Bureau of Clean Water

Chapter 102 / NPDES Construction Permitting

SINKHOLE REMEDIATION IN STORMWATER MANAGEMENT FACILITIES

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Karst terrain is dynamic and as a result there is a risk of sinkhole formation associated with stormwater conveyance or stormwater management. This document outlines a four-step process for sinkhole remediation within stormwater management facilities involving notification, investigation, stabilization and final grading.

For the purposes of this document, *Stormwater Management Facilities* are defined as:

> *Manmade measures designed and constructed to convey stormwater runoff away from structures or improved land uses, or to control, detain or manage stormwater runoff to avoid or reduce downstream damages. The term includes, but is not limited to, transportation and related facility drainage systems and manmade stormwater best management practices*. (Adapted from: 25 Pa. Code § 105.1, Definitions)

The choice of sinkhole remediation techniques is contingent on the scope of the perceived problem, nature of contributing land uses, and the cost and availability of equipment and materials. Please note that this document makes a distinction for sinkhole development within infiltration Best Management Practices (BMPs) since their existence can detrimentally affect functionality. See *Sinkholes in Infiltration BMPs* (below) for more information.

The recommendations in this document do not preclude the need for a detailed design by a geotechnical engineer. This document supplements the sinkhole repair guidance found in the PA Erosion and Sediment Pollution Control Program Manual, Chapter 17, pg. 327-331 (E&S Manual). The information in this document was adapted from the Tennessee Department of Environmental Conservation's (TDEC) *Tennessee Permanent Stormwater Management and Design Guide Manual – Appendix B Stormwater Design Guidelines for Karst Terrain* (TDEC, 2014).

1. **Sinkhole Notification**

   The discovery of a new sinkhole within a temporary erosion control practice, road right of way or stormwater management practice should be reported to the municipality within 24 hours or the next business day. If the stormwater management practice is part of a National Pollutant Discharge Elimination System (NPDES) construction stormwater permit, then the appropriate Department of Environmental Protection (DEP) office and/or delegated county conservation district (CCD) should also be notified. A plan for investigation and stabilization should be coordinated with the local review authority and DEP/CCD (if applicable), and repairs should commence immediately after receiving design approval. Until repairs are completed, a temporary berm should be constructed to divert surface flow away from the sinkhole.

2. **Sinkhole Investigation**

The investigation phase should determine the areal extent and depth of the new sinkhole, as well as the depth of bedrock pinnacles upon which sinkhole stabilization may be founded. The investigation should include a root cause analysis. The investigation may involve visual inspection, excavation, borings and/or geophysical studies, as described below.

Visual Inspection is generally used for smaller sinkholes (less than ten feet in diameter at the ground surface) where the bedrock throat of a sinkhole is entirely visible from the ground surface.

Excavation by backhoe is commonly used for small to moderate-sized sinkholes (up to 20 feet in diameter) when the throat of the sinkhole is not visible from the ground surface. Track hoes, clam shells or other excavating equipment are typically used when soil depths exceed about 20 feet. The equipment is used to remove loose soil from the sinkhole until the bedrock pinnacles and/or throat of the sinkhole are clearly visible.

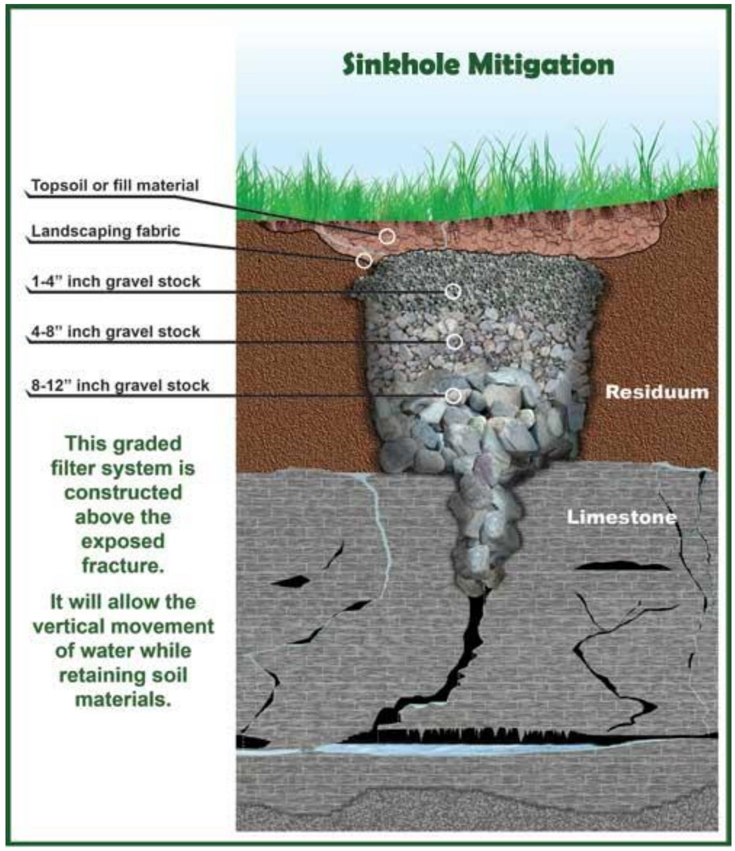
Soil borings may be taken using augers, core, air track or other boring equipment at larger sinkholes, particularly when more extensive sinkhole development is anticipated and/or critical foundation structures are at risk (bridge abutments, major roads, load bearing structures). This investigation involves a closely spaced boring program to determine the location and depth of bedrock pinnacles, cavities and sinkhole throats.

Geophysical studies may be needed in conjunction with more intrusive methods to further delineate the scope of sinkhole dimensions, using techniques such as electromagnetic terrain conductivity, seismic refraction or resistivity.

3. **Sinkhole Stabilization**

Stabilization by reverse-grade backfilling, grouting or subsurface engineering structures, is explained below:

Reverse-graded backfilling is generally applied to small and moderately sized sinkholes. Once the throat of the sinkhole is fully excavated, it is filled with clean, interlocking rock material. The stone diameter of the initial fill layer should generally be one-half the diameter of the throat. Once the initial layer is placed, progressively smaller diameter clean rock fill is installed above, up to or near the ground surface. Compaction of each layer of rock fill is essential. In general, at least three gradation sizes of fill are needed for adequate stabilization.



Grouting is generally discouraged, unless it is combined with the graded filter within moderate to large sinkholes. If grouting is utilized, it should be done under the guidance of a professional engineer. Borings are placed in the ground adjacent to the sinkhole and a concrete (grout) mix is injected by pressure or gravity into the subsurface until the throat is sealed. Grouting may be used to remediate small diameter voids, such as test borings or abandoned wells.

Engineered subsurface structures are used on larger sinkholes or where concentrated load bearing structures are present. The technique involves creating a bridge between bedrock pinnacles to form a stable base, above which appropriate fill and construction may be completed.

4. **Final Grading**

   To provide permanent stabilization and prevent groundwater contamination, final grading at the repaired sinkhole must be completed to avoid excess infiltration from the ground surface. The final grading should include placement of low permeability topsoil or clay and a vegetative cover. A positive grade should also be maintained away from the sinkhole to avoid local ponding or infiltration, although this is not always possible if the sinkhole forms within the stormwater conveyance system or centralized pond.

Sinkholes in Infiltration BMPs

Infiltration BMPs that are not appropriately planned, designed, and/or constructed within a karst area can result in sinkhole formation; these areas should be closely evaluated by a Professional Geologist before siting BMPs. Sinkhole development in an infiltration BMP is problematic. When this situation occurs the infiltration functionality of the BMP will either (1) need to be abandoned, (2) stormwater will need to be diverted to another BMP that can accept the additional volume, or (3) a BMP retrofit transitioning the functionality to Managed Released Concept (MRC) will need to be completed. Depending on the severity of the sinkhole, the BMP may need to be abandoned in its entirety and another commensurate BMP constructed elsewhere. This is due, in part, to the dynamic nature of karst topography. Once a sinkhole develops, even after it is remediated, the likelihood of another sinkhole developing in an infiltration area is high. This highlights the importance of conducting a detailed site investigation prior to siting BMPs in karst areas.

References:

- Tennessee Department of Environmental Conservation (TDEC). 2014. *Tennessee Permanent Stormwater Management and Design Guidance Manual – Appendix B - Stormwater Design Guidelines for Karst Terrain*.
- Pennsylvania Department of Environmental Protection (PADEP). 2012. *Pennsylvania Erosion and Sediment Pollution Control Manual* – Chapter 17 – Sinkhole Repair.
- Pa Code Title 25 Chapter 105, Section 105.1 - Definitions