INSIDE EARTH

A NEWSLETTER OF THE NATIONAL PARK SERVICE
CAVE & KARST PROGRAMS

Edited by Dale L. Pate

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Excerpts from the National Park Service's Geologic Resources Division's "1999-2000 Biennial Report"

THE CAVE AND KARST PROGRAM

by Ronal Kerbo

National Park Service Cave and Karst Areas

In 1999/2000 the cave/karst efforts were focused on the following program components:

- service-wide small cave assessment projects
- technical assistance requests for cave resources management
- attendance at cave and karst professional meetings
- agency and federal government-wide meetings on cave and karst issues.
- Lectures and programs on Service-wide cave and karst issues
- The National Cave and Karst Research Institute (NCKRI)

A break down of the cave program's $30,000 was as follows: **SERVICE-WIDE PROJECTS: $20,260:** $7,160 to bat habitat protection and assessment in two parks and $13,100 to cave assessment projects in three parks; **TECHNICAL ASSISTANCE: $3,800:** provided in cave and karst related issues at four parks. **TRAVEL: $5,940**: for presentations on cave and karst programs, professional meetings and training at four parks, the Oakland Museum of Natural History, The Winter Technical Meeting of the Southwest Region of the National Speleological Society, and the National Speleological Society Annual Convention.

In August the Geologic Resources Division hosted a steering committee meeting for the start-up of the National Cave and Karst Research Institute (NCKRI). Attending the meeting was Rod Horrocks, Joel Despain, Mike Wiles, Dale Pate, Larry Norris, Ron Kerbo, all NPS; Jim Goodbar, Bureau of Land Management (BLM), Jerry Trout, U. S. Forest Service (USFS), and Bob Currie, U. S. Fish and Wildlife Service (USFWS). In addition to his current duties, the Science and Technical Services Branch National Cave Management Coordinator served as the steering committee chair for the fiscal year for the start-up of the NCKRI. The NCKRI Steering Committee refined the stated mission, goals, and objectives of the NCKRI and developed a position description for the institute director. The Steering Committee also prepared a plan that identifies alternatives for the structure of the Institute and recommended this structure to NPS management. The Committee finalized the organizational model for the Institute and helped in the selection of an interim director.

From upper right side around table clockwise: Mike Wiles, NPS (JECA); Joel Despain, NPS (SEKI); Jim Goodbar, BLM; Rod Horrocks, NPS (WICA); Dale Pate NPS (CAVE). (NPS Photo by Ron Kerbo)

Carlsbad Caverns cave specialist Dale Pate was the subject of an interview in the July 1999 edition of the National Speleological Society News. Dale, a fellow of the NSS, came to work at Carlsbad in July of 1991 from the United States Geological Survey. He is respected in the speleological world for his work in the caves of Mexico and as the former editor of the "Texas Caver." In addition to his duties overseeing the exploration, surveying and science projects in Lechuguilla Cave, Dale is currently the editor of *Inside Earth*, the newsletter of the NPS cave and karst program.

Thirteen cave resource specialists from 7 national parks met on July 14 at the National Speleological Society (NSS) Convention in Filer, Idaho. Ron Kerbo led discussions bringing everyone present up to date on the NCKRI. On July 13, the national cave coordinators for the NPS, BLM, USFS and USFWS met in an open forum session with the membership at large of the NSS. Questions for the NPS from the Society members focused on the Institute, the Federal Cave Resources Protection Act and concerns regarding the science programs at individual Park Service areas.

The deputy director of the Western Kentucky University Center for Cave and Karst studies, Dr. Chris Groves, met with the Branch to discuss a program for the continuing education of NPS cave and karst specialists. Groves met with Ron Kerbo to outline preliminary plans for a program that would assist NPS employees enter into a program that would result in a masters degree with emphasis in cave and karst studies. The goal is to develop a program with WKU that will strengthen the scientific approach to cave and karst resources management and tie into the future of the National Cave and Karst Research Institute. At this time two NPS employees are pursuing degrees through this program.

The Branch consulted with the Tonto National Forest in Arizona and reviewed an action plan to set priorities for research and employee safety needs for a new cave discovery. The cave was discovered during highway construction work and deemed to fall within the Federal Cave Resources Protection Act criteria of significant. The plan recommended that employees doing the initial cave survey be connected to the surface by safety lines because of the potential for high CO_2 content in the cave air. This recommendation was deemed unsafe and was modified to require the surveyors to wear self-contained breathing apparatuses if air sampling revealed that the cave atmosphere was high enough in CO_2 to pose a threat to employees.

During three trips into Timpanogos Cave, the Branch provided cave and karst training for the interpretive staff at the Monument from May 7 to 11. Discussions included cavern development, speleothem deposition, cave conservation and protection and interpretive themes. A trip was taken into an off-trail section of the cave where the Monument staff will offer an introduction to caving tour. This section of the cave has no constructed trail, so during the on-site visit we recommended methods to provide for visitor safety and conservation of the cave resources.

Cave assessment and protection projects and a workshop have been funded in Sequoia & Kings Canyon National Park (SEKI), Chickamauga & Chattanooga National Military Park (CHCH), Grand Canyon National Park (GRCA), Natchez Trace Parkway (NATR) and Pinnacles National Monument (PINN). The projects include cave cartographic surveys, inventories of cave minerals, geologic mapping and photographic documentation. At NATR the project will include construction of a gate on the cave entrance to protect an endangered bat species. The CHCH project will also include data collection that will help resolve the overlong three-year closure of the caves due a diesel spill from a pipeline in 1996.

On October 19-22, 1999, Chattanooga, Tennessee, was the location of the 14th National Cave and Karst Management Symposium, hosted by the Southeastern Cave Conservancy, Inc. The theme was "Living with Caves and Karst." This well-attended symposium drew cave and karst managers, researchers, and cavers from all over the United States including Alaska and international guests from as far away as Australia. With many talks focused on water resources issues, history, education, GIS, cave and karst management and research, this year's symposium was a great success.

The Branch was asked to provide the keynote address for the 14th National Cave and Karst Management

Symposium. The National Park Service has been a primary sponsor of the Symposium since the first Symposium in Albuquerque, New Mexico in 1975. A Service representative also sits on the National Cave Management Symposium Steering Committee and past Symposia have been held at MACA, CAVE, and WICA. Ron Kerbo, the keynote speaker, addressed the future of cave and karst management both in the nation and throughout the world.

The Division supported the recent successful cave and karst management workshop at Mammoth Cave National Park. The meeting was well attended by both NPS units with cave and karst resources, and by local private cave operators. Ron Kerbo explained the current status and future of the National Cave and Karst Research Institute, summarized the evolution of the service-wide cave and karst program and reported on an NPS Cave and Karst Handbook, and revisions to NPS-77 and NPS Policy. Perhaps most significantly, the Institute should be a thematic Cooperative Ecosystem Study Unit (CESU) operating on a national scale. Lindsay McClelland discussed another research management topic in NPS caves, bioprospecting. Bioprospecting has far reaching fiscal effects, and collecting permits must address this issue.

Participants assemble for the field trip into ***Mammoth Cave*** prior to the NPS Cave & Karst Management Workshop on October 24,1999. From left to right: Chuck Bitting (BUFF), Neville Michie (Australia), Dale Pate (CAVE), Rod Horrocks (WICA), Dr. Rick Toomey (Illinois State Museum), Mike Wiles (JECA), and Rick Olson (MACA). (NPS Photo by Ron Kerbo)

The Division worked with Chuck Barat of Lava Beds National Monument (LABE) regarding the steps taken to assure the suitability of a site selected for a new visitor center. The staff of LABE has made a great effort to assure protection of the natural resources of the monument. We had suggested that a site for the VC should have the following attributes: It does not overlay any known cave passages, any known cave passage is at least 200 feet away and it would allow for the inclusion of mitigation devices for parking lot run-off. The park followed up by enlisting the services of a geophysical contractor to survey the site, using magnotometry technology to identify potential underground voids. The survey identified small anomalies that might represent very minor voids on the periphery of the proposed site. The voids, if indeed there, are not close enough to the majority of the work site to represent a threat to the natural resources. The park is to be commended for the efforts to survey for underground resources and finding a site that represents the most resource-friendly location for the new visitor center, within the confines of other parameters for the project.

And lastly, a point of interest was the publication of the book *Deep Secrets-The Discovery and Exploration of Lechuguilla Cave,* which chronicles the exploration of Lechuguilla Cave at Carlsbad Caverns National Park. The book is co-authored by four of the caves original explorers and covers the period of exploration from the 1986 "breakthrough" to 1993 when the cave became known as the deepest cave in the U.S. The book is highly charged with the personalities, speleology, and politics that surround major cave exploration efforts. The roles of NPS cave specialists and NPS policies in the efforts to explore this world-class cave are also covered in the new book. The authors have taken an unblinking look at the danger, adventure and ultimate rewards of the efforts to push further and further beneath the New Mexico desert and have created a caving book that will become a classic adventure tale.

PARK UPDATES

BUFFALO NATIONAL RIVER

by Chuck Bitting

Over the past year, Buffalo National River has been involved in several karst conservation projects. The Cave Research Foundation has been working with the park to finish the mapping of Fitton Cave, the longest known cave system in Arkansas, and the mapping of smaller caves throughout the park. We have been working with the Arkansas Subterranean Biodiversity Project to determine the faunal assemblages utilizing caves in the park. Dye tracing has been used to delineate groundwater recharge zones for caves, springs, and surface streams within the Buffalo River watershed. We have also worked with Nature Conservancy volunteers to clean muddy speleothems, and have continued to work with individual cavers and grottos in exploring, mapping, and restoration of caves within Buffalo National River.

Fitton Cave has an estimated twelve miles of passage. It has been the focus of a multi-year project by Cave Research Foundation (CRF) to develop a highly detailed, accurate map of this cave. CRF Ozarks Operations Area leader Scott House has been heading up this project for the last couple of years. CRF volunteers have given greatly of their time. They have logged well over 500 hours in fieldwork mapping these caves over the last year or so. This does not include the endless hours of turning field notes into maps, reports, and other documents. The CRF is to be commended for their assistance in helping us get a better picture of the cave resources at Buffalo National River.

The Arkansas Subterranean Biodiversity Project is a cooperative project between the University of Arkansas at Fayetteville, Department of Biological Sciences, Arkansas Game and Fish Commission, Arkansas Natural Heritage Commission, United States Fish and Wildlife Service, United States Forest Service, National Park Service, and Arkansas Department of Environmental Quality. The project is attempting to take a "snapshot" of the biodiversity of karst faunal communities that are found in caves within the Ozarks plateau section of the state. At Buffalo National River, they have done biological surveys of thirty caves to date. This represents ten percent of the known caves in the park. After a literature search and biological surveys, Fitton Cave has been found to have the greatest faunal richness of caves in Arkansas with 54 macroscopic species present or reported. This project is ongoing. Hopefully, we will be able to get another ten percent of our caves surveyed over the next year. We greatly appreciate the work of Dr. Gary O. Graening and Michael Slay in this undertaking. They and their associates continue to exert a tremendous effort to describe the distribution and dynamics of cave fauna in the southern Ozarks.

A larval salamander in Fitton Cave's Water Passage.
(Photo by Carol Bitting)

Mike Nelson and Micki Feakes preparing for a dive.
(NPS photo by Chuck Bitting)

We are currently determining the groundwater recharge area of John Eddings Cave, the third longest cave at Buffalo National River. We have conducted several dye traces in the area around the cave to perform this delineation. We have also worked with cave divers Mike Nelson and Micki Feakes to determine the course of some of the submerged passages in this cave.

Chuck Bitting injecting rhodamine WT. (NPS photo by Noel Mays)

We are using tracer dyes to understand the hydrologic dynamics of Davis Creek. It has a surface watershed of 28 square miles, yet is nearly dry when it reaches the Buffalo River. Using a variety of tracer dyes at numerous injection points, we are beginning to develop an understanding of the dynamics of this losing stream.

Volunteers with the Nature Conservancy assisted us with a cleanup of Back O' Beyond Cave in the spring. They used water and nylon brushes to scrub mud and graffiti from the walls and speleothems of this small cave. Members of CRAG, a new grotto in Harrison, Arkansas, used brushes and water to remove graffiti in Cave Mountain Cave last summer.

Nature Conservancy volunteers cleaning Back O' Beyond Cave.
(NPS photo by Chuck Bitting)

In addition to the above projects, park staff completed construction of five more mine portal closures this fall. These closures completed the sealing off of the Capps/McIntosh underground mine. This historic zinc mine now has eight bat gates and two other closures on its portals. The two non-bat gate closures are in a zone of unstable ground that is actively subsiding into the underground workings. Future work will be required to stabilize these portals as the ground subsides. This work was accomplished with funding from the Geologic Resources Division of the National Park Service. This mine acts as a hibernaculum for the federally endangered Gray bat (*Myotis grisescens*), and has numerous cultural resources inside dating from the mining era, which basically ran from 1890 to 1920.

Completed bat gate, Capps Mine portal #2.
(NPS photo by Chuck Bitting)

CARLSBAD CAVERNS NATIONAL PARK

by Dale Pate

New PhD. - Congratulations to Diana Northup who recently received her Doctorate studying corrosion residues found in Spider and Lechuguilla Caves. The title of her study was "Geomicrobiological Investigations of a Cave Deep Substrate Environment".

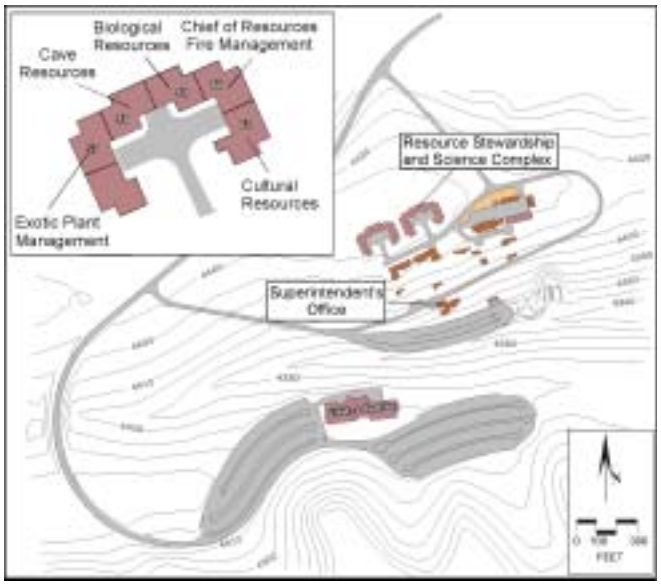
Lower Cave Walkways - The visitor trail through portions of Lower Cave in Carlsbad Cavern traverses through four areas of water. One is a large pool that visitors have had to use stepping-stones to cross and the other three are wet flowstone floors through an area called the Rookery. As visitors walked through these wet areas and onto dirt banks, mud began accumulating in large amounts in the pool and on the flowstone areas. In essence, the areas turned into huge messes. In order to alleviate this problem, the park began installing low walkways made of polyethylene decking and tied together with stainless steel bolts. The size and weight of this decking makes a very stable walkway so there is no need to bolt the walkway to the floor. A total of 53 feet of walkway has been installed in the cave so far, with 59 feet of floor still to be covered by walkways.


Left Photo - A before photo of Scott Sievertsen using the stepping-stones to cross the pool. (NPS Photo by Dale Pate) Right Photo - The same pool with the recently placed polyethylene plastic walkway. (NPS Photo by Jason Richards)


Left Photo - Jason Richards inspects the progress of the walkway installation. (NPS Photo by Dale Pate) Right Photo - Completed sections of the walkway in place. (NPS Photo by Jason Richards)

Lechuguilla Cave Survey Expeditions - Three survey expeditions have taken place in the cave during the last two months of 2001. Before these expeditions, the official length of survey for Lechuguilla Cave was 105.79 miles. The Cave Resources Office led one expedition the week of Nov. 7-11. This expedition added 512 feet of new survey, resketched or resurveyed an additional 1,561 feet and inventoried 76 stations. This brought the official length of the cave to 105.89 miles. Peter Bosted and Ray Keeler led one expedition the week of Dec. 1-8. This expedition added 5.016 feet of new survey and inventoried 347 stations. This brought the length of the cave to 106.84 miles (171.9 kilometers). The Lechuguilla Exploration and Research Network (LEARN) led an expedition the week of Dec. 15-22. Survey additions were not tallied by the time this newsletter was published.

Division Changes - A number of changes have occurred within the Resource Management Division including a new name. The Division is now known as the Resources Stewardship & Science Division. It is composed of the Cultural Resources Office (moved over from the Interpretation and Visitor Services Division), the Fire Management Office, the Biological Resources Office, the Cave Resources Office and the Exotic Plant Management Team. Overseeing the Division is Chuck Barat as Chief and Amelia Tully continues to be administrative support. The Cave and Biological Resources Offices along with Chuck and Amelia's offices were located in the Superintendent's building, but have now moved up the slope to the north into recently vacated Mission 66 housing. The following map shows present office locations for the Division.



NPS Map courtesy of Paul Burger.

New Caves In The Park - Four new small caves have been discovered and surveyed within the last few months. This brings the total number of known caves in the park to 98.

GREAT BASIN NATIONAL PARK

by Krupa Patel

During the spring of 2002 Great Basin National Park will begin a three-year wild cave inventory and management project in the park. The project will consist of several different components including surveying and mapping, physical inventory, cave invertebrate surveys, microbial surveys, human use monitoring, and bat surveys.

Surveys will be completed for the thirty-three known wild caves in the park. From the survey data we will create final paper maps and digital GIS maps of the wild caves in the park. During the course of the project we hope to overlay the cave maps, survey line plots, and cave invertebrate data

onto vegetation and elevation models using 3D and Spatial Analyst. This will allow us to study the relationships between sensitive cave data and surface features.

Comprehensive physical inventories will be conducted in conjunction with the surveys to determine the types of resources present in each cave. Based on information from the physical inventory, we will establish Limits of Acceptable Change (LAC) photo monitoring points in the wild caves in the park. LAC points will be duplicated each year to give us a visual representation of human use impacts on the cave resources over a long period of time.

There will also be a strong biological component to the cave inventory. Cave invertebrates will be collected by cave invertebrate specialists and sent to labs for identification. By the end of the project we will have GIS layers of cave invertebrate species composition and distribution for the wild caves in the park. Microbes will also be collected in sediment samples and sent to a lab for identification. Bat surveys will be conducted through internal searches and external surveys. External survey and monitoring will be conducted using night vision scopes, mist-netting procedures, and AnaBat software. The AnaBat software will be used to compare bat echolocation calls to a pre-recorded library of bat vocalizations for the purposes of identifying free-flying bat species near the cave entrances.

Based on the information and understanding we gain from the cave inventories, we will develop a science-based management plan for the wild caves in the park.

During February and March of 2002, we will be hiring two cave technicians to work with us on the wild cave inventory and management project. Those who are interested should look for the jobs under Physical Science Technician on the usajobs website during January or February of 2002.

TIMPANOGOS CAVE NATIONAL MONUMENT

by Jon Jasper

Timpanogos Cave National Monument has achieved many accomplishments this year. The Resource Management staff, consisting of Jon Jasper, Quincy Bahr, Cami Pulhman, and Trisha Sorber, was able to clean 3,207 ft^2 of cave floor, install a HOBO monitoring system, install photo monitoring points throughout Hansen Cave, create GIS coverages for Timpanogos Cave, perform routine bat surveys, and obtain funding for FY2002.

Cave Cleaning

Cave cleaning occurred throughout the Timpanogos Cave System. The main focus was Middle Cave Lake. During the fall months, water from the lake was drained into a tarp holding basin in the Pump Room. Foreign debris from a catwalk was removed, the bottom of the lake vacuumed, and the walls and floor sprayed. Due to winter weather, the project will not be completed until 2002.

Minor projects included removing debris and lint throughout the cave system. Debris was removed from the Bat Room, Middle Cave Lake, and areas near the Heart of Timpanogos. Lint was removed from the Hansen Cave entrance, the Heart of Timpanogos to Carmel Falls, and along Middle Cave Lake. The total amount of cave cleaning was 3,207 ft^2 of cave surfaces.

Cami Pulham uses a brush to remove lint in the Camel Room.
(NPS Photo by Jon Jasper)

HOBO

A HOBO datalogger network was placed through the caves to monitor temperature, relative humidity, and drip rates. Six HOBO H8 Pro and three rain buckets with HOBO event datalogger were placed. These easy-to-use dataloggers replaced an old, complex Campbell Scientific datalogger system for about the price of one Campbell datalogger.

Photomonitoring

Jim and Val Werker visited the monument over Forth of July weekend to extend the cave photomonitoring project from the main trail into the “Introduction to Caving” route in Hansen Cave. The Werker’s photomonitoring system uses a patented way of having the camera mounted into small permanent anchors ensuring that exact pictures can be taken every year or every decade.

GIS

Brenden McNeil, Brian Carlstrom, Eva Hersey, and Jon Jasper, started a GIS program at Timpanogos Cave. The Timpanogos Cave survey was reentered into the Compass surveying program. Rod Horrock's 1993 map of Timpanogos Cave was scanned and georeferenced to a GPS located lineplot. Brian Carlstrom, from the Intermountain GIS Support Office, is working on the monument's GIS Implementation Plan. University of Denver graduate student, Brenden McNeil, created a high-resolution digital terrain model (DTM) for the entire monument to perform a rockfall analysis as part of his Master degree. With this great start, many cave GIS products may be seen in the near future.

GIS layering within a portion of Timpanogos Cave.

Future Projects

The monument was able to obtain FY2002 funding for additional cave cleaning, installation of new handrails, a cave biology survey, a bat conservation project, and the construction of new gates on the caves' natural entrances. Cave cleaning will continue throughout the Timpanogos Cave System. New stainless steel handrails will be installed to replace iron, aluminum, and prefabricated stainless steel handrails over the summers of 2002 and 2003. The Inventory and Monitoring Program (I&M) will fund a cave biology survey that will include invertebrates. The cave gates on the natural entrance that were cemented in place will be replaced with the more standard "bat-friendly" gates. The monument also received a grant to research how the bats are using the cave, and the new gates, using Anabat detectors. Along with this funding, we are hosting evening programs to educate the public about the importance of bats. With all of these projects, plus the additional resource management concerns of the monument, next year should be full of new accomplishments.

WIND CAVE NATIONAL PARK

by Rod Horrocks

Noah Daniels has completed some preliminary air volume measurements for Wind and Coyote Caves. He found that the wind from the Snake Pit Entrance of Wind Cave was 40% of the volume of the Natural Entrance. He also determined that Wind Cave has a total volume of at least six million cubic meters. This measurement is only a fraction of the volume that Herb Conn measured during his 1960's experiment. He also determined that although Coyote Cave does have barometric winds, our instrumentation is not sensitive enough to measure the volume of such a small cave.

We have finished a draft of our new Cave and Karst Resource Management Plan. We are working on an accompanying environmental assessment (EA) and hope to release a draft of the plan for public review within the next couple of months.

We hosted a Wind Cave 100th mile celebration party on October 13th. For the event, John Scheltens, Jim Nepstad, and Jim Wilson spoke on the 100 miles of exploration. Nearly 130 cavers and past and present park employees attended the event.

We are continuing our monitoring of What the Hell Lake. Over the past few months the lake has dropped a few inches. This lake still has to drop nearly another foot to once again allow access to the passages beyond.

At the National Cave and Karst Management Symposium in Tucson, Rod Horrocks presented a paper titled, "Developing a Cave Potential Map of Wind Cave to Guide Land Management Decisions at Wind Cave National Park". Noah Daniels presented a paper titled, "Using Barometric Winds to Determine the Volume of Wind Cave, South Dakota".

Since the last issue of Inside Earth the surveyed length of Wind Cave has been increased by 1.22 miles, raising the length to 101.5 miles.

ARTICLES

USING BAROMETRIC WINDS TO DETERMINE THE VOLUME OF WIND CAVE, SOUTH DAKOTA

by Noah Daniels

Introduction

The often strong wind coming from the entrance of Wind Cave is one of its defining characteristics. The significance of this airflow was not well understood until the first scientific study of it in the 1960's. Herb Conn's (1966) investigation into the airflow of Wind and Jewel Caves sets the stage for this project. Using barometric airflow, he estimated Wind Cave's volume at 56 million cubic meters. The research presented here is essentially an update of Conn's (1966) research, using the technological advancements of the past 35 years to create a more complete recorded of airflow, and allow for more precise estimates of Wind Cave's volume.

In addition, airflow at Coyote Cave has been noted, but whether this airflow is barometric or chimney effect has not been determined. This mystery can be solved using the dataloggers to monitor barometric pressure and airflow from the cave over a longer period than previously allowed.

Methods

Campbell Scientific CR10 dataloggers were used at both the Natural and Snakepit Entrances. The Natural Entrance datalogger was placed in the 18-inch diameter corrugated steel culvert that had been installed in the crawlway in the late 1980's. An anemometer and wind vane were placed directly in the culvert, with the datalogger in an airtight enclosure just out of the culvert on the inside of the cave. A gate of ½" diameter steel rods makes an X across the cave end of the culvert, but likely does little to restrict airflow through the culvert, and was therefore left in place during the study.

The Snakepit Entrance datalogger set-up presented additional challenges for accurate airflow measurement. The air flows through an approximately 8cm by 25cm hole that tapers to 14cm by 14cm at the surface. A 46cm tall enclosure of fiberboard measuring 30cm by 36cm was placed over this hole to help channel the flow directly at the anemometer. The set ups of these dataloggers are shown in figures 1 & 2.

Figure 1 - The Natural Entrance anemometer and wind vane in the 18-inch culvert. (NPS Photo)

Figure 2 - The Snakepit Entrance Anemometer in the airflow enclosure. (NPS Photo)

Airflow data was collected in meters per second, and the cross-sectional area of the entrances were used to compute the air volume in cubic meters. Figure 3 shows the air volume that moved through the cave entrances from September 20, 2001 to October 3, 2001.

Data analysis

The data from the dataloggers was downloaded into an Excel spreadsheet. The formula for estimating the airflow developed by Conn (1966) is:

$$Q = (Q_0 - rV)^{(-t/KV)} + rV$$

Where: Q = airflow
Q_0 = initial airflow
r = rate of surface barometric pressure change
V = volume estimate
t = time

KV = pressure adjustment time constant

This formula assumes a cave with a balloon-like shape, which Conn (1966) found to best model the behavior of the airflow. The formula was applied to the data in the Excel spreadsheet, allowing for easy adjustments to the KV and V estimates. Conn (1966) found that the best KV estimate for Wind Cave was 1.5 hours.

Three time periods ranging from 40 to 90 hours showing rapid changes in barometric pressure and significant airflow were selected from the total record for analysis and the volume estimates were based on these results.

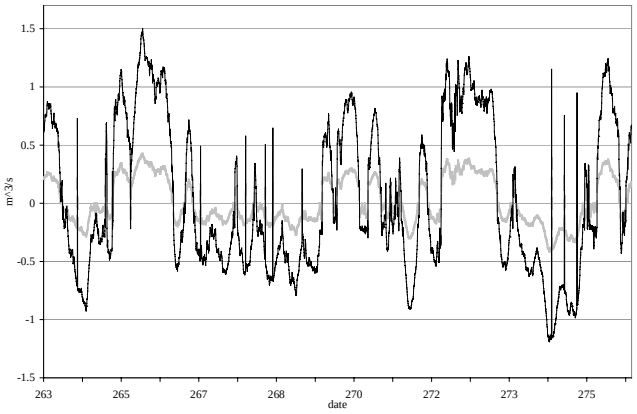


Figure 3 - Airflow data from September 20, 2001 to October 3, 2001. Black line denotes Natural Entrance airflow and gray line denotes Snakepit Entrance airflow.

Results

Figure 3 compares the measured airflow with the estimate based on a volume of 6,000,000m^3 and a KV of 1.0 hours.

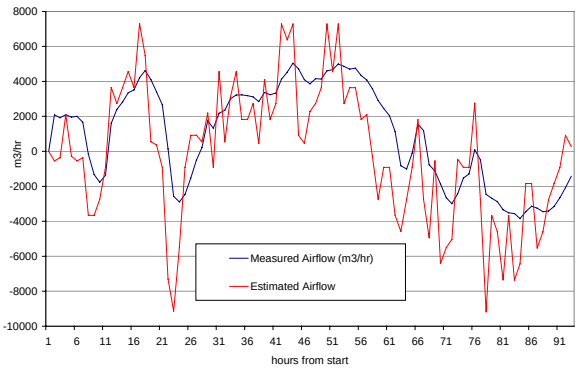


Figure 4 - Comparison of measured and estimated airflow based on a volume of 6,000,000m^3 and a KV of 1.0 hour.

Figure 4 shows that the exact trends of the recorded and estimated airflow are not the same. However, the general scale of the changes is similar, and this comparison is much more important for the volume estimate than the specific fluctuations. The larger fluctuations in the estimated airflow are due to the formula assuming laminar airflow, when turbulent airflow is the reality (and virtually impossible to model). The other time periods that were used to create independent estimates of cave air volume resulted in similar estimates, ranging from 6 to 10,000,000m^3.

The methods and specific techniques that are required to use the Campbell Scientific dataloggers for such an airflow study were summarized in a user-friendly document that avoids most of the technical jargon in Campbell Scientific's manuals. This will allow others to use the dataloggers for further research with a much smaller investment of time and effort than was initially required.

Coyote Cave

Coyote Cave, the second longest cave in Wind Cave National Park, has exhibited airflow, but its remote nature had prevented enough observation to determine whether it is barometric or chimney effect. The dataloggers were used to monitor airflow in the cave for a month, and preliminary analyses show that the airflow is barometric. It may be impossible to estimate a volume from the data, since the airflow was too low to be recorded except during very rapid barometric pressure changes, as shown in figure 5.

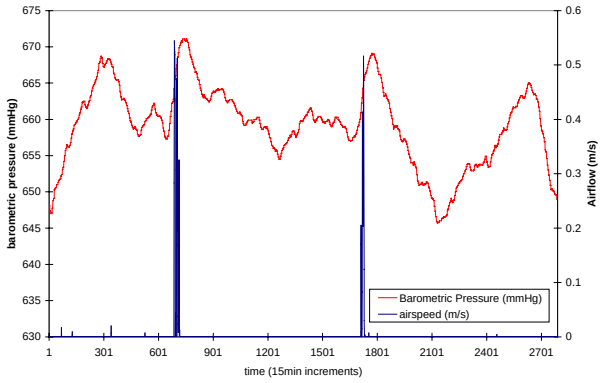


Figure 5 - Comparison of Coyote Cave airflow with barometric pressure changes over a period of approximately 4 weeks.

Conclusions

The estimates of at least 6,000,000m^3 were significantly less than Conn's (1966) estimate of approximately 56,000,000m^3. Several theories may explain this disparity. The first is that while his methodology and conclusions were sound, the technology available at that time may have resulted in poor estimates of airflow. Another credible theory is that the amount of airflow through the entrance has changed in the decades between the two studies because of hydrological or other changes in the cave. Wind Cave hits the water table in the southeast, and

dramatic water level changes have been observed since its discovery in the 1960's. These fluctuations may block off significant amounts of cave air from interaction with the entrances, either by filling the passages in or sumping connecting passages. Therefore, both estimates of cave air volume may be correct, with the difference stemming from changes in air volume over time.

There are several potential sources of error in the measurement of cave airflow. Cave airflow is present in other locations, such as blowholes, the elevator shafts, and through thin layers of overburden. The formula used to estimate volume assumes laminar flow, but the airflow is in actuality turbulent. These error sources will lead to an underestimate of cave air volume, so the actual volume of the cave may be much more than 6,000,000m^3.

The cave survey program, Compass, has been used to calculate the volume of surveyed passage at 1,400,000m^3, therefore it is reasonable to conclude from both Conn's (1966) research and the data presented here that there is a significant amount of cave that has not yet been surveyed or discovered.

References

Conn. W., 1966, Barometric Wind in Wind and Jewel Caves, South Dakota. The National Speleological Society Bulletin, v. 28, n. 2, p. 55-69.

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