (AVI files) that can be linked to specific features.

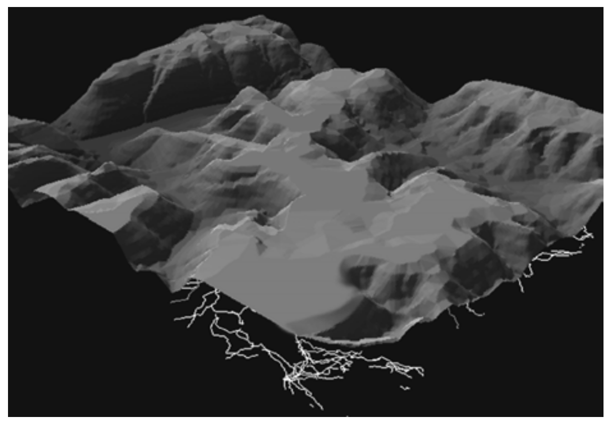
One of the currently most popular uses for cave survey data in GIS is three-dimensional visualization. The examples below show Hidden River Cave, in Horse Cave, Kentucky. On the left the shapefile of the cave survey data is overlaid on a relief map of the area. On the right the same shapefile is overlaid on a DOQQ which in turn is draped over the relief map.







The images below also illustrate three-dimensional visualization. Both show aspects of the Mammoth Cave system in Kentucky.



The use of GIS in cave and karst resource management is at the earliest stages. The primary challenges facing those who would use it are gaining familiarity with GIS software and collecting and storing data in a format that is sufficiently standardized for GIS application. In terms of the software's capability, it is a trivial matter to query: "Find all springs with at least 20cfm flow within 500 feet of the quartzite/marble contact that are located within 1,000 feet of a fault and within a zoning area permitting industrial usage." In terms of data availability and compatibility, that query would be difficult for most researchers.

At this stage, resource managers who are contemplating the use of GIS need to consider several issues:

- the questions that researchers seek to answer by querying data,
- data layers (themes) that might be included,
- existing types and formats of data,
- a "candidate" list of suggested data fields, along with their source,
- metadata, and
- the possible need for systems management and support in developing cave and karst specific GIS applications.

Groundwater Quality in the Caves and Karst of Illinois' Salem Plateau

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Samuel V. Panno

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Abstract

Several factors (examples: row crop agriculture, livestock, private septic systems, and urbanization) have been identified as potential contributors to groundwater contamination in the karst of Illinois' Salem Plateau. We review some of the potential problems and present data from recent and ongoing studies of the groundwater in this area, with an emphasis on four major caves within the range of the federally endangered Illinois Cave Amphipod, *Gammarus acherondytes*, (Amphipoda: *Gammaridae*). Information on microbial contamination, basic water chemistry, and agricultural chemical use are presented. Potential impacts of these contaminants on humans and the Illinois Cave Amphipod are discussed.

In water samples collected monthly from four caves, spring fecal coliform counts were high (some samples with more than 4,800 colony forming units per 100 ml), but dropped during the summer months. Microbial taxa associated with both human and livestock waste were common in groundwater samples. In Stemler Cave, where the Illinois Cave Amphipod has not been found since 1965, dissolved oxygen levels are typically lower than at the other three caves. Agrichemicals have been detected in base level flow groundwater samples mainly during the spring application of agricultural pesticides. Together, these data suggest that several types of human impacts are having a negative impact on groundwater quality in the Salem Plateau.

Acidic Bog Drainage and Limestone Dissolution, Mammoth Cave National Park

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Abstract

Stagnant ponds or bogs produce abundant amounts of humic material and organic acids. Organic acids are also produced on forest floors and by simpler organisms such as bacteria or lichens, thus accumulating in the upper horizon of the soil. The potential impact of these species on karst landscape development has received relatively little study. Organic acids have been found to promote mineral dissolution via two mechanisms, acidification and metal complex formation. In most natural settings, carbonic acid will be the predominant proton donor. The ability to form multifunctional complexes with cations, in addition to their acidic properties alone, allows these compounds to be effective at mineral dissolution.

Two small catchments in similar geologic settings within Mammoth Cave National Park are being examined to study the phenomenon. One of these drainage areas contains a large bog with abundant organic matter and a pH of that has been measured below four. The control stream does not contain bog vegetation and typically has more circumneutral pH levels. An approach combining geochemical modeling with limestone tablet weight loss methods is underway to determine the effect of these organic acids on limestone dissolution and thus potentially on landscape development. Preliminary results indicate significant differences in the geochemistry of the two streams. Conductivity measurements in the bog stream (often microSiemens) are as low as any surface or groundwaters that we know of recorded in the Mammoth Cave area.

The Potential Use of Data-logging Light Intensity and Light On/Off Meters in Mapping Visitor Use of Wild Caves

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Abstract

The Illinois Department of Natural Resources and Illinois Nature Preserves Commission manage several caves that contain the Illinois cave amphipod (*Gammarus acherondytes*) which was recently added to the Federal Endangered Species list. One of the potential threats to the survival of the amphipod cited by the U.S. Fish and Wildlife Service is visitation.

Unfortunately, we have very little real data on the patterns of visitation for these caves. The best data is available for the most visited cave (Illinois Caverns). The main entrance to this cave is owned and managed by Illinois Department of Natural Resources. Current policy allows open visitation by groups of under 25 people with an exploration permit, issued at the cave site. Because of this permitting process we have a good estimate of the number of people entering the cave. However, we have no information on which portions of the cave are visited or on how many groups visit various areas. Three other by Illinois Department of Natural Resources /Illinois Nature Preserves Commission managed caves have poorer information on the number of visitors, but they are much less visited.

For this reason we have proposed using a series of light intensity loggers and light on/off state loggers to determine usage patterns for the caves. We are proposing using approximately StowAway Light Intensity Loggers combined with a few HOBO H6 Light on/off Loggers (both from Onset Computer Corporation) to study patterns of visitor activity in the caves. We have not yet begun this monitoring and are seeking advice and information to help us to do so successfully.

Cave Management vs People Management: Cave and Karst Management and Protection via People Management

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Abstract

Many individuals with a deep interest in caves and/or cave resources have continued their passion by pursuing cave management either as their career or as their avocation. I submit that all who have become involved in cave management have done so as the result of a desire to preserve and protect this specific "non-renewable" resource.

It is timely for us to realize that we, as managers, do not so much manage a resource but find ourselves immersed in managing people and tenuous, more complex social values, particularly professionals employed by public agencies.

In 1995 James J. Kennedy and Jack Ward Thomas wrote:
"How many natural resource managers were attracted to their professions or education in college to understand and manage social value conflict? College students with the desire and temperament to deal with social conflict usually major in social work, labor management, or law. These students accept few values as intrinsic and are educated and role-modeled by their professors to identify, engage in, and resolve social value conflicts. In contrast, natural resources students are usually drawn to their profession by love of nature, a desire to manage or protect intrinsically valuable wildland or environmental resources, and an attraction to work away from the problems of public lands and waters. For all of us living who seek fulfillment of our social values, there are many, many more humans yet to live whose social values must be accommodated by the ecosystems they will inherit from us. They, too, are an important public for us professionals and public servants to serve."

This session will explore managing natural resources as social value and, time allowing, investigate the subject of "Conflict Among User Groups." Participation by all attendees is invited.

Habitat Conservation Planning: A Model for Comprehensive Resource Management in Karst

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Abstract

Habitat conservation plans (HCPs) are effective tools, increasingly used in managing rare and endangered species. The principles in developing Habitat conservation plans can be applied to managing resources in karst areas. First, define the resource, its critical areas, features, and aspects as they naturally occur. Second, define impacts on the resource and assess them by Geographic Information System analyses. Third, set resource management goals. These will vary according to the resource, and may require compromises for unavoidable economic, political, and logistical realities. Fourth, delimit resource protection areas. These areas must meet the goals of resource preservation, assuming the areas are properly managed and even if all other areas are impacted. In some cases, protection areas may need restoration if existing conditions are too degraded. Fifth, a long-term, adequately funded, and effective organization or agency is needed to manage and maintain the resource, and enforce regulations of the resource management plan.

Examples will be given from the central Texas area showing how HCP-style management of rare and endangered cave-dwelling species is compatible with karst groundwater research and protection. Further, such planning can be used to guide the occurrence of traditionally harmful activities to locations that are sound for resource management and often economically advantageous. Sustainable access to caves, karst features, and springs for education, conservation, exploration, and recreation will usually be possible and may be encouraged to certain degrees. how HCP-style resource management does not avoid difficult questions, but it provides the foundation for making sound, long-term decisions.

Site History as an Asset in Preserve Management

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Abstract

The experience of the Michigan Karst Conservancy's Fiborn History Project shows the possible long term contributions of site history to the primary management goals of karst protection at the Michigan Karst Conservancy's Fiborn Karst Preserve (480 acres) in Michigan's Upper Peninsula. Research, including recording interviews, archive searches, and record examinations, contributes to improved site understanding by managers, as well as former and current inhabitants of the Preserve region.

The Preserve site, including the caves and karst features, has been known and visited since at least the 1890s, with a discovered record of near continuous use since then. The site now contains an abandoned quarry and remnant structures. However, the existing published history of the site was barely more than two paragraphs. The investigation found strong, long term local ties to a site which by appearance had been abandoned for more than 40 years. Information uncovered by the Project should contribute to an increased chance of long term viability of the Preserve. By example, it shows the significance of investigation and distribution of general historical information about preserve sites.

Principles and Practice for Design of Cave Preserve Management and Monitoring Plans for Invertebrate Species of Concern, San Antonio, Texas

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Abstract

Karst areas around San Antonio, Texas contain over 300 known caves, some of which contain invertebrate animal species that are unique to the area. The U.S. Fish and Wildlife Service have proposed nine invertebrate species as Endangered Species. Concerned landowners and local agencies, hoping to obviate listing (which would be economically costly and an impediment to use of private property), have formed a coalition to protect, preserve, and manage caves known to have the species. Preserve Management and Monitoring Plans have been prepared for several caves based on guidelines promulgated by Fish and Wildlife Service and evaluation of conditions at each site. Important factors include protection of surface and sub-surface drainage areas, preservation of adequate foraging areas for trogloxenes, reduction of disruptive human access, control of non-native fire ants, and periodic monitoring to evaluate conditions and populations of species of concern. This paper will discuss the principles for design of Monitoring Plans and their practical application at one specific site.

Introduction

In 1991, nine species of invertebrates known only from caves in Bexar County, Texas, were petitioned for listing as Endangered Species under the Federal Endangered Species Act. The taxa include: four apparently different species of blind spider *Cicurina baronia*, *Cicurina madla*, *Cicurina venii*, and *Cicurina vespera*, each known from only one cave at the time the petition to list the species was submitted; *Neoleptoneta microps*, a spider known from one cave; *Texella cokendolpheri*, a harvestman known from one cave for certain and tentatively from another; *Batrisodes venyivi*, a beetle known only from one cave, *Rhadine exilis*, a beetle, known from four sites at the time of the petition; and *Rhadine infernalis*, another beetle, with two described subspecies: *R. infernalis infernalis*, known from two caves, and *R. infernalis ewersi*, known only from one cave, and specimens that could not be identified to subspecies, described as "hybrids," known from at least seven other caves.

The U.S. Fish and Wildlife Service published a proposed rule to list the species as Endangered on December 30, 1998. Threats considered to be potentially endangering these species are listed in the Proposed Rule as: destruction and/or deterioration of habitat by commercial, residential, and road construction; filling of caves; loss of permeable cover; potential contamination from such things as septic effluent, sewer leaks, runoff, and pesticides; predation by and competition with non-native fire ants; and vandalism.

Subsequent to the petition, additional research has found that some of the species are much more widely distributed and abundant than had been known previously. No new locations were found for *Cicurina baronia*, *Cicurina venii*, or *Texella cokendolpheri*. *Cicurina vespera* has been found in one new location, as have *Neoleptoneta microps*, and *Batrisodes venyivi*. *Texella cokendolpheri* has not been positively identified in its previously known habitat and may be extinct. No documented records of this species are known since 1985. *Cicurina madla* has been found in four new locations. Both of the *Rhadine* species were found to be more widespread than previously thought, with many newly discovered sites for each species. The number of caves from which each species is currently known is: *Rhadine exilis*: 31 caves; *Rhadine infernalis*: 22 caves, with three putative subspecies; *Batrisodes venyivi*: two caves; *Cicurina madla*: five caves; *Cicurina baronia*: one cave; *Cicurina venii*: one cave; *Cicurina vespera:* two caves, and *Neoleptoneta microps*: two caves. The species are currently known from a combined total of at least 56 caves.

Most of the land in the area is privately owned, and many landowners have plans for development of their properties. Cooperation of the landowners is essential for the protection of the species and the cave and karst environments in which they are found. In a series of meetings with landowners and local agencies, Fish and Wildlife Service agreed that if the long-term conservation of the nine species could be assured, then the listing proposal would be withdrawn. Specific criteria were issued by Fish and Wildlife Service for protection of caves and Invertebrate Conservation Areas. These were based on the Recovery Plan for Endangered Karst Invertebrates in Travis and Williamson Counties, Texas. This paper describes the criteria and suggests specific ways that they can be implemented to create Preserve Management and Monitoring Plans.

Fish and Wildlife Service Criteria

The karst areas of Bexar County have been divided into six regions, based on geology. At one time it was thought that these regions might be related to the distribution of the species, but this has not been consistently supported by new records of distribution. However, the Fish and Wildlife Service considers these regions to be valid and biologically important, and has laid down the requirement that they be considered in determining the adequacy of protection of the species. For purposes of determining adequacy of protection, the Fish and Wildlife Service requires that for all species that are known from at least three caves in one or more karst regions, protection of at least three Invertebrate Conservation Areas within each region is necessary. The Fish and Wildlife Service has not determined the appropriate course of action for those species known from fewer than three caves, except to require thorough surveys for additional locations.

An Invertebrate Conservation Area is defined by the Fish and Wildlife Service as: "an area known to support one or more locations of a species and is distinct in that it acts as a system that is separated from other karst fauna areas by geologic and hydrologic features and/or processes that create barriers to the movement of water, contaminants, and troglobitic fauna."

This includes one or more caves and the surrounding areas that may provide surface and subsurface drainage, as well as surface foraging areas for trogloxenes.

To protect an Invertebrate Conservation Area, Fish and Wildlife Service specifies certain general considerations that must be taken into account. The first step is to define the area to be protected so that it provides for maintenance of adequate levels of all ecosystem components necessary for survival of the species of concern, and for adequate protection against definable threats. This is necessarily unique for each cave, and must be evaluated by examination of conditions above and below ground.

Important Factors

Fish and Wildlife Service defined the following as important factors for creating preserves: "To be considered 'protected,' a karst fauna area should contain a large enough expanse of contiguous karst and surface area to maintain the integrity of the karst ecosystem on which each species depends. The size and configuration of each karst fauna area should be adequate to maintain moist, humid conditions, air flow, and stable temperatures in the air-filled voids; maintain an adequate nutrient supply; prevent contamination of surface and groundwater entering the ecosystem; prevent or control the invasion of exotic species, such as fire ants; and allow for movement of the karst fauna and nutrients through the interstitium between karst features."

For each preserve designed, and for which a Management Plan is to be created, all of these factors must be examined, and provisions made for them.

Protection of Surface and Subsurface Drainage Areas

The first principle of cave preserve design is to protect the entrance and the surface area above the maximum footprint of the cave from all forms of disturbance and potential contamination by human-generated chemical or biological contaminants. Under conditions designed to eliminate all conceivable threats to the petitioned species, no matter how remote in probability of occurrence and regardless of cost or impact on human land use decisions, preserves would be large areas of undisturbed wilderness. With that level of protection as its implicit objective, the U.S. Fish and Wildlife Service has issued a guideline on karst species preserve size for the Travis and Williamson County species:

"In general, land bounded by the contour interval at the cave floor is the area within which contaminants moving over the surface or through the karst could move toward the cave. Outside this contour, contaminants would move away from the cave."

Applying that principle to the example of a cave that is 100 feet deep with its surface at 1,000 feet above sea level and its floor at 900 feet above sea level, ideally the preserve area should include all land surrounding the cave outward to the 900-foot elevation level. Although the Fish and Wildlife Service guideline may be practicable for caves that are shallow or in rugged topography, it becomes essentially unworkable and unnecessary for deep caves located in flatter landscapes. For example, applying the U.S. Fish and Wildlife Service guideline to one cave known to contain *Rhadine exilis* and to be approximately 115 feet deep, would result in a preserve area of over 125 square miles—that is, most of northwest Bexar County, including a large portion of the developed City of San Antonio. Clearly, the threat of contamination from areas miles away from the cave, even if higher in elevation, is remote. So, certain aspects of the ideal may be impractical and, perhaps, truly irrelevant to the effective protection of the species of concern.

For the karst invertebrates, by far the most important preserve objective will be protection of the surface above the entire cave footprint and the immediate surface and evident subsurface drainage areas directly affecting the cave of concern. This may be best determined by having a hydrogeologist examine the cave and surrounding area and make his or her best approximation on the parameters of the surface and subsurface drainage. Factors relevant to this determination may include but are not limited to regional dip, influences of fractures and faulting, and proximity to potentially related karst features. Often, some portion of these may extend beyond the property owned by or available to the conservation entity creating the preserve. In practice, with local land values exceeding seven dollars per square foot, economy calls for making the preserve size as small as possible, while still maintaining a functioning ecosystem and reducing the potential for contaminants entering the cave. This may call for acquiring additional property, developing cooperative agreements with neighbors, or limiting the area draining into the cave by creating berms around a suitable surface drainage area. In the San Antonio area, strict local regulations prohibit contamination of the aquifer, and greatly reduce the likelihood that any cave habitats would be contaminated.

Preservation of Trogloxene Foraging Areas

The proposed endangered species are very poorly understood by science. Very little is known about their trophic levels and dependencies, although it is presumed that they are predators and/or scavengers that feed either directly or indirectly on the eggs, bodies, or wastes of trogloxenes. Maintenance of a community of trogloxenes is deemed necessary to support populations of the dependent cavernicoles. For most caves in the area, the primary source of nutrient inflow appears to be crickets (*Ceuthophilus* spp.) and daddy-long-legs (*Leiobunum townsendii* Weed). Secondary, and probably much less important, is input from leaves and water falling or draining into the cave entrance or penetrating through seepage. In some caves, droppings of mammals such as bats and raccoons may be important sources of nutrient input, but this is not true of many of the caves from which the species of concern are known.

Specific management actions that can be included in preserve plans to protect and provide for continuing nutrient inflow to the caves are based on protecting sufficient foraging resources and access to provide for a population of trogloxenes typical of the cave. If possible, the preserve design should include an area of undisturbed native vegetation greater than would be necessary for trogloxene foraging, based on current understanding of foraging range. Unfortunately, there are no data to support any notion of the size of trogloxene population necessary to support a viable population of any of the proposed endangered species or the abundance of foraging resources necessary to provide for healthy populations of trogloxenes. A radius of 30 meter (100 feet) from each cave entrance may be considered as the maximum likely foraging distance for crickets, based on data from Elliott. This is the furthest that Elliott found crickets wandering from the cave entrance. Alternatively, it may be possible to enhance the resources available to trogloxenes, thereby enabling smaller areas to provide for the same (or larger) populations. For example, planting persimmons (*Diospyros texana*), an important producer of food for crickets, may increase the resources for these trogloxenes, and indirectly benefit troglobites. Where bats or other mammals contribute to the cave ecosystem, every effort should be made to maintain accessibility of the cave to these animals. Appropriate gates can be designed and installed to permit easy access by trogloxenes while excluding unwanted human access.

Reduction of Disruptive Human Access

Although there has been no evidence that human intruders, other than speleobiologists, actually threaten any of the species of concern, the general concept that human intrusion is bad for the species is strongly held by advocates of preservation. For property owners, reduction of exposure to liability for injury is an important consideration. Limiting human access to the cave preserve is the appropriate answer, either by gates, fences, or both. The best method to do this has not yet been developed—all gates can be breached, and fences can be climbed or cut. Some proponents argue that the least obtrusive type of fence, such as barbed wire, is less likely to invite vandalism than more conspicuous fencing material. However, the Fish and Wildlife Service does not believe that barbed wire fencing is sufficient for cave preserves. It is not currently known what type of fencing would be acceptable to the Fish and Wildlife Service, reasonable in cost, resistant to trespassers, esthetically harmonious with the surroundings, and transparent to trogloxenes. As with any other cave gate, a gate for a preserve must be custom designed and built for that particular cave. It must be resistant to trespass but not disrupt access by trogloxenes, and be accessible to personnel carrying out the monitoring program. Also, provision should be made for access by rescue teams, in the event of an emergency.

Control of Invasive Exotic Species

Several species of exotic animals have invaded Texas caves. Effective Integrated Pest Management programs have not yet been developed and tested for species likely to occur in this situation. Of greatest current concern is the introduced fire ant (*Solenopsis invicta*), which is thought to be a predator on at least some of the species of concern. Although direct predation on any of the petitioned species has not been described, fire ants are known to prey on insects and also to forage inside caves. Fire ant control is considered necessary for the protection of karst ecosystems. Methods that have no impact on desirable insect species are not known to be especially effective for fire ant control. Current research is examining alternative ways of controlling fire ants, and may find more effective methods than those that are currently available. Any preserve plan should include recommendations currently being made by the Fish and Wildlife Service for fire ant control near caves known to have endangered species. All portions of the preserves should be accessible for fire ant control using the most appropriate approved technique. The current approved method calls for application of boiling water to active fire ant mounds within 35 feet of the cave entrances. Access to apply boiling water must be possible to all points within the preserve. Beyond the 35-foot radius, toxic baits can be placed in the morning and picked up before sunset, when the trogloxenes emerge. Fire ant control should be done quarterly, as part of the Preserve Management and Monitoring Plan. Preserve managers should be aware of exotic invasive species in the preserves, and should keep abreast of current techniques available for least toxic Integrated Pest Management in sensitive situations.

Periodic Monitoring and Maintenance

Because the primary reason for establishing and maintaining the cave preserves is protection of biota, some form of biological monitoring is necessary to evaluate the success of the preserves. Funding for the monitoring program could come from the landowner, land trust, or other management agency, or from a public agency such as the Fish and Wildlife Service that was concerned about the welfare of the species. Appropriate biological monitoring would, ideally, provide sufficient data to effectively evaluate conditions, estimate population parameters of species of concern, and detect incipient problems before they become detrimental to the ecosystem.

Biological monitoring over time should lead to accumulation of a body of useful data and information contributing to scientific understanding of the species and their ecosystems. Unfortunately, normal, healthy population parameters for any of the species known to occur in Texas caves are completely unknown. The handful of speleobiologists who have worked in the area have, at best, accumulated lists of species they found on only one or a few expeditions to any particular cave. There is no published knowledge of population size fluctuations in relation to any normal cycles or perturbations for any species of troglobite, trogloxene, or any cave in the area. Even anecdotal accounts are minimal. Therefore, systematic monitoring of populations of karst invertebrates over time and related to changing conditions would be breaking new scientific ground.

Crucial to the success of such an endeavor would be minimal disruption of the system by the monitoring process. Until very recently, the best speleobiology was based on the scorched earth policy of collecting at least one of everything in sight, and turning over rocks and debris in the quest for a complete list of species present. This "bugs in a bottle" science is not appropriate for protection of species of concern in a carefully managed preserve. Monitoring must be performed in the least disruptive manner consistent with acquiring useful data, and the impact of the monitoring process itself must be included as among the factors studied.

The team responsible for the monitoring process would ideally be the same year after year. It would include competent observers familiar with the species of concern and comfortable in the cave environment. The monitoring team should understand the objectives of the preserve and the long-term management goals, and be capable of performing all of the necessary tasks of monitoring and maintenance. Because of the interest of the Fish and Wildlife Service, the monitoring team should provide copies of their monitoring reports to the Fish and Wildlife Service, and should welcome Fish and Wildlife Service biologists' participation in the monitoring process. Because the greatest value of monitoring data would come only after a period of at least several years of study, a central repository of data with continuity of personnel would be ideal.

To establish a baseline, monitoring should be performed quarterly for several years at least. At each monitoring session, the following activities should be performed:

- Count all visible cave fauna in the cave, using minimally disruptive techniques, map the locations of all species observed, using a standard cave map prepared for that purpose.
- Examine the ground surface within and adjacent to the preserve for fire ant mounds and institute control measures as necessary.
- Measure temperature and humidity in at least three consistent locations within the cave. Use of HOBO data loggers permanently installed and downloaded at each monitoring session would give more data, and may be useful.
- Examine all gates and fences and repair or apply preventive maintenance as needed.
- Evaluate for other threats that may be impacting the karst ecosystem and the effects of management techniques employed to control or eliminate these threats.

Who Pays and Who is in Charge?

The most important unanswered question confronting the process of creating and managing preserves is that of responsibility for the costs and continued upkeep of the program. Initially, anticipating a cooperative relationship with the Fish and Wildlife Service, a coalition of land owners formed a non-profit organization for the protection and management of caves in the area, called the Bexar County Cave Protection Alliance. The Texas Parks and Wildlife Department was an active participant in the process. Unfortunately, the relationship between the coalition and the Fish and Wildlife Service has not been as cooperative as the coalition had hoped, and the future of the organization is in some doubt. The Fish and Wildlife Service asserts that only an organization with a history and track record of success in cave invertebrate conservation would be acceptable as a managing agency, and yet there is no such organization active in the area. Resolution of this dilemma is imperative for the successful development of a program of cave protection.

Many of the caves known to contain species of concern are on land owned by the Texas Parks and Wildlife Department and by Camp Bullis Military Reservation. These agencies may develop their own programs for creating and maintaining cave preserves. The remaining caves known to have the species are privately owned. Any expenses incurred in protecting and managing cave preserves accrues to the landowner. Many of the landowners are willing to assume these expenses, and incorporate cave preserves into open space plans for development on their property. However, it is likely that more landowners would be cooperative and proactive if there were reasonable expectation of an agreement from the Fish and Wildlife Service that would ensure against exposure to prosecution under the ESA in the event that the species are listed as endangered.

Conclusions

If these principles are put into practice, the threats defined by the Fish and Wildlife Service as likely to harm karst invertebrates will be removed or reduced to insignificance in this area. These principles assure that:

- The cave is protected from destruction or deterioration.
- Permeable cover and natural vegetation within the cave drainage area is preserved.
- Sufficient drainage and forage area is protected to support a community of cave animals.
- Contamination by drainage of chemicals into the cave is prevented.
- A program of fire ant control is included.
- Vandalism is prevented.
- A monitoring program is established.

The major current impediment to the establishment of a network of preserves is the absence of acceptance by the Fish and Wildlife Service of a responsible management agency or organization that is also acceptable to the landowners in the area and agreement on the details of Preserve Management and Monitoring Plans for each cave of concern. If these obstacles can be overcome, and Preserve Management and Monitoring Plans put in place for at least some of the caves known to be inhabited by the species of concern, the long-term welfare of the species can be increased, and scientific understanding can progress from *speleobiology* toward *speleoecology*.

Fox Mountain
History, Acquisition, Survey, and Access

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Abstract

Fox Mountain has long been in the minds of the members who make up the core of the Southeastern Cave Conservancy, Inc. Early attempts by individuals to acquire some of the land now owned marked the first attempt by cavers in Georgia to acquire caves through purchase. The Conservancy made several acquisitions early on through circumstance: either the cave was offered to them or a high profile cave was at risk. Indeed, when negotiations were coming to a head for Fox Mountain, another cave, Fricks, became threatened by development. The Southeastern Cave Conservancy, Inc. was forced to acquire both simultaneously. This resulted in a huge debt load and stunted acquisitions for some time.

Fox Mountain is the largest purchase made by the Conservancy. It contains some of Georgia's most significant caves along with an abundant karst region. The SCCI is now one of the largest cave conservancies. The first major task was to have the land surveyed. Its location and history made that task difficult and expensive. Indeed, the land had never been surveyed. The way this survey has been accomplished is an example of how to harness the energy and dedication of the sport caver. This project brought together cavers and conservationists from different parts of the country. It has brought many in close contact with the Conservancy. The methods used to gather the volunteers demonstrates the value of the electronic medium. The result has been an example of how to save money needed for acquisitions and garner support from the people the Conservancy is in business to support.

Recently the Southeastern Cave Conservancy Inc. made its largest purchase. It purchased 332 acres of prime caving land on Fox Mountain. The Fox Mountain Cave Preserve is the conservancy's largest acquisition. This land has played a central role in the formation of the Southeastern Cave Conservancy, Inc. It has presented many challenges, which are still being met. It can serve as a model for others interested in acquisition of cave properties.

Fox Mountain is about four miles long and is an offshoot of Sand Mountain. Fox and Sand Mountains are joined at Low Gap, which is well known to local cavers as the area above Moses Tomb and Kudzu Cave. From Low Gap, Fox Mountain runs northeast to the area around the Rising Fawn exit from I-59. It is bounded on the west by Deer Head Cove and on the east by Interstate 59. The mountain lies equally in Dade County, Georgia, and DeKalb County, Alabama. There are about 50 known caves on the flanks of the mountain. The top of the mountain comprises about eight hundred acres and is uninhabited at this time.

The rock in Fox Mountain is for the most part like the surrounding mountains. Starting at the base is the Monteagle Limestone. Above that is the Hartselle Formation (usually shale). Above that is the Bangor Limestone and on top of that is the Pennington Formation, which can be any number of rock types. Near the top is the Raccoon Mountain Shale. On top of the mountain is the Warren Point Sandstone. It is readily visible as the ring of cliffs forming the cap and is erosion resistant.

All of these layers dip slightly toward the center of the mountain in a gentle syncline. However, the rock that contains Rustys Cave, Hurricane Cave, and surrounding small caves slopes down the flank of the mountain. Several cavers who are geologists have been investigating this from the inside out and have come up with an interesting theory. They have concluded that this area of the mountain is an ancient over thrust of the Bangor Limestone. It is 50 to 100 feet thick. This formation has been eroded from the rest of the flank. This would explain the tilt of the passage down the side of the mountain. It has been known that the water in Rustys Cave flows into Hurricane Cave. According to these researchers, the floor of the stream in Hurricane Cave is the Hartselle Formnation. They explored a small cave known as Yellowbox Cave high above the entrance of Rustys Cave and found it is formed at the top of this over thrust. The west wall of the cave is Raccoon Mountain Formation and the east wall is of the steeply dipping Bangor Limestone. Only a caver could have researched this. They are currently preparing an article that will have a more complete explanation.

Fox Mountain was inhabited on the top until the 1930s when the water table dropped. Locals say there were peach orchards and numerous dwellings on the top. The mountain has interested cavers for over 40 years because of all the exposed limestone. In 1961 local cavers found Byers Cave. This cave became a standard for cavers from around the Tennessee, Alabama, and Georgia area. The cave is extensive and challenging. It contains two hydrologic systems and is formed along several different fault zones. In 1963 another local caver found Cemetery Pit. This cave consists of several miles of passage and has been protected from vandalism by the 185-foot entrance shaft. Another popular cave known in that time was Hurricane Cave, which was regularly used for beginner trips. Rustys Cave was found in 1966. This cave is the most scenic cave on the mountain and is also protected by a pit entrance.

Recently, several conservancy members began pushing Hurricane Cave. A difficult push through the Air Chute helped expand the cave under Rustys Cave. Over 2,000 feet of virgin passage were added. The vertical extent was extended to 254 feet. A second entrance was located in the new area. The largest and best-decorated rooms in the cave are in the new section.

In the mid 1960s, construction of Interstate 59 began. At first the Department of Transportation planned just to cover the entrance to Hurricane Cave. Five members of the Dogwood City Grotto were Department of Transportation employees and convinced the engineers that the amount of water issuing from the entrance would undermine the road. The local cavers convinced the construction crew to use a caver-sized culvert, which is used today. The acquisition of land by the state is the reason for the land-locked nature of the current Southeastern Cave Conservancy property. Although it is not supposed to be possible to land lock property in Georgia, this property has a special status. This happened because of the use of imminent domain by the government. Apparently the land was paid for and, after carving out the right of way for the interstate, it was given back.

After the interstate was opened, access to the area was by crawling though drainage culverts and trespassing on state rights of way. Breaches in the boundary fences and four-wheel drive roads were common. In the late 1970s, there were problems between visitors and the landowners at Byers Cave, and the cave was closed. Since that time, NSS cavers have been denied access and the cave has suffered abuse from trespassers and vandals. In about 1987 several cavers from the Atlanta area began negotiations to buy the 160-acre southern tract of the Middleton property, which included much of Byers, Rustys, and Hurricane Caves.

This unsuccessful attempt underscored the difficulty of buying this land. There were problems getting a clear title on a small portion of this section and that was always going to be a problem. The Chairman of the NSS Cave Ownership and Management Committee unsuccessfully tried to get the NSS to buy the Fox Mountain property. These experiences helped form in local cavers an interest in establishing cave preserves. A small group of interested cavers formed the Southeastern Cave Conservancy, Inc. The Conservancy started as an idea and was later propelled into being by a gift of their first cave. Several other properties were acquired. The acquisition of Neversink cemented the conservancy's reputation. Through all of this, the Fox Mountain area was always on the mind of members. Early in 1997 Mark Wolinsky, the Acquisitions Chairman, approached the three families who owned the land and made an offer. To his surprise, negotiations began to move swiftly. A purchase price of $89,640 was agreed on with a monthly payment of $1,622. Owner financing was arranged which helped with the title problem. At $270 an acre, the land was cheap. That is due in large part to the lack of access.

At the same time, Fricks Cave came on the market. The land was going to be sold on short notice. The cave is a significant gray bat hibernaculum. Undeterred, the conservancy applied to The Nature Conservancy for help financing Fricks Cave. As of this writing, they are ahead of the repayment schedule. Fox Mountain was not made available at a convenient time, but the land was too important to pass up. It was at this time that Mark Wolinski made his often-quoted statement, "we have landed on an island and burned our ships."

Most of the land had never been surveyed. There had been a preliminary survey of the southern tract when the earlier effort failed. It showed that the entrance to Byers Cave was not on the property, although over 80 percent of the cave lay under it. Starting in the fall of 1997, the Southeastern Cave Conservancy began an effort to re-survey the property. A surveyor, who had just joined the Chattanooga Grotto, stepped forward to help. When other assets fell through, she agreed to take on the whole project. Access was still a problem. The Department of Transportation could not find the interstate plats. The land lot lines were questionable. Some of the adjoining deeds were hand written in ledger books. These plots had not been surveyed carefully. Our volunteer saw the job as a challenge and a worthy project for her master's license.

A need for manpower was obvious. The terrain was steep and rocky. A call went out to the regional caver population. The Conservancy's Internet mailer was used, along with a regional mailer, TAG-net. All the local grottos had newsletter editors and they were emailed. This proved to be the key to what has proved to be large mobilization of labor. Almost a hundred different cavers have participated. They have hauled equipment, held station, chopped brush, and cooked meals. Whole grottos from as far away as New Orleans have traveled to the area to participate. One large grotto took an entire weekend as theirs. Cavers from Florida and Virginia came just to help. A survey, which would have cost tens of thousands of dollars, was accomplished for virtually nothing.

This experience has been gratifying. It has brought many individuals into contact with their Conservancy and given them a vehicle for participation beyond giving money. At the same time, the efforts of the Conservancy were kept on the minds of the local caver population.

The access problem was later addressed. A local landowner and neighbor was approached about the use of his land to access the property. This landowner had land on both sides of the interstate with a connecting tunnel. This tunnel is suitable for pedestrian use. His only concern was for the condition of his fences, which were sustaining damage from climbing. The conservancy came up with a plan to protect his fences as well as the cavers crossing them. Volunteer efforts constructed these ladders as well as new trails which do not trespass on the interstate right of way. This is a "best case" solution. While pedestrian access is provided, vehicular trespass is not possible. The land has become "caver friendly."

This cave preserve is what the Southeastern Cave Conservancy, Inc. is all about. Not only have we succeeded in protecting a number of Georgia's premier caves, but we have also obtained an area with potential for further discovery. The significant watershed is protected. Fox Mountain will always be there for cavers to enjoy as long as the Southeastern Cave Conservancy is alive. It will never be logged or used in any other fashion. Our experience with The Fox Mountain Cave Preserve will prove to be a model for future acquisitions.

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Jim Wilbanks,NSS 8967 FE, SCCi 89, has been active in cave exploration and survey and the issues surrounding caving for over 30 years. He started in his teens as an explorer but quickly moved to discovery, survey, and preservation. He was part of many of the early efforts in Ellisons Cave.

As an early member of the Southeastern Cave Conservancy, he was acutely aware of the caves on Fox Mountain. He had participated in the original survey and map preparation. When the Conservancy bought the preserve, he stepped forward to help manage it.

He lives in the vicinity of the preserve because of the caves in the area. He is an active member of the Chattanooga Grotto, The Dogwood City Grotto, The Georgia Speleological Survey, The Vertical Section, and the Southeastern Cave Conservancy, Inc.

Tools and Resources for Cave and Karst Education

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Abstract

Teachers and environmental educators must have educational tools and material so they can teach about cave and karst resources. Educating the public about karst resources should include the importance of karst watersheds to drinking water supplies and introduce caves as unique habitats. The making of the IMAX film on caving will increase the demand for cave education materials tremendously. This paper will focus on some of the tools and resources available to help teach about the unique cave and karst environments to various audiences. Sources include a karst groundwater model, Project Underground and Living on Karst.

The karst groundwater model demonstrates groundwater properties and the spread of pollution. This includes how runoff from trash in sinkholes can show up in drinking water supplies. This plexiglass table-top model will be demonstrated during the presentation.

The Project Underground Karst Education Program offers classroom materials for kindergarten through 12th grade students. Training workshops provide lesson plans and background information to the teachers. These hands on, discovery-based activities meet the science teaching standards in most states.

The book, *Living On Karst – A Reference Guide for Landowners in Limestone Regions*, was developed to help residents of karst areas become aware of how day-to-day activities affect the groundwater and fragile ecosystems of their karst regions.

Teachers and environmental educators must have educational tools and materials so they can teach about cave and karst resources. Educating the public about karst resources should include the importance of karst watersheds to drinking water supplies and introduce caves as unique habitats. The making of the IMAX film on caving will increase the demand for cave education materials tremendously. This paper will focus on some of the tools and resources available to help teach about the unique cave and karst environments to various audiences. Sources include a karst groundwater model, Project Underground, and Living On Karst.

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The book, *Living On Karst—A Reference Guide for Landowners in Limestone Regions*, was developed to help residents of karst areas become aware of how day-to-day activities affect the groundwater and fragile ecosystems in their karst regions. This publication can be found on the World Wide Web at http://www.wvcc.net/ccva.htm

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