CONSIDERATION OF CARBONATE GEOLOGY

The following general construction considerations are provided in an effort to minimize the potential for development of sinkholes at the site both during and following construction.

- Surface water should not be allowed to collect or pool in low lying areas of the site and should be directed to appropriate stormwater channels. Expeditious backfilling or grading of low-lying areas will also help minimize the potential for the development of sinkholes.

- The bases of all foundation excavations should be reviewed for unusually soft or wet soil conditions. Any unstable areas encountered should be further excavated and reviewed by the geotechnical engineer to determine the extent of any solution activity so that remedial measures can be designed and implemented.

- The extent of excavations should be kept to a minimum and the influx of surface water into excavations should be minimized.

- Positive drainage away from the proposed improvements should always be maintained.

- Storm sewer conveyance lines should be constructed with watertight joints.

- Unpaved areas, swales or surface basins should be minimized adjacent to foundation areas.

- Exterior backfill around foundations should consist of fine-grained, on-site soils, (i.e. clay) in an effort to limit stormwater infiltration in foundation areas.

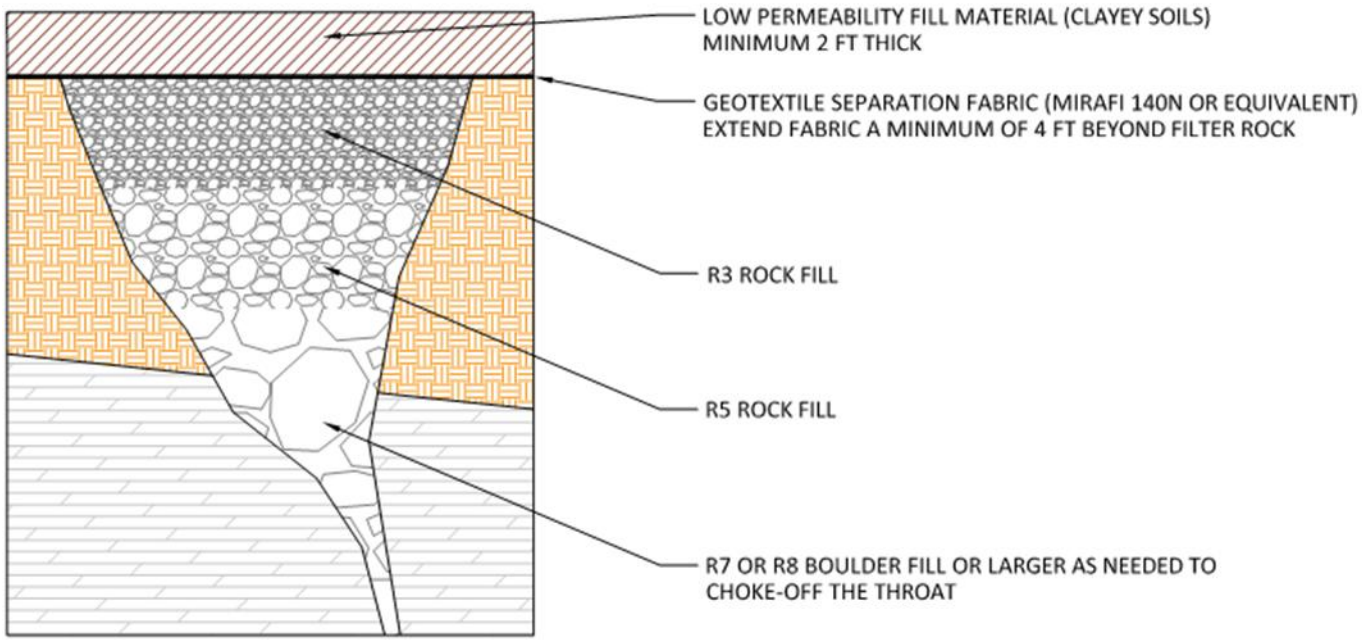
The site Owner must recognize the risks associated with development in areas underlain by karst geologic formations. Contingencies should be made in the construction schedule and budget for the repair of sinkholes and unstable soil conditions encountered during development of the site.

<u>Karst Sinkhole and Subsidence Remediation</u>

If soil subsidence occurs at the site, remediation techniques should be used to arrest the subsidence and mitigate the risk potential of subsidence occurring in the future. Kleinfelder recommends the following general procedures for treatment of areas of soil subsidence as necessary based on conditions encountered. The recommended type of treatment will be evaluated on a case-by-case basis and depends on the size of the area of subsidence and subsurface conditions in the area. Remediation should be performed under full time technical observation in accordance with the recommendations of Kleinfelder. Inverted filter plugs or plugging areas of subsidence with flowable cementitious materials may be recommended. The general approach to these treatments are described below. It is also possible that grouting of areas of subsidence may be recommended depending on conditions encountered and exposed during construction. The general approach to low mobility grouting is described below as well.

Inverted Filter Plug

One option for sinkhole repair consists of the construction of an inverted rock filter. Prior to the construction of an inverted filter, the area of subsidence should be explored and cleared of debris and loose soil materials. The throat/opening into rock and/or convergence of rock on at least two opposing sides of the excavation should be identified and exposed during the exploration and clean-out process. Depending on the depth to rock and subsurface conditions this can require deep/large excavations. The inverted filter construction should then begin with boulder fill placement in the bottom of the excavation. The initial boulders should be sized depending on what is needed to lodge the boulders between the rock surfaces and "choke-off" the throat area. The initial boulder sizes are typically National Crushed Stone Association (NCSA) size R-7 or R-8 but could require larger depending on the situation. The larger boulders should be followed by filling with approximate R-5 size rocks followed by approximate R-3 size rocks. The boulder/rock filter materials should consist of durable angular stone that is clean (free draining without soil). The filter materials should be placed in lifts not exceeding 1.5 times the maximum rock size for the initial two gradations and 18 inches for the final gradation. Each lift should be densified with an excavator bucket. The thickness of each gradation of filter material should roughly fill one-third of the depth needed to reach the transition to soil materials. The top of filter depth may vary based on conditions but typically extends to within 3 to 5 feet below final grade to facilitate further backfilling with soil materials. Prior to soil backfill a geotextile separation fabric (Mirafi 140N or equivalent) should be placed above the last layer of rock filter material and extending at least 4 feet beyond the perimeter of the filter materials. The remainder of the excavation should then be backfilled with relatively low permeability soils (clayey soils). The soil backfill material should be placed in lifts and compacted in accordance with the project guidelines for earthwork activities. A typical diagram of the inverted filter repair is provided below.



Typical Diagram of Inverted Filter Repair

Concrete Plug

Another option for sinkhole repair consists of plugging areas of subsidence with flowable cementitious materials. The area of subsidence should be explored and cleared of debris and loose soil material prior to plugging. Where feasible, the throat into rock should be identified and exposed during the exploration and clean-out process. The feasibility of exposure and clean-out depends on the depth to rock and site constraints for excavation depth and area. Flowable cementitious material (6 to 9-inch slump) with a strength of at least 200 psi should then be placed to a sufficient depth to plug the throat. Plugging depth may vary based on conditions but typically extends to within about 3 to 5 feet below final grade to facilitate further backfilling with soil materials. The flow-fill material should be allowed to cure overnight prior to backfilling the remainder of the area with relatively low permeability soils (clayey soils). The soil backfill material should be placed in lifts and compacted in accordance with the project guidelines for earthwork activities.

DEMOLITION OF EXISTING STRUCTURES/FOUNDATION ELEMENTS/SLABS

Material associated with the demolition of floor slabs, existing foundation elements and subsurface vaults will be suitable for reuse as structural fill provided the material is processed in accordance with the criteria provided below. Existing foundation elements situated within proposed parking areas should be removed to a minimum of 1 foot below the pavement subgrade elevation to minimize reflection through the finished pavement surface.

Subsurface vaults or other subsurface elements should be removed, rubblized, or perforated prior to structural fill placement. Elements left in place may impact foundation/utility construction.

REUSE OF OVERSIZED MATERIAL

Processed Brick & Cementitious Construction Remnants – Demolition of existing foundations and processing of stockpiles containing brick and cementitious materials, will be required during site development. The brick and cementitious construction debris are both considered well-suited for use as structural fill provided the following criteria are adhered to:

- Within the upper 4 feet of the building pad subgrade elevation, retaining wall foundations and within the upper 1 foot of the pavement subgrade elevation, use a well graded mixture with a maximum particle size of 3 inches.
- 4 feet or more below the proposed building pad subgrade elevation and 1 foot or more below of the pavement subgrade, use a well graded mixture with a maximum particle size of 6 inches .
- Where processed brick and cementitious demolition materials are used as pavement or concrete slab subbase material, it should be crushed and screened to a mixture having a gradation matching that of MD-SHA BRG or CR-6, or PennDOT 2A.
- Brick materials may break down further under compaction efforts.

Processed Asphalt Pavement – The existing asphalt pavement may be utilized as structural fill provided that it is processed to a well-graded mixture with a maximum particle size of 6-inches. Processed asphalt pavement must be placed in “fill” areas that are 6-feet or greater from final subgrade elevation.

Processed Bedrock – Excavated bedrock will be suitable for re-use as structural fill provided the following criteria are adhered to and that care is exercised to minimize void space or "nesting" of larger particles during placement.

- Within the **upper 4 feet** of the proposed building pad subgrade elevation and within the **upper 1 foot** of the pavement subgrade elevation: *Well graded mixture with a maximum particle size of 6 inches.*
- **4 to 20 feet** below the proposed building pad subgrade elevation and **1 to 20 feet** below of the pavement subgrade: *Well graded mixture with a maximum particle size of 12 inches. Care should be given to compact the soils surrounding the larger particles which are greater than the lift thickness.*
- **20 feet or more** below the proposed building pad and pavement subgrade: *Well graded mixture with a maximum particle size of 16 inches. Care should be given to compact the soils surrounding the larger particles which are greater than the lift thickness.*
- Processing the rock for use as pavement or concrete slab subbase material, the bedrock should be graded similar to PennDOT 2A and pass quality requirements as per PennDOT Pub 408.

Soil suitability should be confirmed in the field by Kleinfelder during construction.

COMPACTION AND PLACEMENT REQUIREMENTS

Structural fill should be placed in lifts not exceeding 10 inches in loose thickness where heavy compaction equipment can be utilized and 6 inches in loose thickness where hand-operated equipment is necessary. Only hand-operated tampers and rollers should be used immediately behind below-grade and retaining walls during backfilling unless permission is granted by the Structural Engineer to utilize heavy compaction equipment.

The optimum lift thickness and number of repetitive passes with compaction equipment necessary to achieve the required percentage compaction values should be determined in the field with test passes of the chosen compaction equipment. New structural fill should be placed at or deviate nominally from (±2%) the optimum moisture content as determined in accordance with ASTM D698 and compacted to the minimum percentages of maximum dry density as indicated below.

COMPACTION CRITERIA		
Fill Area	**Percent of Maximum Dry Density per Standard Proctor (ASTM D698)**	**Percent of Maximum Dry Density per Modified Proctor (ASTM D1557)**
Foundation Support Fill	98	95
Foundation Backfill	98	95
Slab-On-Grade, Parking Areas	98	95
Non-Structural Areas, Green Areas	92	90