

## **CHAPTER 3**

### **SUBSURFACE INVESTIGATION PLANNING AND SAMPLING REQUIREMENTS**

#### **3.0 GENERAL**

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All geotechnical work performed by a qualified consultant for the State of Indiana or Local Public Agencies (LPA), such as any Indiana local municipalities or county government; involving the use of State or Federal funds, shall meet the requirements as described herein. Dimensions of all equipment shall be in accordance with all applicable requirements of AASHTO, ASTM, and Indiana Test Methods (ITM)s unless otherwise specified herein. All work performed by the licensed geotechnical engineer for state and local agencies under these requirements shall consist of making a complete foundation investigation for the adequate design and construction of bridges, roadways, and any other associated structures.

A complete foundation investigation shall consist of an adequate program of field sampling, laboratory testing, engineering analysis, and evaluation. Results and recommendations of the investigation shall be presented in a geotechnical report in accordance with Chapter 8 of the Geotechnical Design Manual. The investigation shall be performed in accordance with the procedures outlined in this document and accepted principles of sound engineering practice. Project investigations on State and/or National Highway System (NHS) routes shall be subject to the approval of the Manager of the Geotechnical Engineering Division of INDOT. Project investigations on local routes may be reviewed by the Manager of the INDOT Geotechnical Engineering Division if requested by the LPA. Unless otherwise subsequently noted, later references to as approved or directed will imply as approved or directed by the INDOT Manager of the Geotechnical Engineering Division.

#### **3.1 GEOTECHNICAL INVESTIGATION**

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The geotechnical investigation is defined as the exploration of subsurface conditions along new or existing highway alignments as required for the adequate design and construction of bridges, roads, and other necessary structures. This investigation may be preliminary such as a corridor study or it may be more specific, such as the more frequently performed geotechnical exploration for roads, bridges, retaining structures, or landslides. The investigation details will depend upon the requirements of the individual project. Some project classifications include overlays, rubbilization, reconstruction, new construction, bridge rehabilitation, bridge replacements, or landslides. Project classification provides an indication of the extent and complexity of the required geotechnical investigation. The Indiana Design Manual outlines the project types that do not require a geotechnical investigation. A geotechnical investigation should be performed on all other projects. The Federal Highway Administration's 2017 Geotechnical Site Characterization (GEC5) is a helpful resource that encompasses the overall investigation philosophy and may be used as a general reference.

#### **3.2 PURPOSE OF GEOTECHNICAL INVESTIGATION**

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The purpose of the geotechnical investigation is to identify the existing conditions of the in-situ soils, rock types, and groundwater in respect to the project requirements. The investigation will

also identify the chemical and physical properties of the soils and rock. The identification of the conditions and properties will enable engineers to design the most uniform, stable, and cost-effective road or bridge foundation. The investigation can also be used to locate construction material for building embankments along roadways.

### **3.3 OFFICE STUDIES**

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The initial steps for conducting a geotechnical investigation are completed in the office, prior to field work. A review of available information needs to be performed. Indiana is exceptionally fortunate to have state organizations which have published geological, agricultural, and water surveys for many years. These publications provide a wealth of information for nearly every part of the state. Therefore, prior to initiating the field work for any project, a review of this literature, as well as previous studies conducted for and by INDOT, should be undertaken. This literature survey should be followed by an examination of available boring logs and well drilling records, aerial photography, United State Department of Agriculture (USDA), Soil Conservation Survey (SCS) reports, topographic maps, pedologic maps, bedrock surface maps, geologic maps, INDOT's data bank, quaternary deposits maps, and other pertinent studies which have been completed for and near the project site.

#### **3.3.1 PRELIMINARY PLANS**

The proposed route and grade are a part of the preliminary plans. By review of these plans and the available literature, a geotechnical engineer or engineering geologist can identify many of the conditions that could potentially cause problems. These may include the extent of fill, cut, peat/marl deposits, landslides, sinkholes, and abandoned mines.

#### **3.3.2 MAPS**

Maps will be useful in determining the extent to which construction will influence or be influenced by the physical site conditions. Listed below are types of maps that may prove useful.

- Quaternary Geologic Map of Indiana
- 1° x 2° Regional Geologic Maps
- 7 1/2 Minute Topo Quadrangle Maps
- Topograph of the Bedrock Surface
- Thickness of Unconsolidated Deposits
- Soil Conservative Service County Soil Survey Map
- JTRP A-P Soil Survey
- Map for Seismic Design Specification
- Area Maps for Mines

These maps can be used as a guide in planning the geotechnical investigation and defining areas of concern for the site reconnaissance. Additional map types are available through the geological survey's website: [maps.indiana.edu](http://maps.indiana.edu)

### **3.3.3 PREVIOUS WORK**

Studies and construction plans completed for the existing or nearby projects can be useful in identifying problem areas. Previous investigations and construction records give a history of the roadway and bridge.

The INDOT Geotechnical Engineering Division retains geotechnical reports from previous projects. This includes preliminary plans, boring logs, test results, field observations, and correspondence relating to the project. Because of limited space, occasionally older files are eliminated, therefore, not all project files are available.

Proper use of previous geotechnical data can sometimes reduce geotechnical work in some project areas. It can also help define soil types and pinpoint the areas of typical geotechnical problems even before the first on-site field investigation.

### **3.3.4 AERIAL PHOTOGRAPHY**

The first step in any site investigation should be an examination of the area geography. Easy and quick resources for investigating the area geography are the various interactive map sites online. Some examples include, but not limited to the following sites:

- <http://maps.google.com>
- <http://earth.google.com>
- <http://maps.indiana.edu>

Online maps may be more current than the photographs provided in SCS Report for each county, and the online maps are set up to be maneuverable to more closely observe features of the site which are pertinent to the geotechnical investigation.

### **3.3.5 MAINTENANCE OPERATIONS REVIEW**

It is important to obtain past performance, history, frequency, and type of rehabilitation from the maintenance engineer. This information can be obtained during the preliminary field check. Sometimes it is noteworthy to ask questions about the maintenance history from the local INDOT or county transportation workers to obtain more details about past problems.

### **3.3.6 ENVIRONMENTAL CONCERNS**

Any available environmental information which could impact the geotechnical design, should be reviewed. The Environmental Services Division of INDOT performs environmental assessment reports on all state projects. The environmental assessment includes possible presence of contamination from old underground storage tanks and other sources of hazardous material/waste.

## **3.4 FIELD RECONNAISSANCE**

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The geotechnical engineer should attend the preliminary field check and establish the boring locations, rig type requirements, accessibility and record any existing problems such as pavement distresses, slope failures, or any other problems within the project limits. During the field check, the engineer should inquire about any details related to bridges, culverts, retaining structures and

any restrictions, as well as local ordinances about any construction activities. Environmental concerns should also be reviewed at this time.

### **3.5 LOCATIONS AND DEPTHS OF BORINGS**

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The following series of guidelines are presented to enable a geologist, geotechnical engineer, or others to prepare a subsurface drilling and coring program. However, geotechnical judgment should also be used to determine the subsurface profile based on known or mapped geology features and regional experience which could include the knowledge of karst areas, mines, rock elevation extremes, and boulder rich glacial sluiceways.

Prior to any drilling, a copy of the scope of work and the boring location plan should be submitted to the INDOT Geotechnical Engineering Division. Costs estimates should also be submitted for OEA/on-call agreements projects prior to any drilling. An example of a boring location plan can be found in the Appendices.

#### **3.5.1 BRIDGE STRUCTURES**

Locations and depths of soil borings are very important for the geotechnical investigation of the proposed structure. The scope of work should provide the maximum possible information about the subsurface conditions for the design of the structure. The location and the depths of soil borings depend upon the existing topography, type of the structure as well as shape, size, and anticipated loads. The following are guidelines for soil boring locations and depths for various kinds of structures. For additional guidance, Section 10.4.2 of the AASHTO Load and Resistance Factor Design Bridge Design Specifications, as well as current FHWA and NHI manuals should be considered.

##### **3.5.1.1 LOCATION OF BORINGS**

The plans shall consist of road plan and profile sheets, and a plan showing the location of substructure elements and cross-sections of the structure's approaches. The plan and profile sheets should include maximum high-water elevation and the stream bed elevation. In general, there should be a boring located within 10 feet of each pier and end bent. The borings should alternate right and left of the centerline of the structures. Twin structures should be considered as separate structures. For substructure units over 100 feet in width, a minimum of two borings per pier should be performed. Additional borings may be required as described in the following sections, or as directed by the engineer. In the case of skewed structures, the borings should be located at the extreme end of the end bents to better determine any subsurface variation at the maximum end limits of such proposed structure. When the prescribed boring program does not reveal adequate information to define various strata, additional borings may be required.

##### **3.5.1.2 DEPTH OF BORINGS**

Borings should be drilled to a minimum depth of 90 feet below ground elevation, unless bedrock is encountered at a shallower depth. The boring depth should extend below the anticipated pile or shaft tip elevation of a minimum of 20 feet. However, if high pile loads are proposed, deeper borings may be required. Engineering judgment should be used to determine these additional boring depths. The first boring performed should be at an interior pier.

In the case of stream crossings, the boring depth should penetrate a minimum of 15 feet below the Q500 scour depth or the depth that is sufficient to carry the pile loads when the scourable overburden materials are removed. The latter depth should extend 20 feet below the anticipated pile tip elevations. Engineering judgment shall be required to establish the pile tip elevations required to carry the pile loads and should be handled on an individual basis for each structure. Specific guidelines for the final depth of boring in soil and in bedrock are outlined below.

#### 3.5.1.3 BORINGS IN SOIL

Borings in any soil should penetrate to the specified depth and penetrate a minimum of four split spoon samples into material having a standard penetration blow count (N) of 15 or greater. If this minimum penetration of 15 blows per foot material has not been obtained at the proposed boring termination depth, the boring should be extended until this requirement is met or the INDOT project geotechnical engineer should be contacted for further guidance.

When groundwater is encountered, water or drilling mud should be added to the hole to maintain the water level in the hole at or above the groundwater level to aid in avoiding a quick condition when granular soils are encountered. This precaution will keep the sand from coming up into the casing. The ball check valve in the split spoon sampler should not be removed and washing through the spoon will not be permitted.

#### 3.5.1.4 BORING THROUGH ROCK

When rock is encountered in the boring, rock coring will be required in each boring. Rock coring should not begin until auger refusal is obtained. When auger refusal, as specified below, is not achieved within 10 feet of encountering bedrock, the project geotechnical engineer should be contacted for guidance. Auger refusal shall be defined as auger penetration of less than 6 inches under 500 psi of auger-feed down pressure for a period not less than 10 minutes. Rock coring should not begin or end in weathered bedrock, such as weathered shale or weathered limestone unless absolutely necessary. Coring and sampling should not be terminated in coal seams or voids. Recovery and rock quality designation (RQD) should be calculated and recorded before transporting core samples from boring locations.

If rock is encountered during drilling the soil borings for a structure a minimum length of coring of 10 feet into rock will be required at each substructure with a minimum recovery of 75% and a minimum RQD of 50%. For drilled shafts the minimum length of rock cores should be 10 feet or at least three times the diameter of the shaft, whichever is greater, below the shaft tip elevation. If minimum recovery and RQD values are not achieved an additional five feet of coring should be completed. Rock coring should be conducted in five-foot "runs". Ten foot "runs" will only be allowed in special cases and should be pre-approved by the Geotechnical Engineering Division. If the project is in an area in which it is known that geologic conditions will not allow the above criteria to be met, engineering judgment must be applied. A sounding should be performed at the opposite end from the boring made for each pier or bent. These soundings should be terminated in sound rock after achieving auger refusal. If there are layers of soft materials, voids in the

cored rock, or other geological uncertainties are encountered, an additional 10 feet of rock core should be taken from each boring and sounding at each substructure.

### **3.5.2 SEWERS, PIPES, AND CULVERTS**

#### **3.5.2.1 TRENCHLESS PIPE INSTALLATION**

A minimum of two borings for trenchless pipe should be obtained. Engineering judgement should be used to determine the location of the borings to optimize the soil information. The depth of the boring should be a minimum of five feet, or twice the pipe diameter below the invert elevation, whichever is deeper. The sampling should be continuous. Where groundwater is encountered, consideration should be given to installing an observation well. Where rock is encountered within the required boring depths a five-foot rock core should be obtained.

#### **3.5.2.2 STORM SEWERS**

Borings should be located over proposed sewer at points of maximum invert depths with a maximum spacing of 500 feet. A minimum of two split spoon samples should penetrate below the invert elevation. When rock is encountered, coring should be performed, and a minimum five-foot core should be obtained. In areas that are inaccessible to machine drilling; hand auger soundings should be performed to delineate the soils.

#### **3.5.2.3 CULVERTS (LARGER THAN 3 FEET DIAMETER)**

For all drainage structures larger than three feet diameter, the minimum number of borings and soundings required depends on the structure length, as summarized below:

- Drainage structures 150 feet or less in length will require a minimum of one boring near the maximum proposed fill height. The depth of the borings should be a minimum of twice the structure width below the invert elevation, or twice the fill height, whichever is deeper. If rock is encountered within the proposed depth of excavation, coring should be performed. A minimum of one five-foot core should be taken for each structure.
- Drainage structures greater than 150 feet in length will require one boring near each outside shoulder at the proposed maximum fill height. The depth of the borings should be a minimum of twice the drainage structure width below the invert elevation, or twice the fill height, whichever is deeper. If rock is encountered within the proposed depth of excavation, coring should be performed. A minimum of one five-foot core should be taken for each structure.
- In the event the proposed drainage structure crosses an existing ditch, creek, or stream channel, the boring criteria above should be followed, and an additional boring should be located in the existing channel. If the additional boring is inaccessible to machine drilling, a minimum of one hand auger sounding shall be performed at that location to a depth of five feet.

#### **3.5.2.4 PLATE ARCHES ON FOOTINGS**

Borings should be located under the footing within the existing channel along the entire length of the structure at intervals not exceeding 100 feet and at the ends of the structure. The borings should alternate from one side to the other. Soundings should be performed between the borings and at the ends within the existing and the proposed channel. The depth of the borings should be a minimum of twice the structure width below the invert elevation or twice the fill height, whichever is deeper.

### 3.5.2.5 THREE-SIDED BOX CULVERTS ON FOOTINGS

For box culverts wider than 10 feet diameter, the minimum depth of the boring should be 30 feet below the invert of the proposed foundation. Borings should penetrate to the specified depth and penetrate a minimum of four consecutive split spoon samples into material having a standard penetration blow count N of 15 or greater. If this minimum penetration of 15 blows per foot material has not been obtained at the proposed boring termination depth, the boring should be extended until this requirement is met or the project geotechnical engineer should be contacted for further guidance. If the structure is supported on deep foundations, boring requirements shall be in accordance with Section 3.5.1. If rock is encountered within the planned depth of investigation a minimum of one five-foot rock core should be taken for each structure. RQD and recovery percentages should be obtained, as described in Section 3.5.1.4.

## 3.5.3 RETAINING STRUCTURES

At the early stages of planning and development retaining wall type, location, and limits may be not delineated. Therefore, the preliminary engineering report, plans, visual inspection, and discussions with designers should be deliberated to develop a scope of subsurface investigation for retaining structures.

### 3.5.3.1 CANTILEVER RETAINING WALLS

Borings should be located at the proposed extremities and along the proposed alignment of retaining structures as closely as possible. Boring spacing along the alignment should be no more than 100 feet for walls 20 feet high or less, and no more than 50 feet for proposed wall heights greater than 20 feet. Each proposed wall should have a minimum of two borings completed along the proposed alignment. Back borings should be completed at a distance of 1.0 - 1.5 times the proposed wall height behind the proposed alignment and at a spacing of 100 feet along the alignment. The depths of borings should all be a minimum of twice the height of the wall.

Borings should penetrate to the specified depth and penetrate a minimum of two consecutive split spoon samples into material having a standard penetration blow count N of 15 or greater. If this minimum penetration of 15 blows per foot material has not been obtained at the proposed boring termination depth, the boring should be extended until this requirement is met or the project geotechnical engineer should be contacted for further guidance.

Where rock is encountered in the planned depth of investigation, a minimum of one five-foot rock core should be taken for every 150 feet of wall length with a minimum of two cored boreholes for each wall. Non-cored borings should be terminated after achieving auger refusal and a competent rock profile should be developed.

### 3.5.3.2 ANCHORED WALLS

Borings should be located at the proposed extremities and along the proposed alignment of retaining structures as closely as possible. Boring spacing along the alignment should be no more than 100 feet for walls 20 feet high or less and no more than 50 feet for proposed wall heights greater than 20 feet. Each proposed wall should have a minimum of two borings completed along the proposed alignment. Back borings should be completed at a distance of 1.0 - 1.5 times the proposed wall height behind the proposed alignment and at a distance of 100 feet along the alignment. Anchored walls require additional front borings to be completed in front of the proposed wall at a distance of

0.75 - 1.0 times the proposed height and at a spacing of 100 feet along the proposed alignment.

The depths of borings should be a minimum of twice the height of the wall. Borings should penetrate to the specified depth and penetrate a minimum of two consecutive split spoon samples into material where a standard penetration blow count N is 15 or greater. If this minimum penetration of 15 blows per foot material has not been obtained at the proposed boring termination depth, the boring should be extended until this requirement is met, or the project geotechnical engineer should be contacted for further guidance.

Where rock is encountered in the planned depth of the investigation, a minimum of 10-foot rock core, at a five-foot interval, should be taken for every 150-foot interval of wall length with a minimum of two cored boreholes for each wall. A 10-foot rock core should also be obtained from back borings for anchor design. Non-cored borings should be terminated after achieving auger refusal and a competent rock profile should be developed.

#### 3.5.3.3 MSE WALLS

Borings should be located at the proposed extremities and along the proposed alignment of retaining structures as closely as possible. Boring spacing along the alignment should be no more than 100 feet for walls 20 feet high or less and no more than 50 feet for proposed wall heights greater than 20 feet. Each proposed wall should have a minimum of two borings completed along the proposed alignment. Back borings should be completed at a distance behind the proposed wall of 1.0 - 1.5 times the proposed wall height and at a spacing of 100 feet along the alignment.

The depths of borings should be a minimum of twice the height. Borings should penetrate to the specified depth and penetrate a minimum of two consecutive split spoon samples into material having a standard penetration blow count N of 15 or greater. If this minimum penetration of 15 blows per foot material has not been obtained at the proposed boring termination depth, the boring should be extended until this requirement is met, or the project geotechnical engineer should be contacted for further guidance.

Where rock is encountered in the planned depth of investigation, a minimum of one five-foot rock core should be taken for every 150 feet of wall length with a minimum of two cored boreholes for each wall. Non-cored borings should be terminated after achieving auger refusal and a competent rock profile should be developed.

### 3.5.4 NEW ROADWAY ALIGNMENT

In general, soil borings for roadway alignments should be dictated by the topography, geological conditions, visible soil conditions, and other design considerations. Borings should be located at the maximum cut or fill along the cross sections for new horizontal alignments. Soil borings should be spaced at 300 to 500-foot intervals for each two-lane roadway and drilled to a minimum depth of 10 feet below the proposed grade. For divided highways, each bound should be considered a separate roadway when determining the



location and frequency of borings. Engineering judgment should be used in sections of roadway where deeper subsurface investigations may be warranted.

One bag sample for resilient modulus ( $M_R$ ) testing should be collected per mile for each predominant soil within the proposed project limits when the project is two miles or less. When the project is more than two miles, two bag samples for resilient modulus testing should be collected for each major predominant soil type. When the new alignment is in cut or at grade, a Shelby tube sample should be taken at a depth between 2 and 5 feet below the subgrade. Additionally, bag samples of 25 lbs, should be collected from the subgrade for moisture-density relation testing for each predominant subgrade soil.

#### 3.5.4.1 CUT SECTIONS

For cut sections where the proposed depth of the cut is greater than 15 feet, borings should be spaced not more than 200 feet along the length of the proposed cut. Borings should be located at the point of maximum cut and should penetrate to a depth of 10 feet below the proposed grade line. Borings should not stop in soft, very loose, or unsuitable soils but should be extended to a minimum of three feet into firm material, unless otherwise approved. If rock is encountered below the proposed subgrade elevation, the borings on the centerline should extend at least five feet into the rock. Cut section borings made in the ditch line should extend two feet below the proposed flow line or 10 feet below the proposed finished grade line, whichever is deeper. Rock coring done in rock back slopes should be a minimum depth of two feet below the proposed grade.

Soundings conducted to determine the limits of the rock should be discontinued at the rock surface or 4 feet below proposed grade line, whichever depth is encountered first, unless otherwise approved.

#### 3.5.4.2 FILL SECTIONS

Borings should be located in areas of maximum fill at a spacing not greater than 400 feet for proposed fills less than 20 feet for two lane highways. Borings should be located at a spacing not greater than 200 feet for fill heights greater than 20 feet unless otherwise approved. Roadway borings in fill sections should be 10 feet deep or to a depth two times the height of proposed embankment, whichever is greater. Where fill sections cross floodplains, old lake beds, ponds, or other areas of suspected compressible or low-strength foundation soils, the borings should be a minimum depth equal to the fill height plus the unsuitable soil into the firm ground. Borings should not be terminated in soft, very loose, or unsuitable soils but should be extended into firm material with the last two standard penetration N values greater than 10.

If rock is encountered in proposed fill sections, the borings should be discontinued at auger refusal or the proposed depth as determined above, whichever is shallower. One rock core should be made five feet into the rock to establish its quality.

#### 3.5.4.3 SPECIAL CASES

**Side Hill Cut Sections:** A minimum two borings should be conducted at each proposed station such that a geologic cross section can be created. One boring should be located at the maximum up-hill extent of the proposed cut and should be a minimum depth of 10 feet below the proposed final grade. The second boring should be located at the proposed ditch line and should be a depth described above. If the width of the proposed cut is

greater than 100 feet from ditch line to ditch line a third boring should be conducted. The third boring should be located in the proposed ditch line opposite the first ditch line boring.

**Side Hill Cut To Fill Section:** When one side of the centerline is in cut and the other side is in fill, borings should be located in such a way to capture the subsurface conditions of the cut section, the fill section, and the groundwater conditions. As an additional requirement, borings depths should have vertical overlap between the two borings should be a minimum of 10 feet.

**Side Hill Fill Section on Unstable Slopes:** When embankment fill is to be placed on slopes where instability is predicted, a minimum of three borings should be conducted such that a geologic cross section can be created. Locate one boring at the toe of the downhill side and the other at the intersection of the 1:1 slope from the edge of pavement with the ground line. The boring should be terminated at a depth twice the height of the fill or into rock. A rock core of five feet should be taken if bedrock is encountered. If the road is at the toe of the slope, a boring should be performed at the toe of the uphill slope to complete stratigraphy. The three borings should overlap vertically. Soil moisture should be evaluated when common soil should be used as fill in project. The geotechnical engineer should be contacting designers for the cut soil evaluation.

### **3.5.5 PAVEMENT REPLACEMENT, RECONSTRUCTION, RUBBLIZATION, COLD CENTRAL PLANT RECYCLING, OR FULL DEPTH RECLAMATION (FDR)**

Borings should be placed at approximately 600 to 800-foot intervals, alternating from left to right lanes. For divided highways, each bound should be considered a separate roadway when determining the location and frequency of borings and pavement cores. For divided highways, borings should only be completed in the driving lane. Borings may only be completed within the passing lane if there is an area of concern within that lane. Borings may be performed closer in spacing when a geotechnical anomaly is encountered. Borings should extend to a minimum depth of three continuous split samples below the proposed subgrade. Split spoon samples should be taken after augering through the pavement and subbase. Thicknesses of the various pavement and subbase material should be recorded. Locations should be delineated in the event of soft soils with standard penetration N values less than six, organic, unsuitable soils, rocks, or etc. Boring should not be terminated in peat/or marl.

A minimum of one bag sample and one Shelby tube sample per mile should be taken for each predominant subgrade soil type for  $M_R$  testing on projects that are less than two miles for reconstruction and pavement replacement projects. Full depth reclamation (FDR) and rubblization projects require one Shelby tube per mile for each predominant soil for in-situ  $M_R$ . When the project is greater than two miles, at least two bag samples for  $M_R$  testing should be collected for each major predominant soil type. Shelby tube samples for the in-situ  $M_R$  test should be collected from between 2 and 5 feet below the subgrade. FDR and cold central plant recycling projects do not require a bag sample to be taken for  $M_R$  testing and topsoil/plant growth layer testing.

When FDR, cold central plant recycling, or pavement rubblization is proposed, the pavement cores should be collected in accordance with Section 3.5.5.1. Additionally, pulverized

pavement and subbase gradations should be performed at every mile and the results reported in the geotechnical report. Reconstruction projects may not require pavement cores.

#### **3.5.5.1 PAVEMENT CORING**

Pavement cores shall be taken at the frequency described in Chapter 604 of the Indiana Design Manual:

- Two cores per lane per mile in a staggered pattern
- At select joints with distress
- In existing widened areas where different pavement structures from the mainline are obvious
- At cracks to determine top-down or bottom-up cracking
- At predominant distress locations
- If shoulders are to be used for MOT purposes, they should be cored at a frequency of one per every two miles
- Along the longitudinal joint, in the worst areas of spalling

The overall coring program shall be designed to fully characterize the pavement section throughout the project limits in the most thorough yet economical manner. Core reports shall be in accordance with 3.6.9. Pavement core history shall be reviewed using the INDOT Pavement Core Collector Application prior to investigation.

Groundwater monitoring should be performed by completing soundings either on or just adjacent to the shoulder at a spacing of every two miles in a staggered pattern. Monitoring wells should be placed in cut sections or at grade. Soundings should extend to a depth of 10 feet and should remain open to the atmosphere for a minimum of 24 hours for water level readings. Soundings may require a temporary slotted PVC pipe casing or similar measures. When the water level reported is less than six feet, the monitoring period may be extended.

Generally, ground penetrating radar (GPR) and falling weight deflectometer (FWD) testing is performed by INDOT's Research and Development Division prior to the geotechnical investigation. If anomalies are discovered by these tests, they should be delineated, and the subsurface investigation should be planned accordingly.

GPR is a valuable tool for reducing the number of borings for a project by segmenting the project on the basis of similar subsurface features or anomalies identified prior to subsurface investigation. GPR may also be used to investigate the internal composition of many pavement layers and soils. Results from the field observation and GPR surveys could be used to prepare plans for FWD testing. Boring plans should be based on field observation, GPR testing, and FWD testing. Boring plans should cover all the areas with different physical features and characteristics. Borings should be planned in widening areas to cover the entire widening area with respect to total project length or area. If cut or fill is proposed for widening, the geotechnical investigation should follow guidelines in Section 3.5.4.

### **3.5.6 PAVEMENT IMPROVEMENT AND SURFACE TREATMENT PROJECTS**

The geotechnical engineer should evaluate and prescribe soil borings based on the scope, topographic, and variability of subgrade soils. Geotechnical investigation requirements shall be in accordance with Table 3.1.

The following-work types will require an investigation: structural hot mix asphalt (HMA) overlay; minor structural HMA overlay; thin concrete overlay; PCCP cracking and seating and HMA overlay; unbonded PCCP overlay over old PCCP; and thin PCCP overlay bonded to old pavement. Soil borings should be completed at a minimum spacing of two per mile, approximately 2,640 feet, in a staggered pattern for pavement improvement projects. Borings may be performed closer when there is a geotechnical anomaly.

Staggering of soil borings should be per bound. Borings should be located in the wheel paths or in the most distressed locations. For divided highways, each bound should be considered a separate roadway when determining the location and frequency of borings and pavement cores. Engineering judgment should be used in sections of roadway where deeper subsurface investigations may be warranted. Borings should only be completed in the driving lane. Borings may only be completed within the passing lane if there is an area of concern within that lane. Sampling should consist of three continuous split spoon samples. Special geotechnical problems such as peat or marl should be delineated. Borings should not be terminated in peat or marl. Subsurface investigations should be in accordance with Section 3.6.5.

Shelby tubes should be taken in a separate boring. A minimum of two Shelby tube samples should be taken per mile for in-situ subgrade resilient modulus ( $M_R$ ) testing for each predominant soil for pavement improvement projects. When soils are similar in fines content and plasticity,  $M_R$  testing may be reduced. Engineering judgement should be used so that  $M_R$  tests cover all the predominant soils of the project. Shelby tubes for in-situ  $M_R$  testing should be taken within three feet of the subgrade. The bag samples should be taken in accordance with the procedure detailed in Section 3.6.4. Additionally, a bag sample should be collected from the subgrade for moisture-density relation testing for each predominant soil. This evaluation should include a delineation of any anomaly within the project.

Groundwater monitoring should be performed by completing soundings either on or just adjacent to the shoulder at a spacing of every two miles in a staggered pattern. Monitoring wells should be placed in cut sections or at grade. Soundings should extend to a depth of 10 feet and should remain open to the atmosphere for a minimum of 24 hours for water level readings. Soundings may require a temporary slotted PVC pipe casing or similar measures. When the water level reported is less than six feet, the monitoring period may be extended.

The following work types will not require an investigation, but a geotechnical pavement design parameter report should be prepared: concrete pavement restoration (CPR); cold in-place recycle pavement; preventative maintenance HMA microsurfacing surface treatment; thin HMA overlay surface treatment; ultrathin bonded wearing course surface treatment; patching only; crack sealing and filling; fog sealing; seal coat/chip seal; and concrete pavement preservation (CPP).

Geotechnical pavement design parameter reports should be prepared from historical information by the INDOT Geotechnical Engineering Division. AASHTO soil classification, natural resilient modulus ( $M_R$ ), prepared  $M_R$ , subgrade type, and groundwater depth should be included in the geotechnical pavement design parameter report.

The pavement cores should be taken in accordance with Section 3.5.5.1. In addition to the Section 3.5.5.1 pavement core requirement, for CPR projects, pavement cores should be taken approximately five feet from the boring location and for thin concrete overlay projects pavement cores should be located to provide a cross section of the pavement. Crack Sealing and Filling; Fog Sealing; and Seal Coat/Chip Seal project types will not require pavement cores.

Table 3.1 Geotechnical Requirements Based on SPMS Work Type

Pavement Scope	Full Geotechnical Report	Geotech Pavement Design Parameter Report	Pavement Cores (shoulder for MOT)
New Alignment	X		
Pavement Reconstruction	X		X
HMA Overlay, Minor Structural or HMA Overlay, Structural	X		X
PCCP Rubblization and HMA Overlay	X		X
PCCP Cracking and Seating and HMA Overlay	X		X
Unbonded PCCP Overlay over Old PCCP	X		X
Thin PCCP Overlay Bonded to Old Pavement	X		X
Full Depth Pavement Reclamation	X		X
Cold Central Plant Recycling	X		X
HMA Overlay, Preventative Maintenance		X	X
In-Place Recycling (CIR)		X	X
Crack Sealing and Filling			
Fog Sealing			
Seal Coat/Chip Seal			
Microsurfacing		X	X
Ultrathin Bonded Wearing Course		X	X
Concrete Pavement Restoration (CPR)		X	X
Concrete Pavement Preservation (CPP)		X	X

### **3.5.7 PAVEMENT SCOPING PROJECTS**

For scoping purposes on all projects that have unique alternate Designation numbers, the following guidance for network coring efforts is provided below:

Pavement cores should be taken at the frequency described in Chapter 604 of the Indiana Design Manual. As supplemental guidance to the Indiana Design Manual, pavement coring should be based on the pavement type in accordance with the following.

HMA/Composite Pavement:

- At least one core per lane per mile in a staggered pattern. For multi-lane facilities cores should be staggered in adjacent lanes and the coring frequency increased to every 2 miles excluding the rightmost lane
- In existing widened areas where different pavement structures from the mainline are obvious
- At predominant distress locations
- If shoulders are to be used for MOT purposes, they should be cored at a frequency of one per mile per shoulder

Concrete Pavement:

- At least one core per lane per two miles in a staggered pattern. For multi-lane facilities cores should be staggered in adjacent lanes
- If shoulders are to be used for MOT purposes, they should be cored at a frequency of one per mile per shoulder
- Along the longitudinal joint, in the worst areas of spalling
- At select joints with distress

The overall coring program shall be designed to fully characterize the pavement section throughout the project limits in the most thorough yet economical manner. Core reports shall be in accordance with 3.6.9.

**3.5.8 HIGH MAST TOWER LIGHTS & CLOSED CIRCUIT TELEVISION (CCTV) TOWERS**

High mast tower lights and intelligent transportation system (ITS) CCTV or communication towers require a soil investigation at each tower location. These borings should be drilled to a minimum depth of 30 feet. The N values should be greater than 15 for the last 15 feet of the boring. If this criterion is not met, drilling must continue until 15 continuous feet of greater than 15 blow count material is encountered. When soils are suitable, as described in Section 3.6.5, Shelby tubes should be taken from either the same bore hole or an additional borehole should be drilled for the sample. Strength tests should be performed only on Shelby tube samples. When the above criteria cannot be met within a reasonable depth, or rock is encountered within the required depth, the geotechnical project manager should be contacted. Groundwater should be monitored when high mast tower lights are located in cut or at grade.

**3.5.9 TRAFFIC SIGNAL CANTILEVER STRUCTURE**

Traffic signal cantilever structures require a soils investigation at each intersection to be signalized. However, strain poles, pedestal poles, ITS detection assembly poles, and signal or ITS controller cabinet foundations do not require soil investigations. The borings for traffic signal cantilever structures should be drilled to a minimum depth of 25 feet below planned final grade or 15 feet below the foundation bottom elevation with an N value of 15 blows or greater for the last 15 feet of the boring. When the criteria are not met, drilling must continue until 15

continuous feet of greater than a 15 N material has been encountered. A minimum of one boring shall be required for each intersection, two if the intersection is wider than 75 ft. When soils are suitable, as described in Section 3.6.5, Shelby tubes should be taken from either the same borehole or an additional borehole should be drilled for Shelby tube samples. Strength tests should be performed on Shelby tubes only. In case the soil conditions are not encountered as noted above, or rock is encountered within the required depth of the investigation, the geotechnical project manager should be contacted, and engineering judgment will be made as to the extent of additional drilling.

### **3.5.10 TRAFFIC SIGNS & LIGHT POLE**

Dynamic message sign (DMS) truss, box truss, tri-chord truss, cantilever, and monotube span sign structures require a soil investigation at or near each proposed foundation. If multiple foundations are proposed within approximately 75 feet of each other, such as at a small to moderate sized intersection, one exploration point for the foundation group is adequate if conditions are anticipated to be relatively uniform. If more variable site conditions are anticipated, one boring near each foundation should be obtained. These borings should be drilled to a minimum depth of 20 feet, or five feet below the anticipated bottom of the foundation, whichever is greater. New structures to be founded in new or existing embankments known to be constructed with sands, B borrow or select backfill and in accordance with 211 of the INDOT Standard Specifications require only a site review. Overhead cable span signs, ground mounted panel signs, school speed limit or warning sign flashing beacon assemblies, and light poles do not require a soils investigation.

### **3.5.11 CABLE BARRIER SYSTEMS**

Cable barrier systems require soil investigations for barrier termination anchor points. A minimum of one boring should be completed at each proposed termination anchor point. These borings should be drilled to a minimum depth of 25 feet with an N value of 15 blows or greater for the last 15 feet of the boring. If this criterion is not met, drilling must continue until 15 continuous feet of greater than 15 blow material is encountered. When soils are suitable, as described in Section 3.6.5, Shelby tubes should be taken either from the same borehole or an additional borehole drilled. Strength tests should be performed on Shelby tubes only. If the soil does not meet the 15 blow count criteria or rock is encountered within the required depth, the geotechnical project manager should be contacted.

### **3.5.12 NOISE BARRIER SYSTEM**

For noise barrier walls on spread footings, concrete cylinders, or continuous footings, borings should penetrate to a depth of 25 feet at a 400-foot interval spacing. A minimum of four consecutive split spoon samples should have a standard penetration blow count of 15 or greater. If the soil does not meet the 15 blow count criteria or rock is encountered within the required depth, the geotechnical project manager should be contacted.

### **3.5.13 SPECIAL GEOLOGIC CONDITIONS**

#### **3.5.13.1 PEAT, MARL, OR ORGANIC DEPOSITS**

Natural peat bogs often consist of a layer of peat or a combination of organic and mineral deposits overlying stable soils. While the upper layers may vary markedly in composition and exhibit a range of physical properties, they are entirely unsuitable as subgrade for highways. These materials must be dealt with in such a manner that they do not cause detrimental settlement or perhaps failure of the embankments or roads built upon them.

Careful attention must be taken when determining the extent of organic and marl deposits. Borings should be completed on both sides of the roadway at a maximum spacing of 50 feet and should extend a minimum of 10 feet into firm material. Firm material should be defined as mineral soils with an N value of 10 blows or greater. Split spoon samples should be taken continuously for the entire length of the boring and the complete sample should be logged. The boring pattern at the lateral limits of these deposits should be such that the limit can be determined with an accuracy of less than 10 feet delineation.

#### **3.5.13.2 LANDSLIDES**

Boring location plans for landslide projects are site-specific and are subject to the approval of the INDOT geotechnical engineer. The INDOT Geotechnical Engineering Division should be contacted for any available historical information prior to the geotechnical investigation. Borings should be located so that a geologic cross section of the landslide can be constructed. The cross section should include borings above the scarp line, if visible, and within the failure and beyond the toe bulge, if visible. Cross sectional borings should be completed at a maximum spacing of 100 feet perpendicular to the direction of failure. All borings should extend a minimum depth of 10 feet beyond the maximum depth of the suspected failure plane. The most critical section(s) of the slide should have inclinometers for each boring of the given cross section(s). Inclinometers should be installed and abandoned in accordance with INDOT Aquifer Protection Guidelines. Split spoon samples should be taken at 2.5-foot intervals for the entire length of the boring to auger refusal, unless otherwise specified. If bedrock is encountered within the boring, a minimum of two five-foot rock cores should be obtained. Accessibility may be an issue for some of the required borings, engineering judgement should be used for these borings.

#### **3.5.13.3 MINE SUBSIDENCE**

Underground mining occurs mainly in western and southwestern Indiana. There are many undocumented individual sites mined out prior to remediation where subsidence may occur. The presence of underground mines is manifested in local areas of depression or settlement of the ground surface, which can occur gradually or in a very short period of time.

The Indiana Department of Natural Resources (IDNR) Division of Mining and Reclamation and the Indiana Geological and Water Survey (IGWS) working with the state's mining industry, have developed maps of known surface and underground mine locations. Mine locations should always be considered during the planning phase of any new construction. Undocumented mine locations and possible mine subsidence represent a definite risk. Mine subsidence issues are handled on an individual basis because of the site-specific conditions affecting each mine.



The scope of investigation should be determined on a case-by-case basis, and the boring layout should be similar to the peat investigation pattern to help minimize the number of borings to draw the required profile.

#### 3.5.13.4                    KARST

Similar to potential mine subsidence locations, karst areas should always be considered during the planning phase of any new construction. A careful site investigation must be conducted in karst areas to locate any possible settlement areas followed by a geotechnical investigation. The geotechnical investigation should establish the depth to bedrock, the extent of cavities and the drainage pattern of the subsurface water.

The scope of geotechnical investigation should be determined on a case-by-case basis and the boring layout should be similar to the peat or mine subsidence investigation patterns. Geophysical techniques can be very helpful in targeting and refining the boring program proposed to investigate karst areas.

#### 3.5.13.5                    LANDFILLS

A landfill is a feature that results from the disposal of waste and cover material, which generally provides unsuitable material for the roadway substructure. INDOT policy is to suspend all geotechnical drilling and report the condition to the INDOT Geotechnical Engineering Division Manager. All applicable OSHA safety precautions and procedures should be followed in the completion of the geotechnical investigation. The limits and depth of the landfill should be determined to facilitate remediation recommendations in a manner similar to the delineation of peat and marl deposits.

#### 3.5.13.6                    BUILDINGS

Each project is drilled on an individual basis depending upon the areas architectural design. Commonly (but not limited to) geotechnical soil borings are placed at areas of maximum stress and extend a minimum of 15 feet into stiff soil.

#### 3.5.13.7                    WETLANDS

Wetlands and swampy areas usually contain peat or organic soils. The boring pattern should be based on a case-by-case basis. The boring should be extended to a minimum of 15 feet into firm material. Firm material shall be defined as mineral soils with an N value of 10 or greater.

Wetlands are protected under established federal guidelines. Before any investigation is started, all appropriate permits and a list of all work restrictions must be obtained from the Indiana Department of Environmental Management (IDEM) through INDOT's Office of Environmental Services.

In general, studies that are required for wetlands are site specific. Therefore, it is difficult to generalize requirements for geotechnical investigation of such sites. For preliminary studies, the best sources are USDA soil surveys, SCS soil surveys, and the US Fish and Wildlife Service's National Wetlands Inventory map.

### 3.5.13.8 INFILTRATION BASINS AND INFILTRATION TESTING

Infiltration basins require infiltration testing. Infiltration testing requires an exploratory boring to be conducted prior to conducting the infiltration test. The infiltration test and exploratory boring shall be conducted in accordance with the Percolation & Infiltration Guidelines found on INDOT Geotechnical Engineering Division's website. If rock is encountered, the boring shall be discontinued at auger refusal or the proposed depth as described above, whichever is shallower. Groundwater monitoring shall be conducted upon initial digging or drilling, and again 24 hours later in accordance with 4.4.3. 1. For infiltration basins an exploratory boring shall be conducted per basin. The boring shall correspond to the facility's location. The infiltration test shall be conducted adjacent to the exploratory boring.

## **3.6 GEOTECHNICAL SAMPLING REQUIREMENTS**

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For geotechnical analyses, Shelby tube samples and split spoon samples should be taken depending on the soil type. In sandy soils, split spoon samples are generally preferred. In cohesive silty and clayey soils, the Shelby tube samples are more reliable. Other relatively undisturbed sampling systems may also be used at the discretion of the Manager of the Geotechnical Engineering Division. If these systems are used, the wall thickness of the tubes should result in an area ratio ( $A_r$ ) which does not exceed 30%.

The area ratio is defined as the ratio of the volume of soil displacement to the volume of the collected sample and it is expressed as:

$$A_r(\%) = \frac{D_o^2 - D_i^2}{D_i^2} \times 100$$

Where:  $A_r$  = Area ratio  
 $D_o$  = Outside diameter of tube  
 $D_i$  = Inside diameter of cutting edge

An area ratio of 100% means that the in-situ soil was displaced by a volume equal to that of the collected sample. Well-designed tubes have  $A_r < 10\%$ .

### **3.6.1 SPLIT SPOON SAMPLES**

Generally, all borings requiring samples should be taken with a split spoon sampler to obtain the data for the standard penetration test (SPT). The samples are taken at 2.5-foot intervals for the upper 10 feet and at five-foot intervals thereafter unless otherwise specified or requested.

The sampler should be the standard two-inch O.D. and 1 ½ inch I.D., driven with a 140 lb. hammer, and dropped 30 inches. The number of "blows" required of the hammer to drive the split spoon 1 ½ feet, in six-inch intervals, should be recorded. The penetration resistance,  $N$ , shall be defined in AASHTO T 206 standards and shall be the total of the last two intervals (the second and third six inches of penetration), or one foot of the 1 ½ feet drive.

Two jar samples, each approximately six inches long should be obtained from each split spoon sample for laboratory examination or testing. When required for subgrade or peat investigation, a full 18-inch SPT sample should be taken and stored in jars. The sample should

be designated as top or bottom. The samples should be kept as intact as possible. The samples are to be seated in clean glass jars to prevent loss of moisture. The samples should be properly marked with the project designation number, boring number, sample number, blow count, and field identification number. As soon as possible after drilling, the samples should be delivered to the laboratory for tests.

### **3.6.2 SHELBY TUBES**

Undisturbed samples, if required by the engineer, should be obtained by pressing a thin-walled tube into the soil with a slow, continuous push. The Shelby tube should all be three inches O.D., and the length should be as recommended in Table 1 of AASHTO T 207 or longer to avoid overfilling of the tube during sampling. The standard lengths for INDOT are: 30 to 36 inches. A recovery of 50% or greater is required unless otherwise approved by the Manager of the Geotechnical Engineering Division. Immediately upon retrieval, the tubes are to be trimmed and cleaned of excess soil on the ends, sealed with approved air-tight expanders on the top and sealing wax on the bottom. Both ends should be covered with plastic caps, then tape should be applied in such a manner as to seal the open bolt holes and the lip of the cap. Samples should be kept in a vertical position with the top up during transporting and storage. Samples should not be jarred or shaken and should always be protected from temperature extremes, especially freezing. Each tube should be properly tagged inside and out with all the pertinent information including project and designation number, road, boring, station and offset, line, depths, recovery percentage and date. The sample should be delivered promptly to the laboratory for testing. A damaged Shelby tube should not be reused.

#### **3.6.2.1 RESILIENT MODULUS ( $M_R$ )**

In-situ  $M_R$  test should be performed on Shelby tube samples for pavement replacement, reconstruction, rubblization or full depth reclamation (FDR), pavement improvement, and surface treatment projects. Refer to project type for specific  $M_R$  requirements. When soils are similar in fine content and plasticity,  $M_R$  testing frequencies may be reduced. Engineering judgement should be used so  $M_R$  tests cover all the predominant soils of the project. The procedure should be as described below:

- A continuous flight auger should be used to penetrate the existing pavement and pavement subbase material to a depth approximately 4-6 inches below the top of the subgrade.
- The flight auger should then be extracted from the borehole.
- The borehole should be inspected and cleaned to ensure no subbase material will interfere with or contaminate sampling.
- A three-inch diameter and 24-inch-long Shelby tube sample should be collected from the borehole for the subgrade foundation. It should be taken within three feet of the subgrade.
- Deviator and confining stresses should be four psi for subgrade foundation  $M_R$  testing.
- Deviator and confining stresses should be six and two psi for  $M_R$  testing when a Shelby tube is taken for in-situ subgrade.

### **3.6.3 ROCK CORES**

Rock coring involves using a drill rig to core through hard rock which cannot be augured through. Two-inch core barrels, double or triple-tucked, with diamond core bits of NX, NWG, or NWPAM sizes are suggested to obtain an approximate core size of two inches. The core

barrel should be five feet long with an inside diameter of two inches to obtain the minimum size core, unless otherwise approved by the Manager of the Geotechnical Engineering Division. Longer barrels can be used; however, the maximum allowable run is five feet. Wire-line coring should only be permitted in special cases and should be pre-approved by the Manager of the Geotechnical Engineering Division.

If shale or any other non-durable sedimentary rocks are encountered, the core samples should be wrapped tightly in a moisture-proof wrapping such as aluminum foil or plastic wrap to prevent drying of samples. Cores should be measured to determine percent recovery and RQD, and then placed in core boxes with labels indicating “top”, “bottom”, and depths. The core box should be labeled with designation number, station, line, offset, boring number, depths of coring, RQD and percent recovery.

### **3.6.4 BAG SAMPLES**

All bags should be properly tagged, inside and out, with tags showing the project designation number, road, sample number, station and offset, date, and field identification number. Samples should be delivered to the lab in a timely manner.

#### **3.6.4.1 RESILIENT MODULUS ( $M_R$ )**

Bag samples for  $M_R$  testing should be obtained for each prominent soil for the project. When an embankment is constructed for the new roadway, widening or a new alignment is proposed; one bag sample is adequate for  $M_R$  testing. One bag sample should be obtained for every 10 borings performed, or one per mile if boring spacing is greater than 600 feet. The bag sample may be taken from the soil collected from auger cuttings taken below the pavement and subbase material. Approximately 25 lbs of auger cuttings should be collected for the bag sample and care should be taken so that aggregate base material does not contaminate soil cuttings. Two jar samples should be included with each bag sample to be tested for in-situ moisture. Samples should be delivered to the lab in a timely manner. Soil classification tests should be assigned for each  $M_R$  bag sample and unconfined test at 1% strain.

#### **3.6.4.2 MOISTURE AND DENSITY RELATION**

A 25 lb bag sample is required for all cohesive soil types found during a subgrade investigation. The sample should be taken from directly under the pavement or subbase strata, or from the auger cuttings. A jar sample for moisture testing is not necessary if a split spoon sample was taken. Bag samples for moisture and density relation should be obtained for each project, usually from each predominant soil found during the drilling. These samples should be taken from the subgrade. The requirements for the bag sample for moisture density should be eliminated when predominant soil is collected for  $M_R$  testing.

#### **3.6.4.3 SAMPLE FOR PLANT GROWTH LAYER**

Bag samples for plant growth layers should weigh 1 lb.

### **3.6.5. SUBGRADE SAMPLING**

INDOT specifications define subgrade as the upper portion of a roadbed upon which the pavement structure and shoulders are constructed. The horizontal and vertical variation in

subsurface soil types, moisture, densities, strength, groundwater elevations and rock location should all be considered when performing subgrade investigations. Pavement maintenance history, county soils map, GPR, and falling weight deflectometer data are all helpful in developing a thorough subgrade investigation. The purpose of a subgrade investigation is to define the depth, thickness, and location of major soil and rock strata that may reduce the pavement service life. Subgrade investigations also determine the need for any foundation improvement and strengthening that may be required. The guidelines for drilling and sampling for subgrade investigation are as follows:

When the top of the subgrade soil is reached, split spoon samples should be taken and logged. Borings should evaluate the upper approximate 4.5 feet of the proposed subgrade. Borings should penetrate to a depth that allows for three continuous split spoon samples to be collected below the pavement subbase. In the first split spoon sample if the  $N$  value is less than or equal to 10 blows, and the soil is cohesive, a Shelby tube sample should be taken beside the split spoon boring. When a Shelby tube sample is required, it should have a minimum recovery of 50%. If this is not obtained from the first tube, a second tube will be required as described previously depending on the soil encountered, so that a combined total of not less than 16 inches of undisturbed sample is obtained. If the  $N$  value is greater than 10, no Shelby tube sample should be required, and the boring should be extended to the bottom of the first split spoon depth and the procedure repeated.

If the  $N$  value is less than 6 inches in either the second or third split spoon sample and the soil is cohesive, a Shelby tube sample is required at the corresponding depth. Similarly, a 50% minimum recovery is required. If the  $N$  value on the third split spoon is six or greater the boring is to be terminated at this point.

Groundwater monitoring should be performed by completing soundings either on or as close to the shoulder as possible at a spacing of every two miles in a staggered pattern. Monitoring wells should be placed in cut or at grade. These soundings should be to a depth of 10 feet and should be left open for a minimum of 24 hours for water level readings. When the water level reported is less than six feet, monitoring period may be extended. Soundings may require a temporary slotted PVC pipe casing or similar measures. Water level determination is prudent to roadways and other structures.

### **3.6.6 TOPSOIL/PLANT GROWTH LAYER SAMPLING**

Topsoil is described as soil that facilitates grass growth and is defined in Section 629 of the Recurring Special Provisions. Topsoil consists of organic material, silt, sand, clay, gravel, in addition to chemical elements, such as potassium and phosphorus. The topsoil thickness should also be determined during the geotechnical investigation. Soils should be sampled from the uppermost strata of the boring or sounding. Sampling and testing should be performed within the proposed construction limits and should be representative of the surface soils within that area. Split spoon sampling should be in accordance with AASHTO T 206. Borings not taken on the roadway should have organic soils identification. If drilling is not feasible, bag samples should be recovered, and hand auger testing should be completed. The bag sample should be a minimum of 1.0 lbs. Sampling and testing should all be completed for all projects requiring a Rule 5 permit. A Rule 5 permit is required on projects where construction activities are expected to have an acre or more of soil disturbance. New road, bridge, box culverts, ditches, landslides, which require a plant growth layer for grass germination should also have sampling and testing done. FDR projects do not require topsoil sampling or testing.

Engineering judgment should be used to determine the location of sampling unless specified below.

The frequency shall be as follows:

<b>Descriptions</b>	<b>Testing Frequency</b>
New Road / Reconstruction	1 Test / 1,000 Feet
Bridge /Pipe Culvert	1 Test /Quadrant
Rule 5 Permit Projects (if not already specified)	2 Tests / Acre

Samples should be logged, placed in zip lock bags and labeled appropriately. Labels should include project ID, either designation number or contract number, sample location and depth. Finally, topsoil thickness should be determined by either machine or hand auger sounding. A topsoil summary table shall be included in the geotechnical report when applicable. An example of the topsoil summary table is included in the Appendices.

### **3.6.7 PITS**

In areas such as gullies, ravines, or in streambeds where it is not feasible to place a drill rig and information from a hand auger is inadequate, pits may be dug as an alternate method of establishing bedrock elevations and overburden depths. Usually, a series of 10 ft<sup>2</sup> pits, in an acceptable pattern as per the requirements of the project, are dug by hand to confirm expected data. This method of data collection is limited to sites where shallow bedrock is known or expected, usually within a three-foot depth. Generally, no samples are taken although a representative bag or jar sample for grain size analysis and moisture tests may be requested. All pits should comply with OSHA guidelines.

### **3.6.8 HAND AUGERS**

Hand augers are limited to soft cohesive soils and are performed in areas where standard penetration tests are not possible or necessary. They are used to obtain a profile of the existing strata, sometimes with samples. There are five types of hand augers, as follows:

- The sample hand auger (minimum of 1 ½ inch diameter)
- One-inch retraction piston sampler
- A peat sampler
- Hand guide power hand auger
- Three-inch diameter post hole type auger

Hand augers should not exceed 6 inches per increment of advancement and are performed as directed. If samples are obtained, they should be placed in jars, sealed and labeled appropriately.

### **3.6.9 PAVEMENT CORES / SUBBASE**

Specific project work types may have additional pavement core requirements as specified above. In addition to pavement coring requirements as specified above, pavement cores should be obtained when an analysis or test of the core is requested by the Pavement Design Engineer in accordance with the Indiana Design Manual. If testing of the core is not required, then other methods of drilling through the pavement are acceptable.

Core reports should be created for each core taken containing a detailed description of the core along with photographs of the core, the location at which the core was taken, subbase at the base of the pavement core, and the core hole cross section by taking a photo down the empty core hole. Additionally, a compilation report should be prepared summarizing findings and including a summary table in the attached format and file structure. An example of a pavement core report can be found in the Appendices. Core data should also be entered in the Department's Core Collector Application. Prior to creating the proposed coring location plan, the appropriate District Pavement Engineer should be contacted for additional guidance on coring locations and special testing.

Once the pavement core has been extracted, the boring should be extended through the subbase to the subgrade. Hence, the boring depth should be from the bottom of pavement. Subbase material should be carefully logged; however, no sample should be taken for testing unless otherwise specified by the geotechnical engineer.

### **3.7 CONE PENETRATION TESTING (CPT)**

The cone penetrometer test consists of pushing an instrumented penetrometer into the ground while continuously recording sleeve friction, cone resistance, and pore pressure in accordance with ASTM D5778. Shear wave velocities can also be measured at user defined depths. Cone penetration testing can be performed in conjunction with SPT borings for all investigation types covered under Section 3.5 of this document, based on the engineering judgment of the geotechnical engineer and approval of the Manager of the Geotechnical Engineering Division. An example of a CPT log may be found in the appendices.

### **3.8 DILATOMETER TEST (DMT)**

The dilatometer is a 3.75-inch wide and 0.55-inch thick stainless-steel blade with a thin 2.4-inch diameter expandable metal membrane on one side. While the membrane is flush with the blade surface, the blade is either pushed or driven into the soil using a penetrometer or drilling rig. Rods carry pneumatic and electrical lines from the membrane to the surface. At depth intervals of eight inches, the pressurized gas expands the membrane and both the pressure required to begin membrane movement and that required to expand the membrane into the soil 0.04 inches is measured. Additionally, upon venting the pressure corresponding to the return of the membrane to its original position may be recorded.

Through developed correlations, information can be deduced concerning material type, pore water pressure, in-situ horizontal and vertical stresses, void ratio or relative density, modulus, shear strength parameters, and consolidation parameters. Compared to the pressuremeter the flat

dilatometer has the advantage of reduced soil disturbance during penetration. Tests should be performed in accordance with ASTM D6635.

### 3.9 DYNAMIC CONE PENETROMETER (DCP)

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Dynamic cone penetrometer testing should be performed in accordance with ITM 509. The DCP test consists of driving a steel rod with 60° steel cone at one end into the soil by dropping a sliding hammer from a standard height of 22.6 inches. The soil strength is determined by counting blows for every six inches of penetration. The length of the bottom steel rods should be 60 inches. Rods may be fabricated into different combinations of lengths for ease of use. The rod should not be less than twelve inches. A disposable cone is highly recommended for easier extraction of the rods at the completion of the test.

DCP strengths should be based on the following table:

<u>Blows per 6"</u>	<u>Consistency/Density</u>
0 to 3	soft
4 to 6	medium stiff
7 to 12	stiff
Over 13	very stiff

### 3.10 GEOPHYSICS

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Geophysical testing is an important tool for geotechnical engineers and geologists in the performance of subsurface investigations. Commonly employed geophysical methods for transportation projects include seismic refraction, seismic reflection, multichannel analyses of surface waves (MASW), ground penetrating radar (GPR), electrical resistivity (ERT), electromagnetic (EM), magnetics, and gravity. Transportation Research Circular E-C130 (2008), FHWA Geophysical Manual, and National Cooperative Highway Research Program Synthesis No. 357 are helpful resources that contain additional information on geophysical methods. Geophysical testing is often used for the following types of geotechnical investigations:

- to aid in project or corridor scoping, allowing for stratigraphic interpretation prior to a boring program,
- to refine stratigraphic interpretations between exploration points, especially if the project location has difficult terrain or limited access for drill/CPT rigs
- to establish subsurface characterization: bedrock depth, rock type, layer boundaries, water table depth, groundwater flow, locating fractures, weak zones, expansive clays. etc.
- to establish engineering properties of earth materials: stiffness, density, electrical resistivity, porosity, in-situ shear wave velocity etc.
- to detecting cavities beneath roadways caused by sinkholes, underground mines, etc.; and
- to locate buried manmade objects: buried utilities, underground storage tanks, etc.
- design of significant embankments on soft subgrades
- for large or challenging bridges



Table 3.2 Decision Matrix of Geophysical Methods for Specific Investigations

	Seismic Refraction	Seismic Reflection	Multichannel analyses of surface waves (MASW)	Ground penetrating radar (GPR)	Electrical Resistivity (ERT)	Electro-magnetic (EM)	Magnetics	Gravity
<b>Top of Bedrock &lt; 30 ft</b>	Primary	N/R	Primary	Primary	Secondary	Secondary	N/R	N/R
<b>Top of Bedrock &gt; 30 ft</b>	Secondary	Primary	Primary	N/R	N/R	Secondary	N/R	N/R
<b>In Situ Rock Properties</b>	Primary	Secondary	Primary	N/R	Secondary	Secondary	N/R	N/R
<b>Fault Detection</b>	Secondary	Secondary	N/R	Secondary	Secondary	Secondary	Secondary	Secondary
<b>Detection of Water Surface</b>	Secondary	Secondary	N/R	Secondary	Secondary	Secondary	N/R	N/R
<b>Water Filled Cavities, Tunnels</b>	Secondary	Primary	Secondary	Secondary	N/R	N/R	N/R	N/R
<b>Air Filled Cavities, Tunnels &lt; 30 ft</b>	Secondary	Secondary	Secondary	Primary	Primary	Secondary	N/R	Secondary
<b>Air Filled Cavities, Tunnels &gt; 30 ft</b>	Secondary	Primary	N/R	N/R	Secondary	Secondary	N/R	Secondary
<b>Large Ferrous Bodies - Tanks</b>	N/R	N/R	N/R	Secondary	Secondary	Secondary	Primary	N/R
<b>Suspected Voids or Cavity Detection</b>	N/R	Secondary	N/R	Secondary	Secondary	N/R	N/R	Secondary
<b>Abandoned Mine Shafts</b>	N/R	Secondary	N/R	Primary	Secondary	Primary	Secondary	
<b>Near Surface Karstic Sinkholes</b>	Primary	Primary	N/R	Primary	Secondary	Secondary	N/R	Secondary
<b>Material Boundaries</b>	Secondary	Primary	N/R	Secondary	Secondary	Secondary		Secondary
<b>Landfill Boundaries</b>	N/R	N/R	N/R	Secondary	Primary	Secondary	Primary	N/R
<b>Landslide Site Evaluation</b>	Primary	N/R	Secondary	Secondary	Primary	Primary	N/R	N/R
<b>Foundation Integrity Study</b>	Primary	N/R	Primary	Primary	N/R	N/R	N/R	N/R

Note: N/R = not recommended

Geophysical applications indicated as primary in conjunction are applications that may work well in most materials and natural configurations for that investigation type. Geophysical applications indicated as secondary are applications that work well under special circumstances of favorable material or configurations for that investigation type.

Table 3.2 should be used as a guide, as there is no universal approach that works for all applications of geophysics in transportation projects. The deployment of a geophysical technique and each site condition are unique. The FHWA-Geophysical Manual and Table 3.2 shall be considered to determine when geophysical testing may provide an economical means of geotechnical site characterization.

The scope of this manual focuses on preliminary design; however, geophysical testing may be applied to other project phases such as scoping, construction, and special circumstances such as failures or maintenance performance. For most design applications, geophysical shall be considered a secondary exploration method to drilling and shall generally be accompanied by conventional borings. Geophysical studies may be issued as a separate report or combined with the final geotechnical report. All geophysical data shall be provided to a qualified professional such as an experienced geophysicist or licensed geologist for their use in assessing and reporting their findings.

### **3.11 PERFORMANCE OF FIELD WORK ON PRIVATE PROPERTY**

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#### **3.11.1 ENTRY PERMISSION**

When employees and representatives of the State of Indiana must enter and work on private property, they are required to follow **Indiana Code 8-23-7-26-,27,28**, which took effect on July 1, 2008.

The usual information about the project and its impact on the property owner or tenant should start the letter, along with an explanation of the type work, a timetable to expect entry and an estimate how many days the work will take should be given. However, a notice of survey (NOS) letter is required by law to include the following:

1. Include both the occupant and the recorded owner of the property in the notification process.
2. A description of the property owner's right to compensation for damages.
3. The procedure the property owner must follow to obtain the compensation.
4. The name, address, and telephone number of an individual or office where property owners may direct questions about the investigation. *(This would be the geotechnical consultant's information.)*
5. The name, address, and telephone number of an individual or office where property owner's questions about the rights and procedures for damage compensation may be directed. *(This would be the project area's INDOT District Office, to the attention of the district's Real Estate Manager.)*
6. A copy of the **Indiana Code 8-23-7-26, 27, 28** should be included with the letter. This will assist property owners with immediate answers to many of their questions.

After the field work is finished, Form IC-662 is to be immediately completed for crop damages. Property damages are handled by the district in a different manner and are not

claimed on Form IC-662. All Form IC-662 claims are to be promptly directed to the appropriate District Real Estate Manager since a timetable of 60 days for reimbursement of an agreed upon compensation is established in the code.

### **3.11.2 CROP DAMAGE CLAIMS INCURRED ON PRIVATE PROPERTY**

Crop damage claims are to be reported on Indiana Form IC 662. The forms should be filled out completely and accurately, with a sketch, length and width, of the damaged crop areas, the location where the damages occurred on the property in reference to a known point, and the type crop planted. Acreage can be easily converted once the square footage of damages is determined by using the following website:

[www.metric-conversions.org/area/square-feet-to-acres.htm](http://www.metric-conversions.org/area/square-feet-to-acres.htm)

Send the completed forms immediately to the project location's District Real Estate Manager for review and payment. A copy of the form should be sent to INDOT Geotechnical Engineering Division.

### **3.11.3 NON-CROP DAMAGE CLAIMS INCURRED ON PRIVATE PROPERTY**

Damage compensation should be handled as outlined in the aforementioned Indiana Code. If damage is done, the property owner should be referred to the INDOT District Development office of the project area. Compensation of the damages should be handled by the district personnel. If the property owner is not satisfied with the compensation as determined by INDOT, the County Agricultural Agent should be asked to assist. Compensation for the damages of LPA projects should be handled by the design consultant and local government.

## **3.12 EQUIPMENT**

All drilling rigs used for obtaining split spoon samples should be equipped with automatic hammers should be calibrated yearly. Calibration records for each rig's hammer must be available for the INDOT inspection upon request. Pile driving analyzers are the method commonly used for calibration of SPT hammers. Catheads should not be used for sampling on INDOT projects.

Only approved equipment should be mobilized to the project sites as determined by a pre-drilling field check. If it is deemed necessary to change or add rigs during the process of drilling due to unforeseen circumstances at the site, mobilization of the additional rig must be approved by the Geotechnical Engineering Division prior to the remobilization if additional payment for mobilization is requested.

## **3.13 UTILITIES**

Buried utilities must be located prior to the start of all geotechnical investigations. Most Indiana utilities subscribe to the "Indiana 811" network at 1-800-382-5544. Utilities that are not members, in most cases municipal utilities, should be contacted individually. Failure to contact these companies could result in injury or death to geotechnical drill crew members and the public or a loss of utility services.

In addition to clearing standard utilities, when work is done around existing ITS CCTV or communication towers, the area should be cleared with the District Signal Technician Supervisor.

All soil test boring *and pavement coring* locations should be marked in a distinctive manner (laths, flags, and paint). Before contacting the utility companies to locate their buried lines, in order to expedite the process. If the road work is extensive, involving several blocks or miles of roadway, it is recommended that a meeting be planned, onsite, with the utilities' locators so that no boring locations are missed. If a meeting is not feasible, maps of the project with the soil test locations clearly marked (to be given to the locators) are an excellent alternative.

Overhead utilities, although in plain sight, are sometimes forgotten. Drilling crews with high mast rigs should work within the guidelines established by the affected utilities and it is recommended that safety insulators or boots be placed on the wires to protect the workers. If it is imperative that data be obtained from directly under power lines, then an alternative to drilling with a high mast rig must be used such as CPT truck, a tripod, hand auger, pit, etc. Consider all overhead lines to be powered and dangerous.

Older urbanized areas can have abandoned utility lines or tanks, which could be encountered during drilling. Getting information about these lines prior to drilling from the utilities and street departments could help prevent accidental contact with abandoned structures. All utility hits should be treated as active lines, and emergency safety guidelines should be as followed until the utility company can confirm the abandoned line as such.

The American Right-of-Way Association has established color codes to surface mark buried utilities. These color codes are in compliance with the Occupational Safety and Health Acts (OSHA) standards.

Table 3.3 Color Code Identification

Orange	Telephone
Red	Electric
Yellow	Gas
Blue	Water
Green	Sanitary
White	New Construction

INDOT commonly uses pink and white markers for locations where geotechnical drilling is to be done.

### 3.14 RIGHT OF WAY PERMITS

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INDOT standards require any work within INDOT Right of Way (ROW) to obtain a permit. The permit ensures safety for workers and the traveling public and provides information to the State Police. A ROW permit application should be submitted if drilling operations take place within INDOT ROW. The permit application should be filed online through the Electronic Permitting System (EPS). The EPS website can be found at <http://eps.indot.in.gov/Permit/PermitApplication> . If there are project-specific ROW permit questions, please contact the District Area Permit Manager prior to submission. Contact maps can be found at [http://www.in.gov/indot/files/District\\_Permits\\_Map.pdf](http://www.in.gov/indot/files/District_Permits_Map.pdf). Permit submittals are reviewed, approved, and issued online. The INDOT permit investigator should be contacted five days before mobilizing and within five days after the completion of all permitted work.

### **3.15 DRILLING SAFETY**

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#### **3.15.1 TRAINING**

Each consultant is responsible for their own drilling safety training and supplying personal safety gear. An introductory safety course for all new drillers, inspectors, geologists, engineers, and others who are in the field with the drill rig operators is recommended. The “Drilling Safety Guide” published by the International Drilling Federation and the “Drilling Safety” films produced by Mobile Drill Co. and ATC Associates are good examples of the industry safety guidelines.

#### **3.15.2 PERSONAL SAFETY GEAR**

Every person around the drilling operations is required to use personal protection equipment, which includes, but is not necessarily limited to, a safety hardhat, safety shoes, and hearing protection. Those working in close proximity to the augers should not have loose-fitting clothing with straps, drawstrings, belts, loose ends or otherwise which might become entangled in the rotating augers. Rings and other types of jewelry should not be worn at any time and long, loose hair should be pulled back and secured. Personal protective gear should follow all applicable OSHA guidelines.

In cases where there is known contamination (e.g. chemical, biological, and radioactive) and special protection is required, it becomes the responsibility of each consultant to provide their drilling crew with the appropriate equipment and clothing for the project.

#### **3.15.3 SITE MAINTENANCE**

The drilling supervisor is responsible for good upkeep of the drill rig and around the drilling site. There must be suitable storage for all tools, materials and supplies to avoid placing them in areas where they cannot be safely handled or secured. Heavy rods, pipe, casings, augers, cables, and other drilling tools should be stored in an orderly fashion to prevent movement when not in use. Work areas should be free of debris, obstructions, and hazardous substances, such as grease, oil, or ice which could cause surfaces to become slick and hazardous.

When leaving the testing site, it is everyone’s responsibility to make sure all holes have been backfilled properly, dirt mounds scattered, and sod replaced if necessary. If boreholes are to be left open for water readings, all boreholes should be made secure. A safety cone is recommended when not in the roadway, to avoid injuries. All debris should be removed, and the drill site returned to the condition it was in before drilling operations began. If possible, a follow-up inspection to inspect and correct any settlement of the test holes should be done.

#### **3.15.4 TRAFFIC CONTROL AND SAFETY**

This work should consist of providing traffic control services in accordance with the INDOT Worksite Traffic Control Manual, when traffic flow must be restricted in order to conduct drilling or coring operations. In case of an accident on the roadway District Safety Manager should be contacted. Any work on interstates that requires traffic control should be in accordance with the INDOT Interstate Highways Congestion Policy. Coordination with Indiana Toll Road is

required prior to any work that may require lane restrictions or closures on toll roads or toll road ramps.

## **3.16 NATURAL AND MANMADE HAZARDS**

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### **3.16.1 RIVERS AND STREAMS**

Drilling on a river requires a barge setup if it is not possible to access through the existing bridge deck. The drilling needs to be done at a time when flash floods are not likely and should never be done in flood conditions. Drillers should be equipped with life vests or personal floatation devices while working on the water and, because icy conditions could develop quickly, it is not advisable to work on a barge in the winter cold.

### **3.16.2 UTILITY LINES**

Always have buried utility lines located before drilling at the “Indiana 811” number 1-800-382-5544. See section 3.13 for additional information.

### **3.16.3 TOXIC OR HAZARDOUS AREAS**

Most projects have an environmental assessment prior to any geotechnical survey which identifies hazardous areas. Detailed information on this assessment process can be found in the Site Assessment and Management (SAM) Manual at <http://www.in.gov/indot/2523.htm> . While the goal is to identify as many, if not all, of the contaminated sites, unidentified contamination can still be encountered. In the event that contaminated media is encountered, remember that personal safety is always the first priority. Do not endanger yourself by entering hazardous environments. Stay upwind of spills and never taste spilled material or inhale odors to identify a spill.

Reference the process flow diagram in Appendix G of the SAM Manual for guidance on who to contact and what to do if unplanned contamination media is discovered within INDOT-owned right-of-way. In addition to the contacts found in the flowchart “Discovery of Contaminated Materials or Unknown Underground Storage Tanks (USTs) in INDOT Owned Right-of-Way”, the Manager of the Geotechnical Engineering Division, be immediately notified and all drilling operations ceased until guidance has been provided.

### **3.16.4 NATURAL GAS POCKETS**

In Indiana, naturally occurring gas pockets have been opened up several times by standard geotechnical drilling methods over the years. Due to the volatility of the trapped gas, which can escape at high pressures, immediate action must be taken to make the situation as safe as possible for all involved at the drill site as well as the public safety concerns.

Actions to be taken if a trapped natural gas pocket (not piped gas) is opened during drilling operations:

1. Immediately shutdown all equipment being used in order to prevent electrical sparks from igniting the gas and have all on-site workers move away from the equipment.

2. All traffic must be stopped and rerouted away from the scene. Local emergency personnel should be contacted about the situation.
3. Contact the Indiana Department of Natural Resources Division of Oil and Gas Assistant Director (office: 317-232-4055, directly: 317-232-6961) and IDNR should then contact their field personnel about the situation and send someone to the site to assist.
4. *In accordance with directions from the IDNR personnel on site*, observe the pressure and amount of gas being expelled and determine when the situation is safe enough to close up and abandon the hole.

### **3.17 BACKFILLING REQUIREMENTS**

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Boreholes should be backfilled by following INDOT's Aquifer Protection Guidelines. Groundwater contamination and other liability issues exist if a borehole is not backfilled properly. A borehole can act as a conduit for water or contaminants into an aquifer or between porous zones at different depths. Additionally, the area around a borehole may settle excessively and the resulting hole at the surface may become a safety hazard. Boreholes in environmentally sensitive locations, regardless of depth, may require special backfilling requirements. The Division of Geotechnical Engineering must be notified of environmentally sensitive locations. INDOT's Aquifer Protection Guidelines also provide instructions on how to backfill boreholes that contain specialized testing equipment, such as slope inclinometers, piezometers, and standpipes.