GEOTECHNICAL POLICIES AND PROCEDURES

CHAPTER 6

GEOTECHNICAL INVESTIGATION PROCEDURES

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1. PURPOSE

Due to the varying complexity of projects and subsurface conditions, it is difficult to establish a rigid format to be followed in conducting geotechnical investigations. However, there are fundamental required data that should be obtained and basic steps that should be followed for any project investigation. The collected field data and assessments are the basis for all subsequent engineering decisions and, as such, are of paramount importance to the design and success of a project. By outlining and describing these requirements and steps, it will be possible to standardize procedures and considerably reduce time and expense that would be required to return to the project site and obtain important information not obtained during the initial investigation. The following are fundamental required data that should be obtained during a geotechnical investigation:

- Identification and delineation of existing soil and rock strata
- Condition and performance of existing transportation structures
- Qualitative and quantitative information on the character and engineering properties of the soil and rock strata
- Groundwater levels and environmental concerns
- Slope stability condition, faults and other geologic hazards or constraints

The Manual for the NHI course on Subsurface Investigations (No. 132031, 2001) and the AASHTO Manual on Subsurface Investigations (1988) provide extensive information on conducting a geotechnical and subsurface investigation.

2. REVIEW OF PROJECT REQUIREMENTS

The first step in performing a geotechnical investigation is a thorough review of the project requirements. It is important that geotechnical investigations be carefully planned, and coordinated between those who will obtain the field data and the end-users of the information. The Geotechnical Engineer should thoroughly understand the following project details and limitations before planning and performing the geotechnical investigation:

- Project location and size
- Project type (realignment, improvement, bridge, embankment, rehabilitation, etc.)
- Project criteria (alignment, approximate structure locations, approximate structure loads, approximate bridge span lengths and pier locations, cut and fill area locations, etc.)
- Project constraints (ROW, environmental and biological assessments, permitting, etc.)
- Project design and construction schedules and budgets

Depending on the stage of project development, the Geotechnical Engineer should have access to typical section, plan and profile sheets, and cross sections with a template for the proposed roadway showing cuts and fills. This project specific data aids the Geotechnical Engineer in planning the investigation to meet the project requirements. One goal of properly planning a geotechnical investigation is to minimize exploration costs and the number of site visits needed to obtain vital design information. Prior to performing any fieldwork, the Geotechnical Engineer needs to initiate a request to obtain Entry Permits to the site through the Right of Way Division and be prepared to address any environmental concerns or limitations associated with the project. Following the identification of proposed exploration areas, utility locations and clearances need to be obtained.

3. OFFICE REVIEW OF AVAILABLE DATA

After gaining a thorough understanding of the project requirements, all relevant available information on the project site should be collected and reviewed. Available data may consist of reports, maps, journal articles, aerial photographs, previous as built Plans, or even personal communications with individuals with local knowledge. Review of this information can provide a basis for understanding the geology, topography, and geomorphology of the area. An initial understanding of the engineering properties of subsurface materials and groundwater characteristics can often be obtained from this available data, which can help in developing the investigation program.

3.1 Topographic Maps

These maps portray physical features, configuration and elevation of the ground surface, and surface water features. Interpretations of these maps can aid the Geotechnical Engineer in determining: changes in relief and slope angles, landform and drainage characteristics, identification of potential landslide terrain, accessibility for field equipment, and possible problem areas. These maps are prepared by the U.S. Geological Survey (USGS) and are readily available. Topographic maps are sometimes prepared on a larger scale by the Department during early planning phases of a project. In addition, a review of existing data can yield information on the availability of nearby benchmarks that could be used in the field as control points for locating exploration borings.

3.2 Aerial Photographs

Aerial photographs are available from the Department and other sources. They are valuable in planning the site reconnaissance and, depending on the age of the photographs, show manmade structures, excavations, or fills that affect accessibility and the planned depth of exploration. Historical photographs can also provide a better understanding of how the project site has been modified throughout the years.

3.3 Geological Maps and Reports

Considerable information on the geological conditions of an area can be obtained from geological maps and reports. These reports and maps show the location and relative position of the different geological strata and present information on the characteristics of these materials. This data can be used directly to evaluate the rock conditions to be expected and indirectly to estimate possible soil conditions, since the parent material is one of the factors controlling soil types. Geological maps and reports can be obtained from the USGS, Nevada Geological Survey, Nevada Bureau of Mines, university libraries, the Geotechnical Section, and other sources.

3.4 Soil Surveys

Soil surveys are compiled by the U.S. Department of Agriculture (Soil Conservation Service) usually in the form of county soils maps. These surveys can provide valuable data on surface soils including mineralogical composition, grain size distribution, and depth to rock, water table information, drainage characteristics, geologic origin, and presence of organic deposits.

3.5 Adjacent Projects

Data may be available on nearby projects from the Department, or from county or city governments. The Department may have soils data on file from State projects, as built drawings and/or pile driving records for existing structures. Existing boring information and well drilling logs, if available, can contain relevant information. This data can be useful in setting preliminary boring locations and depths and in predicting problem areas. Maintenance records for nearby roadways and structures can provide insight into subsurface conditions. For example, indications of differential settlement or slope stability problems can provide the Geotechnical Engineer with valuable information on the long-term characteristics of the site.

3.6 Rockfall Hazard Rating System

The Department's Rockfall Hazard Rating System (RHRS) database should be reviewed to identify rockfall concerns in or near a project site location. Information obtained from this database provides the Geotechnical Engineer quantitative data in this area of project development.

3.7 Hydrogeological Surveys and Well Logs

Hydrogeological surveys typically focus on the presence, depth, amount, and condition of groundwater. These resources can aid the Geotechnical Engineer by giving some indication about the presence and depth of groundwater in terms of its effect on construction conditions and its control over shear strength of soil and rock masses. The availability of water well logs produced by private drilling contractors that may be recorded by other State agencies should also be researched. In addition to groundwater information, such logs can serve as useful tools in providing general subsurface information.

3.8 Remote Sensing Data

Remote sensing data can effectively be used for large-scale regional interpretations of geologic structure, regional lineaments, drainage patterns, general soil and rock characteristics, and recognition of geologic hazards. Remote sensing methods, including such techniques as Landsat and Lidar, can be used to identify and evaluate topographic, bathymetric, and surface features. The U.S. Army Corps of Engineers Engineering Manual EM-1110-1-1804 and the AASHTO Manual on Subsurface Investigations (1988) provide a more detailed discussion on the types and limitations of remote sensing methods. Remote sensing techniques generally have limited value for site-specific studies; however, they can be very useful for a regional or large-scale setting. The Geotechnical Engineer needs to be familiar with these methods, as well as their limitations and capabilities to determine if they are applicable for their project.

4. FIELD RECONNAISSANCE

It is necessary for the Geotechnical Engineer to perform a field reconnaissance to develop an appreciation of the topographic, geologic and geotechnical concerns at the project site and become knowledgeable of access and working conditions. A reconnaissance should be performed only after an understanding of the project requirements has been reached, a review of the existing data has been completed, and applicable right-of-entry permit(s) have been obtained. The Geotechnical Engineer should perform the field reconnaissance with the final objective of being able to brief the project team on the key issues that will influence project design. Pertinent project information (project development documents) and other conceptual information should be obtained from the Project Designer before performing the site visit. As part of the reconnaissance, key site locations and conditions, and exploration equipment access routes should be photographed. The following factors should be defined by the field reconnaissance:

- Stratigraphy – Compare stratigraphy to information obtained from available data. Subsurface explorations and laboratory testing will ultimately define the soil and rock units.
- Key Outcrops – Delineate outcrops or exposures that warrant further investigation in terms of structural mapping.
- Existing Slopes – Assess the stability factors of major slope-forming geologic units. Natural slopes and any existing soil or rock slope failures should be evaluated and documented. Cut slope angles and orientations should be measured and their relative performance evaluated.
- Ground and Surficial Water – Estimate the general nature of surface water and groundwater regimes at the project site. Develop concepts for future investigations.
- Geologic Constraints – Identify geologic conditions that may tend to adversely affect project development plans (landslides, faults, flooding, erosion, etc.). Devise methods of investigating the degree of potential impact.
- Explorations – Based on the information and the kinds of samples that may be required, determine the type(s) of exploration that would best accomplish the project needs.
- Drilling Logistics – Define the type, approximate locations and depths of geotechnical borings. Determine approximate routes of access to each drilling location. Make note

of any feature that may affect the boring program, such as accessibility, structures, overhead utilities, evidence of buried utilities, or property restrictions. Evaluate potential water sources for use during drilling operations. Evaluate potential concerns that may need to be addressed while planning an exploration program (permits, overhead utilities, equipment security, private property, etc.). If possible, exploration locations should be located with a Field Crew Supervisor. If this is not possible, a Field Crew Supervisor should be consulted regarding the use of borehole location feasibility. The Underground Services Alert (1-800-227-2600) (USADIG) must be called a minimum of two working days (preferably four days) prior to conducting subsurface explorations. It is desirable to review the proposed boring locations following utility locations to determine if any borings need to be relocated to avoid buried utilities. The presence of utilities may need to be rechecked for the adjusted boring locations.

- Environmental Considerations – Identify potential impacts the exploration program and the project may have on: subsurface materials, landforms, and the surrounding area. Determine if project areas are governed by special regulations or have protected status.

5. FIELD MAPPING AND MEASUREMENTS OF ROCK DISCONTINUITIES

Field mapping should begin by observing road cuts, drainage courses, and bank exposures. A site plan or large-scale topographic map of the project area is essential for field mapping. The main objective of these observations is to confirm the general types of soil and rock present. Note any features that may assist in the engineering analysis, such as the angle and performance of existing slopes, or the stability of open excavations or trenches. The type and condition of vegetation may give an indication of ground and surface water regimes, as well as an indication of landslide or slope stability concerns.

In addition, structures should be inspected to ascertain their foundation performance and their susceptibility to damage from construction-related ground vibrations or settlement due to embankment placement.

For rock slopes, performance of slopes and the rockfall history are important indicators of how a new slope in the same material will perform. More detailed rock structural mapping entails observing and measuring lithologic contacts and the engineering characteristics and orientation of rock discontinuities that make up the rock mass. The measurements are typically made with a Brunton or Clar compass and consist of determining the strike and dip (dip and dip direction) of rock discontinuities such as faults, joints, foliation, shear and bedding planes, and contacts with other rock units. These measurements can be presented graphically on a spherical projection such as an equal area stereonet. A more detailed discussion on rock structural mapping is given in the Participant's Manual for the NHI course "Rock Slopes" (Module 5: No. 132035, 1998).

The AASHTO Manual on Subsurface Investigations (1988) describes the procedures for engineering geological mapping. It also provides suggestions for preparing geologic maps for different applications, such as Project Area Geologic Maps, ROW Geologic Maps, File

Geologic Maps, Site Geologic Maps, and other special mapping.

6. FIELD-DEVELOPED CROSS-SECTIONS

Field-developed cross-sections are useful to nearly all types of site-specific geotechnical investigations. Their use can be applied to excavation and placement of materials; foundations and slopes; specific development of groundwater and aggregate resources; and for the graphic portrayal and analysis of significant features related to slope stability, seismicity, drainage, or other characteristics. Although these cross-sections lack the precision of high order engineering surveys, preparing them provides an excellent opportunity to observe the project area and apply the scientific method in resolving surface and subsurface relationships and other field observations.

Standard cross-sections prepared by survey crews or taken from digital terrain models do not depict the interpreted geotechnical relationships and other features that may prove very important during the design process. Another advantage is that the sections are developed and plotted during the reconnaissance, so discrepancies can be identified and resolved immediately. This provides a high level of confidence when used later in the office.

The cross-section field gear typically includes a field notebook, cloth tape, hand clinometer, calculator, and Brunton compass. Laser range finders can simplify measurements, particularly for steep inaccessible slopes. Measurements include all slope breaks and other identifiable, geological features such as landslide cracks and groundwater features. The significance of each feature is described in the field notebook. Since slope breaks commonly occur as the strength characteristics of the subsurface material changes, many times the slope breaks represent contacts between different soil and/or rock units. Measurements of the contact orientation (strike, dip and surface trace) are normally denoted where appropriate in the field notebook.

The points comprising the cross-section should be plotted on graph paper as “x” and “y” coordinates while in the field. The coordinates can be readily calculated from the slope distance and angle between each point with the aid of a calculator. Include the interpretations of the surface and subsurface materials and relationships on the section along with relevant estimates of engineering parameters. The section should show the distribution of soil and rock units, estimated location/elevation(s) of surface and subsurface water, and original ground lines prior to any previous excavation, filling or slope movements. As these interpretations are developed, plan any explorations that may be needed to confirm the subsurface model that will be used in the analysis and design phase. For a reference of this field technique, refer to USDA, Forest Service Publication EM-7170-13, 1994, entitled “Slope Stability Reference Guide for National Forests in the United States”, Volume 1.

7. SUBSURFACE EXPLORATION METHODS

The information obtained from the steps discussed above is used to develop a subsurface exploration program. Field exploration can commence when right-of-entry permit and utility clearances have been issued. Many methods of field explorations exist. The subsections below contain brief descriptions of the most common methods.

7.1 Test Pits and Trenches

Test pits and trenches are the simplest methods of observing subsurface soils. They consist of excavations performed by hand, backhoe, or dozer. Hand excavations are often performed with posthole diggers or shovels. They offer the advantages of speed and ready access for sampling. They are severely hampered by limitations of depth; and they cannot be used in soft or loose soils, boulders or below the water table.

Upon completion, the excavated test pit should be backfilled with the excavated material or other suitable soil material. The backfilled material should be compacted to avoid excessive future settlements. Tampers or rolling equipment may be used ot facilitate compaction of the backfill. Excavations within existing roadways should be backfilled with granular material and compacted in lifts to restore subgrade support and the pavement should be properly patched. Any test pit or excavated area located near planned structure footings or pavement must be surveyed to determine the precise location of the excavation. This information must be presented in Construction Plans and Special Provisions to ensure the area will be re-excavated and properly compacted to the extent required. In the case of test pits excavated through existing pavements, the pavement should be properly patched. The backfilled material should be compacted to avoid excessive future settlements. Tampers or rolling equipment may be used to facilitate compaction of the backfill. Excavations within existing roadways should be backfilled with granular material and compacted in lifts to restore subgrade support.

Where pits are located in agricultural areas or other areas used to support plant growth, the backhoe operator should be instructed to keep the topsoil (or at least the finer upper-layer of the profile) and overburden separate from any gravel encountered in the pit. Upon completion of the pit, the operator should backfill in a sequence (generally with the coarsest material in the bottom of the pit) such that the backfilled pit area is reestablished to support vegetation.

7.2 Hand Auger Probes

Hand auger probes are manually operated. Solid or hollow stem augers can be used to quickly and cheaply observe shallow (less than 15 feet) subsurface conditions. They cause minor disturbance to the ground surface, but are difficult to advance in rocky or dense material.

7.3 Exploration Drilling Techniques

Borings are the most common method of exploration. They can be advanced using a number of methods. Discussions of drilling methods are described in the following manuals: 1) U.S. Army Corps of Engineers, Soil Sampling Engineering Manual, 2) AASHTO, Manual on Subsurface Explorations, and 3) FHWA, Subsurface Investigations, NHI Course No. 132031. The most common methods are discussed below:

7.3.1 Solid Flight Auger Borings

Auger borings are advanced into the ground by rotating the auger while simultaneously applying a downward force using either hydraulic or mechanical pressure. The auger is advanced to the desired depth and then withdrawn. Samples of cuttings can be removed from the auger; however, the depth of the sample can only be approximated. These samples are disturbed and should be used only for material identification. This method is generally used to establish shallow soil strata and water table elevations, or to advance to the desired stratum before Standard Penetration Testing (SPT) or undisturbed sampling is performed. However, it cannot be used effectively in soft or loose soils below the water table. In addition, this method has limited capabilities in dense, rocky material where it may encounter refusal. See ASTM D 1452 (AASHTO T 203).

7.3.2 Hollow-Stem Auger Borings

A hollow-stem auger consists of a continuous flight auger surrounding a hollow drill stem. A central “plug”, or “butterfly” bit, at the end of a drill rod is used to prevent soil from entering the hollow stem as the hole is advanced between samples. The hollow-stem auger is advanced in a manner similar to Solid Flight Auger; however, removal of the hollow stem auger is not necessary for sampling. The “plug”, or “butterfly” bit, is removed and samples are obtained through the hollow drill stem, which acts like a casing to hold the hole open. This increases usage of hollow-stem augers in soft and loose soil. Usually no drilling mud is required, which could otherwise interfere with accurate groundwater level readings. In addition, this method of drilling is extremely fast, cost effective, and requires little to no water. Below the water table, removal of the center “plug”, or “butterfly” bit, can disturb sand and affect the validity of the SPT. One option that can be considered, when this condition develops in leading to questionable SPT results, is to add water or drill mud to the inside of the stem to create a reverse head of water and prevent heaving. Water should also be added to the borehole while auguring clayey soils to help prevent “baking” of the material due to the heat generated during rapid advancement of the augers. This “baking” of clay soils can adversely affect the permeability of the subsurface material. Another disadvantage of this method is that refusal may prematurely be encountered in boulders or dense rocky soils. See ASTM D 6151 (AASHTO T 251).

7.3.3 Wash Borings

In this method, the boring is advanced by a combination of the chopping action of a light “fishtail” bit and the jetting action of water flowing through the bit. This method is used only when precise soil information is not required between sample intervals in loose, fine granular material. Generally, casing is required to stabilize the walls of the borehole. Large quantities of water are required for this method of drilling. Generally, there are better, more efficient methods available to drill a borehole.

7.3.4 Mud Rotary Drilling

This method consists of using a rotary drill with rotating thick-walled, hollow, drill rods usually attached to a tri-cone bit. Drilling mud is circulated from a mud tub, and then through the drilling rods as the drill rod is advanced. The drilling mud lifts the drilling cuttings out of the borehole while maintaining hole stability. The drill cuttings are screened and separated from the drilling mud, which is then recirculated. To collect a sample, the drill rods and bit are pulled out of the hole and are replaced with drill rods and the required sampling device. This method is fast, and provides excellent sampling and in situ testing data due to minimal disturbance to the soils at the bottom of the borehole prior to sampling. It is effective in all soil types except for very gravelly material with cobbles and boulders. No information can be reliably obtained about groundwater levels during the drilling operation, and the soil material between sampling intervals is difficult to observe from the drilling mud return.

7.3.5 Air Drilling

This type of drilling uses compressed air to remove cuttings from the borehole as the drill bit is advanced. Both rotary or percussion techniques can be utilized and either open hole (rotary reverse circulation) or underreamed casing advancement (ODEX) can be used in the drilling process. SPT samples can be obtained; however, the materials between samples are highly disturbed. This type of drilling is generally fast, but expensive, and is most useful when drilling deep holes in dense gravels and boulders where traditional Hollow Stem Auger and Mud Rotary techniques cannot drill or sample.

7.3.6 Percussion Drilling

In this method, the drill bit advances by power chopping with a limited amount of water in the borehole. Slurry must be periodically removed. The method is not recommended for general exploration because of the difficulty in determining stratum changes and in obtaining undisturbed samples. However, it is useful in penetrating materials not easily penetrated by other methods, such as those containing boulders.

7.3.7 Coring

A sampling barrel is advanced through rock by the application of downward pressure during rotation. Circulating water removes ground-up material from the hole, while also cooling the bit. The rate of advance is controlled to obtain the maximum possible core recovery. A continuous rock core sample is sometimes obtained from this drilling method. Core drilling is the most widely used method to explore subsurface rock formations. It is preferable to perform rock coring with as large a core barrel as possible in order to optimize core recovery and minimize core damage due to drilling action. An HQ-Size System is recommended. Refer to ASTM D 2113 (AASHTO T 225). A list of core barrel sizes is shown in Figure 5.1.

7.4 Soundings

A sounding is a method of exploration in which either static or dynamic force is used to cause a rod tipped with a testing device to penetrate soils. This method can be useful to determine the depth to harder strata or rock from the resistance to penetration. Cone penetrometers are the most common equipment that uses the sounding method. The cone penetrometer is utilized to obtain a measure of the soil resistance for the entire depth of the penetration. It is generally used for fine-grained cohesionless and cohesive soils. The disadvantage of this investigation method is that no samples are usually obtained. The resistance to penetration can be measured and correlated to various soil properties.

7.5 Geophysical Methods

Geophysical exploration methods can sometimes provide general subsurface profile information, such as the depth to bedrock, depth to groundwater, and the extent of granular/rock areas, peat deposits, or subsurface anomalies. Geophysical methods of exploration can provide a rapid and economical means of supplementing subsurface borings and test pits. These exploration techniques are most useful for extending the interpretation of subsurface conditions beyond what is determined from small diameter borings. A limitation of these techniques is that no samples are recovered. It must be emphasized that geophysical exploration methods might not be successful in all situations and should be carefully evaluated to determine whether any are appropriate for the specific project requirements and site conditions.

The reliability of geophysical exploration results can be limited by several factors, including the presence of groundwater, nonhomogeneity of soil stratum thickness, gradation or density, and the range of wave velocities within a particular stratum. Subsurface strata that have similar physical properties can be difficult to distinguish with geophysical exploration methods. Because of these limitations, for most design applications, geophysics should be considered a secondary exploration method to drilling, and should generally be accompanied by conventional borings. An experienced professional should interpret the field data. For additional information, see ASTM D 6429 and U.S. Army Corps of Engineers, Engineering Manual EM-1110-1-1802.

Geophysical exploration techniques can be grouped into two categories: 1) methods conducted from the ground surface, and 2) methods conducted in or between boreholes. Passive methods include the use of gravimetric, electric, magnetic, thermometric, and nuclear techniques. Active methods include the use of seismic, acoustic, electric, electromagnetic, and nuclear techniques. Geophysical exploration methods commonly used for transportation engineering purposes include:

7.5.1 Seismic Refraction and Reflection

These methods rely on the fact that shock waves typically travel at different velocities through different materials. The times required for an induced shock wave to travel from the energy source to vibration detectors (geophones) after being refracted or reflected by the various subsurface materials are measured. The measured seismic velocities are used to interpret certain material properties and the thickness of the units that comprise the subsurface profile. Seismic refraction is limited to profiles in which velocities increase with depth. Seismic investigations can be performed from the surface or from various depths within borings. For cross-hole seismic techniques, see ASTM D 4428. For the seismic refraction method, see ASTM D 5777.

7.5.2 Electrical Resistivity

This method is based on the differences in electrical conductivity between subsurface strata. An electric current is passed through the ground between electrodes and the resistivity of the subsurface materials is measured and correlated to material types. Several electrode arrangements have been developed, with the Wenner (four equally spaced electrodes) being the most commonly used in the United States, see ASTM D 6431.

7.6 Ground Penetrating Radar (GPR)

The velocity of electromagnetic radiation is dependent upon the material through which it is traveling. GPR uses this principle to analyze the reflections of radar signals transmitted into the ground by a low frequency antenna. Signals are continuously transmitted and received as the antenna is towed across the area of interest. The interpreted results yield a profile of the subsurface material interfaces. The depth of signal penetration is limited in finer grained soils, see ASTM D 6432.

7.7 Nondestructive Testing - Evaluation of Existing Structures

Occasionally, the Geotechnical Engineer is involved in evaluating an existing structure foundation for new loading conditions. This typically occurs as part of a seismic or scours vulnerability assessment. An important part of the assessment is the type, depth, and condition of the structure foundation. The sources for this information may be as-built drawings, construction records, and Construction Plans for the structure. If no information is available, the Geotechnical Engineer may need to use Nondestructive Testing techniques (NDT) to characterize the foundation elements.

All NDT methods are classified in two general categories, surface methods and downhole methods. Surface methods are generally less expensive, but are limited by foundation geometry and subsurface conditions. Surface methods typically cannot yield any information below the point where there is a sharp change in the impedance of a foundation element. For instance, if NDT methods were used on a bridge column, the test would not tell the Geotechnical Engineer anything about the pile or shaft elements below the pile cap. Downhole methods provide more definitive information regarding foundation geometry, but the costs are generally higher due to drilling requirements.

8. SOIL SAMPLING

Common methods of soil sampling during field explorations include those listed below. All samples should be properly preserved and carefully transported to the laboratory to maintain sample integrity, see ASTM D 4220.

8.1 Disturbed Sampling

Disturbed sampling refers to methods of retrieving samples that incidentally cause the material to be remolded or at least partially altered. It should be understood that disturbed samples are generally not suitable for specialized tests requiring undisturbed soil specimens. However, disturbed samples have value for many geotechnical tests and are usually easier to obtain.

8.1.1 Bag (Bulk) Samples

Bulk samples can provide a large amount of representative soil for compaction and subgrade testing. Bag samples are usually obtained from test pits. In some cases, bulk samples can be obtained during auger drilling, collecting materials as they come to the surface in the flight of the auger. The auger method is less desirable because the depths of the sample cannot be accurately defined and some mixing of the soil occurs. A preferred approach when using an auger is to drill a shallow hole, then to remove the auger and collect a sample from the sidewall of the hole (after first clearing the smear zone). The quantity of a bulk sample depends on the type of testing to be performed, but can range up to 50 pounds or more. Testing performed on these samples could include classification, moisture content, compaction maximum density, R-value and pH and resistivity (corrosivity). A portion of each sample should be placed in a sealed container in order to accurately determine the natural moisture content. The size of bulk samples obtained for testing rock quality for aggregate purposes can be significant in order to process and select representative materials.

8.1.2 Cuttings Samples

In limited cases and as a last resort, samples of cuttings can be obtained from drilling operations to augment materials collected in sampling tubes. Cuttings samples can be used to try to identify major changes in lithology during drilling operations, particularly when normal tube sampling methods do not recover sufficient materials for this purpose. Examples of cuttings samples include material ejected from air rotary drilling, material that is pushed to the surface on the flights of an auger, and material that is screened from the drill mud return (mud rotary method). Cuttings samples are highly disturbed, contaminated, and sometimes altered (in size), and therefore caution and judgment must be exercised when selecting, evaluating and classifying such samples. The depths from which cutting samples are obtained can only be roughly estimated, but these estimates can be aided by noting the depths where changes in drilling action occur.

8.1.3 Split Spoon Sampler

Split spoon samplers, also known as split barrel samplers, are used in conjunction with the Standard Penetration Test. The sampler is a 2-inch (O.D.) split spoon, which is driven into the soil with a 140-pound hammer dropped 30 inches. The split spoon sampler is withdrawn and the sample is removed after the sampler has been driven 18 inches. The sum of the number of hammer blows, required to drive the sampler the second and third six-inch increments is the standard penetration value referred to as the N-value (blows per foot). N-values can be correlated to a number of different design parameters including relative density, angle of withdrawal, friction and shear strength. The sample should be immediately examined, logged and placed in sample jar or bag for storage. These samples are disturbed and are not suitable for strength or consolidation testing. They are suitable for moisture content, gradation, and Atterberg limits tests, and are valuable for visual identification, see ASTM D 1586.

8.1.4 California Modified Sampler

California Modified Sampler (CMS) or Dames and Moore Sampler are two names for the same sampler. The split barrel samples are similar to split spoon samples used with the SPT test. The CMS is a 3-inch (O.D.) split barrel, which is driven into the soil typically with a 300-pound hammer, but the Department currently uses a 140-pound hammer, dropped 30 inches. The CMS is threaded at both ends for accepting inner rings that are 2.36-inches I.D. by .98-inches high. These ring samples can be used for various soil property tests; however, they are considered disturbed samples. Generally, this sampler is used to facilitate sample recovery in coarser-grained material due to its larger diameter as compared to the split spoon (SPT) sampler. N-values obtained from the penetration of this sampler are sometimes correlated to SPT values. However, these correlations are not standardized, and engineering judgment should be applied when they are used.

The CMS can be configured many different ways. With various barrel bodies, the sampler typically ranges from 12 to 30 inches in length. Several different types of shoes (sampler tips) allow for additional accessories to be used with the sampler. Among these are brass liners, soil retainers, and tube extensions. These accessories enhance the sampler's capabilities to collect samples. The CMS can be used with a tube extension in fine-grained soils, typically clays or silts, to obtain relatively undisturbed samples. It acts similar to a Shelby Tube sampler. When the tube extension is used, the sampler is pushed into the ground with a smooth and continuous thrust.

8.2 Undisturbed Block Sampling

Samples can be carefully carved from test pits for special testing in the laboratory. The advantage of block samples is that the test pit offers a broad area to detect critical materials and ability to obtain the exact amount of the desired material. The size of the sample should be large enough to perform planned laboratory testing. The block samples should be carefully handled and should be protected with a moisture-proof barrier (i.e., plastic wrap and wax) and placed within a sturdy and stable container so the sample is fully supported/constrained.

For block samples, the dimensions of the sample are controlled by the thickness of specimen of interest and by the size of the box used to hold the sample. A column of the soil is carefully exposed so that, when the sample box is centered over the column, a one-inch open space is left on all sides of the sample and a half-inch space is left at the top. The empty areas are then filled with microcrystalline wax. After the wax congeals, the top of the box is attached and the sample is carefully detached from the underlying ground with a spade. The sample is inverted and a half-inch of material is removed. This area is filled with wax. After it congeals, the bottom of the box is attached and the sample is ready for transport to the laboratory.

8.3 Undisturbed Sampling Using Thin Wall Samplers

Undisturbed samples are required for certain tests such as peak shear, consolidation, swell potential, permeability, and density tests. There are several methods available for obtaining undisturbed samples, and would depend on the investigation equipment being used and the state of the soils in situ. Care of the samples is also critical to maintaining undisturbed conditions between drilling, transportation, storage and testing.

8.3.1 Shelby Tube Sampler

A Shelby Tube is a thin walled steel tube, usually 3 inches (O.D.) by 30 inches long. The beveled cutting edge of the Shelby tube is slightly smaller in diameter than the inside of the tube, which allows the sample to slide easily in the tube with little disturbance. The thin wall sampler is suitable for sampling all cohesive soils. The tube is pushed 24” with a smooth, continuous thrust. Difficulty may be encountered in sampling very soft and wet soils that tend to drop out of the sampler. Damage to the sampling tube (resulting in a poor sample) sometimes occurs when sampling hard, cemented, or gravelly soils. Good samples must have sufficient cohesion to remain in the tube during withdrawal. Cohesionless soils will likely need improved sampling methods, as described below. If sample recovery becomes difficult, i.e., the sample stays in the ground, the tube should be left in place for roughly 10 to 15 minutes. During this waiting period, the sample will swell slightly to fill the sampler, increasing the likelihood of retaining the sample when the tube is retracted. This produces a relatively undisturbed sample. Care should be taken to not over push the sample to avoid disturbance. The ends of the Shelby Tube should be properly sealed immediately upon withdrawal. Refer to ASTM D 1587 (AASHTO T 207). The sample is suitable for unit weight, triaxial, direct shear, simple shear, and consolidation tests.

8.3.2 Stationary Piston Sampler

This sampler has the same standard dimensions as the Shelby Tube described above. A piston is positioned at the bottom of the thin wall tube while the sampler is lowered to the bottom of the hole, thus preventing disturbed materials from entering the tube. The piston is locked in place on top of the soil to be sampled. A sample is obtained by pressing the tube into the soil with a continuous, steady thrust. The Stationary Piston is held fixed on top of the soil while the sampling tube is advanced. This creates suction while the sampling tube is retrieved, thus aiding in retention of the sample. This sampler is suitable for soft to firm clays and silts. Samples generally have a better recovery ratio than those obtained by use of the Shelby Tube. Care should be taken to not overdrive the sampler to avoid disturbance.

8.3.3 Floating Piston Sampler

This sampler is similar to the stationary piston sampler, except that the piston is not fixed in position but is free to ride on the top of the sample. The soils being sampled must have adequate strength to cause the piston to remain at a fixed depth as the sampling tube is pushed downward. If the soil is too weak, the piston will tend to move downward with the tube and a sample will not be obtained. This method should therefore be limited to stiff or hard cohesive materials.

8.3.4 Retractable Piston Sampler

This sampler is similar to the stationary piston sampler. However, after lowering the sampler into position, the piston is retracted and locked in place at the top of the sampling tube. A sample is then obtained by pushing the entire assembly downward. This sampler is used for loose or soft soils.

8.3.5 Hydraulic (Osterberg) Piston Sampler

This sampler is especially suitable for sampling soft to very soft clays and silts, and is sometimes effective in obtaining samples of cohesionless, silty sands and sands. In this sampler, a movable piston is attached to the top of a thin wall tube. Sampling is accomplished as hydraulic pressure pushes an inner sampler head and attached sample tube until it contacts a stationary piston positioned at the top of the soil sample. The distance over which the sampler is pushed is fixed. It cannot be overpushed.

8.4 Partially Disturbed Sampling

Partially disturbed sampling refers to methods of retrieving samples that incidentally cause the material to be partially altered. Hard soil conditions might make undisturbed sampling impossible, and therefore several methods were developed to obtain specimens of better quality. It should be understood that partially disturbed samples do not represent in situ conditions and generally do not provide reliable results for specialized tests such as peak shear, consolidation, swell potential, and permeability.

8.4.1 Denison Sampler

This sampler is a large diameter, double tube core barrel, which is effective in obtaining 5-7/8-inch diameter samples of hard cohesive soils, soft rock, cemented soils, and soils containing gravel that cannot be obtained with push-type samplers. This sampler consists of a rotating outer barrel with cutting teeth on the bottom and an inner barrel with a smooth cutting shoe. The sample is captured in a very thin inner liner, which facilitates retrieval and handling. Core catchers should not be used unless absolutely necessary to retain the soil sample. Care should be taken not to overdrive the sample to avoid disturbance.

8.4.2 Pitcher Sampler

This sampler is a double tube core barrel and is effective for the same soils as the

Denison sampler. The primary advantage the Pitcher sampler has over the Denison sampler is that the Pitcher sampler automatically adjusts the amount by which the inner barrels lead the cutting bit as the hardness of the soil varies. The Pitcher sampler can also accept a standard thin wall sample tube in lieu of the inner barrel/liner.

8.4.3 Sprague & Henwood Sampler

This is a triple tube sampler designed for sampling overburden materials, and is an improvement over the Denison and Pitcher samplers.

9. ROCK SAMPLING

Rock samples can be obtained from outcrops, test pits, or rock cores using drilling operations. Samples obtained from outcrops or test pits are termed “grab samples”. Typically, the sample sizes should be small enough to carry, but large enough to be tested in a point load device or utilized as hand specimens. These samples should be labeled, and the location where they were obtained should be identified on a site map.

Rock cores are obtained using core barrels equipped with diamond or tungsten carbide tipped bits. There are three basic types of core barrels; single tube, double tube, and triple tube. Use of double and triple tube core barrel systems are preferred since single tube core barrels generally provide poor recovery rates, see below. To protect the integrity of the core from damage (minimize extraneous core breaks), a hydraulic ram should be used to extrude the core from the barrel. See ASTM D 2113 (AASHTO T 225). Refer to ASTM D 5079 for practices of preserving and transporting rock core samples.

9.1 Double Tube Core Barrel

The double tube core barrel consists of an inner core barrel tube and an outer tube that serves as the drill rod. The cutting end of the core barrel is equipped with a diamond or tungsten carbide drill bit. As coring progresses, fluid is introduced downward between the inner and outer tubes to cool the bit and to wash ground-up material to the surface. The inner tube protects the core from the highly erosive action of the drilling fluid. In a rigid type core barrel, both the inner and outer tubes rotate. In a swivel type, the inner tube remains stationary while the outer tube rotates. Several series of swivel type core barrels are available. The size of core that can be recovered is governed by the size of the drill bit. For standard applications, these vary from 1.062-inch up to 3.270-inch O.D. Larger diameters generally obtain better core recovery in softer, highly erodible or highly fractured materials. The minimum diameter core obtained should be no less than A-size (1.062- to 1.185-inch O.D.). As a rule, it is recommended that a core size of H (2.406- to 3.000-inch O.D) be routinely used. Commonly used rock core sizes are included in Figure 5-1.

9.2 Triple Tube Core Barrel

Triple tube core barrel systems are similar to the double tube system, but include an additional inner liner. Two types of inner liners are used to retain the core, a clear plastic solid tube or a thin metal split tube. This barrel best preserves recovered fractured and poor quality rock cores in their in situ state.

9.3 Oriented Core

In some rock slope applications, it is important to understand the precise orientation of rock discontinuities for the design. Orienting recovered rock core so it can be properly mapped and evaluated, as though it were still in place, requires special core barrels. In the past, core barrels were weighted on one side and used in an inclined boring. The heavier side of the barrel generally stayed on the down side of the hole allowing the core to be properly oriented when removed. Other techniques, such as using clay to make an impression of core run ends, have also been used for this purpose. Currently, specialized core barrels that scribe a reference mark (line) on the side of the core as it is drilled are more routinely used. Special recording devices within the core barrel relate known azimuth orientations to the reference mark so that when the core is subsequently removed from the core barrel, it can be oriented to the exact position it existed in situ. These specialized core barrels are relatively expensive, and require additional training for proper use and interpreting the results.

9.4 Borehole Television Camera

Boreholes can be accessed to visually inspect the condition of the sidewalls and distinguish gross changes in lithology by using specialized television cameras. These down-hole cameras can also be used to identify fracture zones, shear zones, and joint patterns in rock core holes. Refer to AASHTO Manual on Subsurface Investigations, Section 6.12.

10. EXPLORATION DIFFICULTIES

As discussed in the AASHTO Manual on Subsurface Investigations Section 7.8, limitations and difficulties may be encountered during explorations, which are common to all exploratory techniques. They are usually a result of site-specific geologic conditions and/or a function of the improper equipment or technique being utilized. Several of these limitations and difficulties are described below.

10.1 Improper Drilling Techniques

All Geotechnical Engineers and field supervisors need to be aware of potential drilling problems and to avoid them in order to properly obtain field information and samples. See AASHTO Manual on Subsurface Investigations, Section 7.12 and FHWA, Subsurface Investigations, NHI Course No. 132031, Section 3.5. The following is a partial listing of common errors:

- Not properly cleaning slough and cuttings from the bottom of the borehole. The driller should not be allowed to sample through slough. Preferably the driller should reenter the boring and remove the slough before proceeding.
- Jetting should not be used to advance a split barrel sampler to the bottom of the boring.
- Poor sample recovery due to improper use of sampling equipment or procedures.

- When sampling soft or noncohesive soils with thin wall samplers (i.e., Shelby Tube), it may not be possible to recover an undisturbed sample because the sample will not stay in the barrel. The driller should be clearly instructed not to force recovery by overdriving the sampling barrel to obtain a sample.
- Improper sample types or insufficient quantity of samples. The driller should be given clear instructions regarding the sample frequency and types of samples required. The field supervisor/driller must keep track of the depth of the borings and the materials being recovered at all stages of the boring to confirm the sampling interval and obtain appropriate samples of changing soil and/or rock formations.
- Improper hole stabilization. Rotary wash borings and hollow-stem auger borings below the groundwater level require a head of fluid to be maintained within the drill stem at all times to prevent materials from surging up into the holes, casings, or augers. When the drill rods are withdrawn, or as the hollow stem auger is advanced, this fluid level will tend to drop, and must be maintained by the addition of more drilling fluid.
- Sampler rods lowered into the boring with pipe wrenches, rather than hoisting plug. The rods may be inclined and the sampler can hit the boring walls, filling the sampler with debris.
- Improper procedures for performing Standard Penetration Tests. The field supervisor and driller must assure that the proper weight and hammer drop are being used.
- Catheads cannot be used on any Department projects. All hammers to be used on Department projects must be automatic, and calibrated within the last two years using a pile driving analyzer.

10.2 Sample Recovery

Occasionally, sampling is attempted and little or no material is recovered. In cases where a split barrel or some other type of sampler is used to recover a disturbed sample, it is appropriate to make a second attempt to recover the material immediately following the first failed attempt. In such instances, the sampling device may be modified to include a retainer basket, a hinged trap valve, or other measures to help retain the sample.

In cases where an undisturbed sample is desired, the Geotechnical Engineer should direct the driller to drill to the bottom of the attempted (disturbed) sampling interval and repeat the sampling attempt. The sampling method should be reviewed, and the sampling equipment should be checked to understand why no sample was recovered (such as a plugged ball valve). It may be appropriate to change the sampling method and/or the sampling equipment, such as waiting a longer period of time before extracting the sampler, or extracting the sampler more slowly and with greater care, etc. If recovering a sample at a specific depth is necessary, a second boring may be advanced to obtain a sample at the prescribed depth using the improved technique.

Generally, sample recovery less than 10% is considered inadequate for representative sampling. However, this criteria may be waived for the specific situation (i.e., in thick, uniform deposits).

Various sampling devices equipped with check and pressure release valves, sample retaining springs, baskets, and lifters should be used. Occasionally, sample recovery may be enhanced by modifying the equipment or the drilling techniques.

10.3 Sample Disturbance

There is no way to obtain a truly “undisturbed” sample using available soil sampling techniques. Block sampling continues to be the most reliable method for minimizing sample disturbance. However, because gaining access to the zone to be sampled can be limited by the depth of overlying material and because the sampling process is fairly rigorous and time consuming, most samples are obtained via drilling.

The selection of the correct sampling tool, drilling technique, and borehole stabilization method should be based on the soil type being sampled and the subsurface conditions. The incorrect preservation and shipment of samples may further disturb the specimens to the point where they are no longer usable.

10.4 Obstructions

The termination of an exploration above the required design depth due to boulders, fill material, excessively dense materials, and other obstructions may occur during any investigation. When this occurs, it usually implies that the correct exploration method might not have been selected for the anticipated subsurface conditions. Specialized tools and equipment are available to enhance the capacity of conventional drilling equipment. In some cases when obstacles are anticipated, a solution is to redrill the boring a few feet away.

10.5 Problematic Geologic Conditions

More thought and care should be given in selecting proper sampling equipment and sampling techniques when conducting subsurface exploration in problematic geologic conditions. Following is a list of some of problematic geologic conditions:

- Organic Soils
- Metastable Soils (loess, alluvial deposits & mudflows)
- Expansive Soils or Rocks
- Sensitive Clays
- Hydrocollapsible Soils
- Moving Ground (slides)
- Meander Loops & Cutoffs
- Abandoned Mined Areas
- Normally Consolidated Clays
- Caliche
- Loose, Granular Soils

- Noxious or Explosive Gases
- Artificial Fill
- Weathered Shale Rocks
- Wet or Saturated Soils

10.6 Groundwater Conditions

Groundwater can affect the stability of boreholes, especially in cohesionless soils (sands and silts). Water flowing into the hole could cause caving and quick (liquefying) conditions, which would artificially reduce the SPT blow counts being measured, as well as make drilling and sampling progress difficult. Drill fluids are typically used to stabilize the borehole in such situations.

Where precise water level data is important, the affects of drilling water additives (bentonite) on the permeability of certain soils should be evaluated. In soils with lower permeability and flow rates, such as in silt or silty sand, the use of bentonite mud can dramatically limit the movement of water by coating the walls of the boring. A bentonite coating can reduce the likelihood that piezometer readings will represent true ground water levels or that the water levels in the boring will respond accurately to natural groundwater changes. In these situations, alternative drilling techniques, such as using a casing advancer or hollow stem auger, should be considered to produce a stable borehole without relying on additives that can affect permeability. Following drilling, especially whenever low permeability conditions exist, the Geotechnical Engineer should wait an adequate period of time for the water level to reach equilibrium within the borehole before initiating groundwater measurements.

It is preferred that a groundwater measurement be taken 24 hours after completing the boring to allow the water level to reach equilibrium. In fine-grained soils, depending on the permeability, this period may not be adequate. The installation of permanent or temporary observation wells, which provide access for measuring the groundwater table over a longer period, can be used in this case. Observation wells are generally an inexpensive safeguard against erroneous data regarding the presence and behavior of the groundwater conditions.

10.7 Contaminated Sites

When an investigation is to be performed, acquisition records for newly obtained right-of- way indicate the most recent land use for the area. On rehabilitation projects, where the only planned activities are shown on the existing right-of-way, the information available may vary from very complete to none. The Geotechnical Section does not perform HazMat explorations, testing, or evaluations. If contaminants are suspected, the Department may hire a Consultant with expertise in this field.

There are many problems and issues inherent in sampling and handling contaminated soils. However, it is necessary for all involved in geotechnical investigations to be aware of the salient points of these procedures. The U.S. Environmental Protection Agency (EPA) document number 625/12-91/002 titled “Description and Sampling of Contaminated Soils – A field Pocket Guide” contains guidelines, background information, and a list of useful references on the topic.

During an investigation, if unexpected contaminants are encountered, the Field Crew staff should immediately cease explorations and inform the Geotechnical Engineer. Initial actions may require demobilization from the site. Some signs of possible contamination are:

- Prior land use (e.g., old fill, landfills, gas stations, etc.).
- Stained soil or rock.
- Apparent unnatural lack of vegetation or presence of dead vegetation and trees in the local site context. While in some places this could indicate contamination, in others it is just normal desert conditions.
- Odors. Highly organic soils often could have a rotten egg odor that should not be construed as evidence of contamination. However, this odor may also be indicative of highly toxic hydrogen sulfide. Field Crew staff should be instructed as such.
- Presence of liquids other than groundwater.
- Marks of prior ground fires (at landfill sites). Established landfills emit methane gas, which is colorless and odorless, and in high concentrations in the presence of sparks or fire, explode.
- Presence of visible elemental metals (i.e., mercury).
- Low (<2.5) or High (>12.5) pH.

11. INSTRUMENTATION

Geotechnical instrumentation may be required, depending on the scope of the project, the design elements, and the site conditions. Selecting and installing the proper instruments correctly are important. A discussion of installation procedures for selected instruments is provided in Appendix A of the AASHTO Manual on Subsurface Investigation, 1988. An in-depth discussion on the installation of Inclinometer Casings is provided in Section 4.1.5 of Chapter 11 of the TRB Special Report 247, Landslides: Investigation and Mitigation. Such summaries are not intended to be a strict guideline, nor are they all inclusive of the variety of methods and procedures that may be used for the installation of instruments. The installation techniques may need to be customized to address particular subsurface issues.

12. BOREHOLE SEALING/BACKFILLING

All borings should be properly backfilled at the completion of the field exploration. This is typically required for safety and to prevent contamination/commingling of groundwater. Boring closure is particularly important for tunnel projects, since an open borehole exposed during tunneling may lead to uncontrolled inflow of water or escape of compressed air.

All boreholes are required to be grouted on the Department projects unless directed by the Principal Geotechnical Engineer. Holes in pavements and slabs should be filled with quick setting concrete, or with asphalt concrete, as appropriate. Backfilling of boreholes is generally accomplished using a grout mixture. The grout mixture is normally pumped through drill rods or other pipes inserted into the borehole. In boreholes filled with water or other drilling fluids, the tremied grout will displace the drill fluid. Provisions should be made to collect and dispose of all displaced drill fluid and waste grout. National Cooperative Highway Research Program Report No. 378 (1995) titled "Recommended Guidelines for Sealing Geotechnical Holes" contains extensive information on sealing and grouting.

13. FIELD EXPLORATION LOGS

A clear and complete record of field exploration activities and findings is essential. This should include the location of the boring, relative to the nearest Department benchmark. A station and offset from the benchmark as well as a top of the boring elevation is required.

14. PHOTOGRAPHIC RECORD

Sites should be photographed to better describe the existing surface and surrounding condition of the project area. Photographing more details of the features of the site would better document the existing condition of the site. These photos should be included in the Geotechnical Report and the project file.

Rock cores, and certain types of drive samples, are usually the only physical sample evidence of the subsurface profile that remain available for a site. In order to maintain the integrity of this record, it is useful to photograph the samples before parts are removed for testing purposes, or drying, or other disturbance occurs. Photographs assist to preserve the sampling record in the event that vandalism, negligence, or natural calamity causes loss or destruction of the physical sample. It also may be desirable to photograph specific sampling techniques and equipment for future reference. Care should be given to optimize the size of the core within the photograph in order to show as much detail as possible. Color photographs are recommended. For more details, refer to AASHTO Manual on Subsurface Investigations, Section 7.10.

15. SAMPLE PRESERVATION AND SHIPPING

Samples of soil and rock are obtained for classification and subsequent testing to determine their various engineering properties. Rock and soil samples represent essential physical information concerning the subject site. In general, these samples can be expensive to obtain. Samples must be preserved, stored, and shipped under conditions that minimize chances of disturbance or loss. More details are provided in AASHTO Manual on Subsurface Investigations, Section 7.9.

All soil samples and rock cores must be clearly, accurately, and permanently labeled to show all pertinent information which may be necessary in identifying the soil samples or rock cores, and in determining the character of the subsurface condition.

The preserving, protecting and transporting of samples may be accomplished using the guidelines described as follows ; but, any method that satisfactorily protects the sample from such things as shock, detrimental temperature changes (such as freezing), and moisture loss can be used.

- All samples should be collected from the borehole sampling sites on a daily basis and transported to the field project office or a suitable alternate location.
- Rock core and thin wall tube soil samples should never be transported away from the field site in other than specially constructed wood, metal, plastic, or fiberglass shipping containers specially designed to protect them from shock and vibration.
- Samples should never be left unattended in vehicles. Any undisturbed sample which is permitted to freeze, even partially, should be replaced.
- Samples intended for laboratory testing should not be held at the site in excess of one week.
- All sample containers should be identified as to borehole, depth interval, box number of total sequence, and project number.

16. GUIDELINES FOR INSPECTIONS OF SUBSURFACE EXPLORATIONS

The following guidelines are summarized from the Subsurface Investigation Manual (NHI-01-031) and AASHTO Manual on Subsurface Investigations (Section 7.11):

- Thoroughly comprehend the purpose of the fieldwork in order to properly characterize the site for the intended engineering applications.
- Be thoroughly familiar with the scope of the exploration program. Maintain a copy of the boring location plan.
- Be familiar with site, access conditions, and any restrictions.
- Review existing subsurface and geologic information before leaving the office.
- Constantly review the field data obtained as it relates to the purpose of the investigation.
- The field person should maintain daily contact with the Geotechnical Engineer regarding work progress, conditions encountered, problems, etc. Geotechnical Engineers log the boreholes for projects conducted in-house by the Department.
- Fill out forms regularly. Obtain a sufficient supply of boring and test pit logs and any other necessary forms to cover the expected explorations.
- Closely observe the driller’s work at all times, paying particular attention to:
  - Current depth (measure length of rods and samplers)
  - Drilling and sampling procedures
  - Any irregularities, loss of water, drop of rods, etc.
  - SPT counts
  - Depth to groundwater and degree of sample moisture
- Do not hesitate to question the driller, or to provide direction to ensure proper procedures are being followed.

- Classify soil and rock samples. Place soil samples in proper containers and label them. Make sure rock cores are properly boxed, photographed, stored, and protected. In handling all samples, the Geotechnical Engineer should follow the appropriate ASTM Standards. See ASTM D 4220-95, Standard Practices for Preserving and Transporting Soil Samples.
- Verify that undisturbed samples are properly taken, handled, sealed, labeled, and transported.
- Bring necessary tools to job.
- Do not hesitate to stop work and call the Principal Geotechnical Engineer if in doubt, or if problems are encountered.
- Remember field data are the basis of all subsequent engineering decisions, and as such, are of paramount importance.

The Geotechnical Engineer has the responsibility of notifying the Field Crew Supervisor when drill holes no longer need to be kept open (usually when final water table depths have been measured) and can be sealed/backfilled. The Geotechnical Engineer needs to follow up to verify that holes have been sealed/backfilled. If the holes are not sealed/backfilled within an appropriate time, the Geotechnical Engineer needs to notify the Principal Geotechnical Engineer.

17. EQUIPMENT FOR FIELD EXPLORATIONS

The following list is from the Manual "FHWA, Subsurface Investigations, NHI Course No. 132031. Geotechnical Engineers need to determine which of the listed items are applicable for each project.

Paperwork/Forms	Site Plan Technical specifications Field Instructions Sheet(s) Daily field memorandum forms Blank boring log forms Forms for special tests (vane shear, permeability tests, etc.) Blank sample labels or white tape Copies of required permits Field book (moisture proof) Health and Safety plan Field Manuals Subcontractor expense forms

Sampling Equipment	Samplers and blank tubes, etc. Knife (to trim samples) Folding rule 100-foot tape with an attachable weight so it can also be used for water level measurements Hand level Rags Proper containers and core boxes Five-gallon bucket Wire brush
Safety/Personal Equipment	Hard hat Safety boots Safety glasses Rubber boots (in some instances) Rain gear (in some instances) Work gloves
Miscellaneous Equipment	Clipboard Pencils, felt markers, grease pencils Scale/straight edge Watch Calculator Camera Compass Wash bottle or test tube Pocket Penetrometer and/or Torvane Communication equipment (two-way radio, cellular phone) Small white board and dry erase markers to make photo-labels

18. SAFETY GUIDELINES

All field personnel, including geologists, Geotechnical Engineers , technicians, and Field Crew staff , should be familiar with the general health and safety procedures, as well as any additional requirements of the project or governing agency.

Typical safety guidelines for drilling into soil and rock are presented in the Manual "FHWA, Subsurface Investigations, NHI Course No.132031, Appendix A. Minimum protective gear for all personnel should include hardhat, safety boots, eye protection, and gloves.

19. SPECIFICATIONS AND STANDARDS

SUBJECT	ASTM	AASHTO
Site Characterization for Engineering, Design, and Construction Purposes	D 420	T 86
Soil Investigation and Sampling by Auger Borings	D 1452	T 203
Penetration Test and Split Barrel Sampling of Soils	D 1586	T 206
Thin Walled Tube Geotechnical Sampling of Soils	D 1587	T 207
Diamond Core Drilling for Site Investigation	D 2113	T 225
Preserving and Transporting Soil Samples	D 4220	-
Cross-hole Seismic Testing	D 4428	-
Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)	D 4750	-
Preserving and Transporting Rock Core Samples	D 5079	-
Field Logging of Subsurface Explorations of Soil and Rock	D 5434	-
Seismic Refraction Method for Subsurface Investigation	D 5777	-
Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling	D 6151	T 251
Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method	G 57	T 288
Provisional Guide for Selecting Surface Geophysical Methods	PS 78	-
Descriptive Nomenclature for Constituents of Natural Mineral Aggregates	C-294	M-146
Test Method for Classification of Soils for Engineering Purposes	D-2487	M-145
Practice for Ring-Lined Barred Sampling of Soils	D-3550	-
Practice for Description and Identification of Soils (Visual-Manual Procedure)	D-2488	-
Selecting Surface Geophysical Methods	D-6429	-
Direct Current Resistivity Method for Subsurface Investigation	D-6431	-
Surface Ground Penetrating Radar Method for Subsurface Investigation	D-6432	-

20. FIGURES

6-1: Core Sizes (from Boart Longyear, 2000)

Core Barrel Type and Size	Rock Core Diameter (in)	Bore Hole Diameter (in)
Conventional		
AWG, AWM, AWL	1.185	1.890
BWG, BWM, BWL	1.655	2.360
NWG, NWM, NWL	2.155	2.980
HW	3.000	3.875
Wireline		
AQ	1.062	1.890
BQ	1.433	2.360
BQ3	1.320	2.360
NQ	1.875	2.980
NQ3	1.775	2.980
HQ	2.406	3.783
PQ3	3.270	4.828

21. REFERENCES

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