AMERICAN ENGINEERING TESTING, INC.

CONSULTANTS
- ENVIRONMENTAL
- GEOTECHNICAL
- MATERIALS
- FORENSICS

# REPORT OF GEOTECHNICAL EVALUATION
## FEMA Certification
## Reach 1 Afton Levee
Afton, Minnesota

Report No. 01-05376B

**Date:**

August 7, 2012

**Prepared for:**

City of Afton
3033 St. Croix Trail
P.O. Box 219
Afton, MN 55001

www.amengtest.com

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August 7, 2012

City of Afton
3033 St. Croix Trail
P.O. Box 219
Afton, MN 55001

Attn: Patricia Snyder, Mayor

RE: Geotechnical Evaluation
FEMA Levee Certification
Reach 1 – Afton Levee
Afton, Minnesota
Report No. 01-05376B

Dear Ms. Snyder:

American Engineering Testing, Inc. (AET) is pleased to present the results of our geotechnical evaluation of the Reach 1 levee. This report provides the geotechnical evaluation required as part of the FEMA levee certification process.

We are submitting two copies of the report to you. Additional copies are being sent to WSB & Associates, as indicated below.

Please contact me if you have any questions about the report.

Sincerely,
**American Engineering Testing, Inc.**

James C. Rudd, P.E.
Vice President/Principal Engineer
Phone: (651) 659-1367
Fax: (651) 659-1347
jrudd@amengtest.com

cc: WSB & Associates, Inc.; Attn: Diane Hankee, P.E.



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## SIGNATURE PAGE

Prepared for:

City of Afton
3033 St. Croix Trail
Afton, Minnesota 55001

Attn: Patricia Snyder, Mayor

Prepared by:

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Authored by:

James C. Rudd, P.E.
Vice President/Principal Engineer

Reviewed by:

Joseph G. Bentler, P.E.
Senior Geotechnical Engineer

**I hereby certify that this plan, specification, or report was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the laws of the state of Minnesota**

**Date:** 8/7/12 **License #: 13996**

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## 1.0 INTRODUCTION

The City of Afton plans to apply for FEMA re-certification of the existing levee system. In order to meet the levee certification requirements of 44 CFR 65.10, a submittal must be provided to FEMA that includes various data and documentation. One of the required elements in the FEMA submittal is a geotechnical engineering analysis of the levee and foundation. The geotechnical engineering analysis must address the following three items: (1) slope stability of the levee and foundation; (2) seepage stability of the levee and foundation; and (3) settlement analysis to assess potential for loss of freeboard.

WSB & Associates will be preparing the various portions of the FEMA submittal. The following report is only intended to meet the FEMA submittal requirements for geotechnical analysis of stability, seepage and settlement for the Reach 1 levee. Other required portions of the submittal (e.g. hydraulics, freeboard, closures, erosion protection, interior drainage, etc.) are not part of this report.

The following report only applies to the Reach 1 levee. Additional geotechnical exploration and analysis will be needed for the Reach 2 levee.

## 2.0 SCOPE OF SERVICES

AET's services consisted of the following:

- Cone Penetration Test (CPT) soundings at ten locations along the Reach 1 levee. The sounding depths ranged from 30 to 86 feet.
- Standard Penetration Test (SPT) soil borings at two locations along the Reach 1 levee. Soil boring depths were 31 feet, each.
- Soil laboratory tests on samples collected in the soil borings. The laboratory test program

included the following: 6 water content tests and 15 grain size distribution (gradation) tests.

- Engineering analysis of settlement, slope stability, and seepage.
- Preparation of design recommendations for levee modifications if USACE design standards are not met for seepage, slope stability or settlement.

## 3.0 PROJECT INFORMATION

The Afton levee system was originally constructed under emergency conditions to protect against flooding from the St. Croix River in 1969. The levee consists of two separate reaches. Reach 1 starts at the intersection of Pike Avenue South and Afton Blvd. South on the north end and extends south approximately 2000 feet to the north bank of Kelle's Coulee on the south end. Attached Figure 1 shows the limits of Reach 1 levee.

The levee height along Reach 1 varies from 3 to 12 feet and the top width varies from 9 to 12 feet. The riverside slope is approximately 3 horizontal to 1 vertical, and the landside slope varies from 4 to 5 horizontal to 1 vertical. The levee slope vegetation consists of mowed grass. There is a bituminous paved path along the levee crest.

Septic drain fields exist on the landside of the levee between approximate Station 24+50 to 35+50. The City of Afton is planning to remove these drain fields.

Our geotechnical analysis assumes that the Base Flood Elevation along Reach 1 is at elevation 693.0 feet. We understand that portions of the existing levee will be raised a maximum of 5 feet to meet minimum freeboard requirements. Our geotechnical analysis assumes a maximum 5 feet of grade raise.

There are 3 pipe crossings through the levee in the vicinity of Station 27+60. These pipe crossings consist of: (1) a 54 inch CMP that was once used as a gravity storm water outfall, but has since been blocked; (2) a 10 inch PVC pipe that is used during flood fights to pump surface water from the landside through the levee at elevation 690.0 feet; and (3) a 12 inch PVC pipe that is used during flood fights to pump surface water from the landside through the levee at elevation 692.9 feet.

The above stated information is an integral part of our engineering review. It is important that you contact us if there are changes from that described so that we can evaluate whether modifications to our analysis or recommendations are appropriate.

## 4.0 SUBSURFACE EXPLORATION AND TESTING

### 4.1 General

Our subsurface exploration program for this project consisted of ten Cone Penetration Test (CPT) soundings and two Standard Penetration Test (SPT) soil borings along the levee crest. The approximate locations of the soundings & borings are shown on attached Figure 1.

### 4.2 Standard Penetration Test (SPT) Soil Borings

Logs of the SPT soil borings and details of the methods used are presented in Appendix A. The logs contain information concerning soil layering, soil classification, geologic description, and moisture condition. Relative density or consistency is also noted for the natural soils, which is based on the standard penetration resistance (N-value).

We drilled the SPT borings using a combination of 3¼-inch inside diameter hollow stem augers and mud-rotary drilling methods. Refer to Appendix A for details on the drilling and sampling methods, the classification methods and the water level measurement methods. All soil borings were sealed with bentonite upon completion.

### 4.3 Cone Penetrometer Test (CPT) Soundings

We performed the CPT soundings with a 20-ton CPT rig. A description of the CPT test method is given in Appendix A.

With the CPT test method, soil layers are classified by Soil Behavior Type (SBT) instead of grain size distribution and plasticity. The SBT uses a relationship between cone tip resistance ($q_t$) and friction ratio ($f_r$) to classify the soil type into nine (9) different categories. A description of the CPT method and an illustration of the SBT classification chart is included in Appendix A. CPT logs with SBT classification (Format 1) are shown in Appendix A.

The CPT soundings are also presented in a format which resembles a traditional SPT soil boring log (Format 2). The logs include an interpreted soil description and an estimated N-value. The interpreted soil description is based on the SBT classification, along with comparison to the companion SPT borings that we drilled on the site. The estimated N-values are based on the correlations with cone tip stress; this correlation is based on published values in literature and local experience.

All CPT sounding holes were sealed with bentonite upon completion.

### 4.4 Soil Laboratory Testing

Laboratory tests were run on samples collected in the soil borings. Results of six water content tests are shown on the boring logs in Appendix A. Appendix A also includes gradation curves for 15 grain size distribution tests.

# 5.0 SUBSURFACE CONDITIONS

## 5.1 Soil Profile along Levee Alignment

The general subsurface profile, based on the soil borings and CPT soundings, consists of three main soil units: (1) levee fill; (2) thin fine-grained surface blanket, and (3) thick coarse alluvium foundation layer. A description of these three main soil units is given below. The general soil profile is also illustrated on attached Figures 2 and 3.

### *5.1.1 Levee Fill*

The existing levee fill is predominantly granular soils (sand and silty sand), with some zones of clayey soils. Total fill thickness varies from about 8 to 17 feet at the test locations. Based on the N values and CPT tip stress values, the relative density of the fill is highly variable. Portions of the embankment are very dense, and portions are loose.

We understand that the levee fill was placed in 1969 under emergency conditions. Based on our test results, it is our opinion that reasonable compaction of the levee was achieved. We found no evidence of buried debris, organic materials or poorly compacted fill materials.

Gradation tests on samples of the levee fill show that the majority of the levee embankment fill material contains less than 10% fines. In our opinion, the permeability of these soils will be relatively high, and seepage through the levee during floods is possible. Further discussion of soil permeability is given in Section 6.3.2 of this report.

Based on gradation, N values and CPT tip stress measurements, we estimate the friction angle of the levee fill between 30 and 35 degrees. For slope stability analyses, we assumed a drained friction angle of 30 degrees.

### *5.1.2 Fine-Grained Surface Blanket*

Directly below the levee embankment fill, we encountered a thin layer of fine grained soils (silty sand, clayey sand and clay). The thickness of this surface blanket varies from about 1.5 feet to 4 feet in the borings/soundings. In our slope stability, settlement and seepage analyses (Sections 6.1, 6.2 and 6.3 of this report), we assume that the surface blanket extends both riverward and landward of the levee. Prior to final design of seepage control measures, we recommend additional soil borings to confirm the existence and depth of the surface blanket on the landside of the levee.

Estimates of shear strength (drained and undrained), permeability and compressibility of the fine grained layer are given in Sections 6.1.2, 6.2.2 and 6.3.2 of this report.

### *5.1.3 Coarse Alluvium Foundation*

Below the fine-grained surface blanket, the soil profile consists mainly of sand (SP & SP-SM) and silty sand (SM) alluvium soils. The soundings indicate that the coarse alluvium extends at least 85 feet deep (Sounding C-02). Based on a review of published bedrock maps, the anticipated top of bedrock is about elevation 600 feet (about 95 feet deep). See Figures 2 and 3 for an illustration of the estimated thickness of the coarse alluvium and the top of bedrock.

Gradation tests show that the levee fill and coarse alluvium both have small fines fraction (%

passing #200 sieve); therefore, permeabilities of the levee and foundation soils are relatively high. Seepage through and below the levee during floods is likely. Further discussion on seepage issues is given in Section 6.3 of this report.

### 5.2 Ground Water

Groundwater measurements were made in the soil borings. At the time of our soil borings, the water table was measured at approximately elevation 675 feet to 676 feet. The water table will fluctuate with the river stage.

## 6.0 ENGINEERING ANALYSES AND RECOMMENDATIONS

### 6.1 Slope Stability

#### *6.1.1 Method*

Slope stability analyses were done in accordance with general USACE guidelines given in EM 1110-3-1913 manual "Design and Construction of Levees". Slope stability computations were made using ReSSA, version 3.0 computer program. The program is a limit-equilibrium method that can analyze both circular failure planes (Bishop Method) and non-circular failure planes (Spencer Method). The slope stability analysis evaluated the following loading conditions:

Case I: End of Construction
Case II: Rapid Drawdown
Case III: Steady Seepage from Full Flood Stage

We did not evaluate "Case IV- Earthquake" due to the very low probability of an earthquake coinciding with the base flood in the low seismic zone of Minnesota.

WSB provided us with cross sections of the existing levee at 50 foot intervals. For our slope stability computations, we used the cross section shown on Figure 4. This cross section represents the highest levee grade raise for the project.

### *6.1.2 Soil Profile and Soil Parameters for Analyses*

Assumptions for soil profile and soil parameters are given in Tables 6-1 and 6-2, respectively.

Table 6-1: Soil Profile for Slope Stability Analyses

| Layer | Soil Description | Layer Extent |
|---|---|---|
| 1 | Levee fill | As shown on Figures 4, 5 & 6 |
| 2 | Fine grained surface blanket | Elev. 675 to 680 ft.<br>[Zones A, B & C as shown on Figures 4, 5 & 6] |
| 3 | Sand alluvium | Below elev. 675 |

Table 6-2: Assumed Soil Parameters

| | | | Case I | | Case II | | Case III | |
|---|---|---|---|---|---|---|---|---|
| Soil Layer | Description | Unit Wt. (pcf) | Friction (deg.) | Cohesion (psf) | Friction (deg.) | Cohesion (psf) | Friction (deg.) | Cohesion (psf) |
| 1 | Levee fill | 125 | 30 | 0 | 30 | 0 | 30 | 0 |
| 2A | Surface blanket Zone A | 130 | 0 | 666 | 0 | 500 | 27 | 500 |
| 2B | Surface blanket Zone B | 130 | 0 | 856 | 0 | 500 | 27 | 500 |
| 2C | Surface blanket Zone C | 130 | 0 | 1235 | 0 | 1000 | 27 | 500 |
| 3 | Sand alluvium | 125 | 30 | 0 | 30 | 0 | 30 | 0 |

The levee fill and sand alluvium layers have high permeabilities; therefore, drained friction angles are assumed for all loading cases. For Layer 2 (Surface Blanket), the following stress states were assumed to estimate shear strength parameters:

- Case I: Undrained shear strength under existing levee geometry consolidation stresses and normal water table elevation (elev. 676 feet).
- Case II: Undrained shear strength under final levee geometry consolidation stresses and pore pressures under full flood stage.
- Case III: Drained shear strengths.

### *6.1.3 Results*

The results of the slope stability computations are given in Table 6-3. ReSSa computer outputs are included in Appendix B.

Table 6-3: Summary of Slope Stability Analysis Results

| Case No. | Design Condition | Required Minimum Factor of Safety | Computed Factor of Safety |
|---|---|---|---|
| 1 | End of Construction | 1.3 | 2.0 |
| 2 | Rapid Drawdown | 1.2 | 2.0 |
| 3 | Steady Seepage from Full Flood Stage | 1.4 | 1.9 |

## 6.2 Settlement Analyses

### *6.2.1 Method*

Settlement estimate was made using the computer program FoSSA (Version 2.0). The settlement estimate assumes a two-dimensional embankment, as shown on Figure 7. Settlements were computed for post-construction (long-term) settlements. Short term settlements that occur during construction (as the levee is raised with 5 feet of new fill) are not considered. This situation occurs in the sand fill and sand alluvium. Short term settlements do not affect loss of freeboard; therefore, were not considered in this analysis.

### *6.2.2 Soil Profile and Soil Parameters for Analyses*

We assume the soil profile in Table 6-4 for the settlement analysis:

Table 6-4: Soil Profile for Settlement Analyses

| Layer # | Soil Description | Layer Extent |
|---|---|---|
| 1 | Levee fill | As shown on Figure 7 |
| 2 | Fine grained surface blanket | Elev. 675 to 680 ft. |
| 3 | Sand alluvium | Below elev. 675 |

The assumed soil parameters for the settlement analysis are shown in Table 6-5 below:

Table 6-5: Assumed Soil Parameters for Settlement Analysis

| Soil Layer | Description | Unit Weight (pcf) | Overconsolidation Ratio (OCR) | $Cc/(1+e_o)$ |
|---|---|---|---|---|
| 1 | Levee fill | 125 | Compression occurs during construction | |
| 2 | Fine grained surface blanket | 130 | 1.0* | 0.08 |
| 3 | Sand alluvium | 125 | Compression occurs during construction | |

* Value is conservative assumption

### *6.2.3 Results*

The computed total settlement under the center of the levee is less than 1 inch.

## 6.3 Seepage Analysis

### *6.3.1. Method*

Seepage through and under the levee is analyzed using SEEP/W 2007 by Geoslope International assuming 2-dimensional, steady seepage conditions.

In general, the seepage analysis consisted of computing the exit seepage gradient at the landside toe. Based on USACE guidelines, the maximum allowable seepage gradient at the landside toe is 0.5. If the computed gradient exceeds 0.5, then seepage control measures are required in order to reduce the gradient.

Several different levee cross sections were analyzed for landside seepage gradient. A discussion of our seepage analysis at Station 30+00 is presented in Section 6.3.3 of this report. The seepage analysis is based on the assumptions given in Table 6-6.

**Table 6-6: Assumptions Used in Seepage Analyses at Station 30+00**

| Parameter | Assumed Value | Parameter | Assumed Value |
|---|---|---|---|
| 100 yr. flood elevation | 693.0 feet | Permeability of levee fill | 1.77 ft/hr |
| Landside ground surface elevation | 683.2 feet | Permeability of landside surface blanket | 0.354 ft/hr |
| Bottom elevation of landside surface blanket | 678.0 feet | Permeability of coarse alluvium foundation layer | 11.8 ft/hr |
| Bottom elevation of coarse alluvium foundation layer | 600.0 feet | | |

### *6.3.2. Soil Permeabilities*

Soil permeability values are estimated from grain size distribution using the Kozeny-Carman equation. A total of 15 grain size distribution tests were run on samples of levee fill and foundation soils. The estimated permeability values of the 15 gradation tests are shown on Table A-1, in Appendix A.

### *6.3.3. Results*

Figure 8 illustrates the results of the seepage analysis at Station 30+00. The total head under the landside blanket is 687 feet at the levee toe. The computed upward gradient at the levee toe is 0.73, which exceeds the maximum allowable gradient of 0.5. Therefore, seepage control measures will be required at Station 30+00.

Based on the seepage analyses at other cross sections of the levee, high exit gradients are computed for the majority of the levee, except for the north end (north of approximate Station 31+50) where large drain field mounds exist on the landside of the levee.

Figure 2 illustrates the levee cross section in this northern reach. The drain field mound on the landside of the levee acts as a seepage berm, which reduces the exit gradient at the toe. Although the drain field mound acts as a seepage berm, there is a potential for internal erosion during a flood since the gradation of the filter material beneath the drain field is unknown.

For the full length of Reach 1, we recommend construction of a landside toe drain to control the seepage gradients.

### 6.4 Toe Drain Recommendations

To reduce upward gradients at the landside toe, we recommend construction of a toe drain at the landside toe, as illustrated in Figure 9. We recommend that the toe drain be constructed by excavating through the landside surface blanket until the coarse alluvium deposit is encountered. Based on the borings/soundings along the levee centerline, the estimated depth of the toe drain excavation will vary from about 5 to 12 feet. Prior to final design, we recommend some additional soil borings along the landside toe to confirm the depth of the surface blanket.

We also recommend that the toe drain be constructed to collect seepage through the pervious embankment fill. The purpose of the toe drain extension into the levee embankment is to prevent saturation of the embankment toe, which could result in slope stability issues.

The levee toe excavation should be backfilled with free-draining gravel protected with a sand filter layer, as shown in Figure 9. Typical material types for the gravel drain and sand filter would be MnDOT 3149.2H and 3149.2J, respectively.

A 6 inch diameter rigid PVC perforated collector pipe is recommended within the toe drain. We recommend that the perforated pipe have ¼ inch to ½ inch diameter holes for the perforations. This collector pipe should be directed to the storm drain system that can be pumped during flood events. The estimated flow rate from the toe drain is 2 GPM per foot of levee.

### 6.5 Existing Drain Field Areas

We recommend that the existing septic drain fields located on the landside of the levee be fully removed. After removal of the drain fields, the toe drain should be constructed.

### 6.6 Existing Culvert & Pipe Crossings

We recommend that the existing 54 inch CMP culvert at Station 27+60 be completely removed. The excavation for the culvert removal should be sloped at 1.5H to 1.0 V. We recommend that the excavation be backfilled with Granular Borrow (MnDOT 3149.2B1). The levee fill should be placed in maximum 6 inch thick lifts and compacted to a minimum of 98% of Standard Proctor density (ASTM:D698).

We recommend that the twin PVC discharge pipes at Station 27+60 be raised so that the pipe invert is above the Base Flood elevation. The pipes should be backfilled with compacted Granular Borrow. We recommend a similar compaction level as given in the previous paragraph.

### 6.7 Levee Raises

Portions of the levee will be raised to meet freeboard requirements. Prior to placement of new levee fill, we recommend that all existing topsoil and/or pavements be removed. The surface should then be scarified prior to placement of new levee fill. The levee fill should consist of Granular Borrow (MnDOT 3149.2B1) compacted to 98% of Standard Proctor density (ASTM:D698).

### 6.8 Erosion Protection

We recommend that river side and land side slopes be protected from erosion. Design of erosion protection is beyond our work scope.

## 7.0 ADDITIONAL SOIL BORINGS

Prior to final design of the toe drain, we recommend additional soil borings along the landside toe to confirm the depth of the surface blanket.

## 8.0 REVIEW OF PLANS AND SPECIFICATIONS

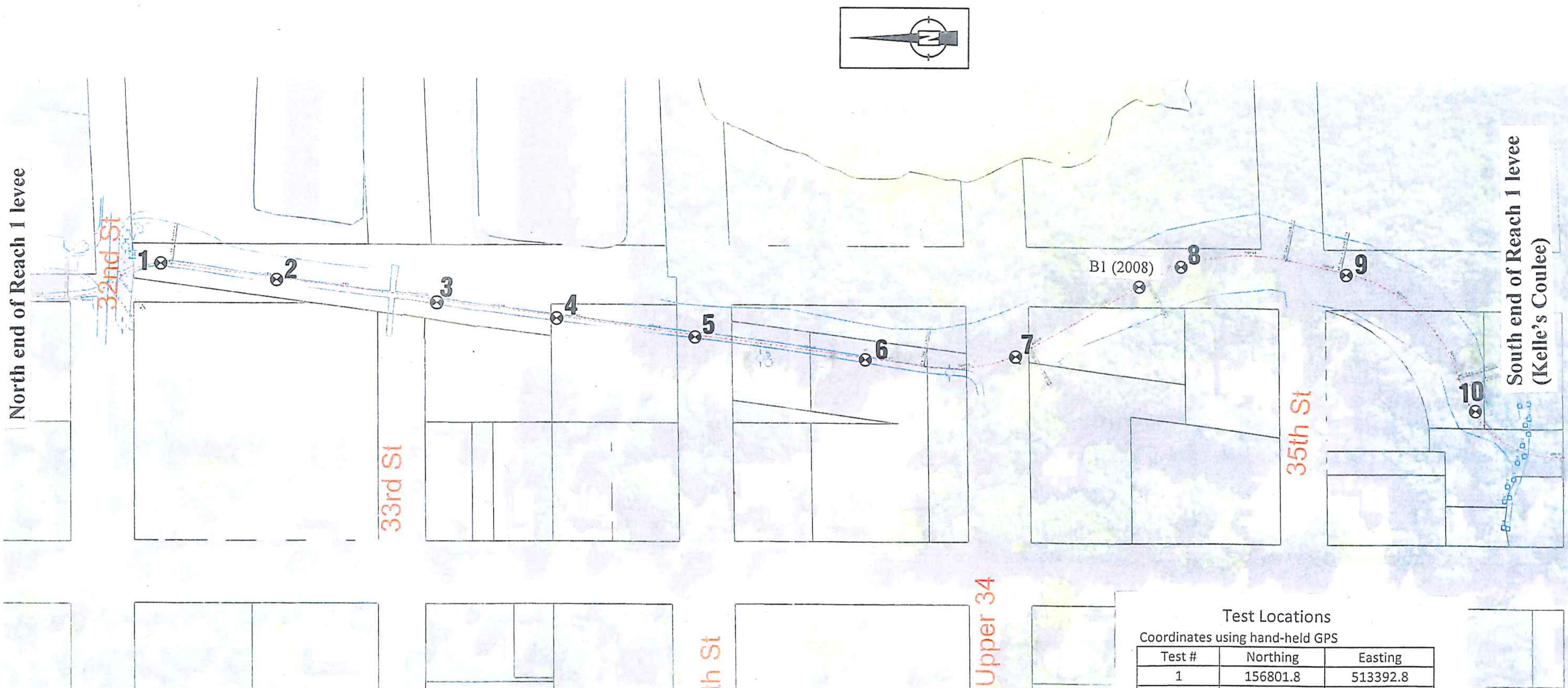
We recommend that AET review the final plans and specifications for the levee modifications to confirm that our recommendations have been incorporated into the design.

## 9.0 LIMITATIONS

Within the limitations of scope, budget, and schedule, our services have been conducted according to generally accepted geotechnical engineering practices at this time and location. Other than this, no warranty, either expressed or implied, is intended.

Important information regarding risk management and proper use of this report is given in Appendix C entitled "Geotechnical Report Limitations and Guidelines for Use."

# Figures




Test Locations

Coordinates using hand-held GPS

| Test # | Northing | Easting |
|---|---|---|
| 1 | 156801.8 | 513392.8 |
| 2 | 156652.5 | 513370 |
| 3 | 156452.3 | 513350.4 |
| 4 | 156301.7 | 513324.6 |
| 5 | 156125.3 | 513304.7 |
| 6 | 155901.6 | 513275.1 |
| 7 | 155701.5 | 513285 |
| 8 | 155503 | 513391.3 |
| 9 | 155299.7 | 513391.9 |
| 10 | 155126.5 | 513222.5 |

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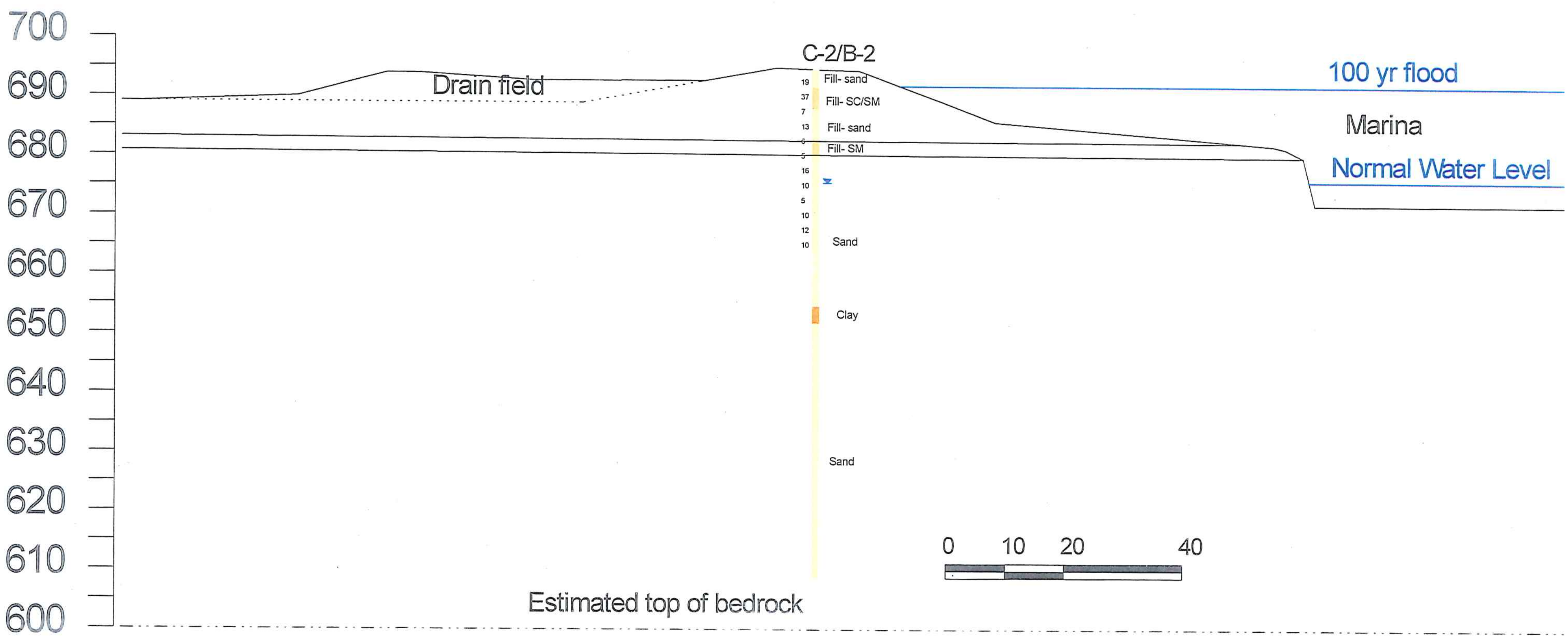
|---|---|---|---|
| AMERICAN ENGINEERING TESTING, INC. | PROJECT: Afton Levee, Afton, Minnesota | | REPORT NO. 01-05376B |
| | SUBJECT: Approximate Soil Boring Locations | | DATE 8/3/12 |
| | SCALE 1 inch = 200 feet | DRAWN BY JCR | Figure 1 |

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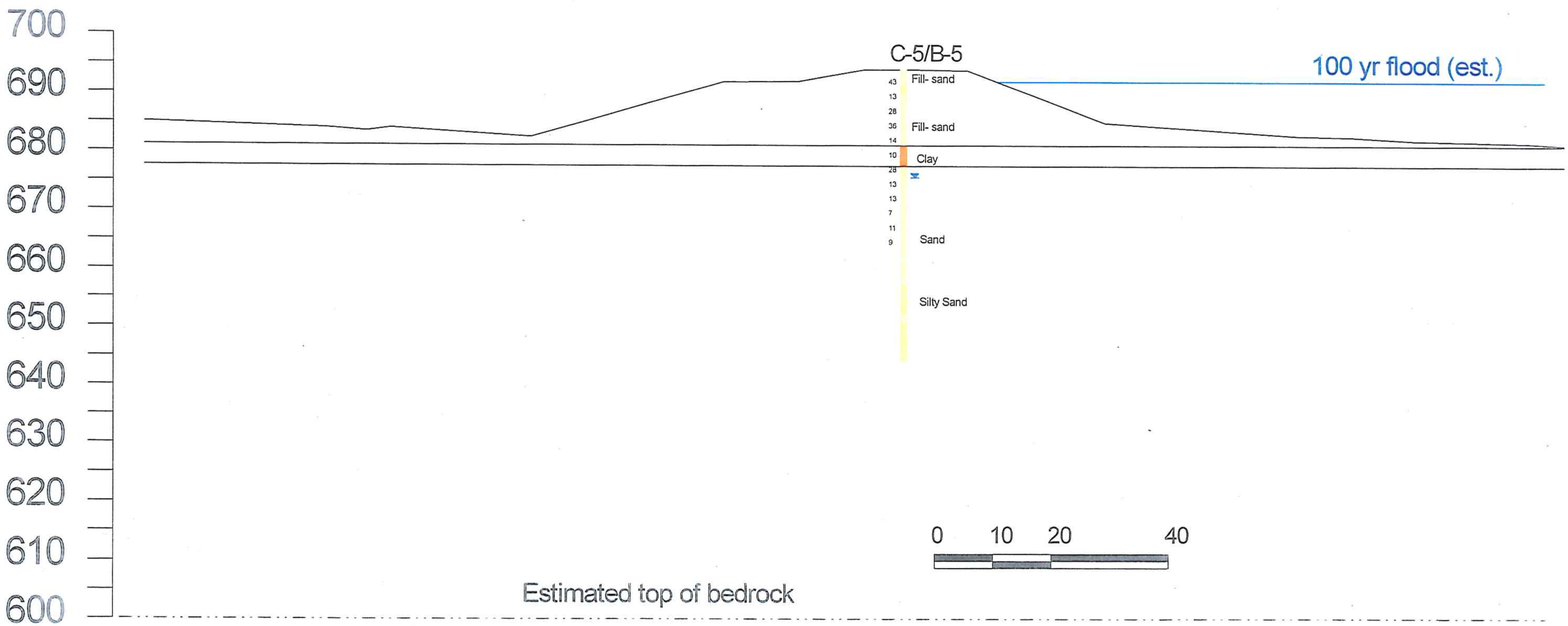
| | SUBJECT | Typical Section at Station 33+50 | | DATE<br>8/3/12 |
| | SCALE | As Shown | DRAWN BY<br>JCR | **Figure 2** |

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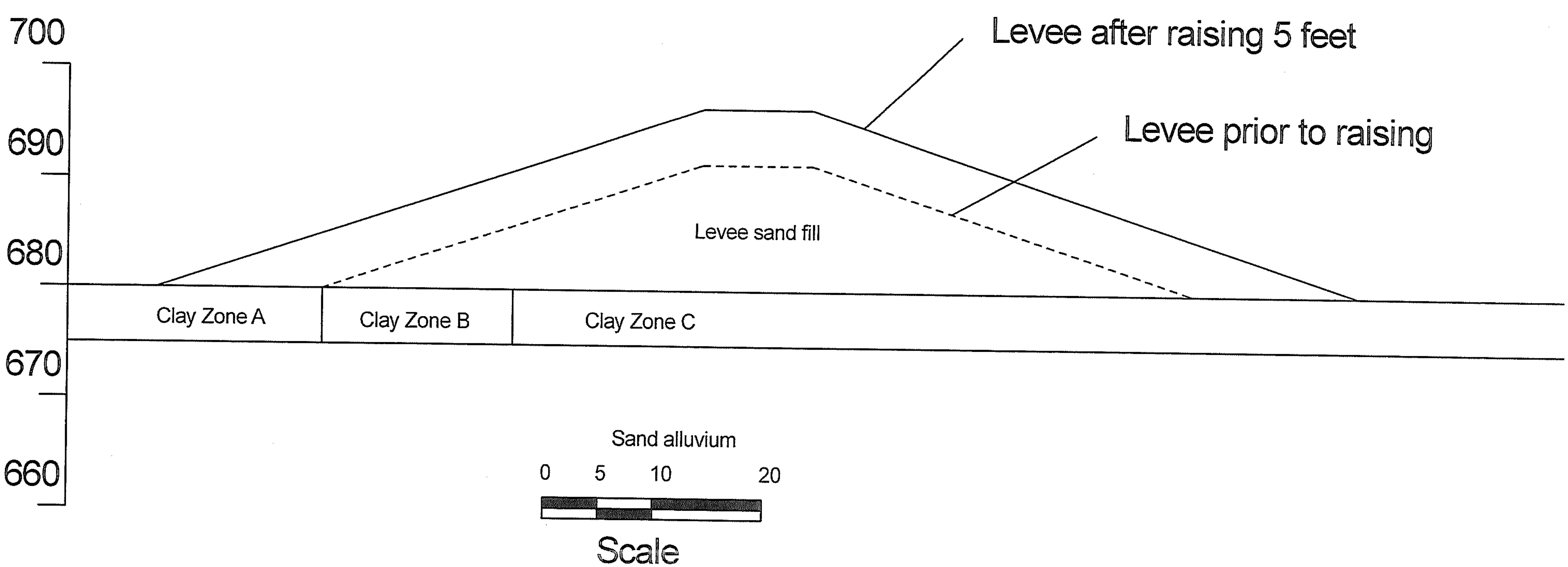
| | SUBJECT Typical Section at Station 28+50 | | DATE 8/3/12 |
| | SCALE As Shown | DRAWN BY JCR | Figure 3 |

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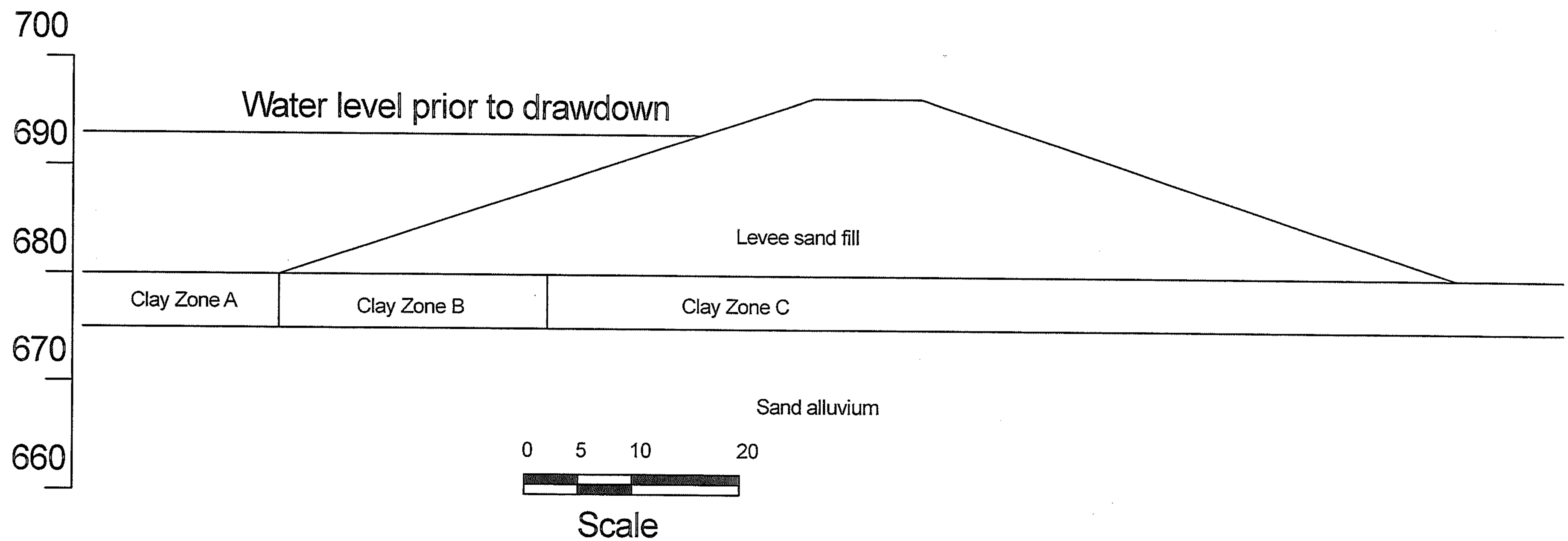
| | SUBJECT: Typical Section for Slope Stability Analysis (Case I) | | DATE 8/3/12 |
| | SCALE: As Shown | DRAWN BY JCR | Figure 4 |

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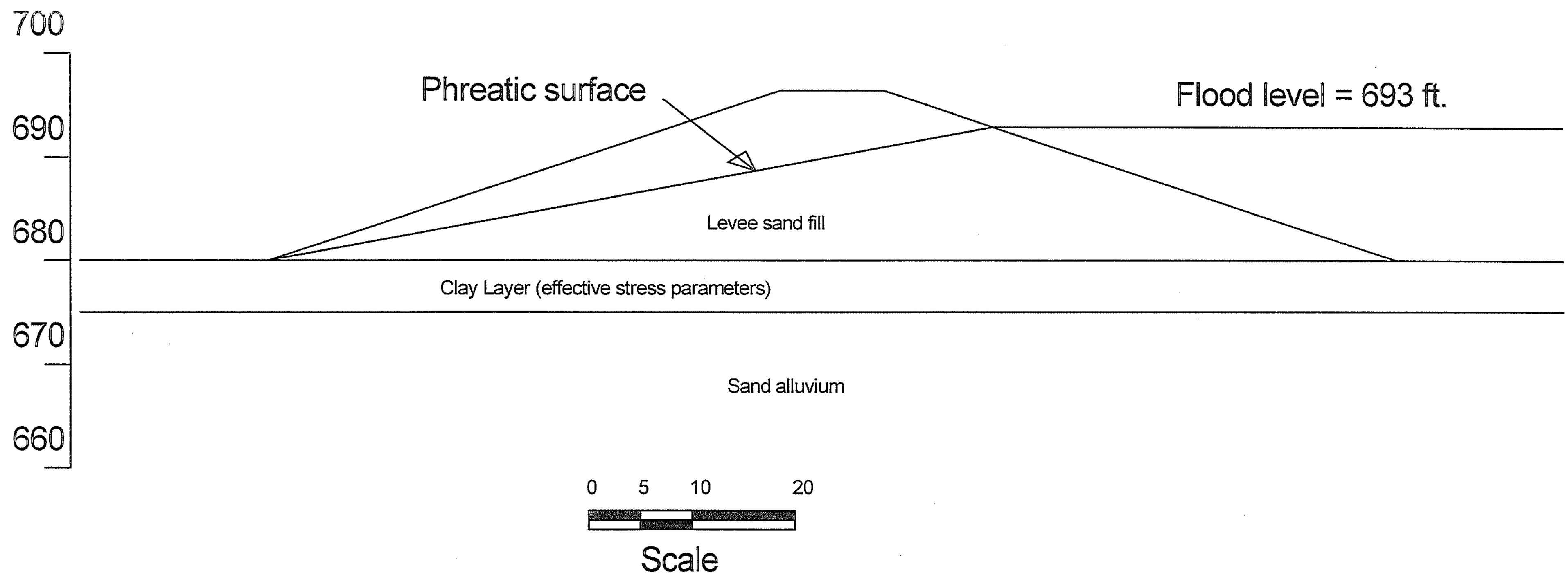
| | SUBJECT | Typical Section for Slope Stability Analysis (Case II) | | DATE<br>8/3/12 |
| | SCALE | As Shown | DRAWN BY<br>JCR | Figure 5 |

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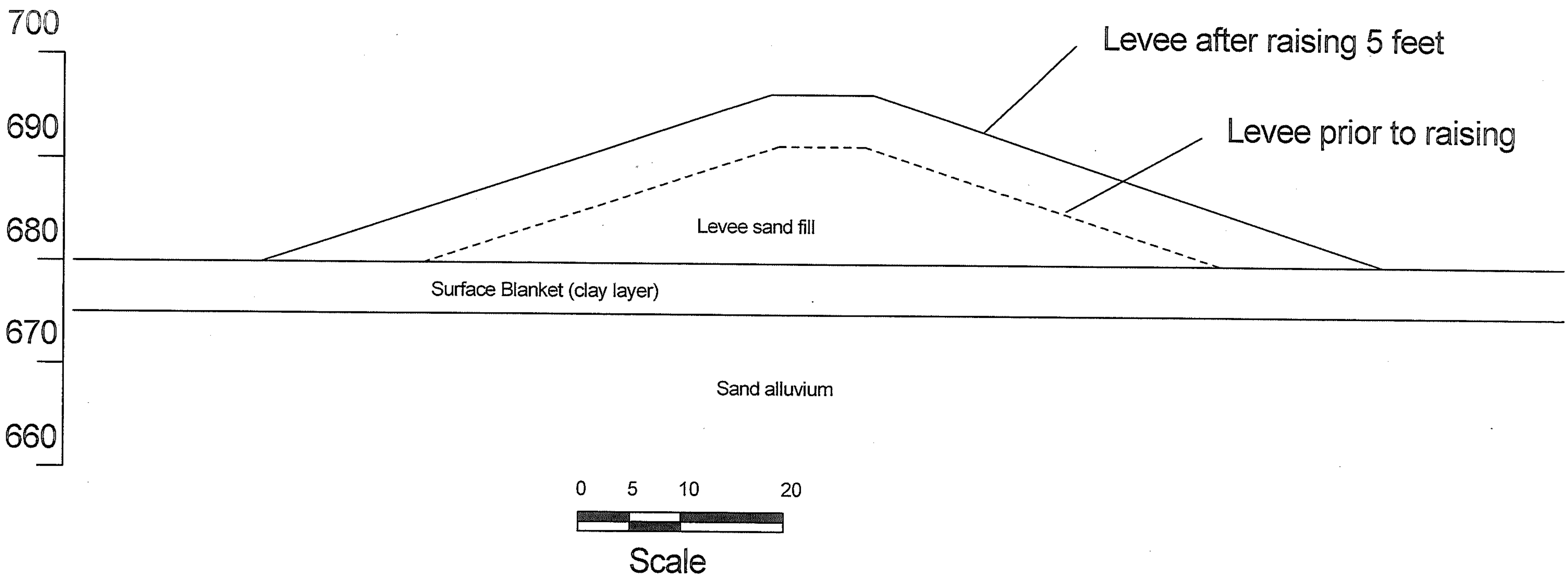
| AMERICAN ENGINEERING TESTING, INC. | PROJECT: | Afton Levee<br>Afton, Minnesota | | REPORT NO.<br>01-05376B |
| | SUBJECT | Typical Section for Slope Stability Analysis (Case III) | | DATE<br>8/3/12 |
| | SCALE | As Shown | DRAWN BY<br>JCR | Figure 6 |

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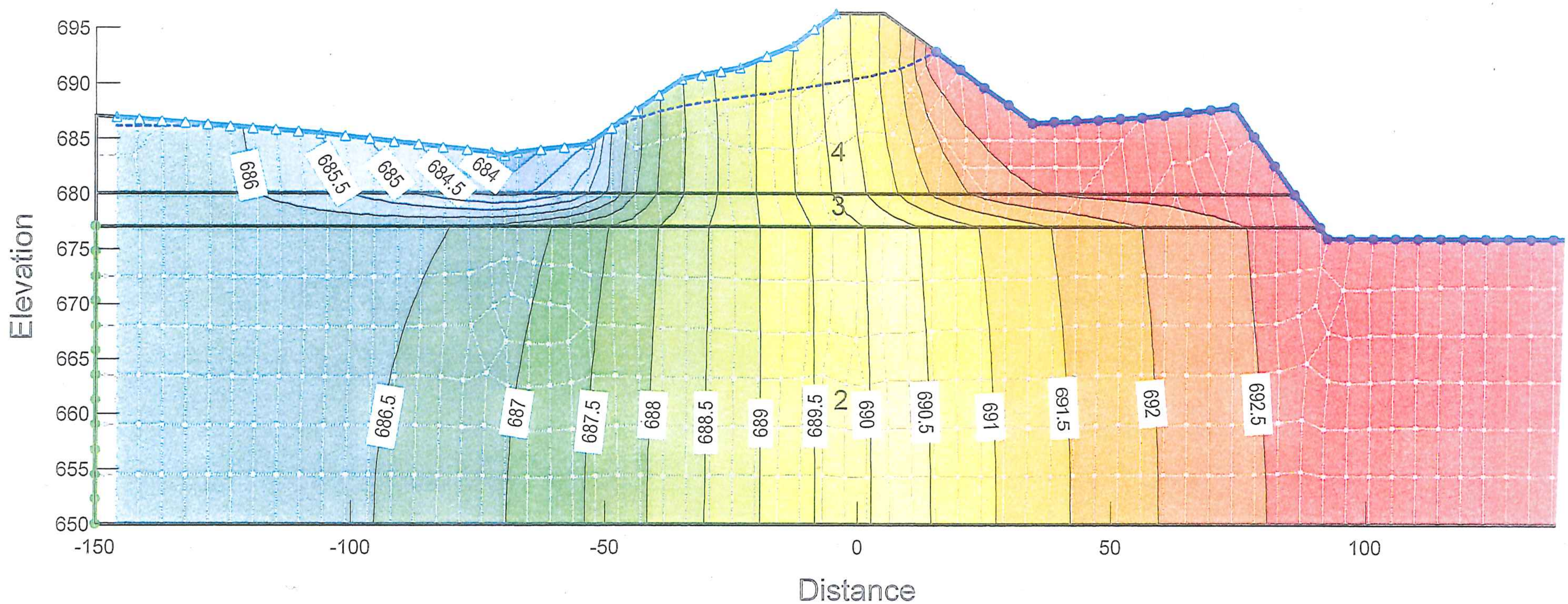
| AMERICAN ENGINEERING TESTING, INC. | PROJECT: Afton Levee, Afton, Minnesota | | REPORT NO. 01-05376B |
| | SUBJECT: Typical Section for Settlement Analysis | | DATE 8/3/12 |
| | SCALE: As Shown | DRAWN BY: JCR | Figure 7 |

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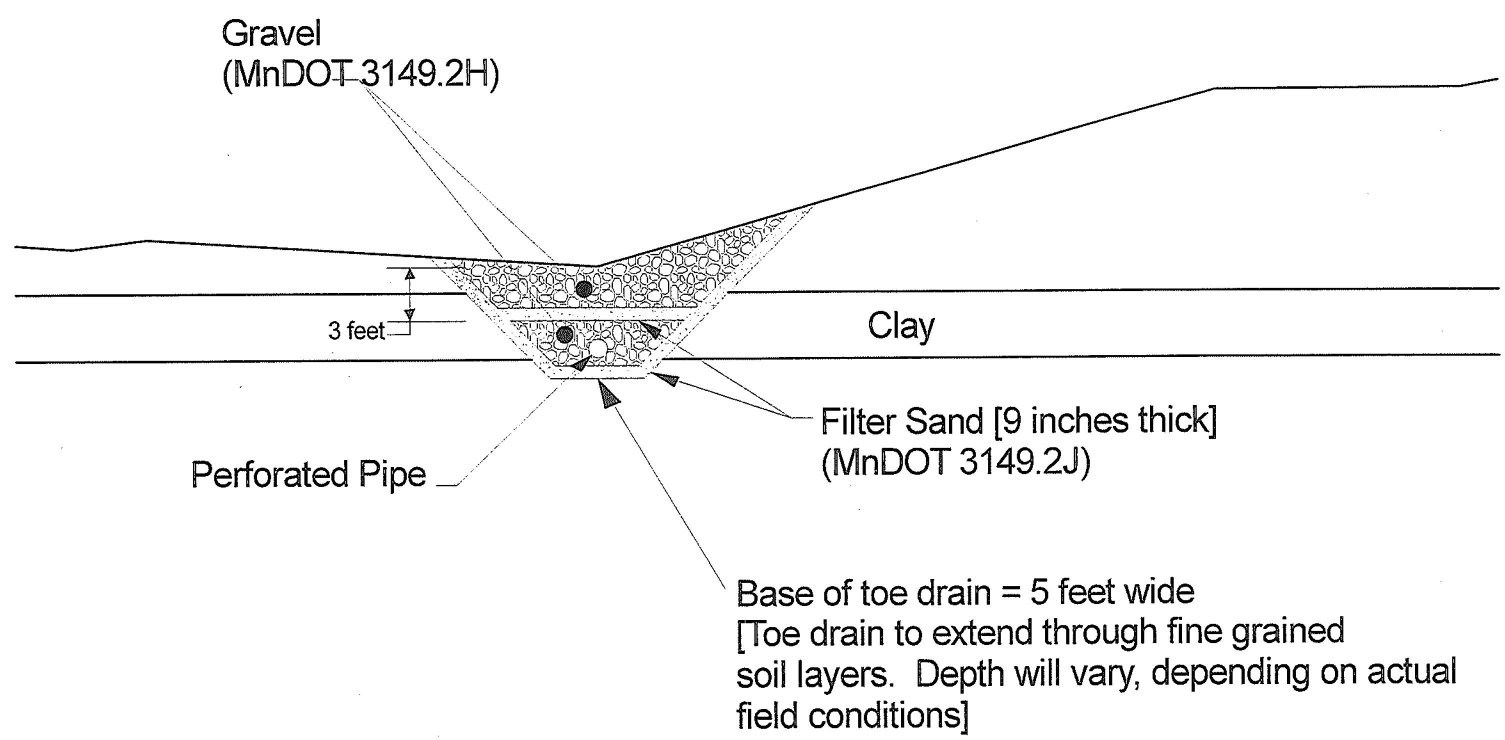
| AMERICAN ENGINEERING TESTING, INC. | PROJECT: Afton Levee, Afton, Minnesota | | REPORT NO. 01-05376B |
| | SUBJECT: Seepage Analysis at Station 30+00 | | DATE 8/3/12 |
| | SCALE: As Shown | DRAWN BY: JCR | **Figure 8** |

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| AMERICAN ENGINEERING TESTING, INC. | PROJECT: | Afton Levee<br>Afton, Minnesota | | REPORT NO.<br>01-05376B |
| | SUBJECT | Typical Toe Drain Detail | | DATE<br>8/3/12 |
| | SCALE None | DRAWN BY<br>JCR | | Figure 9 |

# Appendix A

Geotechnical Field Exploration and Testing
Soil Boring Logs (B2 and B5)
Previous Soil Boring Log B1 (from AET # 01-04004)
CPT Sounding Logs (C-01 through C-10) [Format 2]
CPT Sounding Logs [Format 1]
Gradation Curves (3 pages)
Table A-1: Estimated Permeability Values
Electronic Friction Cone and Piezocone Penetration Testing
Boring Log Notes
Unified Soil Classification System

## A.1 FIELD EXPLORATION

The subsurface conditions at the site were explored with ten Cone Penetration Test soundings and two Standard Penetration test borings. The locations of the soundings and borings are shown on Figure 1 of this report.

## A.2 SAMPLING METHODS

### A.2.1 Split-Spoon Samples (SS) - Calibrated to $N_{60}$ Values

Standard penetration (split-spoon) samples were collected in general accordance with ASTM: D1586 with one primary modification. The ASTM test method consists of driving a 2-inch O.D. split-barrel sampler into the in-situ soil with a 140-pound hammer dropped from a height of 30 inches. The sampler is driven a total of 18 inches into the soil. After an initial set of 6 inches, the number of hammer blows to drive the sampler the final 12 inches is known as the standard penetration resistance or N-value. Our method uses a modified hammer weight, which is determined by measuring the system energy using a Pile Driving Analyzer (PDA) and an instrumented rod.

In the past, standard penetration N-value tests were performed using a rope and cathead for the lift and drop system. The energy transferred to the split-spoon sampler was typically limited to about 60% of its potential energy due to the friction inherent in this system. This converted energy then provides what is known as an $N_{60}$ blow count.

The most recent drill rigs incorporate an automatic hammer lift and drop system, which has higher energy efficiency and subsequently results in lower N-values than the traditional $N_{60}$ values. By using the PDA energy measurement equipment, we are able to determine actual energy generated by the drop hammer. With the various hammer systems available, we have found highly variable energies ranging from 55% to over 100%. Therefore, the intent of AET's hammer calibrations is to vary the hammer weight such that hammer energies lie within about 60% to 65% of the theoretical energy of a 140-pound weight falling 30 inches. The current ASTM procedure acknowledges the wide variation in N-values, stating that N-values of 100% or more have been observed. Although we have not yet determined the statistical measurement uncertainty of our calibrated method to date, we can state that the accuracy deviation of the N-values using this method is significantly better than the standard ASTM Method.

### A.2.2 Disturbed Samples (DS)/Spin-up Samples (SU)

Sample types described as "DS" or "SU" on the boring logs are disturbed samples, which are taken from the flights of the auger. Because the auger disturbs the samples, possible soil layering and contact depths should be considered approximate.

### A.2.3 Sampling Limitations

Unless actually observed in a sample, contacts between soil layers are estimated based on the spacing of samples and the action of drilling tools. Cobbles, boulders, and other large objects generally cannot be recovered from test borings, and they may be present in the ground even if they are not noted on the boring logs.

Determining the thickness of "topsoil" layers is usually limited, due to variations in topsoil definition, sample recovery, and other factors. Visual-manual description often relies on color for determination, and transitioning changes can account for significant variation in thickness judgment. Accordingly, the topsoil thickness presented on the logs should not be the sole basis for calculating topsoil stripping depths and volumes. If more accurate information is needed relating to thickness and topsoil quality definition, alternate methods of sample retrieval and testing should be employed.

## A.3 CLASSIFICATION METHODS

Soil descriptions shown on the boring logs are based on the Unified Soil Classification (USC) system. The USC system is described in ASTM: D2487 and D2488. Where laboratory classification tests (sieve analysis or Atterberg Limits) have been performed, accurate classifications per ASTM: D2487 are possible. Otherwise, soil descriptions shown on the boring logs are visual-manual judgments. Charts are attached which provide information on the USC system, the descriptive terminology, and the symbols used on the boring logs.

Visual-manual judgment of the AASHTO Soil Group is also noted as a part of the soil description. A chart presenting details of the AASHTO Soil Classification System is also attached.

The boring logs include descriptions of apparent geology. The geologic depositional origin of each soil layer is interpreted primarily by observation of the soil samples, which can be limited. Observations of the surrounding topography, vegetation, and development can sometimes aid this judgment.

## A.4 WATER LEVEL MEASUREMENTS

The ground water level measurements are shown at the bottom of the boring logs. The following information appears under "Water Level Measurements" on the logs:

- Date and Time of measurement
- Sampled Depth: lowest depth of soil sampling at the time of measurement
- Casing Depth: depth to bottom of casing or hollow-stem auger at time of measurement
- Cave-in Depth: depth at which measuring tape stops in the borehole
- Water Level: depth in the borehole where free water is encountered
- Drilling Fluid Level: same as Water Level, except that the liquid in the borehole is drilling fluid

The true location of the water table at the boring locations may be different than the water levels measured in the boreholes. This is possible because there are several factors that can affect the water level measurements in the borehole. Some of these factors include: permeability of each soil layer in profile, presence of perched water, amount of time between water level readings, presence of drilling fluid, weather conditions, and use of borehole casing.

## A.5 TEST STANDARD LIMITATIONS

Field and laboratory testing is done in general conformance with the described procedures. Compliance with any other standards referenced within the specified standard is neither inferred nor implied.

## A.6 SAMPLE STORAGE

Unless notified to do otherwise, we routinely retain representative samples of the soils recovered from the borings for a period of 30 days.

AMERICAN ENGINEERING TESTING, INC.

# SUBSURFACE BORING LOG

AET JOB NO: **01-05376** LOG OF BORING NO. **B2 (p. 1 of 2)**

PROJECT: **Afton Levees; Afton, MN**

SURFACE ELEVATION: **694.8±**

| DEPTH IN FEET | MATERIAL DESCRIPTION | GEOLOGY | N | MC | SAMPLE TYPE | REC IN. | WC | DEN | LL | PL | %-#200 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | FILL, mostly silty sand, a little gravel, black | FILL | | | | | 28 | | | | |
| 1 | FILL, mostly sand, brown | | 3 | M | SS | 20 | | | | | |
| 3 | FILL, mixture of clayey sand and silty sand with gravel, dark brown | | 19 | M | SS | 18 | 7 | | | | |
| 5–6 | | | 37 | M | SS | 4 | 12 | | | | |
| 6.5 | FILL, mostly sand with gravel, brown | | 7 | M | SS | 18 | | | | | 6 |
| 10.5 | | | 13 | M | SS | 6 | | | | | 4 |
| 12 | FILL, mixture of silty sand and sand with gravel, brown and dark brown | | 6 | M | SS | 4 | | | | | 11 |
| 14.5 | SILTY SAND, a little gravel, fine to medium grained, dark brown, moist, loose (SM) | COARSE ALLUVIUM | 5 | M | SS | 18 | | | | | 16 |
| 17 | SAND, fine to medium grained, brown, moist, medium dense (SP) | | 16 | M | SS | 18 | | | | | 2 |
| 19.5 | SAND, a little gravel, fine to medium grained, brown, waterbearing, loose (SP) | | 10 | W | SS | 16 | | | | | 2 |

| DEPTH: | DRILLING METHOD |
|---|---|
| 0-19½' | 3.25" HSA |
| 19½-29½' | RD w/DM |

BORING COMPLETED: 3/21/12

DR: **DS** LG: **JJ** Rig: **33C**

WATER LEVEL MEASUREMENTS

| DATE | TIME | SAMPLED DEPTH | CASING DEPTH | CAVE-IN DEPTH | DRILLING FLUID LEVEL | WATER LEVEL |
|---|---|---|---|---|---|---|
| 3/21/12 | 8:50 | 21.5 | 19.5 | 19.9 | | 19.2 |
| 3/21/12 | 9:00 | 21.5 | 19.5 | 19.6 | | 19.2 |

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AET_CORP 01-05376.GPJ AET+CPT+WELL.GDT 4/17/12

AMERICAN ENGINEERING TESTING, INC.

# SUBSURFACE BORING LOG

AET JOB NO: **01-05376** LOG OF BORING NO. **B2 (p. 2 of 2)**

PROJECT: **Afton Levees; Afton, MN**

| DEPTH IN FEET | MATERIAL DESCRIPTION | GEOLOGY | N | MC | SAMPLE TYPE | REC IN. | WC | DEN | LL | PL | %-#200 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | SAND, a little gravel, fine to medium grained, brown, waterbearing, loose (SP) *(continued)* | | 5 | W | SS | 20 | | | | | |
| 24 | | | | | | | | | | | |
| 25 | SAND, a little gravel, medium to fine grained, brown, waterbearing, loose to medium dense (SP) | | 10 | W | SS | 18 | | | | | 1 |
| 26 | | | | | | | | | | | |
| 27 | | | | | | | | | | | |
| 28 | | | 12 | W | SS | 18 | | | | | |
| 29 | SAND, a little gravel, fine to medium grained, brown, waterbearing, loose (SP) | | | | | | | | | | |
| 30 | | | 10 | W | SS | 16 | | | | | 1 |
| 31 | **END OF BORING** | | | | | | | | | | |

AET_CORP 01-05376.GPJ AET+CPT+WELL.GDT 4/17/12

AMERICAN ENGINEERING TESTING, INC.

# SUBSURFACE BORING LOG

AET JOB NO: **01-05376** LOG OF BORING NO. **B5 (p. 1 of 2)**

PROJECT: **Afton Levees; Afton, MN**

| DEPTH IN FEET | SURFACE ELEVATION: 694.1± MATERIAL DESCRIPTION | GEOLOGY | N | MC | SAMPLE TYPE | REC IN. | WC | DEN | LL | PL | %-#200 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0–1 | FILL, mostly lean clay, slightly organic, trace roots, dark brown | FILL | 5 | M | SS | 18 | 29 | | | | |
| 1–2.5 | FILL, mostly sand, a little gravel, brown | | | | | | | | | | |
| 2.5–4 | FILL, mixture of lean clay and silty sand, a little gravel, trace roots, dark brown | | 43 | M | SS | 10 | 13 | | | | |
| 4–9 | FILL, mostly sand with gravel, brown | | 13 | M | SS | 12 | | | | | |
| | | | 28 | M | SS | 16 | | | | | 6 |
| 9–14 | FILL, mostly sand with silt and gravel, brown | | 36 | M | SS | 8 | | | | | 8 |
| | | | 14 | M | SS | 12 | | | | | |
| 14–16.5 | CLAYEY SAND, a little gravel, trace roots, dark brown, stiff (SC) | TOPSOIL OR FILL | 10 | M | SS | 18 | 21 | | | | 42 |
| 16.5–19 | SILTY SAND WITH GRAVEL, medium to fine grained, brown, wet, medium dense (SM) | COARSE ALLUVIUM | 28 | M | SS | 16 | | | | | 5 |
| 19– | SAND, a little gravel, medium to fine grained, brown, waterbearing, medium dense, lenses of fine sand at about 25' and 28' (SP) | | 13 | W | SS | 18 | | | | | 1 |

| DEPTH: | DRILLING METHOD |
|---|---|
| 0-19½' | 3.25" HSA |
| 19½-29½' | RD w/DM |

BORING COMPLETED: 3/21/12

DR: DS LG: JJ Rig: 33C

WATER LEVEL MEASUREMENTS

| DATE | TIME | SAMPLED DEPTH | CASING DEPTH | CAVE-IN DEPTH | DRILLING FLUID LEVEL | WATER LEVEL |
|---|---|---|---|---|---|---|
| 3/21/12 | 10:50 | 21.5 | 19.5 | 19.9 | | 18.8 |
| 3/21/12 | 11:00 | 21.5 | 19.5 | 19.5 | | 18.5 |

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

AET_CORP 01-05376.GPJ AET+CPT+WELL.GDT 4/17/12

AMERICAN ENGINEERING TESTING, INC.

# SUBSURFACE BORING LOG

AET JOB NO: **01-05376**

LOG OF BORING NO. **B5 (p. 2 of 2)**

PROJECT: **Afton Levees; Afton, MN**

| DEPTH IN FEET | MATERIAL DESCRIPTION | GEOLOGY | N | MC | SAMPLE TYPE | REC IN. | WC | DEN | LL | PL | %-#200 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 23 | SAND, a little gravel, medium to fine grained, brown, waterbearing, medium dense, lenses of fine sand at about 25' and 28' (SP) *(continued)* | | 13 | W | SS | 16 | | | | | |
| 24 | | | | | | | | | | | |
| 25 | | | | | | | | | | | |
| 26 | | | 7 | W | SS | 16 | | | | | 2 |
| 27 | | | | | | | | | | | |
| 28 | | | 11 | W | SS | 20 | | | | | |
| 29 | | | | | | | | | | | |
| 30 | | | | | | | | | | | |
| 31 | | | 9 | W | SS | 18 | | | | | 1 |
| | **END OF BORING** | | | | | | | | | | |

(FIELD & LABORATORY TESTS: WC, DEN, LL, PL, %-#200)

AET_CORP 01-05376.GPJ AET+CPT+WELL.GDT 4/17/12

AMERICAN ENGINEERING TESTING, INC.

# SUBSURFACE BORING LOG

AET JOB NO: **01-04004** LOG OF BORING NO. **1 (p. 1 of 1)**

PROJECT: **Afton Levee Evaluation; Afton, MN**

SURFACE ELEVATION: ______

| DEPTH IN FEET | MATERIAL DESCRIPTION | GEOLOGY |
|---|---|---|
| 0–1 | FILL, mixture of clayey sand, lean clay, sand, and crushed limestone, dark brown and brown | FILL |
| 1–2 | FILL, mostly sand, brown | |
| 2–3 | FILL, mostly lean clay, trace roots, black | |
| 3–4 | FILL, mixture of sand and lean clay, trace roots, brown, a little dark brown | |
| 4–15½ | FILL, mixture of sand with silt and sand, a little to with gravel, brown, a little dark brown, few lenses of silty sand about 13' | |
| 15½–16½ | FILL, mostly silty sand, trace roots, dark brown | |
| 16½–19 | CLAYEY SAND, dark brown, firm (SC) | MIXED ALLUVIUM |
| 19–21½ | SILTY SAND WITH GRAVEL, fine to medium grained, brown, wet, medium dense (SM) | COARSE ALLUVIUM |
| 21½–26 | SAND, a little gravel, fine to medium grained, brown, waterbearing, medium dense (SP) | |
| 26 | **END OF BORING** | |

| Depth (ft) | N | MC | SAMPLE TYPE | REC IN. | WC | DEN | LL | PL | %-#200 |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 18 | M | SS | 17 | 18 19 | | | | |
| 3 | 6 | M | SS | 13 | | | | | |
| 5½ | 30 | M | SS | 14 | | | | | |
| 8 | 25 | M | SS | 13 | | | | | 6 |
| 10½ | 64 | M | SS | 9 | | | | | |
| 13 | 35 | M | SS | 15 | | | | | |
| 15½ | 16 | M | SS | 15 | | | | | |
| 18 | 5 | M | SS | 17 | 19 | | | | |
| 20½ | 14 | W | SS | 3 | | | | | |
| 23 | 19 | W | SS | 2 | | | | | |
| 25½ | 11 | W | SS | 16 | | | | | |

| DEPTH: | DRILLING METHOD |
|---|---|
| 0-24½' | 3.25" HSA |

WATER LEVEL MEASUREMENTS

| DATE | TIME | SAMPLED DEPTH | CASING DEPTH | CAVE-IN DEPTH | DRILLING FLUID LEVEL | WATER LEVEL |
|---|---|---|---|---|---|---|
| 4/3/08 | 10:07 | 21.0 | 19.5 | 20.0 | None | 19.1 |
| 4/3/08 | 10:30 | 26.0 | 24.5 | 22.4 | None | 20.2 |

BORING COMPLETED: **4/3/08**

DR: **SD** LG: **SG** Rig: **69C**

NOTE: REFER TO THE ATTACHED SHEETS FOR AN EXPLANATION OF TERMINOLOGY ON THIS LOG

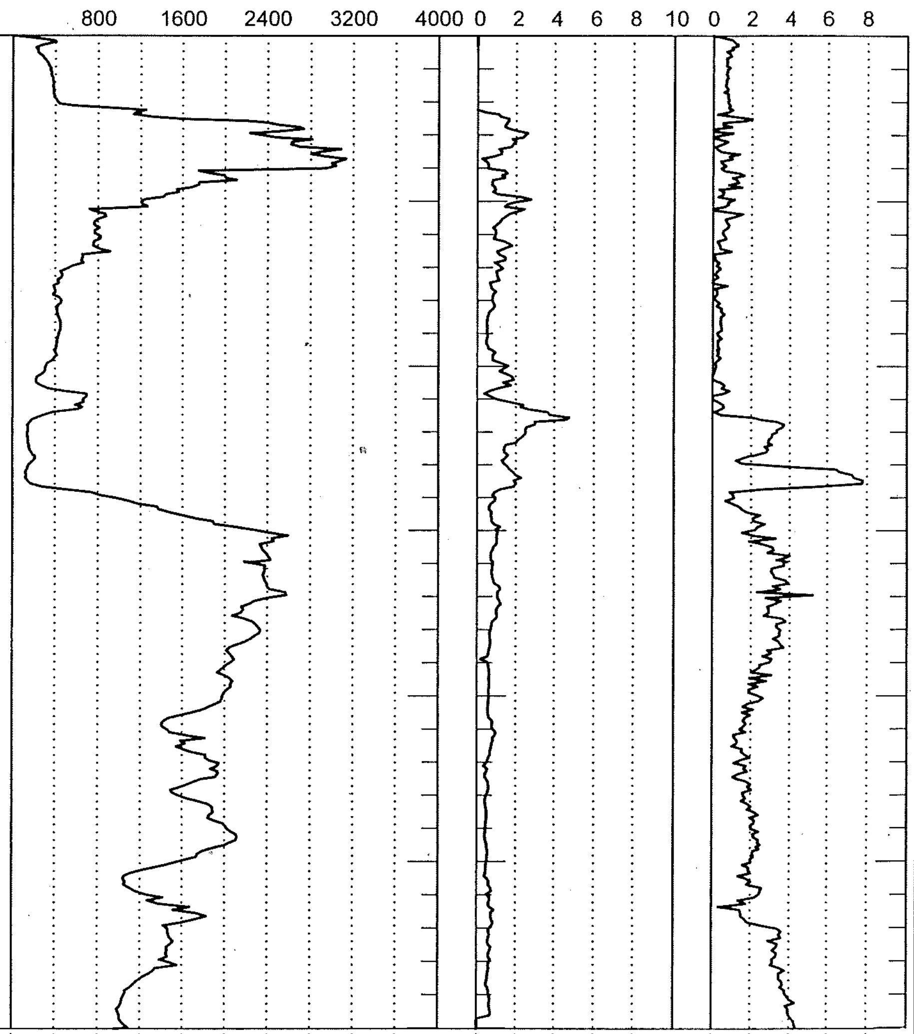
AET_CORP 01-04004.GPJ AET+CPT+WELL.GDT 8/6/12

AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: 01-05376<br>PROJECT: **Afton Levees; Afton, MN** | | SOUNDING NO.<br>**C-01 (p. 1 of 1)** |
| Location | CPT Machine **20**<br>CPT Operator **Adams** | Surface Elevation<br>**693.4±** |
| Co. Coordinate: X=513393 Y=156802 (feet) | Cone # **4583.120XX** | Date Completed: 3/9/12 |

| Depth / Elevation (ft) | Interpreted Soil Description | Est. $N_{60}$ | Sample |
|---|---|---|---|
| 0 – 11 | FILL, mixture of sand, silty sand and clayey sand | 38, 10, 5 | |
| 11 – 14 | CLAYEY SAND | 8 | |
| 14 – 30 | SAND | 17, 11, 11 | |




Bottom of Hole 30.03

AMERICAN
ENGINEERING
TESTING

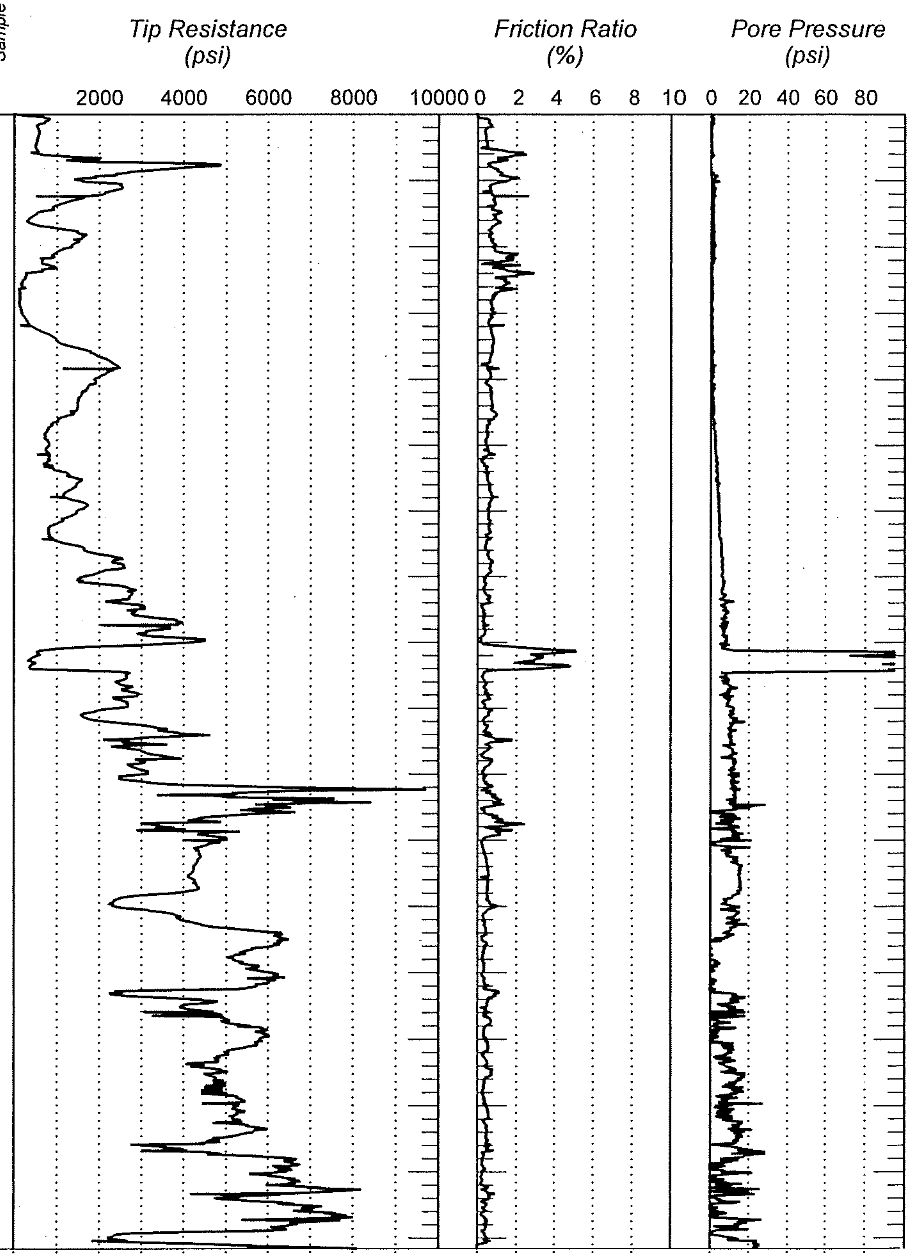
# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: **01-05376** | | SOUNDING NO. |
| PROJECT: **Afton Levees; Afton, MN** | | **C-02 (p. 1 of 1)** |
| Location | CPT Machine **20** | Surface Elevation |
| | CPT Operator **Adams** | **694.8±** |
| Co. Coordinate: X=513370 Y=156653 (feet) | Cone # **4583.120XX** | Date Completed: 3/9/12 |

Depth / Elevation | *Interpreted Soil Description* | *Est. $N_{60}$* | *Sample*

| Interpreted Soil Description | Est. $N_{60}$ |
|---|---|
| FILL, mixture of sand and silty sand | 30 |
| FILL, mixture of silty sand and clayey sand | |
| SAND | 2, 13, 6, 11, 14 |
| CLAY | 21 |
| SAND | 18 |
| SILTY SAND | 21 |
| SAND with lenses of silty sand | 30, 25, 39, 36, 36, 43, 43 |

Depth scale: 0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85



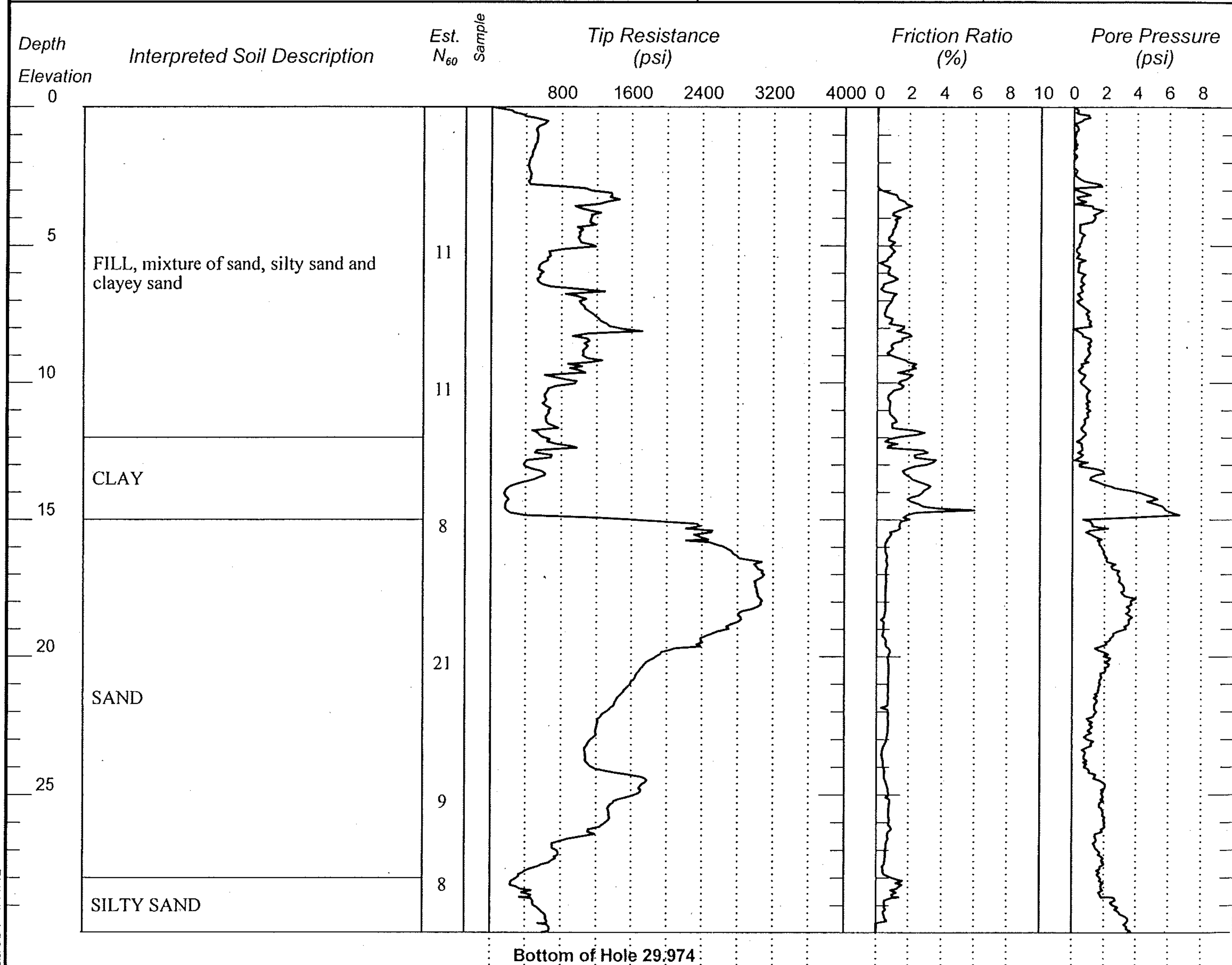

Bottom of Hole 85.818

AET CPT LOG

# AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

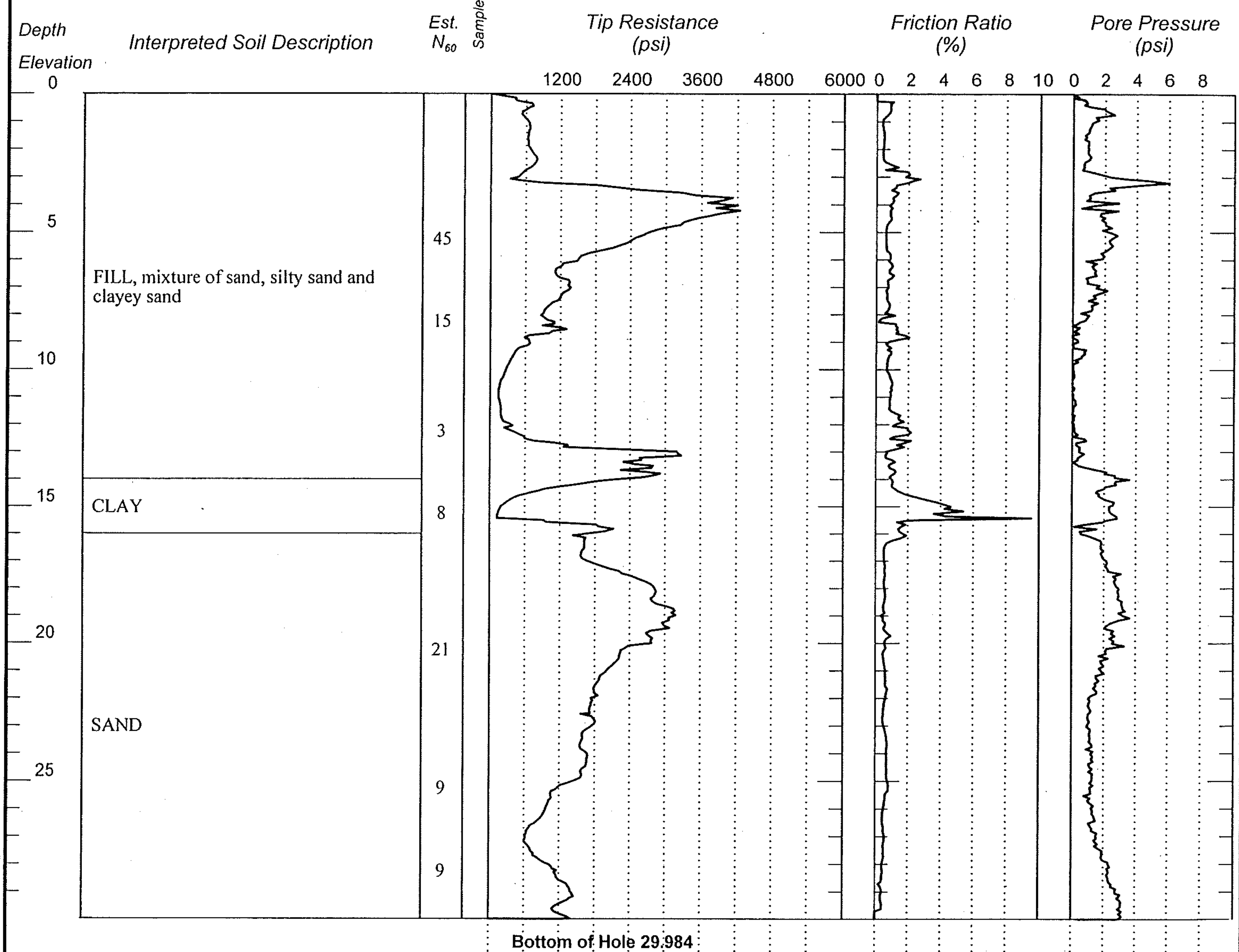
| | | |
|---|---|---|
| AET JOB NO: **01-05376**<br>PROJECT: **Afton Levees; Afton, MN** | | SOUNDING NO.<br>**C-03 (p. 1 of 1)** |
| Location | CPT Machine **20**<br>CPT Operator **Adams** | Surface Elevation<br>**693.3±** |
| Co. Coordinate: X=513350 Y=156452 (feet) | Cone # **4583.120XX** | Date Completed: 3/8/12 |



AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

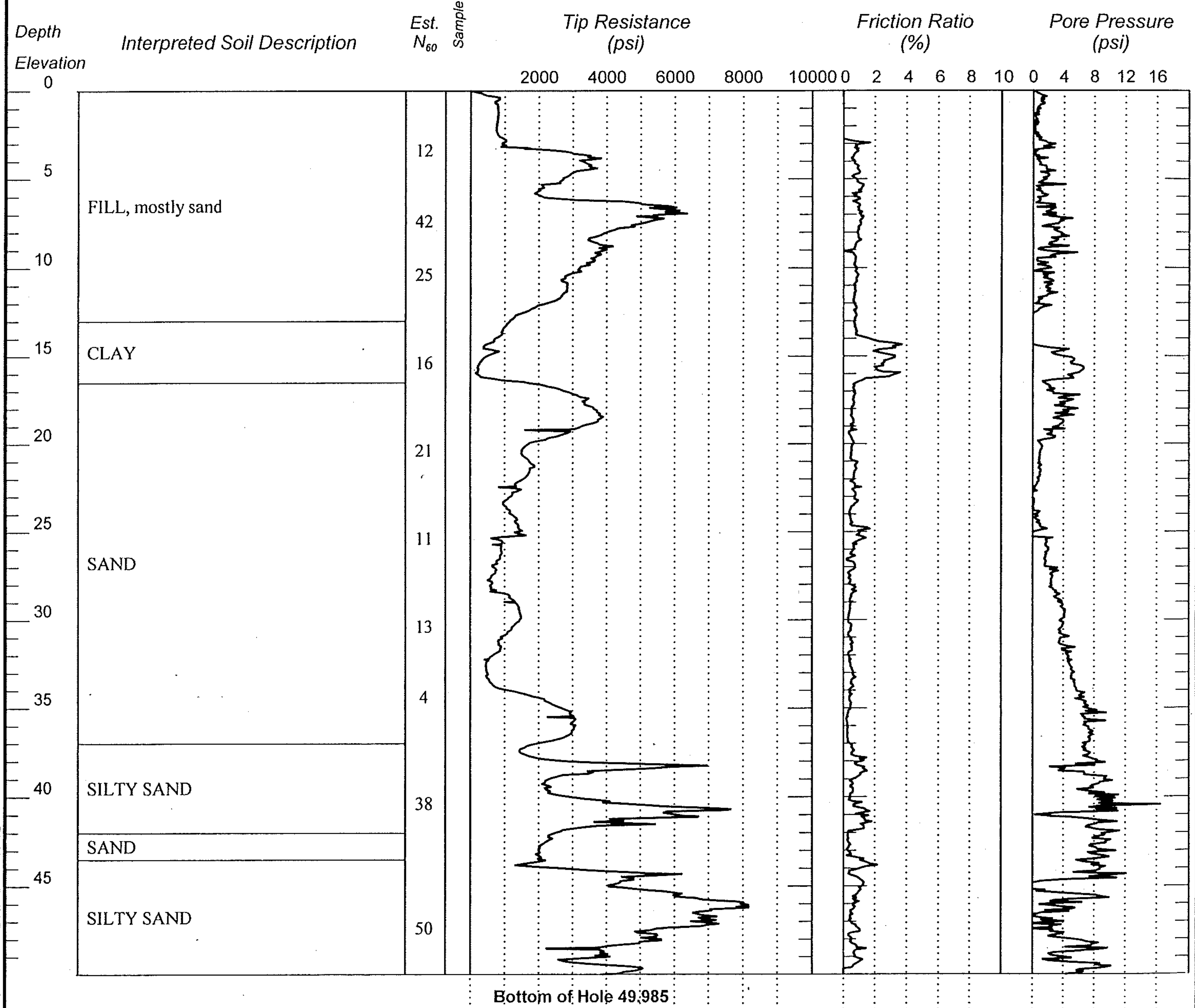
| | | |
|---|---|---|
| AET JOB NO: **01-05376**<br>PROJECT: **Afton Levees; Afton, MN** | | SOUNDING NO.<br>**C-04 (p. 1 of 1)** |
| Location | CPT Machine **20**<br>CPT Operator **Adams** | Surface Elevation<br>**694.5±** |
| Co. Coordinate: X=513325 Y=156302 (feet) | Cone # **4583.120XX** | Date Completed: 3/8/12 |



AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: **01-05376**<br>PROJECT: **Afton Levees; Afton, MN** | | SOUNDING NO.<br>**C-05 (p. 1 of 1)** |
| Location | CPT Machine **20**<br>CPT Operator **Adams** | Surface Elevation<br>**694.1±** |
| Co. Coordinate: X=513305 Y=156125 (feet) | Cone # **4583.120XX** | Date Completed: 3/8/12 |

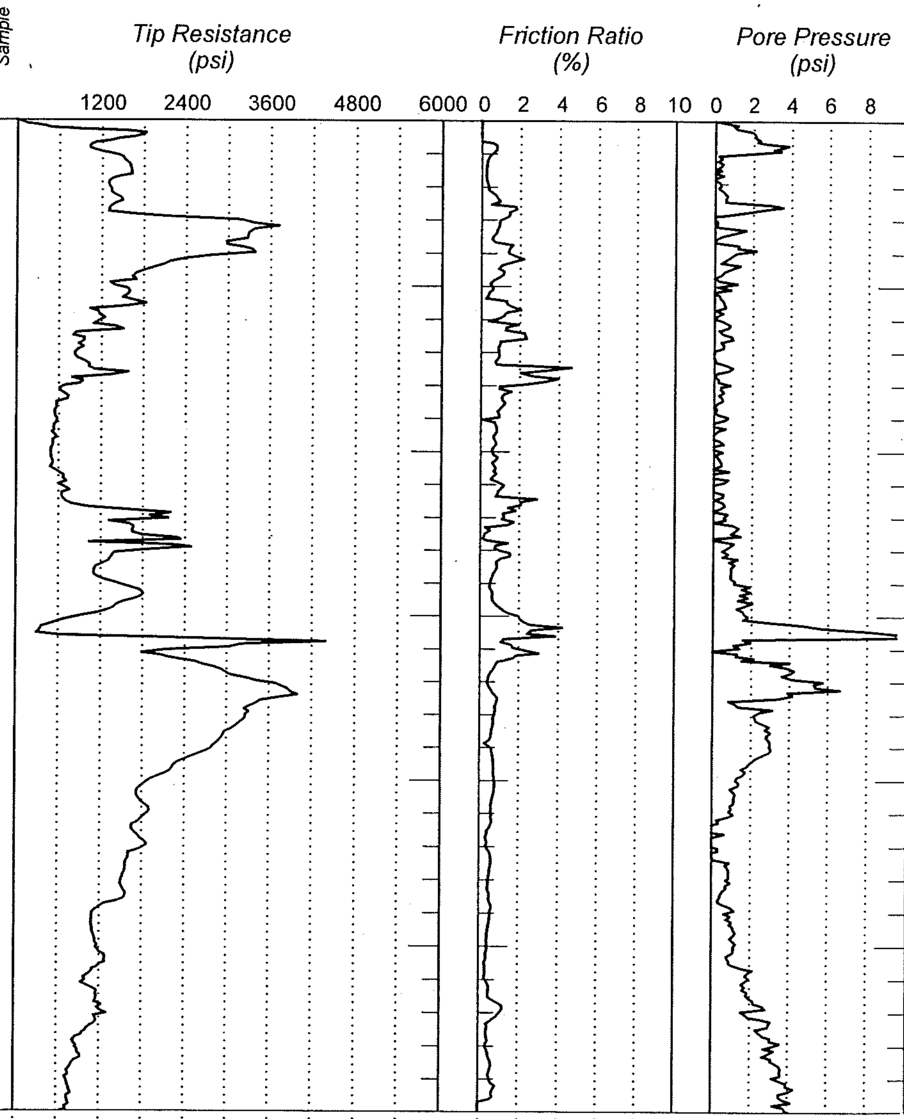


AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: 01-05376<br>PROJECT: Afton Levees; Afton, MN | | SOUNDING NO.<br>C-06 (p. 1 of 1) |
| Location | CPT Machine 20<br>CPT Operator Adams | Surface Elevation<br>694.2± |
| Co. Coordinate: X=513275 Y=155902 (feet) | Cone # 4583.120XX | Date Completed: 3/8/12 |

| Depth / Elevation | Interpreted Soil Description | Est. $N_{60}$ | Sample |
|---|---|---|---|
| 0–15 | FILL, mixture of sand, silty sand and clayey sand | 15, 38, 10, 8, 15 | |
| 15–16.5 | CLAY | | |
| 16.5–26 | SAND | 38, 13, 9 | |
| 26–27 | SILTY SAND | | |
| 27–30 | SAND | 4 | |




Bottom of Hole 29.978

AET CPT LOG

Edit: Date: 6/13/12
X:\01-GEO\GINTW\1 GINT PROJECTS\01-05376.GPJ

AET CPT LOG 01-05376.GPJ AET+CPT+WELL.GDT 6/13/12

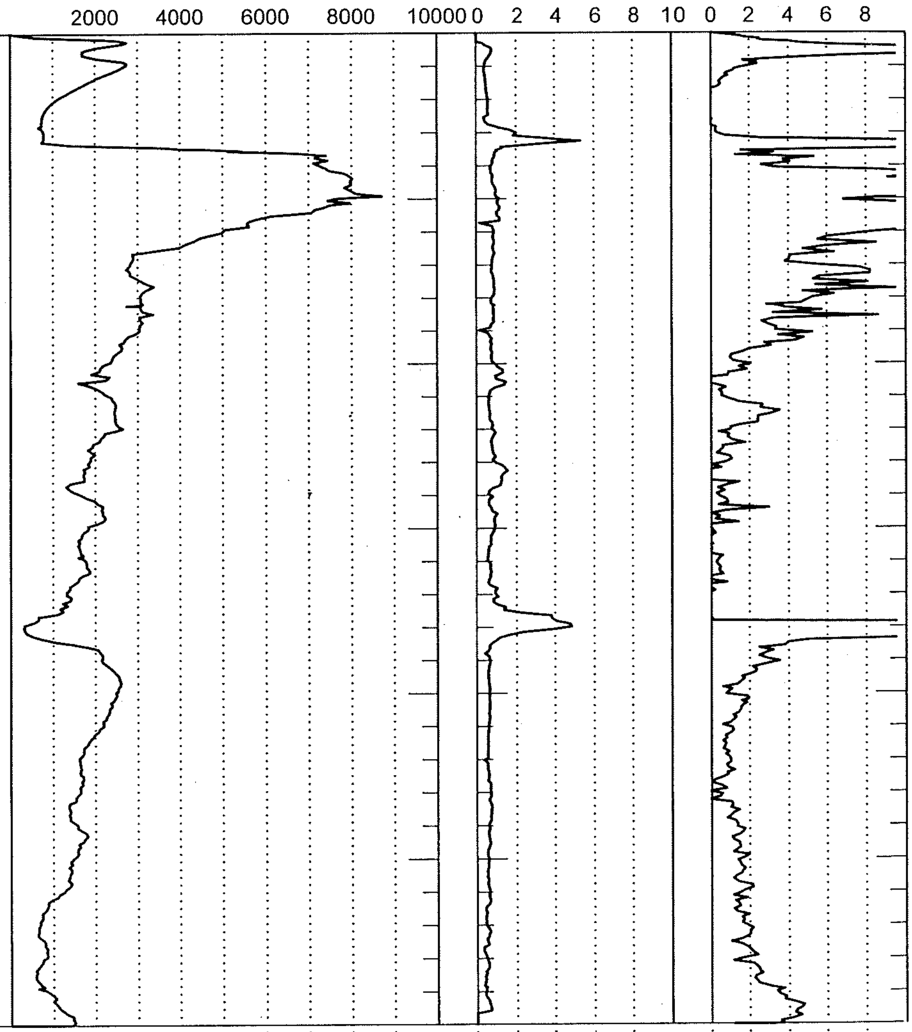
AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | |
|---|---|
| AET JOB NO: 01-05376 | SOUNDING NO. |
| PROJECT: Afton Levees; Afton, MN | C-07 (p. 1 of 1) |

| | | |
|---|---|---|
| Location | CPT Machine **20** | Surface Elevation |
| | CPT Operator **Adams** | 694.4± |
| Co. Coordinate: X=513285 Y=155702 (feet) | Cone # **4583.120XX** | Date Completed: 3/8/12 |

| Depth / Elevation (ft) | Interpreted Soil Description | Est. $N_{60}$ | Sample |
|---|---|---|---|
| 0 – 18 | FILL, mostly sand | 10, 50, 38, 18, 25 | |
| 18 – 19.5 | CLAY | 10 | |
| 19.5 – 30 | SAND | 18, 11, 10, 6 | |



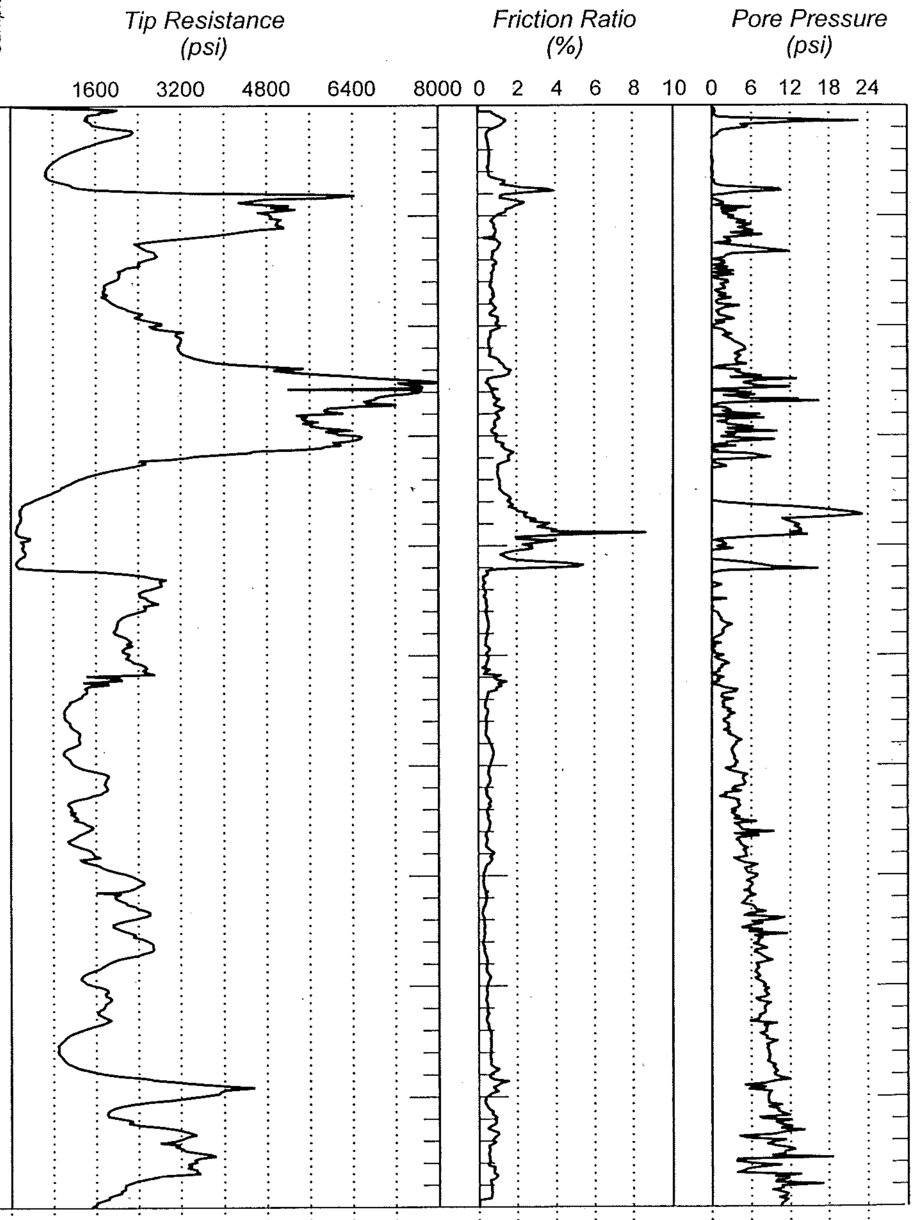

Bottom of Hole 29.976

AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | |
|---|---|
| AET JOB NO: 01-05376<br>PROJECT: Afton Levees; Afton, MN | SOUNDING NO.<br>C-08 (p. 1 of 1) |
| Location: | CPT Machine 20<br>CPT Operator Adams |
| | Surface Elevation 695.0± |
| Co. Coordinate: X=513391 Y=155503 (feet) | Cone # 4583.120XX |
| | Date Completed: 3/8/12 |

| Depth / Elevation | Interpreted Soil Description | Est. $N_{60}$ | Sample |
|---|---|---|---|
| 0 – 5 | FILL, mostly sand and silty sand | 50 | |
| 10 | | 40 | |
| 15 | | 50 | |
| 20 | CLAY | 8 | |
| 25 | SAND | 17 | |
| | SILTY SAND | | |
| 30 – 35 | SAND | 9 | |
| 40 | | 17 | |
| | | 6 | |
| 45 | SILTY SAND | | |
| | SAND | 23 | |



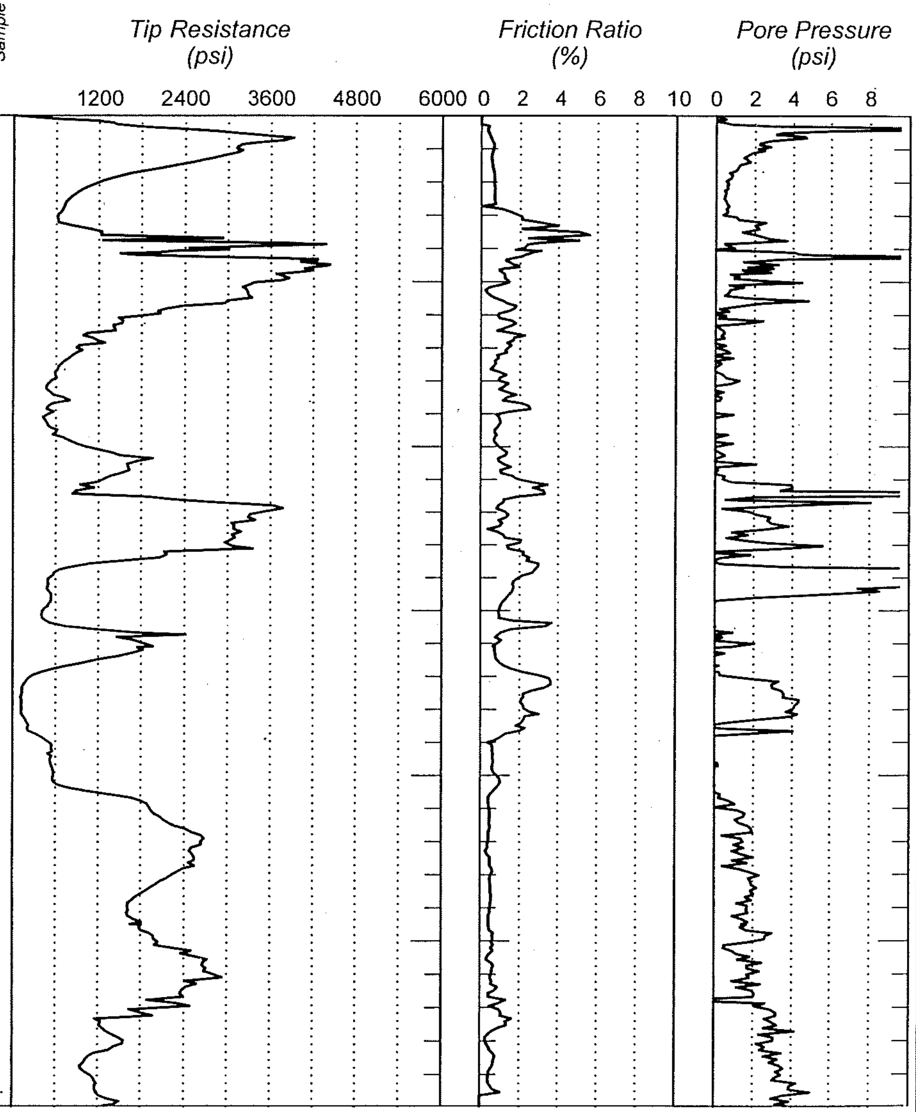

Bottom of Hole 49.987

AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: **01-05376** | | SOUNDING NO. |
| PROJECT: **Afton Levees; Afton, MN** | | **C-09 (p. 1 of 1)** |
| Location | CPT Machine **20** | Surface Elevation |
| | CPT Operator **Adams** | **694.5±** |
| Co. Coordinate: X=513392 Y=155300 (feet) | Cone # **4583.120XX** | Date Completed: 3/8/12 |

| Depth / Elevation | Interpreted Soil Description | Est. $N_{60}$ | Sample |
|---|---|---|---|
| 0 – 10 | FILL, mixture of sand, silty sand and clayey sand | 8, 45, 8 | |
| | SILTY SAND | 38 | |
| 15 | CLAYEY SAND | | |
| | SAND | 13 | |
| | CLAY | | |
| 20 – 25 | SAND | 7, 14 | |
| | SILTY SAND | | |
| | SAND | 9 | |



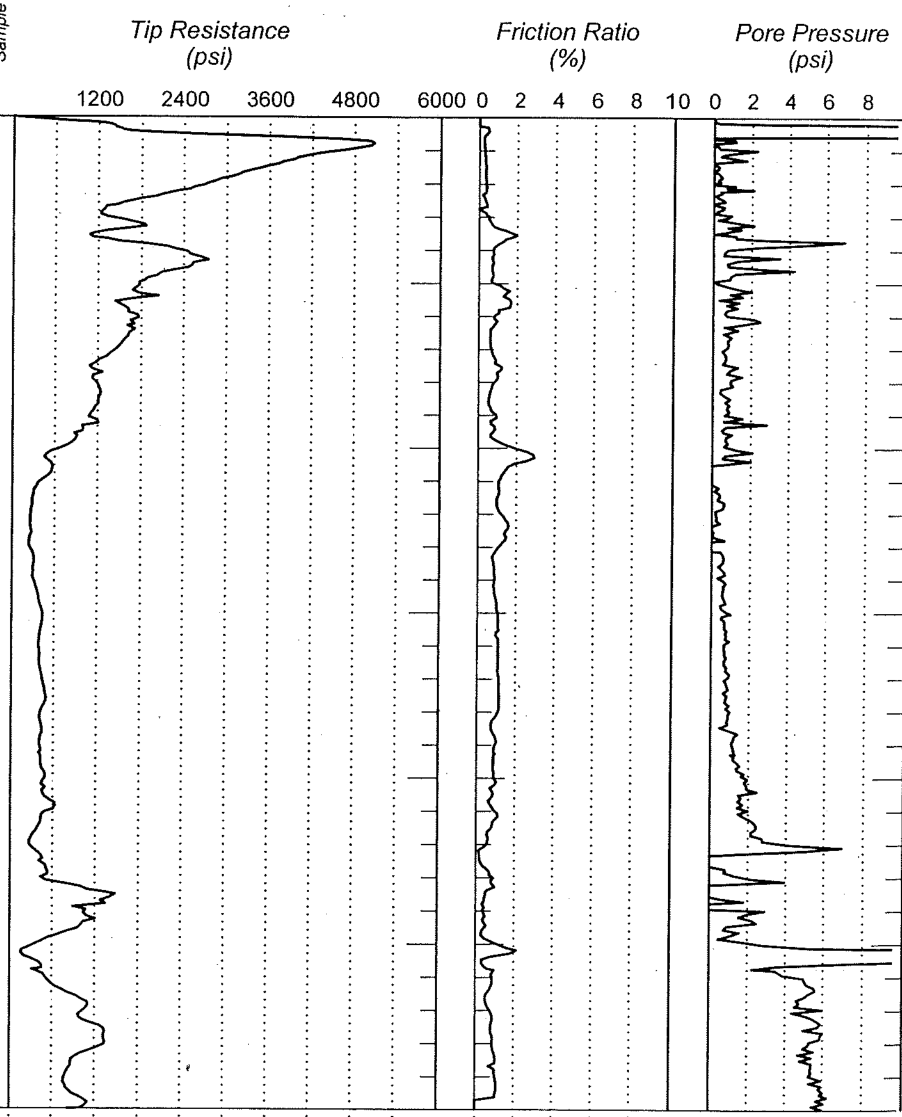

Bottom of Hole 29.952

# AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: 01-05376<br>PROJECT: Afton Levees; Afton, MN | | SOUNDING NO.<br>C-10 (p. 1 of 1) |
| Location | CPT Machine **20**<br>CPT Operator **Adams** | Surface Elevation<br>694.1± |
| Co. Coordinate: X=513223 Y=155127 (feet) | Cone # 4583.120XX | Date Completed: 3/8/12 |

| Depth / Elevation | Interpreted Soil Description | Est. $N_{60}$ | Sample |
|---|---|---|---|
| 0–9 | FILL, mostly sand and silty sand | 23 | |
| 9–10 | CLAYEY SAND | | |
| 10–13 | SILTY SAND | 2 | |
| 13–24.9 | SAND | 4, 4, 7 | |
| 24.9–25.9 | CLAYEY SAND | | |
| 25.9–30 | SAND | 7 | |

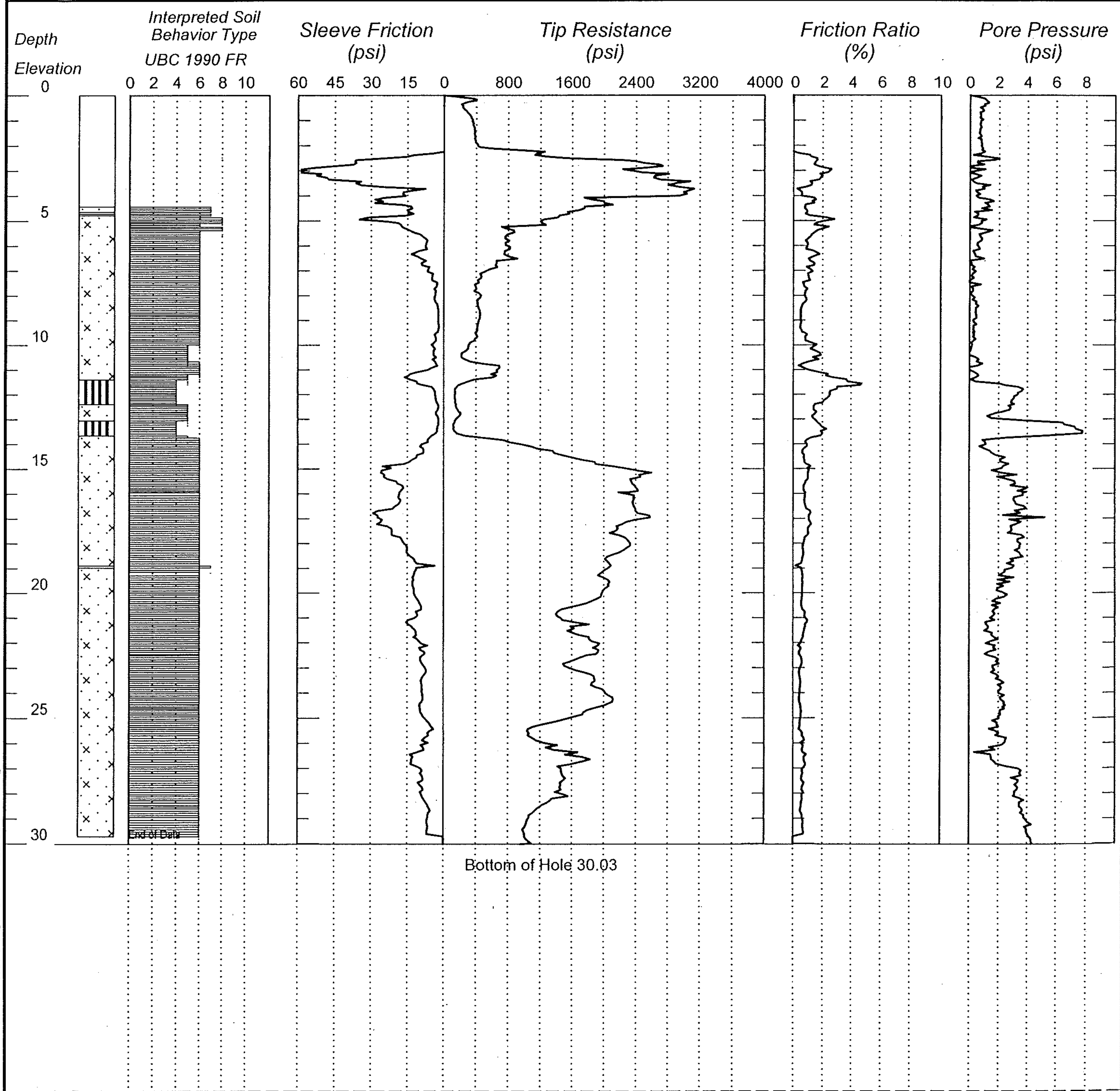



Bottom of Hole 29.986

AMERICAN
ENGINEERING
TESTING

# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: **01-05376**<br>PROJECT: **Afton Levees; Afton, MN** | | SOUNDING NO.<br>**C-01 (p. 1 of 1)** |
| Location | CPT Machine **20**<br>CPT Operator **Adams** | Surface Elevation<br>**693.4±** |
| Co. Coordinate: X=513393 Y=156802 (feet) | Cone # **4583.120XX** | Date Completed: 3/9/12 |

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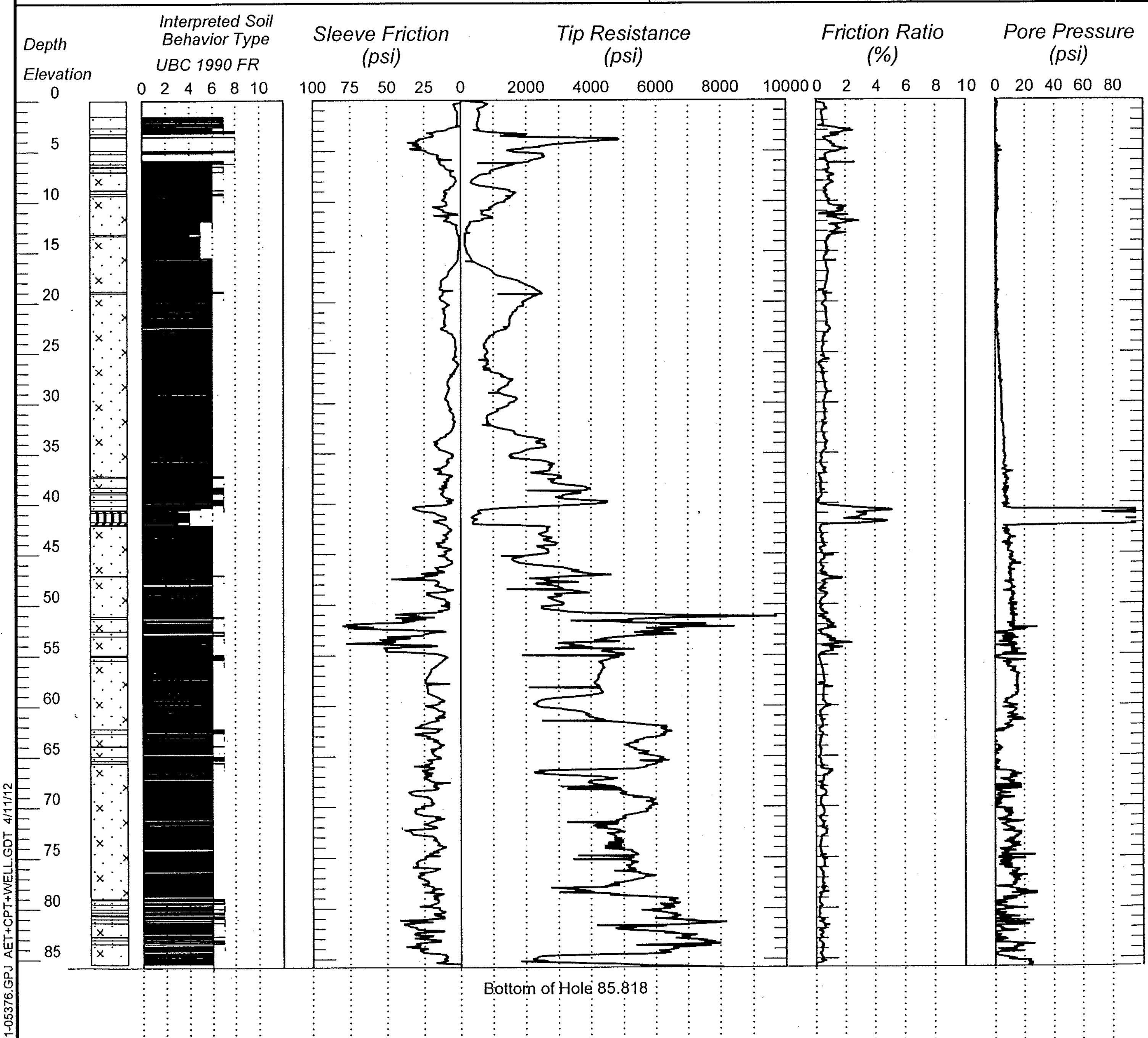
AET CPT GRAPH 01-05376.GPJ AET+CPT+WELL.GDT 4/11/12

AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | |
|---|---|
| AET JOB NO: **01-05376** | SOUNDING NO. |
| PROJECT: **Afton Levees; Afton, MN** | **C-02 (p. 1 of 1)** |

| | | |
|---|---|---|
| Location | CPT Machine **20** / CPT Operator **Adams** | Surface Elevation **694.8±** |
| Co. Coordinate: X=513370 Y=156653 (feet) | Cone # **4583.120XX** | Date Completed: 3/9/12 |

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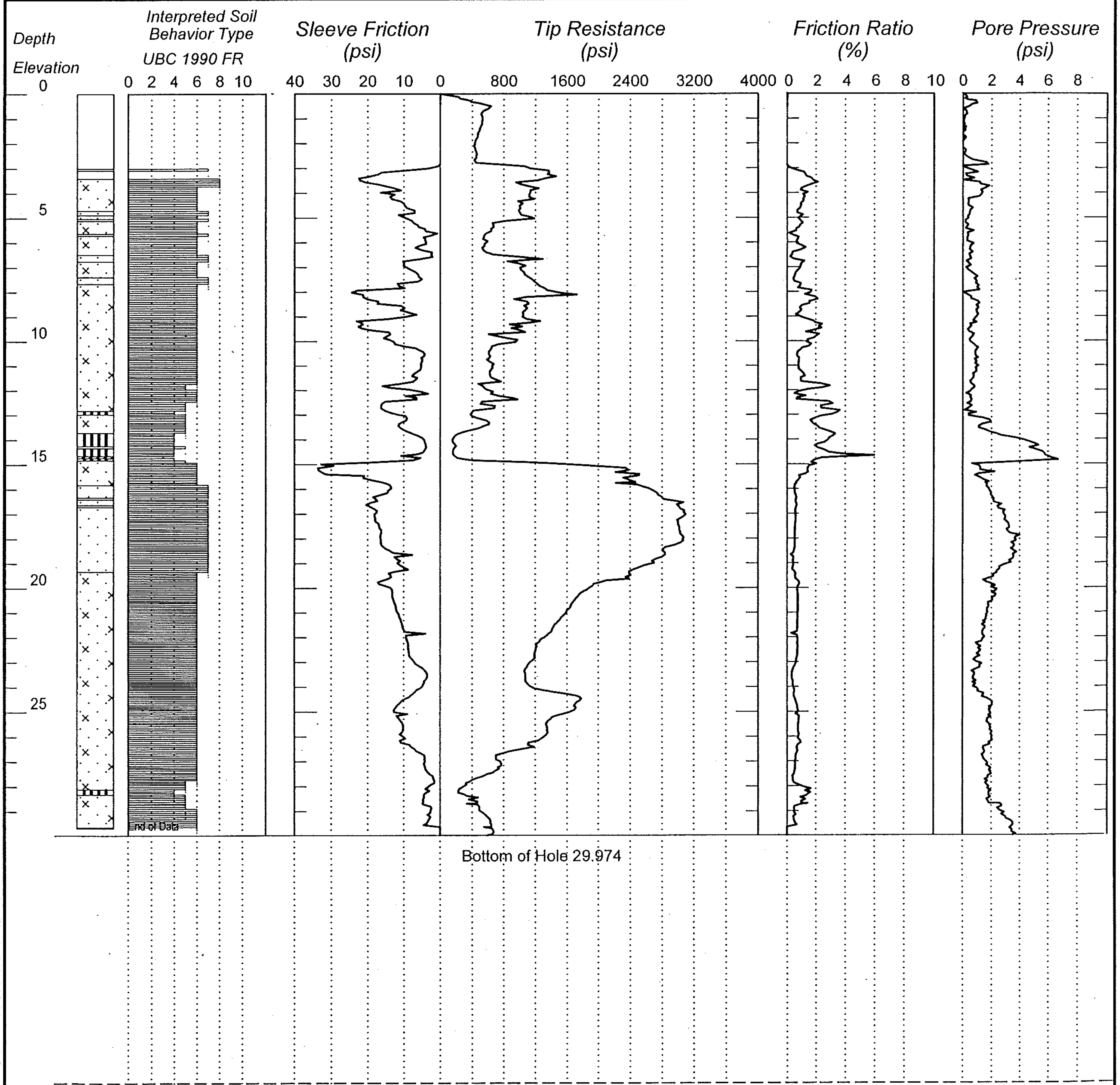
AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: **01-05376**<br>PROJECT: **Afton Levees; Afton, MN** | | SOUNDING NO.<br>**C-03 (p. 1 of 1)** |
| Location | CPT Machine **20**<br>CPT Operator **Adams** | Surface Elevation<br>**693.3±** |
| Co. Coordinate: X=513350 Y=156452 (feet) | Cone # **4583.120XX** | Date Completed: 3/8/12 |

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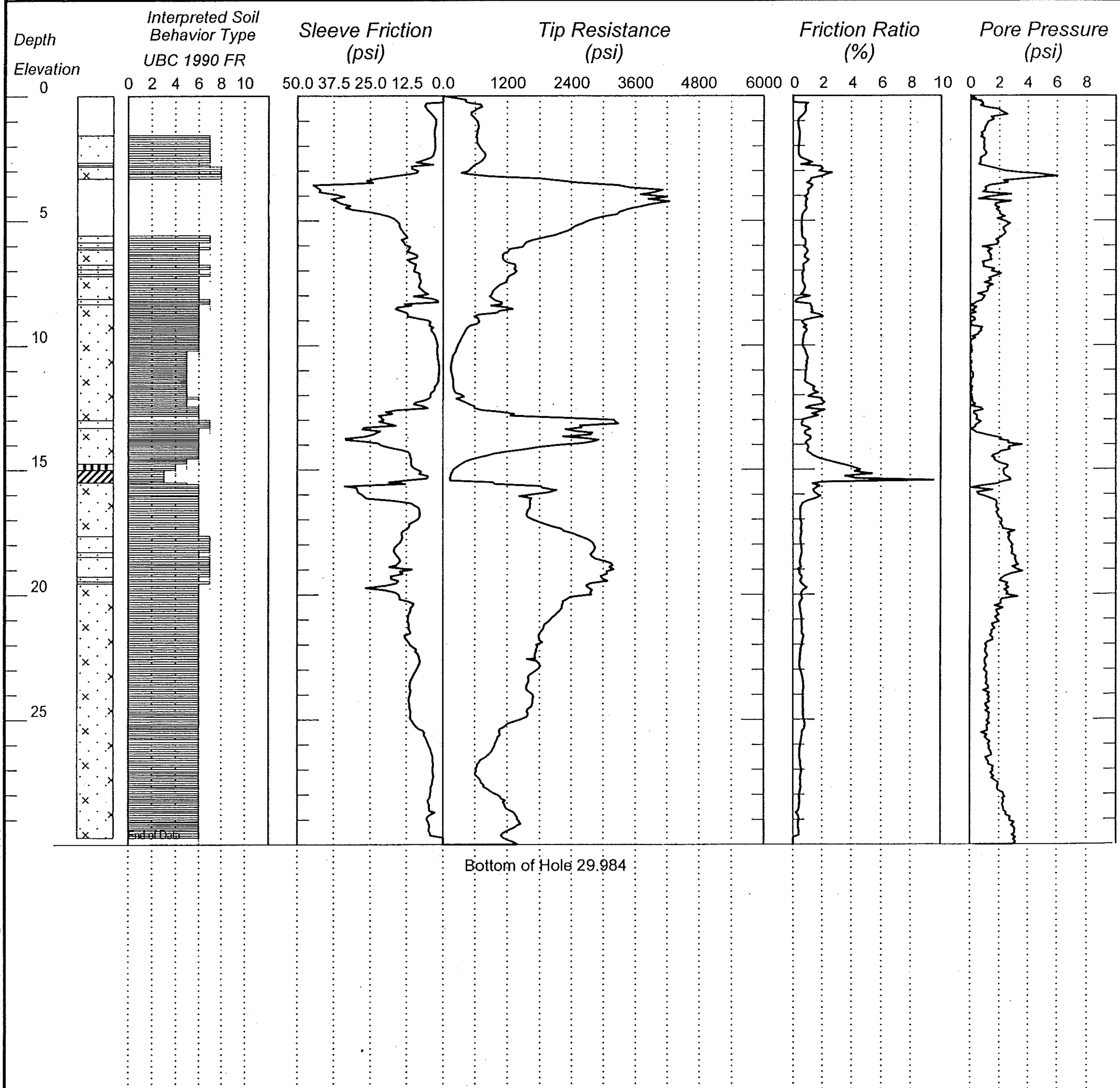
AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | |
|---|---|
| AET JOB NO: **01-05376** PROJECT: **Afton Levees; Afton, MN** | SOUNDING NO. **C-04 (p. 1 of 1)** |
| Location | CPT Machine **20** / CPT Operator **Adams** / Surface Elevation **694.5±** |
| Co. Coordinate: X=513325 Y=156302 (feet) | Cone # **4583.120XX** / Date Completed: 3/8/12 |

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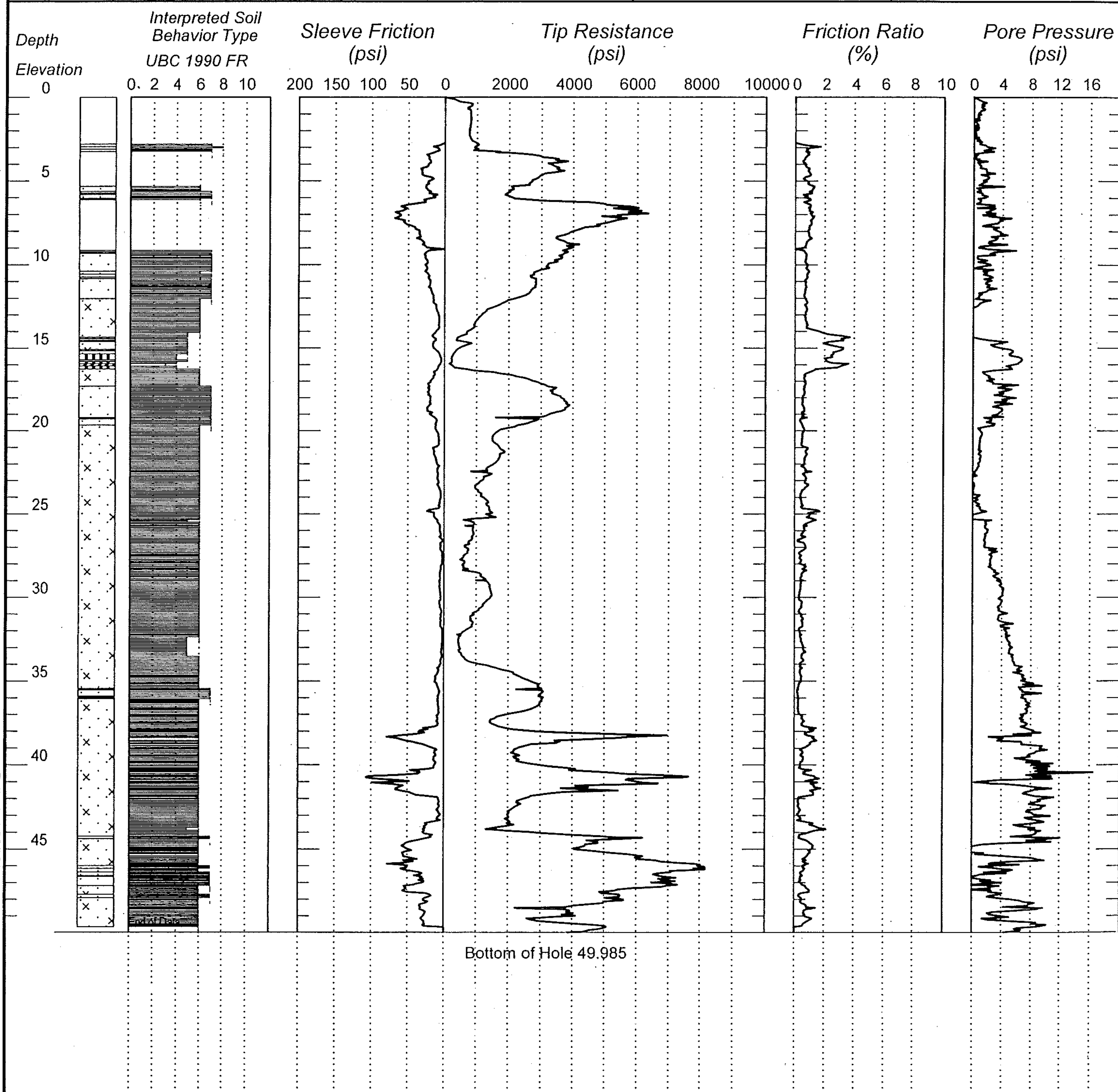
AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: **01-05376**<br>PROJECT: **Afton Levees; Afton, MN** | | SOUNDING NO.<br>**C-05 (p. 1 of 1)** |
| Location | CPT Machine **20**<br>CPT Operator **Adams** | Surface Elevation<br>**694.1±** |
| Co. Coordinate: X=513305 Y=156125 (feet) | Cone # **4583.120XX** | Date Completed: 3/8/12 |

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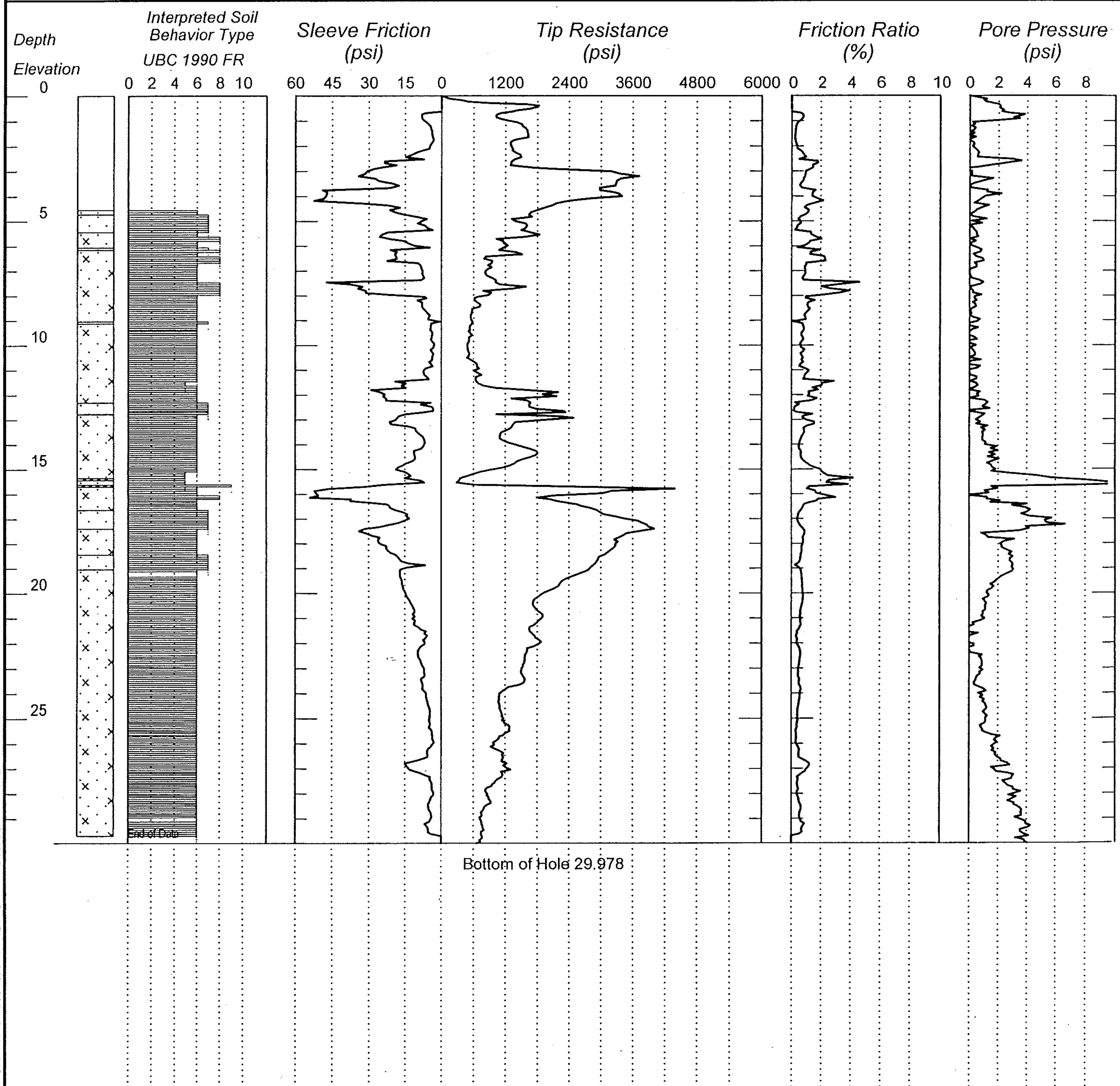
AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: **01-05376**<br>PROJECT: **Afton Levees; Afton, MN** | | SOUNDING NO.<br>**C-06 (p. 1 of 1)** |
| Location | CPT Machine **20**<br>CPT Operator **Adams** | Surface Elevation<br>**694.2±** |
| Co. Coordinate: X=513275 Y=155902 (feet) | Cone # **4583.120XX** | Date Completed: 3/8/12 |

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AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

AET JOB NO: **01-05376**

PROJECT: **Afton Levees; Afton, MN**

SOUNDING NO. **C-07 (p. 1 of 1)**

Location

CPT Machine **20**

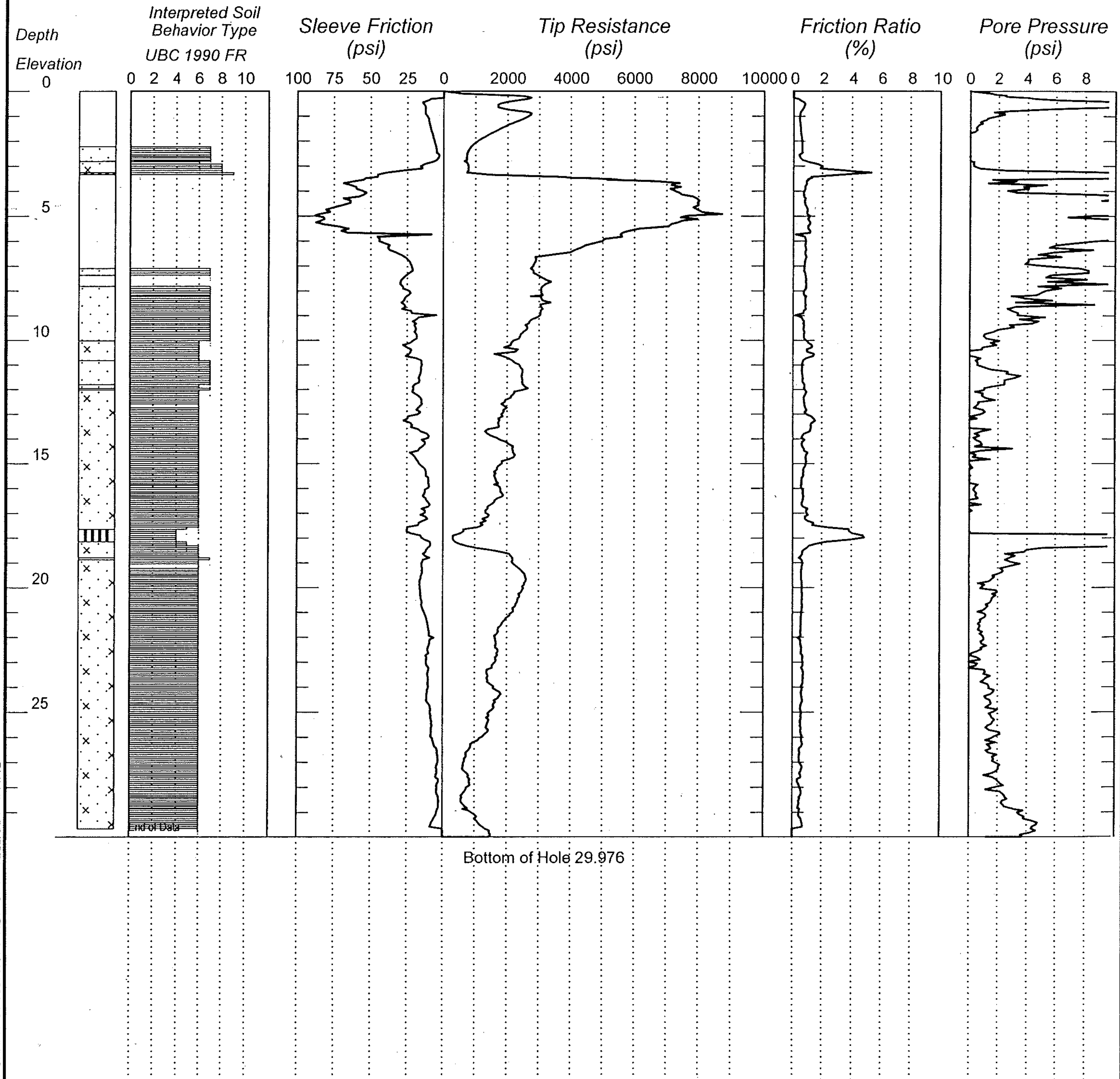
CPT Operator **Adams**

Surface Elevation **694.4±**

Co. Coordinate: X=513285 Y=155702 (feet)

Cone # **4583.120XX**

Date Completed: 3/8/12

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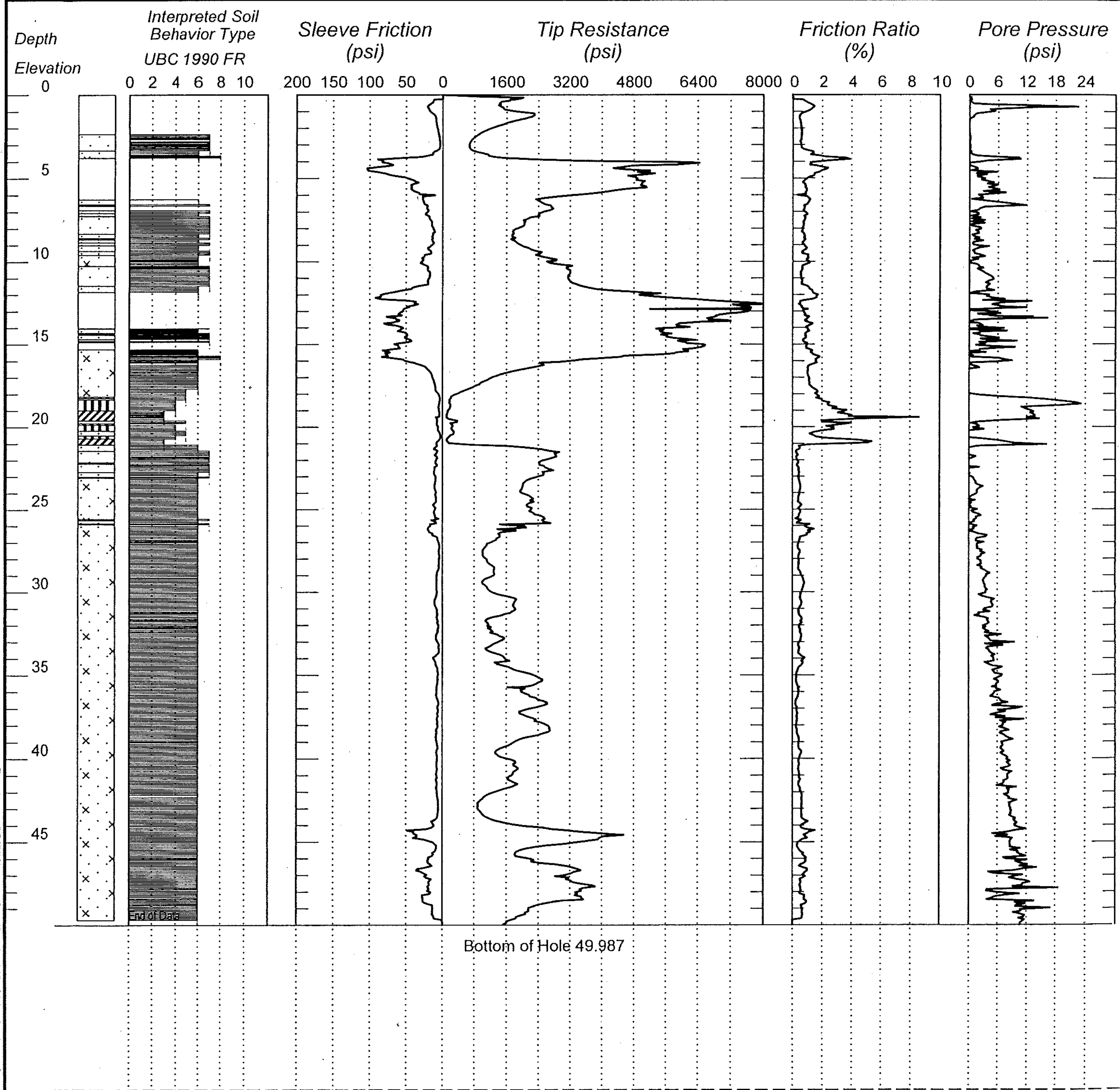
AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | |
|---|---|
| AET JOB NO: **01-05376** | SOUNDING NO. |
| PROJECT: **Afton Levees; Afton, MN** | **C-08 (p. 1 of 1)** |
| Location | CPT Machine **20** / CPT Operator **Adams** / Surface Elevation **695.0±** |
| Co. Coordinate: X=513391 Y=155503 (feet) | Cone # **4583.120XX** / Date Completed: 3/8/12 |

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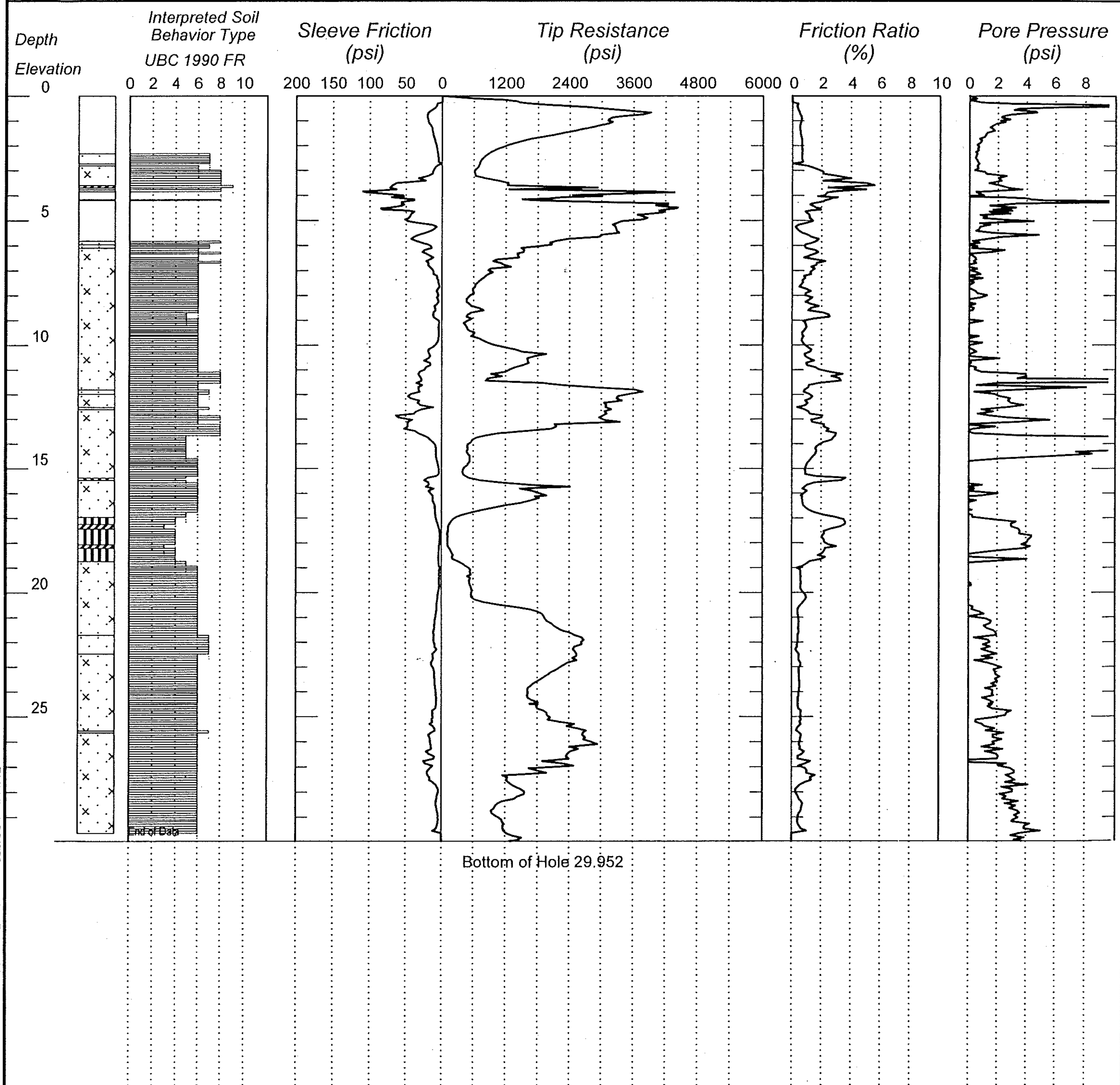
# AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | | |
|---|---|---|
| AET JOB NO: **01-05376**<br>PROJECT: **Afton Levees; Afton, MN** | | SOUNDING NO.<br>**C-09 (p. 1 of 1)** |
| Location | CPT Machine **20**<br>CPT Operator **Adams** | Surface Elevation<br>**694.5±** |
| Co. Coordinate: X=513392 Y=155300 (feet) | Cone # **4583.120XX** | Date Completed: 3/8/12 |

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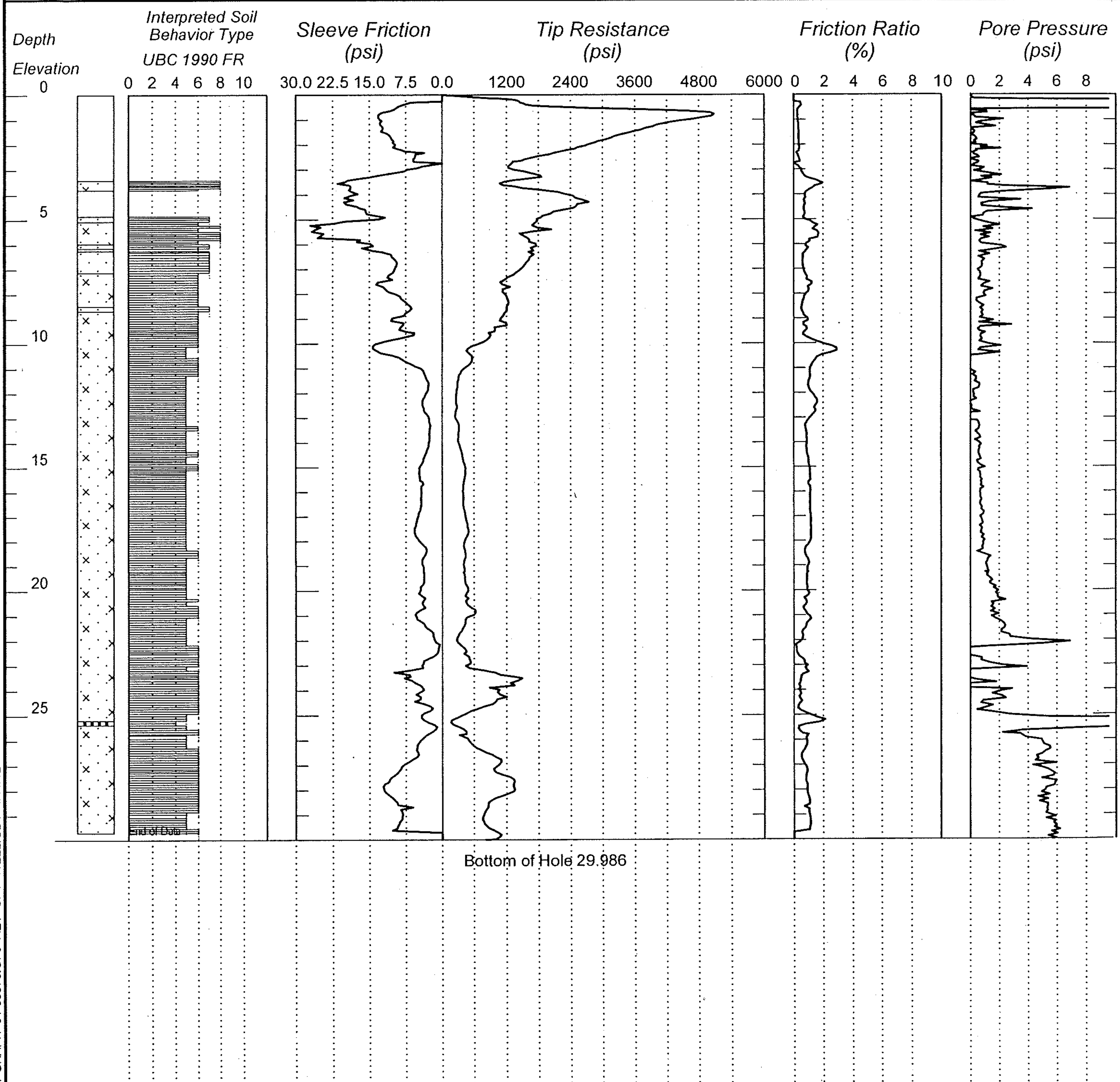
AMERICAN ENGINEERING TESTING

# CONE PENETRATION TEST RESULTS

| | |
|---|---|
| AET JOB NO: **01-05376** | SOUNDING NO. |
| PROJECT: **Afton Levees; Afton, MN** | **C-10 (p. 1 of 1)** |
| Location | CPT Machine **20** |
| | CPT Operator **Adams** |
| Surface Elevation **694.1±** | |
| Co. Coordinate: X=513223 Y=155127 (feet) | Cone # **4583.120XX** |
| Date Completed: 3/8/12 | |

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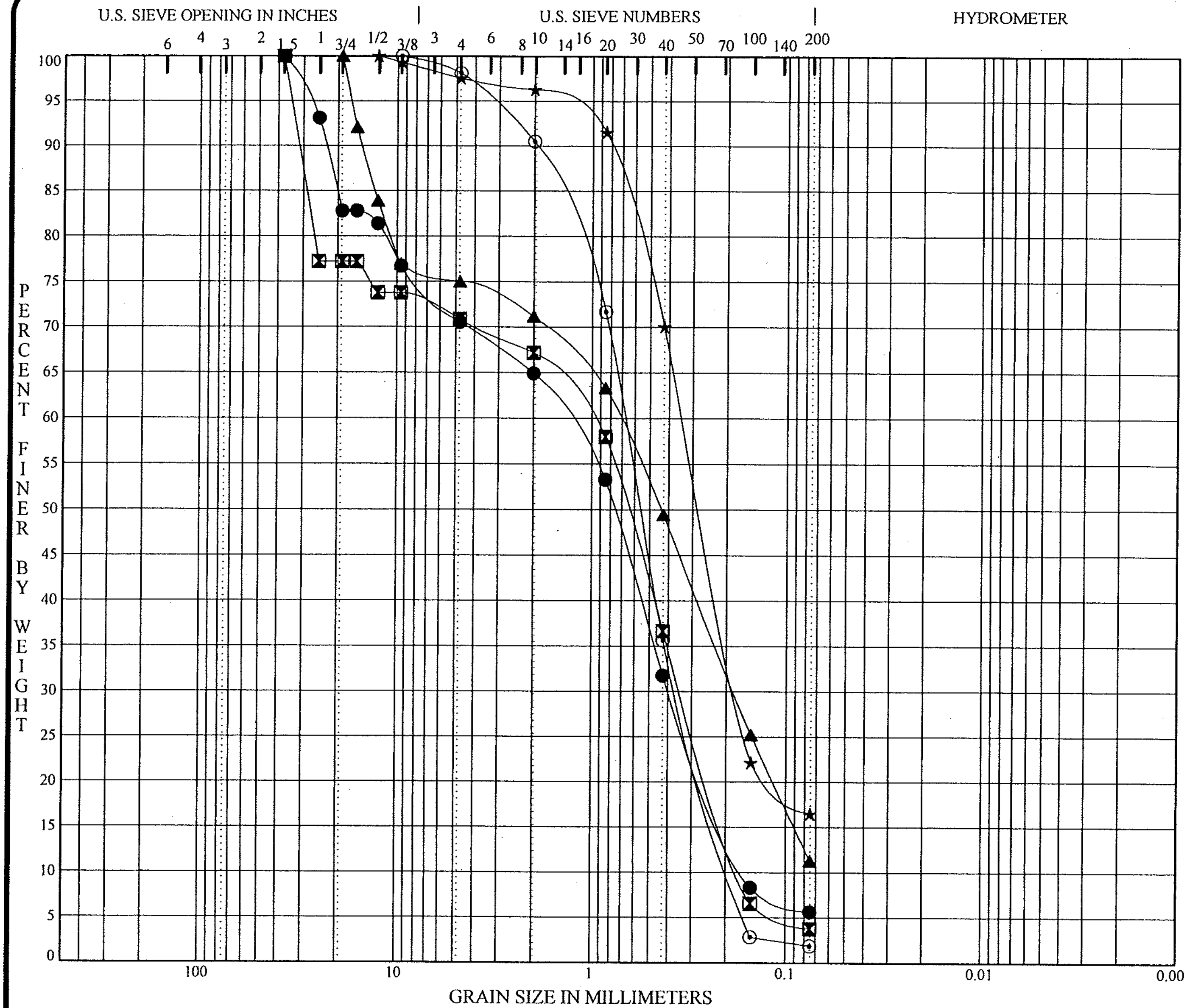



| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | coarse | fine | coarse | medium | fine | |

| Specimen Identification | | | Classification | MC% | LL | PL | PI | Cc | Cu |
|---|---|---|---|---|---|---|---|---|---|
| ● | B2 | 7.0' | POORLY GRADED SAND with SILT & GRAVEL (SP-SM) | | | | | 0.69 | 8.6 |
| ⊠ | B2 | 9.5' | POORLY GRADED SAND with GRAVEL (SP) | | | | | 0.66 | 6.1 |
| ▲ | B2 | 12.0' | POORLY GRADED SAND with SILT & GRAVEL (SP-SM) | | | | | 0.67 | 10.2 |
| ★ | B2 | 14.5' | SILTY SAND (SM) | | | | | | |
| ⊙ | B2 | 17.0' | POORLY GRADED SAND (SP) | | | | | 0.99 | 3.6 |

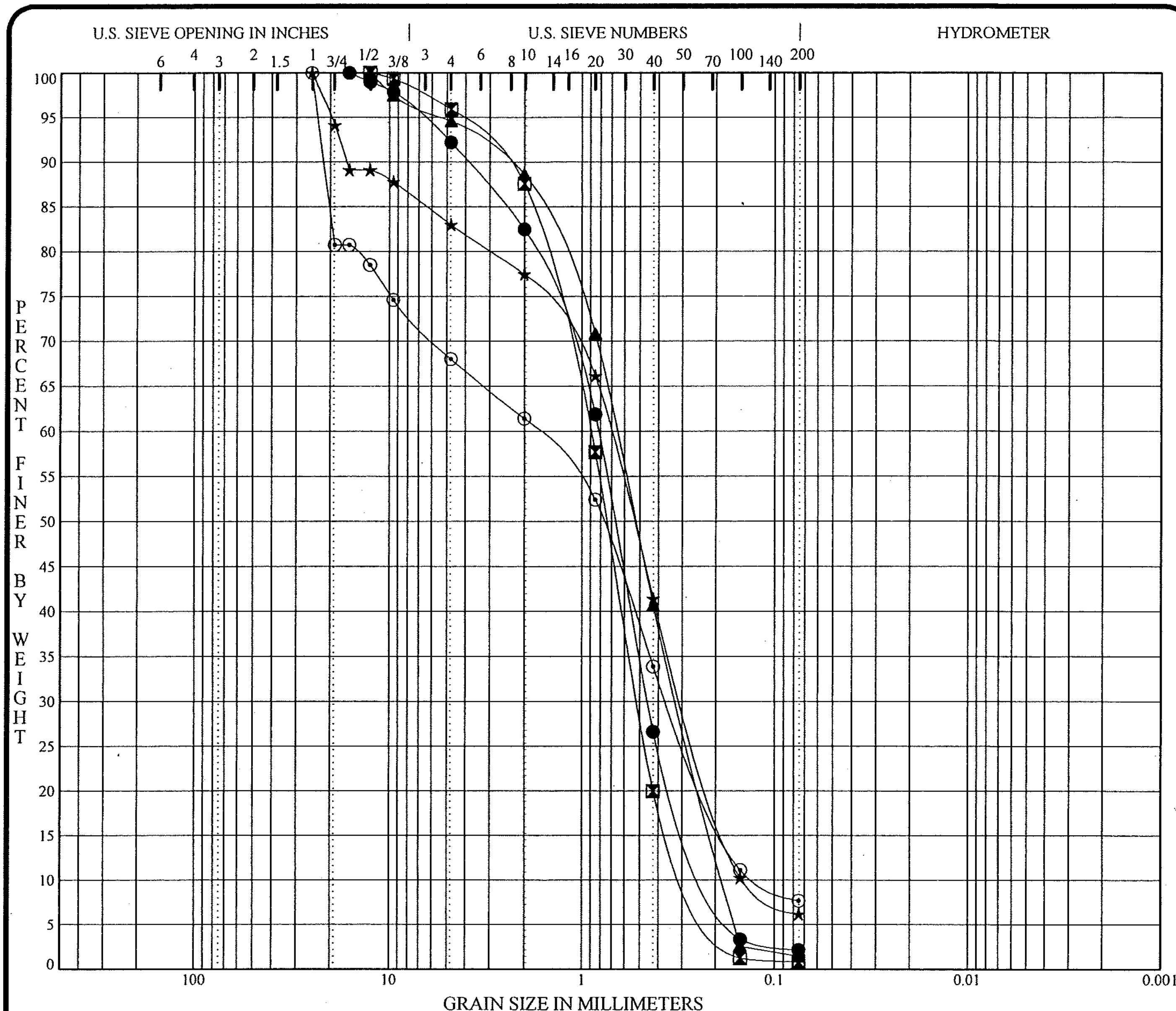
| Specimen Identification | | | D100 | D60 | D30 | D10 | %Gravel | %Sand | %Silt / %Clay |
|---|---|---|---|---|---|---|---|---|---|
| ● | B2 | 7.0' | 37.50 | 1.39 | 0.393 | 0.1617 | 29.5 | 64.9 | 5.6 |
| ⊠ | B2 | 9.5' | 37.50 | 1.03 | 0.338 | 0.1691 | 29.1 | 67.1 | 3.8 |
| ▲ | B2 | 12.0' | 19.00 | 0.72 | 0.184 | | 25.0 | 63.7 | 11.3 |
| ★ | B2 | 14.5' | 12.50 | 0.34 | 0.178 | | 2.4 | 81.1 | 16.5 |
| ⊙ | B2 | 17.0' | 9.50 | 0.68 | 0.355 | 0.1883 | 1.9 | 96.3 | 1.9 |

PROJECT **Afton Levees; Afton, MN**

AET JOB NO. **01-05376**
DATE **3/21/12**

AMERICAN ENGINEERING TESTING, INC.

## GRADATION CURVES




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | coarse | fine | coarse | medium | fine | |

| Specimen Identification | | Classification | MC% | LL | PL | PI | Cc | Cu |
|---|---|---|---|---|---|---|---|---|
| ● B2 | 19.5' | **POORLY GRADED SAND (SP)** | | | | | **1.25** | **4.1** |
| ⊠ B2 | 24.5' | **POORLY GRADED SAND (SP)** | | | | | **1.18** | **3.7** |
| ▲ B2 | 29.5' | **POORLY GRADED SAND (SP)** | | | | | **0.83** | **3.6** |
| ★ B5 | 7.0' | **POORLY GRADED SAND with SILT & GRAVEL (SP-SM)** | | | | | **0.81** | **4.9** |
| ⊙ B5 | 9.5' | **POORLY GRADED SAND with SILT & GRAVEL (SP-SM)** | | | | | **0.60** | **14.6** |

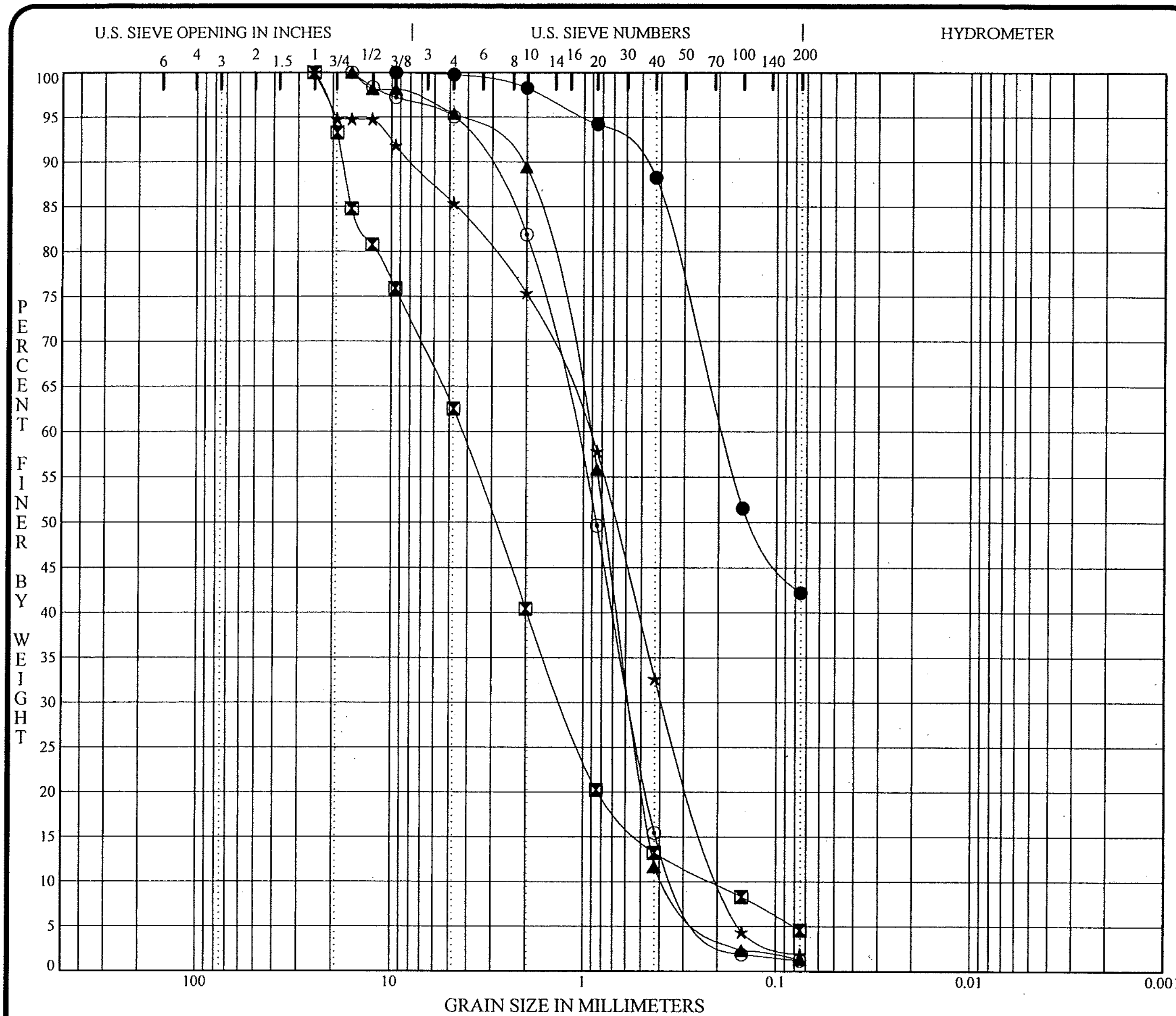
| Specimen Identification | | D100 | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|---|---|---|---|---|---|---|---|---|---|
| ● B2 | 19.5' | **16.00** | **0.82** | **0.454** | **0.2022** | **7.8** | **90.0** | **2.2** | |
| ⊠ B2 | 24.5' | **12.50** | **0.91** | **0.511** | **0.2443** | **4.1** | **95.1** | **0.8** | |
| ▲ B2 | 29.5' | **12.50** | **0.66** | **0.318** | **0.1838** | **5.4** | **93.2** | **1.4** | |
| ★ B5 | 7.0' | **25.00** | **0.72** | **0.290** | **0.1446** | **17.0** | **76.8** | **6.1** | |
| ⊙ B5 | 9.5' | **25.00** | **1.75** | **0.356** | **0.1202** | **32.0** | **60.3** | **7.7** | |

PROJECT **Afton Levees; Afton, MN**

AET JOB NO. **01-05376**
DATE **3/21/12**

AMERICAN ENGINEERING TESTING, INC.

# GRADATION CURVES




| COBBLES | GRAVEL | | SAND | | | SILT OR CLAY |
|---|---|---|---|---|---|---|
| | coarse | fine | coarse | medium | fine | |

| Specimen Identification | | Classification | MC% | LL | PL | PI | Cc | Cu |
|---|---|---|---|---|---|---|---|---|
| ● B5 | 14.5' | CLAYEY SAND (SC) | 21 | | | | | |
| ⊠ B5 | 17.0' | POORLY GRADED SAND with GRAVEL (SP) | | | | | 1.79 | 20.0 |
| ▲ B5 | 19.5' | POORLY GRADED SAND (SP) | | | | | 0.96 | 2.7 |
| ★ B5 | 24.5' | POORLY GRADED SAND (SP) | | | | | 0.85 | 5.1 |
| ⊙ B5 | 29.5' | POORLY GRADED SAND (SP) | | | | | 1.04 | 4.0 |

| Specimen Identification | | D100 | D60 | D30 | D10 | %Gravel | %Sand | %Silt | %Clay |
|---|---|---|---|---|---|---|---|---|---|
| ● B5 | 14.5' | 9.50 | 0.19 | | | 0.2 | 57.6 | 42.2 | |
| ⊠ B5 | 17.0' | 25.00 | 4.30 | 1.285 | 0.2149 | 37.5 | 58.0 | 4.6 | |
| ▲ B5 | 19.5' | 16.00 | 0.95 | 0.567 | 0.3547 | 4.6 | 94.1 | 1.3 | |
| ★ B5 | 24.5' | 25.00 | 0.94 | 0.386 | 0.1847 | 14.7 | 83.5 | 1.9 | |
| ⊙ B5 | 29.5' | 16.00 | 1.12 | 0.571 | 0.2800 | 4.9 | 93.9 | 1.2 | |

PROJECT **Afton Levees; Afton, MN**

AET JOB NO. **01-05376**
DATE **3/21/12**

AMERICAN ENGINEERING TESTING, INC.

# GRADATION CURVES

TABLE A-1: Estimated Permeability Values
(Based on Kozeny-Carmen Equation)

| Boring No. | Sample Depth (ft.) | % fines (-#200 sieve) | USCS | Permeability cm/sec | Permeability ft/hr |
|---|---|---|---|---|---|
| 2 | 7 | 5.6 | SP-SM (Fill) | 0.0364 | 4.30 |
| 2 | 9.5 | 3.8 | SP (Fill) | 0.0242 | 2.86 |
| 2 | 12 | 11.3 | SP-SM (Fill) | 0.0397 | 4.69 |
| 2 | 14.5 | 16.5 | SM(Fill) | 0.0257 | 3.04 |
| 2 | 17 | 3.6 | SP(alluvium) | 0.0486 | 5.74 |
| 2 | 19.5 | 2.2 | SP(alluvium) | 0.0992 | 11.72 |
| 2 | 24.5 | 0.8 | SP(alluvium) | 0.157 | 18.54 |
| 2 | 29.5 | 1.4 | SP(alluvium) | 0.0779 | 9.20 |
| 5 | 7 | 6.1 | SP-SM (Fill) | 0.0166 | 1.96 |
| 5 | 9.5 | 7.7 | SP-SM (Fill) | 0.0131 | 1.55 |
| 5 | 14.5 | 42.2 | SC (surface blanket) | 0.00334 | 0.39 |
| 5 | 17 | 4.6 | SP(alluvium) | 0.0344 | 4.06 |
| 5 | 19.5 | 1.3 | SP(alluvium) | 0.141 | 16.65 |
| 5 | 24.5 | 1.9 | SP(alluvium) | 0.0979 | 11.56 |
| 5 | 29.5 | 1.2 | SP(alluvium) | 0.181 | 21.38 |

## TEST PROCEDURE

The test method is described in ASTM: D5778. This cone test method determines the resistance to penetration of a conical pointed penetrometer and the frictional resistance of a cylindrical sleeve located behind the conical point as the cone is advanced through subsurface soils at a slow and steady rate. The piezocone adds the measurement of pore pressure development behind the tip. The equipment provides a detailed record of cone resistance which is useful for evaluation of site stratigraphy, homogeneity and depth to firm layers, voids or cavities, and other discontinuities. In addition, the cone resistance and friction data can be used to estimate soil classification, and correlations with engineering properties of soils. The pore pressure readings also provide information on soil type and water table depth. Pore pressure dissipation, after a push, can also be monitored for correlation to soil consolidation and permeability. Therefore, the test provides a rapid means for determining subsurface conditions, and can be used for estimating engineering properties of soils for structures, and the behavior of soils under static and dynamic loads.

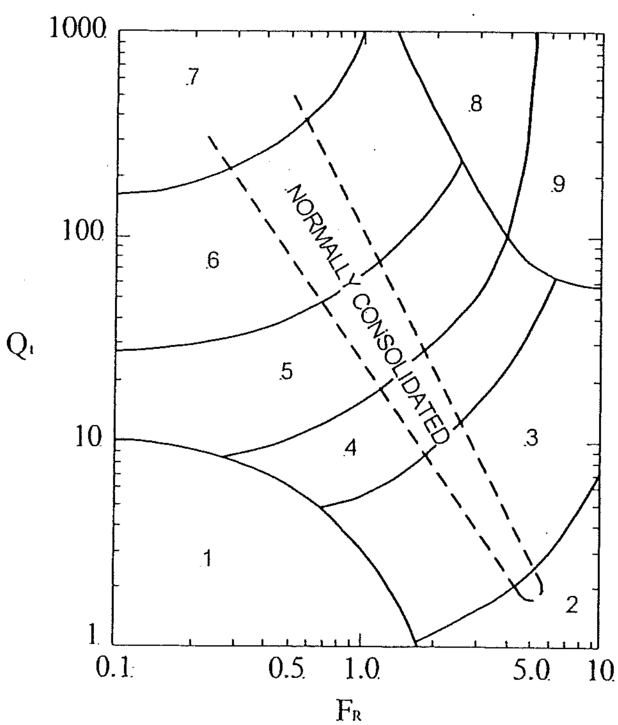
During the testing, a penetrometer tip with a conical point having a 60° apex angle and a cone base area of 10 $cm^2$ or 15$cm^2$ is advanced through the soil at a constant rate of 2 cm/sec. The friction sleeve is present on the penetrometer immediately behind the cone tip. The forces exerted on the conical point (cone) and the friction sleeve required to penetrate the soil are measured by electrical methods, at every 2 cm of penetration. The cone resistance ($q_t$) is calculated by dividing the measured total cone force by the cone base area. The friction sleeve resistance ($f_s$) is obtained by dividing the measured force exerted on the sleeve by its surface area. Pore pressure is measured directly behind the cone ($U_2$ position).

## SOIL BEHAVIOR TYPE (SBT)

Soil Classification methods for the Cone Penetration Test is based on correlation charts developed from observations of CPT data and conventional borings. Please note that these classification charts are meant to provide a guide to Soil Behavior Type and should not be used to infer a soil classification based on grain size distribution.

The following chart is used to provide a Soil Behavior Type of the CPT Data.

**Figure 1: Robertson CPT 1990 (Soil Behavior Type based on Friction Ratio)**




The numbers corresponding to different regions on the charts represent the following soil behavior types:

1. Sensitive, Fine Grained
2. Organic Soils - Peats
3. Clays - Clay to Silty Clay
4. Silt Mixtures - Clayey Silt to Silty Clay
5. Sand Mixtures - Silty Sand to Sandy Silt
6. Sands - Clean Sand to Silty Sand
7. Gravelly Sand to Sand
8. Very Stiff Sand to Clayey Sand
9. Very Stiff, Fine Grained

$$Q_t = \frac{q_t - \sigma_{vo}}{\sigma'_{vo}} \quad F_R = \frac{f_s}{q_t - \sigma_{vo}} \times 100\%$$

where . . .
$Q_T$ .......... normalized cone resistance
$F_R$ ........... normalized friction ratio

Note that engineering judgment and comparison with conventional borings is especially important in the proper interpretation of CPT data in certain geo-materials.

# BORING LOG NOTES

## DRILLING AND SAMPLING SYMBOLS

| Symbol | Definition |
|---|---|
| AR: | Sample of material obtained from cuttings blown out the top of the borehole during air rotary procedure. |
| B, H, N: | Size of flush-joint casing |
| CAS: | Pipe casing, number indicates nominal diameter in inches |
| COT: | Clean-out tube |
| DC: | Drive casing; number indicates diameter in inches |
| DM: | Drilling mud or bentonite slurry |
| DR: | Driller (initials) |
| DS: | Disturbed sample from auger flights |
| DP: | Direct push drilling; a 2.125 inch OD outer casing with an inner 1½ inch ID plastic tube is driven continuously into the ground. |
| FA: | Flight auger; number indicates outside diameter in inches |
| HA: | Hand auger; number indicates outside diameter |
| HSA: | Hollow stem auger; number indicates inside diameter in inches |
| LG: | Field logger (initials) |
| MC: | Column used to describe moisture condition of samples and for the ground water level symbols |
| N (BPF): | Standard penetration resistance (N-value) in blows per foot (see notes) |
| NQ: | NQ wireline core barrel |
| PQ: | PQ wireline core barrel |
| RDA: | Rotary drilling with compressed air and roller or drag bit. |
| RDF: | Rotary drilling with drilling fluid and roller or drag bit |
| REC: | In split-spoon (see notes), direct push and thin-walled tube sampling, the recovered length (in inches) of sample. In rock coring, the length of core recovered (expressed as percent of the total core run). Zero indicates no sample recovered. |
| SS: | Standard split-spoon sampler (steel; 1.5" is inside diameter; 2" outside diameter); unless indicated otherwise |
| SU | Spin-up sample from hollow stem auger |
| TW: | Thin-walled tube; number indicates inside diameter in inches |
| WASH: | Sample of material obtained by screening returning rotary drilling fluid or by which has collected inside the borehole after "falling" through drilling fluid |
| WH: | Sampler advanced by static weight of drill rod and hammer |
| WR: | Sampler advanced by static weight of drill rod |
| 94mm: | 94 millimeter wireline core barrel |
| ▼: | Water level directly measured in boring |
| ▽: | Estimated water level based solely on sample appearance |

## TEST SYMBOLS

| Symbol | Definition |
|---|---|
| CONS: | One-dimensional consolidation test |
| DEN: | Dry density, pcf |
| DST: | Direct shear test |
| E: | Pressuremeter Modulus, tsf |
| HYD: | Hydrometer analysis |
| LL: | Liquid Limit, % |
| LP: | Pressuremeter Limit Pressure, tsf |
| OC: | Organic Content, % |
| PERM: | Coefficient of permeability (K) test; F - Field; L - Laboratory |
| PL: | Plastic Limit, % |
| $q_p$: | Pocket Penetrometer strength, tsf (approximate) |
| $q_c$: | Static cone bearing pressure, tsf |
| $q_u$: | Unconfined compressive strength, psf |
| R: | Electrical Resistivity, ohm-cms |
| RQD: | Rock Quality Designation of Rock Core, in percent (aggregate length of core pieces 4" or more in length as a percent of total core run) |
| SA: | Sieve analysis |
| TRX: | Triaxial compression test |
| VSR: | Vane shear strength, remolded (field), psf |
| VSU: | Vane shear strength, undisturbed (field), psf |
| WC: | Water content, as percent of dry weight |
| %-200: | Percent of material finer than #200 sieve |

## STANDARD PENETRATION TEST NOTES
### (Calibrated Hammer Weight)

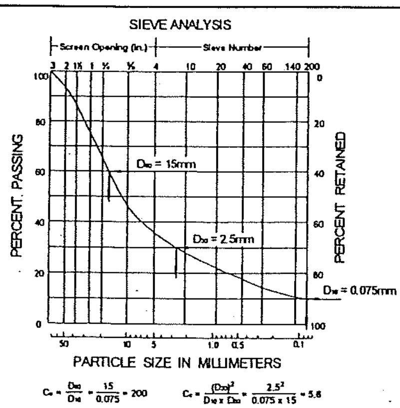
The standard penetration test consists of driving a split-spoon sampler with a drop hammer (calibrated weight varies to provide $N_{60}$ values) and counting the number of blows applied in each of three 6" increments of penetration. If the sampler is driven less than 18" (usually in highly resistant material), permitted in ASTM: D1586, the blows for each complete 6" increment and for each partial increment is on the boring log. For partial increments, the number of blows is shown to the nearest 0.1' below the slash.

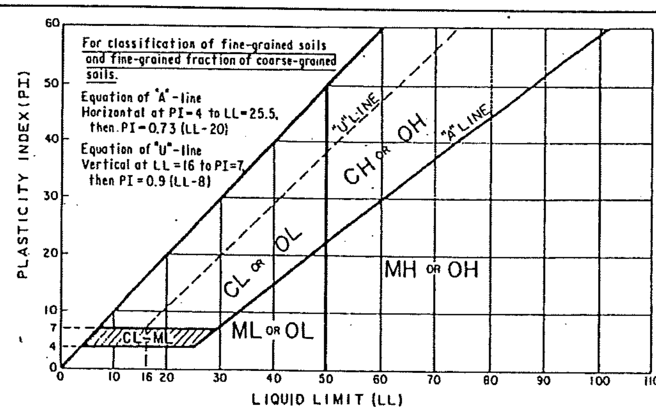
The length of sample recovered, as shown on the "REC" column, may be greater than the distance indicated in the N column. The disparity is because the N-value is recorded below the initial 6" set (unless partial penetration defined in ASTM: D1586 is encountered) whereas the length of sample recovered is for the entire sampler drive (which may even extend more than 18").

# UNIFIED SOIL CLASSIFICATION SYSTEM
## ASTM Designations: D 2487, D2488

**AMERICAN ENGINEERING TESTING, INC.**

| Criteria for Assigning Group Symbols and Group Names Using Laboratory Tests[A] | | | | Soil Classification Group Symbol | Soil Classification Group Name[B] |
|---|---|---|---|---|---|
| Coarse-Grained Soils More than 50% retained on No. 200 sieve | Gravels More than 50% coarse fraction retained on No. 4 sieve | Clean Gravels Less than 5% fines[C] | Cu≥4 and 1≤Cc≤3[E] | GW | Well graded gravel[F] |
| | | | Cu<4 and/or 1>Cc>3[E] | GP | Poorly graded gravel[F] |
| | | Gravels with Fines more than 12% fines [C] | Fines classify as ML or MH | GM | Silty gravel[F,G,H] |
| | | | Fines classify as CL or CH | GC | Clayey gravel[F,G,H] |
| | Sands 50% or more of coarse fraction passes No. 4 sieve | Clean Sands Less than 5% fines[D] | Cu≥6 and 1≤Cc≤3[E] | SW | Well-graded sand[I] |
| | | | Cu<6 and/or 1>Cc>3[E] | SP | Poorly-graded sand[I] |
| | | Sands with Fines more than 12% fines [D] | Fines classify as ML or MH | SM | Silty sand[G,H,I] |
| | | | Fines classify as CL or CH | SC | Clayey sand[G,H,I] |
| Fine-Grained Soils 50% or more passes the No. 200 sieve (see Plasticity Chart below) | Silts and Clays Liquid limit less than 50 | inorganic | PI>7 and plots on or above "A" line[J] | CL | Lean clay[K,L,M] |
| | | | PI<4 or plots below "A" line[J] | ML | Silt[K,L,M] |
| | | organic | Liquid limit–oven dried / Liquid limit – not dried <0.75 | OL | Organic clay[K,L,M,N] <br> Organic silt[K,L,M,O] |
| | Silts and Clays Liquid limit 50 or more | inorganic | PI plots on or above "A" line | CH | Fat clay[K,L,M] |
| | | | PI plots below "A" line | MH | Elastic silt[K,L,M] |
| | | organic | Liquid limit–oven dried / Liquid limit – not dried <0.75 | OH | Organic clay[K,L,M,P] <br> Organic silt[K,L,M,Q] |
| Highly organic soil | | | Primarily organic matter, dark in color, and organic in odor | PT | Peat[R] |



Plasticity Chart

### Notes

[A]Based on the material passing the 3-in (75-mm) sieve.

[B]If field sample contained cobbles or boulders, or both, add "with cobbles or boulders, or both" to group name.

[C]Gravels with 5 to 12% fines require dual symbols:
- GW-GM well-graded gravel with silt
- GW-GC well-graded gravel with clay
- GP-GM poorly graded gravel with silt
- GP-GC poorly graded gravel with clay

[D]Sands with 5 to 12% fines require dual symbols:
- SW-SM well-graded sand with silt
- SW-SC well-graded sand with clay
- SP-SM poorly graded sand with silt
- SP-SC poorly graded sand with clay

[E]$Cu = D_{60} / D_{10}$, $Cc = \frac{(D_{30})^2}{D_{10} \times D_{60}}$

[F]If soil contains ≥15% sand, add "with sand" to group name.

[G]If fines classify as CL-ML, use dual symbol GC-GM, or SC-SM.

[H]If fines are organic, add "with organic fines" to group name.

[I]If soil contains ≥15% gravel, add "with gravel" to group name.

[J]If Atterberg limits plot is hatched area, soils is a CL-ML silty clay.

[K]If soil contains 15 to 29% plus No. 200 add "with sand" or "with gravel", whichever is predominant.

[L]If soil contains ≥30% plus No. 200, predominantly sand, add "sandy" to group name.

[M]If soil contains ≥30% plus No. 200, predominantly gravel, add "gravelly" to group name.

[N]PI≥4 and plots on or above "A" line.

[O]PI<4 or plots below "A" line.

[P]PI plots on or above "A" line.

[Q]PI plots below "A" line.

[R]Fiber Content description shown below.

## ADDITIONAL TERMINOLOGY NOTES USED BY AET FOR SOIL IDENTIFICATION AND DESCRIPTION

**Grain Size**

| Term | Particle Size |
|---|---|
| Boulders | Over 12" |
| Cobbles | 3" to 12" |
| Gravel | #4 sieve to 3" |
| Sand | #200 to #4 sieve |
| Fines (silt & clay) | Pass #200 sieve |

**Gravel Percentages**

| Term | Percent |
|---|---|
| A Little Gravel | 3% - 14% |
| With Gravel | 15% - 29% |
| Gravelly | 30% - 50% |

**Consistency of Plastic Soils**

| Term | N-Value, BPF |
|---|---|
| Very Soft | less than 2 |
| Soft | 2 - 4 |
| Firm | 5 - 8 |
| Stiff | 9 - 15 |
| Very Stiff | 16 - 30 |
| Hard | Greater than 30 |

**Relative Density of Non-Plastic Soils**

| Term | N-Value, BPF |
|---|---|
| Very Loose | 0 - 4 |
| Loose | 5 - 10 |
| Medium Dense | 11 - 30 |
| Dense | 31 - 50 |
| Very Dense | Greater than 50 |

**Moisture/Frost Condition** (MC Column)

- D (Dry): Absense of moisture, dusty, dry to touch.
- M (Moist): Damp, although free water not visible. Soil may still have a high water content (over "optimum").
- W (Wet/ Waterbearing): Free water visible intended to describe non-plastic soils. Waterbearing usually relates to sands and sand with silt.
- F (Frozen): Soil frozen

**Layering Notes**

- Laminations: Layers less than ½" thick of differing material or color.
- Lenses: Pockets or layers greater than ½" thick of differing material or color.

**Peat Description**

| Term | Fiber Content (Visual Estimate) |
|---|---|
| Fibric Peat: | Greater than 67% |
| Hemic Peat: | 33 – 67% |
| Sapric Peat: | Less than 33% |

**Organic Description (if no lab tests)**

Soils are described as *organic*, if soil is not peat and is judged to have sufficient organic fines content to influence the Liquid Limit properties. *Slightly organic* used for borderline cases.

**Root Inclusions**

- With roots: Judged to have sufficient quantity of roots to influence the soil properties.
- Trace roots: Small roots present, but not judged to be in sufficient quantity to significantly affect soil properties.

# Appendix B

# Afton Levee



PROJECT IDENTIFICATION

| | |
|---|---|
| Title: | Afton Levee |
| Project Number: | 01-05376 - |
| Client: | City of Afton |
| Designer: | J. RUDD |
| Station Number: | Limiting |

**Description:**
Landside Slope Stability; Case I End of Construction

**Company's information:**

| | |
|---|---|
| Name: | AMERICAN ENGINEERING TESTING, INC. |
| Street: | 550 CLEVELAND AVENUE NORTH<br>ST. PAUL, MN 55114 |
| Telephone #: | |
| Fax #: | |
| E-Mail: | |

**Original file path and name:** Z:\Data\AC ..... 1-05376 afton levee\ReSSA\LandsideSlope-Case I.MSE
**Original date and time of creating this file:** Tue Jul 31 13:38:55 2012

PROGRAM MODE: Analysis of a General Slope using NO reinforcement material.

## INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

### SOIL DATA

| ========== Soil Layer #: ========== | Unit weight, γ [lb/ft ³] | Internal angle of friction, ϕ [deg.] | Cohesion, c [lb/ft ²] |
|---|---|---|---|
| ....1......Sand Fill............................................... | 125.0 | 30.0 | 0.0 |
| ....2......Surface Blanket - Zone A..................... | 130.0 | 0.0 | 666.0 |
| ....3......Surface Blanket - Zone B..................... | 130.0 | 0.0 | 856.0 |
| ....4......Surface Blanket - Zone C..................... | 130.0 | 0.0 | 1235.0 |
| ....5......Coarse Alluvium.................................. | 125.0 | 35.0 | 0.0 |

### REINFORCEMENT

Analysis of slope WITHOUT reinforcement.

### WATER

Water is not present

### SEISMICITY

Not Applicable

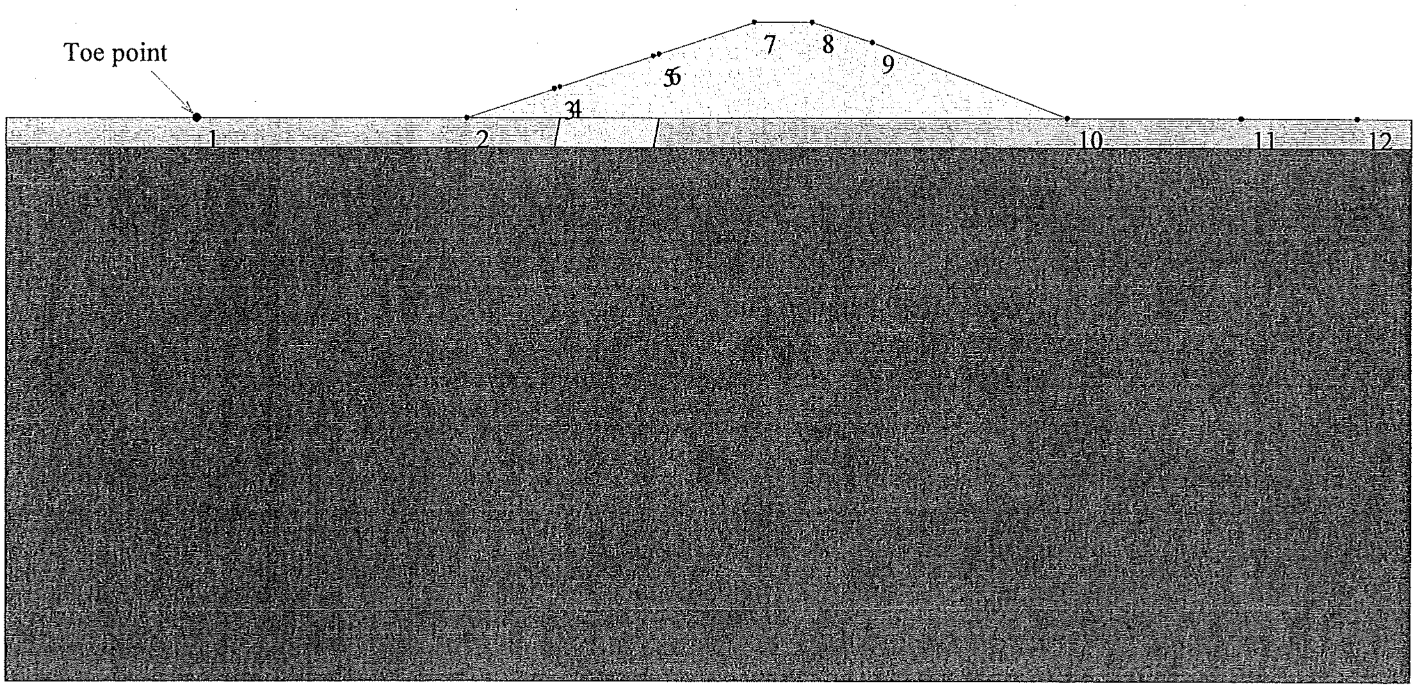
DRAWING OF SPECIFIED GEOMETRY - COMPLEX - Quick Input

-- Problem geometry is defined along sections selected by user at x,y coordinates.
-- X1,Y1 represents the coordinates of soil surface. X2,Y2 represent the coordinates of the end of soil layer 1 and start of soil layer 2, and so on.

GEOMETRY
Soil profile contains 5 layers (see details in next page)

UNIFORM SURCHARGE
Surcharge load, Q1.....................................None
Surcharge load, Q2.....................................None
Surcharge load, Q3.....................................None

STRIP LOAD
............................None...................................




SCALE:

0246 [ft]

## TABULATED DETAILS OF QUICK SPECIFIED GEOMETRY

Soil profile contains 5 layers. Coordinates in [ft.]

| | # | Xi | Yi |
|---|---|---|---|
| Top of Layer 1 | 1 | 0.00 | 80.00 |
| | 2 | 46.50 | 80.00 |
| | 3 | 96.00 | 96.50 |
| | 4 | 106.00 | 96.50 |
| | 5 | 116.50 | 93.00 |
| | 6 | 150.00 | 80.00 |
| | 7 | 180.00 | 80.00 |
| Top of Layer 2 | 8 | 0.00 | 80.00 |
| | 9 | 46.50 | 80.00 |
| | 10 | 180.00 | 80.00 |
| Top of Layer 3 | 11 | 0.00 | 75.00 |
| | 12 | 61.50 | 75.00 |
| | 13 | 62.50 | 80.00 |
| | 14 | 200.00 | 80.00 |
| Top of Layer 4 | 15 | 0.00 | 75.00 |
| | 16 | 78.50 | 75.00 |
| | 17 | 79.50 | 80.00 |
| Top of Layer 5 | 18 | 0.00 | 75.00 |
| | 19 | 180.00 | 75.00 |

## TABULATED DETAILS OF SPECIFIED GEOMETRY

Soil profile contains 5 layers. Coordinates in [ft.]

| # | X | Y1 | Y2 | Y3 | Y4 | Y5 |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 80.00 | 80.00 | 75.00 | 75.00 | 75.00 |
| 2 | 46.50 | 80.00 | 80.00 | 75.00 | 75.00 | 75.00 |
| 3 | 61.50 | 85.00 | 80.00 | 75.00 | 75.00 | 75.00 |
| 4 | 62.50 | 85.33 | 80.00 | 80.00 | 75.00 | 75.00 |
| 5 | 78.50 | 90.67 | 80.00 | 80.00 | 75.00 | 75.00 |
| 6 | 79.50 | 91.00 | 80.00 | 80.00 | 80.00 | 75.00 |
| 7 | 96.00 | 96.50 | 80.00 | 80.00 | 80.00 | 75.00 |
| 8 | 106.00 | 96.50 | 80.00 | 80.00 | 80.00 | 75.00 |
| 9 | 116.50 | 93.00 | 80.00 | 80.00 | 80.00 | 75.00 |
| 10 | 150.00 | 80.00 | 80.00 | 80.00 | 80.00 | 75.00 |
| 11 | 180.00 | 80.00 | 80.00 | 80.00 | 80.00 | 75.00 |
| 12 | 200.00 | 80.00 | 80.00 | 80.00 | 80.00 | 75.00 |

## RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

**Critical circles for each entry point (considering all specified exit points)**

| Entry Point # | Entry Point (X, Y) [ft] | | Exit Point (X, Y) [ft] | | Critical Circle (Xc, Yc, R) [ft] | | | Fs | STATUS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 106.70 | 96.27 | 47.69 | 80.43 | 32.61 | 254.55 | 174.77 | 2.04 | On extreme X-entry |
| 2 | 109.83 | 95.22 | 47.42 | 80.44 | 45.25 | 228.74 | 148.32 | 2.25 | |
| 3 | 112.96 | 94.18 | 47.44 | 80.46 | 52.67 | 218.81 | 138.45 | 2.51 | |
| 4 | 116.09 | 93.14 | 47.22 | 80.49 | 57.49 | 218.44 | 138.33 | 2.82 | |
| 5 | 119.22 | 91.94 | 47.40 | 80.48 | 58.92 | 238.97 | 158.91 | 3.22 | |
| 6 | 122.35 | 90.73 | 47.51 | 80.47 | 60.61 | 263.04 | 183.04 | 3.74 | |
| 7 | 125.48 | 89.51 | 47.24 | 80.48 | 60.03 | 313.01 | 232.88 | 4.44 | |
| 8 | 128.61 | 88.30 | 41.28 | 80.00 | 74.37 | 195.40 | 120.05 | 5.14 | |
| 9 | 131.74 | 87.09 | 27.29 | 80.22 | 68.99 | 243.76 | 168.77 | 5.96 | |
| 10 | 134.87 | 85.87 | 33.82 | 80.23 | 75.40 | 243.17 | 168.16 | 6.96 | |
| 11 | 138.00 | 84.66 | 8.13 | 80.19 | 69.22 | 194.23 | 129.37 | 8.15 | |

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

*************************

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

**Critical circles for each exit point (considering all specified entry points)**

| Exit Point # | Exit Point (X, Y) [ft] | | Entry Point (X, Y) [ft] | | Critical Circle (Xc, Yc, R) [ft] | | | Fs | STATUS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | -11.96 | 80.28 | 109.83 | 95.22 | 34.49 | 205.52 | 133.58 | 4.50 | |
| 2 | -4.68 | 80.01 | 109.83 | 95.22 | 37.38 | 202.04 | 129.07 | 4.21 | |
| 3 | 1.55 | 80.14 | 109.83 | 95.22 | 41.58 | 188.96 | 115.96 | 3.95 | |
| 4 | 8.22 | 80.11 | 106.70 | 96.27 | 44.27 | 168.58 | 95.54 | 3.70 | |
| 5 | 14.85 | 80.08 | 106.70 | 96.27 | 47.89 | 161.30 | 87.69 | 3.48 | |
| 6 | 21.10 | 80.22 | 106.70 | 96.27 | 52.01 | 151.65 | 77.83 | 3.29 | |
| 7 | 28.04 | 80.05 | 106.70 | 96.27 | 56.11 | 142.78 | 68.73 | 3.16 | |
| 8 | 34.11 | 80.25 | 106.70 | 96.27 | 58.98 | 140.05 | 64.76 | 3.00 | |
| 9 | 40.68 | 80.01 | 109.83 | 95.22 | 43.90 | 230.17 | 150.19 | 2.61 | |
| 10 | 47.69 | 80.43 | 106.70 | 96.27 | 32.61 | 254.55 | 174.77 | 2.04 | OK |
| 11 | 54.10 | 82.61 | 106.70 | 96.27 | 44.16 | 229.08 | 146.80 | 2.10 | |

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 2.04

Critical Circle: Xc = 32.61[ft], Yc = 254.55[ft], R = 174.77[ft]. (Number of slices used = 53 )

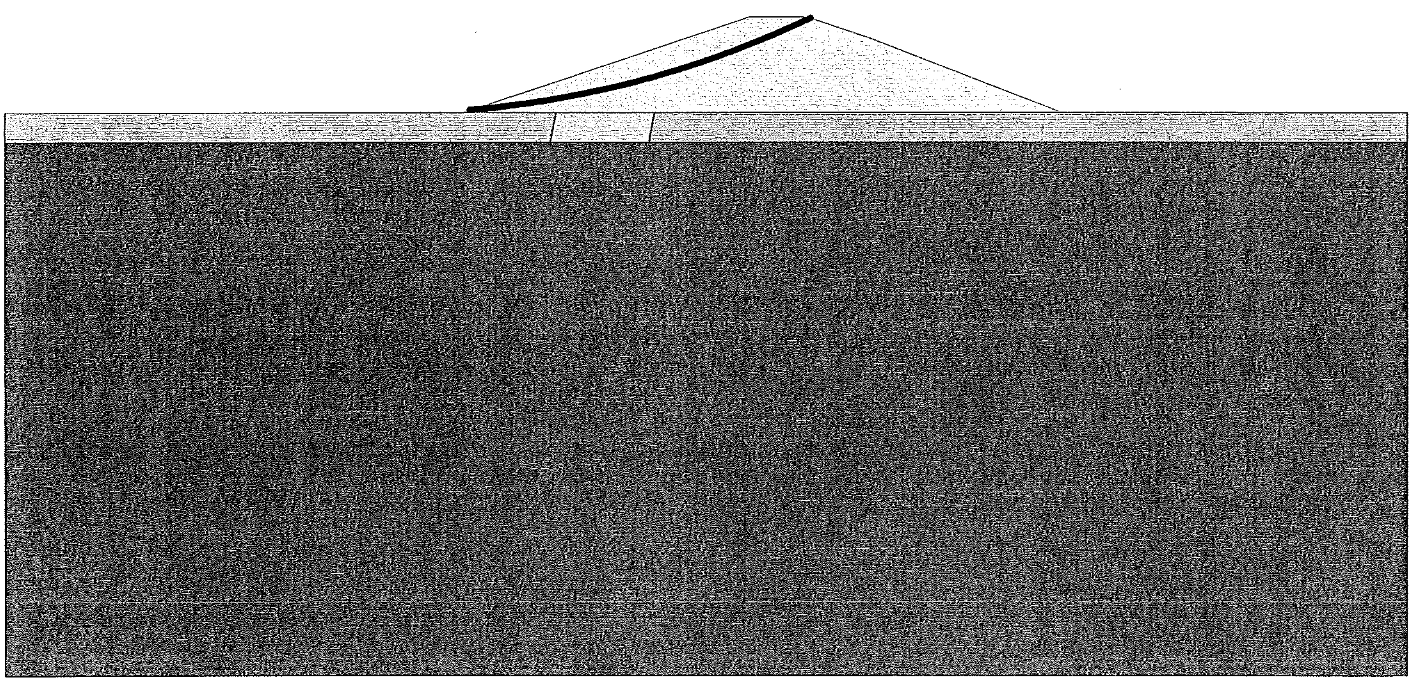
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

NOT CONDUCTED

Three-Part Wedge Stability Analysis

NOT CONDUCTED

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0246[ft]

# Afton Levee

Report created by ReSSA(3.0): Copyright (c) 2001-2008, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

| | |
|---|---|
| Title: | Afton Levee |
| Project Number: | 01-05376 - |
| Client: | City of Afton |
| Designer: | J. RUDD |
| Station Number: | Limiting |

**Description:**
Landside Slope Stability; Case II Rapid Drawdown

**Company's information:**

| | |
|---|---|
| Name: | AMERICAN ENGINEERING TESTING, INC. |
| Street: | 550 CLEVELAND AVENUE NORTH<br>ST. PAUL, MN 55114 |
| Telephone #: | |
| Fax #: | |
| E-Mail: | |

**Original file path and name:** Z:\Data\AC ..... afton levee\ReSSA\RiversideSlope-RapidDrawdown.MSE
**Original date and time of creating this file:** Tue Jul 31 13:38:55 2012

PROGRAM MODE: Analysis of a General Slope using NO reinforcement material.

INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

SOIL DATA

| =========== Soil Layer #: =========== | Unit weight, γ [lb/ft³] | Internal angle of friction, ϕ [deg.] | Cohesion, c [lb/ft²] |
|---|---|---|---|
| ....1.......Sand Fill................................................ | 125.0 | 30.0 | 0.0 |
| ....2.......Surface Blanket - Zone A...................... | 130.0 | 0.0 | 500.0 |
| ....3.......Surface Blanket - Zone B...................... | 130.0 | 0.0 | 500.0 |
| ....4.......Surface Blanket - Zone C...................... | 130.0 | 0.0 | 1000.0 |
| ....5.......Coarse Alluvium.................................. | 125.0 | 35.0 | 0.0 |

REINFORCEMENT

Analysis of slope WITHOUT reinforcement.

WATER

Water is not present

SEISMICITY

Not Applicable

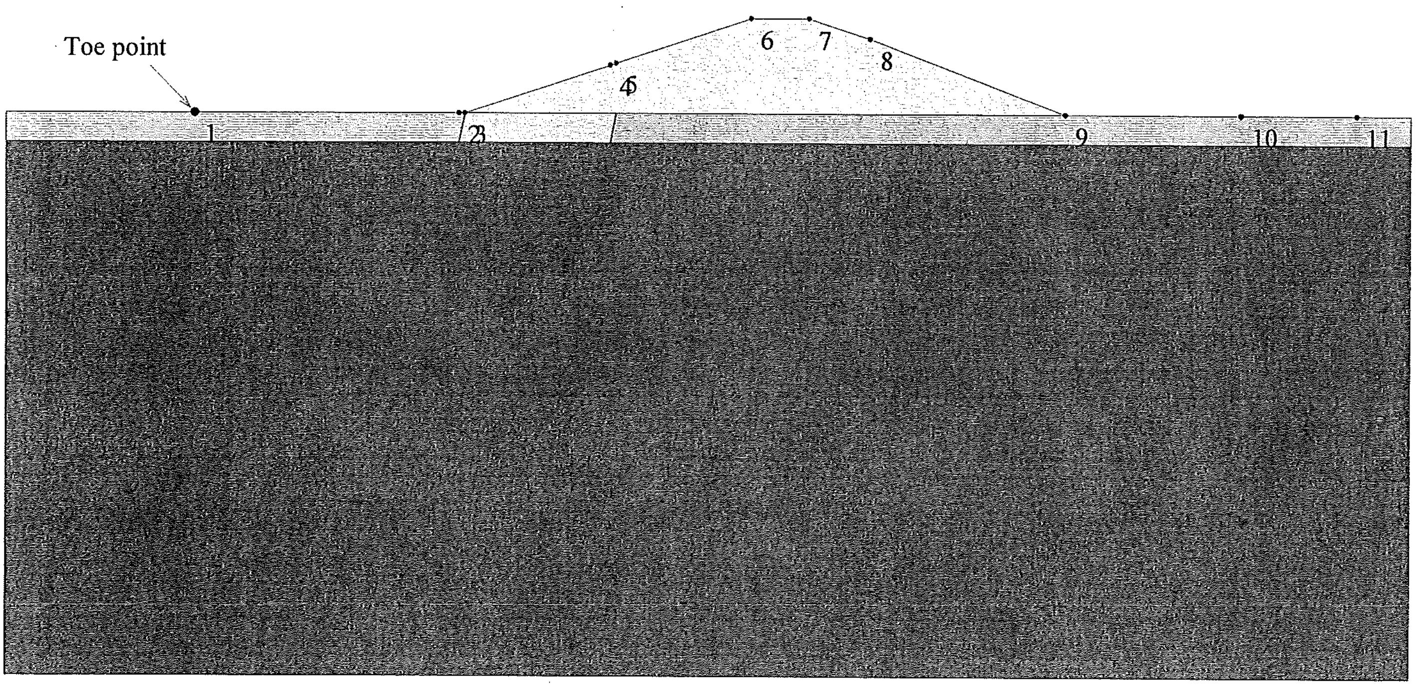
DRAWING OF SPECIFIED GEOMETRY - COMPLEX - Quick Input

-- Problem geometry is defined along sections selected by user at x,y coordinates.
-- X1,Y1 represents the coordinates of soil surface. X2,Y2 represent the coordinates of the end of soil layer 1 and start of soil layer 2, and so on.

GEOMETRY
Soil profile contains 5 layers (see details in next page)

UNIFORM SURCHARGE
Surcharge load, Q1....................................None
Surcharge load, Q2....................................None
Surcharge load, Q3....................................None

STRIP LOAD
...........................None..................................




SCALE:

0246 [ft]

## TABULATED DETAILS OF QUICK SPECIFIED GEOMETRY

Soil profile contains 5 layers. Coordinates in [ft.]

| | # | Xi | Yi |
|---|---|---|---|
| Top of Layer 1 | 1 | 0.00 | 80.00 |
| | 2 | 46.50 | 80.00 |
| | 3 | 96.00 | 96.50 |
| | 4 | 106.00 | 96.50 |
| | 5 | 116.50 | 93.00 |
| | 6 | 150.00 | 80.00 |
| | 7 | 180.00 | 80.00 |
| Top of Layer 2 | 8 | 0.00 | 80.00 |
| | 9 | 46.50 | 80.00 |
| | 10 | 180.00 | 80.00 |
| Top of Layer 3 | 11 | 0.00 | 75.00 |
| | 12 | 45.50 | 75.00 |
| | 13 | 46.50 | 80.00 |
| | 14 | 200.00 | 80.00 |
| Top of Layer 4 | 15 | 0.00 | 75.00 |
| | 16 | 71.50 | 75.00 |
| | 17 | 72.50 | 80.00 |
| Top of Layer 5 | 18 | 0.00 | 75.00 |
| | 19 | 180.00 | 75.00 |

## TABULATED DETAILS OF SPECIFIED GEOMETRY

Soil profile contains 5 layers. Coordinates in [ft.]

| # | X | Y1 | Y2 | Y3 | Y4 | Y5 |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 80.00 | 80.00 | 75.00 | 75.00 | 75.00 |
| 2 | 45.50 | 80.00 | 80.00 | 75.00 | 75.00 | 75.00 |
| 3 | 46.50 | 80.00 | 80.00 | 80.00 | 75.00 | 75.00 |
| 4 | 71.50 | 88.33 | 80.00 | 80.00 | 75.00 | 75.00 |
| 5 | 72.50 | 88.67 | 80.00 | 80.00 | 80.00 | 75.00 |
| 6 | 96.00 | 96.50 | 80.00 | 80.00 | 80.00 | 75.00 |
| 7 | 106.00 | 96.50 | 80.00 | 80.00 | 80.00 | 75.00 |
| 8 | 116.50 | 93.00 | 80.00 | 80.00 | 80.00 | 75.00 |
| 9 | 150.00 | 80.00 | 80.00 | 80.00 | 80.00 | 75.00 |
| 10 | 180.00 | 80.00 | 80.00 | 80.00 | 80.00 | 75.00 |
| 11 | 200.00 | 80.00 | 80.00 | 80.00 | 80.00 | 75.00 |

## RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

**Critical circles for each entry point (considering all specified exit points)**

| Entry Point # | Entry Point (X, Y) [ft] | | Exit Point (X, Y) [ft] | | Critical Circle (Xc, Yc, R) [ft] | | | Fs | STATUS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 106.70 | 96.27 | 47.50 | 80.42 | 32.61 | 254.55 | 174.77 | 2.04 | On extreme X-entry |
| 2 | 109.83 | 95.22 | 47.50 | 80.44 | 45.25 | 228.74 | 148.32 | 2.25 | |
| 3 | 112.96 | 94.18 | 47.44 | 80.46 | 52.67 | 218.81 | 138.45 | 2.51 | |
| 4 | 116.09 | 93.14 | 40.68 | 80.23 | 67.74 | 148.92 | 73.83 | 2.81 | |
| 5 | 119.22 | 91.94 | 40.73 | 80.20 | 69.35 | 157.12 | 82.07 | 3.03 | |
| 6 | 122.35 | 90.73 | 40.79 | 80.17 | 71.07 | 166.53 | 91.51 | 3.32 | |
| 7 | 125.48 | 89.51 | 40.85 | 80.14 | 72.92 | 177.37 | 102.38 | 3.74 | |
| 8 | 128.61 | 88.30 | 40.90 | 80.12 | 74.89 | 189.94 | 114.96 | 4.28 | |
| 9 | 131.74 | 87.09 | 34.17 | 80.14 | 72.44 | 231.29 | 155.92 | 4.94 | |
| 10 | 134.87 | 85.87 | 34.31 | 80.10 | 75.40 | 243.17 | 168.16 | 5.70 | |
| 11 | 138.00 | 84.66 | 27.16 | 80.21 | 74.03 | 295.80 | 220.62 | 6.96 | |

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

*************************

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

**Critical circles for each exit point (considering all specified entry points)**

| Exit Point # | Exit Point (X, Y) [ft] | | Entry Point (X, Y) [ft] | | Critical Circle (Xc, Yc, R) [ft] | | | Fs | STATUS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | -11.93 | 80.21 | 109.83 | 95.22 | 31.53 | 229.02 | 155.03 | 4.08 | |
| 2 | -4.67 | 80.01 | 109.83 | 95.22 | 35.95 | 212.77 | 138.84 | 3.80 | |
| 3 | 1.15 | 80.25 | 106.70 | 96.27 | 38.23 | 191.74 | 117.49 | 3.54 | |
| 4 | 7.92 | 80.18 | 106.70 | 96.27 | 41.90 | 182.87 | 108.16 | 3.29 | |
| 5 | 14.12 | 80.32 | 106.70 | 96.27 | 46.24 | 170.60 | 95.82 | 3.06 | |
| 6 | 21.20 | 80.15 | 106.70 | 96.27 | 50.52 | 159.46 | 84.56 | 2.88 | |
| 7 | 27.70 | 80.18 | 106.70 | 96.27 | 54.76 | 149.30 | 74.24 | 2.67 | |
| 8 | 34.58 | 80.06 | 106.70 | 96.27 | 58.98 | 140.05 | 64.76 | 2.53 | |
| 9 | 41.20 | 80.04 | 106.70 | 96.27 | 63.57 | 130.06 | 54.80 | 2.44 | |
| 10 | 47.50 | 80.42 | 106.70 | 96.27 | 32.61 | 254.55 | 174.77 | 2.04 | OK |
| 11 | 53.93 | 82.60 | 106.70 | 96.27 | 44.16 | 229.08 | 146.80 | 2.10 | |

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 2.04

Critical Circle: Xc = 32.61[ft], Yc = 254.55[ft], R = 174.77[ft]. (Number of slices used = 52 )

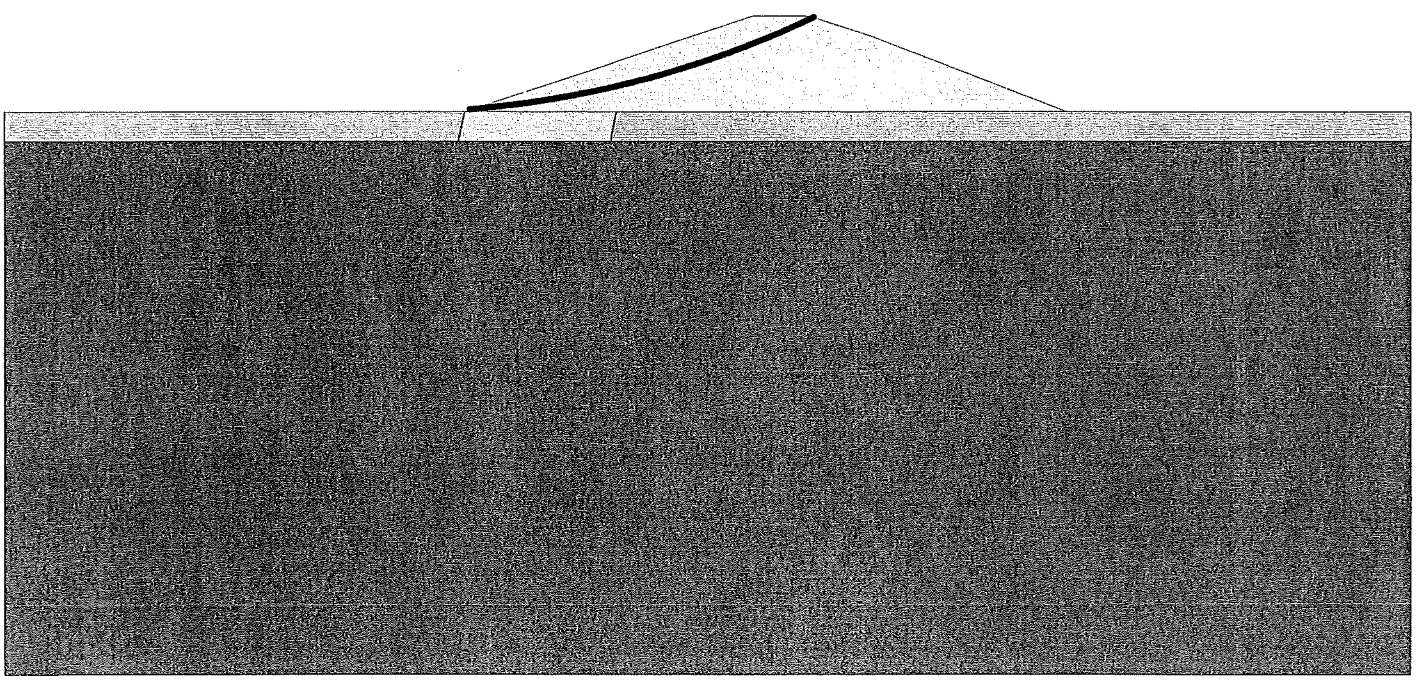
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

NOT CONDUCTED

Three-Part Wedge Stability Analysis

NOT CONDUCTED

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0246[ft]

# Afton Levee

Report created by ReSSA(3.0): Copyright (c) 2001-2008, ADAMA Engineering, Inc.

PROJECT IDENTIFICATION

| | |
|---|---|
| Title: | Afton Levee |
| Project Number: | 01-05376 - |
| Client: | City of Afton |
| Designer: | J. RUDD |
| Station Number: | Limiting |

**Description:**
Landside Slope Stability; Case III Steady Seepage

**Company's information:**

| | |
|---|---|
| Name: | AMERICAN ENGINEERING TESTING, INC. |
| Street: | 550 CLEVELAND AVENUE NORTH<br>ST. PAUL, MN 55114 |
| Telephone #: | |
| Fax #: | |
| E-Mail: | |

**Original file path and name:** Z:\Data\AC ..... 05376 afton levee\ReSSA\LandsideSlope-Case III.MSE
**Original date and time of creating this file:** Tue Jul 31 13:38:55 2012

PROGRAM MODE: Analysis of a General Slope using NO reinforcement material.

## INPUT DATA (EXCLUDING REINFORCEMENT LAYOUT)

### SOIL DATA

| ========== Soil Layer #: ========== | Unit weight, γ [lb/ft ³] | Internal angle of friction, ϕ [deg.] | Cohesion, c [lb/ft ²] |
|---|---|---|---|
| ....1......Sand Fill.............................................. | 125.0 | 30.0 | 0.0 |
| ....2......Surface Blanket - Zone A..................... | 130.0 | 27.0 | 500.0 |
| ....3......Surface Blanket - Zone B..................... | 130.0 | 27.0 | 500.0 |
| ....4......Surface Blanket - Zone C..................... | 130.0 | 27.0 | 500.0 |
| ....5......Coarse Alluvium................................. | 125.0 | 35.0 | 0.0 |

### REINFORCEMENT

Analysis of slope WITHOUT reinforcement.

### WATER

Unit weight of water = 62.45 [lb/ft ³]
Water pressure is defined by phreatic surface in Effective Stress Analysis.

### SEISMICITY

Not Applicable

DRAWING OF SPECIFIED GEOMETRY - COMPLEX - Quick Input

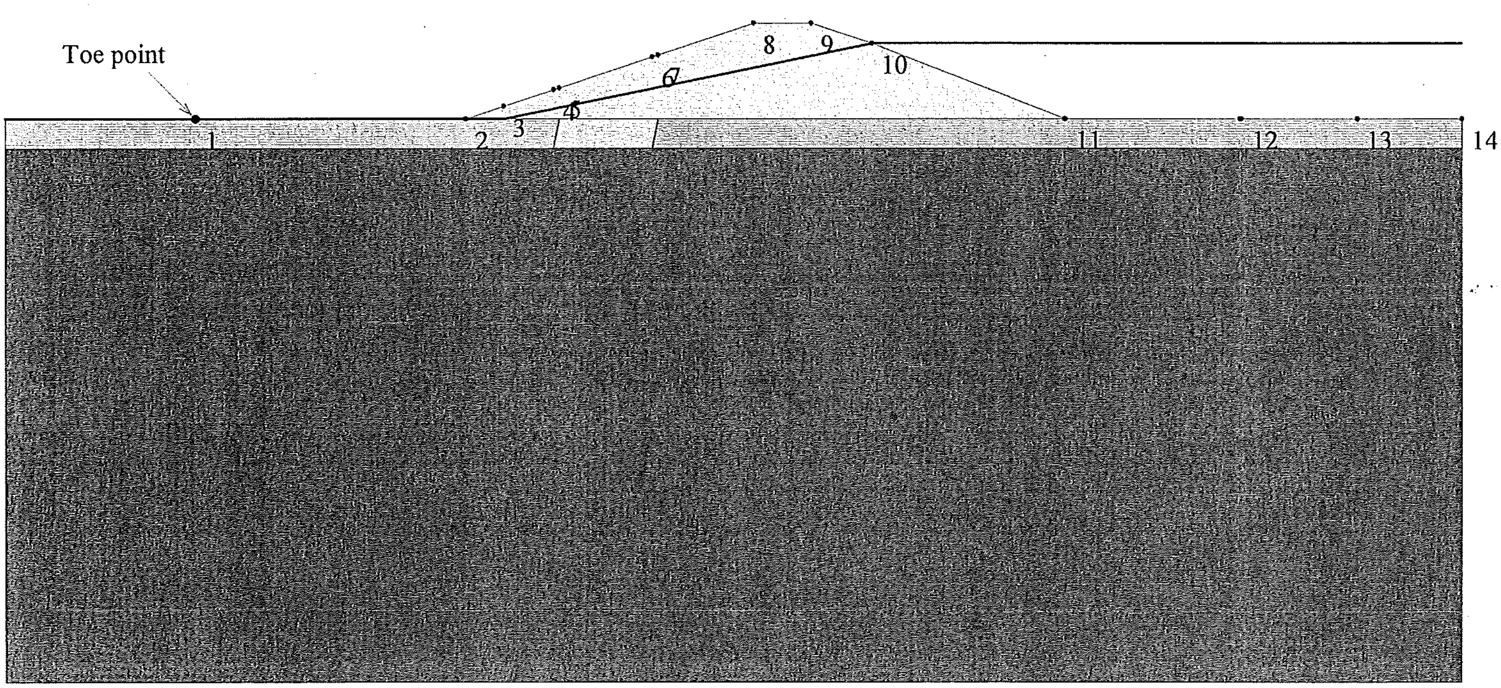
-- Problem geometry is defined along sections selected by user at x,y coordinates.
-- X1,Y1 represents the coordinates of soil surface. X2,Y2 represent the coordinates of the end of soil layer 1 and start of soil layer 2, and so on.
-- Xw,Yw represents the coordinates of phreatic surface.

GEOMETRY
Soil profile contains 5 layers (see details in next page)

WATER GEOMETRY
Phreatic line was specified.

UNIFORM SURCHARGE
Surcharge load, Q1 ....................................None
Surcharge load, Q2 ....................................None
Surcharge load, Q3 ....................................None

STRIP LOAD
...........................None..................................




SCALE:

0246 [ft]

## TABULATED DETAILS OF QUICK SPECIFIED GEOMETRY

Soil profile contains 5 layers. Coordinates in [ft.]
Water was described by phreatic line.

| | # | Xi | Yi |
|---|---|---|---|
| Top of Layer 1 | 1 | 0.00 | 80.00 |
| | 2 | 46.50 | 80.00 |
| | 3 | 96.00 | 96.50 |
| | 4 | 106.00 | 96.50 |
| | 5 | 116.50 | 93.00 |
| | 6 | 150.00 | 80.00 |
| | 7 | 180.00 | 80.00 |
| Top of Layer 2 | 8 | 0.00 | 80.00 |
| | 9 | 46.50 | 80.00 |
| | 10 | 180.00 | 80.00 |
| Top of Layer 3 | 11 | 0.00 | 75.00 |
| | 12 | 61.50 | 75.00 |
| | 13 | 62.50 | 80.00 |
| | 14 | 200.00 | 80.00 |
| Top of Layer 4 | 15 | 0.00 | 75.00 |
| | 16 | 78.50 | 75.00 |
| | 17 | 79.50 | 80.00 |
| Top of Layer 5 | 18 | 0.00 | 75.00 |
| | 19 | 180.00 | 75.00 |
| Top of Phreatic Line | 21 | 0.00 | 80.00 |
| | 22 | 53.00 | 80.00 |
| | 23 | 116.50 | 93.00 |
| | 24 | 218.00 | 93.00 |

## TABULATED DETAILS OF SPECIFIED GEOMETRY

Soil profile contains 5 layers. Coordinates in [ft.]
Water was described by phreatic line. Y values are tabulated in the right most column.

| # | X | Y1 | Y2 | Y3 | Y4 | Y5 | (phreatic) Yw |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 80.00 | 80.00 | 75.00 | 75.00 | 75.00 | 80.00 |
| 2 | 46.50 | 80.00 | 80.00 | 75.00 | 75.00 | 75.00 | 80.00 |
| 3 | 53.00 | 82.17 | 80.00 | 75.00 | 75.00 | 75.00 | 80.00 |
| 4 | 61.50 | 85.00 | 80.00 | 75.00 | 75.00 | 75.00 | 81.74 |
| 5 | 62.50 | 85.33 | 80.00 | 80.00 | 75.00 | 75.00 | 81.94 |
| 6 | 78.50 | 90.67 | 80.00 | 80.00 | 75.00 | 75.00 | 85.22 |
| 7 | 79.50 | 91.00 | 80.00 | 80.00 | 80.00 | 75.00 | 85.43 |
| 8 | 96.00 | 96.50 | 80.00 | 80.00 | 80.00 | 75.00 | 88.80 |
| 9 | 106.00 | 96.50 | 80.00 | 80.00 | 80.00 | 75.00 | 90.85 |
| 10 | 116.50 | 93.00 | 80.00 | 80.00 | 80.00 | 75.00 | 93.00 |
| 11 | 150.00 | 80.00 | 80.00 | 80.00 | 80.00 | 75.00 | 93.00 |
| 12 | 180.00 | 80.00 | 80.00 | 80.00 | 80.00 | 75.00 | 93.00 |
| 13 | 200.00 | 80.00 | 80.00 | 80.00 | 80.00 | 75.00 | 93.00 |
| 14 | 218.00 | 80.00 | 80.00 | 80.00 | 80.00 | 75.00 | 93.00 |

## RESULTS OF ROTATIONAL STABILITY ANALYSIS

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

**Critical circles for each entry point (considering all specified exit points)**

| Entry Point # | Entry Point (X , Y) [ft] | | Exit Point (X , Y) [ft] | | Critical Circle (Xc , Yc , R) [ft] | | | Fs | STATUS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 106.70 | 96.27 | 50.29 | 81.54 | 64.11 | 144.04 | 64.01 | 1.89 | On extreme X-entry |
| 2 | 109.83 | 95.22 | 50.32 | 81.53 | 64.94 | 154.17 | 74.09 | 2.01 | |
| 3 | 112.96 | 94.18 | 50.34 | 81.52 | 65.77 | 166.36 | 86.24 | 2.18 | |
| 4 | 116.09 | 93.14 | 50.37 | 81.50 | 66.61 | 181.24 | 101.05 | 2.38 | |
| 5 | 119.22 | 91.94 | 50.40 | 81.50 | 68.58 | 193.67 | 113.64 | 2.62 | |
| 6 | 122.35 | 90.73 | 50.42 | 81.49 | 69.70 | 215.94 | 135.83 | 2.92 | |
| 7 | 125.48 | 89.51 | 19.23 | 80.36 | 66.36 | 154.51 | 87.86 | 3.21 | |
| 8 | 128.61 | 88.30 | 19.51 | 80.19 | 68.77 | 155.41 | 89.91 | 3.43 | |
| 9 | 131.74 | 87.09 | 13.52 | 80.05 | 67.69 | 166.56 | 102.07 | 3.66 | |
| 10 | 134.87 | 85.87 | 12.84 | 80.52 | 70.31 | 164.07 | 101.41 | 3.91 | |
| 11 | 138.00 | 84.66 | 6.77 | 80.41 | 69.38 | 175.44 | 113.80 | 4.17 | |

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-entry' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

*************************

Results in the tables below represent critical circles identified between specified points on entry and exit. (Theta-exit set to 50.00 deg.) The most critical circle is obtained from a search considering all the combinations of input entry and exit points.

**Critical circles for each exit point (considering all specified entry points)**

| Exit Point # | Exit Point (X , Y) [ft] | | Entry Point (X , Y) [ft] | | Critical Circle (Xc , Yc , R) [ft] | | | Fs | STATUS |
|---|---|---|---|---|---|---|---|---|---|
| 1 | -11.34 | 80.08 | 112.96 | 94.18 | 41.31 | 170.94 | 105.01 | 3.16 | |
| 2 | -5.31 | 80.19 | 109.83 | 95.22 | 42.87 | 159.66 | 92.94 | 3.01 | |
| 3 | 0.61 | 80.36 | 109.83 | 95.22 | 46.11 | 154.74 | 87.20 | 2.87 | |
| 4 | 6.73 | 80.42 | 109.83 | 95.22 | 49.69 | 147.68 | 79.80 | 2.75 | |
| 5 | 13.59 | 80.01 | 106.70 | 96.27 | 51.40 | 138.21 | 69.41 | 2.65 | |
| 6 | 19.63 | 80.12 | 106.70 | 96.27 | 55.00 | 132.19 | 62.96 | 2.56 | |
| 7 | 25.49 | 80.34 | 106.70 | 96.27 | 58.33 | 127.93 | 57.82 | 2.49 | |
| 8 | 32.05 | 80.10 | 106.70 | 96.27 | 61.68 | 123.71 | 52.73 | 2.47 | |
| 9 | 37.83 | 80.40 | 106.70 | 96.27 | 65.33 | 118.46 | 46.95 | 2.50 | |
| 10 | 46.16 | 80.06 | 106.70 | 96.27 | 39.50 | 226.18 | 146.27 | 2.01 | |
| 11 | 50.29 | 81.54 | 106.70 | 96.27 | 64.11 | 144.04 | 64.01 | 1.89 | On extreme X-exit |

Note: In the 'Status' column, OK means the critical circle was identified within the specified search domain. 'On extreme X-exit' means that the critical result is on the edge of the search domain; a lower Fs may result if the search domain is expanded.

CRITICAL RESULTS OF ROTATIONAL AND TRANSLATIONAL STABILITY ANALYSES

Rotational (Circular Arc; Bishop) Stability Analysis

Minimum Factor of Safety = 1.89

Critical Circle: Xc = 64.11[ft], Yc = 144.04[ft], R = 64.01[ft]. (Number of slices used = 54 )

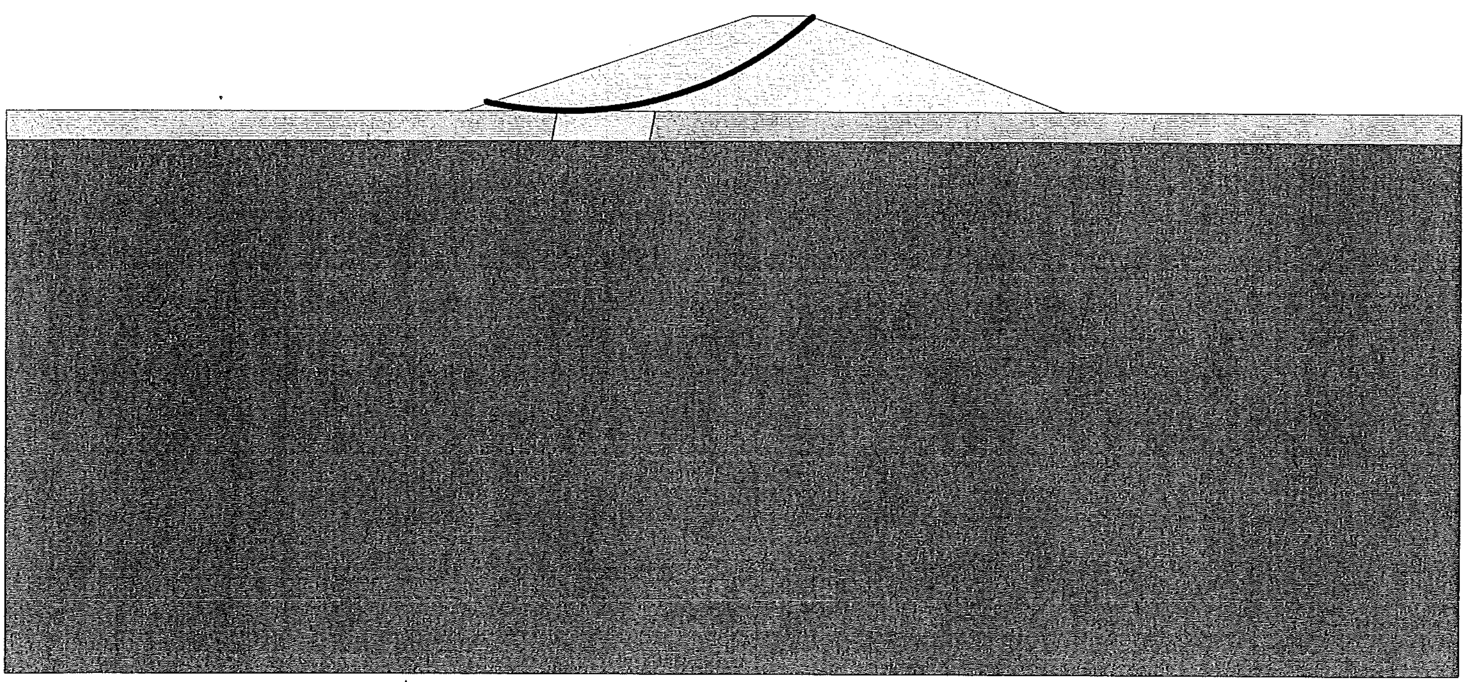
Translational (2-Part Wedge; Spencer), Direct Sliding, Stability Analysis

NOT CONDUCTED

Three-Part Wedge Stability Analysis

NOT CONDUCTED

REINFORCEMENT LAYOUT: DRAWING



SCALE:

0246 [ft]

# Afton Levee

**Report created by FoSSA(2.0): Copyright (c) 2003-2007, ADAMA Engineering, Inc.**

## PROJECT IDENTIFICATION

| | |
|---|---|
| Title: | Afton Levee |
| Project Number: | 01-5376 - |
| Client: | City of Afton |
| Designer: | J. Rudd |
| Station Number: | Composite |

**Description:**

Long Term settlement due to 5 foot grade raise.

**Company's information:**

| | |
|---|---|
| Name: | AMERICAN ENGINEERING TESTING, INC. |
| Street: | 550 CLEVELAND AVENUE NORTH |
| | ST. PAUL, MN 55114 |
| Telephone #: | |
| Fax #: | |
| E-Mail: | |

**Original file path and name:**
**Original date and time of creating this file:** Mon Aug 06 12:19:57 2012

**GEOMETRY:** Analysis of a 2D geometry

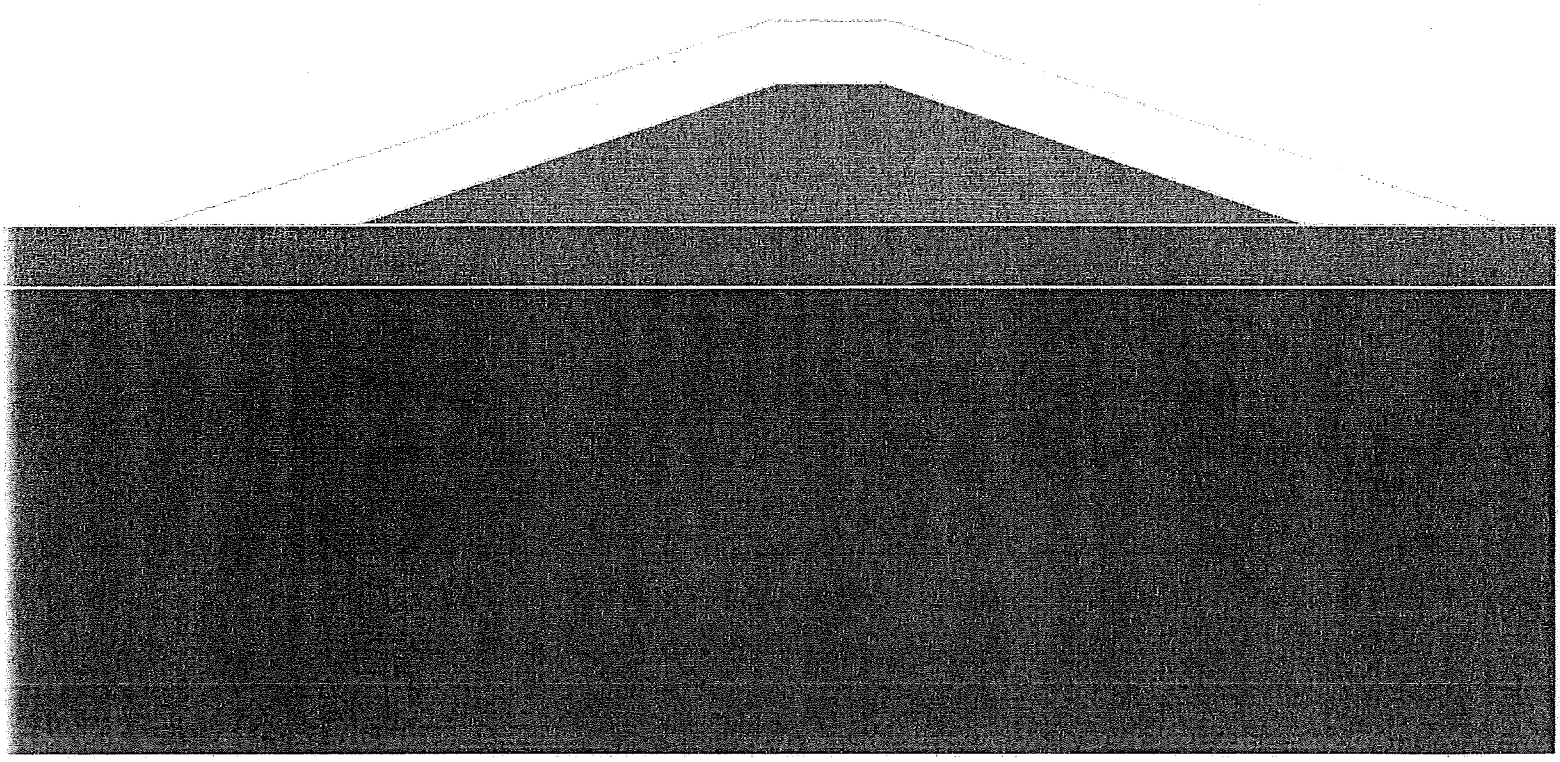
## INPUT DATA – FOUNDATION LAYERS – 3 layers

| | Wet Unit Weight, γ [lb/ft³] | Poisson's Ratio μ | Description of Soil |
|---|---|---|---|
| 1 | 125.00 | 0.33 | Existing Levee Fill |
| 2 | 130.00 | 0.45 | Surface Blanket |
| 3 | 125.00 | 0.33 | Coarse Alluvium |

## INPUT DATA – EMBANKMENT LAYERS – 1 layers

| | Wet Unit Weight, γ [lb/ft³] | Description of Soil |
|---|---|---|
| 1 | 125.00 | |

## DRAWING OF SPECIFIED GEOMETRY



## INPUT DATA FOR CONSOLIDATION -- $\alpha = 1/2$

| Layer # | Underging Consolidation [Yes/No] | OCR = Pc / Po | Cc | Cr | e0 | Cv [ft $^2$/day] | Drains at : |
|---|---|---|---|---|---|---|---|
| 1 | No | N/A | N/A | N/A | N/A | N/A | N/A |
| 2 | Yes | 1.00 | 0.16 | 0.02 | 1.00 | 0.2153 | Top & Bot. |
| 3 | No | N/A | N/A | N/A | N/A | N/A | N/A |

## ULTIMATE SETTLEMENT, Sc

| Node # | X [ ft.] | Y [ ft.] | Original Z [ ft.] | Settlement Sc [ ft.] | Final Z * [ ft.] |
|---|---|---|---|---|---|
| 1 | 90.00 | 0.00 | 108.12 | 0.07 | 108.05 |
| 2 | 91.58 | 0.00 | 108.65 | 0.07 | 108.59 |
| 3 | 93.16 | 0.00 | 109.19 | 0.06 | 109.12 |
| 4 | 94.74 | 0.00 | 109.72 | 0.06 | 109.66 |
| 5 | 96.32 | 0.00 | 110.25 | 0.06 | 110.19 |
| 6 | 97.89 | 0.00 | 110.79 | 0.06 | 110.73 |
| 7 | 99.47 | 0.00 | 111.32 | 0.05 | 111.27 |
| 8 | 101.05 | 0.00 | 111.50 | 0.05 | 111.45 |
| 9 | 102.63 | 0.00 | 111.50 | 0.05 | 111.45 |
| 10 | 104.21 | 0.00 | 111.50 | 0.05 | 111.45 |
| 11 | 105.79 | 0.00 | 111.50 | 0.05 | 111.45 |
| 12 | 107.37 | 0.00 | 111.50 | 0.05 | 111.45 |
| 13 | 108.95 | 0.00 | 111.50 | 0.05 | 111.45 |
| 14 | 110.53 | 0.00 | 110.98 | 0.06 | 110.93 |
| 15 | 112.11 | 0.00 | 110.45 | 0.06 | 110.39 |
| 16 | 113.68 | 0.00 | 109.92 | 0.06 | 109.86 |
| 17 | 115.26 | 0.00 | 109.38 | 0.06 | 109.32 |
| 18 | 116.84 | 0.00 | 108.85 | 0.07 | 108.78 |
| 19 | 118.42 | 0.00 | 108.31 | 0.07 | 108.25 |
| 20 | 120.00 | 0.00 | 107.78 | 0.07 | 107.71 |

*Note: Final Z is calculated assuming only 'Ultimate Settlement' exists.

## TABULATED GEOMETRY: INPUT OF FOUNDATION SOILS

| Found. Soil # | Point # | Coordinates (X, Z) : (X) [ ft.] | (Z) [ ft.] | DESCRIPTION |
|---|---|---|---|---|
| 1 | 1 | 0.00 | 100.00 | Existing Levee Fill |
| | 2 | 66.00 | 100.00 | |
| | 3 | 100.00 | 111.50 | |
| | 4 | 109.00 | 111.50 | |
| | 5 | 143.00 | 100.00 | |
| | 6 | 200.00 | 100.00 | |
| 2 | 1 | 0.00 | 100.00 | Surface Blanket |
| | 2 | 200.00 | 100.00 | |
| 3 | 1 | 0.00 | 95.00 | Coarse Alluvium |
| | 2 | 200.00 | 95.00 | |

## TABULATED GEOMETRY: INPUT OF EMBANKMENT SOILS

| Embank. Soil # | | Point # | Coordinates (X, Z) : (X) [ ft.] | (Z) [ ft.] | DESCRIPTION |
|---|---|---|---|---|---|
| 1 | X1 = 50.00 [ft] | 1 | 50.00 | 100.00 | |
| | X2 = 159.00 [ft] | 2 | 99.50 | 116.50 | |
| | | 3 | 109.50 | 116.50 | |
| | | 4 | 159.00 | 100.00 | |

# Appendix C

Geotechnical Report Limitations and Guidelines for Use

# Appendix C
# Geotechnical Report Limitations and Guidelines for Use
# Report No. 01-05376A

## C.1 REFERENCE

This appendix provides information to help you manage your risks relating to subsurface problems which are caused by construction delays, cost overruns, claims, and disputes. This information was developed and provided by ASFE[1], of which, we are a member firm.

## C.2 RISK MANAGEMENT INFORMATION

### C.2.1 Geotechnical Services are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared solely for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. And no one, not even you, should apply the report for any purpose or project except the one originally contemplated.

### C.2.2 Read the Full Report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

### C.2.3 A Geotechnical Engineering Report is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typically factors include: the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, always inform your geotechnical engineer of project changes, even minor ones, and request an assessment of their impact. Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.

### C.2.4 Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. Do not rely on a geotechnical engineering report whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. Always contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

1 ASFE, 8811 Colesville Road/Suite G106, Silver Spring, MD 20910
Telephone: 301/565-2733: www.asfe.org

**C.2.5 Most Geotechnical Findings Are Professional Opinions**
Site exploration identified subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

**C.2.6 A Report's Recommendations Are Not Final**
Do not overrely on the construction recommendations included in your report. Those recommendations are not final, because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual subsurface conditions revealed during construction. The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.

**C.2.7 A Geotechnical Engineering Report Is Subject to Misinterpretation**
Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

**C.2.8 Do Not Redraw the Engineer's Logs**
Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognizes that separating logs from the report can elevate risk.

**C.2.9 Give Contractors a Complete Report and Guidance**
Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, but preface it with a clearly written letter of transmittal. In the letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

**C.2.10 Read Responsibility Provisions Closely**
Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their report. Sometimes labeled "limitations" many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. Read these provisions closely. Ask questions. Your geotechnical engineer should respond fully and frankly.

**C.2.11 Geoenvironmental Concerns Are Not Covered**
The equipment, techniques, and personnel used to perform a geoenvironmental study differ significantly from those used to perform a geotechnical study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Unanticipated environmental problems have led to numerous project failures. If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. Do not rely on an environmental report prepared for someone else.