Cave Restoration Specifications

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General

Caves play important roles in supplying recharge to aquifers and springs, reducing local flooding, providing ecosystems for rare and endangered species habitat, and supplying educational and heritage recreational resources. The removal of trash from caves improves aquifer water-quality. Cave restoration should follow all federal, state, and municipal regulations including U.S. Fish & Wildlife Service endangered species regulations, Texas Commission on Environmental Quality Edwards Rules, USFWS Balcones Canyonlands Conservation Plan (BCCP) and associated Land Management Plans (for BCCP-listed caves and caves within the Balcones Canyonland Preserve) City of Austin Land Development Code, Environmental Criteria Manual, Development Services General Permit requirements. By its very nature, cave restoration projects that remove sediment and trash from caves practice the highest level of sedimentation erosion control. Since cave restoration on sensitive preserve sites differs from development sites, innovative practices are necessary.

Cave Excavation

Cave excavation involves the removal of sediment and trash from a cave by cave stewards to increase karst habitat for rare and endangered karst species, remove potential contamination sources, allow nutrient influx through cave crickets, bats, and other mammals, reduce surface flooding, increase the humanly accessible portion of the cave for monitoring, hydrogeologic studies of water sources, and in some cases public access for guided education tours. Specialized safety training and equipment is required for cave work.

- The supervising cave restoration lead steward should have a minimum of 200 hours experience.
- USFWS (2015) recommends that 10(a)(1)(A) permitted cave surveyors supervise cave restoration beyond reconnaissance excavation for caves where take of endangered karst invertebrate species is possible. The participation of cave biologists and increasing the understanding of cave stewards excavating the cave will increase the sensitivity of the cave restoration to the cave ecosystem.
- Some cave ecosystems are particularly vulnerable to disturbance. Bats hibernating through the winter and nursing young through the spring if disturbed, may prove fatal. Vultures tend to hatch and nurse young in caves during the spring.

- Contractors and other workers will adhere to USFWS decontamination protocol for white-nose syndrome in caves where bats are present.
- The tools and methods utilized in cave excavation involve digging sediment using picks shovels, and other hand-held tools, and placing the sediment into sandbags. The filled sandbags can be used to make berms in other parts of the cave toward the entrance where floodwater flows can be slowed and sediment deposition encouraged. The filled sandbags can also be removed from the cave, utilizing soil to fill road/trail ruts, spread across areas to increase soil, or create berms as drainage controls. Other tools, such as pumps, conveyors, and other mechanized tools, may be useful to remove sediment.
- Where constrictions in the cave passage restrict access, the rock can be shaved or fractured by drilling a pilot hole into the rock and hammering in one or a series of bull pins to fracture the rock. This technique can also be used to reduce larger rocks into smaller rocks for removal from the cave. In some cases, rock hammering using a jackhammer may be used to widen a passage, particularly near the cave entrance.
- Cave entrance security is often necessary after restoring a previously filled cave to protect public safety and the cave. There are many forms of cave security to consider, including discretion for non-education caves, natural vegetation such as prickly pear cactus for caves within sight of a facility, fences, security cameras, and cave gates. Special attention must be given when considering whether to gate a cave if the cave has or had historical bat roost. Tuttle (1977) noted that from the 1950's to 1970's that caves gates were resulting in roost abandonment at times when bat populations were already challenged by loss of natural habitat from widespread cave filling. Numerous studies show that bat populations may be reduced or eliminated with cave gates (Ludlow & Gore 2000; Pugh & Altringham 2005; Spanjer & Fenton 2005; Slade & Law 2008; Bethinussen et al., 2017), and caves with bats may be best protected with fences around the entrance area, rather than a gate over the entrance. Caves where bats are present or potentially can utilize after restoration require special gate construction, as described by Fant et al., 2009. Gates for caves in drainages may be designed primarily to prevent sediment and debris from entering.
- Obstructions to entry, including cave fill may restrict nutrient input by cave crickets and mammals, alter the cave temperature and airflow (Richter *et al* 1993), alter chemistry of cave pools, and increase carbon dioxide gas concentrations.

Sedimentation/Erosion Control

On sensitive preserve lands traditional sedimentation/erosion controls may be excessively destructive in relation to benefits for sedimentation in some cases and innovative controls utilizing onsite materials are generally most efficient. For example:

- The trenching involved with silt fencing can cause extensive damage to roots, affect soil ecosystem, or divert natural drainages and should be minimized or eliminated.
- Silt fencing is not appropriate for well-defined drainages where they are likely to be breached.

- Silt fencing or other controls that restrict runoff on the downstream side of a sinkhole being restored is generally not desirable as it can force runoff into the cave before the sinkhole slope is stabilized.
- Controls such as silt fencing may potentially create barriers to movement of wildlife to and from the cave entrance and can potentially impact the cave ecosystem by reducing nutrients and water sources that support the cave ecosystem. Netting material can trap wildlife attempting to cross them.
- Materials derived from offsite areas can potentially carry exotic species such as red-imported fire ants *(Solenopsis invicta)* or tawny crazy ants (*Nylanderia fulva*) onto a sensitive cave preserve. Once red-imported fire ants are brought to the site and encouraged by canopy clearing, a cave preserve site will require twice annual surveys and treatment using boiling water. Tawny crazy ants have no known treatment options for ecologically sensitive areas at this time, is commonly transported in landscape materials, and would have catastrophic consequences on cave ecosystems once introduced. The risk of introducing harmful pests to a cave preserve through offsite mulch socks, gravel, and other materials is sufficiently high such that that local materials should be utilized for sedimentation erosion controls whenever possible. Sediment and erosion controls should follow Travis County/City of Austin (2015 or later) guidelines for averting tawny crazy ants. Materials excavated from caves, if not utilized immediately, should be stored such that it will not wash back into the cave or downstream caves or drainages. Ideally where piles are stored on catchment divides, the potentially erosive runoff can be reduced or eliminated. Note that while Environmental Criteria Manual 1.4.0 Erosion and Sedimentation Control Criteria Rocks Section 5 I. Site Management e. states that "*spoils may not be located in the 100-year flood plain, Critical Water Quality Zone, within 150 feet of a CEF or within 25 feet of a concentrated flow path with more than 5 acres contributing drainage.*" However, in some cases on preserve lands there may be less disturbance overall if the spoils are temporarily placed within 150 feet of the cave, than if it is left closer to the cave, but not where it is likely to flow back into the cave or flow downstream during a rain event. Material excavated from the cave can serve to create berms in drainages upgradient of the sinkhole or in some cases to fill a sinkhole bowl as a water-quality control. Soil is a valuable commodity for a preserve. Sand, silt, and clay excavated from the cave can be used to fill ruts in access roads, or to make berms perpendicular to access roads to eliminate artificial drainage. Excavated materials can be evenly and thinly distributed down slope and >5 m from feature entrances to minimize promotion of fire ant activity (USFWS 2015).
- Where trees have died or require removal they may be chipped to make mulch berms for low velocity runoff from disturbed areas or soil piles.
- In cave restoration when working inside the sinkhole bowl, it may be possible in cases to temporarily block the cave entrance using an inflatable bladder, silt fencing, rocks, vegetative debris or other non-toxic materials to block the inflow of sediment until the sediment can be removed and slopes stabilized.
- Complete removal of sediment accumulation in a sinkhole bowl to the bedrock is one way to stabilize a sinkhole bowl. Where loose materials remain along the sinkhole rim,

large rocks or boulders can be placed to stabilize the rim. Rocks can also replace accumulated soil within the sinkhole bowl to reduce the erosive gradient, reduce public safety threats from falling, and act as filter media to reduce entry of fine sediment that can obstruct cave passages or enter the groundwater.

- The cave restoration should focus on the removal of sediment in the cave originating from historical surface disturbance. All sediment entering the cave during restoration should be removed.
- Management practices for the preserve, including excluding livestock, maintaining open caves and recharge features, alternatives to driving unimproved roads, limiting construction of impervious cover, and maintaining natural vegetation serve to stabilize soil on preserve lands so that erosion and sediment transport into caves can be minimized. The 2014 Land Management Plan for BCP karst preserves, and 2011 USFW Karst Preserve Management Recommendations provide guidelines for karst preserve management.

Vegetation

Ideal vegetation for a cave preserve includes a mixture of woody vegetation.

- The deeper roots of trees and other woody vegetation are essential to stabilize slopes within the sinkhole bowl and drainages into the cave.
- Tree canopies suppress red-imported fire ants, which if unmanaged can prey on karst invertebrates within the cave ecosystem as well as cave crickets and other important sources of nutrients to the cave.
- Nutritive plants such as Texas persimmon, agarita, mustang grape, prickly pear, hackberry, and others, may provide food sources for cave crickets that support the deeper cave ecosystem.
- Trogloxenes including snakes and mammals such as bats, raccoons, opossum, ringtail cats, porcupines, and bobcats may play a similar role as nutrient sources for cave ecosystems.
- Trees and woody vegetation reduce erosive runoff velocity. In open upland areas grasses, such as switch grass, can do similarly.
- In cave preserves in remote areas where water supplies are not available or installation of irrigation systems are potentially damaging or prohibitively expensive, there may be cases discussed with permitting in advance where natural revegetation augmented by seeding with desirable species may be advisable to allow for cave restoration.
- Revegetation may not be practical for caves within major stream channels.

Vehicular Access

Vehicular access to sensitive preserve sites generally limit scope of restoration, sediment/erosion control, revegetation, emergency access, and preserve maintenance.

- In general, restoration is preferably accomplished using hand-held tools without heavy machinery.

- Impacts to vegetation can include compaction of tree roots and impacting trees with heavy machinery. Placement of construction foam mats over shallow root areas may help protect vegetation.
- Where heavy machinery must be used, foam mats can be used to protect roots and 2”x4” boards or fallen native branches can be wired around a branch or trunk to protect the tree.
- Because vehicular traffic into preserve areas should be limited or may not be feasible without excessive disturbance, the use of onsite materials for incorporating sediment and erosion controls is required.
- Caution is needed when access to cave restoration area follows or crosses hazardous pipelines, particularly where excavation occurs in the vicinity of a hazardous pipeline right-of-way. Notification to the pipeline company may be required.
- Unimproved access roads over time tend to becomes drainages that can divert runoff from natural destinations such as sinkholes, and even carry flow beyond natural internal drainage basins. Diversions of this sort can reduce recharge, cave ecosystem moisture and exasperate local creek flooding.

Scientific Studies

Scientific data collection deepens the understanding of the cave system which is necessary for adaptive management of restored caves. Cave preserves are also important sources of hydrogeological, paleontological, archeological and historical information, much of which should be collected during the cave restoration phase:

- Archeological artifacts (stone tools, pottery, etc..) and paleontological remains (bones) encountered during excavation require notification to the land manager or program manager to determine next steps.
- Deep sinkhole fill devoid of modern artifacts (trash) can be sampled at 1 feet depth intervals into two 1 gallon ziplock bags for carbon isotope dating and pollen analysis, to determine the age of fill and what the ecosystem was like at the time.
- Sinkholes filled with trash can frequently be dated from the trash to determine the interval of filling.
- Cave faunal and cave cricket exit counts can be used before and after cave restoration to evaluate effects to the ecosystem.
- Drip gauges placed in the cave before and after excavation may help document moisture changes as result of restoration, if a control drip in another site is also included.
- Measurement of airflow, oxygen, carbon dioxide before and after restoration can help evaluate potential effects of reopening filled caves or widening cave passages.
- Restoration may allow access to more areas of the cave for cave drip metering, faunal surveys, water-quality sampling, and tracing studies.
- For caves with significant catchment area, possibly indicated by the sinkhole bowl volume, flood debris directed at the entrance, or location in a drainage channel, recharge into the cave can potentially be measured with flow meters, flumes, weirs, etc.

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