# CITY UTILITIES
# DESIGN STANDARDS MANUAL

**Book 1**
**General Requirements (GR)**
**GR8 Subsurface Investigations**

June 2015

## GR8.01 Purpose

This Chapter establishes the standards for performing subsurface investigations for CUE Projects.  Although not required for all DVS Projects, subsurface investigations may be required for project approval on a case-by-case basis.

This Chapter covers the following:

- geotechnical borings
- pavement cores
- pot-holing/daylighting
- soil infiltration testing

A Subsurface Investigation Scope Checklist form is found in Exhibit GR8-1.

Reasons for performing subsurface investigations include, but are not limited to the following:

- determining the subsurface profile and properties (texture, moisture content, density, shear strength, compressibility, etc.) of soil and bedrock materials
- detecting subsurface contamination
- investigating the subsurface conditions for trenchless technology;  the composition and nature of materials at underground crossings are needed to establish the conditions (soft ground, hard ground, or mixed face tunneling) and determine the appropriate construction method
- providing information regarding groundwater including seasonal high groundwater tables
- determining pavement section makeup, layer thicknesses and condition by performing pavement cores
- determining depth and vertical location of existing utilities by performing pothole utility locates
- determining soil permeability for the purpose of determining the suitability of green stormwater infrastructure
- determining the need for underdrain systems by performing soil infiltration testing

Soil investigation and evaluation shall be conducted under supervision of soil scientists, engineers, professional geologists, or other qualified professionals and technicians.

## GR8.02 Right of Access

When the subsurface investigation requires access to public or private property, the landowner shall be first contacted, the work described, and permission to enter obtained.

A Sample Right of Access Agreement is found in Exhibit GR8-2.

## GR8.03 Protection of Underground Structures and Utilities

Protection of underground structures and utilities shall be a priority, and include the following:

- Prior to subsurface investigation and sampling, Indiana 811 or 1-800-382-5544 shall be called and a request to mark the locations of existing underground facilities shall be made; non-Indiana 811 utilities shall be notified for location services as well
- A minimum notice of 48-hours shall be provided
- Confirmation numbers shall be documented so that a record of the request is available
- Subsurface investigation shall not begin until clearance has been provided or notification has been received that all underground utility lines are marked

It may be necessary to employ the property owner's assistance and knowledge of service lines, underground storage tanks, septic tank facilities, geothermal systems, water wells, and/or use visible surface features, such as meter vaults, shut-off valves, etc. to estimate the locations of underground facilities.

If there is any reason to believe that an underground facility exists in an area to be bored for samples and its location cannot be determined with reasonable accuracy, then that boring(s) shall not be advanced.

## GR8.04 Safety

As with all field work and testing, compliance with all applicable OSHA regulations and local guidelines related to earthwork and excavation is required. Excavations shall never be left unsecured or unmarked, and all applicable authorities shall be notified prior to any work.

## GR8.05 Restoration

Restoration shall include:

- backfilling and compaction of the boring, pavement core, potholing site, soil infiltration test site, or test pit; and
- surface restoration to pre-existing condition as required by the governing authority having jurisdiction at the restoration site.

## GR8.06 Geotechnical Borings

1. Methods and Equipment

   In general, all soil test borings shall be performed in accordance with ASTM D 1686 "Standard Method for Penetration Test and Split Barrel Sampling of Soils". Split-barrel (split-spoon) samples shall be taken at five foot depth intervals and at changes in strata. When undisturbed samples in clay soils are required (for example, when shear strength determinations are needed), samples shall be obtained in accordance with ASTM D 1587 "Standard Practice for Thin-Walled Tube Sampling of Soils".

Rock core drilling shall be performed in accordance with ASTM D 2113 “Standard Practice for Diamond Core Drilling for Site Investigation”, except that wire line drilling will be permitted. The diameter of the rock core shall not be less than 2 ⅛-inches.

2. Location, Frequency and Depth Requirements for Soundings and Borings

Rock soundings shall be performed at intervals of 50-feet where rock is encountered and reduced to 100-feet intervals where rock is not encountered along the proposed alignment. The soundings shall be advanced to a maximum depth which corresponds to one foot below the invert elevation, or to auger refusal, whichever occurs first. The requirements for rock soundings may be waived by City Utilities in areas where the bedrock surface is known to be deeper than proposed excavation depths.

When required, soil test borings shall be drilled at approximate intervals of 500-feet and shall be terminated 4-feet below the invert elevation, or at auger refusal, whichever occurs first. If bedrock occurs higher than the invert elevation, rock core drilling shall extend the boring to 2-feet below the invert elevation.

Whenever possible, the boring plan shall be developed to position test borings at locations of special interest. For example, test borings should be sited at the deepest excavation or where the open trench may affect existing buildings or major utilities. Borings shall be drilled at the access pits or shafts or tunnels. If access is available, intermediate borings along the alignment shall be drilled at 100-foot intervals. For large structures the number of borings needed may vary based on the number and layout of the individual facilities.

3. Laboratory Analyses

Representative split-barrel (split-spoon) samples shall be analyzed for the following:

- Atterberg limits (ASTM D 4318)
- particle size distribution (ASTM D 422)
- specific gravity (ASTM D 854)
- moisture content (ASTM D 2216)

The samples shall then be classified in accordance with ASTM D 2487 “Test Method for Classification of Soils for Engineering Purposes”. Representative samples of soil materials which are to be placed and compacted to controlled moisture-density conditions shall be subjected to Standard Proctor moisture-density tests (ASTM D 698) to determine the maximum dry density and optimum moisture content. Additionally, for any projects requiring pavement design, representative samples of proposed subgrade soils shall be subjected to laboratory California Bearing Ratio (CBR)Tests (ASTM D 1883) to provide design values for the CBR or Resilient Modulus.

When shear strength parameters are required for geotechnical analyses, these parameters shall be determined as follows:

- the shear strength for non-cohesive materials (Sand and sand-gravel mixtures) shall be measured in accordance with ASTM D 3080 “Standard Test Method for Direct Shear Test of Soils under Consolidated-Drained Conditions”
- the undrained shear strength for cohesive soils (clays) shall be measured in accordance with ASTM D 2166 “Standard Test Method for Unconfined Compressive Strength of Cohesive Soil”
- the drained shear strength for cohesive soils shall be measured in accordance with ASTM D 4767 “Standard Test Method for Consolidated-Undrained Triaxial Compression Test on Cohesive Soils”

4. Report Development and Drafting

Reports of geotechnical investigations shall include the following.

- Discussion of the Project

  The site description shall include discussions of site topography, site drainage characteristics, existing improvements, etc.

- General Site Conditions

  Site conditions shall include a site geology description of underlying soil types and rock formations. Other geologic features such as faults or susceptibility to sinkholes shall also be included.

- Scope of Services

  Description of scope shall also be provided, and shall include a description of the drilling, sampling and laboratory analysis programs.

- Results of the Investigation

  The results of the investigation shall include information such as descriptions of soil types, depths, the presence of groundwater, soil classifications, a soil stratum profile, etc. Descriptions of rock cores shall note the presence of joints, voids, recovery ratios and rock quality designation values. References to site locations shall also be included. In addition, any engineering analysis performed (slope stability, settlement, etc.) shall be discussed.

- Conclusions and recommendations relative to the proposed design and construction shall be provided.

The following geotechnical investigation data shall be shown in plan and profile on a drawing(s) included in the geotechnical report:

- boring locations,
- graphical boring logs,
- sounding systems,
- penetration test blowcounts,
- unconfined compressive strengths,
- natural moisture contents, and
- groundwater elevations.

## GR8.07 Pavement Cores

Some projects may require pavement cores to determine pavement section makeup and layer thicknesses for pavement patching and restoration. For CUE Projects that are within the City street right-of-way, a request for pavement cores shall be given to the City Transportation Engineering Services (TES). Other pavement cores will be coordinated through the respective jurisdictional entity, such as the County Highway Department or INDOT.

The pavement core report shall consist of the following items:

- location description
- core section dimensions for the different material composition such as asphalt, concrete, stone
- subgrade material
- photograph

A sample Pavement Core Report Log Sheet is provided in Exhibit GR8-3.

## GR8.08 Potholing/Daylighting

Potholing is a preferred method to visually confirm the location and depth of underground utilities. Potholing shall be performed using non-destructive vacuum excavation equipment, through small holes (8 to 12-inches) at the surface. The holes shall be backfilled and the surface replaced to pre-existing condition.

1. Standard Guidelines

   All aspects of the subsurface utility engineering shall be in accordance with ASCE Standard 38-02 “Standard Guidelines for the Collection and Depiction of Existing Subsurface Utility Data”.

2. Potholing Report
   Potholing reports shall include:
   - location description of test hole
   - type of utility
   - material of utility
   - size of utility (diameter)
   - depth of utility from surface

- USGS Elevation (when available)

## GR8.09 Soil Infiltration Testing

Soil infiltration testing shall be done to determine suitability of a specific site for infiltration facilities.

For reference, a Hydrologic Soil Group Map for Allen County is provided in Exhibit GR8-4.

1. Test pits (deep holes) for Infiltration Testing

   A test pit (deep hole) allows visual observation of the soil horizons and overall soil conditions both horizontally and vertically:

   It is important that the test pit provide information related to conditions at the specified elevation or depth.

   A test pit (deep hole) consists of an excavated trench, excavated to a specified elevation or depth, or until bedrock or fully saturated conditions are encountered. The trench shall be benched at a depth of 2 to 3-feet for access and/or infiltration testing. At each test pit, the following conditions shall be noted and described: (Depth measurements shall be described as depth below the ground surface.)

   - soil horizons (upper and lower boundary)
   - soil texture, structure, and color for each horizon
   - color patterns (mottling) and observed depth
   - depth to water table
   - depth to bedrock
   - observance of pores or roots (size, depth)
   - estimated type and percent coarse fragments
   - hardpan or limiting layers
   - strike and dip of horizons (especially lateral direction of flow at limiting layers)
   - additional comments or observations

   A sample Soil Test Pit Log Sheet, provided in Exhibit GR8-5, may be used for documenting each test pit. Following testing, the test pits shall be refilled with the original soil and the topsoil replaced.

2. Acquiring Design Infiltration Rate from Infiltration Testing

   A variety of field tests exist for determining the infiltration capacity of a soil. Laboratory tests are not recommended, as a homogeneous laboratory sample does not represent field conditions. Infiltration tests shall be conducted in the field. Infiltration tests shall not be conducted in the rain, within 24 hours of significant rainfall events (>0.5-inches), or when the temperature is below freezing. At least one test shall be conducted at the specified elevation or depth, and a minimum of two tests per test pit are recommended. Personnel conducting infiltration tests shall be prepared to adjust test locations and depths depending on observed conditions.

Methodologies discussed in this protocol include:

- double-ring infiltrometer tests
- percolation tests (such as for onsite wastewater systems)

There are differences between the two methods. A double-ring infiltrometer test estimates the vertical movement of water through the bottom of the test area. The outer ring helps to reduce the lateral movement of water in the soil from the inner ring. A percolation test allows water movement through both the bottom and sides of the test area. For this reason, the measured rate of water level drop in a percolation test shall be adjusted to represent the discharge that is occurring on both the bottom and sides of the percolation test hole. Other testing methodologies and standards that are available but not discussed in detail in this protocol include (but are not limited to):

- constant head double-ring infiltrometer
- testing as described in the Maryland Stormwater Manual Appendix D.1, using 5-inch diameter casing
- ASTM 2003 Volume 4.08, Soil and Rock (I): Designation D 3385-03, Standard Test Method for Infiltration Rate of Soils in Field Using a Double-Ring Infiltrometer
- ASTM 2002 Volume 4.09, Soil and Rock (II): Designation D 5093-90, Standard Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer with a Sealed-Inner Ring
- Guelph permeameter
- constant head permeameter (Amoozemeter)

3. Methodology for Double-Ring Infiltrometer Field Test

A double-ring infiltrometer consists of two concentric metal rings. The rings are driven into the ground and filled with water. The outer ring helps to prevent divergent flow. The drop-in water level or volume in the inner ring is used to calculate an infiltration rate. The infiltration rate is the amount of water per surface area and time unit which penetrates the soils. The diameter of the inner ring shall be approximately 50-70 percent of the diameter of the outer ring, with a minimum inner ring size of four inches.

4. Equipment for Double-Ring Infiltrometer Test

- two concentric cylinder rings 6 inches or greater in height; inner ring diameter equal to 50-70 percent of outer ring diameter, (i.e., an 8-inch ring and a 12-inch ring)
- water supply
- stopwatch or timer
- ruler or metal measuring tape
- flat wooden board for driving cylinders uniformly into soil
- rubber mallet
- log sheets for recording data

5. Procedure for Double-Ring Infiltrometer Test

- Prepare level testing area.
- Set outer ring in place; place flat board on ring and drive ring into soil to a minimum depth of 2-inches.
- Place inner ring in center of outer ring; place flat board on ring and drive ring into soil a minimum of 2-inches. The bottom rim of both rings shall be at the same level.
- Presoak the test area immediately prior to testing. Fill both rings with water to water level indicator mark or rim at 30-minute intervals for one hour. The minimum water depth shall be four inches. The drop in the water level during the last 30-minutes of the presoaking period shall be applied to the following standard to determine the time interval between readings:
  - If water level drop is 2-inches or more, use 10-minute measurement intervals.
  - If water level drop is less than 2-inches, use 30-minute measurement intervals.
- Obtain a reading of the drop in water level in the center ring at appropriate time intervals. After each reading, refill both rings to water level indicator mark or rim. Measurement to the water level in the center ring shall be made from a fixed reference point and shall continue at the interval determined until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of ¼ -inch or less of drop between the highest and lowest readings of four consecutive readings.
- The drop that occurs in the center ring during the final period or the average stabilized rate, expressed as inches per hour, shall represent the infiltration rate for that test location.

6. Methodology for Percolation Test

   Equipment for Percolation Test

   - post hole digger or auger
   - water supply
   - stopwatch or timer
   - ruler or metal measuring tape
   - log sheets for recording data
   - knife blade or sharp-pointed instrument (for soil scarification),
   - course sand or fine gravel
   - object for fixed-reference point during measurement (nail, toothpick, etc.)

7. Procedure for Percolation Test

   - Prepare level testing area.

- Prepare hole having a uniform diameter of 6 to 10-inches and a depth of 8 to 12-inches. The bottom and sides of the hole shall be scarified with a knife blade or sharp-pointed instrument to completely remove any smeared soil surfaces and to provide a natural soil interface into which water may percolate. Loose material shall be removed from the hole.
- (Optional) 2-inches of coarse sand or fine gravel may be placed in the bottom of the hole to protect the soil from scouring and clogging of the pores.
- Presoak test holes immediately prior to testing. Water shall be placed in the hole to a minimum depth of six inches over the bottom and readjusted every 30-minute for one hour.
- The drop in the water level during the last 30-minutes of the final presoaking period shall be applied to the following standard to determine the time interval between readings for each percolation hole:
    - If water remains in the hole, the interval for readings during the percolation test shall be 30-minutes.
    - If no water remains in the hole, the interval for readings during the percolation test may be reduced to 10-minutes.
- After the final presoaking period, water in the hole shall again be adjusted to a minimum depth of 6-inches and readjusted when necessary after each reading. A nail or marker shall be placed at a fixed reference point to indicate the water refill level. The water level depth and hole diameter shall be recorded.
- Measurement to the water level in the individual percolation holes shall be made from a fixed reference point and shall continue at the interval determined from the previous step for each individual percolation hole until a minimum of eight readings are completed or until a stabilized rate of drop is obtained, whichever occurs first. A stabilized rate of drop means a difference of ¼-inch or less of drop between the highest and lowest readings of four consecutive readings.
- The drop that occurs in the percolation hole during the final period, expressed as inches per hour, shall represent the percolation rate for that test location.
- The average measured rate shall be adjusted to account for the discharge of water from both the sides and bottom of the hole and to develop a representative infiltration rate. The average/ final percolation rate shall be adjusted for each percolation test according to the following formula:

$$\text{Infiltration Rate} = \frac{\text{Percolation Rate}}{\text{Reduction Factor}}$$

Where the Reduction Factor is given by:

$$R_f = \frac{(2d_1 - \Delta d)}{DIA} + 1$$

With:

$R_f$ = Reduction factor
$d_{1=}$Initial Water Depth (in.)
$\Delta d$ = Average Water level Drop (in.)
$DIA$ = Diameter of the Pecolation Hole (in.)

The percolation rate is simply divided by the reduction factor as calculated above to yield the representative infiltration rate. An example of this calculation is shown in Figure GR8-1. In most cases, the reduction factor varies from about two to four depending on the percolation hole dimensions and water level drop – wider and shallower tests have lower reduction factors because proportionately less water exfiltrates through the sides.
Note: The area reduction factor accounts for the exfiltration occurring through the sides of percolation hole. It assumes that the percolation rate is affected by the depth of water in the hole and that the percolating surface of the hole is in uniform soil. If there are significant problems with either of these assumptions then other adjustments may be necessary.

**Figure GR8-1 Sample Percolation Rate Adjustments**

| Perc. Hole Diameter (in.) | Initial Water Depth, $D_1$ (in.) | Ave./Final Water Level Drop, $\Delta d$ (in.) | Reduction Factor, $R_f$ |
|---|---|---|---|
| 6 | 6 | 0.1 | 3 |
| | | 0.5 | 2.9 |
| | | 2.5 | 2.6 |
| | 8 | 0.1 | 3.7 |
| | | 0.5 | 3.6 |
| | | 2.5 | 3.3 |
| | 10 | 0.1 | 4.3 |
| | | 0.5 | 4.3 |
| | | 2.5 | 3.9 |
| 8 | 6 | 0.1 | 2.5 |
| | | 0.5 | 2.4 |
| | | 2.5 | 2.2 |
| | 8 | 0.1 | 3 |
| | | 0.5 | 2.9 |
| | | 2.5 | 2.7 |
| | 10 | 0.1 | 3.5 |
| | | 0.5 | 3.4 |
| | | 2.5 | 3.2 |
| 10 | 6 | 0.1 | 2.2 |
| | | 0.5 | 2.2 |
| | | 2.5 | 2 |
| | 8 | 0.1 | 2.6 |
| | | 0.5 | 2.6 |
| | | 2.5 | 2.4 |
| | 10 | 0.1 | 3 |
| | | 0.5 | 3 |
| | | 2.5 | 2.8 |

8. Hotspot Investigation Procedures (For Preliminary Planning)

This policy is intended to encourage infiltration on most sites while addressing potential contamination of groundwater and surface water caused by infiltration on sites with contaminated soils.

- Determine the prior land use at the site to be developed, and review any data on soil or groundwater quality.
- For larger development sites, a formal Phase I site assessment is often required by the lender in order to determine if any environmental hazard exists on the site. A determination of prior land use is part of this assessment.

- On sites where a formal Phase I is not conducted, methods to determine prior land use may include a title search, aerial photographs, soil surveys, topographic maps, city and state regulatory databases, and a review of state and local records.

- Determine the potential for contamination based on available data and prior land use. The following land uses are considered to have a potential for contaminated soil which may adversely affect the quality of groundwater discharging to surface water. Infiltration is prohibited on these sites unless the applicant can show that there is no potential for contaminant migration due to infiltration.
  - sites designated as CERCLA (Superfund) sites
  - auto recycler facilities and junk yards
  - commercial laundry and dry cleaning
  - commercial nurseries
  - vehicle fueling stations, service and maintenance areas
  - toxic chemical manufacturing and storage
  - petroleum storage and refining
  - public works storage areas
  - Airports and deicing facilities, railroads and rail yards, marinas and ports
  - heavy manufacturing and power generation
  - metal production, plating and engraving operations
  - landfills and hazardous waste material disposal
  - sites on subsurface material such as fly ash known to contain mobile heavy metals and toxins

For sites that do not qualify as hotspots, proceed with design of infiltration facilities including pre-treatment. For hotspots, proceed with design of water quality treatment facilities.