Geotechnical Investigations for the Anacostia River Projects

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ABSTRACT: The Anacostia River Projects (ARP) is the major component of the Long Term Control Plan (LTCP) for the District of Columbia Water and Sewer Authority (DC WASA). The ARP consists of an approximately 20.4-km-long (12.7 mile) tunnel system, including 18 large-diameter deep shafts and supporting structures. This paper presents the ongoing geotechnical investigations used to characterize the subsurface for the ARP. Drilling methods include sonic and conventional, and boring spacing is about 190 m (600 ft). Field testing includes pressuremeter, vane shear, and crosshole seismic. Laboratory testing includes index, triaxial, consolidation, soil abrasion testing (SAT), soil chemistry, and water quality. Estimated cost for the investigations is $6.5 million.

INTRODUCTION

The District of Columbia Water and Sewer Authority (WASA or Authority) provides wastewater collection and treatment for the District of Columbia, and wastewater treatment for surrounding areas, including parts of suburban Virginia and Maryland, at the District's Advanced Wastewater Treatment Plant at Blue Plains (Blue Plains). Like many older cities, the District of Columbia's storm water and sanitary conveyance system is combined in many geographic areas. During heavy storms, this results in direct discharge of untreated combined sewer overflows (CSOs) into rivers or streams. Hence, the Authority negotiated an agreement with the U.S Environmental Protection Agency (EPA) to improve water quality in the city's waterways by implementing both short- and long-term plans to control storm water discharges contaminated with sewage and other pollutants. Currently, WASA is in the process of implementing their Long Term Control Plan (LTCP) of facilities, infrastructure, and system improvements needed to enhance the quality of the receiving waterways and achieve (and maintain) the water quality standards in accordance with WASA's National Pollutant Discharge Elimination System permit (NPDES).

PROJECT OVERVIEW

The LTCP includes the construction of several miles of storage and flood relief tunnels in addition to other components such as shafts, diversion chambers, and overflow facilities. Cumulatively, these facilities are considered the Anacostia River CSO Control Project (ARP). The tunnels system and the major ARP Contract Divisions are shown on Figure 1. The term Contract Division refers to the separation of each design and construction contract. The LTCP will capture, store, and convey the combined sewer flow of existing CSO outfalls along the Anacostia River. The flow captured in the tunnels will be treated at Blue Plains and flows in excess of the tunnels storage capacity and Blue Plains treatment capacity will overflow to the Potomac and Anacostia Rivers at locations C and D shown on Figure 1. Geotechnical investigations will be performed to characterize the ground conditions for the final design of the LTCP structures.

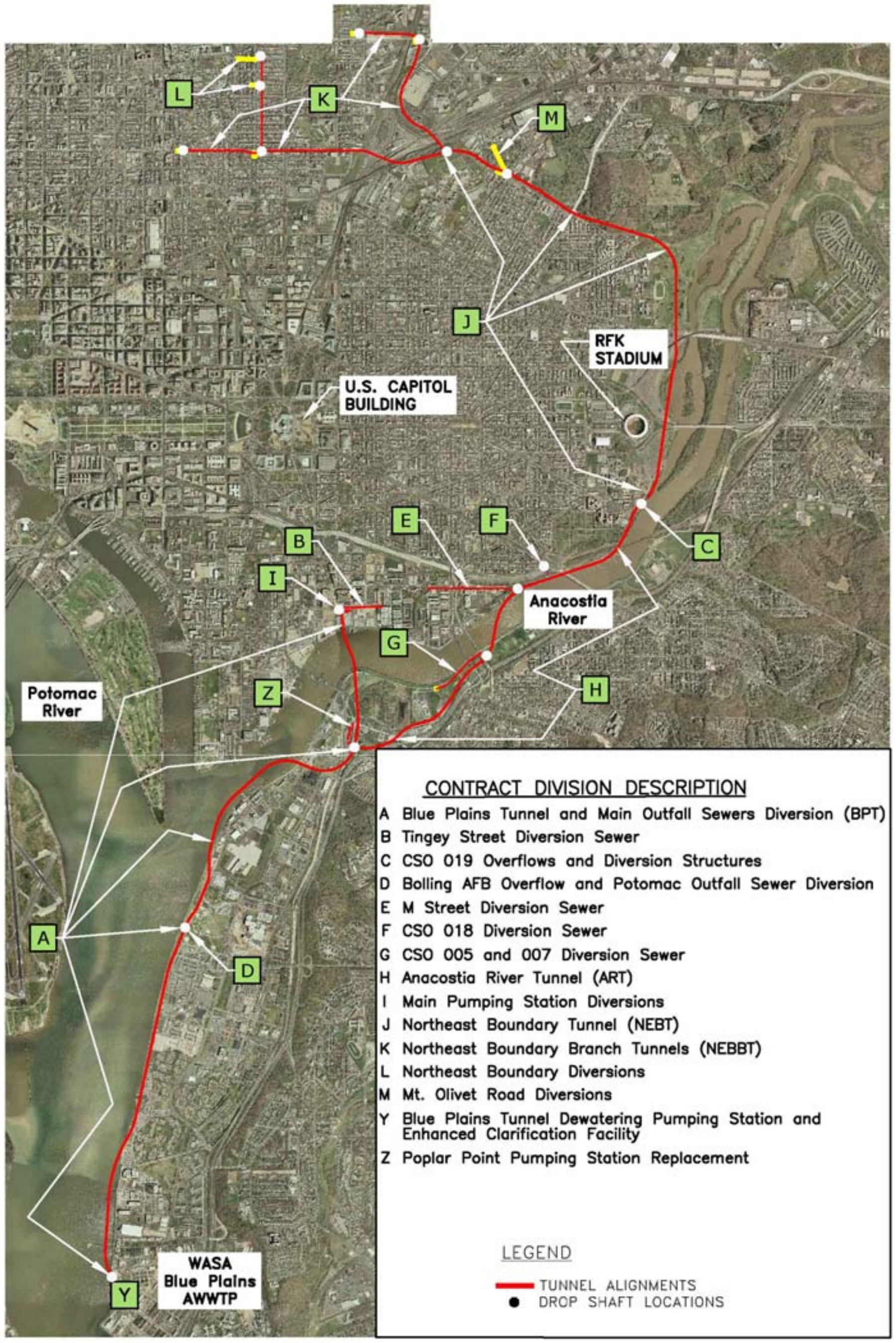

Figure 1: DC WASA LTCP Contract Divisions for the ARP

There are approximately 13 miles of tunnels to be constructed for the LTCP and 18 shafts. The tunnels and shaft inverts will be constructed at depths to invert between 18.3 and 48.9 m (60 and 160 ft) below existing ground elevation. The diameters of these shafts range from 9.1 to 33.5 m (30 to 110 ft). The principal tunnels that comprise the LTCP are show on Figure 1 as Contract Divisions A, H, J and K. The tunnels for Contract Divisions A, H, and J will have an inside diameter of 7 m (23 ft), and Contract Division K will have an inside diameter of approximately 3.7 m (12 ft).

To capture and convey flows from the existing combined sewer system to the respective drop shaft facilities, diversion chambers will be constructed at the points of diversion, and diversion sewers will be constructed from those points to the nearest drop shafts. The invert of the diversion chambers and sewers are typically about 9.1 to 12.2 m (30 to 40 ft) below the existing ground surface. The most significant diversion sewer alignments can be seen on Figure 1 as Contract Divisions B, E, M and L. The diameters range from 914 to 2,438 mm (36 to 96 in.) and have the potential to be larger based on hydraulic requirements.

This paper discusses project information available during the early stages of the LTCP's 30% design. As of the writing of this paper, the final phase of the geotechnical investigation is approximately 75% complete for the first tunnel contract, the Blue Plains Tunnel (BPT).

GEOLOGIC SETTING

The Blue Plains facility lies within the Atlantic Coastal Plan physiographic province, which is a broad belt of sedimentary soils that were deposited on older bedrock. Coastal Plain formations in the vicinity of the site include, from oldest to youngest: Cretaceous period Potomac Group sediments, Pleistocene epoch terrace deposits, and relatively recent Quaternary period alluvium. The Potomac soils were deposited in relatively shallow seas from steams flowing eastward out of the continental interior. Pleistocene Terrace sediments were carried in braided streams charged by glacial melt water and were deposited on top of Potomac Group soils. More recently, river alluvium was deposited over Terrace soils. The uppermost soils at the site consist of existing fill that is believed to be associated with previous development.

The fill deposits frequently contain fragments of construction debris, metal, cinders, and/or trash in varying amounts. The alluvial deposits consist of loose/soft organic silt, clay and fine sand. Sand and gravel are also present at some locations, usually at depths underlying the fine grained material. The Terrace deposits consist of older alluvial sand and gravel that are often yellow or orange in color The Potomac Group consists of sediments that have been subdivided into the Patapsco/Arundel formations and the underlying Patuxent Formation. The Patapsco/Arundel formations typically consist of hard, reddish brown silt and clay with minor sand. The Patuxent generally consists of silty and/or clayey sand, locally with minor gravel. The bedrock generally consists of crystalline schist and gneiss that is more than 450 million years old.

Figure 2 shows a general geologic profile of the ARP for the DC WASA LTCP. The majority of the tunnels will be excavated in the Potomac Group soils. This geologic profile will be continuously updated based on the findings of the additional investigations of the LTCP, which are presently ongoing and which are the focus of this paper.

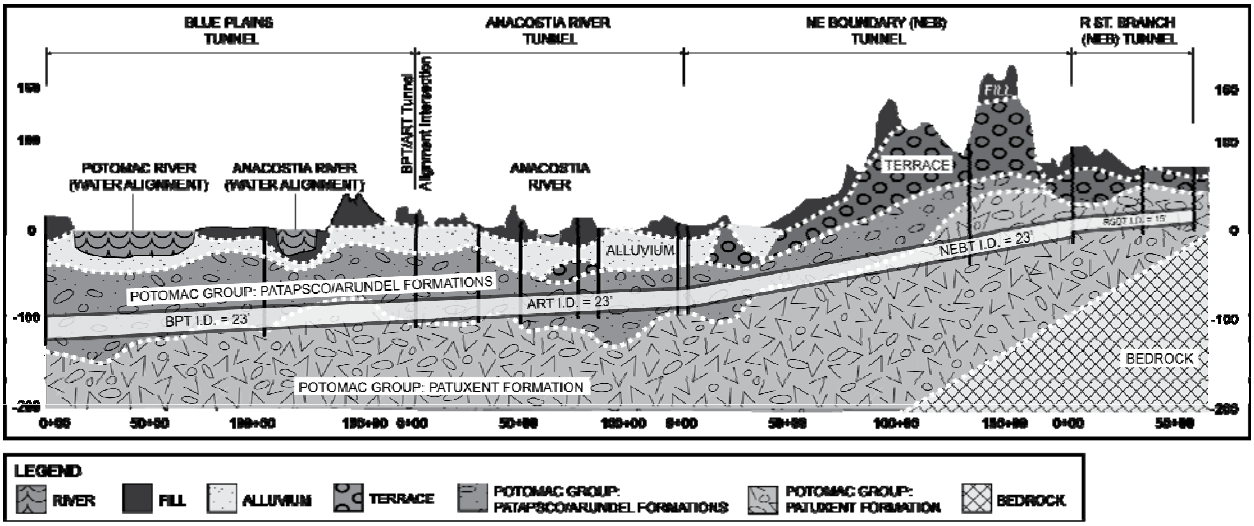

Figure 2: General Geologic Profile for the ARP

GEOTECHNICAL CONSIDERATIONS

The structures for the LTCP will be designed and built by a variety of construction methods. Table 1 lists the main design and construction considerations for each of the main LTCP structures. These considerations have been used in the development of the geotechnical investigation program for the LTCP. The following sections discuss the details for the design and construction considerations for each of the proposed LTCP structures.

Table 1. Geotechnical design and construction considerations

Proposed Structure	Design								Construction											
	Foundation Bearing Capacity /Settlement	Lateral Earth and Water Pressure	Global slope Stability	Buoyancy and Uplift Resistance	Ground improvement	Liner and Wall Loads	Backfill Materials	Site Preparation And Grading	Ground Deformation	Subgrade Preparation	Obstructions	Mixed-Face Tunneling	Gas/Ventilation	Soil Disposal Or Reuse	Groundwater Control And Disposal	Soil Abrasiveness	Soil Stickiness Potential	Support of Excavation	Temporary Dewatering	Ground Improvement
Tunnels					●	●			●		●	●	●	●		●	●			●
Shafts		●		●	●	●		●	●	●	●			●	●			●	●	●
Overflow & Chamber	●	●	●	●	●	●	●	●	●	●	●			●	●			●	●	●
Sewers					●	●			●		●	●	●	●		●	●			●

Tunnels

The main design and construction considerations for tunneling include the liner design, machine selection and design, obstructions along the tunnel alignment, tunneling-induced ground settlements, and ground improvement. The tunnel liner will be designed to resist static and dynamic ground loads as well as hydrostatic loads. Other loading such as structure loads above the tunnel on the tunnel will also be considered. Other geotechnical considerations for liner design include chemical testing of the soil and groundwater to ensure there are no constituents in the ground that could adversely affect the concrete. The selection of a tunnel boring machine (TBM) mostly depends on the anticipated soil types and groundwater pressure.

Obstructions are objects that are encountered within the planned tunnel such as utilities and piles. The most common obstruction that has been found along the BPT is piles. Forensic studies are being performed to determine the length of piles where as-builts and constriction records are missing, which requires stratigraphy at the site in question and defined soil properties.

Ground settlement caused from tunneling and excavations is also being considered. The magnitude of the settlement will depend on the subsurface conditions, construction methods, equipment utilized, structure geometry, and the contractor's means and methods. The impact of the estimated settlement on structures is being evaluated and ground improvement techniques may be required to reduce the effects of settlement on utilities and structures. Properties such as grain-size distribution, moisture content, and soil strength are important factors when selecting ground improvement techniques.

Shafts

The design and construction issues for the large-diameter, deep shafts include excavation support, ground deformation, water inflow, excavation bottom stability, and break-in and break-out of TBMs. Geotechnical information at each shaft site will play a critical role in its design. Subsurface profiles will be used to determine the lateral forces that will act on the shafts. Information concerning the groundwater head and permeability of the soil at the base of the shafts will be required. Water-tight excavation support systems, such as slurry walls, secant pile walls, steel sheet piling, or ground freezing, will most likely be required.

Overflow and Diversion Chambers

Structures, including overflow facilities and diversion chambers, are expected to be built by open-cut excavation methods. Considerations for such construction include excavation support, ground deformation, dewatering, and excavation bottom stability. Relatively stiff excavation support systems, such as slurry walls, anchored or braced sheeting systems, etc., are required if ground deformation is a concern. Groundwater drawdown outside the excavation may result in the settlement of ground surface, nearby structures, and utilities due to the consolidation of soils caused by dewatering. Measures to stabilize excavated bottoms will also need to be considered.

Sewers

Many of the design and construction considerations discussed in the previous tunnel section are also applicable for the diversion sewers. The diversion sewers may be constructed using microtunneling, pipe jacking, and/or hand mining methods. Open-cut excavation methods are also being considered for some of the shallower sewer locations.

GEOTECHNICAL INVESTIGATION PROGRAM

The investigations discussed in this paper are being performed to support the final design of the LTCP tunnels, shafts and shallow structures. All geotechnical data collected will provide a basis for understanding the subsurface conditions and the geotechnical parameters for the final design and construction of the proposed LTCP facilities. Both the physical characteristics and engineering properties of the soil are important for the design and construction of the LTCP structures.

To simplify the soil profile in terms of soil behavior for tunneling, a system for grouping of soil has been developed. The tunnels are anticipated to be constructed primarily within the Potomac Formation. For this reason, the Potomac Formation was further divided into five soil groups (G1 through G5). The engineering properties of the five soil groups are being defined by field and laboratory testing data. The following sections describe the drilling, in situ testing, and laboratory testing being used to characterize the ground conditions for the LTCP.

Geotechnical Drilling and Sampling

The location and spacing of the borings, as well as the depths, are structure specific. The spacing of the borings along the tunnel and sewer alignments is approximately 183 m (600 ft). The depth of the borings along the tunnel and sewer alignments is about two tunnel diameters below the tunnel invert. At shaft locations, borings are being drilled to approximately 1 to 1.5 shaft diameters below shaft inverts, depending on the size of the shafts and the ground conditions encountered. At shaft locations, generally two borings will be drilled, depending on the size of the shaft. At structure locations, generally two borings will be drilled, depending on the structure size, the accessibility of the site to obtain borings, and the ground conditions encountered during drilling.

Drilling is being performed using both mud rotary and sonic drilling methods. Borings are being performed from land and water using barges. Standard penetration test (SPT) sampling is being performed and hammer energy testing will be performed for all drill rigs using hammers. The SPT sampling zone will be continuous starting one diameter above the tunnel, continuing within the tunnel, and going one diameter below the tunnel. The remaining depths will be sampled on 1.5-m (5-ft) spacing. The sampling zone for a structure and shaft boring spans from the ground surface to the depth of the boring. SPT sampling in structure borings will use 1.5-m (5-ft) spacing. Undisturbed soil samples will be obtained and are being collected using a thin-walled Shelby tube sampler, Pitcher Sampler, or Denison sampler.

In Situ Testing

The objectives of in situ testing are to gather additional information regarding site geology, hydrogeology, and physical and engineering properties of soils. In situ tests include those for the determination of the strength, stiffness, and permeability of major strata, as well as quality. Table 2 summarizes the in situ testing methods planned for the geotechnical investigations. The field testing methodologies are discussed in detail below.

Table 2: In situ testing methods

Geotechnical Design and Construction Issues	Test Methods							
	SPT	Pressuremeter	Vane shear	Groundwater Monitoring	Soil gas screening	Groundwater quality test	Slug test	Geophysical surveys
All Underground Facilities								
Shoring/under pinning	●	●	●			●		
Soil/muck reuse/disposal								
Ground water level/pressure				●				
Corrosion						●		
Tunnels								
Tunnel liner earth load		●	●	●				
Obstructions	●							●
Abrasiveness	●							●
Stickiness								
Gas					●			
Face stability	●	●	●	●				
Groundwater inflow & disposal				●		●	●	
Ground surface subsidence	●	●	●	●				●
Shafts								
Water inflow/dewatering				●		●	●	
Excavator resistance	●	●	●					●
Ground movement	●	●	●	●			●	●
Excavation bottom stability	●	●	●	●			●	
Lateral earth pressure	●	●	●	●				
Backfill materials								
Gas					●			
Overflows & Chambers								
Foundation capacity/settlement	●	●	●	●				
Obstructions	●							
Lateral earth pressure	●	●	●	●				
Ground movement		●	●	●				
Buoyancy & uplift resistance				●			●	
Water inflow/dewatering				●		●	●	
Excavation bottom stability	●	●	●	●			●	
Backfill materials								
Sewers								
Tunnel liner earth load		●	●	●				
Obstructions	●							●
Abrasiveness	●							
Stickiness								
Gas					●			
Face stability	●	●	●	●				
Groundwater inflow & disposal				●		●	●	
Ground surface subsidence	●	●	●	●				●

Standard penetration tests (SPTs)

The SPT blow counts provide a qualitative indication regarding soil density or consistency. Soil samples collected by the SPT samplers are used for soil classification and index testing. SPT testing has been generally easy to obtain; however, there has been an occasional borehole stability issue when drilling in the deep coarse-grained Patuxent Formation. Bottom instability of the borehole has been encountered, leading to inaccurate blow counts. This issue has been corrected by ensuring the drilling mud is thick enough and there is enough mud in the hole.

Pressuremeter tests

Pressuremeter tests are being performed using a Menard pressuremeter. Test results are used to estimate in situ lateral earth pressures, soil stiffness, and shear strength for the design of tunnel and other structures. The tests are applicable for sandy and cohesive soils; however, they are more difficult to perform in the sandy soils because of borehole stability issues. No tests are being performed for gravelly materials. The tests are generally being performed in borings along the tunnel alignments and at shaft locations. Undisturbed samples are being obtained adjacent to test locations to determine if there is agreement between the in situ tests and laboratory tests. Approximately four tests are being performed in tunnel borings and six tests are being performed shaft borings. Tests for the tunnel borings are generally located in the tunnel zone, and tests performed for shaft borings are along the shaft profile.

Field vane shear tests
The field vane shear test is used to determine in situ undrained shear strength within soft to medium stiff (SPT blow counts <9) clayey or silty soils. This test is not applicable for testing granular soils or stiffer clays. Soft soils are anticipated to be encountered in the alluvial materials at locations adjacent to the rivers and areas where old marshes and tributaries to the rivers existed. The vane shear test requires the apparatus to be calibrated to account for the friction along the rods connecting to the vane. The vane shear test has been performed in three areas thus far in the ongoing geotechnical investigation: the main pumping station; the CSO-019 area; and the second river crossing, adjacent to the Naval Annex. Approximately five tests are performed in one boring, and undisturbed samples are obtained adjacent to the test for comparison purposes.

Groundwater monitoring, permeability testing, and quality
Two kinds of groundwater monitoring methods are being used: monitoring wells and vibrating wire piezometers (VWPZs). Monitoring wells are being placed in coarse-grained materials in the tunnel zone, shaft inverts, and gravel layers within surface structures. Vibrating wire piezometers (VWP) are being placed in the fine-grained materials in and near the tunnel zone and within shafts. Slug testing is being performed in all monitoring wells to determine the permeability of the material. These test results are the basis for defining the groundwater conditions for all LTCP facilities. Groundwater quality testing is being conducted in a few wells within the tunnel zone to evaluate the chemistry of the groundwater. Parameters such as alkalinity, total dissolved solids, calcium content, sulfate, pH, etc., are being obtained through laboratory and field testing.

Soil gas screening
The potential for encountering explosive and toxic gases during construction of the LTCP facilities is being assessed by testing both the soil and groundwater. The soil is being screened using a photoionization detector (PID) and confined space monitor, which detects both hydrocarbons and methane. Groundwater samples are being collected from monitoring wells within the tunnel zone and are being tested for concentrations of hydrogen sulfide and methane. Gas is not anticipated to be encountered within the tunnel zone.

Geophysical investigations
Geophysical survey methods being used include seismic reflection and cross-hole seismic surveys to gain additional information about the characteristics of subsurface layers. Seismic reflection is being used in the three water crossing for the BPT to delineate the Potomac clay contact between borings. Cross-hole seismic surveys are being performed at most shaft sites to determine the shear wave velocities of the soil strata within the shafts, which can be used to determine geotechnical properties of soil, including Poisson's ratio and elastic moduli.

Laboratory Testing
The objectives of geotechnical laboratory testing are to measure physical and engineering properties of soil and water samples obtained during the field investigation. The test results, combined with the data collected by field tests, provide a basis for understanding subsurface conditions and soil parameters for design and construction. In general, there are two types of soil samples that can be tested in a laboratory: disturbed and undisturbed. Disturbed soil testing generally yields the physical properties of the soil, while the undisturbed testing yields the engineering strength properties of the soil. Table 3 presents a matrix of proposed laboratory tests and the geotechnical design and construction issues the tests will be used to support. These laboratory testing methodologies are discussed below.

Table 3: Laboratory testing methods

Geotechnical Design and Construction Issues	Test Method														
	Unit weight	Moisture Content	Atterberg Limits	Gradation	Strength	Compressibility	Compaction	Permeability	Organic Content	Soil Corrosion	Water Quality	Dissolved Gas	Rock/Boulder Hardness and Strength	Mineralogy	Soil Abrasion
All underground facilities															
Shoring/under pinning	●	●	●	●	●	●									
Soil reuse/muck disposal	●	●	●	●			●								
Groundwater level/pressure		●													
Corrosion		●								●	●				
Tunnels															
Tunnel liner earth load	●	●	●	●	●	●									
Obstructions													●		
Abrasiveness	●			●									●	●	●
Stickiness		●	●											●	
Gas									●			●			
Face stability	●	●	●	●	●			●							
Groundwater inflow & disposal		●						●							
Ground surface subsidence	●	●	●	●	●	●									
Shafts															
Water inflow/dewatering		●		●				●			●				
Excavator resistance	●		●	●	●								●		
Ground movement	●	●	●	●	●	●									
Excavation bottom stability	●	●	●	●	●	●		●							
Lateral earth pressure	●	●	●	●	●										
Backfill materials	●	●	●	●			●								
Gas									●			●			
Overflows & Chambers															
Foundation capacity/settlement	●	●	●	●	●	●			●						
Obstructions															
Lateral earth pressure	●	●	●	●	●										
Ground movement	●	●	●	●	●	●									
Buoyancy & uplift resistance		●		●											
Water inflow/dewatering		●		●				●			●				
Excavation bottom stability	●	●	●	●	●	●		●							
Backfill materials	●	●	●	●			●								
Sewers															
Tunnel liner earth load	●	●	●	●	●	●									
Obstructions													●		
Abrasiveness	●			●									●	●	●
Stickiness		●	●											●	
Gas									●			●			
Face stability	●		●	●	●										
Groundwater inflow & disposal		●		●							●				
Ground surface subsidence	●	●	●	●	●	●									

Disturbed testing

Disturbed soil tests are being performed to characterize the physical properties of the soils, such as amount of natural moisture. These disturbed properties are being used to provide insight into the anticipated behavior of the soil.

Moisture content, Atterberg limits, and grain-size distribution. The majority of the disturbed soil tests performed are moisture content, Atterberg limits, and grain-size distribution. Grain-size analyses include sieve analysis and hydrometer analysis and are used to determine the percentages of various soil grain sizes for the purposes of USCS classification. Properties gained from these three types of disturbed tests are being correlated with other physical and engineering properties such as soil stickiness and liquidity index and permeability and strength. On average, five of each type of test are being performed in each boring. For tunnel borings, testing is focused in the tunnel zone. For shaft borings, testing is being performed throughout the boring, targeting the shaft invert and any permeable layers.

Unit weight and specific gravity. Unit weight and specific gravity tests are generally being performed in conjunction with other tests, such as consolidation tests and triaxial tests. Both tests are used in geotechnical calculations. A few tests are being performed without an undisturbed test; however, this is not typical of the investigation.

Organic content. The purpose of the organic content test is to determine the percentage of organic materials in a soil sample if the sample has been classified as organic or if the sample has any notes of organic materials. This test is being performed on peaty soils or soils having high moisture contents within shaft and shallow structure areas.

Soil abrasion and mineralogy. The purpose of soil abrasion tests is to provide an understanding of the abrasivity of the soil particles and help in the selection of soil conditioners for reducing the wear on cutter tools of the TBMs. Currently, there are no standard methods to measure and evaluate the impacts of abrasive soils on cutter tools for soft ground excavation. Two types of tests are being performed to quantify the abrasivity of the soil for the LTCP: X-ray diffraction testing, and the Norwegian University of Science and Technology (NTNU) Soil Abrasion Test (SAT). These tests are being performed on coarse-grained soils and sandy and gravelly fine-grained soils obtained from the tunnel zones.

X-ray diffraction testing is being performed to identify the minerals in the representative soil samples and quantify their relative abundance. The NTNU SAT is an extension of the existing NTNU Abrasion Value (AV) test and the Abrasion Value Cutter Steel (AVS) test for rock. The SAT result is a value calculated as the mean value of the measured weight loss in milligrams (mg). Approximately 10 of each type of test have been performed on coarse-grained material in the BPT tunnel zone.

Soil corrosion tests. Soil corrosion tests are being performed to determine concentrations of soil parameters such as sulfate, chloride, and sulfide. Other properties obtained during this test are pH, moisture content, electrical resistivity, and redox potential. The test results will be used to determine the potential adverse impacts of soil on concrete and steel during design. The corrosion tests are distinct from and not intended to substitute for appropriate environmental chemical analyses for evaluation of potential contamination. Corrosion tests are being performed at various locations at the tunnel level and near the ground surface at all shafts and shallow structure locations.

Undisturbed testing

Undisturbed soil tests are being performed to characterize engineering properties of the soils such as the undrained shear strength. These engineering properties, as well as the physical properties, are being used to provide insight into the anticipated behavior of the soil. Disturbed tests for moisture content and Atterberg Limits are also performed for each undisturbed sample that is tested. All undisturbed samples are being examined by X-ray radiography to determine their suitability for testing. The target is to obtain five tubes from each boring; however, it is not always possible to get all five tubes because of the difficulty in sampling the Potomac clays. In addition, it is anticipated that undisturbed testing will not be performed on all tubes obtained. Some of the tubes will be disturbed, and some will be kept for backup.

X-ray radiography. Undisturbed soil samples are being transported vertically in racks to from the field to storage and from storage to the two laboratories. All tubes are radiographed upon arrival to the laboratory in order to assess the sample quality and any potential disturbance, general material type, presence of inclusions, and variation in macro-fabric. Based on the radiography results, suitable zones are identified to assign samples for testing; therefore, relatively high-quality samples are used for strength and deformation tests. The biggest challenge in performing X-ray radiography was finding a facility that performed the testing and was close to one of the two undisturbed testing laboratories. The radiography lab used on this project had never tested soil before, only concrete. Laboratory technicians from the soil lab trained the concrete radiography lab to test the soil using the ASTM standard.

One-dimensional consolidation/swelling. One-dimensional constant rate of strain (CRS) consolidation tests, one-dimensional incremental consolidation tests, and swelling tests are being performed on fine-grained soils. The consolidation tests measure the coefficient of consolidation for estimating the rate of soil consolidation and provide an estimate of the maximum past pressure. These parameters will be used to evaluate strength-deformation properties and the degree of overconsolidation (OCR) of fine-grained soils. Determination of the maximum past pressure provides a better understanding of the strength-deformation behavior obtained from triaxial test results.

The swelling tests are anticipated to provide swell pressures in the Potomac clays that should be considered for the tunnel liner and TBM machine design, as well as the shaft design. Approximately 10 swell tests have been performed for the BPT alignment.

Triaxial tests. Triaxial tests are being performed to measure the undrained shear strength (Su), effective soil strength parameters (c′, ϕ′), and deformation properties (E) of cohesive soils. There are currently three types of triaxial tests being performed to define the strength properties of the fine-grained soils: SHANSEP CK_0U, Recompression CK_0U, and CIU. SHANSEP refers to the Stress History and Normalized Soil Engineering Properties technique (Ladd and Foott 1974) for estimating strength properties of cohesive soils. CK_0UTC refers to K_0-Consolidated Undrained Triaxial Compression and CIU refers to Isotropically Consolidated Triaxial Compression. The recompression technique (Bjerrum 1973) involves reconsolidating specimens to in situ vertical stresses, and then the specimens are sheared to failure. In SHANSEP tests, test specimens are reconsolidated to a normally consolidated state (to stresses in excess of maximum past pressure) and then unloaded to varying OCRs, where required. The purpose of the SHANSEP technique is to minimize the effects of sample disturbance and to develop relationships between normalized undrained shear strength properties as a function of OCR.

SHANSEP testing is more expensive than recompression testing, and it is time consuming. Also, since the Potomac clays are highly overconsolidated materials, the test requires triaxial equipment that can handle high pressures, which is not common for the typical soils laboratory. A small number of SHANSEP tests are being performed to evaluate the usefulness of the testing for this project. Based on test results, additional tests may be assigned. The majority of the strength tests being performed are Recompression CK_0U. Approximately 25 tests have been performed along the BPT alignment. Additional testing may be required based on the results for each fine-grained soil group.

SUMMARY

For the Anacostia River, one of the Districts's receiving waterways, the LTCP includes the construction of several miles of storage and flood relief tunnels in addition to other components such as shafts, diversion chambers, and overflow facilities. There are numerous design and construction considerations for each of the main LTCP structures, and these considerations have been used in the development of the geotechnical investigation program for the LTCP. Geotechnical investigations are currently underway to support the final design of these structures, starting with the BPT. Both the physical characteristics and engineering properties of the soil are important for the design and construction of the LTCP structures and are determined using field and laboratory testing methods. The types of field and laboratory testing performed for each structure depends on the construction and design issues for each and are often site specific.

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