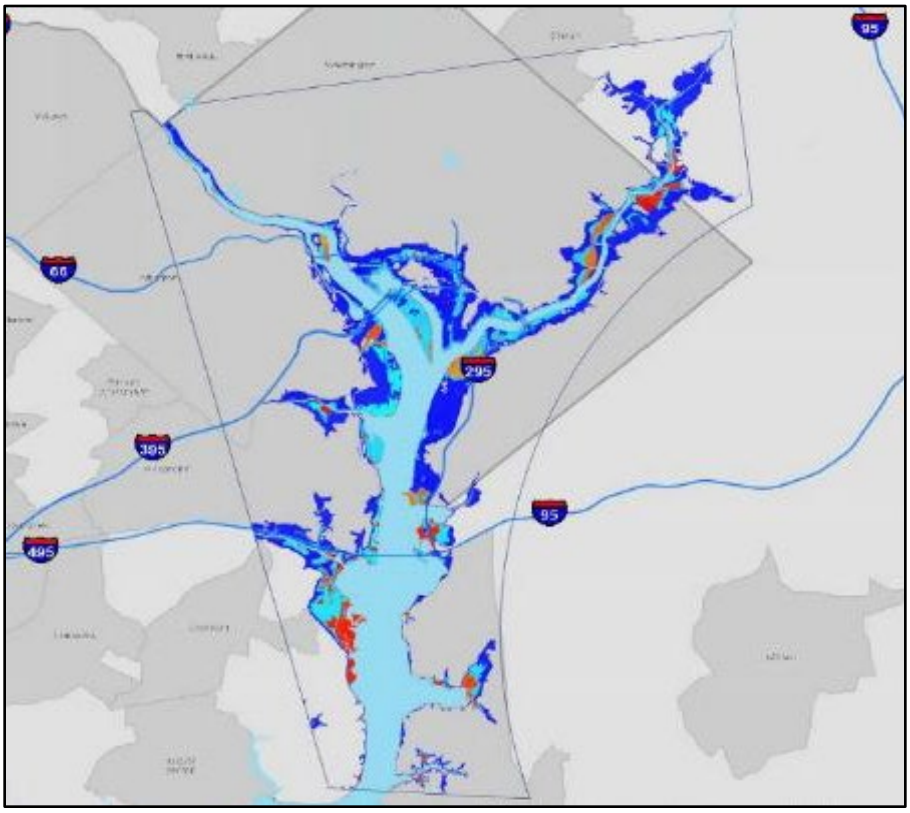
Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study

Appendix D: Geotechnical Analysis



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1. INTRODUCTION

The purpose of this report is to summarize results of the preliminary desktop study of the existing geotechnical information at the various sites associated with the Metropolitan Washington District of Columbia Coastal Storm Risk Management Feasibility Study (DC Coastal). This desktop study focused on areas where structural measures are proposed, specifically Alternatives 4b (Reagan Airport flood walls and perimeter road elevation), 4c (Arlington Water Pollution Control Plant flood wall), 5a (Four Mile Run flood wall and levee), and 5c (Greater Belle Haven Neighborhood flood wall and levee). Information and discussion in this report was developed through a desktop study of existing geotechnical information and it is intended for use by design engineers and planners to evaluate feasibility alternatives for the proposed coastal storm control structures. Information in this report is not intended for use in construction contract documents. A project area map is provided below in Figure 1-1.

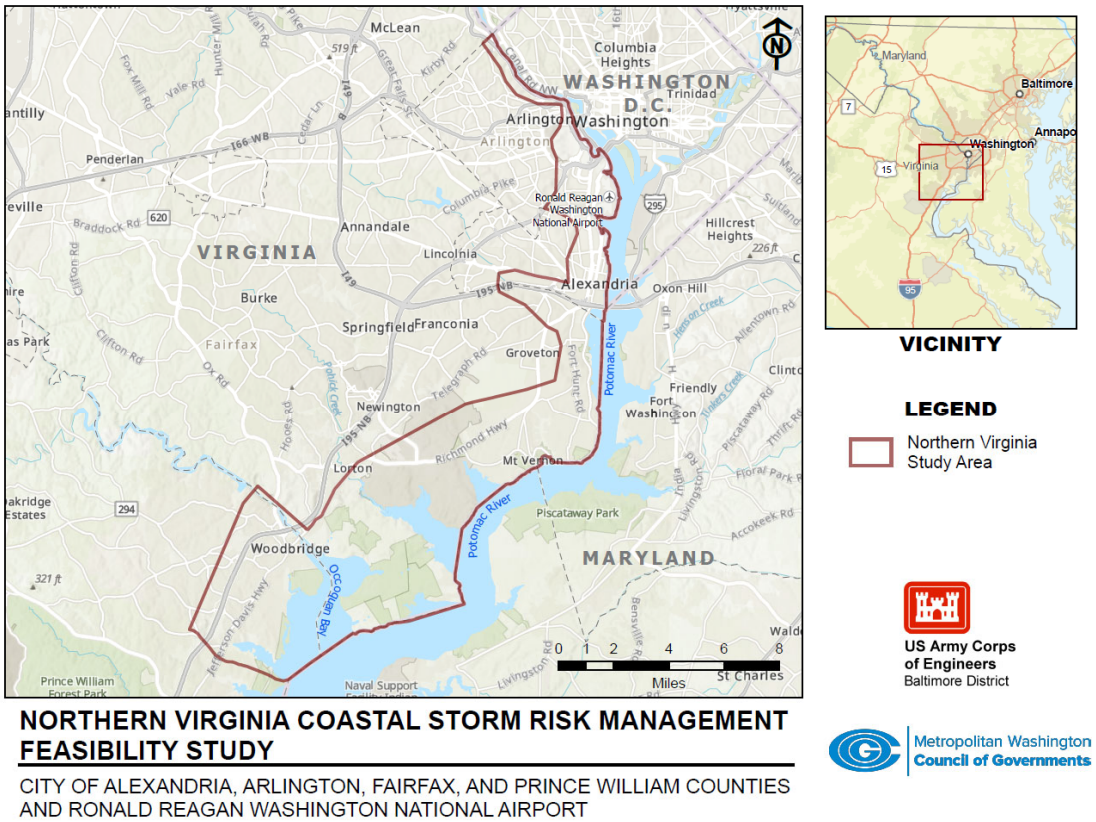

Figure 1-1 – Project Area Map

2. PREVIOUS GEOTECHNICAL STUDIES

A desktop study revealed that a number of previous geotechnical studies have been performed either within or in close proximity to the limits of each of the four areas where structural measures are proposed for coastal storm damage reduction. The geotechnical data obtained from

these previous studies is described below in the Existing Geotechnical Information section, and is included in Attachment A.

3. GEOLOGY

3.1 Regional Geology

All the sites associated with the project lie within the Coastal Plain physiographic province of Virginia, specifically in the lowland subprovince, which is characterized as a flat, low-lying region along major rivers and near the Chesapeake Bay. The study area is characterized by Mesozoic-era, quaternary sediments consisting of sand, mud, and gravel.

3.2 Local Geology

3.2.1 Ronald Reagan Washington National Airport (Reagan Airport)

Based on the soil survey of Arlington County, Virginia (USDA-NRCS, 2022) shown in Figure 3.1, the soils within the proposed project limits of Reagan Airport consist of the Urban land-Udorthents complex. The soil properties include 2 to 15 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table also greater than 80 inches.

Figure 3-1 – Soil Survey Map of Reagan National Airport

3.2.2 Arlington Water Pollution Control Plant (WPCP)

Based on the soil survey of Arlington County, Virginia (USDA-NRCS, 2022) shown in Figure 3-2, the soils within the proposed project limits of the WPCP consist of the Urban land-Udorthents complex and the Udorthents, loamy complex. As noted above, the Urban land-Udorthents complex soil properties include 2 to 15 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table also greater than 80 inches. The Udorthents, loamy complex

soil properties are similar, including 0 to 10 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table also greater than 80 inches.

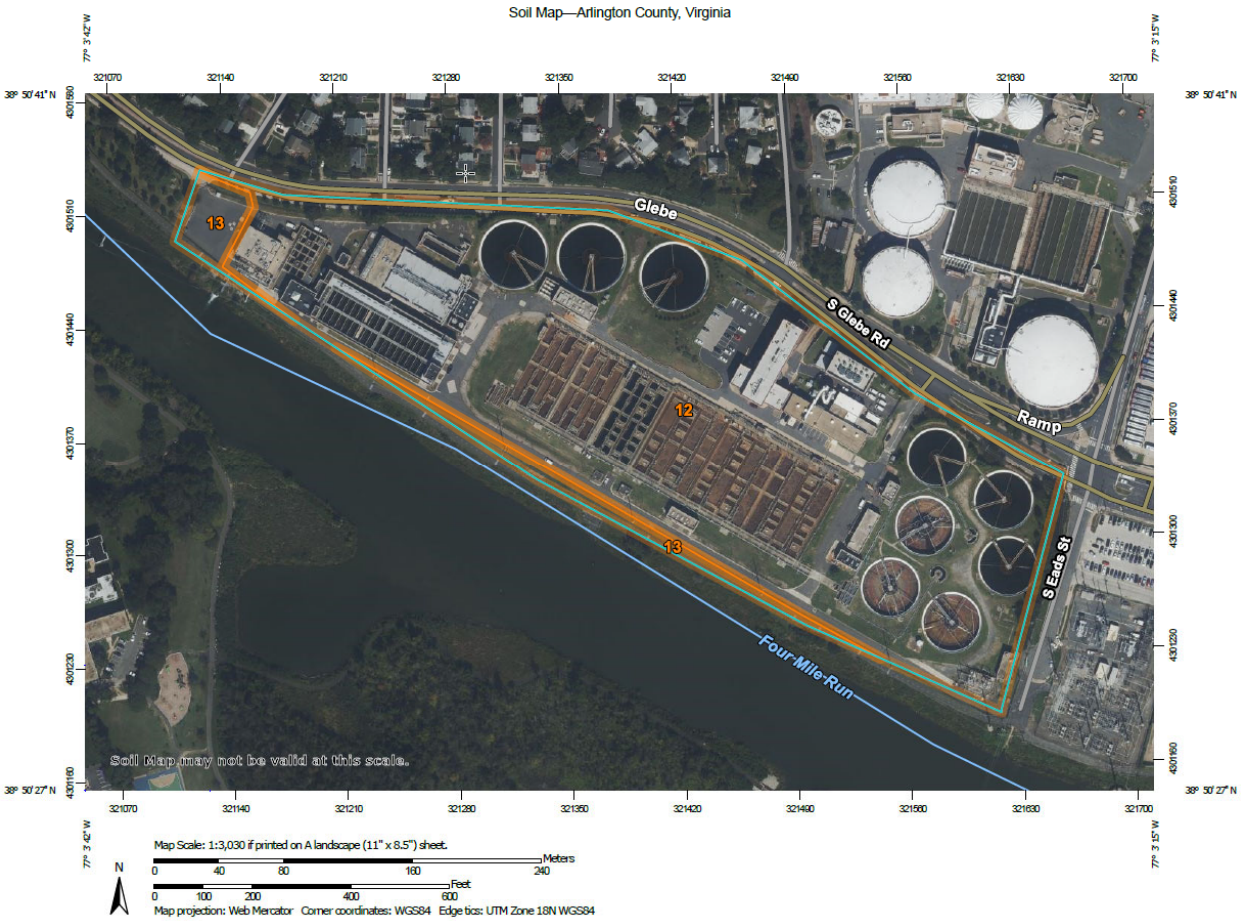

Figure 3-2 – Soil Survey Map of Arlington WPCP

3.2.3 Four Mile Run

Based on the soil survey of Alexandria City, Virginia (USDA-NRCS, 2022) shown in Figure 3-3, the soils within the proposed project limits of Four Mile Run consist of Grist Mill sandy loam and Woodstown sandy loam, as well as a segment of Urban land in the northwestern corner of the site. Grist Mill sandy loam properties include 0 to 25 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table ranging from 24 to 79 inches. Grist Mill sandy loam is a well drained material that originates from earthy fill of fluviomarine deposits. Woodstown sandy loam properties include 2 to 7 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table ranging from 18 to 42 inches. Woodstown sandy loam is a moderately well drained material that originates from fluviomarine deposits.

Figure 3-3 – Soil Survey Map of Four Mile Run

3.2.4 Belle Haven

Based on the soil survey of Fairfax County, Virginia (USDA-NRCS, 2022) shown in Figure 3-4, the soils within the proposed project limits of Belle Haven consist of Grist Mill sandy loam, Grist Mill-Matapeake, Grist Mill-Woodstown, Gunston silt loam, Honga peat, Matapeake silt loam, Mattapex loam, Urban Land-Grist Mill, and Urban land. Grist Mill sandy loam properties were discussed above in Section 3.2.3. Grist Mill-Matapeake soil properties include 0 to 15 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table ranging from 24 to 79 inches. Grist Mill-Matapeake is a well drained material that originates from earthy fill of fluviomarine deposits. Grist Mill-Woodstown soil properties include 0 to 20 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table ranging from 24 to 79 inches. Grist Mill-Woodstown is also a well drained material that originates from earthy fill of fluviomarine deposits. Gunston silt loam soil properties include 0 to 2 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table ranging from 8 to 30 inches. Gunston silt loam is a somewhat poorly drained material that originates from fluviomarine deposits. Honga peat soil properties include 0 to 1 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table of about 0 inches. Honga peat is a very poorly drained material that originates from organic material over loamy

alluvium. Matapeake silt loam soil properties include 2 to 7 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table greater than 80 inches. Matapeake silt loam is a well drained material that originates from fluviomarine deposits. Mattapex silt loam soil properties include 2 to 7 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table of 24 to 36 inches. Mattapex silt loam is a moderately well drained material that originates from fluviomarine deposits. Urban Land-Grist Mill soil properties include 0 to 25 percent slopes, depth to restrictive features greater than 80 inches, and depth to water table of 24 to 79 inches. Urban Land-Grist Mill is a well drained material that originates from earthy fill of fluviomarine deposits.

Figure 3-4 – Soil Survey Map of Belle Haven

4. TOPOGRAPHY

The Coastal Plain is an area of low elevation and low relief characterized by narrow well-drained ridges, broad poorly-drained flats, and marine coastal areas. The coastal areas consist of marshland and wetlands adjacent to the Potomac River. The natural terrain in the vicinity of the proposed project areas is flat, with much of the area near sea level.

5. EXISTING GEOTECHNICAL INFORMATION

This section provides an overview of the existing geotechnical information available for the locations where structural coastal storm risk management measures are proposed. No information was obtained for locations not listed below. Borings that happen to have fallen along or adjacent to proposed flood wall or levee structures were used to create basic soil profiles to depict the subsurface conditions beneath the coastal storm risk control structures. These soil profiles are presented in Attachment A, along with the boring logs and associated subsurface exploration plans, and soils laboratory data, as available.

5.1 Reagan Airport

A series of 25 soil borings were performed for the South Area Roads Project No. 3 project by the Metropolitan Washington Airports Authority at Reagan Airport. A boring location plan and boring logs were included in a plan set dated 1 November 1994. A second series of 8 soil borings for the South Area Roads Project No. 4B project was also performed and was provided along with a partial boring location plan in a plan set dated 17 August 1999. Soil borings were advanced to depths ranging from 17 to 65 feet below grade. The soil borings from both of these past projects were located in the southwestern area of the airport property.

The subsurface conditions disclosed by the South Area Roads borings consisted of an upper stratum of fill material that ranged from 7 to 22 feet thick. The fill stratum was underlain by an organic silt stratum in some locations, and by clayey sand interbedded with sandy clay in other locations. Where penetrated, the organic silt stratum ranged from 9 to 34.5 feet thick and was underlain by a sand stratum. This sand stratum was penetrated in one of the 65-foot-deep borings and was underlain by a stratum of clay in which the boring was terminated.

The fill stratum consisted of grey-brown to black sand with varying percentages of gravel, silt and clay and contained concrete, asphalt, wood, and glass fragments. Standard penetration test (SPT) N-values collected in the fill stratum ranged widely from 2 blows per foot (bpf) to 100 bpf, indicating a range of relative densities from very loose to very dense. There was no observed trend in the observed N-values with depth, indicating that the fill material is of highly variable composition and was likely placed in an uncontrolled manner.

The organic silt stratum consisted of green-grey clayey silt with trace sand, mica, and fibrous organic material. SPT N-values collected in the organic silt stratum ranged from weight of sampling hammer (W.O.H.) to 2 bpf, indicating a very soft consistency. Considering the observed consistency and organic content, the organic silt is believed to be highly compressible.

The clayey sand/sandy clay stratum consisted of brown to grey sand and clay in near equal proportions. SPT N-values in the clayey sand/sandy clay ranged from 10 bpf to 14 bpf with an average value of 11 bpf in the primarily coarse-grained material, which corresponds to a medium dense material, and from 13 bpf to 26 bpf with an average value of 21 bpf in the primarily fine-grained material, which corresponds to a very stiff consistency.

The sand stratum underlying the organic silt consisted of grey to grey-green fine to medium sand with trace to some fines. SPT N-values in the sand ranged from 3 bpf to 100 bpf, with lower N-values consistently observed in the upper portion of the stratum that then increase with depth. The observed N-values correspond to a range of relative densities from very loose to very dense.

The clay stratum beneath the sand stratum was encountered at a depth of 63 feet below grade and consisted of grey-green silty clay with an SPT N-value of 22, corresponding to a very stiff consistency.

5.2 Arlington WPCP and Four Mile Run

A series of 105 soil borings and 6 test pits were performed along Four Mile Run during the 1978 subsurface exploration for the Four Mile Run Flood Control Project Channel Improvements. These soil borings were located along the north and south banks of Four Mile Run between Interstate Route 95 on the west and U.S. Route 1 on the east, with several borings located along the proposed alignment of flood wall and levee structures on the Arlington WPCP and Four Mile Run sites. Approximately one-third of the 1978 soil borings were sampled using a 3-inch outer diameter split spoon sampler, while the remaining two-thirds were sampled using a standard 2-inch outer diameter split spoon.

5.2.1 Arlington WPCP

Eight borings located along the proposed flood wall alignment were reviewed to evaluate the subsurface conditions beneath the structure. The subsurface conditions disclosed by these eight borings consist of an upper stratum of fill material that ranged from 5 to 23 feet thick that was underlain by an organic silt stratum. The organic silt stratum was penetrated in five of the eight borings, where the stratum ranged from 10 to 14 feet thick and extended to between 16.5 and 21 feet below grade. The remaining three borings terminated in the organic silt stratum at depths ranging from 25 to 40 feet below grade. Where penetrated, the organic silt was underlain by a sand and gravel stratum.

The fill stratum consisted of grey-brown to black sandy silt with varying percentages of gravel, and clay and contained concrete, brick, wood, cinders, and glass fragments. Standard penetration test (SPT) N-values collected in the fill stratum ranged widely from 4 bpf to 92 bpf, indicating a range of relative densities from loose to very dense. There was no observed trend in the observed N-values with depth, indicating that the fill material is of highly variable composition and was likely placed in an uncontrolled manner.

The organic silt stratum consisted of dark brown to green-grey clayey silt with trace sand, mica, and fibrous organic material. SPT N-values collected in the organic silt stratum ranged from 3

bpf to 15 bpf with an average value of 7 bpf, indicating a medium consistency. Considering the observed consistency and organic content, the organic silt is believed to be highly compressible.

The sand and gravel stratum underlying the organic silt consisted of brown-grey gravelly fine to medium sand with varying amounts of fines. SPT N-values in the sand and gravel ranged from 8 bpf to 38 bpf with an average value of 23 bpf, indicating a medium-dense relative density.

5.2.2 Four Mile Run

Fourteen borings located along the proposed flood wall and levee alignment were reviewed to evaluate the subsurface conditions beneath the structures. The subsurface conditions disclosed by these fourteen borings are similar to those encountered on the north side of Four Mile Run beneath the Arlington Wastewater Treatment Plant flood wall, with an upper stratum of fill material overlying organic silt and sand and gravel. However, two additional soil strata were observed beneath the proposed Four Mile Run Coastal storm risk control structures: an upper stratum of clayey sand, and a deeper stratum of sandy silt. The fill stratum was encountered in all but four of the fourteen evaluated soil borings, ranging in thickness from 2.5 to 14.5 feet. The clayey sand stratum was encountered beneath the fill in five borings and beginning at ground surface in one boring. The clayey sand ranged from 3 to 14.5 feet thick where penetrated, and one boring terminated in the clayey sand at 25 feet below grade. The organic silt stratum was encountered in eleven of the fourteen evaluated borings, typically beneath the fill or clayey sand strata. However, the organic silt was encountered beginning at ground surface in three borings located in Four Mile Run Park adjacent to existing wetlands. The organic silt was consistently underlain by the sand and gravel stratum, wherein the majority of the borings were terminated at depths ranging from 25 to 30 feet below grade. The sand and gravel stratum was penetrated in four of the evaluated soil borings, and was underlain by the sandy silt stratum. Five of the evaluated soil borings terminated in the sandy silt stratum at depths ranging from 30 to 60 feet below grade.

The fill stratum consisted of grey-brown to black sandy silt with varying percentages of gravel, and clay and contained concrete, brick, wood, cinders, and glass fragments. Standard penetration test (SPT) N-values collected in the fill stratum ranged from 3 bpf to 17 bpf, indicating a range of relative densities from loose to medium dense. There was no observed trend in the observed N-values with depth, indicating that the fill material is of highly variable composition and was likely placed in an uncontrolled manner.

The clayey sand stratum consisted of brown to grey sand and clay in near equal proportions. SPT N-values in the clayey sand ranged from 6 bpf to 39 bpf with an average value of 21 bpf which corresponds to a medium dense material.

The organic silt stratum consisted of dark brown to green-grey clayey silt with trace sand, mica, and fibrous organic material. SPT N-values collected in the organic silt stratum ranged from 2 bpf to 11 bpf with an average value of 7 bpf, indicating a medium consistency. Considering the observed consistency and organic content, the organic silt is believed to be highly compressible.

The sand and gravel stratum underlying the organic silt, fill, or clayey sand consisted of brown-grey gravelly fine to medium sand with varying amounts of fines. SPT N-values in the sand and gravel ranged from 6 bpf to 22 bpf with an average value of 11 bpf, indicating a medium-dense relative density.

The sandy silt stratum consisted of green-grey sandy silt. SPT N-values in the sandy clay ranged from 16 bpf to 67 bpf with an average value of 42 bpf, which corresponds to a hard consistency.

5.3 Belle Haven

The available geotechnical data was somewhat limited for the Belle Haven site, consisting of two soil borings (B-9A and B-10A) performed as part of a small subsurface exploration for the Final Flood Damage Reduction Analysis for Belle Haven Watershed, prepared by the USACE Baltimore District. The two soil borings are located in the central portion of the Belle Haven site, with one boring near the alignment of the proposed flood wall.

The subsurface conditions disclosed by the Belle Haven borings consisted of an upper stratum of fill material that ranged from 2.5 to 12 feet thick. The fill stratum was underlain by a 9-foot-thick sandy clay stratum in one of the two borings (B-10A). Beneath the sandy clay in boring B-10A and the fill in B-9A is a 20 to 24.5-foot-thick stratum of silty sand, followed by a sand and gravel stratum wherein the borings were terminated at 50 feet below grade.

The fill stratum consisted of grey-brown sand and silt with varying percentages of gravel and clay and contained trace amounts of asphalt fragments. Standard penetration test (SPT) N-values collected in the fill stratum ranged from 2 bpf to 7 bpf with an average value of 5 bpf, indicating a loose relative density.

The sandy clay stratum consisted of brown clay with sand. SPT N-values in the sandy clay ranged from 3 bpf to 6 bpf with an average value of 5 bpf, which corresponds to a soft to medium consistency.

The silty sand stratum consisted of brown silty medium to fine sand with trace gravel. SPT N-values collected in the silty sand stratum ranged from weight of sampling hammer (W.O.H.) to 12 bpf, with lower N-values observed in the upper portion of the stratum that then increase with depth. The observed range of SPT N-values corresponds to a range of relative densities from very loose to medium dense.

The sand and gravel stratum consisted of light- to orange-brown sand and gravel with trace to some fines. Standard penetration test (SPT) N-values collected in the sand and gravel stratum ranged from 12 bpf to 28 bpf with an average value of 18 bpf, indicating a medium-dense relative density.

6. GROUNDWATER

Groundwater levels encountered at the time of drilling were recorded on the boring logs of the previous subsurface explorations and are summarized below:

- Reagan Airport: groundwater depth range of 4.5 to 11.3 feet below grade, corresponding to an elevation range of EL 7.2 to EL 0.4.
- Arlington WPCP: groundwater depth range of 4.5 to 14 feet below grade, corresponding to an elevation range of EL 2.7 to EL -0.9.
- Four Mile Run: groundwater depth range of 0 to 11.5 feet below grade, corresponding to an elevation range of EL 8.0 to EL -0.4.
- Belle Haven: groundwater depth range of 1.2 to 5.7 feet below grade, corresponding to an elevation range of EL 4.4 to EL 3.8.

It should be noted that as all of the sites of the proposed coastal storm risk protection measures are near tidally-influenced waterways, and so the groundwater levels will be affected by the tidal cycle as well as seasonal variation.

7. SEISMICITY

The seismic hazard in Arlington and Fairfax Counties is low. Virginia is not located near tectonic plate boundaries; however, the commonwealth does host three seismic zones, defined as "an area of seismicity probably sharing a common cause" by the U.S. Geological Survey. The closest seismic zone to the project area is the Central Virginia Seismic Zone (CVSV), which stretches from Richmond to Charlottesville and has been recognized as an area of long-term, low-magnitude seismic activity. The largest earthquake to hit Virginia in the past 30 years was a magnitude 5.8 event in Mineral, VA on 8/23/11, approximately 90 miles southwest of the Arlington area. Other recorded seismic events near the Arlington area are summarized in Table 7-1 below.

Table 7-1 – Summary of Past Seismic Events Near Proposed Project Site

Date	Location	Magnitude	Distance to Arlington Area (miles)
8/4/2021	Clarksville, MD	2.1	40
8/17/2018	Belmont, VA	1.3	30
8/9/2015	Crofton, MD	1.9	30
5/6/2008	Ravensworth, VA	2.0	15
9/29/1997	Manassas, VA	2.5	30

8. COASTAL STORM RISK MANAGEMENT STRUCTURES

Coastal storm risk management structures under consideration for this project include earthen levees and concrete T-walls, to be constructed in various orientations among the sites to employ structural coastal storm risk control measures. Additional ancillary structures include aluminum stop log closure gates, elevated curbing, and concrete box culverts with pump stations. Wall heights are expected to range from 5 to 8 feet for earthen levees and from 3 to 9 feet for proposed T-wall structures.

9. GEOTECHNICAL CONCERNS

Based on a review of the available subsurface information, three primary geotechnical items of concern arise: the nature of the existing fill material, the presence of the highly compressible organic silt stratum, and the loose state of the fill and natural soil deposits encountered at the Belle Haven site.

Fill material was encountered at all four of the project sites. The variable composition and density of the fill is typical of urban environments, particularly in low-lying areas that were reclaimed for their original construction as is the case for Reagan Airport. Fills placed during land reclamation are often placed with little to no engineering controls or compactive effort, resulting in a material with poor engineering characteristics that is unsuitable for the support of new loading associated with pavements or shallow foundations. It is therefore necessary to consider improving the fill material to correspondingly improve its engineering properties or bypass the fill through the use of deep foundation systems to support new structures.

The presence of highly compressible organic cohesive material is not uncommon in waterfront construction, where sometimes thick alluvial deposits of soft, fine-grained material are found. The nature of coastal storm risk control structures is to raise grade, whether through the construction of earthen levees or concrete T-wall structures. Design and construction of the proposed levee and wall systems will need to include detailed settlement and global stability analyses to properly evaluate the short- and long-term effects of the compressible stratum on the structure's performance.

The loose state of the fill and natural materials disclosed in the two Belle Haven soil borings is of particular concern due to the primarily cohesionless nature of the soil profile. Granular soils in a loose state of relative density are subject to liquefaction under seismic loading and can become the controlling factor in geotechnical design. A related challenge associated with the loose, granular nature is the elevated hydraulic conductivity of the soil mass and resulting seepage implications beneath coastal storm risk control structures during storm events.

10. GEOTECHNICAL DESIGN AND RECOMMENDATIONS

10.1 Material Properties

The historic boring logs and laboratory test results were used to develop preliminary design soil profiles for use in the geotechnical evaluations. Soil properties were developed considering laboratory test results, correlation with SPT N-values, and documented typical values based on soil type and consistency. Soil properties used for the 10% design effort for the Arlington WPCP and Belle Haven sites are provided below in Tables 10-1 and 10-2, respectively.

Table 10-1 – Summary of Soil Strength Parameters, Arlington WPCP Site

Layer	Elevation		USCS	γ (pcf)	Q-Strength (Short-Term)		S-Strength (Long-Term)	
	Top	Bottom			c (psf)	φ	c (psf)	φ
1	13.5	3.5	SM	120	0	30	0	30
2	3.5	-8.5	ML	110	750	0	0	28
3	-8.5	-	SW	125	0	34	0	34

Table 10-2 – Summary of Soil Strength Parameters, Belle Haven Site

Layer	Elevation		USCS	γ (pcf)	Q-Strength (Short-Term)		S-Strength (Long-Term)	
	Top	Bottom			c (psf)	φ	c (psf)	φ
1	10	7.5	SM	120	0	30	0	30
2	7.5	-1.5	CL	110	750	0	0	28
3	-1.5	-26.5	SM	110	0	28	0	28
4	-26.5	-	SW	125	0	34	0	34

10.2 Settlement

Fill placement will be necessary to raise grades for the construction of proposed levees in the southern limit of the coastal storm risk protection measures of the Belle Haven site. Levee heights ranging from 3 to 8 feet are expected, with a 10-foot crest width and 3.0H:1.0V side slopes. The effect of this fill placement will induce consolidation and immediate settlement of the underlying existing fill, clay, and sand strata.

Soil settlement analysis was performed in accordance with methods listed in EM 1110-1-1904. Immediate settlement of cohesive soil was estimated using the Perloff approximation, provided in section 3-8.b of the EM. Consolidation settlement was evaluated using the one-dimensional consolidation test results performed on the clay stratum. Immediate settlement of the underlying sand stratum was estimated using the Schmertmann approximation, provided in Section 3-3.d. Stress influence values were selected using the influence value chart for vertical stresses beneath an embankment of infinite length (NAVFAC DM 7.1, Chapter 4, Figure 6). Using these methods and an embankment height of 7 feet, an immediate settlement of approximately 0.4 inches and a consolidation settlement of approximately 2.8 inches is expected beneath the 7-foot-high fill, for a total post-construction settlement of 3.2 inches. The immediate settlement portion is expected to occur relatively quickly during placement of new fill material, whereas the consolidation settlement is expected to occur gradually over the life of the project.

Soil settlement calculations are included in Attachment B.

10.3 Liquefaction Screening

Liquefiable soils typically consist of saturated loose sand of uniform gradation or low-plasticity silt of soft consistency. No instances of such materials were observed in the historic boring logs

performed at the Arlington WPCP site, but loose sands were observed in the boring logs performed at the Belle Haven site.

A liquefaction screening was performed for both sites following the method described in Youd and Idriss, 2001 and is included in Attachment B. The peak ground acceleration (PGA) used in the liquefaction screening was obtained from the USGS site specific hazard tool using a 2% probability of exceedance in 50 years, which corresponds to an event with a return period of 475 years. The results of the liquefaction screening indicate that the soils underlying the Arlington WPCP are not susceptible to liquefaction under the evaluated seismic load, whereas the loose sand stratum underlying the sandy clay stratum at the Belle Haven site is susceptible to liquefaction.

10.4 Seismic Site Class

The seismic site class was evaluated using the site classification defined in Section C3.10.3 of the LRFD Bridge Design Specifications, 8th Edition (LRFD 8) (AASHTO 2017b). The average corrected N-value method (Method B) was used to establish the site classification.

The average corrected N-value was calculated at all four of the 2-inch split spoon-sampled SPT historic soil boring locations along or adjacent to the proposed flood wall alignment at the Arlington WPCP site. The average corrected N-value for each boring ranged from 10 to 29, with an overall average of 18. Per Table 3.10.3.1-1 of LRFD 8 seismic site class methodology, the Arlington WPCP site classifies as Site Class D. It should be noted that corrected SPT blow counts within 100 feet of ground surface are needed to properly evaluate seismic site class, and the available historic borings were limited to a depth range from 22.5 to 30 feet. Therefore, additional depth data is necessary before a proper evaluation of seismic site class can be made. A copy of the seismic site class determination spreadsheet for Arlington WPCP is included in Attachment B.

Due to the presence of liquefiable soils beneath the Belle Haven site, the seismic site class for this site classifies as Site Class F. As with the Arlington site, the current assessment of seismic site class for Belle Haven is based on a very limited amount of soil borings and must be substantiated through the performance of additional subsurface exploration.

10.5 Foundations

10.5.1 Arlington WPCP Flood Wall

The proposed flood T-wall structure protecting the Arlington WPCP may be supported on shallow foundations designed for a net allowable bearing pressure of up to 3,000 pounds per square foot (psf). Shallow foundation elements shall be constructed a minimum of 2 feet below adjacent ground surface elevation for frost protection. Geometry of the proposed stream bank improvements shall be considered when determining foundation subgrade elevation. In addition, foundation elements shall not be constructed until the following foundation subgrade improvement procedures have been implemented.

The existing soils should first be excavated to a depth of 3 feet below the planned bottom of foundation level. The excavation should extend laterally a distance of at least 1.5 feet from the outside edges of the foundations. The exposed subgrade should then be thoroughly compacted with at least six passes of a vibratory roller with a static drum weight of at least 12,000 pounds. Following proof compaction, the excavation should be backfilled to restore foundation subgrade elevation using structural fill placed and compacted in controlled lifts not exceeding 12 inches in loose thickness.

Shallow foundation geometry for the proposed T-walls was evaluated using the USACE program CTWALL-R. CTWALL-R runs were performed for four wall heights: 3-foot, 4-foot, 5-foot, and 6-foot, resulting in footing base widths of 5 feet, 6 feet, 7 feet, and 8 feet, respectively. CTWALL-R analysis outputs are provided in Attachment B.

10.5.2 Belle Haven Flood Wall

The proposed flood T-wall structure protecting the Belle Haven site must be designed to resist the possible liquefaction of the loose sand stratum in the event of a seismic event. The options available can be broadly grouped into two categories: shallow foundations combined with a subgrade improvement program, or deep foundations to bypass the problematic soils. Following discussion with the project team, it was decided to move toward using deep foundations in lieu of subgrade improvement, at least at this early stage of the project.

Both driven and drilled pile types could be suitable to support the proposed Belle Haven flood walls and pump house structures, which are expected to range in height from 5 feet to 9 feet for the flood walls, and up to 12 feet for the pump houses. A pile capacity evaluation was performed for two types of 14-inch-diameter drilled piles: standard continuous flight auger (CFA) piles and drilled displacement (DD) piles using guidance provided in Geotechnical Engineering Circular (GEC) No. 8, Design and Construction of Continuous Flight Auger Piles. Drilled displacement piles offer advantages over standard continuous flight auger piles due to their unique tooling, including increased capacity and reduced cuttings generation during installation.

The pile capacity evaluation assumed no contribution to capacity from the soils between ground surface and the liquefiable loose sand stratum (Stratums 1 through 3) and a 60-foot pile length. This resulted in an allowable pile capacity of approximately 32 tons for the CFA pile and 48 tons for the DD pile. Pile capacity spreadsheets are provided in Attachment B.

10.6 Global Stability Analysis

A preliminary global stability analysis was performed for the proposed 7-foot-high levee of the Belle Haven site using the SlopeW module of GeoStudio. SlopeW performs a two-dimensional limit equilibrium stability analysis. The analyses were run using Spencer's Method and were based on a steady-state condition, wherein the embankment is hydraulically loaded to flood stage and steady-state seepage is occurring. Under these conditions, it was observed that the proposed levee did not achieve a satisfactory factor of safety against slope stability failure. Subsequent

SlopeW runs were performed following the addition of a clay core within the embankment cross section, which resulted in a factor of safety against slope stability failure of 1.3.

10.7 Seepage Analysis

10.7.1 Seepage Analysis of Levees

Preliminary seepage analysis was performed assuming a 7-foot-high levee with a 10 foot wide crest and 3 horizontal to 1 vertical slopes. Permeability constants for native materials and the levee materials were chosen to be consistent with published values corresponding to similar materials placed via standard construction techniques. GeoStudio SEEP/W is a finite element program that can identify phreatic levels, exit gradients, and pore- water pressures in both steady state and transient cases. Analysis was completed using the SEEP/W software. The total seepage rate for the steady state case is provided below in Table 10-3.

Table 10-3 – Summary of Seepage Rates – Belle Haven Levee

Evaluated Case	Total Seepage Rate (ft^3/sec)
Levee without Clay Core	1.5×10^{-5}
Levee with Clay Core	5.6×10^{-6}

10.7.2 Seepage Analysis of Flood Walls

Preliminary seepage analysis was also performed for the proposed T-Wall flood walls for both the Arlington WPCP site and Belle Haven site. The seepage analysis for Arlington WPCP was based on a 5-foot-high T-Wall founded on shallow foundations, whereas the seepage analysis for Belle Haven was based on an 8-foot-high T-wall founded on pile foundations. The Belle Haven T-Wall was evaluated with and without a 25-foot-deep sheet pile cutoff to observe the effect of a cutoff wall on the seepage rate. The total seepage rates for the flood wall cases are provided below in Table 10-4.

Table 10-4 – Summary of Seepage Rates – Flood Walls

Evaluated Case	Total Seepage Rate (ft^3/sec)
Arlington WPCP T-Wall	5.9×10^{-5}
Belle Haven T-Wall, No Cutoff	5.5×10^{-6}
Belle Haven T-Wall, with Cutoff	5.1×10^{-6}

Based on the data in Table 10-4, there is little difference in the observed total seepage rates of the Belle Haven T-Wall with and without the sheet pile cutoff; however, additional analysis and subsurface data collection is necessary before the cutoff can be ruled out, and so for the time being the cutoff should be included in the preliminary Belle Haven T-Wall design.

11. RECOMMENDATIONS FOR ADDITIONAL SUBSURFACE EXPLORATION

Additional geotechnical subsurface exploration activities are necessary to supplement the available geotechnical data and enable the proper design and construction of the proposed coastal storm risk control structures. This additional subsurface exploration would be completed during the pre-construction engineering & design (PED) stage. Subsurface exploration activity should follow the guidance in EM 1110-2-1913, Design and Construction of Levees, and is expected to consist of field exploration activity including but not limited to soil borings, cone penetrometer soundings, geophysical testing, and in situ strength testing.

With regard to levee design, future subsurface exploration activity will be crafted to identify subsurface characteristics that affect levee design, such as the fines content of soil strata and the presence of any confining aquicludes.

12. REFERENCES

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13. ATTACHMENTS

13.1 Attachment A – Existing Geotechnical Data

13.1.1 Reagan Airport

13.1.2 Arlington WPCP and Four Mile Run

13.1.3 Belle Haven

13.2 Attachment B – Geotechnical Evaluations

13.2.1 Settlement

13.2.2 Liquefaction Screening

13.2.3 Seismic Site Class

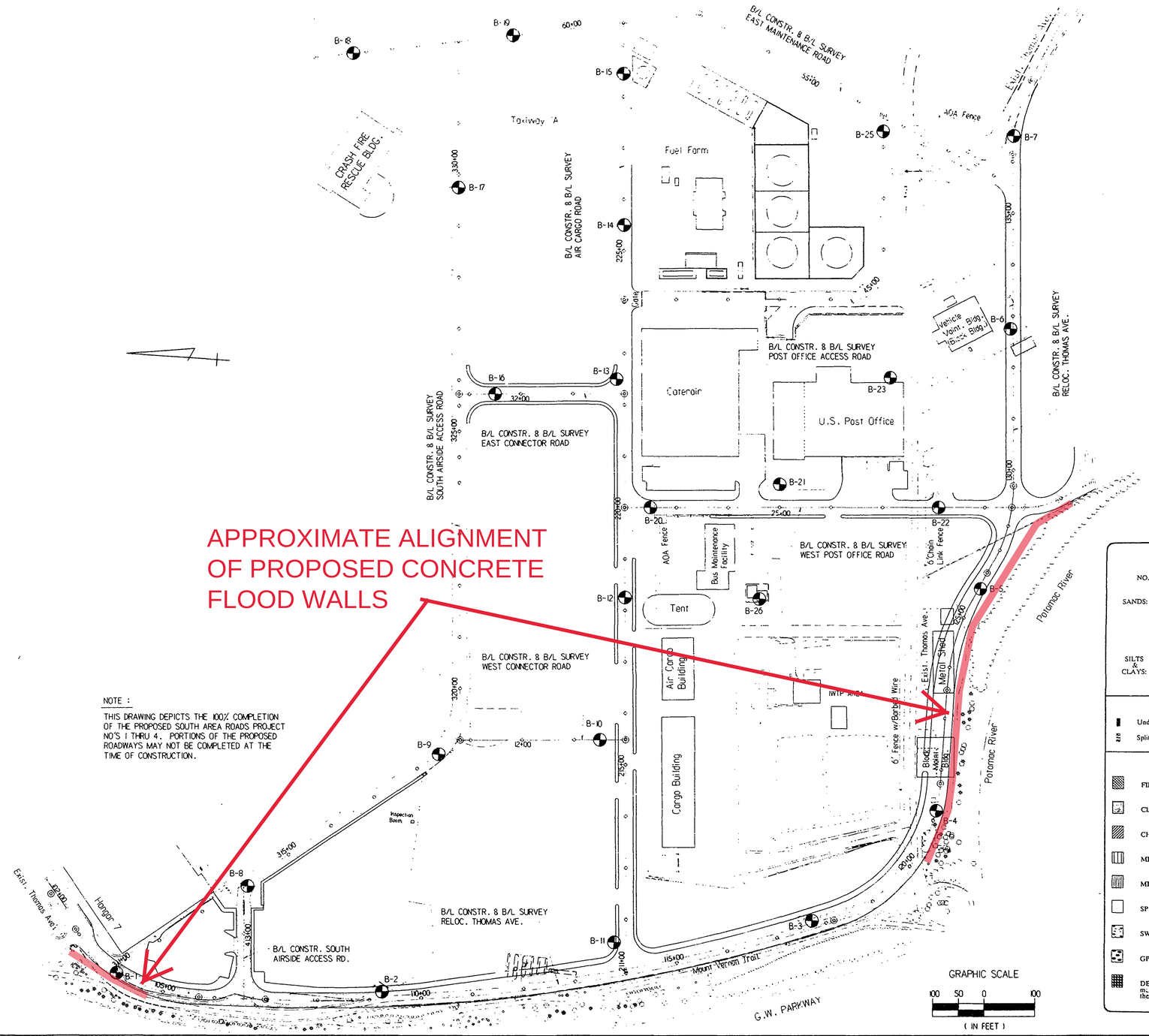
13.2.4 Arlington WPCP Flood Wall Foundations

13.2.5 Belle Haven Flood Wall Foundations

13.2.6 Global Stability Analysis

13.2.7 Seepage Analysis

12.1.1 – Reagan Airport Geotechnical Data



NOTE :

THIS DRAWING DEPICTS THE 100% COMPLETION OF THE PROPOSED SOUTH AREA ROADS PROJECT NO'S 1 THRU 4. PORTIONS OF THE PROPOSED ROADWAYS MAY NOT BE COMPLETED AT THE TIME OF CONSTRUCTION.

BORING SCHEDULE

	Boring No.	Roadway	Station	Offset	Existing Ground Elev.
FOR BORING LOGS SEE SHEET C7.2	B-1	Relocated Thomas Ave.	104+04	4' RT.	13.7
	B-2	Relocated Thomas Ave.	109+25	15' LT.	11.8
	B-3	Relocated Thomas Ave.	117+75	12' LT.	11.0
BORING LOGS NOT PROVIDED	B-4	Relocated Thomas Ave.	121+20	0	12.0
	B-5	Relocated Thomas Ave.	125+66	5' RT.	14.8
	B-6	Relocated Thomas Ave.	132+75	5' LT.	8.3
	B-7	Relocated Thomas Ave.	136+50	0	10.4
FOR BORING LOGS SEE SHEET C7.2	B-8	South Airside Access Rd.	314+00	7' RT.	12.7
	B-9	South Airside Access Rd.	318+50	0	12.6
	B-10	West Connector Road	10+50	0	14.7
	B-11	Air Cargo Road	211+56	23' LT.	14.0
	B-12	Air Cargo Road	218+25	0	13.0
	B-13	Air Cargo Road	222+50	15' LT.	13.6
	B-14	Air Cargo Road	225+50	0	11.7
	B-15	Air Cargo Road	228+45	0	11.6
	B-16	East Connector Road	32+50	0	13.0
	B-17	South Airside Access Rd.	329+75	0	11.8
BORING LOGS NOT PROVIDED	B-18	East Maintenance Road	64+25	0	14.1
	B-19	East Maintenance Road	61+15	0	12.8
	B-20	West Post Office Road	27+50	0	12.6
	B-21	West Post Office Road	25+00	45' RT.	12.2
	B-22	West Post Office Road	21+90	0	11.0
	B-23	Relocated Thomas Ave.	131+80	240' LT.	10.4
	B-25	Post Office Access Rd.	48+30	0	8.2
	B-26	West Post Office Road	25+40	178' LT.	10.8

CORRELATION OF PENETRATION RESISTANCE WITH RELATIVE DENSITY AND CONSISTENCY

	NO. OF BLOWS, N	RELATIVE DENSITY
SANDS:	0-4	Very Loose
	5-10	Loose
	11-30	Firm
	31-50	Dense
	OVER 50	Very Dense

		CONSISTENCY
SILTS & CLAYS:	0-2	Very Soft
	3-4	Soft
	5-8	Firm
	9-15	Stiff
	16-30	Very stiff
	31-50	Hard
	OVER 50	Very Hard

PARTICAL SIZE IDENTIFICATION

BOULDERS:		Greater than 300 mm
COBBLES:		75 mm to 300 mm
GRAVEL:	Coarse	- 19.0 mm to 75 mm
	Fine	- 4.75 mm to 19.0 mm
SANDS:	Coarse	- 2.00 mm to 4.75 mm
	Medium	- 0.425 mm to 2.00 mm
	Fine	- 0.075 mm to 0.425 mm
SILTS & CLAYS:		Less than 0.075 mm

KEY TO DRILLING SYMBOLS

- Undisturbed Sample
- Split Spoon Sample
- Water Table 24 HR.
- Water Table at Time of Drilling
- C Caved Depth
- Loss of Drilling Water

KEY TO SOIL CLASSIFICATIONS

- FILL
- CL - Low plasticity inorganic clays
- CH - High plasticity inorganic clays
- ML - Low plasticity inorganic silts
- MH - High plasticity inorganic silts
- SP - Poorly graded sands
- SW - Well graded sands
- GP - Poorly graded gravels
- DECOMPOSED ROCK - A transitional material between soil and rock which retains the relict structure of the parent rock
- GW - Well graded gravels
- OL - Low plasticity organic silts and clays
- OH - High plasticity organic silts and clays
- SM - Silty sands
- GM - Silty gravels
- SC - Clayey sands
- GC - Clayey gravels
- SP-SM - Typical Dual Classification

NO.	REVISION	DATE

Johnson, Mirmiran & Thompson, P.A.

ENGINEERS - PLANNERS - SURVEYORS - LANDSCAPE ARCHITECTS
72 LOVETON CIRCLE SPARKS, MD. 21152
(410) 329-3100

COMMONWEALTH OF VIRGINIA — DANIEL T. CHENG — 020282 — PROFESSIONAL ENGINEER — 11/1/94

DATE	NOVEMBER 1, 1994
SCALE	1" = 100'
DESIGNED	D.A.L.
CHECKED	D.A.L.
DRAWN	A. DANIEL
ACCEPTED	D.R.H.
SUBMITTED	D.A.J.
APPROVED	T.D.H.

METROPOLITAN WASHINGTON AIRPORTS AUTHORITY

ENGINEERING DIVISION
DESIGN BRANCH

SOUTH AREA ROADS PROJECT No. 3

WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.

BORING LOCATION PLAN

DRAWING NUMBER: DCA-3017-47

SHEET NUMBER: C7.1

DEPTH (FT.)	DESCRIPTION
0.0	GRAVEL
0.5	FILL - brown clayey fine sand with little to trace fine gravel
9.8	Very soft gray clayey SILT(ML-MH) with little fine sand
13.0	Very soft gray clayey SILT (MH)
19.0	Loose gray clayey SAND(SC) with some si
23.0	Firm clayey fine to coarse SAND(SC)
27.0	BORING TERMINATED AT 27, 4-2-92.

ATV Rig
Drilling Method: Hollow Stem Augers
Driller: Dorian Dowd
Driller's Helper: Jorge Del-Cid
Logged by: J.C. Giese

ELEVATION (FT.) 13.7, 8.7, 3.7, -1.3, -6.3, -11.3, -16.3

● PENETRATION - BLOWS/FOOT: 6, 11, 18, 3, 2, 2, 3, 11

REMARKS:

TEST BORING RECORD

BORING NUMBER	B-1
DATE DRILLED	April 2, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING

DEPTH (FT.)	DESCRIPTION
0.0	ASPHALT
0.5	GRAVEL BASE
7.0	FILL - brown clayey fine to medium sand with little fine to medium gravel
17.0	Firm brown fine to medium SAND(SC) with some to little clay

BORING TERMINATED AT 17, 4-7-92.

ATV Rig
Drilling Method: Hollow Stem Augers
Driller: Thomas Chew
Driller's Helper: Paul Welty
Logged by: J.C. Giese

ELEVATION (FT.) 11.8, 6.8, 1.8, -3.2, -8.2, -13.2, -18.2

● PENETRATION - BLOWS/FOOT: 28, 26, 31, 11, 10, 14, 11

REMARKS:

TEST BORING RECORD

BORING NUMBER	B-2
DATE DRILLED	April 7, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING

DEPTH (FT.)	DESCRIPTION
0.0	ASPHALT
3.0	FILL - brown fine to medium sandy clay with trace fine gravel
5.0	FILL - brown gray clayey medium sand
7.5	FILL - brown fine to medium sandy clay
10.0	FILL - brown clayey fine to medium sand with little fine to coarse gravel
12.5	Stiff brown gray fine sandy CLAY(CL) with trace organics
17.0	Firm brown clayey SAND (SC)

BORING TERMINATED AT 17, 4-7-92.

Note: Boring dry at time of drilling and to caved depth at 24 hours.

ATV Rig
Drilling Method: Hollow Stem Augers
Driller: Thomas Chew
Driller's Helper: Paul Welty
Logged by: J.C. Giese

ELEVATION (FT.) 11.0, 6.0, 1.0, -4.0, -9.0, -14.0, -19.0

● PENETRATION - BLOWS/FOOT: 11, 15, 6, 20, 13, 12

REMARKS:

TEST BORING RECORD

BORING NUMBER	B-3
DATE DRILLED	April 7, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING

DEPTH (FT.)	DESCRIPTION
0.0	ASPHALT
0.6	FILL - brown clayey medium sand with some fine to coarse gravel
5.0	Firm gray tan fine to medium sandy CLAY (CL) with trace fine gravel
13.0	Loose tan fine to medium SAND(SC) with some clay
17.0	BORING TERMINATED AT 17, 4-10-92

Note: Final water level is 15 minutes after end of boring.
ATV Rig
Drilling Method: Hollow Stem Augers
Driller: Thomas Chew
Driller's Helper: Kevin Hammond
Logged by: J.C. Giese

ELEVATION (FT.) 12.7, 7.7, 2.7, -2.3, -7.3, -12.3, -17.3

● PENETRATION - BLOWS/FOOT: 24, 17, 6, 10, 5, 9

REMARKS:

TEST BORING RECORD

BORING NUMBER	B-8
DATE DRILLED	April 10, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING

DEPTH (FT.)	DESCRIPTION
0.0	ASPHALT
0.5	GRAVEL BASE
1.5	FILL - tan orange clayey medium sand with some fine to coarse gravel
5.0	FILL - tan brown clayey fine to medium sand
7.0	Loose to firm tan brown fine to medium SAND (SC) with little clay
17.0	BORING TERMINATED AT 17, 4-10-92.

Note: Water level shown is at time of boring and 15 minutes after end of boring.

ATV Rig
Drilling Method: Hollow Stem Augers
Driller: Thomas Chew
Driller's Helper: Kevin Hammond
Logged by: J.C. Giese

ELEVATION (FT.) 12.6, 7.6, 2.6, -2.4, -7.4, -12.4, -17.4

● PENETRATION - BLOWS/FOOT: 33, 40, 30, 7, 15, 10

REMARKS:

TEST BORING RECORD

BORING NUMBER	B-9
DATE DRILLED	April 10, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING

DEPTH (FT.)	DESCRIPTION
0.0	ASPHALT
2.5	FILL - brown clay with little fine sand and trace fine gravel
5.0	FILL - brown gray clayey fine to medium sand
7.5	FILL - brown gray clayey fine to medium sand with some fine to coarse gravel
9.0	Firm gray medium SAND (SC) with little fine gravel and little to trace clay
13.0	Loose to firm brown fine to coarse SAND (SM) with some silt
17.0	BORING TERMINATED AT 17, 4-10-92.

Note: Final water level is 15 minutes after end of boring.

ATV Rig
Drilling Method: Hollow Stem Augers
Driller: Thomas Chew
Driller's Helper: Kevin Hammond
Logged by: J.C. Giese

ELEVATION (FT.) 14.7, 9.7, 4.7, -0.4, -5.4, -10.4, -15.4

● PENETRATION - BLOWS/FOOT: 17, 21, 28, 21, 10

REMARKS:

TEST BORING RECORD

BORING NUMBER	B-10
DATE DRILLED	April 10, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING

DEPTH (FT.)	DESCRIPTION
0.0	ASPHALT
0.3	FILL - brown fine to medium sandy clay
7.0	Very stiff brown fine to medium sandy CLAY(CL)
13.0	Loose to firm gray fine to medium SAND(SC) with little clay
17.0	BORING TERMINATED AT 17, 4-7-92.

ATV Rig
Drilling Method: Hollow Stem Augers
Driller: Thomas Chew
Driller's Helper: Paul Welty
Logged by: J.C. Giese

ELEVATION (FT.) 14.0, 9.0, 4.0, -1.0, -6.0, -11.0, -16.0

● PENETRATION - BLOWS/FOOT: 10, 16, 12, 24, 26, 10

REMARKS:

TEST BORING RECORD

BORING NUMBER	B-11
DATE DRILLED	April 7, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING

NOTE : FOR BORING LOCATIONS SEE BORING LOCATON PLAN

NO.	REVISION	DATE

Johnson, Mirmiran & Thompson, P.A.
ENGINEERS - PLANNERS - SURVEYORS - LANDSCAPE ARCHITECTS
72 LOVETON CIRCLE SPARKS, MD. 21152
(410) 329-3100

COMMONWEALTH OF VIRGINIA
DANIEL T. CHENG
020262
PROFESSIONAL ENGINEER
11/1/94

DATE	NOVEMBER 1, 1994
SCALE	NONE
DESIGNED	M.R.M.
CHECKED	D.A.L.
DRAWN	L.E.E.
ACCEPTED	D.R.H.
SUBMITTED	D.A.J.
APPROVED	F.D.H.

METROPOLITAN WASHINGTON AIRPORTS AUTHORITY

ENGINEERING DIVISION
DESIGN BRANCH

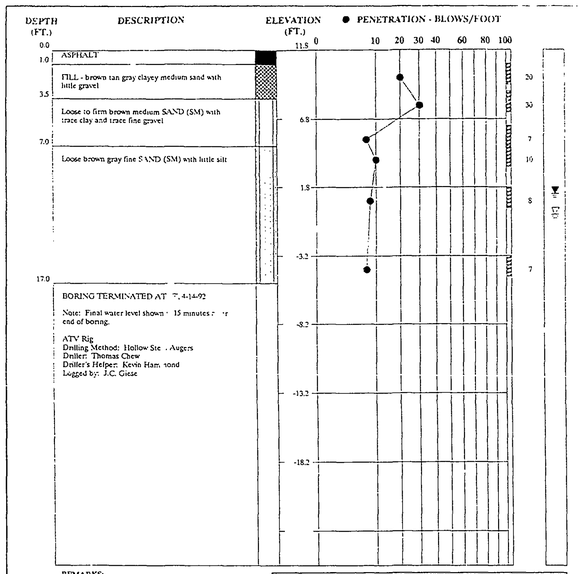
SOUTH AREA ROADS
PROJECT No. 3

WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.

BORING LOGS

DRAWING NUMBER
DCA-3017-48

SHEET NUMBER
C7.2



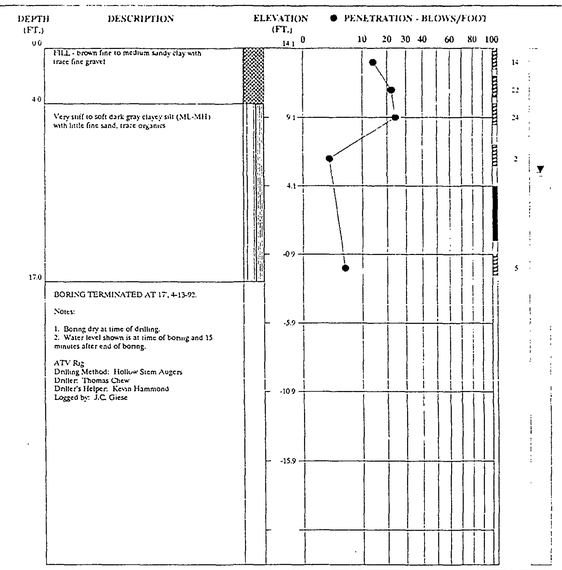
REMARKS:

TEST BORING RECORD

BORING NUMBER	B-17
DATE DRILLED	April 14, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING



REMARKS:

TEST BORING RECORD

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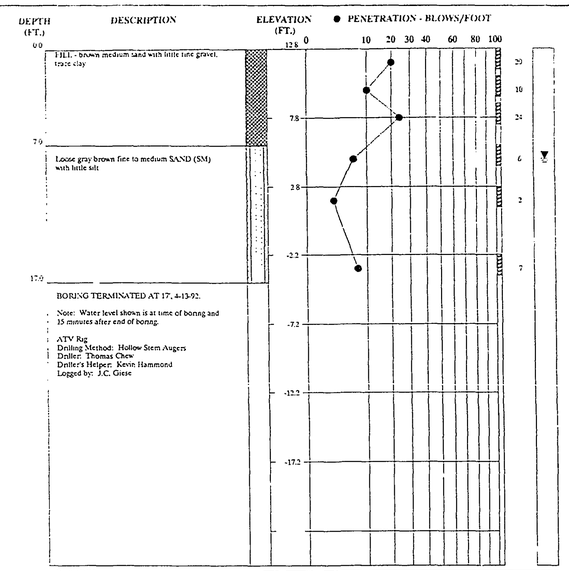
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING



REMARKS:

TEST BORING RECORD

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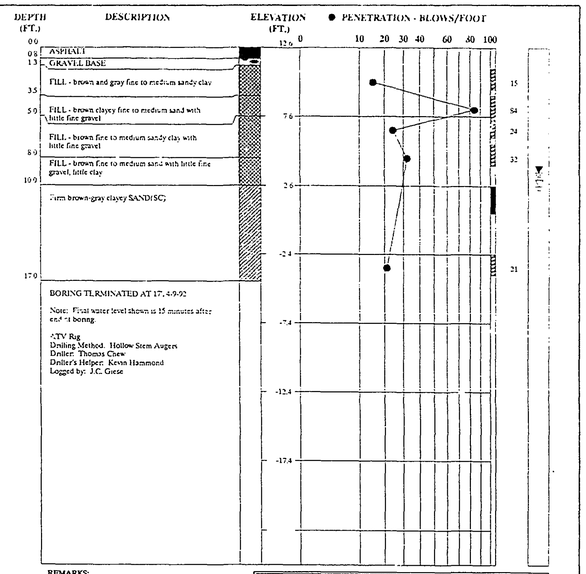
DATE DRILLED	April 13, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING



REMARKS:

TEST BORING RECORD

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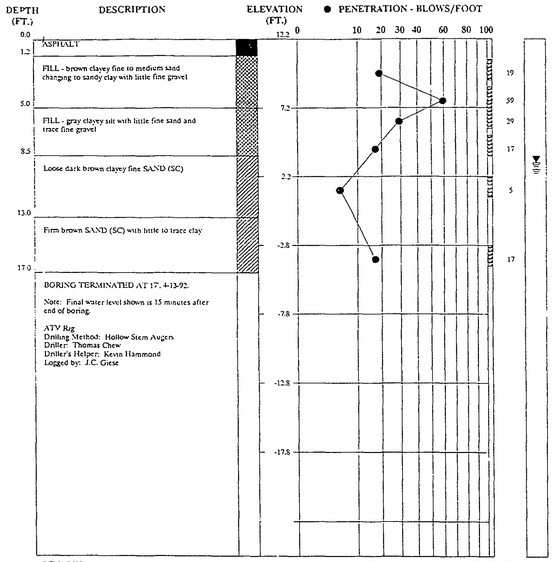
DATE DRILLED	April 9, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING



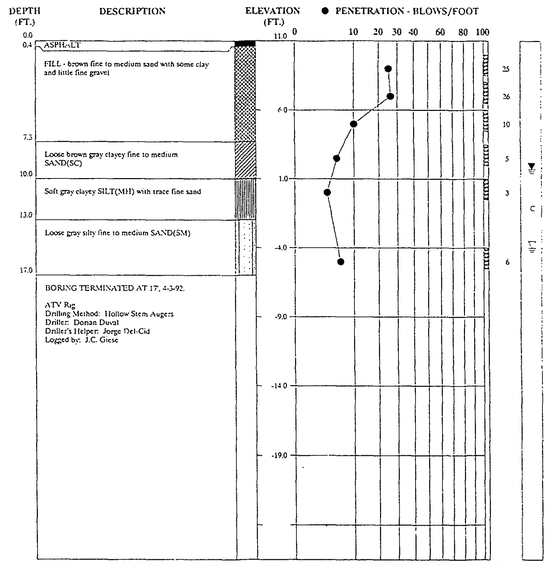
REMARKS:

TEST BORING RECORD

BORING NUMBER	B-21
DATE DRILLED	April 13, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING



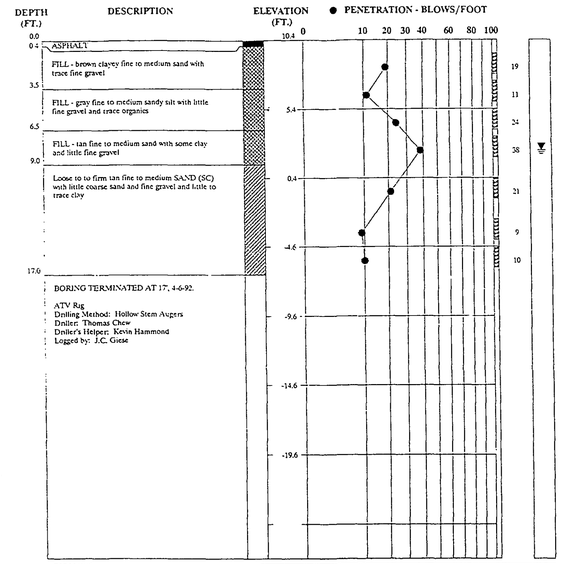
REMARKS:

TEST BORING RECORD

BORING NUMBER	B-22
DATE DRILLED	April 3, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING



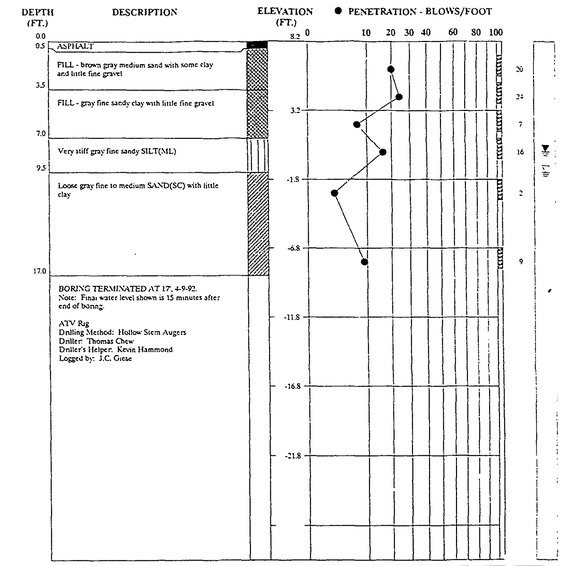
REMARKS:

TEST BORING RECORD

BORING NUMBER	B-23
DATE DRILLED	April 6, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING



REMARKS:

TEST BORING RECORD

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DATE DRILLED	April 9, 1992
PROJECT NUMBER	482-9352-01
PROJECT	National Airport, South Area Roads
PAGE 1 OF 1	

SEE KEY SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS USED ABOVE

LAW ENGINEERING

NO.	REVISION	DATE

Johnson, Mirmiran & Thompson, P.A.

ENGINEERS - PLANNERS - SURVEYORS - LANDSCAPE ARCHITECTS
72 LOVETON CIRCLE SPARKS, MD. 21152
(410) 329-3100

COMMONWEALTH OF VIRGINIA
DANIEL T. CHENG
020282
PROFESSIONAL ENGINEER
5-11-93

DATE	MARCH 10, 1993
SCALE	NONE
DESIGNED	M.R.M.
CHECKED D.A.L.	DRAWN L.E.E.
ACCEPTED	D.F.K.
SUBMITTED	D.A.J.
APPROVED	F.D.H.

METROPOLITAN WASHINGTON AIRPORTS AUTHORITY

ENGINEERING DIVISION
DESIGN BRANCH

SOUTH AREA ROADS

WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.

BORING LOGS

DRAWING NUMBER
DCA-3016-40

SHEET NUMBER
C7.2

INDEX OF DRAWINGS

SHEET COUNT	DRAWING NO.	SHEET NO.	SHEET TITLE
1 OF 52	DJCT0001	T0.1	TITLE SHEET
2 OF 52	DJCC0001	C0.1	INDEX OF DRAWINGS AND KEY MAP
3 OF 52	DJCC0002	C0.2	PROJECT OVERVIEW
4 OF 52	DJCC0003	C0.3	LEGEND, GENERAL NOTES, AND ABBREVIATIONS
5 OF 52	DJCC1001	C1.1	SITE ACCESS AND CONSTRUCTION STAGING PLAN
6 OF 52	DJCC1002	C1.2	GEOMETRIC LAYOUT
7 OF 52	DJCC1003	C1.3	MAINTENANCE OF TRAFFIC GENERAL NOTES AND DETAILS
8 OF 52	DJCC1004	C1.4	FAR PART 77 SURFACE PLAN
9 OF 52	DJCC1005	C1.5	FAR PART 77 SURFACE PLAN
10 OF 52	DJCC1006	C1.6	MAINTENANCE OF TRAFFIC AND PHASING PLAN PHASE I AND II
11 OF 52	DJCC1007	C1.7	MAINTENANCE OF TRAFFIC AND PHASING PLAN PHASE IIB AND IIC
12 OF 52	DJCC1008	C1.8	MAINTENANCE OF TRAFFIC AND PHASING PLAN PHASE III AND IV
13 OF 52	DJCC1009	C1.9	ROADWAY AND STORM DRAIN PLAN 1
14 OF 52	DJCC1010	C1.10	ROADWAY AND STORM DRAIN PLAN 2
15 OF 52	DJCC1011	C1.11	ROADWAY AND STORM DRAIN PLAN 3
16 OF 52	DJCC1012	C1.12	GRADING PLAN
17 OF 52	DJCC1013	C1.13	DRAINAGE AREA MAP
18 OF 52	DJCC1014	C1.14	STORMWATER POLLUTION PREVENTION
19 OF 52	DJCC1015	C1.15	STORMWATER POLLUTION PREVENTION NOTES AND DETAILS
20 OF 52	DJCC1016	C1.16	STORMWATER POLLUTION PREVENTION DETAILS
21 OF 52	DJCC1017	C1.17	PAVEMENT MARKING PLAN 1
22 OF 52	DJCC1018	C1.18	PAVEMENT MARKING PLAN 2
23 OF 52	DJCC1019	C1.19	PAVEMENT MARKING PLAN 3
24 OF 52	DJCC1020	C1.20	SIGNING PLAN
25 OF 52	DJCC1021	C1.21	PERMANENT SIGN SCHEDULE AND DETAILS
26 OF 52	DJCC2001	C2.1	DEMOLITION PLAN 1
27 OF 52	DJCC2002	C2.2	DEMOLITION PLAN 2
28 OF 52	DJCC2003	C2.3	DEMOLITION PLAN 3
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30 OF 52	DJCC3001	C3.1	TYPICAL SECTIONS AND PAVEMENT DETAILS
31 OF 52	DJCC3002	C3.2	ROADWAY PROFILE
32 OF 52	DJCC4001	C4.1	GUARDRAIL DETAILS
33 OF 52	DJCC4002	C4.2	GUARDRAIL DETAILS
34 OF 52	DJCC4003	C4.3	PERMANENT AOA SECURITY FENCE DETAILS
35 OF 52	DJCC4004	C4.4	STORM DRAIN PROFILES AND DETAILS
36 OF 52	DJCC4005	C4.5	STORM DRAIN DETAILS
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45 OF 52	DJCS1002	S1.2	SEDIMENT COLLECTION CULVERT TYPICAL SECTION AND DETAILS
46 OF 52	DJCS1003	S1.3	MISCELLANEOUS DETAILS
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48 OF 52	DJCE1002	E1.2	ELECTRICAL ENCLOSURE DETAILS
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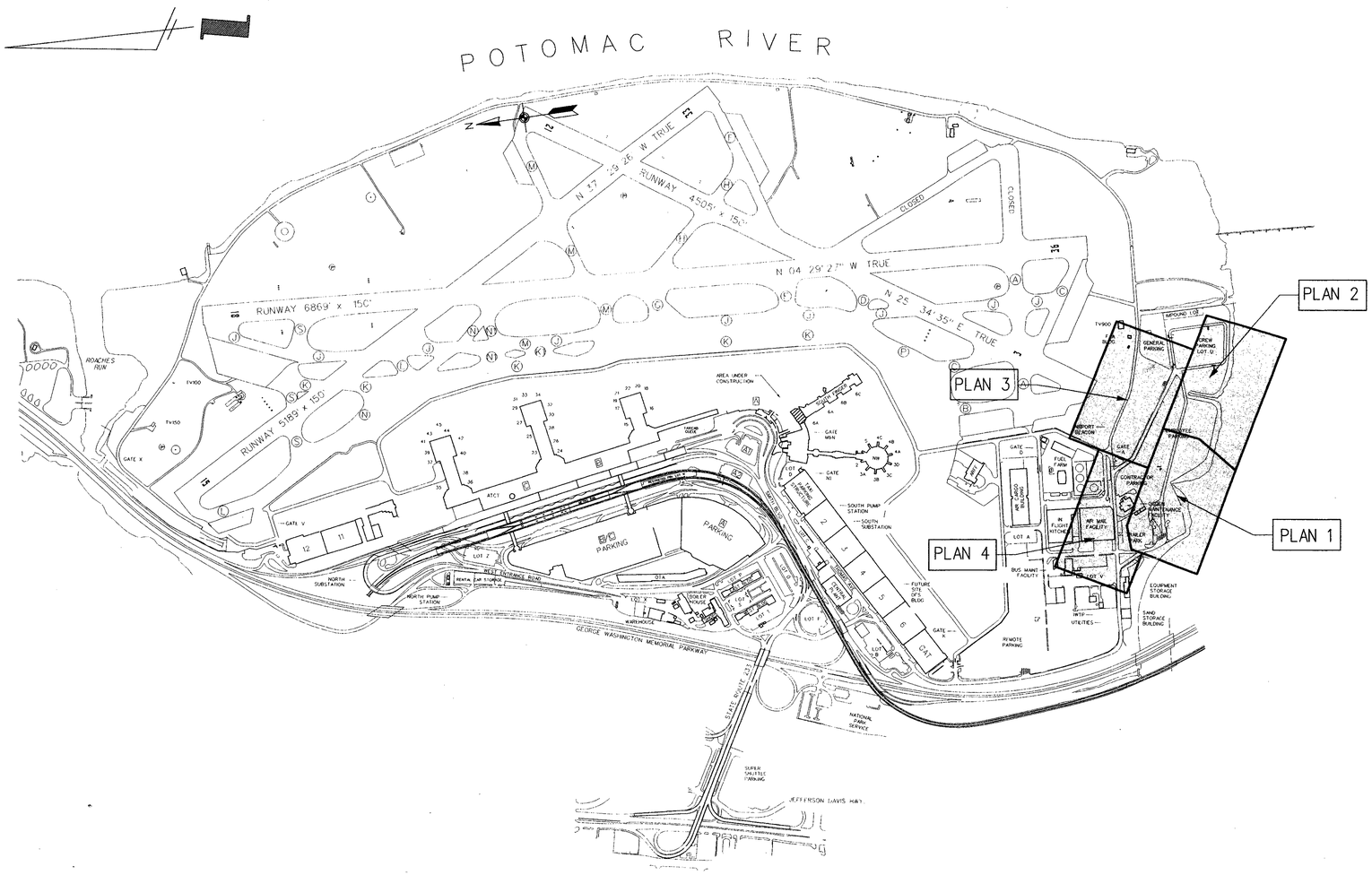
51 OF 52	DJCE2003	E2.3	ELECTRICAL AND LIGHTING PLAN 3
52 OF 52	DJCE7001	E7.1	LIGHTING DETAILS



KEY MAP

500 250 0 500 1000

SCALE: 1"=500'

NO.	REVISION	DATE

JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future
72 Loveton Circle Baltimore, Maryland 21152-0949

Daniel T. Chang
8-17-99

DATE	AUG 17, 1999
SCALE	AS NOTED
DESIGNED	C.D.L.
DRAWN	E.B.B.
CHECKED	D.A.L.
ACCEPTED	D.R.H.
SUBMITTED	D.A.J.
APPROVED	F.D.H.

METROPOLITAN WASHINGTON AIRPORTS AUTHORITY

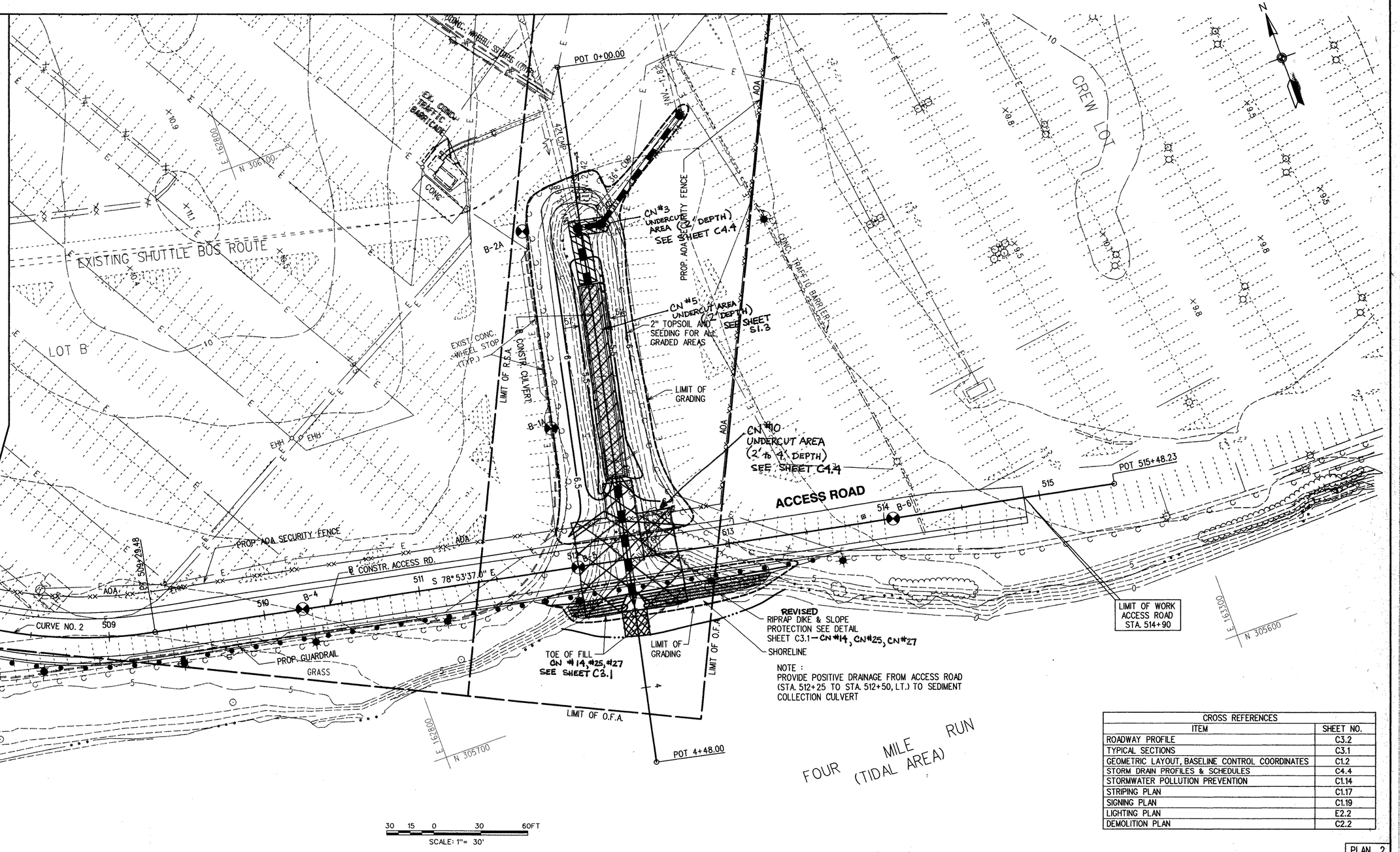
OFFICE OF ENGINEERING DESIGN DEPARTMENT

DRAWING TITLE
SOUTH AREA ROADS PROJECT 4B
RONALD REAGAN WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.
INDEX OF DRAWINGS AND KEY MAP

DRAWING NUMBER
DJCC0001

SHEET NUMBER
C0.1
sh 2 of 52

DJCC0001.dgn
DATE: 03-Aug-99 08:00



NOTE :
PROVIDE POSITIVE DRAINAGE FROM ACCESS ROAD (STA. 512+25 TO STA. 512+50, LT.) TO SEDIMENT COLLECTION CULVERT

30 15 0 30 60FT
SCALE: 1"= 30'

CROSS REFERENCES	
ITEM	SHEET NO.
ROADWAY PROFILE	C3.2
TYPICAL SECTIONS	C3.1
GEOMETRIC LAYOUT, BASELINE CONTROL COORDINATES	C1.2
STORM DRAIN PROFILES & SCHEDULES	C4.4
STORMWATER POLLUTION PREVENTION	C1.14
STRIPING PLAN	C1.17
SIGNING PLAN	C1.19
LIGHTING PLAN	E2.2
DEMOLITION PLAN	C2.2

PLAN 2

NO.	REVISION	DATE
CN #3	UNDERCUT @ MANHOLES 2-1 AND 2-2	3/23/00
CN #5	UNDERCUT @ STORMWATER DRAINAGE CULVERT	3/23/00
CN #10	UNDERCUT @ ROADWAY SECTION IN OUTFALL #017	4/04/00
CN #14	REVISED SLOPE @ OUTFALL #017	5/25/00
CN #25	ADDITIONAL SLOPE @ OUTFALL	7/13/00
CN #27	54" RCP CHANNEL EXCAVATION	8/8/00

JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future
72 Loveton Circle Baltimore, Maryland 21152-0949

COMMONWEALTH OF VIRGINIA
DANIEL T. CHENG
020262
PROFESSIONAL ENGINEER
8-17-99

DATE	AUG 17, 1999
SCALE	1" = 30'
DESIGNED	C.D.L.
DRAWN	E.B.B. CHECKED D.A.L.
ACCEPTED	D.R.H.
SUBMITTED	D.A.J.
APPROVED	F.D.H.

METROPOLITAN WASHINGTON AIRPORTS AUTHORITY

OFFICE OF ENGINEERING
DESIGN DEPARTMENT

DRAWING TITLE
SOUTH AREA ROADS PROJECT 4B
RONALD REAGAN WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.
GRADING PLAN

DRAWING NUMBER
DJCC1012

SHEET NUMBER
C1.12
sh 16 of 52

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DRAINAGE STRUCTURES SCHEDULE			
NUMBER	* STATION	TYPE	T.G. ELEV.
MH 2-1	STA. 1+05, 14.0' LT.	STANDARD PRECAST 60" MH	6.00
MH 2-2	STA. 1+05, 2.0' RT.	STANDARD PRECAST 96" MH	5.76
EW 2-1	STA. 3+41, ℄	PRECAST ENDWALL FOR 54" CIRCULAR PIPE CULVERT	---

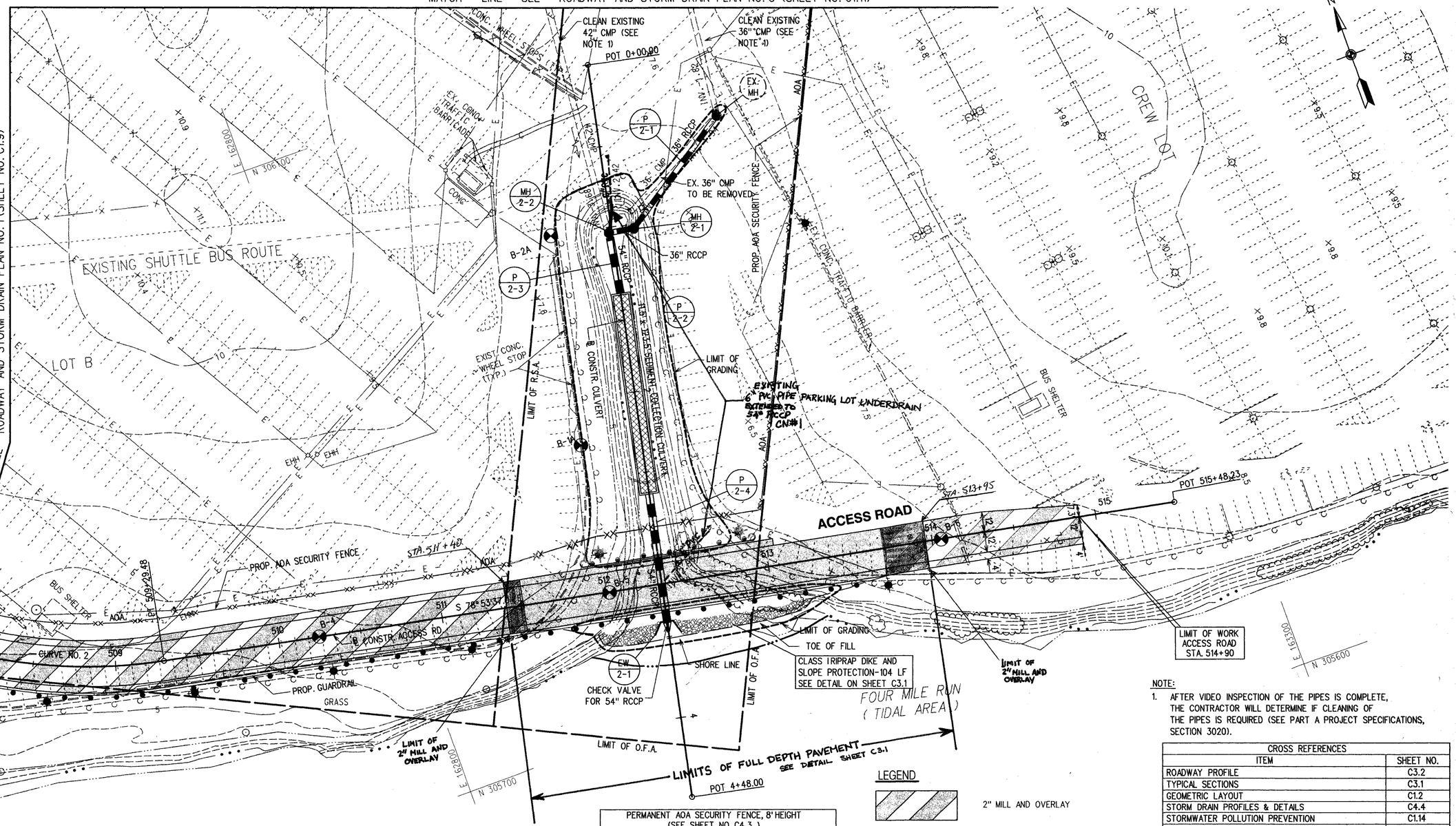
* BASELINE CONSTRUCTION CULVERT

PIPE SCHEDULE				
NUMBER	TYPE	LENGTH	INVERT IN	INVERT OUT
P 2-1	36" RCCP	83.0'	-1.91	-2.71
P 2-2	36" RCCP	13.0'	-2.81	-2.91
P 2-3	54" RCCP	36.0'	-3.73	-3.94
P 2-4	54" RCCP	79.0'	0.25	-0.16

NOTE: CONNECTION BETWEEN SEDIMENT COLLECTION CULVERT AND PIPES P 2-3 AND P 2-4 SHALL BE RESILIANT TO SHEAR CAUSED BY DIFFERENTIAL SETTLEMENT AND SHALL PROVIDE A WATERTIGHT SEAL.

MATCH LINE SEE ROADWAY AND STORM DRAIN PLAN NO. 3 (SHEET NO. C1.11)

MATCH LINE SEE ROADWAY AND STORM DRAIN PLAN NO. 1 (SHEET NO. C1.9)



CURVE NO. 2

Δ = 46° 45'42.8"
D = 19° 00' 00.0 "
R = 301.56 '
T = 130.38'
L = 246.12'
E = 26.98 '

W-BEAM GUARDRAIL, STD. GR-2 (SEE SHEET NO. C4.1 & C4.2)		
STATION TO STATION	LENGTH	REMARKS
508+00, 16' RT. TO 513+66, 16' RT.	566 L.F.	MEET EX. GUARDRAIL

PERMANENT AOA SECURITY FENCE, 8' HEIGHT (SEE SHEET NO. C4.3)	
STATION	LENGTH
508+00, 26' LT. TO 512+99, 26' LT.	499 L.F.
512+99, 26' LT. TO 513+78, 330.0' LT.	314 L.F.

30 15 0 30 60FT

SCALE: 1"= 30'

LEGEND

- 2" MILL AND OVERLAY
- —xx— PERMANENT AOA SECURITY FENCE
- PROPOSED GUARDRAIL
- PROPOSED LIGHT POLE

NOTE:

1. AFTER VIDEO INSPECTION OF THE PIPES IS COMPLETE, THE CONTRACTOR WILL DETERMINE IF CLEANING OF THE PIPES IS REQUIRED (SEE PART A PROJECT SPECIFICATIONS, SECTION 3020).

CROSS REFERENCES	
ITEM	SHEET NO.
ROADWAY PROFILE	C3.2
TYPICAL SECTIONS	C3.1
GEOMETRIC LAYOUT	C1.2
STORM DRAIN PROFILES & DETAILS	C4.4
STORMWATER POLLUTION PREVENTION	C1.14
PAVEMENT MARKING PLAN	C1.18
SIGNING PLAN	C1.20
ELECTRICAL AND LIGHTING PLAN	E2.2
DEMOLITION PLAN	C2.2
GRADING PLAN	C1.12

PLAN 2

NO.	REVISION	DATE
CN#1	EXTEND EXISTING 6" PVC UNDERDRAIN OUTFALLS	3/21/00

FILE : M:\survey3\sa02ex4.dgn
DATE : JUNE 16, 1999 - 10:50AM

JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future
72 Loveton Circle Baltimore, Maryland 21152-0949

COMMONWEALTH OF VIRGINIA
DANIEL T. CHENG
020282
8-17-99
PROFESSIONAL ENGINEER

DATE	AUG 17, 1999
SCALE	1" = 30'
DESIGNED	C.D.L.
DRAWN	E.B.B. CHECKED D.A.L.
ACCEPTED	D.R.H.
SUBMITTED	D.A.J.
APPROVED	F.D.H.

METROPOLITAN WASHINGTON AIRPORTS AUTHORITY
OFFICE OF ENGINEERING DESIGN DEPARTMENT

DRAWING TITLE
SOUTH AREA ROADS PROJECT 4B
RONALD REAGAN WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.
ROADWAY AND STORM DRAIN PLAN

DRAWING NUMBER
DJCC1010

SHEET NUMBER
C1.10
sh 14 of 52

MAJOR DIVISIONS			GROUP SYMBOLS		TYPICAL NAMES
COARSE GRAINED SOILS (More than 50% of material is LARGER than No 200 sieve size)	GRAVELS (More than 50% of coarse fraction is LARGER than the No 4 sieve size)	CLEAN GRAVELS (Little or no fines)		GW	Well graded gravels, gravel - sand mixtures, little or no fines.
				GP	Poorly graded gravels or gravel - sand mixtures, little or no fines.
		GRAVELS WITH FINES (Appreciable amount of fines)		GM	Silty gravels, gravel - sand - silt mixtures.
				GC	Clayey gravels, gravel - sand - clay mixtures.
	SANDS (More than 50% of coarse fraction is SMALLER than the No 4 Sieve Size)	CLEAN SANDS (Little or no fines)		SW	Well graded sands, gravelly sands, little or no fines.
				SP	Poorly graded sands or gravelly sands, little or no fines.
		SANDS WITH FINES (Appreciable amount of fines)		SM	Silty sands, sand - silt mixtures
				SC	Clayey sands, sand - clay mixtures
FINE GRAINED SOILS (More than 50% of material is SMALLER than No 200 sieve size)	SILTS AND CLAYS (Liquid limit LESS than 50)			ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts and with slight plasticity.
				CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
				OL	Organic silts and organic silty clays of low plasticity.
	SILTS AND CLAYS (Liquid limit GREATER than 50)			MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
				CH	Inorganic clays of high plasticity, fat clays
				OH	Organic clays of medium to high plasticity, organic silts.
HIGHLY ORGANIC SOILS				PT	Peat and other highly organic soils.

BOUNDARY CLASSIFICATIONS: Soils possessing characteristics of two groups are designated by combinations of group symbols.

SILT OR CLAY	SAND			GRAVEL		Cobbles	Boulders
	Fine	Medium	Coarse	Fine	Coarse		

No 200 No 40 No 10 No 4 3/4" 3" 12"

U.S. STANDARD SIEVE SIZE

Reference: The Unified Soil Classification System, Corps of Engineers, U.S. Army Technical Memorandum No. 3-357, Vol. 1. March. 1953 (Revised April. 1960)

■	Undisturbed Sample	▌	Auger Cuttings
╳	Split Spoon Sample	▒	Bulk Sample
▌	Rock Core	▒	Crandall Sampler
▒	Dilatometer	⁘	Pressure Meter
▌	Packer	○	No Recovery
▽	Water Table at time of drilling	▼	Water Table after 24 hours

Correlation of Penetration Resistance with Relative Density and Consistency

SAND & GRAVEL		SILT & CLAY	
No. of Blows	Relative Density	No. of Blows	Consistency
0 - 4	Very Loose	0 - 1	Very Soft
5 - 10	Loose	2 - 4	Soft
11 - 20	Firm	5 - 8	Firm
21 - 30	Very Firm	9 - 15	Stiff
31 - 50	Dense	16 - 30	Very Stiff
Over 50	Very Dense	Over 31	Hard

KEY TO SYMBOLS AND DESCRIPTIONS

LAW
LAWGIBB Group Member

SOIL CLASSIFICATION AND REMARKS

SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.

DEPTH (ft)	ELEV (ft)	SAMPLES IDENT	TYPE	N-COUNT 1st 6" 2nd 6" 3rd 6"	PL (%) NM (%) LL (%) ▲ FINES (%) ● SPT (bpf)
0	8.5				
5	3.5	SPT - 1		13-12-12 N=24	
		SPT - 2		4-2-6 N=8	
10	-1.5	SPT - 3		2-2-1 N=3	
		SPT - 4		1-1-0 N=1	
15	-6.5	SPT - 5		WOH/18"	
20	-11.5				
25	-16.5				
30	-21.5				
35	-26.5				
40	-31.5				
45	-36.5				

ASPHALT: 18 inches

FILL - sampled as loose to firm brown fine to medium sand, some silt, little to some gravel, moist

- very loose, some clay below 6 feet

Very loose gray fine to medium SAND (SM), little to some silt, wet

Very soft gray SILT (ML), trace fine sand, wet

Very soft gray clayey SILT (MH), trace fine sand, wet

BORING TERMINATED AT 15.0 FEET.

NOTES:
1. Ground water was encountered at 9.1 feet on 10/10/98.
2. Cave-in depth was measured at 9.2 feet on 10/10/98.

20310 82222.GPJ LAW GIBB.GDT 11/16/98

DRILLER: LAW M. Potter
EQUIPMENT: CME-55
METHOD: HSA
HOLE DIA.: 3-1/4"
Logged by: E. Leipski
Checked by:
REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BEWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

SOIL TEST BORING RECORD

PROJECT South Area Roads and Pipe Extension
BORING NO. B-1
DRILLED: November 10, 1998
PROJ. NO: 20310-8-2222 **PAGE 1 OF 1**

LAW
LAWGIBB Group Member

SOIL CLASSIFICATION AND REMARKS

SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.

DEPTH (ft)	ELEV (ft)	SAMPLES IDENT	TYPE	N-COUNT 1st 6" 2nd 6" 3rd 6"	PL (%) NM (%) LL (%) ▲ FINES (%) ● SPT (bpf)
0	7.1				
5	2.1	SPT - 1		13-13-13 N=26	
		SPT - 2		2-1-3 N=4	
		SPT - 3		WOH-1-2 N=3	
10	-2.9	SPT - 4		WOH-1-1 N=2	
15	-7.9	SPT - 5		WOH-3-1 N=4	
20	-12.9				
25	-17.9				
30	-22.9				
35	-27.9				
40	-32.9				
45	-37.9				

ASPHALT: 18 inches

FILL - sampled as very loose to firm gray-brown fine to medium sand, some silt, trace to some clay, little gravel, moist to wet

- petroleum odor at 5 feet and at 8.5 feet

Very loose gray silty fine SAND (SM), wet

- fine to medium SAND (SP), trace silt below 13.5 feet
- blue-green silty fine SAND (SM) at 15 feet

BORING TERMINATED AT 15 FEET.

NOTES:
1. Ground water was encountered at 8 feet on 11/10/98.
2. Cave-in depth was measured at 9.5 feet on 11/10/98.

20310 82222.GPJ LAW GIBB.GDT 11/16/98

DRILLER: LAW M. Potter
EQUIPMENT: CME-55
METHOD: HSA
HOLE DIA.: 3-1/4"
Logged by: E. Leipski
Checked by:
REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BEWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

SOIL TEST BORING RECORD

PROJECT South Area Roads and Pipe Extension
BORING NO. B-2
DRILLED: November 10, 1998
PROJ. NO: 20310-8-2222 **PAGE 1 OF 1**

LAW
LAWGIBB Group Member

NOTE:

REFER TO ROADWAY AND STORMDRAIN PLANS, SHEET NO.'S C1.9 AND C1.10 FOR SOIL BORING LOCATIONS.

NO.	REVISION	DATE

JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future
72 Loveton Circle Baltimore, Maryland 21152-0949

DANIEL T. CHENG 12296 8-17-99

DATE	AUG 17, 1999
SCALE	1"=30'-0"
DESIGNED	C.D.L.
DRAWN	E.B.B. CHECKED D.A.L.
ACCEPTED	D.R.H.
SUBMITTED	D.A.J.
APPROVED	F.D.H.

METROPOLITAN WASHINGTON AIRPORTS AUTHORITY
OFFICE OF ENGINEERING DESIGN DEPARTMENT

DRAWING TITLE
SOUTH AREA ROADS PROJECT 4B
RONALD REAGAN WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.
BORING LOGS

DRAWING NUMBER
DJCC7001

SHEET NUMBER
C7.1
sh 40 of 52

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DATE: 11/16/1999
11:16:39 AM

SOIL CLASSIFICATION AND REMARKS

SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.

DEPTH (ft)	SOIL CLASSIFICATION AND REMARKS	ELEV (ft)	SAMPLE IDENT	TYPE	N-COUNT (1st 6" 2nd 6" 3rd 6")	N
0	ASPHALT: 12 inches	7.5				
	FILL - sampled as loose to dense gray-brown fine to medium sand, some silt, little to some gravel, little to some concrete, trace to some clay, trace wood, moist to wet		SPT - 1		2-5-7	N=12
		2.5	SPT - 2		12-17-28	N=45
			SPT - 3		4-3-8	N=11
		-2.5	SPT - 4		4-4-5	N=9
15	**BORING TERMINATED AT 15 FEET.**	-7.5	SPT - 5		12-8-8	N=16
	NOTES: 1. Ground water was encountered at 6.5 feet on 11/10/98. 2. Cave-in depth was measured at 11.5 feet on 11/10/98.					

PL (%) NM (%) LL (%) ▲ FINES (%) ● SPT (bpf)

20310 8222 GPJ LAW GIBB GDT 11/16/98

DRILLER: LAW M. Potter
EQUIPMENT: CME-55
METHOD: HSA
HOLE DIA.: 3-1/4"
Logged by: E. Leipski
Checked by:
REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BEWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

SOIL TEST BORING RECORD

PROJECT South Area Roads and Pipe Extension
BORING NO. B-6
DRILLED: November 10, 1998
PROJ. NO: 20310-8-2222 **PAGE 1 OF 1**

LAW
LAWGIBB Group Member

SOIL CLASSIFICATION AND REMARKS

SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.

DEPTH (ft)	SOIL CLASSIFICATION AND REMARKS	ELEV (ft)	SAMPLE IDENT	TYPE	N-COUNT (1st 6" 2nd 6" 3rd 6")	N
0	ASPHALT: 4 inches	6.9				
	BASE: 8 inches					
	FILL: sampled as LOOSE gray, green, black fine to medium sand, little mica, some silt, some gravel, moist		SPT - 1		4-2-3	N=5
	FILL: sampled as LOOSE brown sandy gravel, little clay, moist	1.9	SPT - 2		2-4-5	N=9
	FILL: sampled as VERY LOOSE dark gray-brown clayey fine to medium sand, some gravel, moist		SPT - 3		WOH-1-1	N=2
	FILL: sampled as SOFT dark gray clayey silt, trace fine sand, moist	-3.1	SPT - 4		WOH-1-2	N=3
	FILL: sampled as asphalt and concrete fragments	-8.1	SPT - 5		6-20-22	N=42
			SPT - 6		100/3	N=100+
	VERY SOFT green, gray, black clayey SILT (MH), trace to little fine sand, trace mica, moist to wet	-13.1	SPT - 7		WOH	N=0
		-18.1	SPT - 8		WOH/18	N=0
		-23.1	SPT - 9		WOH/18	N=0
		-28.1	SPT - 10		WOH/18	N=0
		-33.1	SPT - 11		WOH/18	N=0
		-38.1	SPT - 12		WOH/18	N=0

PL (%) NM (%) LL (%) ▲ FINES (%) ● SPT (bpf)

SMM REVISED 20310 8222-01 GPJ LAW_ILF.GDT 6/9/99

DRILLER: LAW. M. Potter
EQUIPMENT: CME-55
METHOD: 3.25" ID HSA
HOLE DIA.
Logged by: C. Tin
Checked by:
REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BEWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

SOIL TEST BORING RECORD

PROJECT South Area Roads Box Culvert - DCA
BORING NO. B-1A
DRILLED: May 24, 1999
PROJ. NO: 20310-8-2222.01 **PAGE 1 OF 2**

LAW
LAWGIBB Group Member

SOIL CLASSIFICATION AND REMARKS

SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW.

DEPTH (ft)	SOIL CLASSIFICATION AND REMARKS	ELEV (ft)	SAMPLE IDENT	TYPE	N-COUNT (1st 6" 2nd 6" 3rd 6")	N
45	VERY SOFT green, gray, black clayey SILT (MH), trace to little fine sand, trace mica, moist to wet	-38.1				
			SPT - 13		WOH	N=0
50	LOOSE gray fine to medium SAND (SP), trace clay, wet	-43.1				
			SPT - 14		WOH/12-3	N=3
55	VERY DENSE gray fine to medium SAND (SP), trace clay, wet	-48.1				
			SPT - 15		30-70	N=100
60	VERY STIFF gray-green silty CLAY (CL), trace fine sand, little gravel, moist	-53.1				
65	**BORING TERMINATED AT 65.0 FEET BELOW GROUND SURFACE (BGS) ON 5/24/99.**	-58.1	SPT - 16		18-8-14	N=22
	NOTES: 1. Ground water level was measured at 6.5 feet bgs on 5/24/99. 2. Cave-in depth was measured at 51.7 feet bgs on 5/24/99.					

PL (%) NM (%) LL (%) ▲ FINES (%) ● SPT (bpf)

SMM REVISED 20310 8222-01 GPJ LAW_ILF.GDT 6/9/99

DRILLER: LAW. M. Potter
EQUIPMENT: CME-55
METHOD: 3.25" ID HSA
HOLE DIA.
Logged by: C. Tin
Checked by:
REMARKS:

THIS RECORD IS A REASONABLE INTERPRETATION OF SUBSURFACE CONDITIONS AT THE EXPLORATION LOCATION. SUBSURFACE CONDITIONS AT OTHER LOCATIONS AND AT OTHER TIMES MAY DIFFER. INTERFACES BEWEEN STRATA ARE APPROXIMATE. TRANSITIONS BETWEEN STRATA MAY BE GRADUAL.

SOIL TEST BORING RECORD

PROJECT South Area Roads Box Culvert - DCA
BORING NO. B-1A
DRILLED: May 24, 1999
PROJ. NO: 20310-8-2222.01 **PAGE 2 OF 2**

LAW
LAWGIBB Group Member

NOTE:

REFER TO ROADWAY AND STORMDRAIN PLANS, SHEET NO.'S C1.9 AND C1.10 FOR SOIL BORING LOCATIONS.

NO.	REVISION	DATE

JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future
72 Loveton Circle Baltimore, Maryland 21152-0949

DANIEL T. CHENG 8-17-99

DATE	AUG 17, 1999
SCALE	1"=30'-0"
DESIGNED	LAW
DRAWN	E.B.B. CHECKED D.A.L.
ACCEPTED	D.R.H.
SUBMITTED	D.A.J.
APPROVED	F.D.H.

METROPOLITAN WASHINGTON AIRPORTS AUTHORITY

OFFICE OF ENGINEERING
DESIGN DEPARTMENT

DRAWING TITLE
SOUTH AREA ROADS PROJECT 4B
RONALD REAGAN WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.
BORING LOGS

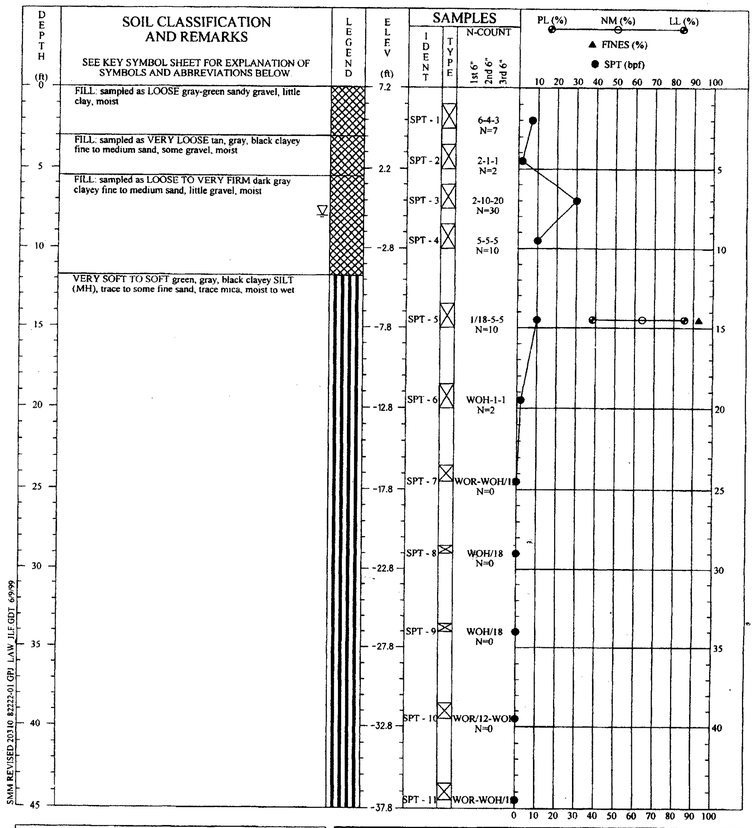
DRAWING NUMBER
DJCC7003

SHEET NUMBER
C7.3
sh. 42 of 52

SOIL CLASSIFICATION AND REMARKS

SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW

Depth (ft)	Elev (ft)	Description	Sample Ident	Type	N-Count (1st 6" / 2nd 6" / 3rd 6")	N
0	7.2	FILL: sampled as LOOSE gray-green sandy gravel, little clay, moist	SPT - 1		6-4-3	N=7
5	2.2	FILL: sampled as VERY LOOSE tan, gray, black clayey fine to medium sand, some gravel, moist	SPT - 2		2-1-1	N=2
		FILL: sampled as LOOSE TO VERY FIRM dark gray clayey fine to medium sand, little gravel, moist	SPT - 3		2-10-20	N=30
10	-2.8		SPT - 4		5-5-5	N=10
		VERY SOFT TO SOFT green, gray, black clayey SILT (MH), trace to some fine sand, trace mica, moist to wet	SPT - 5		1/18-5-5	N=10
15	-7.8					
20	-12.8		SPT - 6		WOH-1-1	N=2
25	-17.8		SPT - 7		WOR-WOH/18	N=0
30	-22.8		SPT - 8		WOH/18	N=0
35	-27.8		SPT - 9		WOH/18	N=0
40	-32.8		SPT - 10		WOR/12-WOH	N=0
45	-37.8		SPT - 11		WOR-WOH/18	



SMM REVISED 20310 8222-01 GPJ LAW JLF GDT 6/9/99

DRILLER: LAW M. Potter
EQUIPMENT: CME-55
METHOD: 3.25" ID HSA
HOLE DIA.:
Logged by: C. Tin
Checked by:
REMARKS:

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SOIL TEST BORING RECORD

PROJECT South Area Roads Box Culvert - DCA
BORING NO. B-2 A

DRILLED: May 25, 1999
PROJ. NO: 20310-8-2222.01

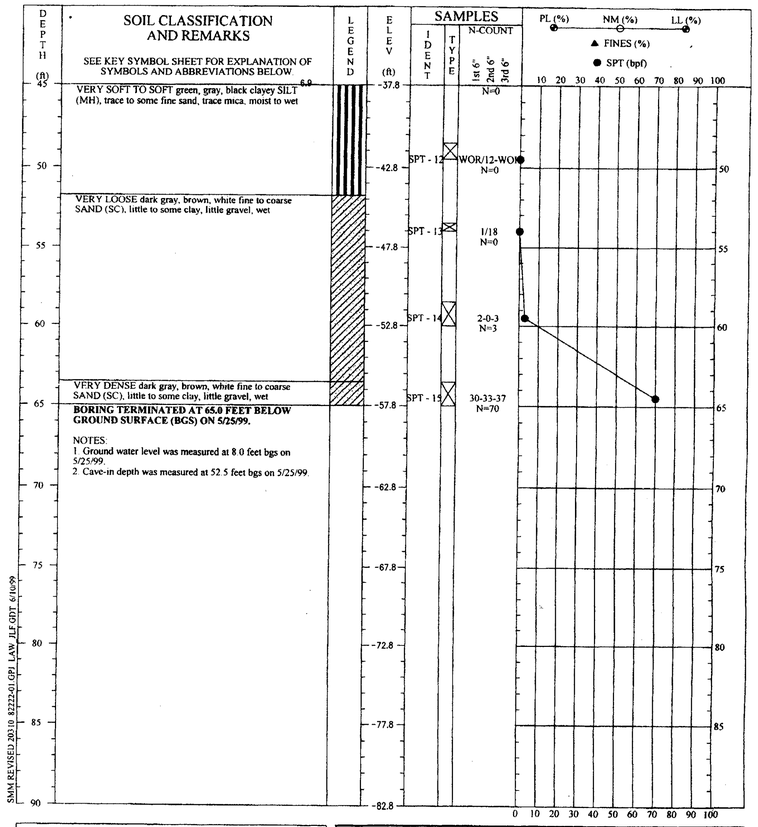
LAW
LAWGIBB Group Member

SOIL CLASSIFICATION AND REMARKS

SEE KEY SYMBOL SHEET FOR EXPLANATION OF SYMBOLS AND ABBREVIATIONS BELOW

Depth (ft)	Elev (ft)	Description	Sample Ident	Type	N-Count (1st 6" / 2nd 6" / 3rd 6")	N
	6.9	VERY SOFT TO SOFT green, gray, black clayey SILT (MH), trace to some fine sand, trace mica, moist to wet				
50	-42.8		SPT - 12		WOR/12-WOH	N=0
		VERY LOOSE dark gray, brown, white fine to coarse SAND (SC), little to some clay, little gravel, wet	SPT - 13		1/18	N=0
55	-47.8					
60	-52.8		SPT - 14		2-0-3	N=3
		VERY DENSE dark gray, brown, white fine to coarse SAND (SC), little to some clay, little gravel, wet				
65	-57.8	**BORING TERMINATED AT 65.0 FEET BELOW GROUND SURFACE (BGS) ON 5/25/99.**	SPT - 15		30-33-37	N=70
70	-62.8					
75	-67.8					
80	-72.8					
85	-77.8					
90	-82.8					

NOTES:
1. Ground water level was measured at 8.0 feet bgs on 5/25/99.
2. Cave-in depth was measured at 52.5 feet bgs on 5/25/99.



SMM REVISED 20310 8222-01 GPJ LAW JLF GDT 6/16/99

DRILLER: LAW M. Potter
EQUIPMENT: CME-55
METHOD: 3.25" ID HSA
HOLE DIA.:
Logged by: C. Tin
Checked by:
REMARKS:

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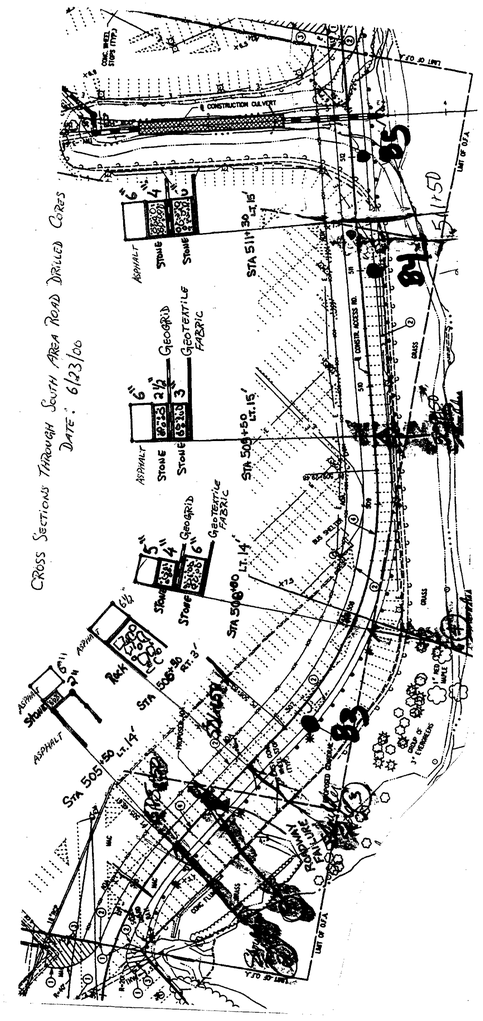
SOIL TEST BORING RECORD

PROJECT South Area Roads Box Culvert - DCA
BORING NO. B-2 A

DRILLED: May 25, 1999
PROJ. NO: 20310-8-2222.01

LAW
LAWGIBB Group Member



EXISTING PAVEMENT BORINGS
(N.T.S.)

NOTE: ADDITIONAL BORINGS WERE TAKEN DUE TO ROADWAY FAILURE AT ≈ STA 506+00 APPROX. 2 WEEKS AFTER VEHICLE LOADS WERE IMPOSED ON THE NEW ROADWAY SURFACE. SEE SHEET C1.9 FOR LOCATION OF REPAIRED ROADWAY SECTION. (CN #22).

NOTE:
REFER TO ROADWAY AND STORMDRAIN PLANS, SHEET NO.'S C1.9 AND C1.10 FOR SOIL BORING LOCATIONS.

NO.	REVISION	DATE
CN #22	REPAIR EXISTING ROADWAY SUBGRADE	6/19/00

JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future
72 Loveton Circle Baltimore, Maryland 21152-0949

DANIEL T. CHENG
Daniel T. Cheng
2-17-99

DATE	AUG 17, 1999
SCALE	1"=30'-0"
DESIGNED	LAW
DRAWN	E.B.B.
CHECKED	D.A.L.
ACCEPTED	D.R.H.
SUBMITTED	D.A.J.
APPROVED	F.D.H.

METROPOLITAN WASHINGTON AIRPORTS AUTHORITY

OFFICE OF ENGINEERING DESIGN DEPARTMENT

DRAWING TITLE
SOUTH AREA ROADS PROJECT 4B
RONALD REAGAN WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.
BORING LOGS

DRAWING NUMBER
DJCC7004

SHEET NUMBER
C7.4
sh 43 of 52

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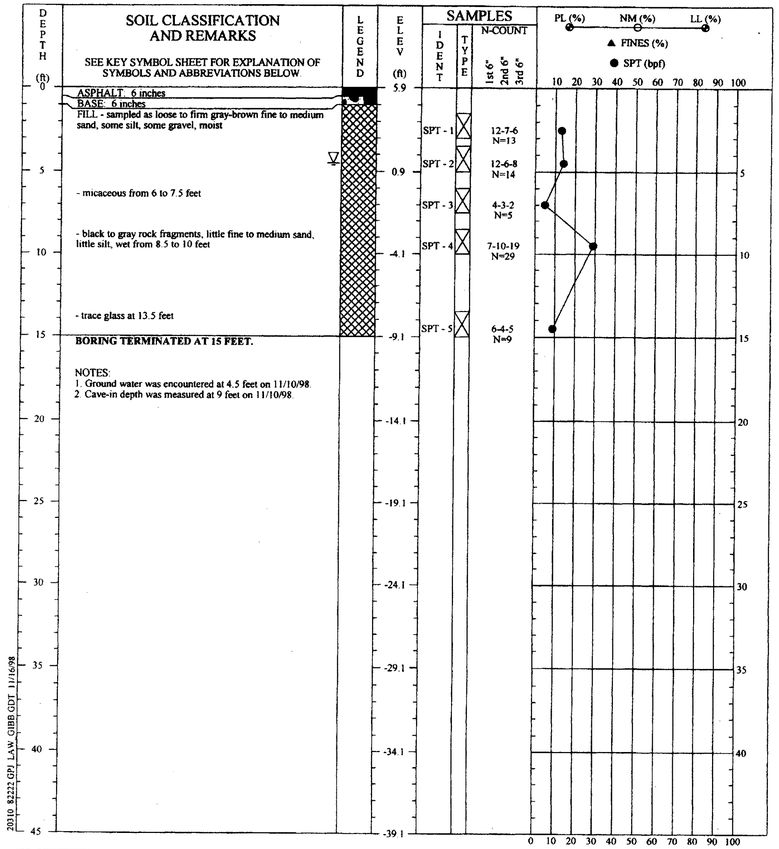

DRILLER: LAW: M. Potter
EQUIPMENT: CME-55
METHOD: HSA
HOLE DIA.: 3-1/4"
Logged by: E. Lepski
Checked by:
REMARKS:

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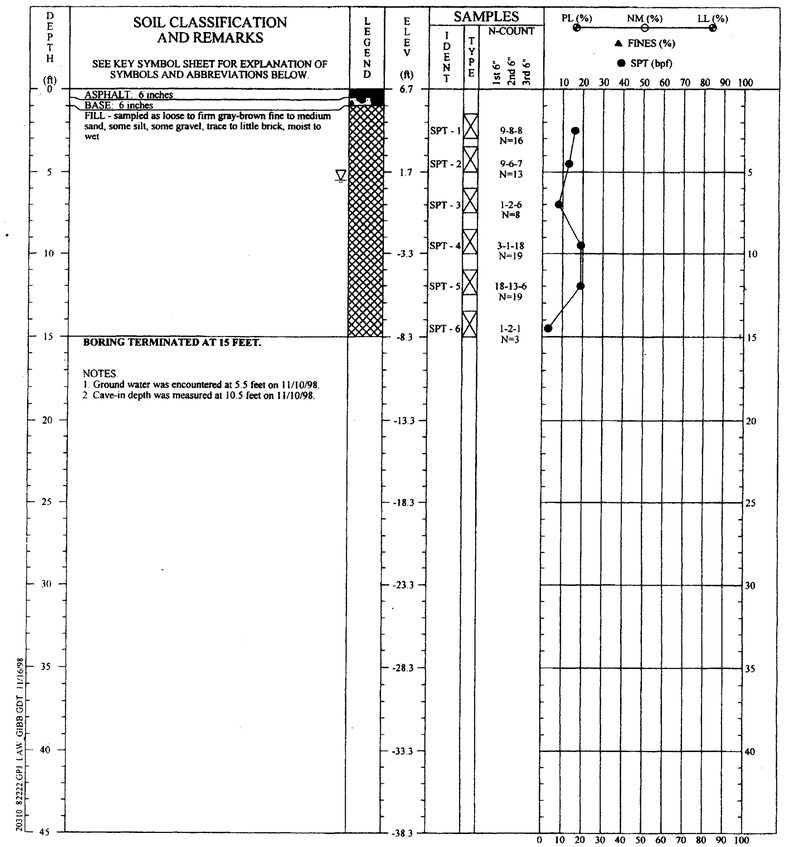
SOIL TEST BORING RECORD

PROJECT South Area Roads and Pipe Extension
BORING NO. B-3
DRILLED: November 10, 1998
PROJ. NO: 20310-8-2222 **PAGE 1 OF 1**

LAW
LAWGIBB Group Member



DRILLER: LAW: M. Potter
EQUIPMENT: CME-55
METHOD: HSA
HOLE DIA.: 3-1/4"
Logged by: E. Lepski
Checked by:
REMARKS:

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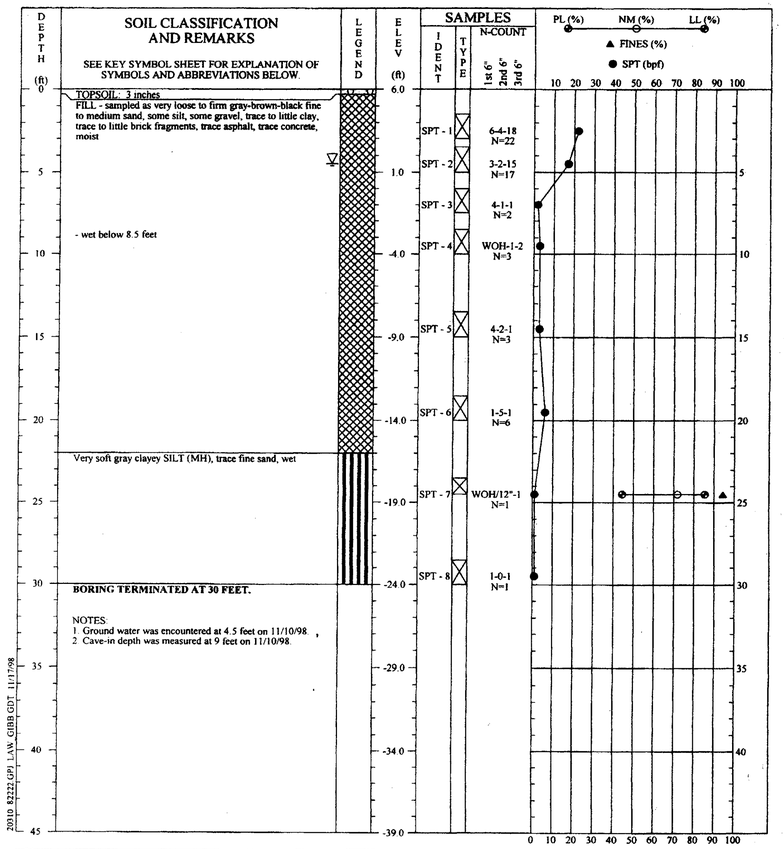
SOIL TEST BORING RECORD

PROJECT South Area Roads and Pipe Extension
BORING NO. B-4
DRILLED: November 10, 1998
PROJ. NO: 20310-8-2222 **PAGE 1 OF 1**

LAW
LAWGIBB Group Member



DRILLER: LAW: M. Potter
EQUIPMENT: CME-55
METHOD: HSA
HOLE DIA.: 3-1/4"
Logged by: E. Lepski
Checked by:
REMARKS:

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SOIL TEST BORING RECORD

PROJECT South Area Roads and Pipe Extension
BORING NO. B-5
DRILLED: November 10, 1998
PROJ. NO: 20310-8-2222 **PAGE 1 OF 1**

LAW
LAWGIBB Group Member

NOTE:
REFER TO ROADWAY AND STORMDRAIN PLANS, SHEET NO.'S C1.9 AND C1.10 FOR SOIL BORING LOCATIONS.

NO.	REVISION	DATE

JOHNSON, MIRMIRAN & THOMPSON
Engineering A Brighter Future
72 Loveton Circle Baltimore, Maryland 21152-0949

DATE AUG 17, 1999
SCALE 1"=30'-0"
DESIGNED C.D.L.
DRAWN E.B.B. CHECKED D.A.L.
ACCEPTED D.R.H.
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DRAWING TITLE
SOUTH AREA ROADS PROJECT 4B
RONALD REAGAN WASHINGTON NATIONAL AIRPORT
WASHINGTON, D.C.
BORING LOGS

DRAWING NUMBER
DJCC7002

SHEET NUMBER
C7.2
sh 41 of 52

DC Coastal Geotechnical Data Summary

Reagan International Airport

South Area Roads - Project 3B and 4B

Drill Year	1992	1992	1992	1992	1998	1998	1998
G.S. EL	13.7	11.8	14	11	6.7	6.9	6
GW Depth (ft)	6.5	10.2	11.3	dry	5.5	6.5	4.5
GW EL	7.2	1.6	2.7	N/A	1.2	0.4	1.5

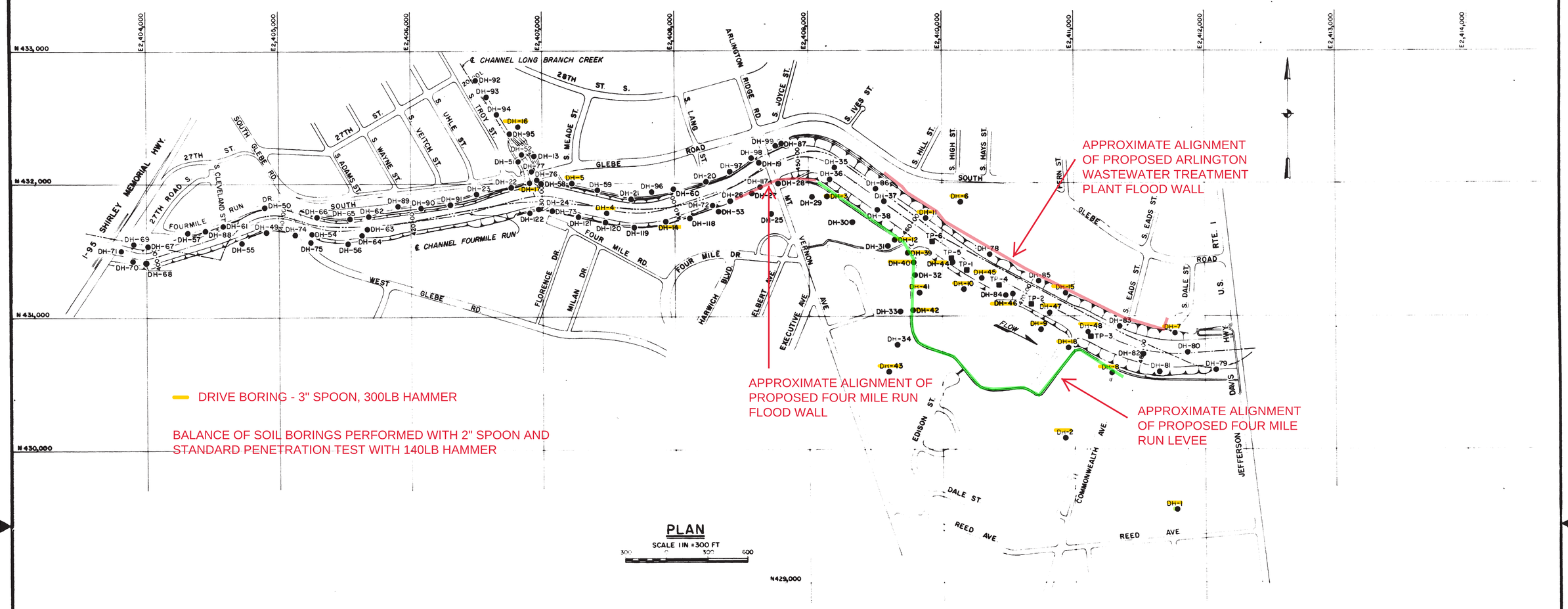
Depth	B-1	B-2	B-11	B-3	B-4	B-1A	B-5	Depth
0.5	6							0.5
1								1
1.5		28	10	11		5		1.5
2					16		22	2
2.5								2.5
3								3
3.5	14	26	16	15				3.5
4					13	9	17	4
4.5								4.5
5								5
5.5	18	31	12	6				5.5
6								6
6.5					8	2	2	6.5
7								7
7.5		11	24	20				7.5
8	3							8
8.5								8.5
9					19	3	3	9
9.5								9.5
10								10
10.5	2	10	26	13				10.5
11								11
11.5					19			11.5
12								12
12.5		14						12.5
13								13
13.5								13.5
14					3	42	3	14
14.5								14.5
15								15
15.5	2	11	10	12	15'-0"			15.5
16								16
16.5								16.5
17								17
17.5		17'-0"	17'-0"	17'-0"		100+		17.5
18								18
18.5								18.5
19						W.O.H.	6	19
19.5								19.5
20								20
20.5	3							20.5
21								21
21.5								21.5
22								22
22.5								22.5
23								23
23.5								23.5
24						W.O.H.	1	24
24.5								24.5
25								25
25.5	11							25.5
26								26
26.5								26.5
27								27
27.5	27'-0"							27.5
28								28
28.5								28.5
29						W.O.H.	1	29
29.5								29.5
30								30
30.5							30'-0"	30.5
31								31
31.5								31.5
32								32
32.5								32.5
33								33
33.5								33.5
34						W.O.H.		34
34.5								34.5
35								35
35.5								35.5
36								36
36.5								36.5
37								37
37.5								37.5
38								38
38.5								38.5
39						W.O.H.		39
39.5								39.5
40								40
40.5								40.5
41								41
41.5								41.5
42								42
42.5								42.5
43								43
43.5								43.5
44						W.O.H.		44
44.5								44.5
45								45
45.5								45.5
46								46
46.5								46.5
47								47
47.5								47.5
48								48
48.5								48.5
49						W.O.H.		49
49.5								49.5
50								50
50.5								50.5
51								51
51.5								51.5
52								52
52.5								52.5
53								53
53.5								53.5
54						3		54
54.5								54.5
55								55
55.5								55.5
56								56
56.5								56.5
57								57
57.5								57.5
58								58
58.5								58.5
59						100		59
59.5								59.5
60								60
60.5								60.5
61								61
61.5								61.5
62								62
62.5								62.5
63								63
63.5								63.5
64						22		64
64.5								64.5
65								65
						65'-0"		

N-Value Summary				
Stratum		MIN	MAX	AVG
FILL		2	100	16
Sandy CLAY		13	26	21
Clayey SAND		10	14	11
Organic SILT/CLAY		W.O.H	2	1
SAND & GRAVEL		3	100	29
CLAY		22	22	22

12.1.2 – Arlington WPCP and Four Mile Run Geotechnical Data

CORPS OF ENGINEERS

U. S. ARMY



REV	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

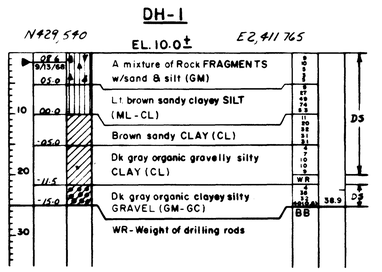
POTOMAC RIVER BASIN
FOURMILE RUN, VIRGINIA

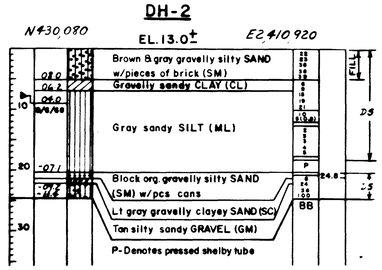
FOURMILE RUN FLOOD CONTROL PROJECT
CHANNEL IMPROVEMENTS

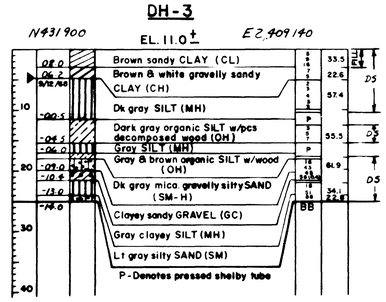
SUBSURFACE EXPLORATION PLAN

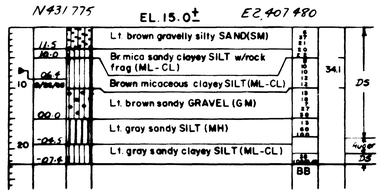
DRAWING NUMBER	PLATE
15768-1	B-1

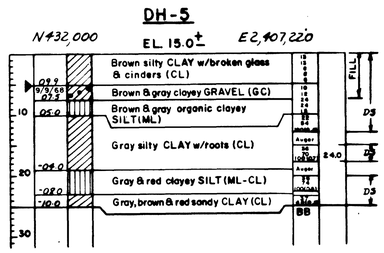
SCALE AS SHOWN | DATE 1 MAY 1978 | SHEET 73

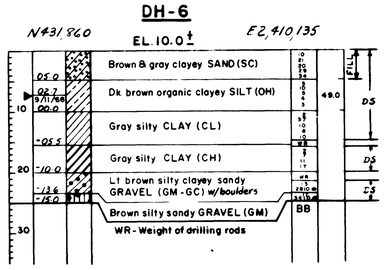


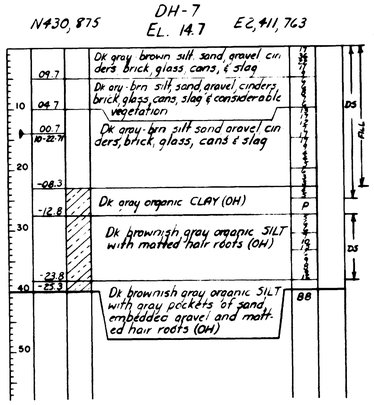


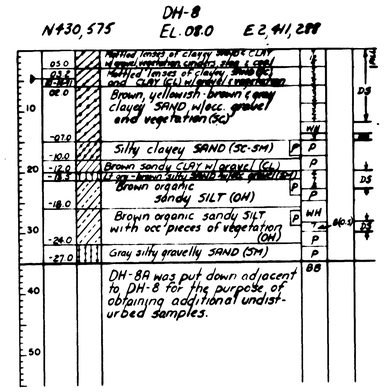


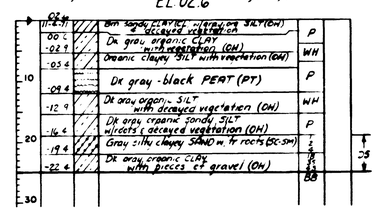


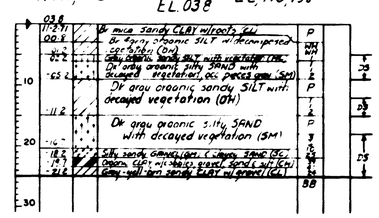


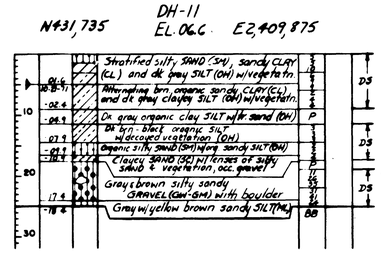


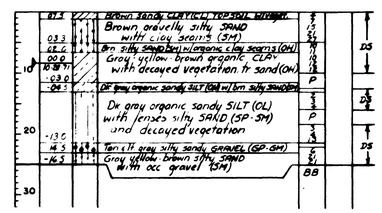


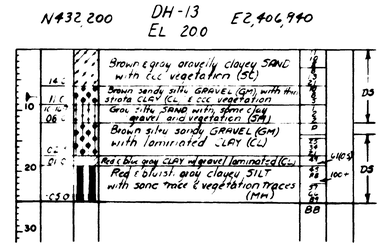


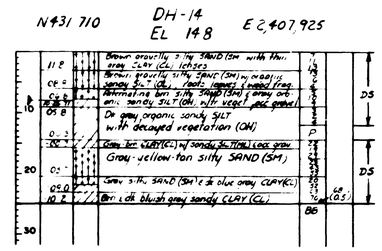


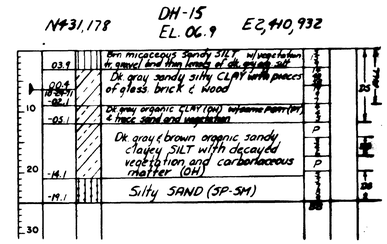


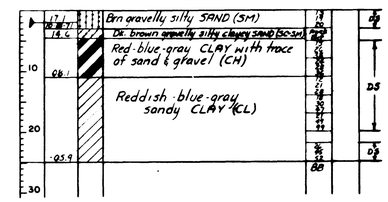


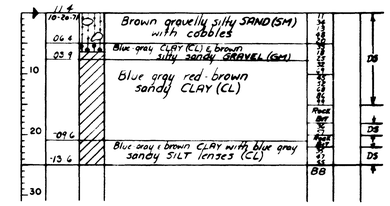


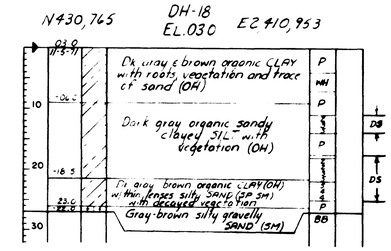








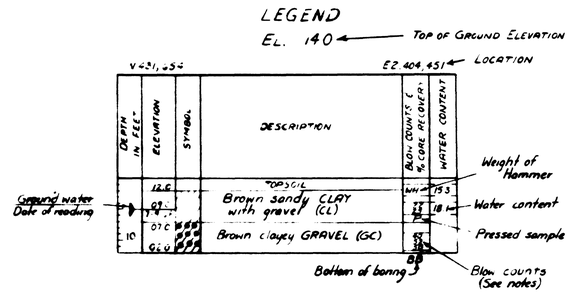




SYMBOLS

- Silty SAND (SM)
- Clayey SAND (SC)
- SAND (SP or SW)
- Silty or sandy CLAY (CL)
- CLAY (CH) highly compressible
- Organic CLAY (OH)
- SILT (ML)
- SILT (MH) highly elastic
- Organic SILT (OL)
- Clayey GRAVEL (GC)
- Silty GRAVEL (GM)
- GRAVEL (GP or GW)
- PEAT (PT)

LEGEND



Note - Sampling method is shown in the right-hand margin.
140± = Estimated elevation

SUBSURFACE EXPLORATION NOTES

1. LETTER SYMBOLS SUCH AS GC, SC, AND CL ARE IN ACCORDANCE WITH THE UNIFIED SOIL CLASSIFICATION SYSTEM OF THE DEPARTMENT OF DEFENSE (MIL-STD-619B).

2. DRILL HOLES (DH) WERE ACCOMPLISHED USING THE FOLLOWING PROCEDURES. THE PROCEDURE ABBREVIATION IS SHOWN IN THE RIGHT-HAND MARGIN OF EACH BORING LOG.

   SPT - ADVANCED BY STANDARD PENETRATION TEST PROCEDURE USING A 1-3/8" I.D. x 1'-8" LONG SPLIT SPOON. THIS SAMPLE SPOON WAS ADVANCED BY A 140# HAMMER FALLING 30". BLOW COUNTS REPRESENT 0.5' OF DRIVE UNLESS OTHERWISE INDICATED.

   DS - ADVANCED BY DRIVE BORING PROCEDURE USING A 3" I.D. x 5'0" LONG SPOON FOR DISTURBED SAMPLES. THE SAMPLE SPOON WAS ADVANCED BY A 300# HAMMER FALLING 18". BLOW COUNTS REPRESENT 1.0' OF DRIVE UNLESS OTHERWISE INDICATED.

3. THE GROUNDWATER LEVEL SHOWN ON THE LOGS REPRESENTS THE LEVEL AT WHICH WATER HAD STABILIZED IN THE HOLE; IT IS NOT NECESSARILY THE LEVEL AT WHICH WATER WAS FIRST ENCOUNTERED IN THE DRILLING OPERATION. GROUNDWATER LEVELS MAY VARY DEPENDING UPON SEASONAL FLUCTUATIONS AND PRECIPITATION INTENSITIES.

4. WATER CONTENTS SHOWN IN THE RIGHT-HAND COLUMN OF THE BORING LOGS ARE WATER CONTENTS (% OF DRY WEIGHT) OF THE TOTAL SAMPLE OF SOIL.

5. TEST PITS (TP) WERE BACKFILLED.

REV	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

POTOMAC RIVER BASIN
FOURMILE RUN, VIRGINIA

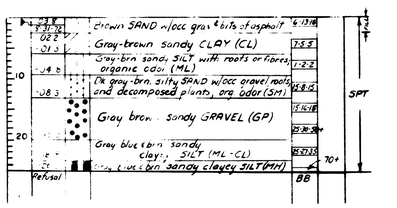
FOURMILE RUN FLOOD CONTROL PROJECT
CHANNEL IMPROVEMENTS

FOUNDATION EXPLORATION
LOGS OF CORE BORINGS-SHEET 1

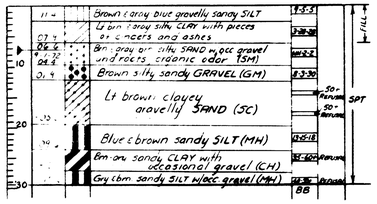
A-E NO. 15768-1 | B-2

AS SHOWN | 1 MAY 1978 | 74

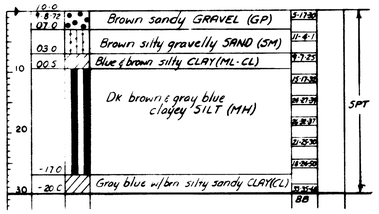
N432,145 DH-19 EL. 04.7 E2,408,625



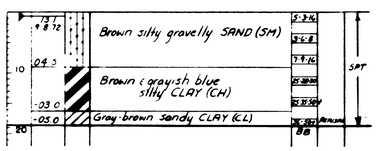
N432,015 DH-20 EL. 13.9 E2,408,235



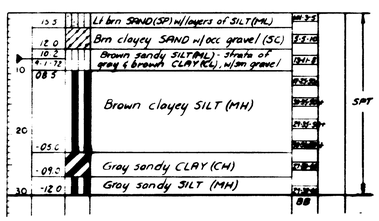
N431,880 DH-21 EL. 10.0± E2,407,670



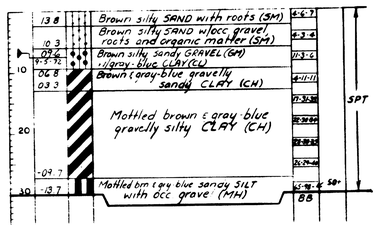
N431,965 DH-22 EL. 13.5± E2,406,760



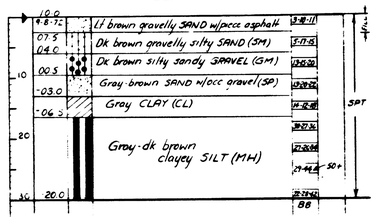
N431,920 DH-23 EL. 18.0 E2,406,500



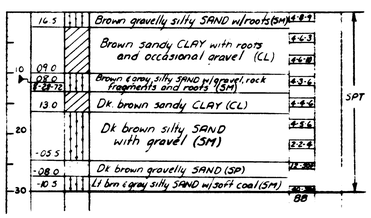
N431,805 DH-24 EL. 16.3 E2,406,965



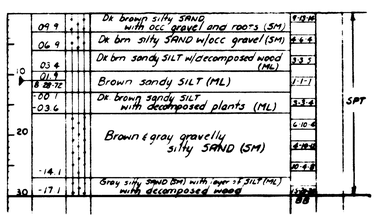
N431,770 DH-25 EL. 10.0± E2,408,725



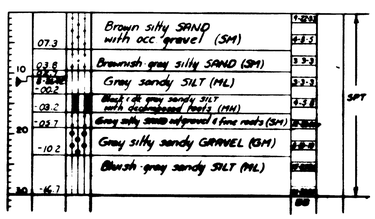
N431,865 DH-26 EL. 19.0 E2,408,410



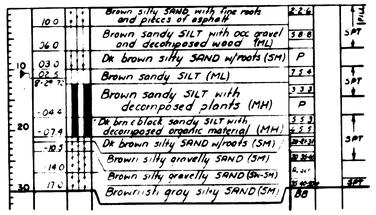
N431,920 DH-27 EL. 12.9 E2,408,577



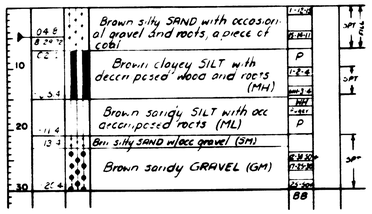
N431,995 DH-28 EL. 13.3 E2,408,795



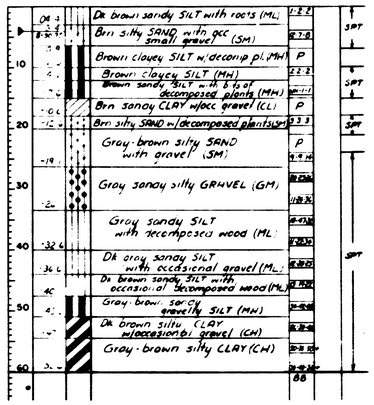
N431,895 DH-29 EL. 13.0 E2,409,025



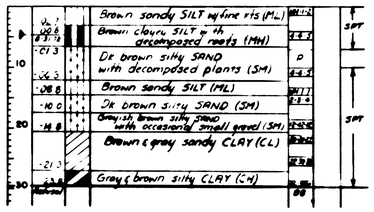
N431,705 DH-30 EL. 09.6 E2,409,325



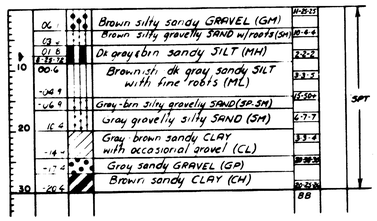
N431,525 DH-31 EL. 07.4 E2,409,595



N431,310 DH-32 EL. 05.7 E2,407,795



N431,035 DH-33 EL. 09.6 E2,409,680



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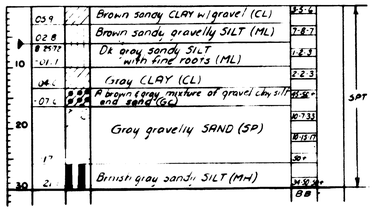
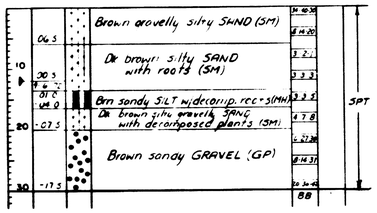
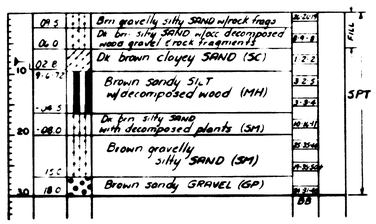


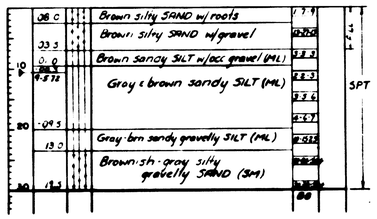
N432,115 DH-35 EL. 12.5± E2,409,195



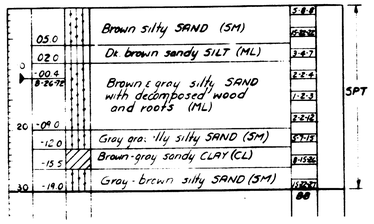
N432,025 DH-36 EL. 12.0± E2,409,160



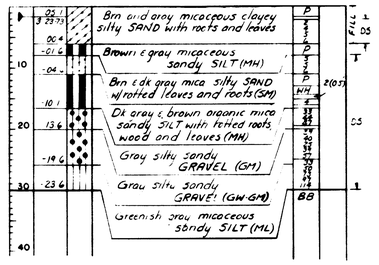
N431,860 DH-37 EL. 10.5± E2,409,560



N431,800 DH-38 EL. 11.0± E2,409,515



N431,475 DH-39 EL. 06.4 E2,409,735



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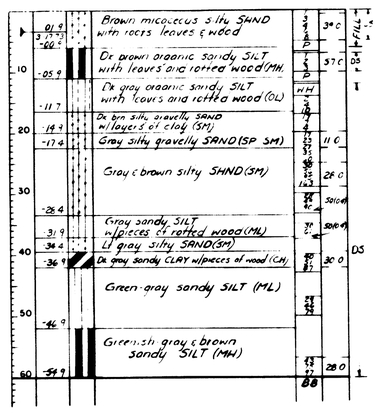


DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

POTOMAC RIVER BASIN
FOURMILE RUN, VIRGINIA

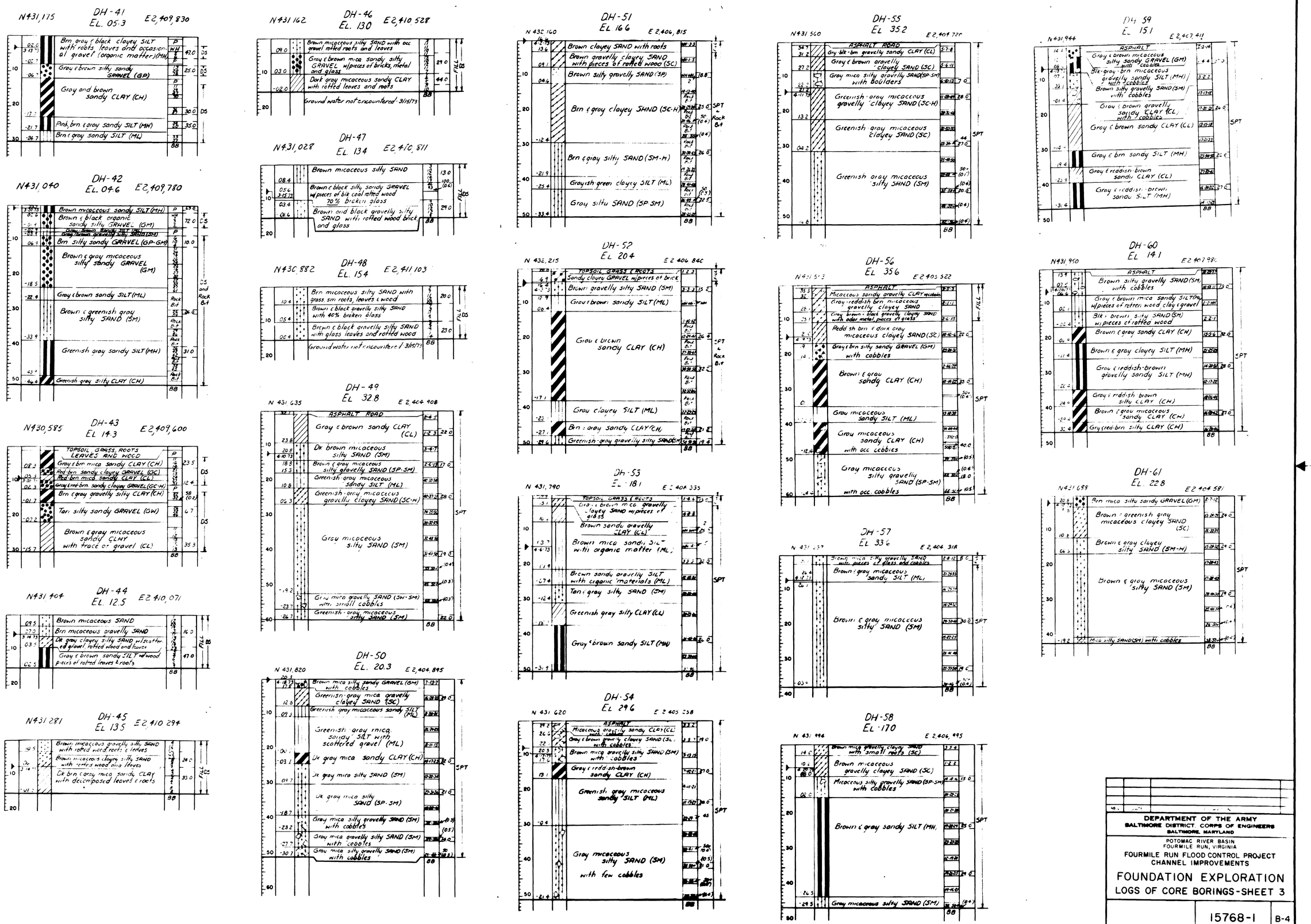
FOURMILE RUN FLOOD CONTROL PROJECT
CHANNEL IMPROVEMENTS

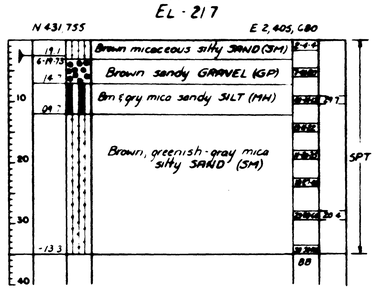
FOUNDATION EXPLORATION
LOGS OF CORE BORINGS-SHEET 2

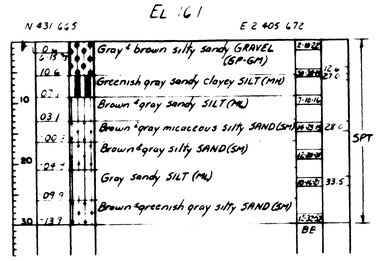
	15768-1	B-3
AS SHOWN	1 MAY 1978	75

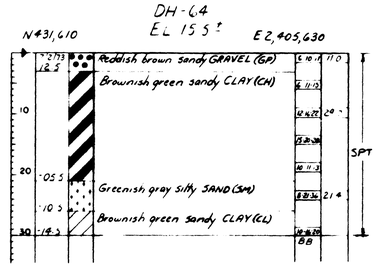
CORPS OF ENGINEERS

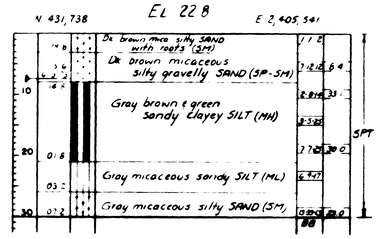
U S ARMY

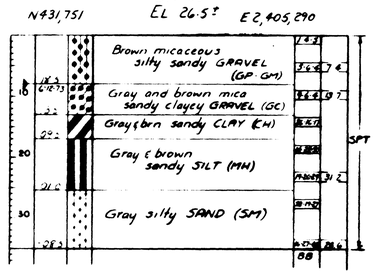


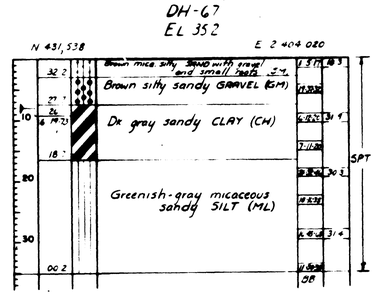


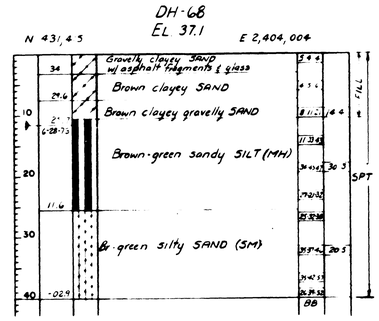


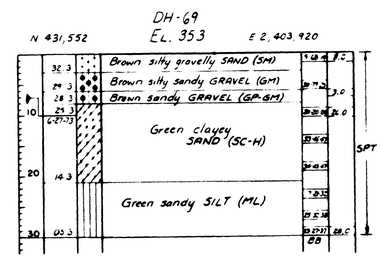


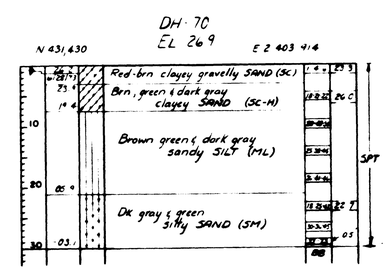


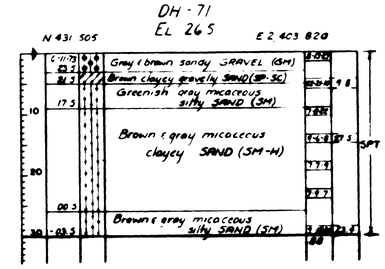


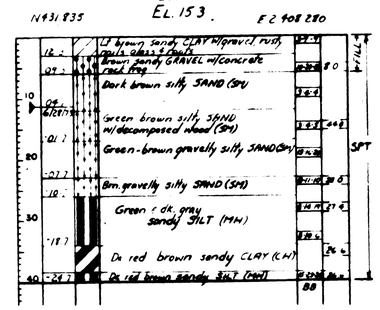


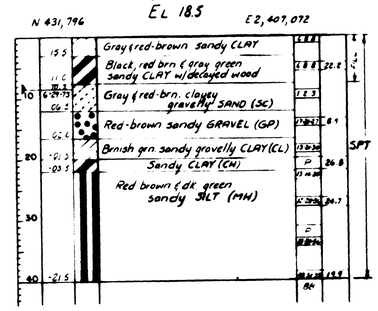


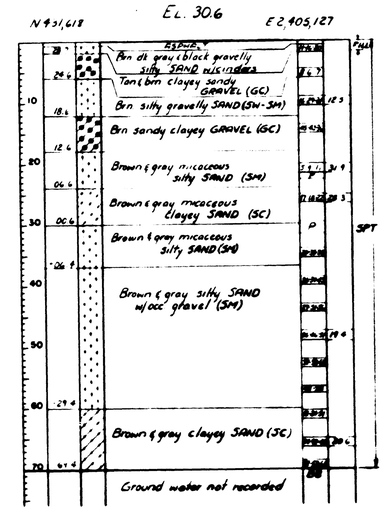


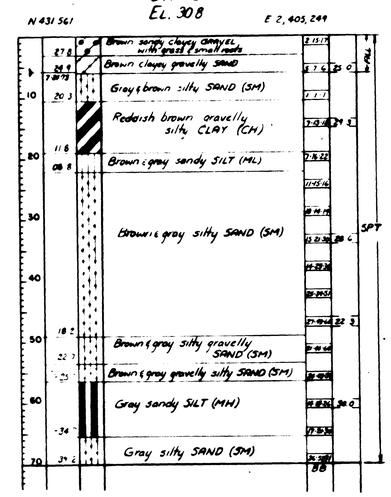


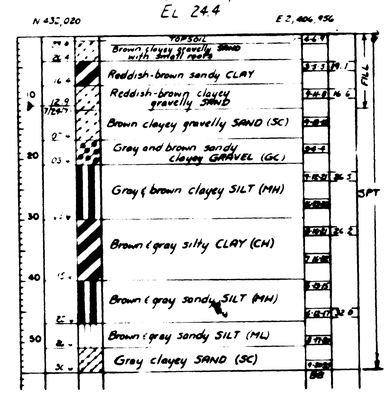


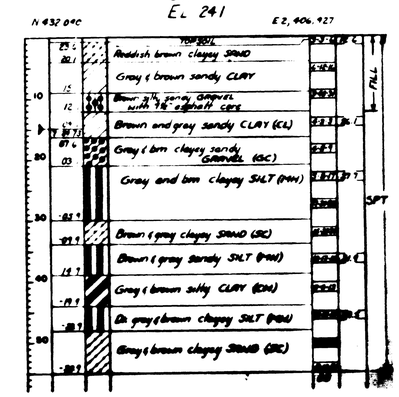


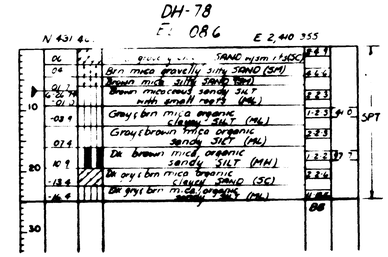


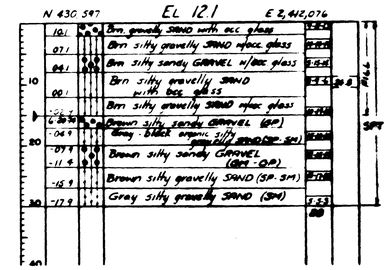


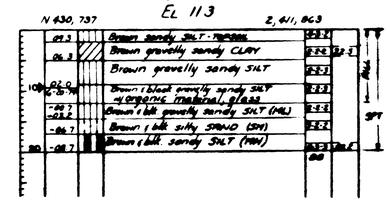


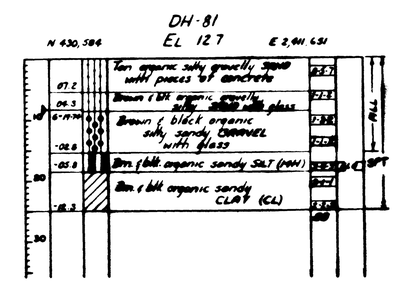












REV	DATE	DESCRIPTION	BY

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

POTOMAC RIVER BASIN
FOURMILE RUN, VIRGINIA

FOURMILE RUN FLOOD CONTROL PROJECT
CHANNEL IMPROVEMENTS

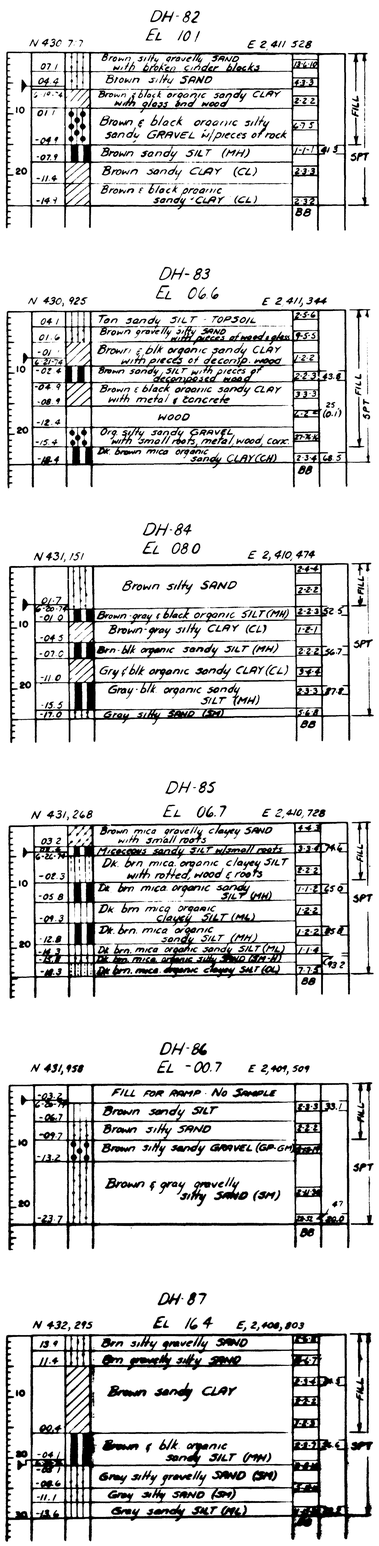
FOUNDATION EXPLORATION

LOGS OF CORE BORINGS-SHEET 4

DRAWING NUMBER 15768-1 PLATE B-5

SCALE AS SHOWN DATE 1 MAY 1978 SHEET 77

15



REV	DATE	REMARKS	BY

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

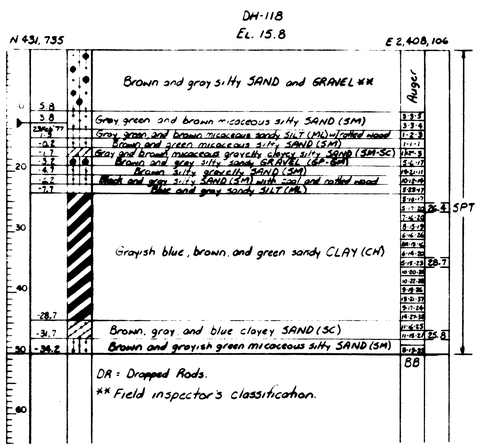
POTOMAC RIVER BASIN
FOURMILE RUN, VIRGINIA

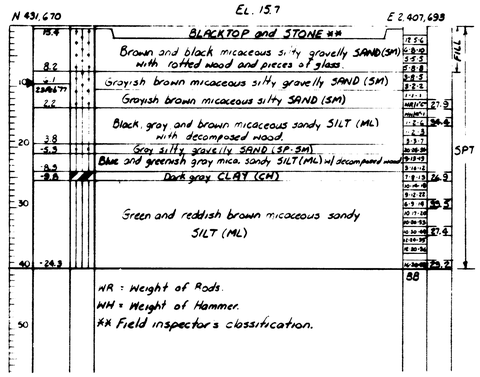
FOURMILE RUN FLOOD CONTROL PROJECT
CHANNEL IMPROVEMENTS

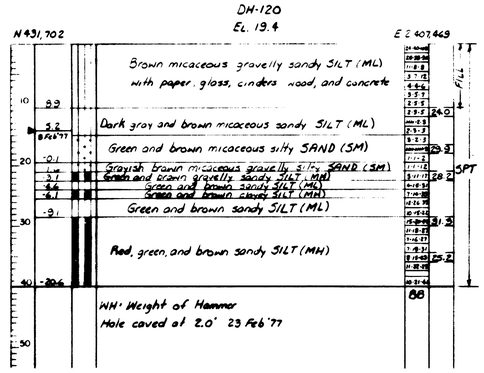
FOUNDATION EXPLORATION
LOGS OF CORE BORINGS-SHEET 5

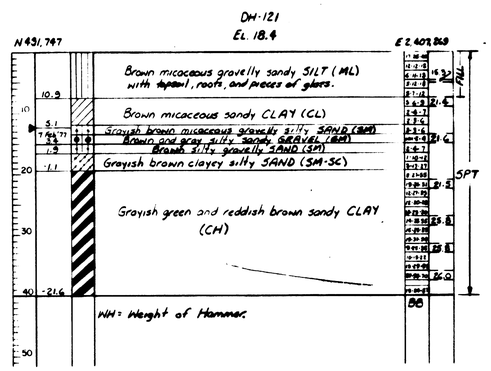
	15768-1	B-6
AS SHOWN	1 MAY 1978	78

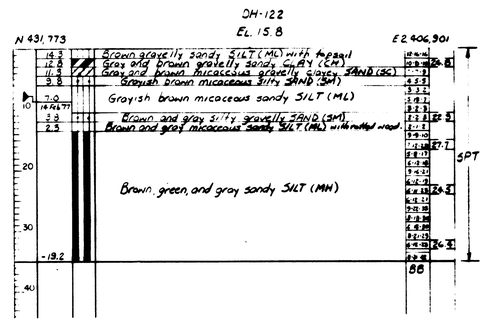
16

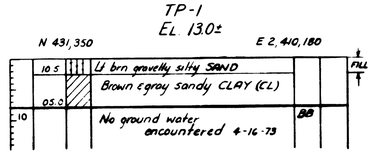


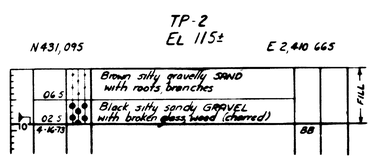


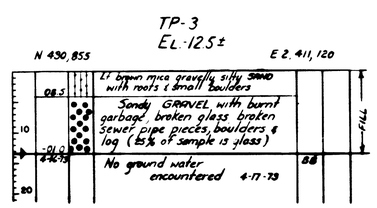


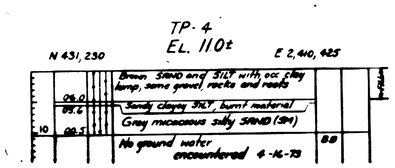


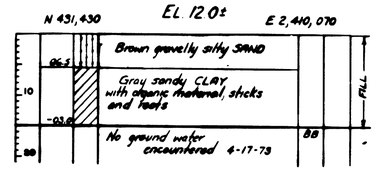


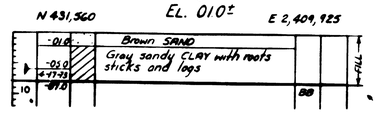












REV.	DATE	REVISION	BY

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
BALTIMORE, MARYLAND

POTOMAC RIVER BASIN
FOURMILE RUN, VIRGINIA

FOURMILE RUN FLOOD CONTROL PROJECT
CHANNEL IMPROVEMENTS

FOUNDATION EXPLORATION
LOGS OF CORE BORINGS-SHEET 6

15768-1 | B-7

AS SHOWN | 1 MAY 1978 | 79

DC Coastal Geotechnical Data Summary

Arlington Wastewater Treatment Plant Flood Wall

Four Mile Run Flood Control Project Channel Improvements - 1978

G.S. EL	10.5	6.6	10	8.6	6.7	6.9	6.6	14.7
GW Depth	10.5	5	7.3	7	4.5	6.5	7.5	14
GW EL	0	1.6	2.7	1.6	2.2	0.4	-0.9	0.7

Depth	DH-37	*DH-11*	*DH-6*	DH-78	DH-85	*DH-15*	DH-83	*DH-7*	Depth
0.5	16	5	10	13	7	5	11	17	0.5
1									1
1.5		5	21			15		36	1.5
2									2
2.5		10	20			9		22	2.5
3									3
3.5		6	29		7	14		11	3.5
4	40			12			10		4
4.5		4	34			40		9	4.5
5									5
5.5		4	5			50		6	5.5
6									6
6.5		2	10			14		6	6.5
7									7
7.5	6	4	5	5	4	4	4	8	7.5
8									8
8.5		4	4			7		7	8.5
9									9
9.5		PUSH	3			4		6	9.5
10									10
10.5			2			4	5	13	10.5
11	5			6					11
11.5		3	37		3	5		17	11.5
12									12
12.5		3	10			PUSH		12	12.5
13							6		13
13.5		3	6					7	13.5
14									14
14.5	9	2	10	4	4			17	14.5
15									15
15.5		2	W.O.R.			3		17	15.5
16									16
16.5		4	2			4	7	9	16.5
17									17
17.5		PUSH	7			2		4	17.5
18	15			8	4	PUSH			18
18.5			11					4	18.5
19									19
19.5		11	17					5	19.5
20							92		20
20.5		26	13		5	5		6	20.5
21									21
21.5	38	35	28	##		5		3	21.5
22									22
22.5		31	10			7		3	22.5
23									23
23.5		41	17			8		4	23.5
24									24
24.5		24	34		12	8	7	5	24.5
25									25
25.5	##	25'-0"	25'-0"		25'-0"	25'-0"	25'-0"		25.5
26								PUSH	26
26.5									26.5
27									27
27.5									27.5
28								5	28
28.5									28.5
29	##							6	29
29.5									29.5
30								6	30
	30-'0"								30.5
								7	31
									31.5
								10	32
									32.5
								13	33
									33.5
								6	34
									34.5
								9	35
									35.5
								8	36
									36.5
								9	37
									37.5
								12	38
									38.5
									39
									39.5
									40
								40'-0"	

N-Value Summary - 2-inch spoon				
Stratum		MIN	MAX	AVG
FILL		4	92	17
Organic SILT/CLAY		3	15	7
SAND & GRAVEL		8	38	23

N-Value Summary - 3-inch spoon				
Stratum		MIN	MAX	AVG
FILL		3	50	13
Organic SILT/CLAY		W.O.R.	37	6
SAND & GRAVEL		5	41	20

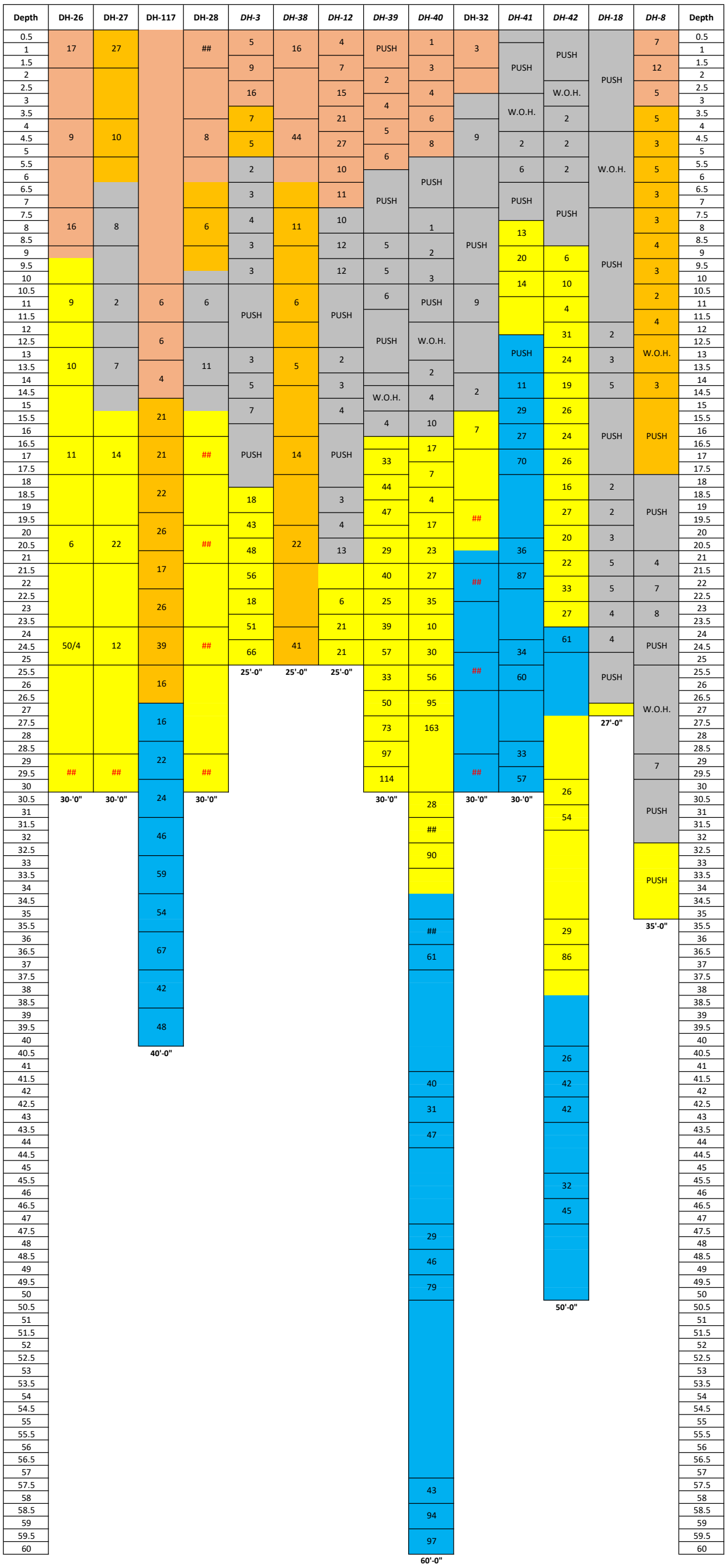
Denotes an Illegible Number on the Historic Drawings

DC Coastal Geotechnical Data Summary

Four Mile Run Flood Wall and Levee

Four Mile Run Flood Control Project Channel Improvements - 1978

	DH-26	DH-27	DH-117	DH-28	DH-3	DH-38	DH-12	DH-39	DH-40	DH-32	DH-41	DH-42	DH-18	DH-8
G.S. EL	19	12.9	14.6	13.3	11	11	8.5	6.4	5.1	5.7	5.3	4.6	3	8
GW Depth	11	11	11.5	11.5	5	11.4	8.5	1.3	3.2	5.1	3.3	0.9	0	4.8
GW EL	8	1.9	3.1	1.8	6	-0.4	0	5.1	1.9	0.6	2	3.7	3	3.2

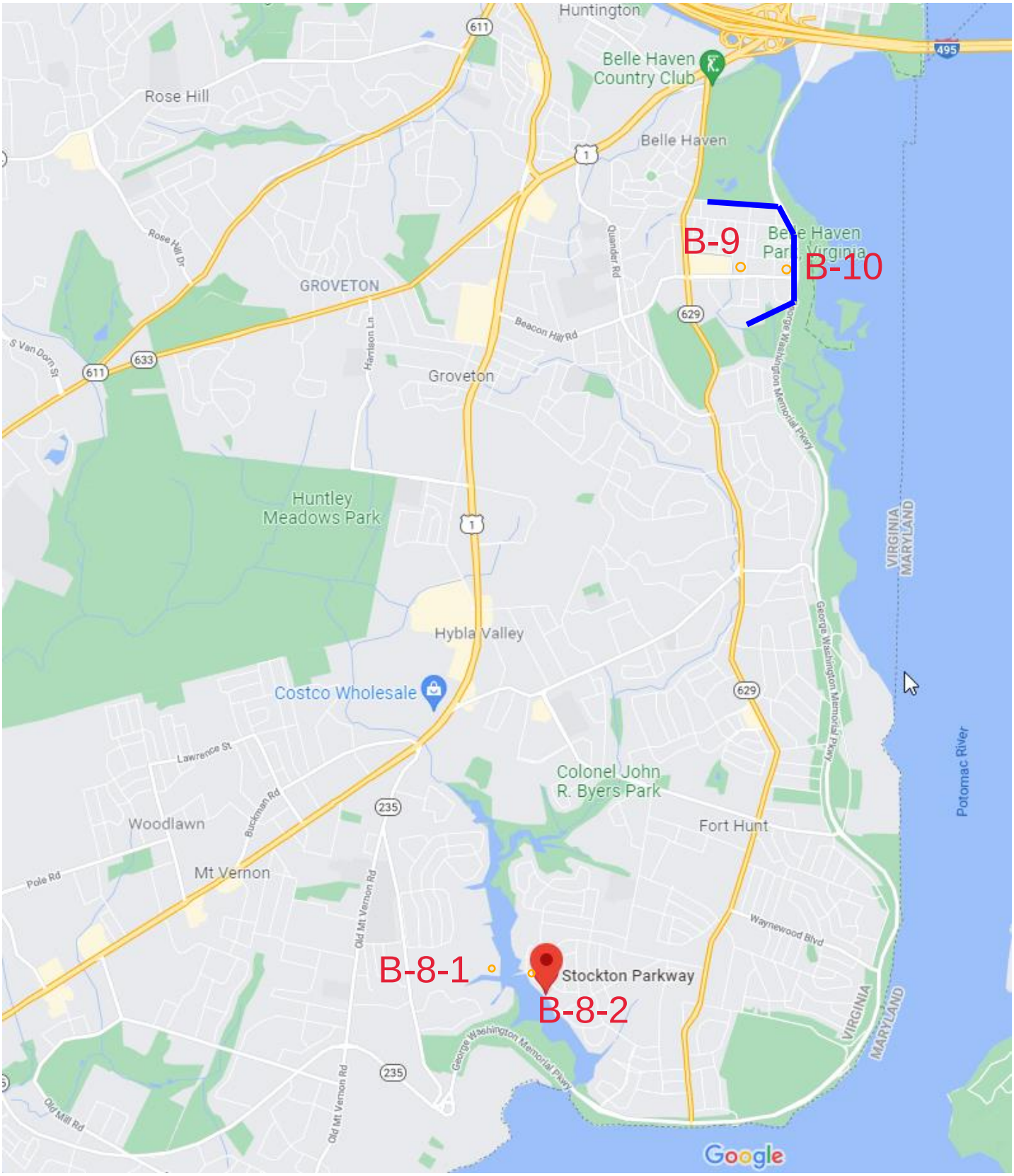


N-Value Summary - 2-inch spoon				
Stratum		MIN	MAX	AVG
FILL		3	17	9
Clayey SAND		6	39	21
Organic SILT/CLAY		2	11	7
SAND & GRAVEL		6	22	11
CLAY/SILT		16	67	42

N-Value Summary - 3-inch spoon				
Stratum		MIN	MAX	AVG
FILL		1	44	10
Clayey SAND		W.O.H.	41	8
Organic SILT/CLAY		W.O.H.	13	4
SAND & GRAVEL		4	163	37
CLAY/SILT		11	97	48

Denotes an Illegible Number on the Historic Drawings

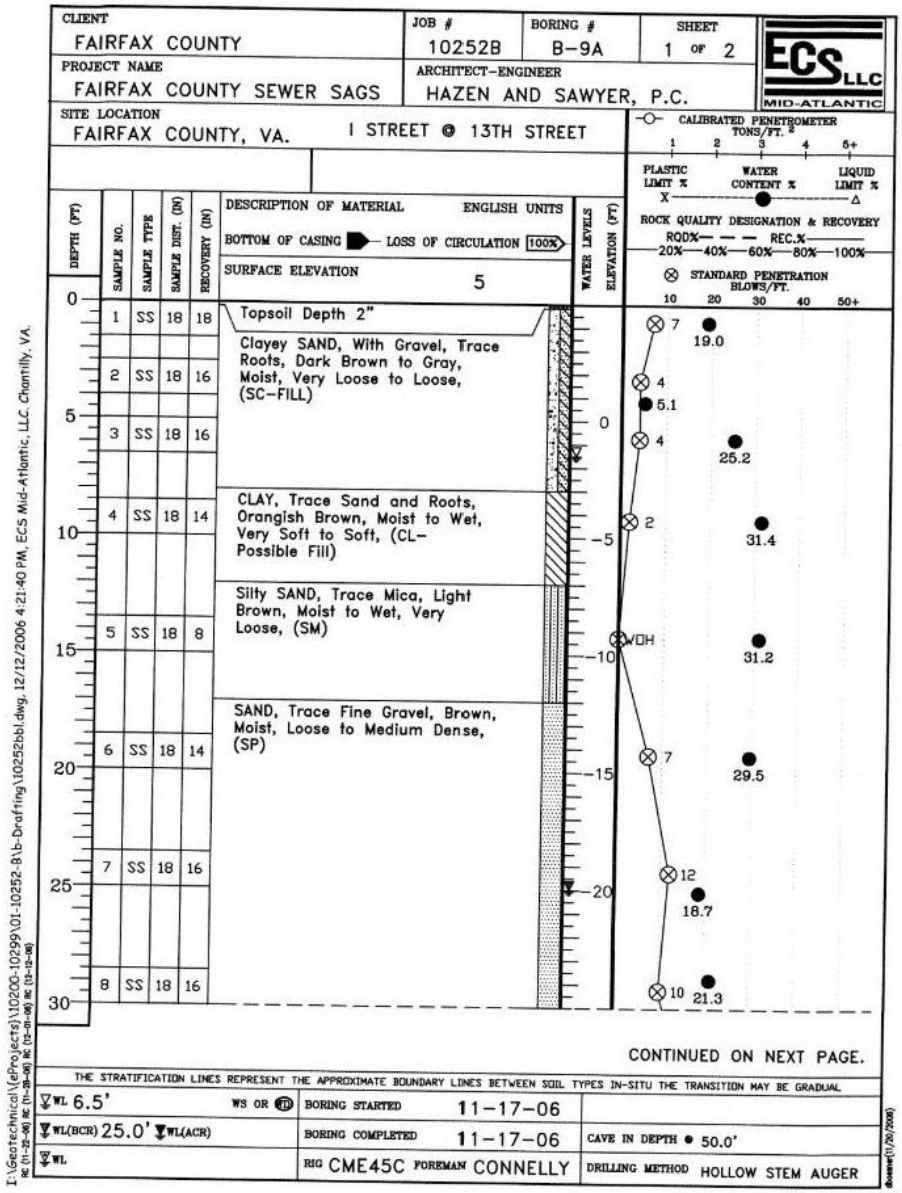
12.1.3 – Belle Haven Geotechnical Data



BELLE HAVEN BORING LOCATION PLAN

APPROXIMATE ALIGNMENT OF PROPOSED FLOOD MITIGATION STRUCTURE(S)

Appendix D – Soil Borings



CLIENT	JOB #	BORING #	SHEET
FAIRFAX COUNTY	10252B	B-9A	2 OF 2
PROJECT NAME: FAIRFAX COUNTY SEWER SAGS	ARCHITECT-ENGINEER: HAZEN AND SAWYER, P.C.		
SITE LOCATION: FAIRFAX COUNTY, VA. I STREET @ 13TH STREET			

ECS LLC MID-ATLANTIC

CALIBRATED PENETROMETER TONS/FT.^{2} 1 2 3 4 5+

PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % Δ

ROCK QUALITY DESIGNATION & RECOVERY RQD% — — — REC.% 20% 40% 60% 80% 100%

⊗ STANDARD PENETRATION BLOWS/FT. 10 20 30 40 50+

BOTTOM OF CASING ▶ — LOSS OF CIRCULATION 100%

SURFACE ELEVATION 5

DEPTH (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL (ENGLISH UNITS)	ELEVATION (FT)	STANDARD PENETRATION BLOWS/FT.	PLASTIC LIMIT %	WATER CONTENT %	LIQUID LIMIT %
30					SAND, Trace Fine Gravel, Brown, Moist, Loose to Medium Dense, (SP)					
35	9	SS	18	16		30	11		21.3	
					Silty SAND, With Gravel, Orangish Brown, Moist, Medium Dense, (SM)					
40	10	SS	18	16		35	12		9.8	
45	11	SS	18	12		40	23		10.4	
50	12	SS	18	12		45	28		8.2	
					END OF BORING @ 50.00'					
55						50				
60										

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL.

▽WL 6.5' WS OR PD	BORING STARTED 11-17-06	
▽WL(BCR) 25.0' ▽WL(ACR)	BORING COMPLETED 11-17-06	CAVE IN DEPTH ● 50.0'
▽WL	RIG CME45C FOREMAN CONNELLY	DRILLING METHOD HOLLOW STEM AUGER

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CLIENT	JOB #	BORING #	SHEET
FAIRFAX COUNTY	10252B	B-10A	1 OF 2
PROJECT NAME: FAIRFAX COUNTY SEWER SAGS	ARCHITECT-ENGINEER: HAZEN AND SAWYER, P.C.		
SITE LOCATION: FAIRFAX COUNTY, VA. BELLE VIEW BLVD.			

ECS LLC MID-ATLANTIC

CALIBRATED PENETROMETER TONS/FT.^{2} 1 2 3 4 5+

PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % Δ

ROCK QUALITY DESIGNATION & RECOVERY RQD% — — — REC.% 20% 40% 60% 80% 100%

⊗ STANDARD PENETRATION BLOWS/FT. 10 20 30 40 50+

BOTTOM OF CASING ▶ — LOSS OF CIRCULATION 100%

SURFACE ELEVATION 10

DEPTH (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL (ENGLISH UNITS)	ELEVATION (FT)	STANDARD PENETRATION BLOWS/FT.	PLASTIC LIMIT %	WATER CONTENT %	LIQUID LIMIT %
0	1	SS	18	12	Asphalt Depth 3"		6		14.3	
					Gravel Depth 6"					
5	2	SS	18	18	Fine Sandy SILT, With Gravel, Trace Asphalt, Brown to Dark Brown, Moist, Loose, (ML-FILL)	5	5		23.5	
	3	SS	18	18	Lean CLAY, With Sand, Trace Mica, Brown, Moist to Wet, Soft to Medium Stiff, (CL)	0	6	19	27.1	31
10	4	SS	18	14			3		32.8	
15	5	SS	18	10	Silty SAND, Trace Clay, Brown, Moist to Wet, Very Loose, (SM)	-5	1		25.6	
20	6	SS	18	16	Fine Sandy SILT, Light Brown, Moist to Wet, Very Loose, (ML)	-10	3		33.2	
25	7	SS	18	16	SAND, Trace Clay, Brown, Moist to Wet, Very Loose to Loose, (SP)	-15	4		26.2	
30	8	SS	18	18			7		23.7	

CONTINUED ON NEXT PAGE.

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL.

▽WL 7.5' WS OR PD	BORING STARTED 11-14-06	
▽WL(BCR) 38.0' ▽WL(ACR)	BORING COMPLETED 11-14-06	CAVE IN DEPTH ● 50.0'
▽WL	RIG CME45C FOREMAN CONNELLY	DRILLING METHOD HOLLOW STEM AUGER

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CLIENT	JOB #	BORING #	SHEET
FAIRFAX COUNTY	10252B	B-10A	2 OF 2
PROJECT NAME: FAIRFAX COUNTY SEWER SAGS	ARCHITECT-ENGINEER: HAZEN AND SAWYER, P.C.		
SITE LOCATION: FAIRFAX COUNTY, VA. BELLE VIEW BLVD.			

ECS LLC MID-ATLANTIC

CALIBRATED PENETROMETER TONS/FT.^{2} 1 2 3 4 5+

PLASTIC LIMIT % X — WATER CONTENT % ● — LIQUID LIMIT % △

ROCK QUALITY DESIGNATION & RECOVERY RQD% — — — REC.% 20% 40% 60% 80% 100%

⊗ STANDARD PENETRATION BLOWS/FT. 10 20 30 40 50+

DESCRIPTION OF MATERIAL — ENGLISH UNITS

BOTTOM OF CASING ▶ — LOSS OF CIRCULATION 100%

SURFACE ELEVATION 10

DEPTH (FT)	SAMPLE NO.	SAMPLE TYPE	SAMPLE DIST. (IN)	RECOVERY (IN)	DESCRIPTION OF MATERIAL	WATER LEVELS ELEVATION (FT)	STANDARD PENETRATION BLOWS/FT.	ROCK QUALITY DESIGNATION & RECOVERY
30					SAND, Trace Clay, Brown, Moist to Wet, Very Loose to Loose, (SP)			
35	9	SS	18	16	SAND, With Fine Gravel, Brown to Dark Brown, Moist to Wet, Medium Dense, (SP)	25	13	17.2
40	10	SS	18	14		30	15	16.2
45	11	SS	18	16	Gravelly SAND, Trace Clay, Light Brown, Moist, Medium Dense, (SP)	35	16	13.1
50	12	SS	18	14		40	19	17.7
55						45		
60								

END OF BORING @ 50.00'

THE STRATIFICATION LINES REPRESENT THE APPROXIMATE BOUNDARY LINES BETWEEN SOIL TYPES IN-SITU THE TRANSITION MAY BE GRADUAL

▽WL 7.5' WS OR WD	BORING STARTED 11-14-06	
▽WL(BCR) 38.0' ▽WL(ACR)	BORING COMPLETED 11-14-06	CAVE IN DEPTH ● 50.0'
▽WL	RIG CME45C FOREMAN CONNELLY	DRILLING METHOD HOLLOW STEM AUGER

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Temporary Piezometer No.	Date	Approx. Elevation of Temporary Piezometer (ft)	Water Level (ft)	Approx. Water Elevation (ft)
B6-2A	11/21/2006	5	1.7	3.3
B8-1A	11/21/2006	6.6	1.9	4.7
B8-2A	11/21/2006	12.6	10.3	2.3
B9-A	11/21/2006	5	1.3	3.7
B10-A	11/21/2006	10	6.0	4.1
B6-2A	11/29/2006	5	1.2	3.8
B8-1A	11/29/2006	6.6	1.2	5.4
B8-2A	11/29/2006	12.6	9.9	2.7
B9-A	11/29/2006	5	1.2	3.8
B10-A	11/29/2006	10	5.7	4.4

ECS Mid-Atlantic, LLC
Chantilly, Virginia
Laboratory Testing Summary

Project Number: 10252-B

Project Name: Fairfax County Sewer Sags

Date: 11/27/06

Project Engineer: TKM

Principal Engineer: KAH

Summary By: HNT

Boring Number	Sample Number	Depth (feet)	Moisture Content (%)	USCS	Liquid Limit	Plastic Limit	Plasticity Index	Percent Passing No. 200 Sieve	Compaction Maximum Density (pcf)	Compaction Optimum Moisture (%)	CBR Value	Other
B-10A	S-1	0-1.5	14.3									
B-10A	S-2	2.5-4.0	23.5									
B-10A	S-3	5.0 - 6.5	27.1	CL	31	19	12	77.0				
B-10A	S-4	8.5 - 10.0	32.8									
B-10A	S-5	13.5 - 15.0	25.6									
B-10A	S-6	18.5 - 20.0	33.2									
B-10A	S-7	23.5 - 25.0	26.2									
B-10A	S-8	28.5 - 30.0	23.7									
B-10A	S-9	33.5 - 35.0	17.2									
B-10A	S-10	38.5 - 40.0	16.2									
B-10A	S-11	43.5 - 45.0	13.1									
B-10A	S-12	48.5 - 50.0	17.7									
B9-A	S-1	0-1.5	19.0									
B9-A	S-2	2.5-4.0	5.1									
B9-A	S-3	5.0 - 6.5	25.2									
B9-A	S-4	8.5 - 10.0	31.4									
B9-A	S-5	13.5 - 15.0	31.2	SM	NP	NP	NP	33.6				
B9-A	S-6	18.5 - 20.0	29.5									
B9-A	S-7	23.5 - 25.0	18.7									
B9-A	S-8	28.5 - 30.0	21.3									
B9-A	S-9	33.5 - 35.0	21.3									

Summary Key:
SA = See Attached
S = Standard Proctor
M= Modified Proctor
V = Virginia Test Method
OC = Organic Content

Hyd = Hydrometer
Con = Consolidation
DS = Direct Shear
GS = Specific Gravity

UCS = Unconfined Compression Soil
UCR = Unconfined Compression Rock
LS = Lime Stabilization
CS = Cement Staibilization

109768M.xls

ECS Mid-Atlantic, LLC
Chantilly, Virginia
Laboratory Testing Summary

Project Number: 10252-B

Project Name: Fairfax County Sewer Sags

Date: 11/27/06

Project Engineer: TKM

Principal Engineer: KAH

Summary By: HNT

Boring Number	Sample Number	Depth (feet)	Moisture Content (%)	USCS	Liquid Limit	Plastic Limit	Plasticity Index	Percent Passing No. 200 Sieve	Compaction Maximum Density (pcf)	Compaction Optimum Moisture (%)	CBR Value	Other
B9-A	S-10	38.5 - 40.0	9.8									
B9-A	S-11	43.5 - 45.0	10.4									
B9-A	S-12	48.5 - 50.0	8.2									
B6-2A	S-1	0-1.5	12.2									
B6-2A	S-2	2.5-4.0	19.9									
B6-2A	S-3	5.0 - 6.5	23.4									
B6-2A	S-4	8.5 - 10.0	14.5									
B6-2A	S-5	13.5 - 15.0	25.8									
B6-2A	S-6	18.5 - 20.0	26.8	SM	NP	NP	NP	31.1				
B6-2A	S-7	23.5 - 25.0	38.3									
B6-2A	S-8	28.5 - 30.0	35.6									
B6-2A	S-9	33.5 - 35.0	37.8									
B6-2A	S-10	38.5 - 40.0	36.6									
B6-2A	S-11	43.5 - 45.0	44.2									
B6-2A	S-12	48.5 - 50.0	34.2									

Summary Key:
SA = See Attached
S = Standard Proctor
M= Modified Proctor
V = Virginia Test Method
OC = Organic Content

Hyd = Hydrometer
Con = Consolidation
DS = Direct Shear
GS = Specific Gravity

UCS = Unconfined Compression Soil
UCR = Unconfined Compression Rock
LS = Lime Stabilization
CS = Cement Staibilization

109768M.xls

ECS Mid-Atlantic, LLC
Chantilly, Virginia
Laboratory Testing Summary

Project Number: 10252-B

Project Name: Fairfax County Sewer Sags

Completed Date: 11/29/06

Project Engineer: TKM

Principal Engineer: KAH

Summary By: HNT

Boring Number	Sample Number	Depth (feet)	Moisture Content (%)	USCS	Liquid Limit	Plastic Limit	Plasticity Index	Percent Passing No. 200 Sieve	Compaction Maximum Density (pcf)	Compaction Optimum Moisture (%)	CBR Value	Other
8A-2A	S-10	38.5 - 40.0	46.0									
8A-2A	S-11	43.5 - 45.0	43.3									
8A-2A	S-12	48.5 - 50.0	258.8									

Summary Key:

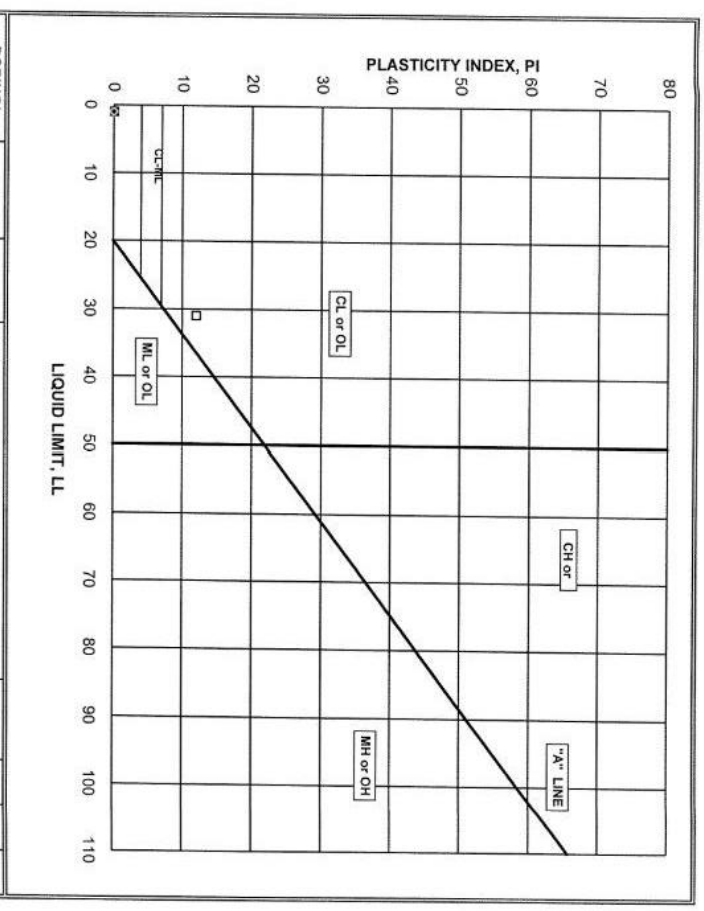
SA = See Attached
S = Standard Proctor
M= Modified Proctor
V = Virginia Test Method
OC = Organic Content

Hyd = Hydrometer
Con = Consolidation
DS = Direct Shear
GS = Specific Gravity

UCS = Unconfined Compression Soil
UCR = Unconfined Compression Rock
LS = Lime Stabilization
CS = Cement Stabilization

NP = Non Plastic

109779M.xls



BORING/ SAMPLE No.	DEPTH (feet)	TEST SYMBOL	DESCRIPTION	WATER CONTENT (%)	LL	PL	PI
B-10A / S-3	5.0-6.5	□	Lean Clay w/Sand Tr/Mica Yellowish Brown (CL)	27.1	31	19	12
B9-A / S-5	13.5-15.0	■	Silty Sand Tr/Mica Yellow Brown (SM)	31.2	NP	NP	NP
B6-2A / S-6	18.5-20.0	△	Silty Sand Tr/Mica Grayish Brown (SM)	26.8	NP	NP	NP
/		▶		-	-	-	-
/		×		-	-	-	-
/		○		-	-	-	-
/		●		-	-	-	-
/		◇		-	-	-	-
/		◆		-	-	-	-
/		+		-	-	-	-
		×					

Project: Fairfax County Sewer Sags

Project No.: 10252-B

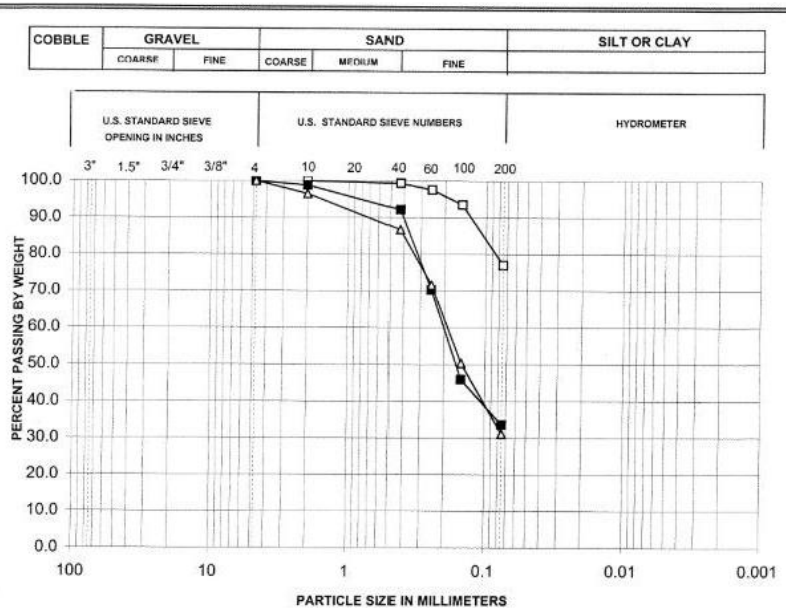
Date: 11/22/06

ECS Mid-Atlantic, LLC

Chantilly, Virginia

Plasticity Chart

109768M.xls



Boring/ Sample No.	Depth (feet)	Symbol	LL	PI	Description
B-10A S-3	5.0-6.5	□	31	12	Lean Clay w/Sand Tr/Mica Yellowish Brown (CL)
B-9A S-5	13.5-15.0	■	NP	NP	Silty Sand Tr/Mica Yellow L/Brown (SM)
B6-2A S-6	18.5-20.0	△	NP	NP	Silty Sand Grayish Brown (SM)
		▲			

Applicable ASTM: D-422

Project: Fairfax County Sewer Sags

Project No: 10252-B

Performed Date: 11/22/06

ECS MID-ATLANTIC. LLC

Chantilly, Virginia

Grain Size Analysis

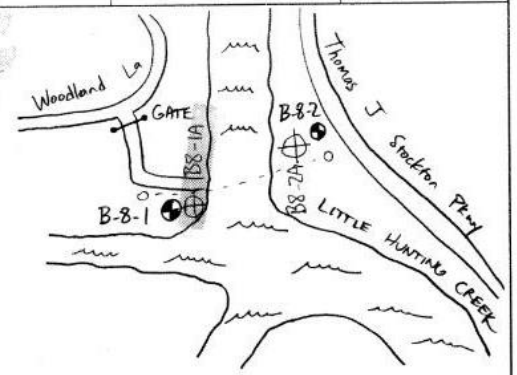
109768G.xls

ECS LTD
ENGINEERING CONSULTING SERVICES, LTD.
CALCULATION SHEET

PROJECT: Fairfax Co Sewer Sags			FIGURE NO.
TITLE: BLD - Sites 8, 9, 10, 12			JOB NO.
			SCALE:
BY:	DATE:	APPROVED BY:	DATE

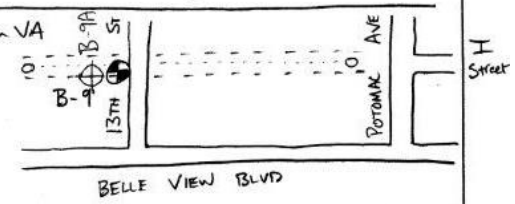
SITE 8: Little Hunting Creek between Woodland Lane + Thomas J. Stockton Parkway

2 Borings: B-8-1
B-8-2



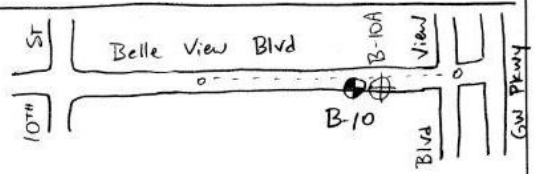
SITE 9: 13th + I Streets, Huntington VA

1 Boring: B-9



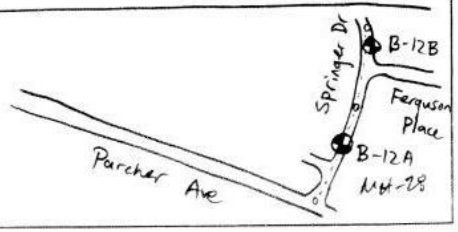
SITE 10: Belle View Blvd

1 Boring: B-10



SITE 12: Springer Dr, Herndon VA

2 Borings: B-12A
B-12B



DC Coastal Geotechnical Data Summary

Belle Haven Flood Wall and Levee

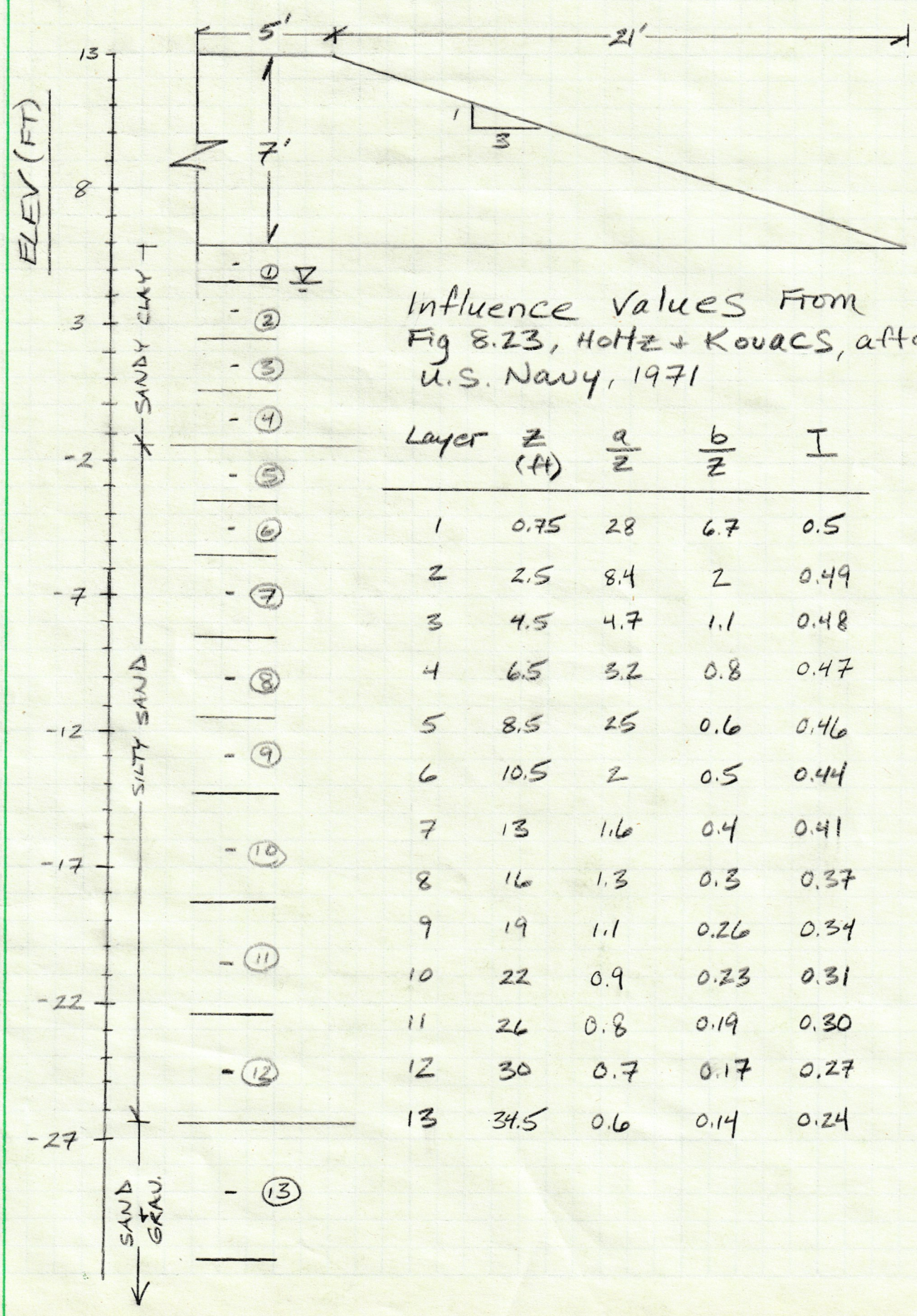
Final Flood Damage Reduction Analysis for Belle Haven Watershed - 2006

Depth	B-9A	B-10A
0.5	7	6
1		
1.5		
2		
2.5		
3	4	5
3.5		
4		
4.5		
5		
5.5	4	6
6		
6.5		
7		
7.5		
8		
8.5		
9	2	3
9.5		
10		
10.5		
11		
11.5		
12		
12.5		
13		
13.5		
14	W.O.H.	1
14.5		
15		
15.5		
16		
16.5		
17		
17.5		
18		
18.5		
19	7	3
19.5		
20		
20.5		
21		
21.5		
22		
22.5		
23		
23.5		
24	12	4
24.5		
25		
25.5		
26		
26.5		
27		
27.5		
28		
28.5		
29	10	7
29.5		
30		
30.5		
31		
31.5		
32		
32.5		
33		
33.5		
34	11	13
34.5		
35		
35.5		
36		
36.5		
37		
37.5		
38		
38.5		
39	12	15
39.5		
40		
40.5		
41		
41.5		
42		
42.5		
43		
43.5		
44	23	16
44.5		
45		
45.5		
46		
46.5		
47		
47.5		
48		
48.5		
49	28	19
49.5		
50		
	50'-0"	50'-0"

N-Value Summary				
Stratum		MIN	MAX	AVG
FILL		2	7	5
Sandy CLAY		3	6	5
Silty SAND		W.O.H.	12	6
SAND & GRAVEL		12	28	18

13.2.1 – Settlement Analysis

Calculate Estimated Levee Embankment Settlement



Influence Values From Fig 8.23, Holtz + Kovacs, after U.S. Navy, 1971

Layer	z (ft)	a/z	b/z	I
1	0.75	28	6.7	0.5
2	2.5	8.4	2	0.49
3	4.5	4.7	1.1	0.48
4	6.5	3.2	0.8	0.47
5	8.5	2.5	0.6	0.46
6	10.5	2	0.5	0.44
7	13	1.6	0.4	0.41
8	16	1.3	0.3	0.37
9	19	1.1	0.26	0.34
10	22	0.9	0.23	0.31
11	26	0.8	0.19	0.30
12	30	0.7	0.17	0.27
13	34.5	0.6	0.14	0.24

Immediate Sett. of Cohesive Soil (Layer 1)

$$\delta = I_q B \left(\frac{1 - \nu_s^2}{E_s} \right) \alpha$$

Eqn. 3-18
EM-1110-1-1904

$$\delta_1 = (0.5) \frac{(7ft)(125pcf)}{2{,}000\ lb/ton} (52\ ft) \left(\frac{1 - 0.4^2}{500\ tsf} \right) (1.0)$$

$$\delta_1 = 0.019\ ft\ (12\ in/ft) = \underline{0.23\ in}$$

Cohesive Soil Below Layer 1 is beneath groundwater
→ Calculate Consolidation Settlement for Layers 2, 3, 4

Consolidation Settlement

Assume: Normally Consolidated
$e_o = 0.8$

Estimate C_c

$C_c \cong 0.01(LL - 13)$ — From Table 3-7 EM-1110-1-1904

$LL = 31$ From Belle Haven Lab Data

$$C_c \cong 0.01(31 - 13) = 0.18$$

$$\delta = \frac{\Delta e}{1 + e_{o_i}} H_i$$

Eqn 3-20, EM-1110-1-1904

$$\Delta e = C_c \log \frac{\sigma_{f_i}}{\sigma_{o_i}}$$

Eqn 3-21, EM-1110-1-1904

Soil Layer 2 Calculation

$\sigma_o' = (110\,pcf)(2.5\,ft) - (62.4\,pcf)(1\,ft) = 212.6\,psf$

$\Delta\sigma = \gamma H I_2 = (125\,pcf)(7\,ft)(0.49) = 428.8\,psf$

$\sigma_f' = (212.6 + 428.8)\,psf = 641.4\,psf$

$\Delta e_2 = 0.18 \log\left(\frac{641.4}{212.6}\right) = 0.086$

$\delta = \frac{0.086}{(1+0.8)}(2\,ft) = 0.096\,ft = 1.15\,in$

See attached spreadsheet for rest of consol. calcs

Immediate Settlement of Sand

Schmertman Approx.

$\delta_i = C_1 \cdot C_t \cdot \Delta P \cdot \sum \frac{\Delta z}{E_s} \cdot I_{z_i}$ Eqn. 3-8 EM-1110-1-1904

$C_1 = 1 - 0.5\,\sigma_{cd}'/\Delta P \geq 0.5$

$C_t = 1 + 0.2 \log\left(\frac{t}{0.1}\right)$

Soil Layer 5 Calculations

$C_1 = 1 - 0.5(0\,psf)/(125\,pcf)(7\,ft) = 0.001 \geq 0.5$

$C_1 = 0.5$

$C_t = 1 + 0.2 \log\left(\frac{50}{0.1}\right)$ Assume $t = 50$ years

$C_t = 1.539$

$\delta_5 = (0.5)(1.539)(125\,pcf)(7\,ft)\frac{2\,ft}{200\,tsf\left(\frac{2000\,lb}{ton}\right)}(0.46)$

$\delta_5 = 0.0015\,ft = 0.018\,ft$

From Spreadsheet

Immediate Sett. Clay = 0.23 in
Consolidation Sett. Clay = 2.78 in
Immediate Sett. Sand = 0.16 in

Σ = 3.17 in

ıired:

a. Compute the stress under the center of the tank at a depth of 2 m below the tank.
b. Compute the stress under the edge of the tank, also a depth of 2 m.

ıtion:

a. Refer to Fig. 8.22.

$$z = 2 \text{ m}$$
$$r = 3.91/2 = 1.95 \text{ m}$$
$$x = 0; \text{ then}$$
$$z/r = 2/1.95 = 1.02$$
$$x/r = 0/1.95 = 0.$$

ı $I = 0.63$. Using Eq. 8-30 we obtain,

$$\sigma_z = q_o I = 117 \times 0.63 = 74 \text{ kPa}$$

ıs compares exactly with $\sigma_z = 74$ kPa at the center for a 3×4 m angular area in Example 8.18. In both cases, the area is 12 m^2.)

b. Again, refer to Fig. 8.22. For the edge of the circular loaded area

$$z = 2 \text{ m}$$
$$r = 1.95 \text{ m}$$
$$x = r = 1.95 \text{ m}$$
$$z/r = 2/1.95 = 1.02$$
$$x/r = 1.0$$

d $I = 0.33$; then using Eq. 8-30,

$$\sigma_z = q_o I = 117 \times 0.33 = 39 \text{ kPa}$$

is compares with $\sigma_z = 26$ kPa at a corner for a 3×4 m uniformly led rectangular area. In both cases, the area of the loaded area is the ıe.)

Another useful integration of the Boussinesq equations is the ›ezoidal loading shown in Fig. 8.23, which models the loading caused a *long embankment*. Influence values are in terms of the dimensions a l b, as shown in the figure. If the embankment is not infinitely long n use Fig. 8.24 together with Fig. 8.21 to represent different load ıfigurations.

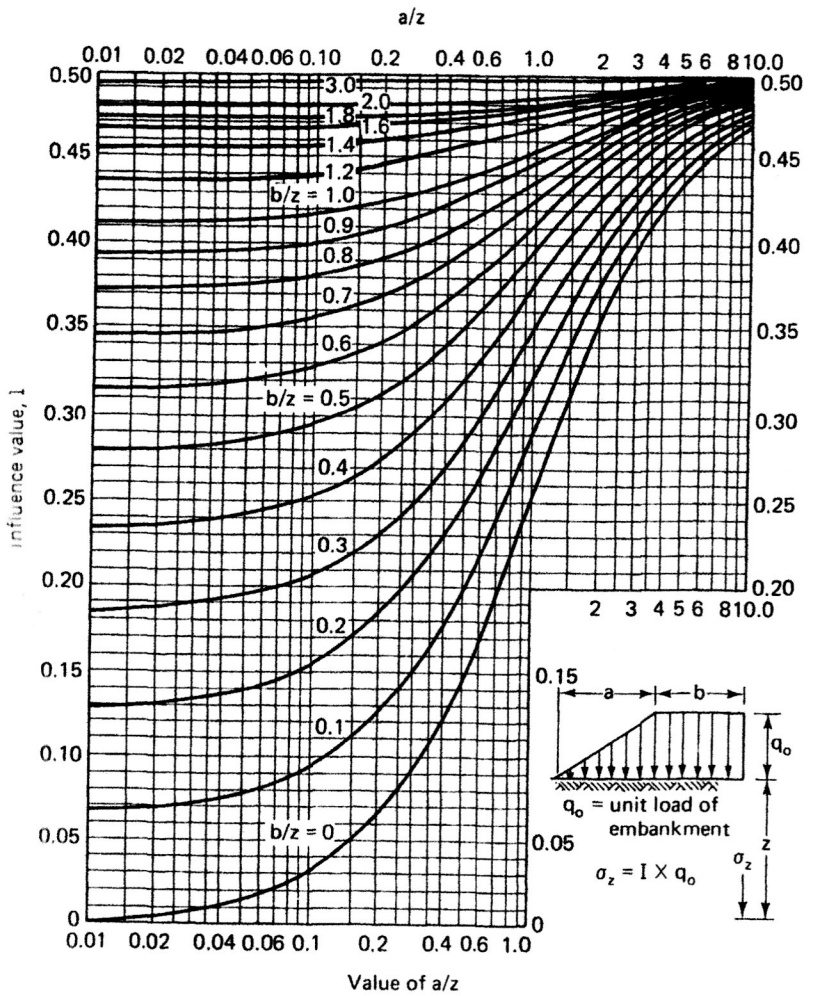


Fig. 8.23 Influence values for vertical stress under a very long embankment; length = ∞ (from U.S. Navy, 1971, after Osterberg, 1957).

Project Name:	DC Coastal - Belle Haven Site - 10% Design
Project Location:	Belle Haven, VA
Project Number:	
Calculations By:	Michael Fritzges, PE
Date:	2/9/2023

ΔP (psf)	875
Width (ft)	52
Poisson's Ratio	0.4

Immediate Settlement of Clay Stratum

Layer	Top EL (ft)	Bott. EL (ft)	Thickness (ft)	I	Es (tsf)	Settlement (ft)
1	6	4.5	1.5	0.5	500	0.019
					SUM:	0.019 ft
						0.229 in

Consolidation Settlement of Clay Stratum

Layer	Top EL (ft)	Bott. EL (ft)	Thickness (ft)	γ (pcf)	Cc	e_0	P'_o (psf)	I	P'_f (psf)	Δe	Settlement (ft)
2	4.5	2.5	2	110	0.18	0.8	212.6	0.49	641.35	0.09	0.096
3	2.5	0.5	2	110	0.18	0.8	307.8	0.48	727.8	0.07	0.075
4	0.5	-1.5	2	110	0.18	0.8	403	0.47	814.25	0.05	0.061
										SUM:	0.232 ft
											2.781 in

Immediate Settlement of Sand Stratum

Schmertmann Input Parameters

Δp (tsf)	0.4375
t (years)	50
C1	0.5
Ct	1.5398

Layer	Top EL (ft)	Bott. EL (ft)	Thickness (ft)	γ (pcf)	I	Es (tsf)	Settlement (ft)
5	-1.5	-3.5	2	110	0.46	200	0.0015
6	-3.5	-5.5	2	110	0.44	200	0.0015
7	-5.5	-8.5	3	110	0.41	200	0.0021
8	-8.5	-11.5	3	110	0.37	200	0.0019
9	-11.5	-14.5	3	110	0.34	250	0.0014
10	-14.5	-18.5	4	110	0.31	250	0.0017
11	-18.5	-22.5	4	110	0.3	250	0.0016
12	-22.5	-26.5	4	110	0.27	400	0.0009
13	-26.5	-31.5	5	125	0.24	750	0.0005
						SUM:	0.013 ft
							0.157 in

Total Anticipated Soil Settlement

Immediate Clay	0.229	in
Consolidation	2.781	in
Immediate Sand	0.157	in
Total	**3.167**	**in**

13.2.2 – Liquefaction Screening

DC Coastal Feasibility Analysis
Liquefaction Screening

PGA: 0.0688 Water Depth: 11

Note: Greyed out soils are not subject to liquafaction because they either, 1) are not granular; 2) have an (N1)60 value greater than 30; or are above water table

Depth (ft)	Depth (m)	USCS	γ	σ_{vo}	σ_{vo}'	r_d	N	CSR	FC	α	β	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60cs}$	CRR7.5	FS
1	0.30	SM	120	120	120	1.00	16	0.04	13	1.89	1.04	1.75	0.80	1.00	0.75	1.00	17	19	0.21	**4.63**
4.5	1.37	SM	120	540	540	0.99	40	0.04	13	1.89	1.04	1.51	0.80	1.00	0.75	1.00	36	40	0.11	**2.40**
8	2.44	ML	110	925	925	0.98	6	0.04	13	1.89	1.04	1.34	0.80	1.00	0.75	1.00	5	7	0.09	**1.98**
11.5	3.51	ML	110	1310	1279	0.98	5	0.04	13	1.89	1.04	1.22	0.80	1.00	0.80	1.00	4	6	0.08	**1.77**
15	4.57	ML	110	1695	1445	0.97	9	0.05	13	1.89	1.04	1.17	0.80	1.00	0.85	1.00	7	9	0.11	**2.11**
18.5	5.64	ML	110	2080	1612	0.96	15	0.06	13	1.89	1.04	1.12	0.80	1.00	0.85	1.00	11	14	0.15	**2.67**
22	6.71	SM	125	2518	1831	0.95	38	0.06	13	1.89	1.04	1.07	0.80	1.00	0.95	1.00	31	34	4.93	**84.33**

Stratum	
FILL	120
Organic SILT/CLAY	110
SAND & GRAVEL	125

DC Coastal Feasibility Analysis
Liquefaction Screening

PGA: 0.0688 Water Depth: 7

Note: Greyed out soils are not subject to liquafaction because they either, 1) are not granular; 2) have an (N1)60 value greater than 30; or are above water table

Depth (ft)	Depth (m)	USCS	γ	σ_{vo}	σ_{vo}'	r_d	N	CSR	FC	α	β	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60cs}$	CRR7.5	FS
1	0.30	SM	120	120	120	1.00	13	0.04	13	1.89	1.04	1.75	0.80	1.00	0.75	1.00	14	16	0.17	**3.82**
4.5	1.37	SM	120	540	540	0.99	12	0.04	13	1.89	1.04	1.51	0.80	1.00	0.75	1.00	11	13	0.14	**3.21**
8	2.44	ML	110	925	863	0.98	5	0.05	13	1.89	1.04	1.37	0.80	1.00	0.75	1.00	4	6	0.08	**1.71**
11.5	3.51	ML	110	1310	1029	0.98	6	0.06	13	1.89	1.04	1.30	0.80	1.00	0.80	1.00	5	7	0.09	**1.59**
15	4.57	ML	110	1695	1196	0.97	4	0.06	13	1.89	1.04	1.25	0.80	1.00	0.85	1.00	3	5	0.08	**1.22**
18.5	5.64	ML	125	2133	1415	0.96	8	0.06	13	1.89	1.04	1.18	0.80	1.00	0.85	1.00	6	9	0.10	**1.55**

Stratum	
FILL	120
Organic SILT/CLAY	110
SAND & GRAVEL	125

DC Coastal Feasibility Analysis
Liquefaction Screening

PGA: 0.0688 Water Depth: 8

Note: Greyed out soils are not subject to liquafaction because they either, 1) are not granular; 2) have an (N1)60 value greater than 30; or are above water table

Depth (ft)	Depth (m)	USCS	γ	σ_{vo}	σ_{vo}'	r_d	N	CSR	FC	α	β	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60cs}$	CRR7.5	FS
1	0.30	SM	120	120	120	1.00	11	0.04	13	1.89	1.04	1.75	0.80	1.00	0.75	1.00	12	14	0.15	**3.33**
4	1.22	SM	120	480	480	0.99	10	0.04	13	1.89	1.04	1.54	0.80	1.00	0.75	1.00	9	11	0.13	**2.85**
8	2.44	SM	120	960	960	0.98	4	0.04	13	1.89	1.04	1.33	0.80	1.00	0.75	1.00	3	5	0.07	**1.67**
12	3.66	SM	120	1440	1190	0.97	5	0.05	13	1.89	1.04	1.25	0.80	1.00	0.80	1.00	4	6	0.08	**1.52**
14.5	4.42	SM	120	1740	1334	0.97	6	0.06	13	1.89	1.04	1.20	0.80	1.00	0.85	1.00	5	7	0.09	**1.55**
18	5.49	SM	120	2160	1536	0.96	7	0.06	13	1.89	1.04	1.14	0.80	1.00	0.85	1.00	5	8	0.09	**1.52**
21	6.40	SM	120	2520	1709	0.95	92	0.06	13	1.89	1.04	1.10	0.80	1.00	0.95	1.00	77	81	0.58	**9.16**
24.5	7.47	ML	110	2905	1875	0.94	7	0.07	13	1.89	1.04	1.05	0.80	1.00	0.95	1.00	6	8	0.09	**1.43**

Stratum	
FILL	120
Organic SILT/CLAY	110
SAND & GRAVEL	125

DC Coastal Feasibility Analysis
Liquefaction Screening

PGA: 0.0688 Water Depth: 5

Note: Greyed out soils are not subject to liquafaction because they either, 1) are not granular; 2) have an (N1)60 value greater than 30; or are above water table

Depth (ft)	Depth (m)	USCS	γ	σ_{vo}	σ_{vo}'	r_d	N	CSR	FC	α	β	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60cs}$	CRR7.5	FS
1	0.30	SM	120	120	120	1.00	7	0.04	13	1.89	1.04	1.75	0.80	1.00	0.75	1.00	7	10	0.11	**2.43**
4	1.22	SM	120	480	480	0.99	7	0.04	13	1.89	1.04	1.54	0.80	1.00	0.75	1.00	6	9	0.10	**2.28**
8.0	2.44	SM	120	960	773	0.98	4	0.05	13	1.89	1.04	1.41	0.80	1.00	0.75	1.00	3	5	0.07	**1.37**
12.0	3.66	ML	110	1400	963	0.97	3	0.06	13	1.89	1.04	1.33	0.80	1.00	0.80	1.00	3	5	0.07	**1.08**
14.5	4.42	ML	110	1675	1082	0.97	4	0.07	13	1.89	1.04	1.29	0.80	1.00	0.85	1.00	3	6	0.08	**1.13**
18.0	5.49	ML	110	2060	1249	0.96	4	0.07	13	1.89	1.04	1.23	0.80	1.00	0.85	1.00	3	5	0.07	**1.05**
21.0	6.40	ML	110	2390	1392	0.95	5	0.07	13	1.89	1.04	1.18	0.80	1.00	0.95	1.00	5	7	0.08	**1.15**
24.5	7.47	ML	110	2775	1558	0.94	12	0.08	13	1.89	1.04	1.14	0.80	1.00	0.95	1.00	10	13	0.14	**1.82**

Stratum	
FILL	120
Organic SILT/CLAY	110
SAND & GRAVEL	125

DC Coastal Feasibility Analysis
Liquefaction Screening

PGA: 0.0688 Water Depth: 1

Note: Greyed out soils are not subject to liquafaction because they either, 1) are not granular; 2) have an (N1)60 value greater than 30; or are above water table

Depth (ft)	Depth (m)	USCS	γ	σ_{vo}	σ_{vo}'	r_d	N	CSR	FC	α	β	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60cs}$	CRR7.5	FS
1	0.30	SM	120	120	120	1.00	7	0.04	13	1.89	1.04	1.75	0.80	1.00	0.75	1.00	7	10	0.11	**2.43**
3.5	1.07	SM	120	420	264	0.99	4	0.07	13	1.89	1.04	1.66	0.80	1.00	0.75	1.00	4	6	0.08	**1.13**
6	1.83	SM	120	720	408	0.99	4	0.08	13	1.89	1.04	1.58	0.80	1.00	0.75	1.00	4	6	0.08	1.00
9.5	2.90	SM	120	1140	610	0.98	2	0.08	13	1.89	1.04	1.48	0.80	1.00	0.75	1.00	2	4	0.06	0.77
14.5	4.42	SM	110	1690	848	0.97	0	0.09	13	1.89	1.04	1.37	0.80	1.00	0.85	1.00	0	2	0.05	0.61
19.5	5.95	SM	110	2240	1086	0.96	7	0.09	13	1.89	1.04	1.28	0.80	1.00	0.85	1.00	6	8	0.10	**1.11**
24.5	7.47	SM	110	2790	1324	0.94	12	0.09	13	1.89	1.04	1.21	0.80	1.00	0.95	1.00	11	13	0.14	**1.61**
29.5	8.99	SM	110	3340	1562	0.92	10	0.09	13	1.89	1.04	1.14	0.80	1.00	0.95	1.00	9	11	0.12	**1.37**
34.5	10.52	SM	110	3890	1800	0.89	11	0.09	13	1.89	1.04	1.07	0.80	1.00	1.00	1.00	9	12	0.13	**1.48**
39.5	12.04	SW	125	4515	2113	0.86	12	0.08	0	0.00	1.00	1.00	0.80	1.00	1.00	1.00	10	10	0.11	**1.34**
44.5	13.57	SW	125	5140	2426	0.81	23	0.08	0	0.00	1.00	0.94	0.80	1.00	1.00	1.00	17	17	0.18	**2.40**
49.5	15.09	SW	125	5765	2739	0.76	28	0.07	0	0.00	1.00	0.88	0.80	1.00	1.00	1.00	20	20	0.21	**2.98**

Stratum	γ
FILL	120
Sandy CLAY	110
Silty SAND	110
SAND & GRAVEL	125

DC Coastal Feasibility Analysis
Liquefaction Screening

PGA: 0.0688 Water Depth: 6

Note: Greyed out soils are not subject to liquafaction because they either, 1) are not granular; 2) have an (N1)60 value greater than 30; or are above water table

Depth (ft)	Depth (m)	USCS	γ	σ_{vo}	σ_{vo}'	r_d	N	CSR	FC	α	β	C_N	C_E	C_B	C_R	C_S	$(N_1)_{60}$	$(N_1)_{60cs}$	CRR7.5	FS
1	0.30	SM	120	120	120	1.00	6	0.04	13	1.89	1.04	1.75	0.80	1.00	0.75	1.00	6	8	0.10	**2.23**
3.5	1.07	CL	110	395	395	0.99	5	0.04	13	1.89	1.04	1.59	0.80	1.00	0.75	1.00	5	7	0.09	1.94056
6	1.83	CL	110	670	670	0.99	6	0.04	13	1.89	1.04	1.45	0.80	1.00	0.75	1.00	5	7	0.09	2.04038
9.5	2.90	CL	110	1055	837	0.98	3	0.06	13	1.89	1.04	1.38	0.80	1.00	0.75	1.00	2	4	0.07	1.23255
14.5	4.42	SM	110	1605	1075	0.97	1	0.06	13	1.89	1.04	1.29	0.80	1.00	0.85	1.00	1	3	0.06	0.88
19.5	5.95	SM	110	2155	1313	0.96	3	0.07	13	1.89	1.04	1.21	0.80	1.00	0.85	1.00	2	4	0.07	0.97
24.5	7.47	SM	110	2705	1551	0.94	4	0.07	13	1.89	1.04	1.14	0.80	1.00	0.95	1.00	3	5	0.08	**1.03**
29.5	8.99	SM	110	3255	1789	0.92	7	0.08	13	1.89	1.04	1.08	0.80	1.00	0.95	1.00	6	8	0.09	**1.26**
34.5	10.52	SW	125	3880	2102	0.89	13	0.07	0	0.00	1.00	1.00	0.80	1.00	1.00	1.00	10	10	0.12	**1.58**
39.5	12.04	SW	125	4505	2415	0.86	15	0.07	0	0.00	1.00	0.94	0.80	1.00	1.00	1.00	11	11	0.12	**1.75**
44.5	13.57	SW	125	5130	2728	0.81	16	0.07	0	0.00	1.00	0.88	0.80	1.00	1.00	1.00	11	11	0.12	**1.84**
49.5	15.09	SW	125	5755	3041	0.76	19	0.06	0	0.00	1.00	0.83	0.80	1.00	1.00	1.00	13	13	0.14	**2.14**

Stratum	γ
FILL	120
Sandy CLAY	110
Silty SAND	110
SAND & GRAVEL	125

13.2.3 – Seismic Site Class

DC Coastal Geotechnical Data Summary

Field Boring Log Data

Boring Data Summary for
2-inch O.D. Split Spoon Borings

G.S. EL	10.5	8.6	6.7	6.6
GW Depth	10.5	7	4.5	7.5
GW EL	0	1.6	2.2	-0.9

Depth (ft)	DH-37	DH-78	DH-85	DH-83
0.5				
1	16	13	7	11
1.5				
2				
2.5				
3				
3.5				
4			7	
4.5	40	12		10
5				
5.5				
6				
6.5				
7				
7.5				
8	6	5	4	4
8.5				
9				
9.5				
10				
10.5				5
11				
11.5	5	6		
12			3	
12.5				
13				
13.5				6
14				
14.5			4	
15	9	4		
15.5				
16				
16.5				
17				7
17.5				
18			4	
18.5	15	8		
19				
19.5				
20				
20.5				92
21			5	
21.5				
22	38	##		
22.5				
23				
23.5				
24				
24.5			12	7
25				
25.5	##			
26			25'-0"	25'-0"
26.5				
27				
27.5				
28				
28.5				
29				
29.5	##			
30				
30.5	30'-0"			

N-Value Correction

N-Value Summary - 2-inch spoon				Unit Weight (pcf)
Stratum	MIN	MAX	AVG	
FILL	4	92	17	120
Organic SILT/CLAY	3	15	7	110
SAND & GRAVEL	8	38	23	125

Depth (ft)	DH-37 Data				DH-78 Data				DH-85 Data				DH-83 Data				C_R	C_E	DH-37	DH-78	DH-85	DH-83
	σ_t (psf)	σ_w (psf)	σ' (psf)	C_N	σ_t (psf)	σ_w (psf)	σ' (psf)	C_N	σ_t (psf)	σ_w (psf)	σ' (psf)	C_N	σ_t (psf)	σ_w (psf)	σ' (psf)	C_N						
0.5	60	0	60	2.17	60	0	60	2.17	60	0	60	2.17	60	0	60	2.17	0.75	1				
1	120	0	120	1.94	120	0	120	1.94	120	0	120	1.94	120	0	120	1.94	0.75	1	23	19	10	16
1.5	180	0	180	1.81	180	0	180	1.81	180	0	180	1.81	180	0	180	1.81	0.75	1				
2	240	0	240	1.71	240	0	240	1.71	240	0	240	1.71	240	0	240	1.71	0.75	1				
2.5	300	0	300	1.64	300	0	300	1.64	300	0	300	1.64	300	0	300	1.64	0.75	1				
3	360	0	360	1.58	360	0	360	1.58	360	0	360	1.58	360	0	360	1.58	0.75	1				
3.5	420	0	420	1.52	420	0	420	1.52	420	0	420	1.52	420	0	420	1.52	0.75	1				
4	480	0	480	1.48	480	0	480	1.48	480	0	480	1.48	480	0	480	1.48	0.75	1			8	
4.5	540	0	540	1.44	540	0	540	1.44	540	0	540	1.44	540	0	540	1.44	0.75	1	43	13		11
5	600	0	600	1.40	600	0	600	1.40	600	31.2	568.8	1.42	600	0	600	1.40	0.75	1				
5.5	660	0	660	1.37	660	0	660	1.37	660	62.4	597.6	1.41	660	0	660	1.37	0.75	1				
6	720	0	720	1.34	720	0	720	1.34	720	93.6	626.4	1.39	720	0	720	1.34	0.75	1				
6.5	780	0	780	1.32	775	0	775	1.32	780	124.8	655.2	1.37	780	0	780	1.32	0.75	1				
7	840	0	840	1.29	830	0	830	1.30	840	156	684	1.36	840	0	840	1.29	0.75	1				
7.5	895	0	895	1.27	885	31.2	853.8	1.29	900	187.2	712.8	1.35	900	0	900	1.27	0.75	1				
8	950	0	950	1.25	940	62.4	877.6	1.28	960	218.4	741.6	1.33	960	31.2	928.8	1.26	0.75	1	6	5	4	4
8.5	1005	0	1005	1.23	995	93.6	901.4	1.27	1020	249.6	770.4	1.32	1020	62.4	957.6	1.25	0.75	1				
9	1060	0	1060	1.21	1050	124.8	925.2	1.26	1080	280.8	799.2	1.31	1080	93.6	986.4	1.24	0.75	1				
9.5	1115	0	1115	1.20	1105	156	949	1.25	1140	312	828	1.30	1140	124.8	1015.2	1.23	0.75	1				
10	1170	0	1170	1.18	1160	187.2	972.8	1.24	1195	343.2	851.8	1.29	1200	156	1044	1.22	0.75	1				
10.5	1225	0	1225	1.17	1215	218.4	996.6	1.23	1250	374.4	875.6	1.28	1260	187.2	1072.8	1.21	0.75	1				
11	1280	31.2	1248.8	1.16	1270	249.6	1020.4	1.23	1305	405.6	899.4	1.27	1320	218.4	1101.6	1.20	0.75	1				5
11.5	1335	62.4	1272.6	1.15	1325	280.8	1044.2	1.22	1360	436.8	923.2	1.26	1380	249.6	1130.4	1.19	0.75	1	4	5		
12	1390	93.6	1296.4	1.15	1380	312	1068	1.21	1415	468	947	1.25	1440	280.8	1159.2	1.18	0.75	1			3	
12.5	1445	124.8	1320.2	1.14	1435	343.2	1091.8	1.20	1470	499.2	970.8	1.24	1500	312	1188	1.18	0.75	1				
13	1500	156	1344	1.13	1490	374.4	1115.6	1.20	1525	530.4	994.6	1.24	1560	343.2	1216.8	1.17	0.75	1				
13.5	1555	187.2	1367.8	1.13	1545	405.6	1139.4	1.19	1580	561.6	1018.4	1.23	1620	374.4	1245.6	1.16	0.85	1				6
14	1610	218.4	1391.6	1.12	1600	436.8	1163.2	1.18	1635	592.8	1042.2	1.22	1680	405.6	1274.4	1.15	0.85	1				
14.5	1665	249.6	1415.4	1.12	1655	468	1187	1.18	1690	624	1066	1.21	1740	436.8	1303.2	1.15	0.85	1			4	
15	1720	280.8	1439.2	1.11	1710	499.2	1210.8	1.17	1745	655.2	1089.8	1.20	1800	468	1332	1.14	0.85	1	9	4		
15.5	1775	312	1463	1.11	1765	530.4	1234.6	1.16	1800	686.4	1113.6	1.20	1860	499.2	1360.8	1.13	0.85	1				
16	1830	343.2	1486.8	1.10	1820	561.6	1258.4	1.16	1855	717.6	1137.4	1.19	1920	530.4	1389.6	1.12	0.85	1				
16.5	1885	374.4	1510.6	1.10	1875	592.8	1282.2	1.15	1910	748.8	1161.2	1.18	1980	561.6	1418.4	1.12	0.85	1				
17	1940	405.6	1534.4	1.09	1937.5	624	1313.5	1.14	1965	780	1185	1.18	2040	592.8	1447.2	1.11	0.85	1				7
17.5	1995	436.8	1558.2	1.09	2000	655.2	1344.8	1.13	2020	811.2	1208.8	1.17	2100	624	1476	1.10	0.85	1				
18	2050	468	1582	1.08	2062.5	686.4	1376.1	1.13	2075	842.4	1232.6	1.16	2160	655.2	1504.8	1.10	0.85	1			4	
18.5	2105	499.2	1605.8	1.08	2125	717.6	1407.4	1.12	2130	873.6	1256.4	1.16	2220	686.4	1533.6	1.09	0.85	1	14	8		
19	2160	530.4	1629.6	1.07	2187.5	748.8	1438.7	1.11	2185	904.8	1280.2	1.15	2280	717.6	1562.4	1.08	0.85	1				
19.5	2215	561.6	1653.4	1.07	2250	780	1470	1.10	2240	936	1304	1.14	2340	748.8	1591.2	1.08	0.85	1				
20	2270	592.8	1677.2	1.06	2312.5	811.2	1501.3	1.10	2295	967.2	1327.8	1.14	2400	780	1620	1.07	0.85	1				
20.5	2332.5	624	1708.5	1.05	2375	842.4	1532.6	1.09	2350	998.4	1351.6	1.13	2460	811.2	1648.8	1.07	0.95	1				93
21	2395	655.2	1739.8	1.05	2437.5	873.6	1563.9	1.08	2405	1029.6	1375.4	1.13	2520	842.4	1677.6	1.06	0.95	1			5	
21.5	2457.5	686.4	1771.1	1.04	2500	904.8	1595.2	1.08	2460	1060.8	1399.2	1.12	2580	873.6	1706.4	1.05	0.95	1				
22	2520	717.6	1802.4	1.04	2562.5	936	1626.5	1.07	2515	1092	1423	1.12	2640	904.8	1735.2	1.05	0.95	1	37	#VALUE!		
22.5	2582.5	748.8	1833.7	1.03	2625	967.2	1657.8	1.06	2570	1123.2	1446.8	1.11	2700	936	1764	1.04	0.95	1				
23	2645	780	1865	1.03					2625	1154.4	1470.6	1.10	2755	967.2	1787.8	1.04	0.95	1				
23.5	2707.5	811.2	1896.3	1.02					2680	1185.6	1494.4	1.10	2810	998.4	1811.6	1.03	0.95	1				
24	2770	842.4	1927.6	1.01					2735	1216.8	1518.2	1.09	2865	1029.6	1835.4	1.03	0.95	1				
24.5	2832.5	873.6	1958.9	1.01					2790	1248	1542	1.09	2920	1060.8	1859.2	1.03	0.95	1				
25	2895	904.8	1990.2	1.00					2845	1279.2	1565.8	1.08	2975	1092	1883	1.02	0.95	1				
25.5	2957.5	936	2021.5	1.00													0.95	1	#VALUE!			
26	3020	967.2	2052.8	0.99													0.95	1				
26.5	3082.5	998.4	2084.1	0.99													0.95	1				
27	3145	1029.6	2115.4	0.98													0.95	1				
27.5	3207.5	1060.8	2146.7	0.98													0.95	1				
28	3270	1092	2178	0.97													0.95	1				
28.5	3332.5	1123.2	2209.3	0.97													0.95	1				
29	3395	1154.4	2240.6	0.96													0.95	1	#VALUE!			
29.5	3457.5	1185.6	2271.9	0.96													0.95	1				
30	3520	1216.8	2303.2	0.95													0.95	1				

Corrected N-Value with Elevation

Site Class Determination

Flood EL 14.3 Feet

Proposed Subgrade EL at Wall Alignment

Elevation (ft)	DH-37	DH-78	DH-85	DH-83
15				
14.5				
14				
13.5				
13				
12.5				
12				
11.5				
11				
10.5	10.5			
10				
9.5	23			
9				
8.5		8.6		
8				
7.5		19		
7				
6.5			6.7	6.6
6	43			
5.5			10	16
5				
4.5				
4		13		
3.5				
3				
2.5	6		8	
2				11
1.5				
1				
0.5		5		
0				
-0.5				
-1	4			
-1.5			4	4
-2				
-2.5				
-3		5		
-3.5				
-4				
-4.5	9			5
-5				
-5.5			3	
-6				
-6.5		4		
-7				6
-7.5				
-8	14		4	
-8.5				
-9				
-9.5				
-10		8		
-10.5				7
-11				
-11.5	37		4	
-12				
-12.5				
-13				
-13.5		##		
-14				93
-14.5			5	
-15	##			
-15.5				
-16				
-16.5				
-17				
-17.5				
-18			12	7
-18.5				
-19	##		25'-0"	25'-0"
-19.5				
-20	30'-0"			

	DH-37	DH-78	DH-85	DH-83
d_i (ft)	1.5	1.5	1.5	1.5
Σd_i (ft)	30	23	25	25
$\Sigma (di/N_i)$	1.04	1.36	2.39	1.60
Nbar	29	17	10	16

Boring	Nbar	Overall Avg.
DH-37	29	18
DH-78	17	
DH-85	10	
DH-83	16	

13.2.4 – Arlington WPCP Flood Wall Foundations

********** Echoprint of Input Data **********

Date: 2022/12/19 Time: 10.23.55

Structural geometry data:

Elevation of top of stem (ELTS)	=	14.30 ft
Height of stem (HTS)	=	3.50 ft
Thickness top of stem (TTS)	=	1.50 ft
Thickness bottom of stem (TBS)	=	1.50 ft
Dist. of batter at bot. of stem (TBSR)	=	0.00 ft
Depth of heel (THEEL)	=	1.50 ft
Distance of batter for heel (BTRH)	=	0.50 ft
Depth of toe (TTOE)	=	1.50 ft
Width of toe (TWIDTH)	=	1.50 ft
Distance of batter for toe (BTRT)	=	0.00 ft
Width of base (BWIDTH)	=	5.00 ft
Depth of key (HK)	=	0.00 ft
Width of bottom of key (TK)	=	0.00 ft
Dist. of batter at bot. of key (BTRK)	=	0.00 ft

Structure coordinates:

x (ft)	y (ft)
0.00	8.80
0.00	10.30
2.00	10.80
2.00	14.30
3.50	14.30
3.50	10.80
5.00	10.80
5.00	9.30

NOTE: X=0 is located at the left-hand side of the structure. The Y values correspond to the actual elevation used.

Structural property data:

Unit weight of concrete = 0.150 kcf

Driving side soil property data:

Phi (deg)	c (ksf)	Moist Unit wt. (kcf)	Saturated unit wt. (kcf)	Delta (deg)	Elev. soil (ft)

```
=========================================================
   30.00    0.000     0.120     0.125     0.00   11.30

Driving side soil geometry:

  Soil      Batter    Distance
  point    (in:1ft)     (ft)
  ==============================
   1         0.00    500.00
   2         0.00      0.00
   3         0.00    500.00

Driving side soil profile:

  Soil        x          y
  point      (ft)       (ft)
  ==============================
   1     -1498.00     11.30
   2         2.00     11.30

Resisting side soil property data:

                       Moist   Saturated  Elev.
   Phi        c      Unit wt.  unit wt.  soil    Batter
  (deg)     (ksf)     (kcf)     (kcf)    (ft)   (in:1ft)
=========================================================
   30.00    0.000     0.120     0.125    11.30    0.00

Resisting side soil profile:

  Soil        x          y
  point      (ft)       (ft)
  ==============================
   1         3.50     11.30
   2       503.50     11.30

Foundation property data:
  phi for soil-structure interface =    30.00 (deg)
  c for soil-structure interface   =    0.000 (ksf)
  phi for soil-soil interface      =    30.00 (deg)
  c for soil-soil interface        =    0.000 (ksf)

Water data:
  Driving side elevation   =    14.30 ft
  Resisting side elevation =     9.80 ft
  Unit weight of water     =   0.0624 kcf
  Seepage pressures computed by Line of Creep method.

Minimum required factors of safety:
  Sliding FS   =    1.50
```

```
  Overturning  =  100.00% base in compression

Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water

Strength mobilization factor =   0.6667

At-rest pressures on the resisting side *are used*
in the overturning analysis.

Forces on the resisting side *are used* in the sliding analysis.

*Do* iterate in overturning analysis.




***** Summary of Results *****

***************    *** Satisfied ***
* Overturning *    Required base in comp. = 100.00 %
***************    Actual base in comp.   = 100.00 %
                   Overturning ratio      =   2.01

Xr (measured from toe) =   1.84 ft
Resultant ratio        = 0.3669
Stem ratio             = 0.3000
Base pressure at heel =    0.0795 ksf
Base pressure at toe  =    0.7107 ksf

***********    *** Satisfied ***
* Sliding *    Min. Required =   1.50
***********    Actual FS     =   2.77

***********
* Bearing *
***********

Net ultimate bearing pressure =     2.7069 (ksf)
Factor of safety =      5.052



********************** Output Results **********************


Date: 2022/12/19                                Time: 10.23.55
```

```
***************************
**  Overturning Results  **
***************************

Solution converged in  1 iterations.

SMF used to calculate K's =   0.6667
Alpha for the SMF          = -55.5496
Calculated earth pressure coefficients:
  Driving side at rest K    =   0.4714
  Driving side at rest Kc   =   0.6866
  Resisting side at rest K  =   0.5000
  Resisting side at rest Kc =   0.7071
  At-rest K's for resisting side calculated.

Depth of cracking =     0.00 ft

** Driving side pressures **

  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        14.30     0.0000
        11.30     0.1872
         8.80     0.2557

  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        11.30     0.0000
         8.80     0.1150

** Resisting side pressures **

  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         9.80     0.0000
         9.30     0.0487
         8.80     0.2557

  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        11.30     0.0000
         9.30     0.0969
```

** Uplift pressures **

Water pressures:

x-coord. (ft)	Pressure (ksf)
0.00	0.2557
5.00	0.0487

** Forces and moments **

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight.....	2.025		-2.41	-4.88
Structure, driving side:				
Moist soil.....	0.000		0.00	0.00
Saturated soil.....	0.188		-4.11	-0.77
Water above structure.....	0.000		0.00	0.00
Water above soil.....	0.374		-4.00	-1.50
External vertical loads....	0.000		0.00	0.00
Ext. horz. pressure loads..		0.000	0.00	0.00
Ext. horz. line loads.....		0.000	0.00	0.00
Structure, resisting side:				
Moist soil.....	0.090		-0.75	-0.07
Saturated soil.....	0.000		0.00	0.00
Water above structure.....	0.000		0.00	0.00
Water above soil.....	0.000		0.00	0.00
Driving side:				
Effective earth loads.....		0.144	0.33	0.05
Shear (due to delta).....	0.000		0.00	0.00
Horiz. surcharge effects...		0.000	0.00	0.00
Water loads.....		0.834	1.46	1.22
Resisting side:				
Effective earth loads.....		-0.097	0.67	-0.06
Water loads.....		-0.088	-0.24	0.02
Foundation:				
Components of normal.....	-1.975	-0.198	-1.84	3.66
Components of shear.....	0.060	-0.596	0.00	0.00
Uplift.....	-0.761		-3.07	2.33
** Statics Check ** SUMS =	0.000	0.000		0.00

Angle of base = 5.71 degrees
Normal force on base = 1.985 kips
Shear force on base = 0.598 kips
Max. available shear force = 1.146 kips

```
Base pressure at heel =   0.0795 ksf
Base pressure at toe  =   0.7107 ksf

Xr (measured from toe) =     1.84 ft
Resultant ratio        =   0.3669
Stem ratio             =   0.3000
Base in compression    =   100.00 %
Overturning ratio      =     2.01

Volume of concrete =     0.50 cubic yds/ft of wall

NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.




**********************
**  Sliding Results  **
**********************

Solution converged.  Summation of forces = 0.

           Horizontal   Vertical
  Wedge      Loads       Loads
  Number    (kips)       (kips)
  ==================================
     1       0.000       0.380
     2       0.281       0.374
     3       0.000       0.000

  Water pressures on wedges:

             Top      Bottom
    Wedge    press.   press.   x-coord.    press.
    number   (ksf)    (ksf)     (ft)       (ksf)
  ================================================
      1    0.1872    0.2557
      2                         0.0000     0.2557
      2                         5.0000     0.0487
      3    0.0000    0.0487

Points of sliding plane:
  Point 1 (left),  x =     0.00 ft,   y =     8.80 ft
```

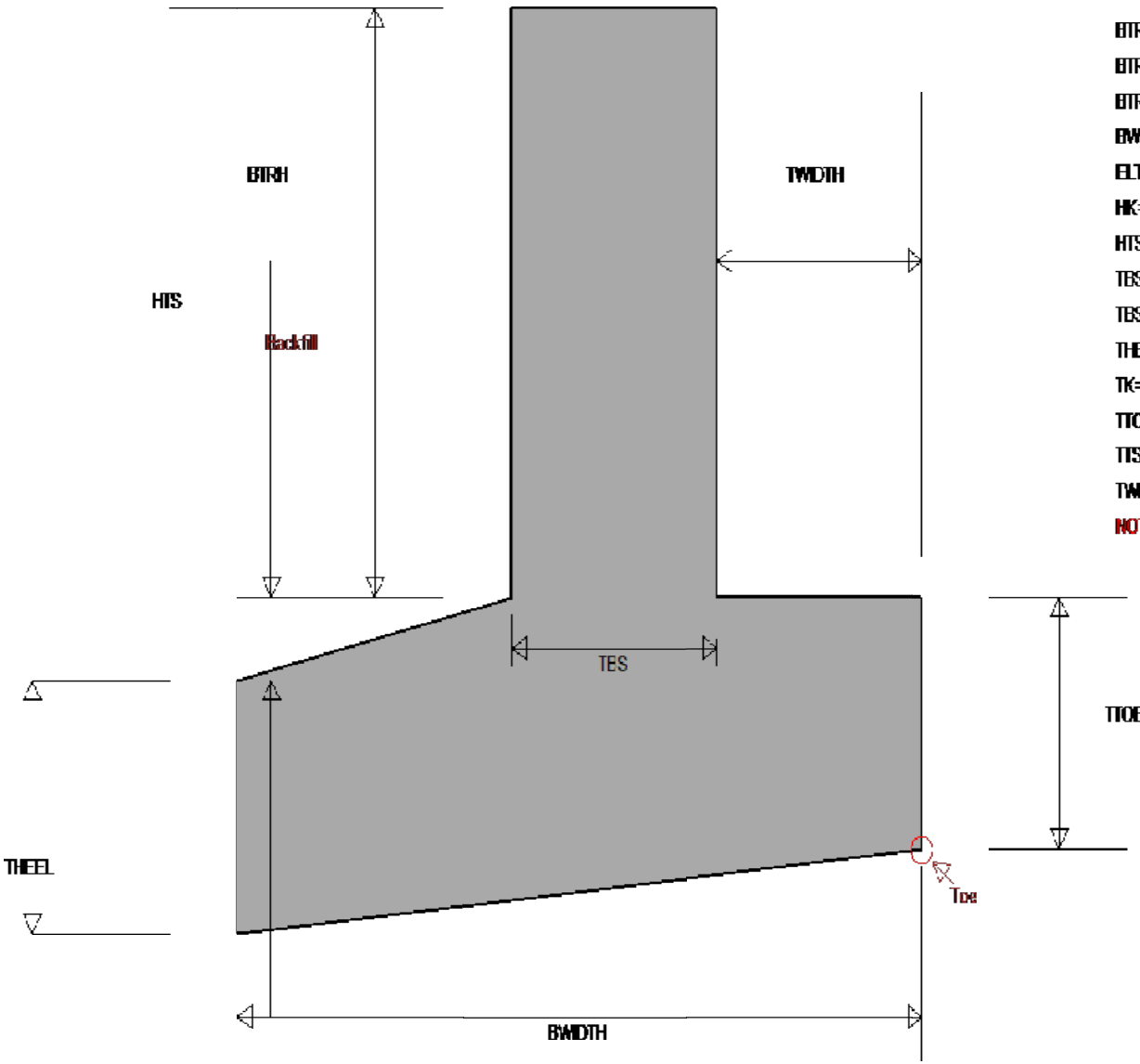
```
  Point 2 (right), x =     5.00 ft,   y =     9.30 ft

Depth of cracking =     0.00 ft

          Failure   Total    Weight    Submerged   Uplift
  Wedge    angle    length  of wedge    length     force
  number   (deg)     (ft)    (kips)      (ft)      (kips)
  ==========================================================
     1   -50.916     3.221      0.317    3.221     0.713
     2     5.711     5.025      2.303    5.025     0.765
     3    39.146     3.168      0.296    0.792     0.019

  Wedge     Net force
  number     (kips)
  ===================
     1       -0.755
     2        0.398
     3        0.358
  ===================
     SUM =    0.000

+-----------------------------+
| Factor of safety =    2.775 |
+-----------------------------+




**********************
**  Bearing Results  **
**********************

            Base width =      5.025 (ft)
                    Xr =      1.843 (ft)
  Effective base width =      3.705 (ft)
   (measured along slope)
            Base slope =     5.7106 (deg)

                   phi =     30.000 (deg)
                     c =      0.000 (ksf)
       Effective gamma =     0.0626 (kcf)

           Normal load =      1.985 (kips)
      Load inclination =     16.776 (deg)
     Load eccentricity =      0.660 (ft)

             Surcharge =     0.2113 (ksf)
             Embedment =      2.000 (ft)
          Ground slope =     0.0000 (deg)
```

Bearing Capacity Factors

	C	Q	G
Bearing	30.1396	18.4011	15.6680
Embedment	1.1870	1.0935	1.0935
Inclination	0.6619	0.6619	0.1943
Base Tilt	0.8818	0.8882	0.8882
Ground Slope	1.0000	1.0000	1.0000

Net ultimate bearing pressure = 2.7069 (ksf)

Factor of safety = 5.052



BTRH=	0.50
BTRK=	0.00
BTRT=	0.00
BWIDTH=	5.00
ELTS=	14.30
HK=	0.00
HTS=	3.50
TES=	1.50
TESR=	0.00
THEEL=	1.50
TK=	0.00
TTOE=	1.50
TTS=	1.50
TWIDTH=	1.50

NOTE: All units in feet

********** Echoprint of Input Data **********

Date: 2022/12/19 Time: 11.23.10

Structural geometry data:

Elevation of top of stem (ELTS)	=	14.30 ft
Height of stem (HTS)	=	4.50 ft
Thickness top of stem (TTS)	=	1.50 ft
Thickness bottom of stem (TBS)	=	1.50 ft
Dist. of batter at bot. of stem (TBSR)	=	0.00 ft
Depth of heel (THEEL)	=	1.50 ft
Distance of batter for heel (BTRH)	=	0.50 ft
Depth of toe (TTOE)	=	1.50 ft
Width of toe (TWIDTH)	=	2.00 ft
Distance of batter for toe (BTRT)	=	0.00 ft
Width of base (BWIDTH)	=	6.00 ft
Depth of key (HK)	=	0.00 ft
Width of bottom of key (TK)	=	0.00 ft
Dist. of batter at bot. of key (BTRK)	=	0.00 ft

Structure coordinates:

x (ft)	y (ft)
0.00	7.80
0.00	9.30
2.50	9.80
2.50	14.30
4.00	14.30
4.00	9.80
6.00	9.80
6.00	8.30

NOTE: X=0 is located at the left-hand side of the structure. The Y values correspond to the actual elevation used.

Structural property data:
Unit weight of concrete = 0.150 kcf

Driving side soil property data:

Phi (deg)	c (ksf)	Moist Unit wt. (kcf)	Saturated unit wt. (kcf)	Delta (deg)	Elev. soil (ft)

```
=========================================================
   30.00    0.000     0.120     0.125     0.00   11.30

Driving side soil geometry:

  Soil      Batter    Distance
  point    (in:1ft)     (ft)
  ==============================
   1         0.00    500.00
   2         0.00      0.00
   3         0.00    500.00

Driving side soil profile:

  Soil        x          y
  point      (ft)       (ft)
  ==============================
   1     -1497.50     11.30
   2         2.50     11.30

Resisting side soil property data:

                       Moist   Saturated  Elev.
   Phi        c      Unit wt.  unit wt.  soil    Batter
  (deg)     (ksf)     (kcf)     (kcf)    (ft)   (in:1ft)
=========================================================
   30.00    0.000     0.120     0.125    11.30    0.00

Resisting side soil profile:

  Soil        x          y
  point      (ft)       (ft)
  ==============================
   1         4.00     11.30
   2       504.00     11.30

Foundation property data:
  phi for soil-structure interface =    30.00 (deg)
  c for soil-structure interface   =    0.000 (ksf)
  phi for soil-soil interface      =    30.00 (deg)
  c for soil-soil interface        =    0.000 (ksf)

Water data:
  Driving side elevation   =    14.30 ft
  Resisting side elevation =     8.80 ft
  Unit weight of water     =   0.0624 kcf
  Seepage pressures computed by Line of Creep method.

Minimum required factors of safety:
  Sliding FS   =    1.50
```

```
  Overturning  =  100.00% base in compression

Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water

Strength mobilization factor =   0.6667

At-rest pressures on the resisting side *are used*
in the overturning analysis.

Forces on the resisting side *are used* in the sliding analysis.

*Do* iterate in overturning analysis.




***** Summary of Results *****

***************    *** Satisfied ***
* Overturning *    Required base in comp. = 100.00 %
***************    Actual base in comp.   = 100.00 %
                   Overturning ratio      =   2.12

Xr (measured from toe) =   2.28 ft
Resultant ratio        = 0.3787
Stem ratio             = 0.3333
Base pressure at heel =    0.1330 ksf
Base pressure at toe  =    0.8450 ksf

***********    *** Satisfied ***
* Sliding *    Min. Required =   1.50
***********    Actual FS     =   3.56

***********
* Bearing *
***********

Net ultimate bearing pressure =     4.5202 (ksf)
Factor of safety =      7.025



********************** Output Results **********************


Date: 2022/12/19                                Time: 11.23.10
```

```
***************************
**  Overturning Results  **
***************************

Solution converged in  1 iterations.

SMF used to calculate K's =   0.6667
Alpha for the SMF          = -55.5397
Calculated earth pressure coefficients:
  Driving side at rest K    =   0.4714
  Driving side at rest Kc   =   0.6866
  Resisting side at rest K  =   0.5000
  Resisting side at rest Kc =   0.7071
  At-rest K's for resisting side calculated.

Depth of cracking =     0.00 ft

** Driving side pressures **

  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        14.30     0.0000
        11.30     0.1872
         7.80     0.2857

  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        11.30     0.0000
         7.80     0.1598

** Resisting side pressures **

  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         8.80     0.0000
         8.30     0.0483
         7.80     0.2857

  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        11.30     0.0000
         8.30     0.1571
```

** Uplift pressures **

Water pressures:

x-coord. (ft)	Pressure (ksf)
0.00	0.2857
6.00	0.0483

** Forces and moments **

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight.....	2.494		-2.91	-7.25
Structure, driving side:				
Moist soil.....	0.000		0.00	0.00
Saturated soil.....	0.547		-4.81	-2.63
Water above structure.....	0.000		0.00	0.00
Water above soil.....	0.468		-4.75	-2.22
External vertical loads....	0.000		0.00	0.00
Ext. horz. pressure loads..		0.000	0.00	0.00
Ext. horz. line loads.....		0.000	0.00	0.00
Structure, resisting side:				
Moist soil.....	0.360		-1.00	-0.36
Saturated soil.....	0.000		0.00	0.00
Water above structure.....	0.000		0.00	0.00
Water above soil.....	0.000		0.00	0.00
Driving side:				
Effective earth loads.....		0.280	0.67	0.19
Shear (due to delta).....	0.000		0.00	0.00
Horiz. surcharge effects...		0.000	0.00	0.00
Water loads.....		1.108	1.86	2.06
Resisting side:				
Effective earth loads.....		-0.236	1.00	-0.24
Water loads.....		-0.096	-0.25	0.02
Foundation:				
Components of normal.....	-2.934	-0.245	-2.28	6.71
Components of shear.....	0.068	-0.812	0.00	0.00
Uplift.....	-1.002		-3.71	3.72
** Statics Check ** SUMS =	0.000	0.000		0.00

Angle of base = 4.76 degrees
Normal force on base = 2.944 kips
Shear force on base = 0.815 kips
Max. available shear force = 1.700 kips

```
Base pressure at heel =   0.1330 ksf
Base pressure at toe  =   0.8450 ksf

Xr (measured from toe) =     2.28 ft
Resultant ratio        =   0.3787
Stem ratio             =   0.3333
Base in compression    =   100.00 %
Overturning ratio      =     2.12

Volume of concrete =     0.62 cubic yds/ft of wall

NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.



**********************
**  Sliding Results  **
**********************

Solution converged.  Summation of forces = 0.

           Horizontal   Vertical
  Wedge      Loads       Loads
  Number    (kips)       (kips)
  ================================
     1       0.000       0.558
     2       0.281       0.468
     3       0.000       0.000

  Water pressures on wedges:

             Top      Bottom
    Wedge    press.   press.   x-coord.    press.
    number   (ksf)    (ksf)     (ft)       (ksf)
  ================================================
      1    0.1872    0.2857
      2                         0.0000     0.2857
      2                         6.0000     0.0483
      3    0.0000    0.0483

Points of sliding plane:
  Point 1 (left),  x =     0.00 ft,   y =     7.80 ft
```

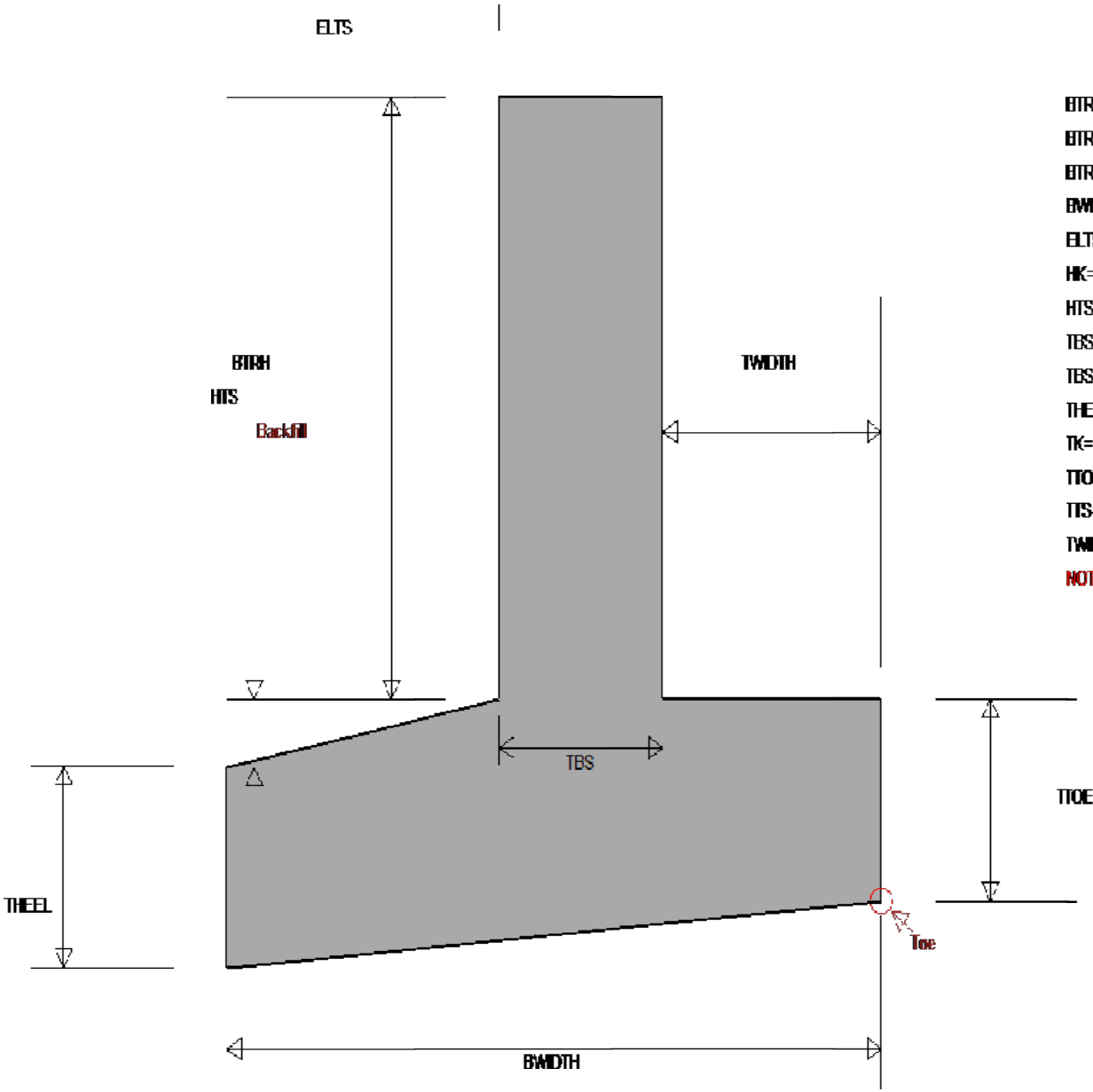
```
  Point 2 (right), x =     6.00 ft,   y =     8.30 ft

Depth of cracking =     0.00 ft

          Failure   Total    Weight    Submerged   Uplift
  Wedge    angle    length  of wedge    length     force
  number   (deg)     (ft)    (kips)      (ft)      (kips)
  ==========================================================
     1   -49.593     4.596      0.652    4.596     1.087
     2     4.764     6.021      3.401    6.021     1.006
     3    40.463     4.623      0.634    0.770     0.019

  Wedge     Net force
  number     (kips)
  ===================
     1       -1.257
     2        0.516
     3        0.742
  ===================
     SUM =    0.000

+-----------------------------+
| Factor of safety =    3.564 |
+-----------------------------+



**********************
**  Bearing Results  **
**********************

            Base width =      6.021 (ft)
                    Xr =      2.280 (ft)
  Effective base width =      4.576 (ft)
   (measured along slope)
            Base slope =     4.7636 (deg)

                   phi =     30.000 (deg)
                     c =      0.000 (ksf)
       Effective gamma =     0.0626 (kcf)

           Normal load =      2.944 (kips)
      Load inclination =     15.475 (deg)
     Load eccentricity =      0.723 (ft)

             Surcharge =     0.3313 (ksf)
             Embedment =      3.000 (ft)
          Ground slope =     0.0000 (deg)
```

Bearing Capacity Factors

	C	Q	G
Bearing	30.1396	18.4011	15.6680
Embedment	1.2271	1.1136	1.1136
Inclination	0.6857	0.6857	0.2344
Base Tilt	0.9009	0.9063	0.9063
Ground Slope	1.0000	1.0000	1.0000

Net ultimate bearing pressure = 4.5202 (ksf)

Factor of safety = 7.025



BTRH=	0.50
BTRK=	0.00
BTRT=	0.00
BWIDTH=	6.00
ELTS=	14.30
HK=	0.00
HTS=	4.50
TBS=	1.50
TBSR=	0.00
THEEL=	1.50
TK=	0.00
TTOE=	1.50
TTS=	1.50
TWIDTH=	2.00

NOTE: All units in feet

********** Echoprint of Input Data **********

Date: 2022/12/19 Time: 11.11.59

Structural geometry data:

Elevation of top of stem (ELTS)	=	14.30 ft
Height of stem (HTS)	=	5.50 ft
Thickness top of stem (TTS)	=	1.50 ft
Thickness bottom of stem (TBS)	=	1.50 ft
Dist. of batter at bot. of stem (TBSR)	=	0.00 ft
Depth of heel (THEEL)	=	1.50 ft
Distance of batter for heel (BTRH)	=	0.50 ft
Depth of toe (TTOE)	=	1.50 ft
Width of toe (TWIDTH)	=	2.50 ft
Distance of batter for toe (BTRT)	=	0.00 ft
Width of base (BWIDTH)	=	7.00 ft
Depth of key (HK)	=	0.00 ft
Width of bottom of key (TK)	=	0.00 ft
Dist. of batter at bot. of key (BTRK)	=	0.00 ft

Structure coordinates:

x (ft)	y (ft)
0.00	6.80
0.00	8.30
3.00	8.80
3.00	14.30
4.50	14.30
4.50	8.80
7.00	8.80
7.00	7.30

NOTE: X=0 is located at the left-hand side of the structure. The Y values correspond to the actual elevation used.

Structural property data:
Unit weight of concrete = 0.150 kcf

Driving side soil property data:

Phi (deg)	c (ksf)	Moist Unit wt. (kcf)	Saturated unit wt. (kcf)	Delta (deg)	Elev. soil (ft)

```
=========================================================
   30.00    0.000     0.120     0.125     0.00    9.30

Driving side soil geometry:

  Soil      Batter    Distance
  point    (in:1ft)     (ft)
  ==============================
   1         0.00    500.00
   2         0.00      0.00
   3         0.00    500.00

Driving side soil profile:

  Soil        x          y
  point      (ft)       (ft)
  ==============================
   1     -1497.00      9.30
   2         3.00      9.30

Resisting side soil property data:

                       Moist   Saturated  Elev.
   Phi        c      Unit wt.  unit wt.  soil    Batter
  (deg)     (ksf)     (kcf)     (kcf)    (ft)   (in:1ft)
=========================================================
   30.00    0.000     0.120     0.125     9.30    0.00

Resisting side soil profile:

  Soil        x          y
  point      (ft)       (ft)
  ==============================
   1         4.50      9.30
   2       504.50      9.30

Foundation property data:
  phi for soil-structure interface =    30.00 (deg)
  c for soil-structure interface   =    0.000 (ksf)
  phi for soil-soil interface      =    30.00 (deg)
  c for soil-soil interface        =    0.000 (ksf)

Water data:
  Driving side elevation   =    14.30 ft
  Resisting side elevation =     7.80 ft
  Unit weight of water     =   0.0624 kcf
  Seepage pressures computed by Line of Creep method.

Minimum required factors of safety:
  Sliding FS   =    1.50
```

```
  Overturning  =  100.00% base in compression

Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water

Strength mobilization factor =   0.6667

At-rest pressures on the resisting side *are used*
in the overturning analysis.

Forces on the resisting side *are used* in the sliding analysis.

*Do* iterate in overturning analysis.




***** Summary of Results *****

***************    *** Satisfied ***
* Overturning *    Required base in comp. = 100.00 %
***************    Actual base in comp.   = 100.00 %
                   Overturning ratio      =   1.72

Xr (measured from toe) =   2.40 ft
Resultant ratio        = 0.3421
Stem ratio             = 0.3571
Base pressure at heel =    0.0224 ksf
Base pressure at toe  =    0.8262 ksf

***********    *** Satisfied ***
* Sliding *    Min. Required =   1.50
***********    Actual FS     =   1.67

***********
* Bearing *
***********

Net ultimate bearing pressure =     1.8603 (ksf)
Factor of safety =      3.008



********************** Output Results **********************


Date: 2022/12/19                                Time: 11.11.59
```

```
***************************
**  Overturning Results  **
***************************

Solution converged in  1 iterations.

SMF used to calculate K's =   0.6667
Alpha for the SMF          = -55.5659
Calculated earth pressure coefficients:
  Driving side at rest K    =   0.4714
  Driving side at rest Kc   =   0.6866
  Resisting side at rest K  =   0.5000
  Resisting side at rest Kc =   0.7071
  At-rest K's for resisting side calculated.

Depth of cracking =     0.00 ft

** Driving side pressures **

  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        14.30     0.0000
         9.30     0.3120
         6.80     0.3668

  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         9.30     0.0000
         6.80     0.1215

** Resisting side pressures **

  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         7.80     0.0000
         7.30     0.0514

  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         9.30     0.0000
         7.30     0.0955
```

** Uplift pressures **

Water pressures:

x-coord. (ft)	Pressure (ksf)
0.00	0.3668
7.00	0.0514

** Forces and moments **

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight.....	2.963		-3.40	-10.08
Structure, driving side:				
Moist soil.....	0.000		0.00	0.00
Saturated soil.....	0.281		-5.67	-1.59
Water above structure.....	0.000		0.00	0.00
Water above soil.....	0.936		-5.50	-5.15
External vertical loads....	0.000		0.00	0.00
Ext. horz. pressure loads..		0.000	0.00	0.00
Ext. horz. line loads.....		0.000	0.00	0.00
Structure, resisting side:				
Moist soil.....	0.150		-1.25	-0.19
Saturated soil.....	0.000		0.00	0.00
Water above structure.....	0.000		0.00	0.00
Water above soil.....	0.000		0.00	0.00
Driving side:				
Effective earth loads.....		0.152	0.33	0.05
Shear (due to delta).....	0.000		0.00	0.00
Horiz. surcharge effects...		0.000	0.00	0.00
Water loads.....		1.628	2.13	3.47
Resisting side:				
Effective earth loads.....		-0.096	0.67	-0.06
Water loads.....		-0.013	0.17	0.00
Foundation:				
Components of normal.....	-2.970	-0.212	-2.40	7.15
Components of shear.....	0.104	-1.460	0.00	0.00
Uplift.....	-1.464		-4.38	6.41
** Statics Check ** SUMS =	0.000	0.000		0.00

Angle of base = 4.09 degrees
Normal force on base = 2.978 kips
Shear force on base = 1.464 kips
Max. available shear force = 1.719 kips

```
Base pressure at heel =   0.0224 ksf
Base pressure at toe  =   0.8262 ksf

Xr (measured from toe) =     2.40 ft
Resultant ratio        =   0.3421
Stem ratio             =   0.3571
Base in compression    =   100.00 %
Overturning ratio      =     1.72

Volume of concrete =     0.73 cubic yds/ft of wall

NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.




***********************
**  Sliding Results  **
***********************

Solution converged.  Summation of forces = 0.

           Horizontal   Vertical
  Wedge      Loads       Loads
  Number    (kips)       (kips)
  ==================================
     1       0.000       0.555
     2       0.780       0.936
     3       0.000       0.000

  Water pressures on wedges:

             Top      Bottom
    Wedge    press.   press.   x-coord.    press.
    number   (ksf)    (ksf)     (ft)       (ksf)
  ================================================
      1    0.3120    0.3668
      2                         0.0000     0.3668
      2                         7.0000     0.0514
      3    0.0000    0.0514

Points of sliding plane:
  Point 1 (left),  x =     0.00 ft,   y =     6.80 ft
  Point 2 (right), x =     7.00 ft,   y =     7.30 ft
```

Depth of cracking = 0.00 ft

Wedge number	Failure angle (deg)	Total length (ft)	Weight of wedge (kips)	Submerged length (ft)	Uplift force (kips)
1	-54.554	3.069	0.278	3.069	1.042
2	4.086	7.018	3.394	7.018	1.468
3	35.509	3.443	0.337	0.861	0.022

Wedge number	Net force (kips)
1	-1.012
2	0.550
3	0.462
SUM =	0.000

```
+-----------------------------+
| Factor of safety =    1.670 |
+-----------------------------+
```

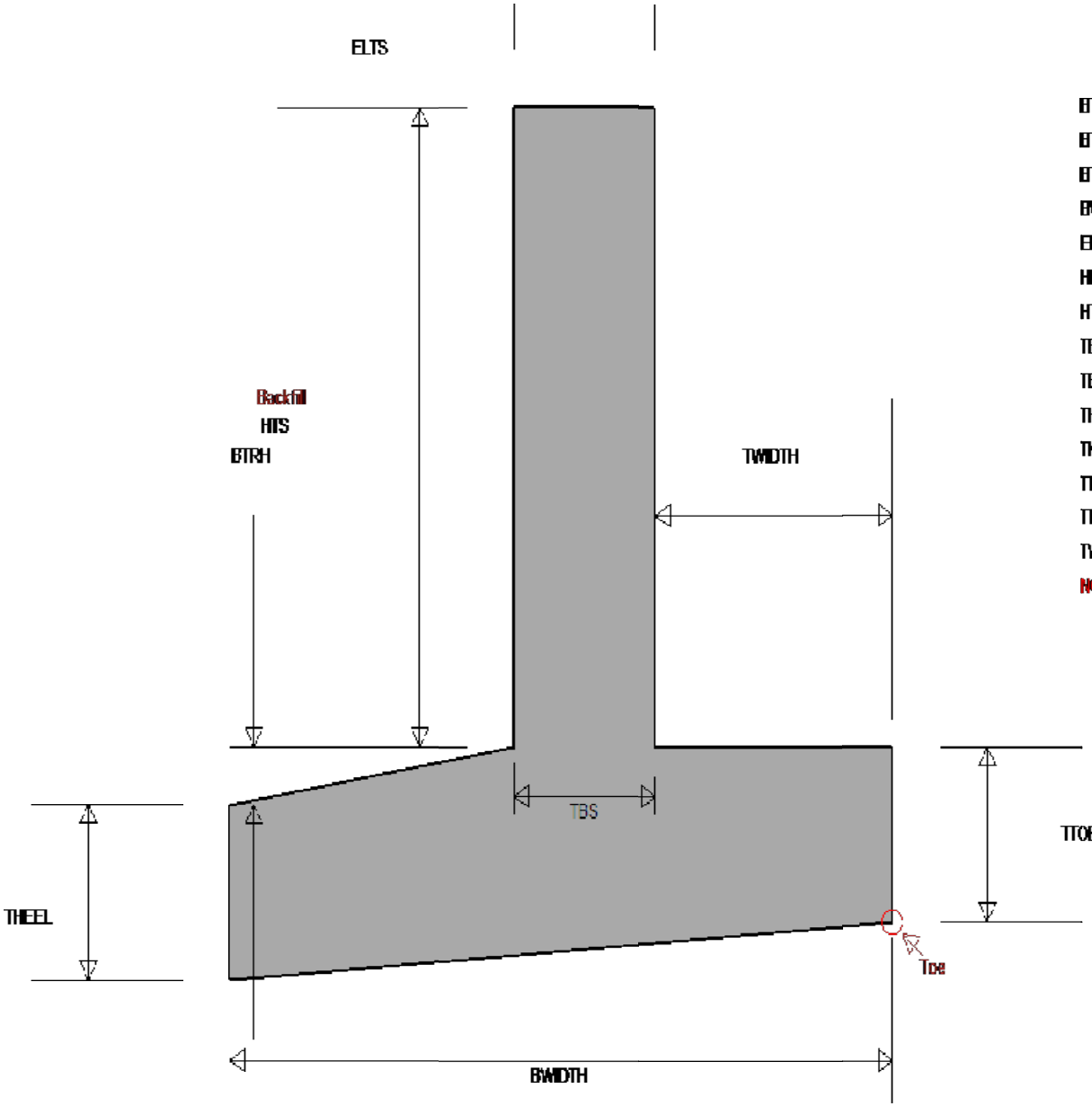
```
***********************
**  Bearing Results  **
***********************

            Base width =      7.018 (ft)
                    Xr =      2.401 (ft)
  Effective base width =      4.815 (ft)
   (measured along slope)
            Base slope =     4.0856 (deg)

                   phi =     30.000 (deg)
                     c =      0.000 (ksf)
       Effective gamma =     0.0626 (kcf)

           Normal load =      2.978 (kips)
      Load inclination =     26.173 (deg)
     Load eccentricity =      1.102 (ft)

             Surcharge =     0.2113 (ksf)
             Embedment =      2.000 (ft)
          Ground slope =     0.0000 (deg)
```

Bearing Capacity Factors

	C	Q	G
Bearing	30.1396	18.4011	15.6680
Embedment	1.1439	1.0720	1.0720
Inclination	0.5029	0.5029	0.0163
Base Tilt	0.9147	0.9194	0.9194
Ground Slope	1.0000	1.0000	1.0000

Net ultimate bearing pressure = 1.8603 (ksf)

Factor of safety = 3.008



BTRH=	0.50
BTRK=	0.00
BTRT=	0.00
BWIDTH=	7.00
ELTS=	14.30
HK=	0.00
HTS=	5.50
TBS=	1.50
TBSR=	0.00
THEEL=	1.50
TK=	0.00
TTOE=	1.50
TTS=	1.50
TWIDTH=	2.50

NOTE: All units in feet

********** Echoprint of Input Data **********

Date: 2023/ 2/16 Time: 9.15.44

Structural geometry data:

Elevation of top of stem (ELTS)	=	14.30 ft
Height of stem (HTS)	=	6.50 ft
Thickness top of stem (TTS)	=	1.50 ft
Thickness bottom of stem (TBS)	=	1.50 ft
Dist. of batter at bot. of stem (TBSR)	=	0.00 ft
Depth of heel (THEEL)	=	1.50 ft
Distance of batter for heel (BTRH)	=	0.50 ft
Depth of toe (TTOE)	=	1.50 ft
Width of toe (TWIDTH)	=	2.50 ft
Distance of batter for toe (BTRT)	=	0.00 ft
Width of base (BWIDTH)	=	8.00 ft
Depth of key (HK)	=	0.00 ft
Width of bottom of key (TK)	=	0.00 ft
Dist. of batter at bot. of key (BTRK)	=	0.00 ft

Structure coordinates:

x (ft)	y (ft)
0.00	5.80
0.00	7.30
4.00	7.80
4.00	14.30
5.50	14.30
5.50	7.80
8.00	7.80
8.00	6.30

NOTE: X=0 is located at the left-hand side of the structure. The Y values correspond to the actual elevation used.

Structural property data:
Unit weight of concrete = 0.150 kcf

Driving side soil property data:

Phi (deg)	c (ksf)	Moist Unit wt. (kcf)	Saturated unit wt. (kcf)	Delta (deg)	Elev. soil (ft)

```
=========================================================
   30.00    0.000     0.120     0.125     0.00    9.30

Driving side soil geometry:

  Soil      Batter    Distance
  point    (in:1ft)     (ft)
  ==============================
   1         0.00    500.00
   2         0.00      0.00
   3         0.00    500.00

Driving side soil profile:

  Soil        x          y
  point      (ft)       (ft)
  ==============================
   1     -1496.00      9.30
   2         4.00      9.30

Resisting side soil property data:

                       Moist   Saturated  Elev.
   Phi        c      Unit wt.  unit wt.  soil    Batter
  (deg)     (ksf)     (kcf)     (kcf)    (ft)   (in:1ft)
=========================================================
   30.00    0.000     0.120     0.125     9.30    0.00

Resisting side soil profile:

  Soil        x          y
  point      (ft)       (ft)
  ==============================
   1         5.50      9.30
   2       505.50      9.30

Foundation property data:
  phi for soil-structure interface =    30.00 (deg)
  c for soil-structure interface   =    0.000 (ksf)
  phi for soil-soil interface      =    30.00 (deg)
  c for soil-soil interface        =    0.000 (ksf)

Water data:
  Driving side elevation   =    14.30 ft
  Resisting side elevation =     7.80 ft
  Unit weight of water     =   0.0624 kcf
  Seepage pressures computed by Line of Creep method.

Minimum required factors of safety:
  Sliding FS   =    1.50
```

```
  Overturning  =  100.00% base in compression

Crack options:
  o  Crack depth is to be calculated
  o  Computed cracks *will* be filled with water

Strength mobilization factor =   0.6667

At-rest pressures on the resisting side *are used*
in the overturning analysis.

Forces on the resisting side *are used* in the sliding analysis.

*Do* iterate in overturning analysis.




***** Summary of Results *****

***************    *** Satisfied ***
* Overturning *    Required base in comp. = 100.00 %
***************    Actual base in comp.   = 100.00 %
                   Overturning ratio      =   1.65

Xr (measured from toe) =   2.68 ft
Resultant ratio        = 0.3343
Stem ratio             = 0.3125
Base pressure at heel =    0.0029 ksf
Base pressure at toe  =    0.9580 ksf

***********    *** Satisfied ***
* Sliding *    Min. Required =   1.50
***********    Actual FS     =   1.97

***********
* Bearing *
***********

Net ultimate bearing pressure =     2.7682 (ksf)
Factor of safety =      3.860



********************** Output Results **********************


Date: 2023/ 2/16                                Time:  9.15.44
```

```
**************************
**  Overturning Results  **
**************************

Solution converged in  1 iterations.

SMF used to calculate K's =   0.6667
Alpha for the SMF          = -55.5432
Calculated earth pressure coefficients:
  Driving side at rest K    =   0.4714
  Driving side at rest Kc   =   0.6866
  Resisting side at rest K  =   0.5000
  Resisting side at rest Kc =   0.7071
  At-rest K's for resisting side calculated.

Depth of cracking =     0.00 ft

** Driving side pressures **

  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
        14.30     0.0000
         9.30     0.3120
         5.80     0.4213

  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         9.30     0.0000
         5.80     0.1547

** Resisting side pressures **

  Water pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         7.80     0.0000
         6.30     0.1403
         5.80     0.4213

  Earth pressures:
    Elevation   Pressure
      (ft)        (ksf)
    ======================
         9.30     0.0000
         6.30     0.1136
```

** Uplift pressures **

Water pressures:

x-coord. (ft)	Pressure (ksf)
0.00	0.4213
8.00	0.1403

** Forces and moments **

Part	Force (kips) Vert.	Force (kips) Horiz.	Mom. Arm (ft)	Moment (ft-k)
Structure:				
Structure weight.....	3.413		-3.68	-12.55
Structure, driving side:				
Moist soil.....	0.000		0.00	0.00
Saturated soil.....	0.875		-6.10	-5.33
Water above structure.....	0.000		0.00	0.00
Water above soil.....	1.248		-6.00	-7.49
External vertical loads....	0.000		0.00	0.00
Ext. horz. pressure loads..		0.000	0.00	0.00
Ext. horz. line loads.....		0.000	0.00	0.00
Structure, resisting side:				
Moist soil.....	0.450		-1.25	-0.56
Saturated soil.....	0.000		0.00	0.00
Water above structure.....	0.000		0.00	0.00
Water above soil.....	0.000		0.00	0.00
Driving side:				
Effective earth loads.....		0.271	0.67	0.18
Shear (due to delta).....	0.000		0.00	0.00
Horiz. surcharge effects...		0.000	0.00	0.00
Water loads.....		2.063	2.49	5.13
Resisting side:				
Effective earth loads.....		-0.170	1.00	-0.17
Water loads.....		-0.246	0.05	-0.01
Foundation:				
Components of normal.....	-3.844	-0.240	-2.68	10.32
Components of shear.....	0.105	-1.678	0.00	0.00
Uplift.....	-2.247		-4.67	10.49
** Statics Check ** SUMS =	0.000	0.000		0.00

Angle of base = 3.58 degrees
Normal force on base = 3.851 kips
Shear force on base = 1.681 kips
Max. available shear force = 2.223 kips

```
Base pressure at heel =   0.0029 ksf
Base pressure at toe  =   0.9580 ksf

Xr (measured from toe) =     2.68 ft
Resultant ratio        =   0.3343
Stem ratio             =   0.3125
Base in compression    =   100.00 %
Overturning ratio      =     1.65

Volume of concrete =     0.84 cubic yds/ft of wall

NOTE:  The engineer shall verify that the computed
bearing pressures below the wall do not exceed the
allowable foundation bearing pressure, or, perform a
bearing capacity analysis using the program CBEAR.
Also, the engineer shall verify that the base pressures
do not result in excessive differential settlement of
the wall foundation.



**********************
**  Sliding Results  **
**********************

Solution converged.  Summation of forces = 0.

           Horizontal   Vertical
  Wedge      Loads       Loads
  Number    (kips)       (kips)
  ==================================
     1       0.000       0.816
     2       0.780       1.248
     3       0.000       0.000

  Water pressures on wedges:

             Top      Bottom
    Wedge    press.   press.   x-coord.    press.
    number   (ksf)    (ksf)     (ft)       (ksf)
  ================================================
      1    0.3120    0.4213
      2                         0.0000     0.4213
      2                         8.0000     0.1403
      3    0.0000    0.1403

Points of sliding plane:
  Point 1 (left),  x =     0.00 ft,   y =     5.80 ft
```

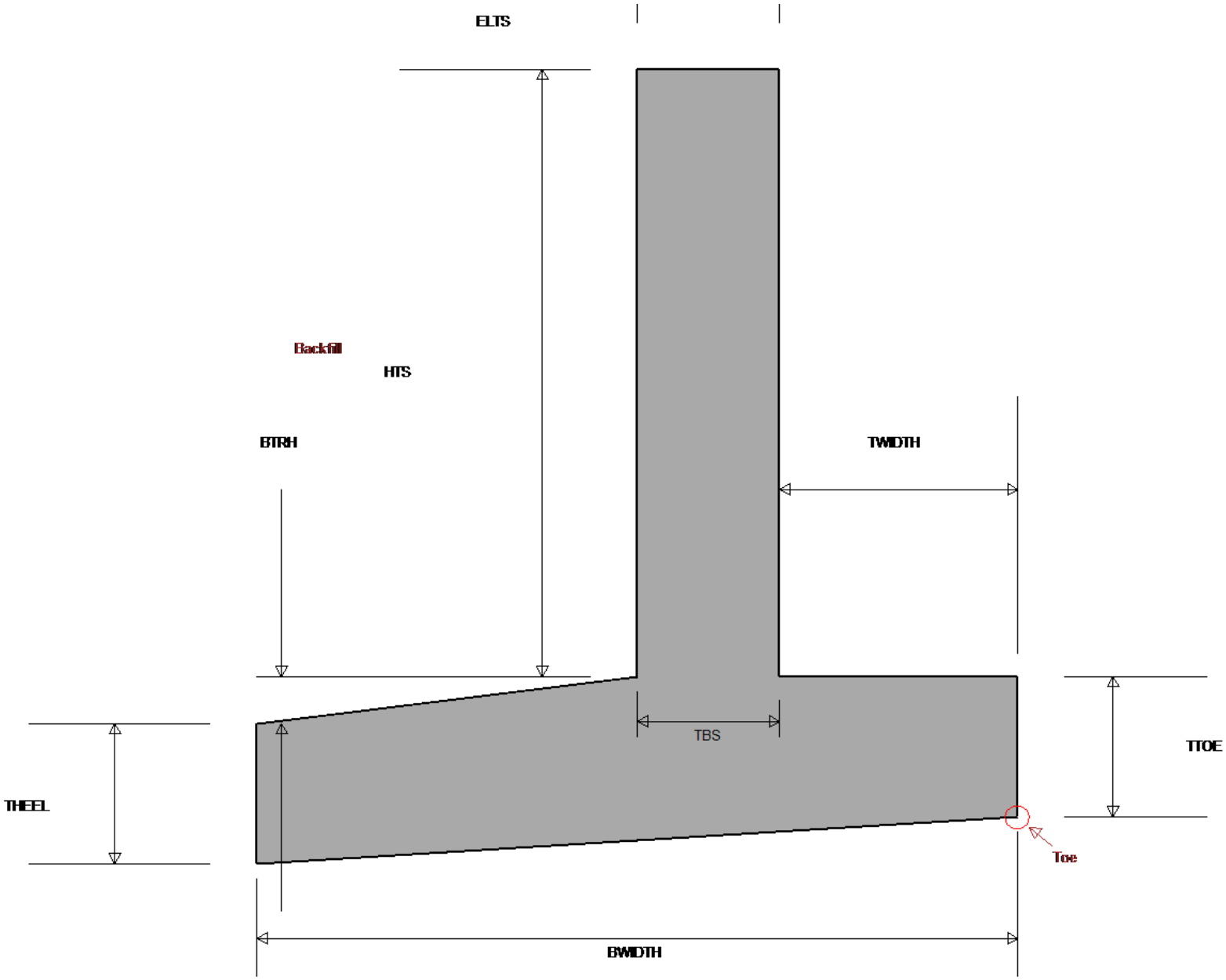
```
  Point 2 (right), x =     8.00 ft,   y =     6.30 ft

Depth of cracking =     0.00 ft

          Failure   Total    Weight    Submerged   Uplift
  Wedge    angle    length  of wedge    length     force
  number   (deg)     (ft)    (kips)      (ft)      (kips)
  ==========================================================
     1   -53.218     4.370      0.572    4.370     1.602
     2     3.576     8.016      4.738    8.016     2.251
     3    36.875     4.999      0.727    2.500     0.175

  Wedge     Net force
  number     (kips)
  ===================
     1       -1.605
     2        0.715
     3        0.890
  ===================
     SUM =    0.000

+-----------------------------+
| Factor of safety =    1.969 |
+-----------------------------+



**********************
**  Bearing Results  **
**********************

            Base width =      8.016 (ft)
                    Xr =      2.680 (ft)
  Effective base width =      5.370 (ft)
   (measured along slope)
            Base slope =     3.5763 (deg)

                   phi =     30.000 (deg)
                     c =      0.000 (ksf)
       Effective gamma =     0.0626 (kcf)

           Normal load =      3.851 (kips)
      Load inclination =     23.582 (deg)
     Load eccentricity =      1.323 (ft)

             Surcharge =     0.2739 (ksf)
             Embedment =      3.000 (ft)
          Ground slope =     0.0000 (deg)
```

Bearing Capacity Factors

	C	Q	G
Bearing	30.1396	18.4011	15.6680
Embedment	1.1935	1.0968	1.0968
Inclination	0.5446	0.5446	0.0458
Base Tilt	0.9252	0.9292	0.9292
Ground Slope	1.0000	1.0000	1.0000

Net ultimate bearing pressure = 2.7682 (ksf)

Factor of safety = 3.860



BTRH=	0.50
BTRK=	0.00
BTRT=	0.00
BWIDTH=	8.00
ELTS=	14.30
HK=	0.00
HTS=	6.50
TBS=	1.50
TBSR=	0.00
THEEL=	1.50
TK=	0.00
TTOE=	1.50
TTS=	1.50
TWIDTH=	2.50

NOTE: All units in feet

13.2.5 – Belle Haven Flood Wall Foundations

CFA Pile Capacity Analysis Per Geotechnical Engineering Circular No. 8 (FHWA) Design and Construction of Continuous Flight Auger Piles

$R_t = R_s + R_b$

$R_s = f_s * A_{shaft}$

$R_b = q_p * A_{base}$

Variables/Symbols	
R_t	Ultimate pile capacity
R_s	Shaft resistance
R_b	End-bearing resistance
A_{shaft}	Area of shaft
A_{base}	Area of base
f_s	Unit side-shear resistance
q_p	Unit end-bearing resistance
α	Side-shear coefficient
S_u	Undrained shear strength
K	Lateral earth pressure coefficient
σ_v'	Effective vertical stress (average along pile segment)
ϕ	Internal friction angle
N^*_c	Bearing capacity factor
L	Pile embedment depth
D	Pile diameter
N_{60}	SPT N-value uncorrected for overburden
P_a	Atmospheric pressure, 1.06 tsf
I_r	Rigidity index
E_s	Undrained Young's Modulus
Z	Depth from ground surface to middle of segment in feet

NOTE: Requires separate calculation of effective vertical stress

Cohesive Soils

Unit side-shear resistance

$$f_s = \alpha \cdot S_u$$

$$\alpha = 0.55 \quad for\ S_u/P_a \le 1.5$$

$$\alpha = 0.55 - 0.1\left(\frac{S_u}{P_a} - 1.5\right) \quad for\ 1.5 \le S_u/P_a \le 2.5$$

$$\alpha = 0.45 \quad for\ S_u/P_a > 2.5$$

Unit end-bearing resistance

$$q_p = N_c^* \cdot S_u \quad for\ L \ge 3D$$

$$N_c^* = 9 \quad for\ 2\ tsf \le S_u \le 2.6\ tsf$$

$$N_c^* = \frac{4}{3}[\ln I_r + 1] \quad for\ S_u < 2\ tsf$$

$$I_r = \frac{E_s}{3S_u} \quad (E_s, S_u\ at\ pile\ tip)$$

If E_s not measured, estimate I_r using table below

S_u	I_r	N^*_c
0.25 tsf	50	6.5
0.50 tsf	150	8.0
1.00 tsf	250	8.7
2.00 tsf	300	8.9

Cohesionless Soils

Unit side-shear resistance

$$f_s = K \cdot \sigma_v' \cdot tan\varphi \le 2\ tsf$$

$$\beta = K \cdot tan\varphi, \quad where\ 0.25 \le \beta \le 1.2$$

$$\beta = 1.5 - 0.135 \cdot Z^{0.5} \quad for\ N \ge 15\ bpf$$

$$\beta = \frac{N}{15}(1.5 - 0.135 \cdot Z^{0.5}) \quad for\ N < 15\ bpf$$

Unit end-bearing resistance

$$q_p(tsf) = 0.6N_{60} \quad for\ 0 \le N_{60} \le 75$$

$$q_p = 45\ tsf \quad for\ N_{60} > 75$$

Scenario: CFA pile bearing in Sand & Gravel Stratum, 14" pile diameter, assuming no capacity from Fill, Clay, and Sand due to liquefaction

gwt @ 6'

								Cohesive soil							*Cohesionless*							
								Side friction			*End bearing*				*Side friction*				*End bearing*			
Soil Layer	**Type**	**Layer Thickness (ft)**	**Pile Dia. (ft)**	**Z (ft)**	**Segment Length (ft)**	**S_u (tsf)**	**N (bpf)**	**S_u/P_a**	**α**	**f_s (tsf)**	**E_s**	**I_r**	**N^*_c**	**q_p (tsf)**	**β**	**σ_v' (psf)**	**σ_v' (tsf)**	**f_s (tsf)**	**q_p (tsf)**	**A_{shaft} (sf)**	**A_{base} (sf)**	**R_t (tons)**
1	Fill	2.5	1.17	1.25	0	--	9								0.809439	150	0.075	0.06070794		0		0
2	Clay	9	1.17	7	0	0.38	5	0.35849	0.55	0.209			7.1	2.698						0		0
3	Sand	23	1.17	23	0	--	4								0.22735	1432	0.716	0.16278265	2.4	0		0
4	Sand & Grav	25.5	1.17	47.3	25.5	--	18								0.571538	2605	1.3025	0.74442767	10.8	93.7294	1.07513	81.3862

Σ= 81.3862

NOTE: If bearing on clay, neglect one pile diameter from bottom of pile for side friction.
NOTE: Neglect upper-most 5' for side friction due to shrinkage and/or frost effects

After neglecting upper 5ft		
A_{shaft} (-)	R (-)	R_t
0	0	81.38619

If bearing on clay, neglect one pile diamter at bottom		
A_{shaft} (-)	R (-)	R_t
0	0	81.3862

Ultimate Capacity (tons)	FS	Allowable Capacity (tons)
81.38619241	2.5	32.55447696

Total Pile Length (ft)
60

Accounting for downdrag				
Downdrag (tons)	R_{ult}	FS	R_{allow}	$R_{allow,downdrag}$ (tons)
0	81.3862	2.5	32.5545	32.55447696

Drilled Displacement Pile Capacity Analysis

Per Geotechnical Engineering Circular No. 8 (FHWA) Design and Construction of Continuous Flight Auger Pile

$R_t = R_s + R_b$

$R_s = f_s * A_{shaft}$

$R_b = q_p * A_{base}$

Cohesive Soils

Unit side-shear resistance

$$f_s = \alpha \cdot S_u$$

$$\alpha = 0.55 \quad for\ S_u/P_a \le 1.5$$

$$\alpha = 0.55 - 0.1\left(\frac{S_u}{P_a} - 1.5\right) \quad for\ 1.5 \le S_u/P_a \le 2.5$$

$$\alpha = 0.45 \quad for\ S_u/P_a > 2.5$$

Unit end-bearing resistance

$$q_p = N_c^* \cdot S_u \quad for\ L \ge 3D$$

$$N_c^* = 9 \quad for\ 2\ tsf \le S_u \le 2.6\ tsf$$

$$N_c^* = \frac{4}{3}[\ln I_r + 1] \quad for\ S_u < 2\ tsf$$

$$I_r = \frac{E_s}{3S_u} \quad (E_s, S_u\ at\ pile\ tip)$$

If E_s not measured, estimate I_r using table below

S_u	I_r	N^*_c
0.25 tsf	50	6.5
0.50 tsf	150	8.0
1.00 tsf	250	8.7
2.00 tsf	300	8.9

Cohesionless Soils

Unit side-shear resistance

$$f_s(tsf) = 0.05N + Ws\ for\ N \le 50$$

$Ws = 0, and\ fs \le 1.7$ tsf for uniform, rounded soil up to 40% fines

$Ws = 0.5\ tsf, and\ fs \le 2.2$ tsf for well-graded, angular soil up to 10% fines

Unit end-bearing resistance

$$q_p(tsf) = 1.9N_{60} + Wt\ for\ N_{60} \le 50$$

$Wt = 0\ for\ qp \le 75$ tsf and uniform, rounded soil up to 40% fines

$Wt = 14\ tsf\ for\ qp \le 89$ tsf and well-graded, angular soil up to 10% fines

Variables/Symbols	
R_t	Ultimate pile capacity
R_s	Shaft resistance
R_b	End-bearing resistance
A_{shaft}	Area of shaft
A_{base}	Area of base
f_s	Unit side-shear resistance
q_p	Unit end-bearing resistance
α	Side-shear coefficient
S_u	Undrained shear strength
K	Lateral earth pressure coefficient
σ_v'	Effective vertical stress (average along pile segment)
ϕ	Internal friction angle
N^*_c	Bearing capacity factor
L	Pile embedment depth
D	Pile diameter
N_{60}	SPT N-value uncorrected for overburden
P_a	Atmospheric pressure, 1.06 tsf
I_r	Rigidity index
E_s	Undrained Young's Modulus
Z	Depth from ground surface to middle of segment in feet

NOTE: Requires separate calculation of effective vertical stress

Scenario: CFA pile bearing in Sand & Gravel Stratum, 14" pile diameter, assuming no capacity from Fill, Clay, and Sand due to liquefactio

gwt @ 6'

								Cohesive soil							*Cohesionless*							
								Side friction			*End bearing*				*Side friction*				*End bearing*			
Soil Layer	**Type**	**Layer Thickness (ft)**	**Pile Dia. (ft)**	**Z (ft)**	**Segment Length (ft)**	**S_u (tsf)**	**N (bpf)**	**S_u/P_a**	**α**	**f_s (tsf)**	**E_s**	**I_r**	**N^*_c**	**q_p (tsf)**	**β**	**σ_v' (psf)**	**σ_v' (tsf)**	**f_s (tsf)**	**q_p (tsf)**	**A_{shaft} (sf)**	**A_{base} (sf)**	**R_t (tons)**
1	Fill	2.5	1.17	1.25	0	--	9								0.809439	150	0.075	0.45		0		0
2	Clay	9	1.17	7	0	0.38	5	0.35849	0.55	0.209			7.1	2.698						0		0
3	Sand	23	1.17	23	0	--	4								0.22735	1432	0.716	0.2		0		0
4	and & Gra	25.5	1.17	47.3	25.5	--	18								0.571538	2605	1.3025	0.9	34.2	93.7294	1.07513	121.126

Σ= 121.126

NOTE: If bearing on clay, neglect one pile diameter from bottom of pile for side friction.
NOTE: Neglect upper-most 5' for side friction due to shrinkage and/or frost effects

After neglecting upper 5ft

A_{shaft} (-)	R (-)	R_t
0	0	121.126

If bearing on clay, neglect one pile diamter at bottom

A_{shaft} (-)	R (-)	R_t
0	0	121.126

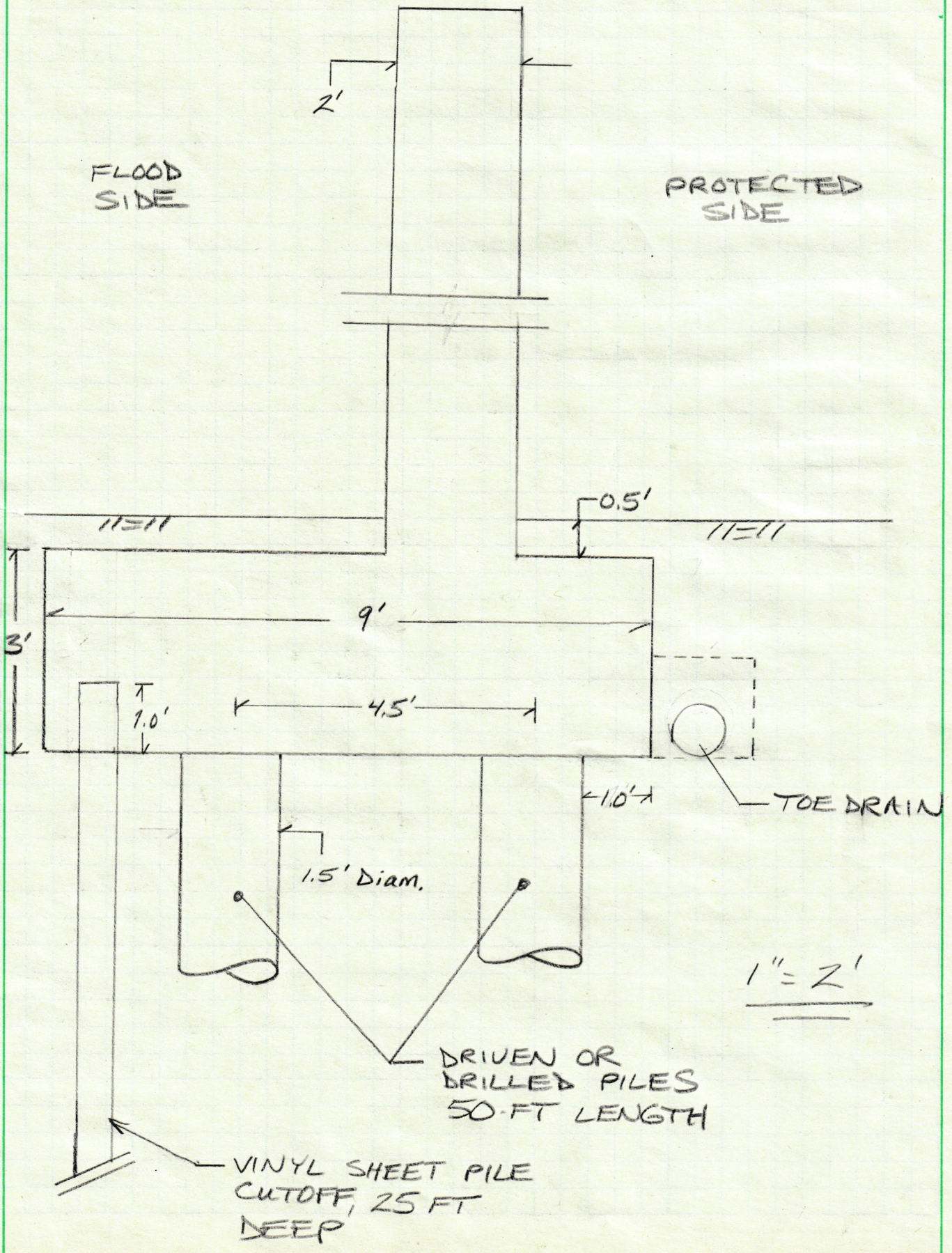
Ultimate Capacity (tons)	FS	Allowable Capacity (tons)
121.125974	2.5	48.4503896

Total Pile Length (ft)
60

Accounting for downdrag

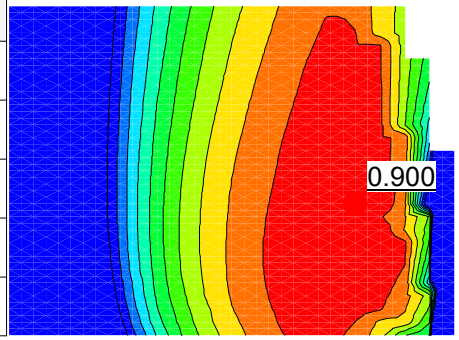
Downdrag (tons)	R_{ult}	FS	R_{allow}	$R_{allow,downdrag}$ (tons)
0	121.126	2.5	48.4504	48.4503896

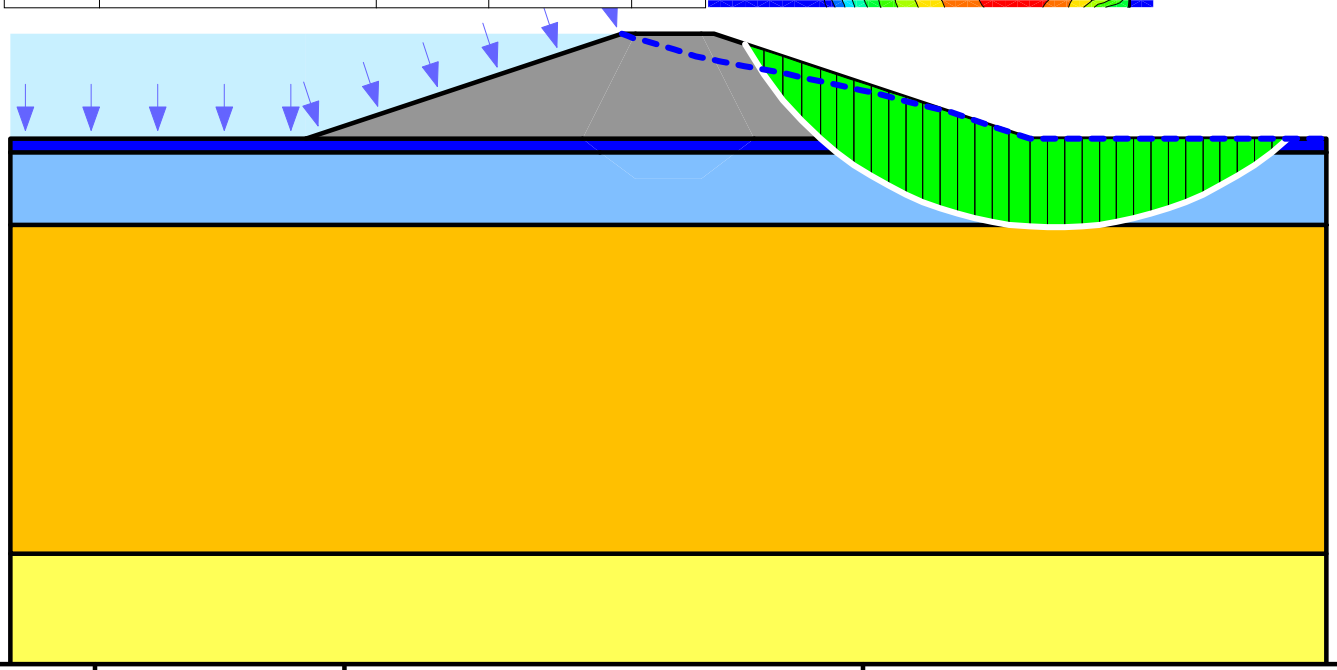
BELLE HAVEN SITE



13.2.6 – Global Stability Analysis

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Embankment (SM/ML)	125	0	34
	Fill (SM)	120	0	30
	Sand & Gravel (SW)	125	0	34
	Sandy Clay (CL)	110	0	28
	Silty Sand (SM)	110	0	28





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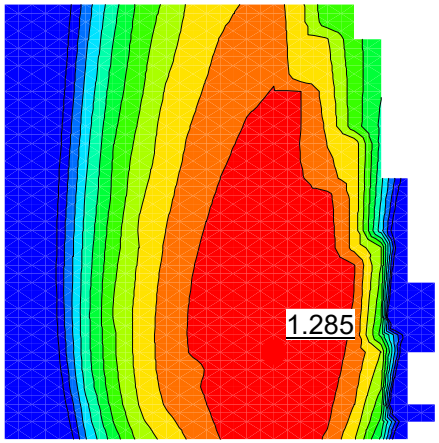
FILE NAME:

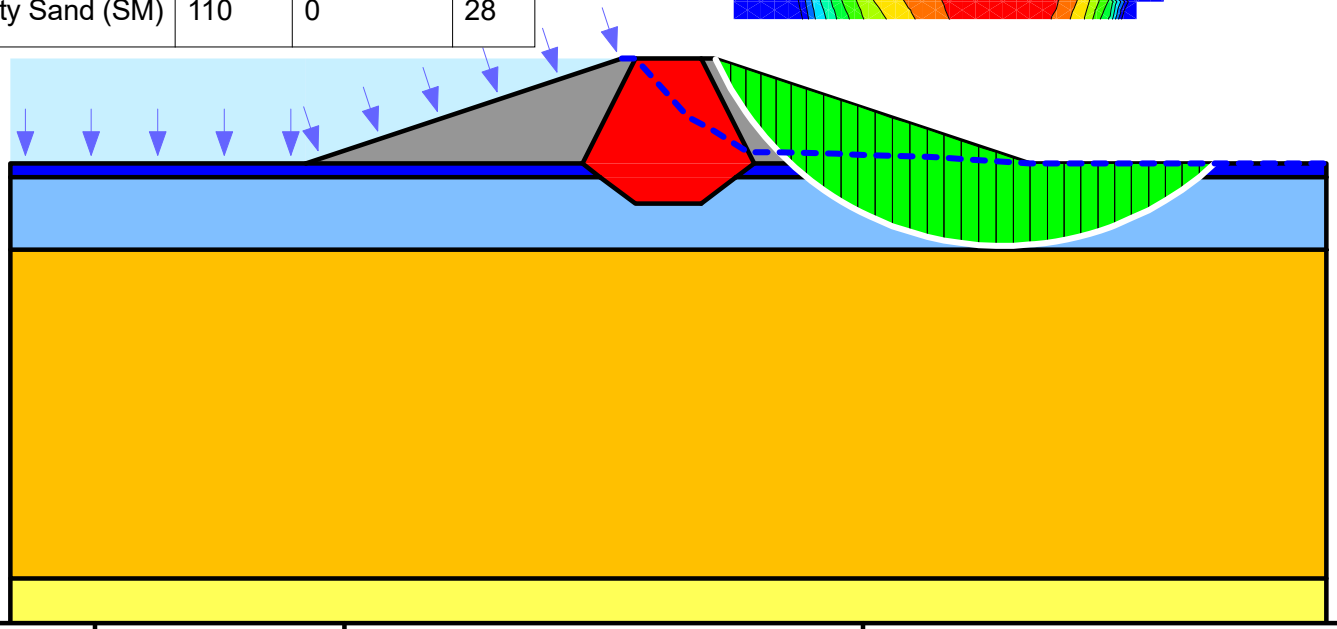
SLOPE STABILITY RESULTS
W/o Clay Core
Method: Spencer

DC Coastal Feasibility Study
BELLE HAVEN LEVEE

PLATE

Color	Name	Unit Weight (pcf)	Cohesion' (psf)	Phi' (°)
	Clay Core	125	0	33
	Embankment (SM/ML)	125	0	34
	Fill (SM)	120	0	30
	Sand & Gravel (SW)	125	0	34
	Sandy Clay (CL)	110	0	28
	Silty Sand (SM)	110	0	28





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SLOPE STABILITY RESULTS
With Clay Core
Method: Spencer

DC Coastal Feasibility Study
BELLE HAVEN LEVEE

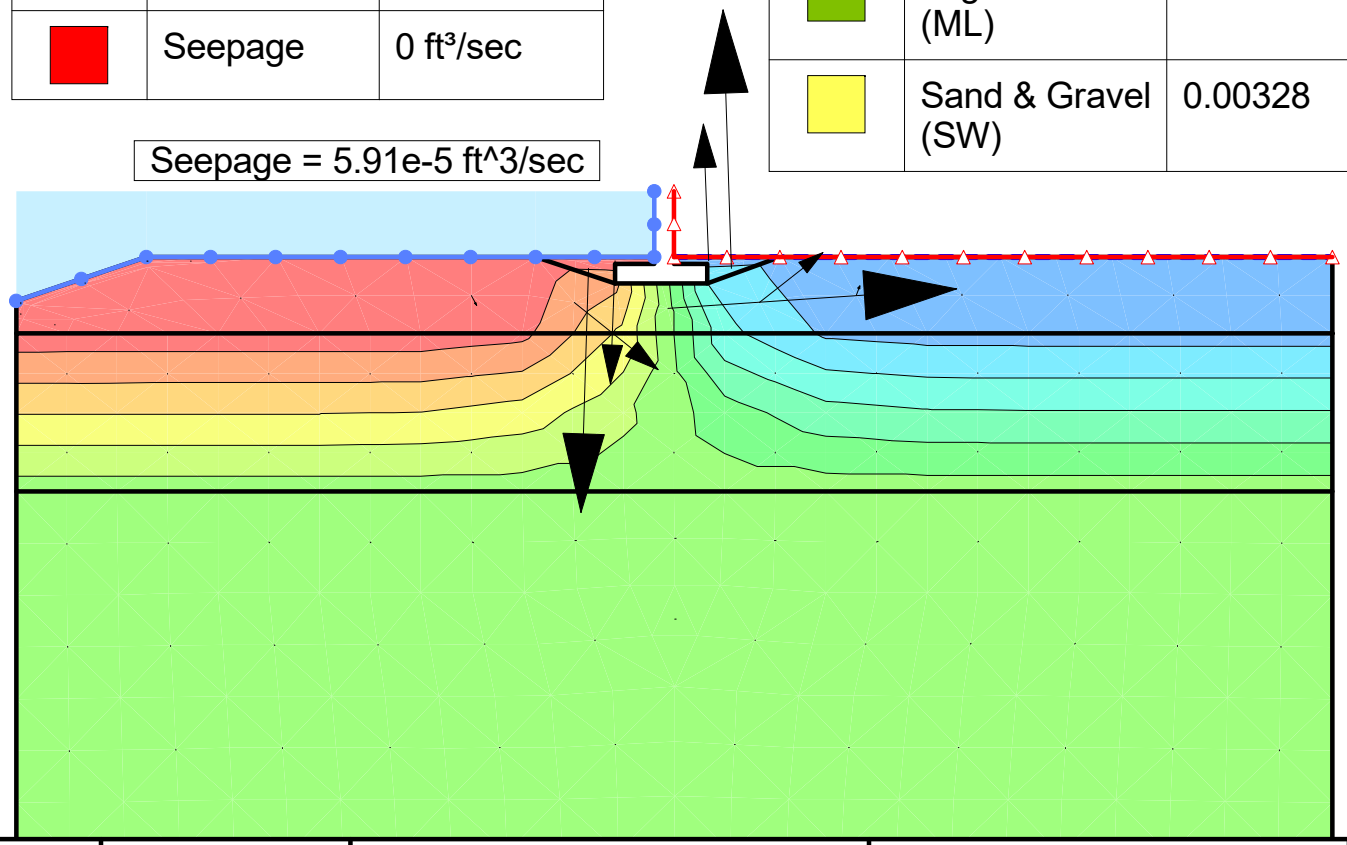
PLATE

13.2.7 – Seepage Analysis

Color	Name	Parameters
	Flood Stage Arlington	14.3 ft
	Seepage	0 ft³/sec

Color	Name	Sat Kx (ft/sec)
	Backfill (SM)	3.28e-05
	Fill (SM)	3.28e-05
	Organic Silt (ML)	3.28e-07
	Sand & Gravel (SW)	0.00328

Seepage = 5.91e-5 ft^3/sec



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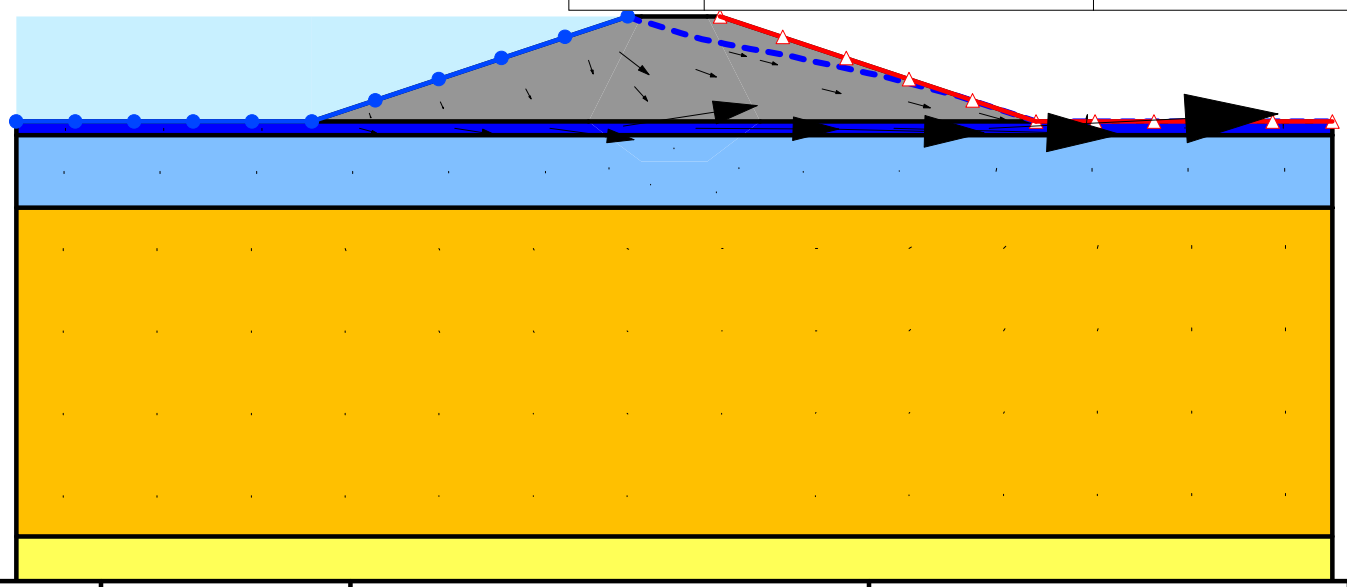
Color	Name	Sat Kx (ft/sec)
	Embankment (SM/ML)	3.28e-06
	Fill (SM)	3.28e-05
	Sand & Gravel (SW)	0.00328
	Sandy Clay (CL)	1.64e-07
	Silty Sand (SM)	3.28e-05

Seepage = 1.49 e-5 ft^3/sec



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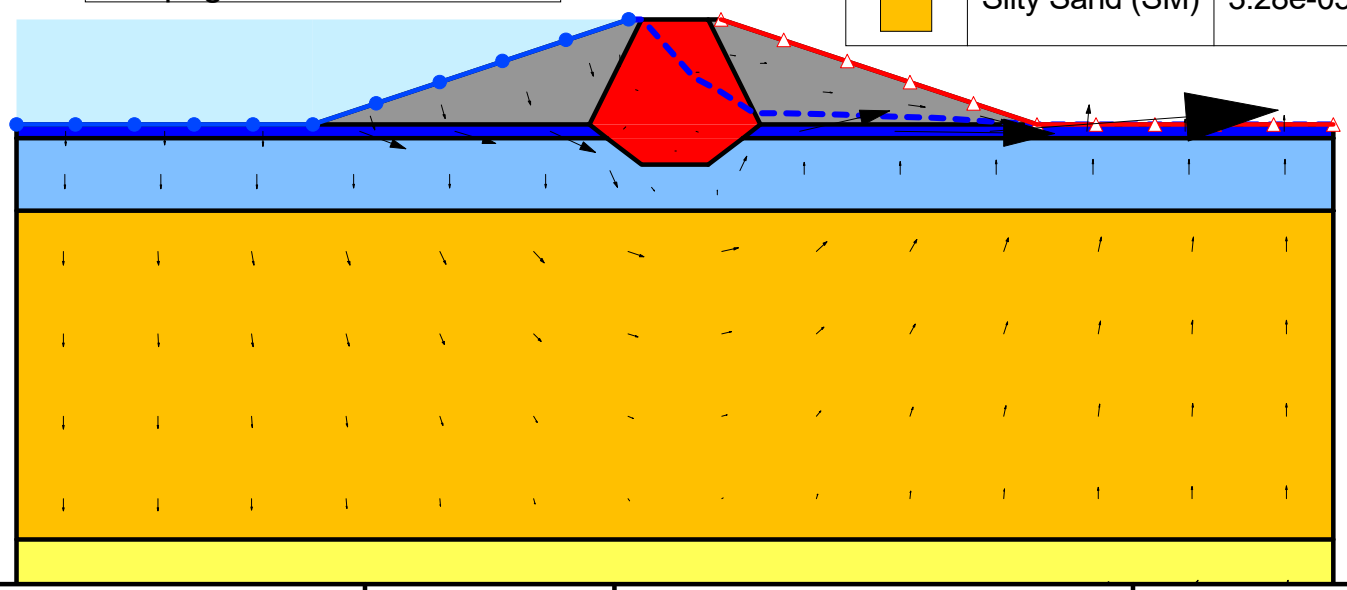
SEEPAGE ANALYSIS RESULTS
W/o Clay Core

DC Coastal Feasibility Study
BELLE HAVEN LEVEE

PLATE

Color	Name	Sat Kx (ft/sec)
	Clay Core	3.28e-08
	Embankment (SM/ML)	3.28e-06
	Fill (SM)	3.28e-05
	Sand & Gravel (SW)	0.00328
	Sandy Clay (CL)	1.64e-07
	Silty Sand (SM)	3.28e-05

Seepage = 5.62 e-6 ft^3/sec



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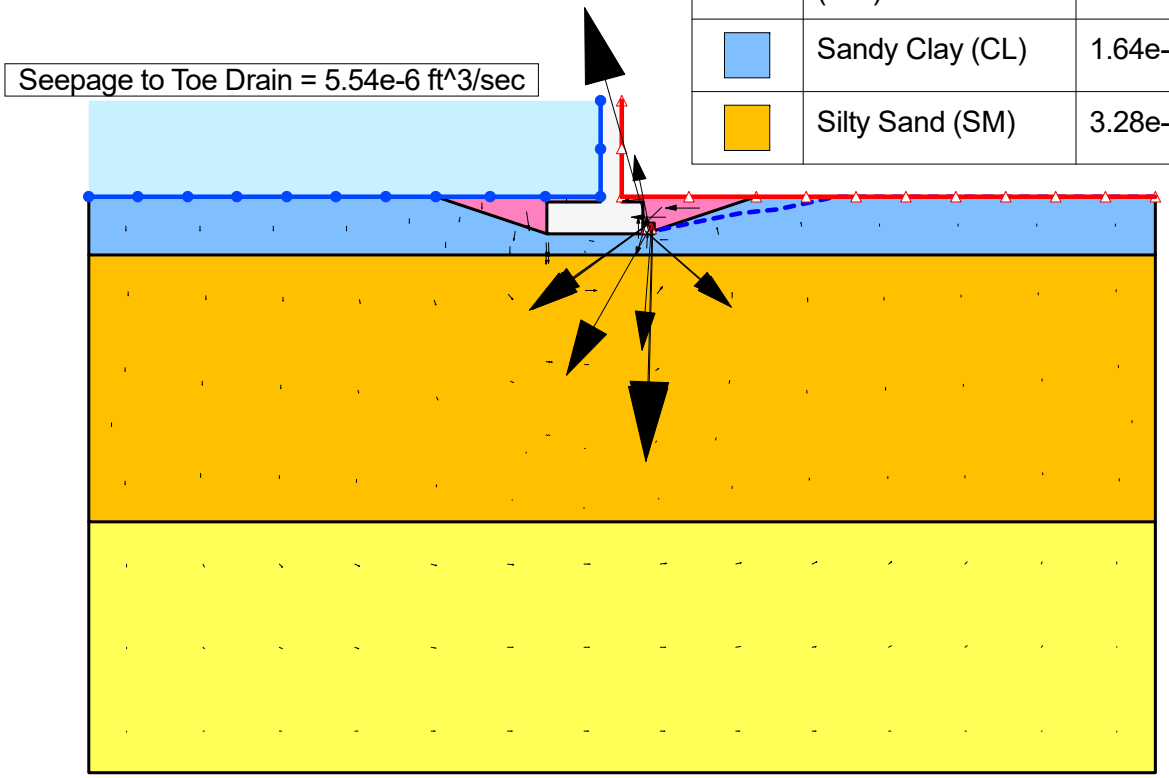
SEEPAGE ANALYSIS RESULTS
With Clay Core

DC Coastal Feasibility Study
BELLE HAVEN LEVEE

PLATE

Color	Name	Parameters
	Flood Stage Belle Havon	13 ft
	Seepage	0 ft³/sec

Color	Name	Sat Kx (ft/sec)
	Backfill (SM)	3.28e-05
	Drainage Sand and Gravell (SW)	0.0328
	Sand & Gravel (SW)	0.00328
	Sandy Clay (CL)	1.64e-07
	Silty Sand (SM)	3.28e-05



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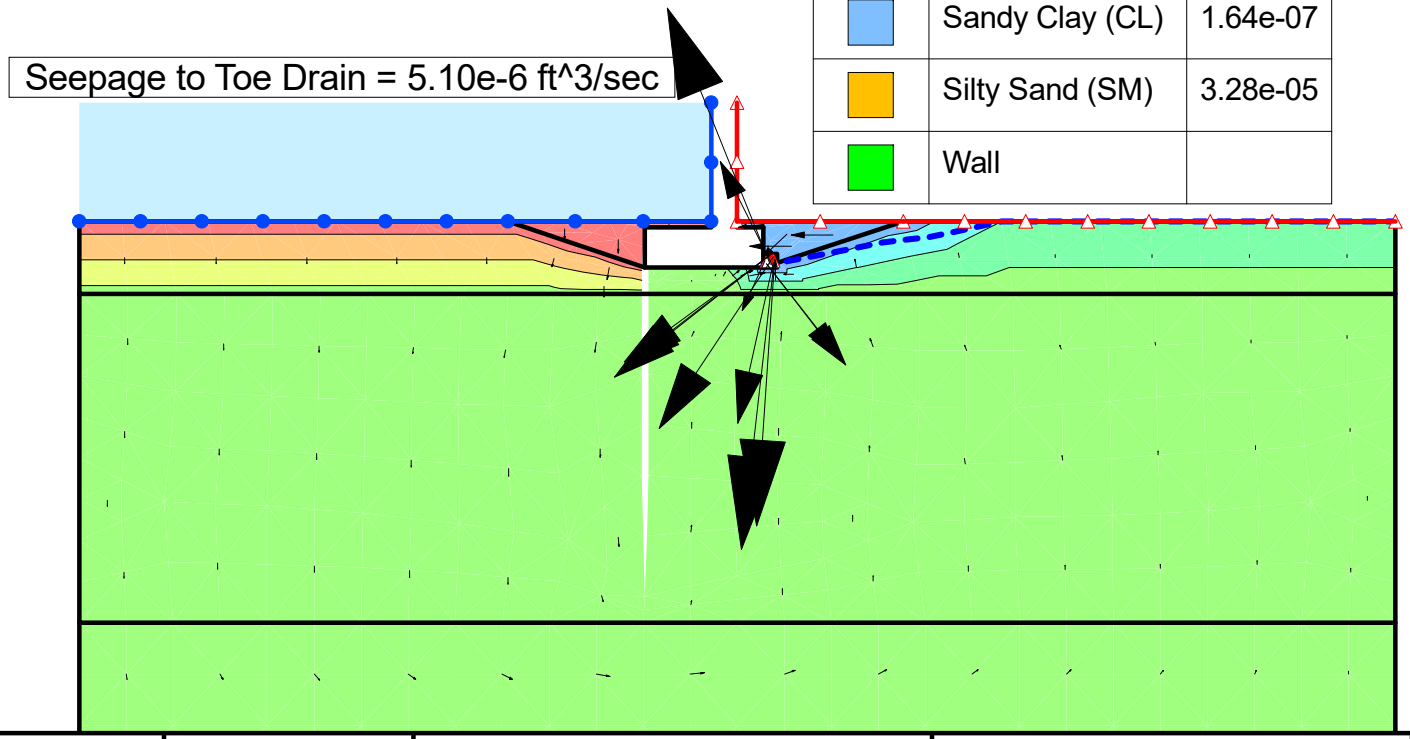
SEEPAGE ANALYSIS RESULTS
Without Cutoff Wall

DC Coastal Feasibility Study
BELLE HAVEN FLOODWALL

PLATE

Color	Name	Parameters
	Flood Stage Belle Havon	13 ft
	Seepage	0 ft³/sec

Color	Name	Sat Kx (ft/sec)
	Backfill (SM)	3.28e-05
	Drainage Sand and Gravell (SW)	0.0328
	Sand & Gravel (SW)	0.00328
	Sandy Clay (CL)	1.64e-07
	Silty Sand (SM)	3.28e-05
	Wall	



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SEEPAGE ANALYSIS RESULTS
With Cutoff Wall

DC Coastal Feasibility Study
BELLE HAVEN LEVEE

PLATE