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

John Fry
Natural Resources Specialist
Division of Science and Resources Management
Mammoth Cave National Park
Mammoth Cave, Kentucky 42259

Rick Olson
Ecologist
Division of Science and Resources Management
Mammoth Cave National Park
Mammoth Cave, Kentucky 42259

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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