REPORT OF PROPOSED DOWNSTREAM WIDENING OF HORSESHOE FARM PARK DAM

RALEIGH, NORTH CAROLINA
F&R PROJECT NO. 66M-0065

Prepared For:

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August 26, 2010

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August 26, 2010

Lappas & Havener
215 Morris Street, Suite 150
Durham, North Carolina 27701

Attn.: Mr. Eric Davis
Principal

Re: Proposed Downstream Widening of Horseshoe Farm Park Dam
Horseshoe Farm Road
Raleigh, North Carolina
F&R Project No. 66M-0065G

Dear Mr. Davis:

Froehling and Robertson, Inc. (F&R) has completed the authorized subsurface exploration and geotechnical engineering evaluation for the Horseshoe Farm Park Dam in Raleigh, North Carolina. The work was performed in general accordance with F&R's Proposal No. 1166-074G dated June 10, 2010. This report contains a description of the project information provided to F&R, a discussion of the general subsurface conditions encountered during the subsurface exploration, and geotechnical engineering recommendations for the roadway embankment construction along the downstream side of the existing dam.

Please do not hesitate to contact us if you should have any questions regarding this report.

Sincerely,
FROEHLING & ROBERTSON, INC.

Michael S. Sabodish, Jr., Ph.D., P.E.
Geotechnical Engineer

NORTH CAROLINA PROFESSIONAL SEAL 029927 ENGINEER MICHAEL S. SABODISH, JR. 8-26-10

Ralph E. Sanders, P.E.
Chief Geotechnical Engineer

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1.0 PURPOSE AND SCOPE OF SERVICES

The purpose of the subsurface exploration and geotechnical engineering evaluation was to explore the subsurface conditions at the site, and to provide a geotechnical evaluation of the existing dam and proposed dam embankment modifications. In addition, F&R will provide design recommendations for site preparation and earthwork and quality control measures related to these design aspects.

F&R's scope of services included the following:

- Completion of 5 soil test borings to depths ranging from approximately 15 to 35 feet;
- Completion of laboratory index testing on selected soil samples consisting of natural moisture content, Atterberg limits and grain size distribution;
- Preparation of typed Boring Logs and development of Subsurface Profiles;
- Evaluation of the subsurface conditions with regard to slope stability;
- Preparation of this geotechnical report by professional engineers.

2.0 PROJECT INFORMATION

The project site is located near the intersection of Horseshoe Farm Road and Ligon Mill Road in Raleigh, North Carolina (see Figure 1 in Appendix I). The dam has a length of approximately 300 feet, a crest width of approximately 12 feet, and an estimated freeboard height of 4 feet. A one-lane gravel road traverses the length of the dam. Based on at topographic map created by the City of Raleigh and provided to F&R by Lappas & Havener, the upstream slope has a grade of approximately 2.75H:1V (Horizontal to Vertical). The downstream slope has a grade of approximately 3.2H:1V. An 8-inch diameter PVC pipe discharges at the base of the downstream slope into a stream channel. The overall height of the dam as measured from the bottom of the stream channel to the crest is approximately 17 feet. A riser pipe was noted at a distance of approximately 35 to 40 feet into the pond from the edge of the slope; however, the functionality, size and type of the riser pipe could not be determined at the time of our site visit. The upstream and downstream slopes are covered with grass that appears to be maintained. The dam does not appear to have a conventional emergency spillway; however, a culvert pipe located beneath a driveway near the west abutment of the dam may be serving as an emergency spillway.

Based on information presented to F&R by Mr. Chris Flythe of Mulkey Engineering (Project Civil Engineer), it is our understanding that the crest of the dam may be widened approximately 28 feet (for a total crest width of 43 feet) in order to accommodate a 2-lane road, guardrails and pedestrian sidewalk. Information regarding other potential modifications to the existing principal spillway (existing barrel & riser) or need for an emergency spillway was not available. Based on recent discussions about the project with Mulkey, it is F&R's understanding that Mulkey may be performing the Hydrology & Hydraulics (H&H) evaluation and Civil Engineering services (plans & specs) associated with any proposed modifications to the embankment and spillway systems. F&R assumes that Mulkey will determine the need and/or requirements for the existing riser & barrel, a new riser & barrel, and emergency spillway based on the flood routing study.

3.0 EXPLORATION PROCEDURES

3.1 FIELD EXPLORATION

The subsurface conditions at the project site were explored by performing a total of 5 soil test borings (B-1 through B-5). Borings B-1 through B-3 were performed along the crest of the existing dam. Borings B-4 and B-5 were located in the downstream toe area of the dam. The borings were drilled at the approximate locations shown on the enclosed Boring Location Plan (see Figure 2). The test borings were drilled to depths ranging from approximately 15 to 35 feet below the existing ground surface. The test borings were backfilled with grout upon completion of the exploration. The boring elevations were interpolated from a topographic map created by the City of Raleigh and supplied to F&R by representatives of Lappas & Havener, and as such, the estimated elevation at the boring locations should be considered approximate.

Representatives of F&R established the boring locations in the field based on our experience with similar dam structures. The boring locations were marked in the field by making taped measurements from existing site landmarks and estimating right angles. Given the method of determination, the boring locations should only be considered approximate.

The test borings were advanced with an ATV-mounted drill rig using hollow stem augers for borehole stabilization and hand auger with dynamic cone penetrometer testing (Boring B-1). Representative soil samples were obtained using a standard two-inch outside diameter (O.D.) split barrel sampler in general accordance with ASTM D 1586, Penetration Test and Split-Barrel Sampling of Soils (Standard Penetration Test). The number of blows required to drive the split barrel sampler three consecutive 6-inch increments with an automatic hammer is recorded and the blows of the last two 6-inch increments are added to obtain the Standard Penetration Test (SPT) N-values representing the penetration resistance of the soil. Standard Penetration Tests were performed almost continuously to a depth of 10 feet and at intervals not exceeding 5 feet below a depth of 10 feet in order to evaluate the consistency and general engineering properties of the subsurface soils.

It is noted that one of the borings (B-1) had to be advanced by hand augering methods due to drill rig access difficulties. Boring B-1 was drilled along the outside edge of the upstream slope. Portable Dynamic Cone Penetrometer (DCP) testing was performed at this boring at one foot intervals to a depth of 15 feet where the boring was terminated. The DC testing was performed in accordance with ASTM STP 399 and the data can be correlated with the SPT data to evaluate soils strength and consistency.

Representative portions of the soil samples obtained from each SPT interval were sealed in a container, labeled and transported to our laboratory for final classification by a geotechnical engineer. The soil samples were visually classified in general accordance with the Unified Soil Classification System (USCS), using visual-manual identification procedures (ASTM D 2488). Laboratory soil testing was not performed during our investigation. The Boring Log for each test boring is presented in Appendix II of this report.

Groundwater levels were recorded in the borings immediately after drilling activities were completed and after a stabilization period of at least 24-hours. In addition, temporary handslotted PVC piezometers were installed in the soil test borings to obtain stabilized groundwater levels.

3.2 LABORATORY TESTING

Five samples of the on-site soils obtained during the exploration were subjected to laboratory testing. Tests performed included natural moisture content, Atterberg limits and grain size distribution. The testing program was designed to determine selected engineering properties of the on-site soils relative to their use for the project. The results of the soil test performed for this study are presented in Appendix III.

4.0 REGIONAL GEOLOGY

The referenced property is located in the Piedmont Physiographic Province. The Piedmont Province generally consists of hills and ridges that are intertwined with an established system of draws and streams. The Piedmont Province is predominately underlain by igneous rock (formed from molten material) and metamorphic rock (formed by heat, pressure and/or chemical action), initially formed during the Precambrian and Paleozoic eras.

The site is specifically located in the Rolesville batholith, a body of massive to well foliated granite undated, but believed to have formed as an igneous pluton in the late Paleozoic Era, approximately 290 million years ago.

5.0 SUBSURFACE CONDITIONS

A generalized subsurface profile along the dam alignment has been prepared from the boring data to graphically illustrate the subsurface conditions encountered at the site (see Figure 3 in Appendix I). A cross section through the dam in the vicinity of Borings B-1 and B-5 is shown in Figure 4. More detailed descriptions of the subsurface conditions at the individual boring locations are then presented in the boring logs enclosed in Appendix II. Strata breaks designated on the Boring Logs and Subsurface Profile represent approximate boundaries between soil types. The actual transition from one soil type to another may be gradual or occur between soil samples. The generalized subsurface conditions at the site are described below.

For more detailed soil descriptions and stratifications at a particular boring location, the respective Boring Logs provided in Appendix II should be reviewed.

5.1 FILL SOILS

Fill soils were encountered in borings B-1 through B-4 from the existing ground surface to depths ranging from approximately 3 to 19 feet below existing ground surface. The fill generally consisted of loose to medium dense silty and clayey fine to medium sands (USCS – SM & SC) and soft to stiff fine to medium sandy clays (USCS – CL & CH). The fill exhibited standard penetration test (SPT) resistances ranging from 3 to 29 blows per foot (bpf) with values typically in the range of 8 to 12 bpf. These SPT values indicate generally moderately well to well compacted conditions since similar type soils would be expected to exhibited SPT values of 9 to 12 bpf or higher when well compacted. It was also noted that the fill at the drilled locations did appeared to be relatively clean, i.e., without significant concentrations of organics or other debris, however a majority of the soil samples contained traces of wood and root fragments.

It is noted that a 2 to 3 foot thick layer of soft, sandy clay was encountered in boring B-2 at a depth of approximately 16.5 to 19 feet. The soft clay exhibited an SPT N-value of 3 bpf. Some wood (19.0 to 19.5 feet) was encountered below the clay layer. The presence of the relatively thin layer of soft clay and wood is probably associated with the placement of an initial bridge lift of soil over the original ground surface during the early stages of construction of the dam several decades ago.

5.2 RESIDUAL SOILS

Underlying the fill soils, and at the ground surface of boring B-5, native soils were encountered. The native soils consisted of loose to very dense silty and clayey fine to medium sands (USCS – SM & SC) with SPT N-values ranging from 2 to 89 bpf, The SPT N-values of the native soils were typically in the range of 11 to 14 bpf, with a majority of the SPT N-values greater than 20 bpf.

In boring B-2, an approximate 2 foot layer (EL 185.5 to EL 187.5) of relatively clean fine to coarse sand (USCS – SP) was encountered at depths of 19.5 to 21.5 feet. In addition, PWR materials were encountered in this boring from a depth of 33.5 feet to the 34 foot termination depth of the boring. The PWR was sampled as very dense, silty fine to medium sand (SM) which exhibited SPT values of over 100 bpf.

5.3 SOIL MOISTURE AND GROUNDWATER CONDITIONS

Groundwater levels were recorded in each boring and after 24 hours following drilling operations to obtain stabilized water levels. Additionally, temporary piezometers were installed in borings B-1, B-3 and B-4 to obtain more accurate stabilized water level readings. Based on the water level measurements, the stabilized water levels ranged between approximately 5 and 15.5 feet below the existing ground surface (EL 190 and EL 191.5).

The recorded water levels within the embankment cross section at borings B-1 and B-5 generally reflect typical lowered or depressed groundwater levels of the phreatic line as seepage develops through the dam.

Within the fill soils, soil moisture appeared to be moist for a majority of the soil test borings. However, wet soils were observed in boring B-2 from approximately 2 to 19.5 feet (EL 205 to 187.5) below existing ground surface.

Saturated soils were observed in borings B-2 (19.5 to 21.4 feet), B-3 (18.5 to 23.5 feet), B-4 (3.5 to 14.6 feet) and B-5 (3.5 to 8.5).

It should be noted that soil moisture and groundwater elevations vary depending upon seasonal factors such as precipitation and temperature. As such, soil moisture and groundwater conditions at other times of the year may vary or be different from those observed at the time of this exploration and described in this report.

6.0 PRELIMINARY ENGINEERING ANALYSIS

6.1 EVALUATION OF PROPOSED CONSTRUCTION

The preliminary conclusions and recommendations contained in this section of the report are based upon the results of the 5 soil test borings, site observations, and information provided regarding the proposed construction. It is our opinion that the subsurface conditions encountered on the project site are suitable for the proposed construction from a geotechnical point of view provided the following measures are considered and recommendations presented in subsequent sections of this report are followed throughout the design and construction phases of this project.

Our evaluation of the boring data indicates that the fill within the original dam is generally moderately well to well compacted based on SPT values in the range of typically 8 to 12 bpf. It is also noted that the dam has apparently performed well over the past several years and that no major deficiencies or repairs have been required to our knowledge. Based on the above information and our site observations, it is our opinion that the proposed modifications to the dam (downstream embankment construction) can be performed provided that procedures are implemented to: 1) intercept possible seepage (long term) in the downstream toe area of the dam, 2) address the condition and support of the existing spillway pipe/bottom drain due to the new fill loading in the downstream slope area if the existing pipe is left in-place and 3) address groundwater control and undercutting of soft soils along the existing spillway pipe, if required.

It should be noted that at the time of report preparation, the final design for the new cross-section of the dam is in the very preliminary planning stages. Based on information provided by Mulkey, there are currently no plans to provide any improvements to the dam or principle and emergency spillways. In addition, a hydrology and hydrogeologic (H &H) study has not been performed for the dam. It is expected that due to the height of the dam and upstream impoundment, approval for modifications to the dam may need to be provided by NC DENR (North Carolina Department of Environment and Natural Resources). Once a finalized design concept is prepared, F&R requests an opportunity to review the design to assess whether additional field exploration and engineering analysis are considered necessary to confirm these preliminary findings.

6.2 SEEPAGE INTERCEPTOR

In order to safely collect seepage and reduce the potential for seepage to exit the widened embankment slope, a toe drain system should be installed along the toe of the new embankment cross section. The toe drain should extend to a depth of approximately 4 to 5 feet below the surface of the new downstream slope. The toe drain should be 2 feet wide and consist of a 4-inch diameter perforated PVC pipe (schedule 40) installed in clean washed No. 67 stone, which is wrapped in non-woven filter fabric such as Mirafi 180N or equivalent. The perforated drain pipe should be installed 2 to 3 inches above the bottom of the washed stone. Care must be taken during the drain construction to keep the washed stone clean and free of soil contamination; otherwise, the effectiveness of the drain can be seriously jeopardized.

The toe drain should extend across the downstream slope from each abutment to a low point at the toe of the dam. The collected seepage should be routed through a discharge pipe to outlet in headwalls at the toe of the new embankment slope. The first 10 foot section of the discharge pipe should be perforated and encased in washed stone and fabric. However, below this point the pipe should be solid and backfilled with soil type materials. Discharge of collected seepage through the headwall will allow visual observation of the seepage and allow the quantity of flow to be monitored for the life of the structure.

It is not considered necessary at this time to require a blanket drain to extend across portions of the downstream slope. It is noted that the phreatic line within the embankment was 4 to 5 feet or more below the slope surface in the toe area (see borings B-4 & B-5) and no seepage was observed exiting the downstream slope at the time of our exploration. As such, it does not appear that a blanket drain on the downstream slope is necessary at this time; however, a final decision regarding the need for a blanket drain should be based on actual proposed modifications to the dam in conjunction with the subsurface conditions encountered.

The location/details of the toe and blanket drain (if considered necessary) should be determined once the grading plans have developed for the project.

6.3 Slope Stability Analysis

Slope stability analyses of the upstream and downstream existing embankments and new widened embankment downstream slope (expected to vary from 2.5H:1V to 3H:1V) were performed using the Stable 7 Computer Model developed by Purdue University. The stability analysis was run for the normal pool and rapid drawdown condition of the upstream slope, and long term conditions for the downstream slope along the approximate center of the dam near borings B-1 and B-5. The soil parameters used in the stability analyses were based on empirical correlations of soil strength with the soil test boring data as well as our familiarity with strength parameters based on similar-type soils on past projects; however, the actual parameters used in the analyses are considered somewhat conservative. The results of the stability analysis for the various operating conditions are summarized below and are presented in Figures 5 through 8 in Appendix I. The full computer printouts are presented in Appendix IV.

SUMMARY OF STABILITY ANALYSIS

Case	Computed Factor of Safety	Required Factor of Safety
1. Upstream-Normal Pool	2.86	1.50
2. Upstream-Rapid Drawdown	2.11	1.25
3. Downstream-Normal Pool	2.84	1.50
4. Downstream – Widened Embankment Slope-Long Term	2.02	1.50

The above stability analyses indicate that the existing 2.75H:1V (horizontal to vertical) upstream slope and 2.5H:1V to 3H:1V proposed widened downstream slope should produce adequate factors of safety against slope instability for the assumed strength parameters.

6.4 Spillway Pipe

6.4.1 New Spillway Pipe

Depending on the H & H analyses and input from NC DENR, it is possible that it will be necessary to remove the existing spillway pipe/bottom drain and replace it with a new bottom drain. If this is required, it would necessary to drain the pond and make an excavation along the new spillway alignment. F&R can provide specific recommendations regarding the installation of a new spillway pipe/bottom drain based on the finalized alignment and invert levels. For a new pipe, we would expect the pipe to be somewhat larger and that some soft subgrade conditions and groundwater could be encountered along the pipe alignment.

Any unsuitable or very soft subgrade conditions along the pipe alignment should be removed as directed by the geotechnical engineer and the undercut materials should be replaced with adequately compacted structural fill. If seepage or groundwater develops into the excavation, the water will need to be removed or lowered 2 to 3 feet below the base of the excavation in order to allow for effective backfilling operations to proceed. It is very important that water is not allowed to collect or stand above the exposed subgrade because the subgrade soils would then likely become softened and have to be undercut. Therefore, procedures should be implemented by the grading contractor to maintain groundwater levels 2 to 3 feet below the design subgrade of the pipe during installation and backfilling operations.

Depending on weather and groundwater conditions, it may be economical to backfill any undercut areas along the pipe with flowable fill (NC DOT specification of min. 28 day compression strength of 500 psi) or lean concrete (28 day compression strength of 2,000 psi). Use of flowable fill or lean concrete may be most effective if wet subgrade conditions prevent adequate compaction of soil type backfill.

If an RCP pipe is specified for the barrel, it is recommended that the pipe be supported on a concrete cradle. The cradle should extend neat line to each side of the pipe excavation, which should have a minimum width of 4 feet wider (2 feet on each side of the pipe) than the outside pipe diameter. The cradle should extend at least 8 inches below the bottom of the pipe and 1/3 the pipe diameter above the bottom of the pipe. The cradle should be appropriately reinforced.

6.4.2 EXISTING BOTTOM DRAIN TO REMAIN IN-PLACE

If consideration is given to leaving the existing spillway pipe in-place, the condition and support of the existing pipe should be further evaluated. As part of this evaluation, it may be necessary to run a camera up through the existing pipe to check for settlement or joint separation along the pipe. It should also be noted that up to 8 to 10 feet or more of new fill may be placed on the downstream slope which could add significant loading to the existing pipe depending on the condition of the pipe and subgrade support conditions. Due to the fill loading, it may also be necessary to expose portions of the pipe to evaluate existing subgrade conditions and the need for subgrade repairs in relation to pipe settlement and seepage considerations.

Regardless of the approach to the spillway construction (leaving the existing pipe in-place or replacing it), there is a need to limit excessive seepage along the pipe. In order to help limit the potential for adverse seepage along the spillway pipe, it is recommended that a filter diaphragm, consisting of washed stone encased in filter fabric (Mirafi 180N or equivalent) be constructed at the downstream end of the barrel behind the headwall. A typical detail of the headwall filter is shown in Figure 9. A larger filter diaphragm or cutoff collars often installed along the spillway just downstream of the core or crest of the dam is not considered necessary on this project due to the relatively small seepage pressures and low water height (9' to 10') in the impoundment as well as a relatively wide embankment section.

7.0 RECOMMENDATIONS FOR CONSTRUCTION

7.1 GENERAL

Normally, site preparation would be initiated by lowering or pumping down of the pond prior to performing the downstream slope modifications. Of course draining of the pond will be required if a new spillway pipe is installed. However, if the existing spillway pipe/bottom drain is left in-place and the pond is not drained before new embankment construction begins, procedures will need to be implemented by the contractor for the protection and safety of personnel working on the downstream side of the dam while water remains impounded. Such downstream work could include modifications/repairs to portions of the existing bottom drain and pipe subgrade as well as well as general fill placement in the downstream slope area. Clear lines of responsibility and assumptions of risk should be established prior to initiating work in the downstream slope area if the pond is not drained. It may be necessary for NC DENR to approve procedures for modifications to the existing dam, especially if the pond is not drained.

7.2 SITE PREPARATION

Once approved erosion control measures are installed, site preparation operations may be initiated. One of the initial repairs to the dam will be the clearing and grubbing of surface vegetation, organic surface soils and trees in the downstream slope area. The tress should be removed to a point of at least 10 feet beyond the new toe limits of the dam. Should any trees be located within the fill slope envelope, the tree stumps and root systems should be removed by pulling of the stumps instead of attempting to push over the stumps with a dozer. All stump holes within the limits of structural fill placement should be thoroughly cleaned to remove roots and loose soils and backfilled with properly compacted silty or sandy clayey soils. All fill should be compacted to at least 95 percent of the standard Proctor maximum dry density (ASTM D-698). F&R should monitor these repairs.

All exposed subgrades should be approved by F&R prior to fill placement. Thereafter, approved fill soils may be utilized to re-construct the downstream slope. As the new fill is placed, soft, wet or unsuitable soils exposed on the slope will need to be removed as recommended by F&R. Approved fill materials should be spread in 8 to 10 inch level lifts and compacted to at least 95 percent of the standard Proctor maximum dry density at moisture contents varying from 2 percent below optimum moisture content to 3 percent above optimum moisture. Each lift of new structural fill should be benched into firm to stiff soils along the slope. The surface of each lift of fill should be scarified prior to placement of the next lift in order to effectively tie the next lift of fill into the previous lift.

7.3 STRUCTURAL FILL

General structural fill for the modifications to the dam should consist of low to moderately plastic silty or sandy clayey soils or silty sands having USCS classifications of CL, ML, SM or SC. The more sandy soils should have at least 40 percent passing the No. 200 sieve and should have natural moisture contents at the time of placement ranging from 2 percent below optimum moisture content to 3 percent above optimum. Backfill within 3 to 4 feet of the bottom drain or spillway pipes should be a silty or clayey type soil and have USCS classifications of CL, ML or SC with a minimum plasticity index (PI) of 15. All proposed borrow soils should be subject to classification testing and approval by the geotechnical engineer prior to usage.

7.4 FILL PLACEMENT AND COMPACTION

Structural fill should typically be spread in 8 to 10 inch level lifts and compacted to at least 95 percent of the standard Proctor maximum dry density (ASTM D-698) with a sheepsfoot or rubber tired compactor. As fill is brought up in elevation, care should be implemented to bench into the existing slopes with each lift in order to form a good bond between the in-place soils and new fill materials. Additionally, the surface of each lift of fill should be scarified prior to placement of the next lift of fill. Inspection of all fill placement operations should be provided by the on-site soils technician working under the direct supervision of the geotechnical engineer.

No heavy mechanized equipment should operate within 4 to 5 feet of the bottom drain or spillway pipe during backfilling operations. Backfill in confined areas and along pipes should be spread in 4 inch thick lifts and require the use of hand tamps or light self propelled walk-behind equipment to prevent over stressing the walls of the pipe structures during compaction operations. Backfilling of the pipe excavations will require close monitoring, and density testing of the backfill by the on-site soils technician must be performed to verify that adequate compaction is being obtained and that adequate bonding is being achieved between the new backfill and adjacent excavation face.

It is recommended that repairs to the dam be performed during the normally warmer drier weather periods of May through October when grading operations can be most effectively performed and drying of wet soils can be most efficiently accomplished.

The slope areas should be vegetated following the modifications to the dam to promote a dense cover of grass or low ground cover. The downstream slope of the dam should be maintained by mowing to prevent the growth of woody vegetation.

7.5 GROUNDWATER MONITORING

In order to monitor groundwater (phreatic) levels within the embankment on a long-term basis, it is recommended that two piezometers (P-1 & P-2) be installed across the crest of the dam and surface of the street embankment. Once the final cross-section of the dam is defined, F&R can provide approximate piezometer locations. The groundwater level in the piezometers should be monitored periodically to evaluate groundwater conditions within the embankment cross-section. A locking cap should be installed over the piezometers as a protection from damage.

7.6 CONSTRUCTION INSPECTION

Periodic inspection of construction by the geotechnical engineer and full-time inspection services by the soils technician working under the direct supervision of the geotechnical engineer will be necessary to verify that the dam is properly constructed in accordance with the recommendations presented in this report. A detailed evaluation of foundation conditions should be performed by the geotechnical engineer prior to placement of any new fill within the proposed embankment limits or within excavations to be backfilled. A soils technician should monitor all aspects of construction including fill placement, blanket and toe drain installation, backfilling of the bottom drain barrel and emergency spillway pipe, etc. to verify that proper construction techniques and procedures are followed. Any changes to the recommended design should be reviewed by and made in concurrence with the geotechnical engineer.

8.0 LIMITATIONS

This report has been prepared for the exclusive use of Lappas & Havener and their agents for specific application to the referenced property in accordance with generally accepted soil and foundation engineering practices. No other warranty, expressed or implied, is made. These conclusions and recommendations do not reflect variations in subsurface conditions that could exist intermediate of the boring locations or in unexplored areas of the site. Should such variations become apparent during construction, we reserve the right to re-evaluate our conclusions and recommendations based upon on-site observations of the conditions. In the event changes are made in the proposed construction plans, the recommendations presented in this report shall not be considered valid unless reviewed by our firm and this report modified or verified in writing.

Important Information About Your

Geotechnical Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

The following information is provided to help you manage your risks.

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.

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.

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. Typical 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.*

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.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies 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.

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.*

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.

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 recognize that separating logs from the report can elevate risk.*

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 that 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.

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 such risks, geotechnical engineers commonly include a variety of explanatory provisions in their reports. 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.

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.*

Rely on Your Geotechnical Engineer for Additional Assistance

Membership in ASFE exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with your ASFE-member geotechnical engineer for more information.

ASFE

8811 Colesville Road Suite G106 Silver Spring, MD 20910

Telephone: 301-565-2733 Facsimile: 301-589-2017

email: info@asfe.org www.asfe.org

IIGER1000.10M

APPENDIX I

SITE VICINITY MAP

North ▲

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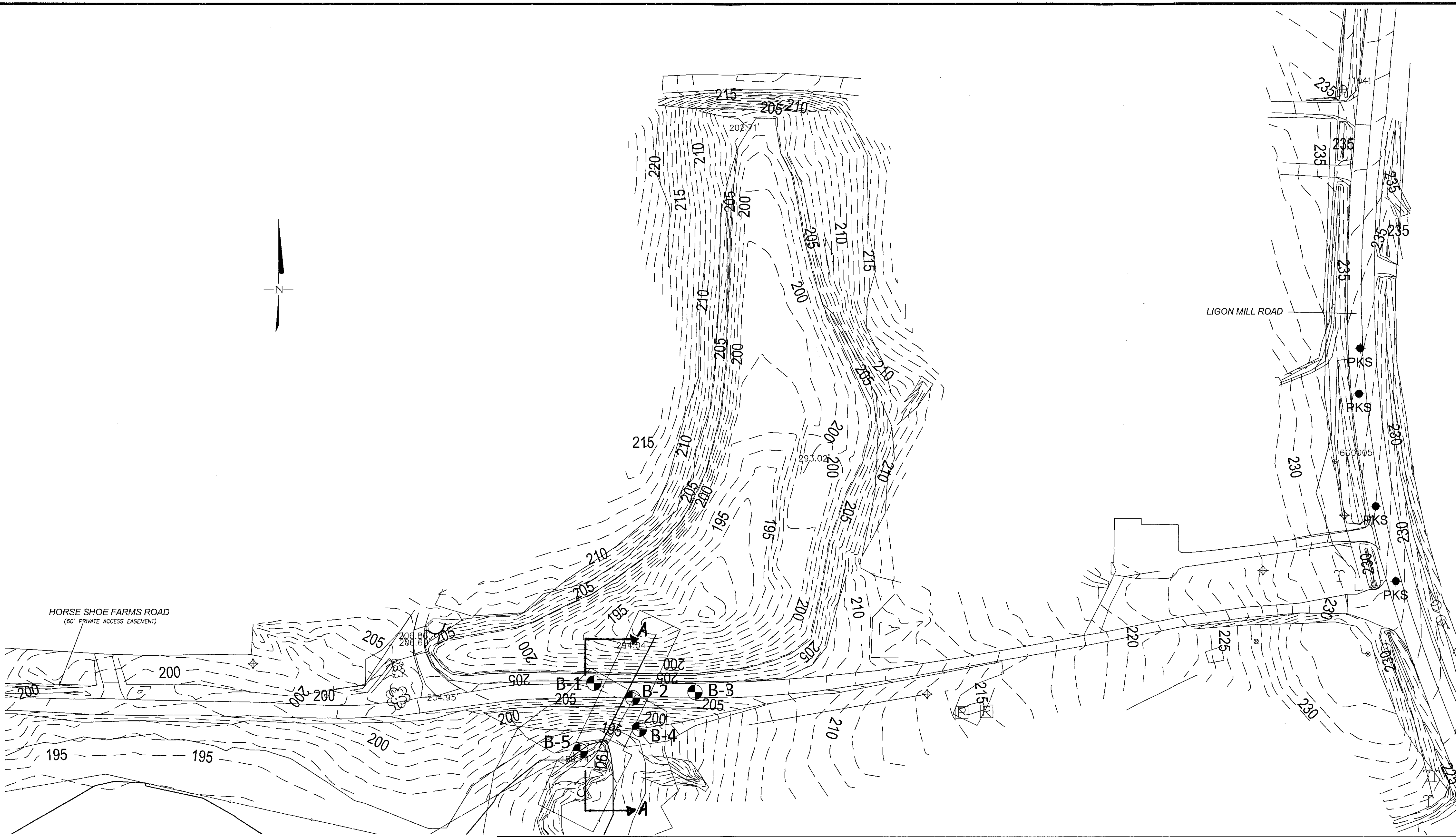
www.FandR.com

CLIENT: Lappas & Havener, PA		
PROJECT: Horseshoe Farm Park		
LOCATION: Raleigh, NC		
F&R PROJECT No: 66M-0065		
DRAWN BY: M. Sabodish		
DATE: August 2010	SCALE: NTS	FIGURE No.: 1



NOTE: This Plan Furnished to F+R by Mulkey Engineering

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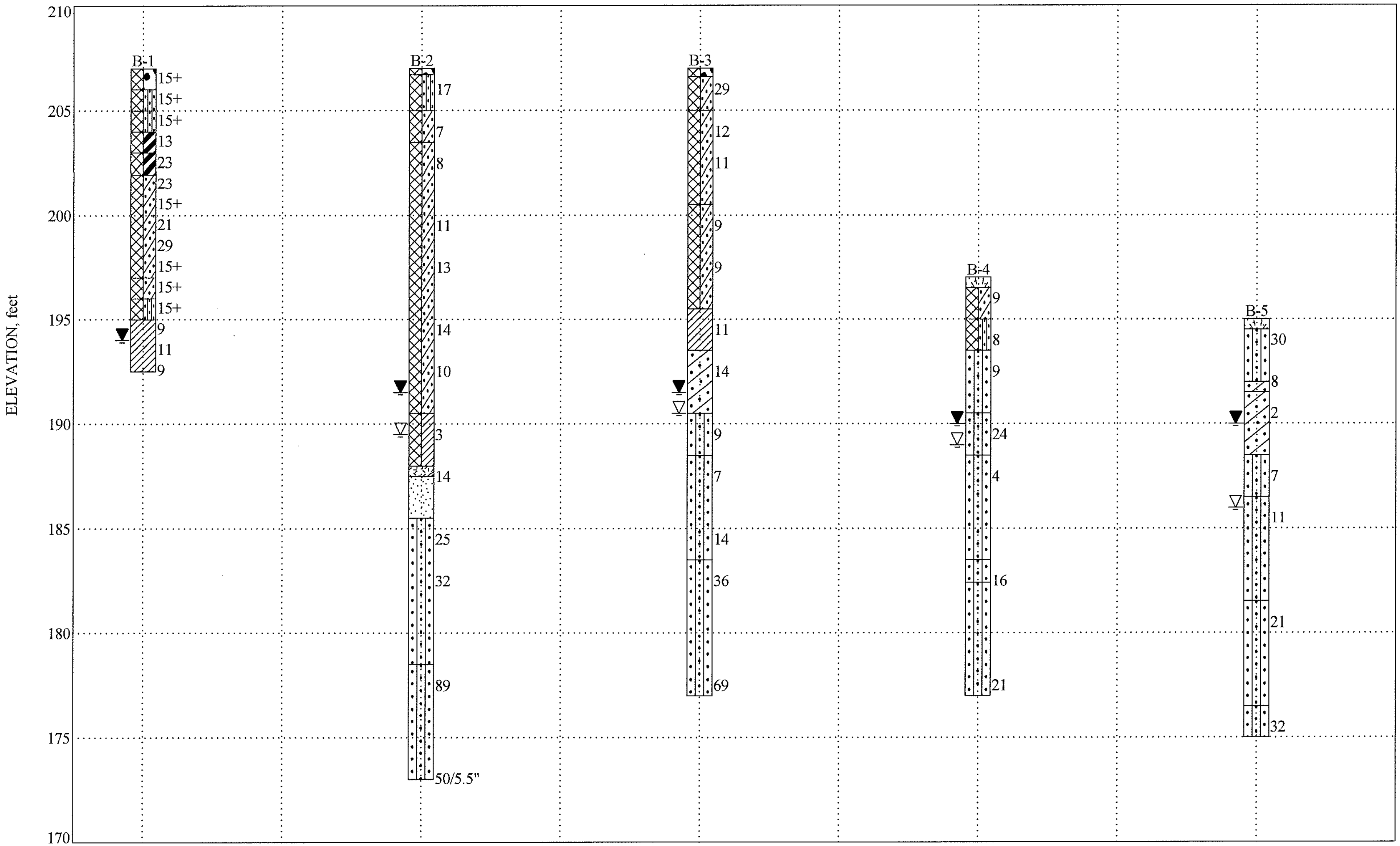
LEGEND

Approximate F&R Boring Location

SCALE (FEET)
0 40' 80'
1"=80'

BORING LOCATION PLAN

CLIENT: Lappas + Havener, PA	
PROJECT: Existing Dam - Horseshoe Farm Park	
LOCATION: Raleigh, Wake County, NC	
F&R PROJECT No.: 66M-0065	FIGURE No.: 2
DRAWN BY: D. Racey	CHECKED BY: M. Sabodish, P.E.
DATE: August 2010	SCALE: 1"=80'



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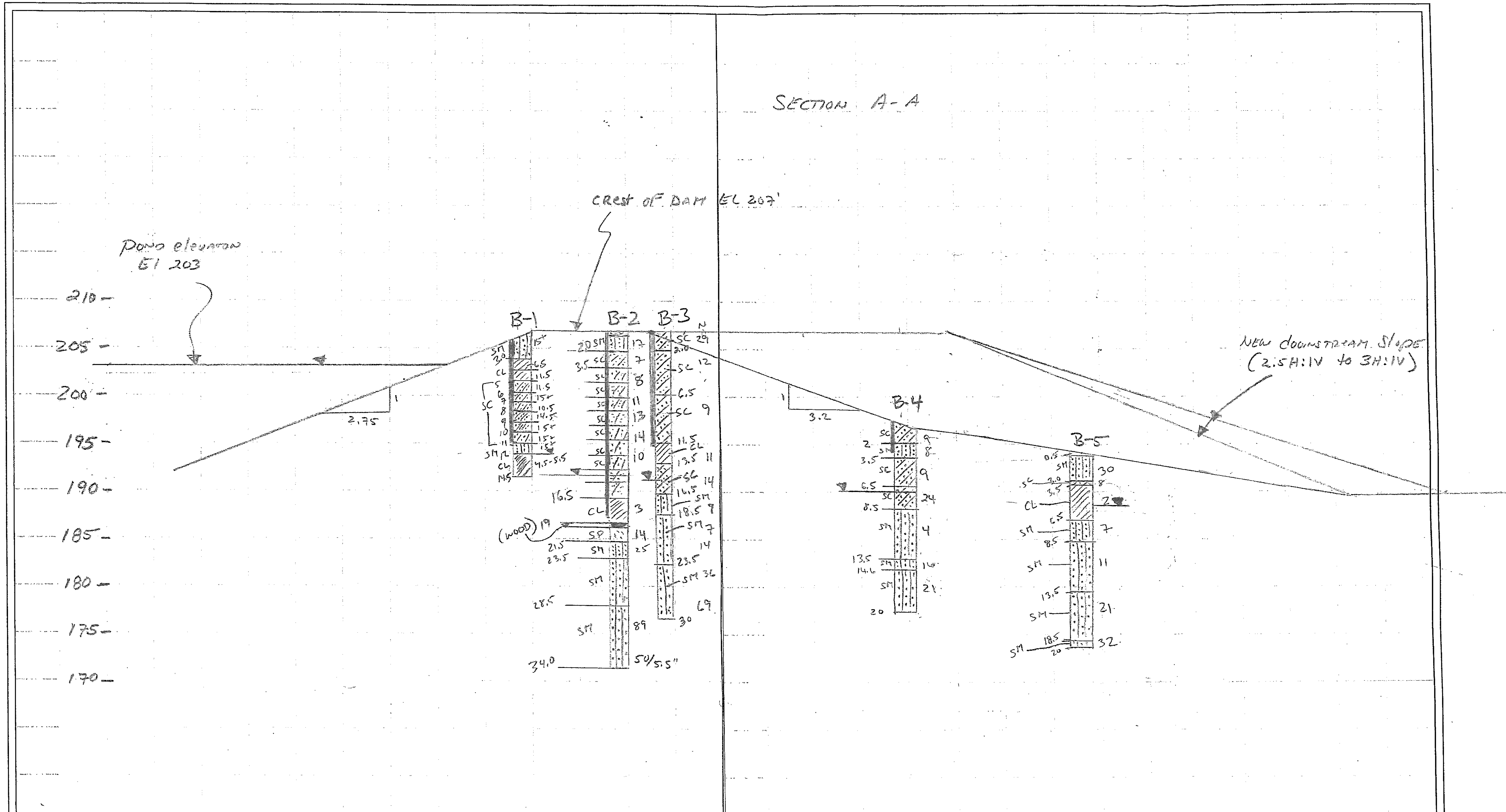
CLIENT : Lappas & Havener, PA
PROJECT : Horseshoe Farm Park
LOCATION : Raleigh, North Carolina
DATE : August 23, 2010

SUBSURFACE PROFILE Figure No. 3



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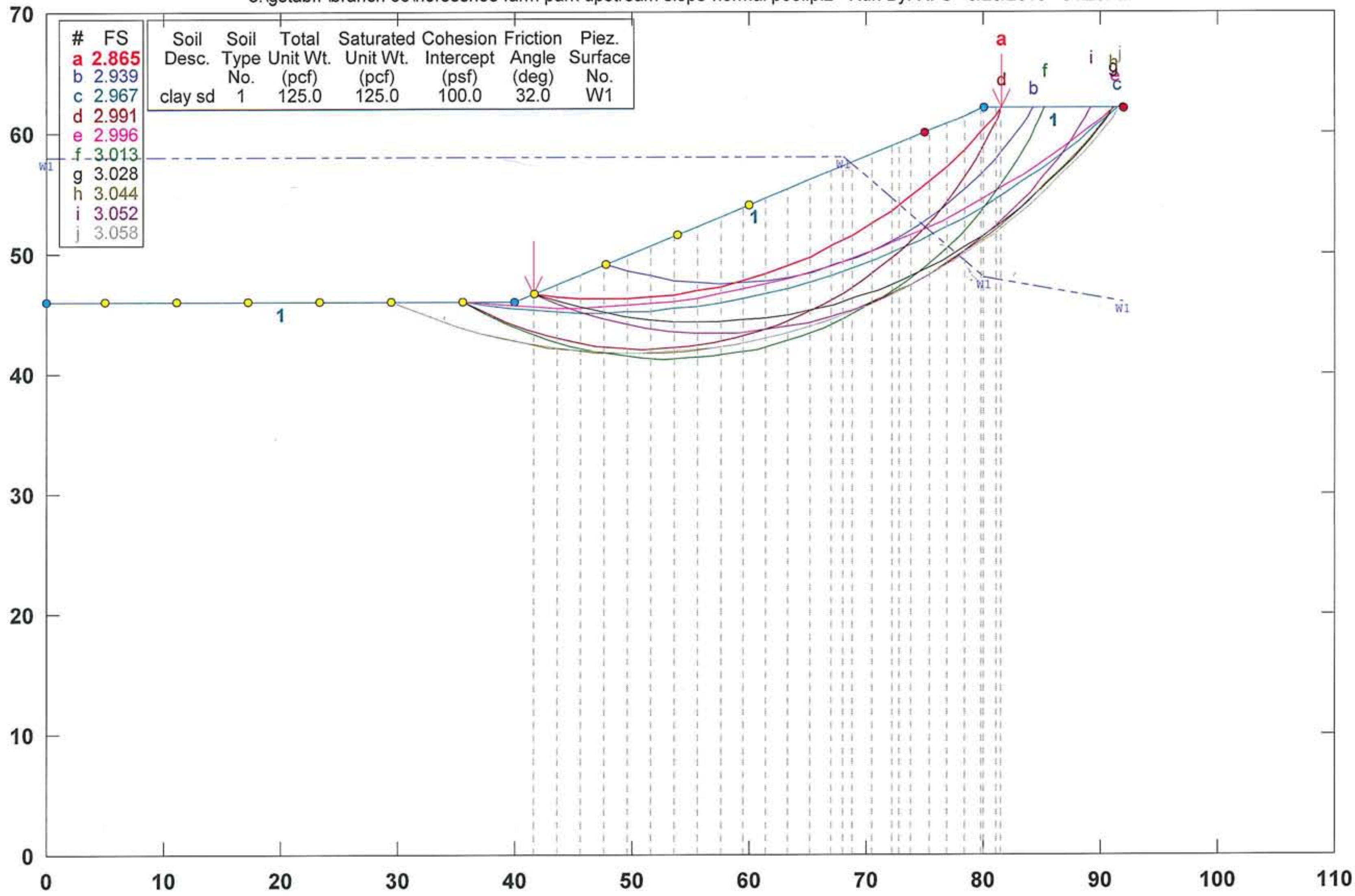
DATE:	August 2010
SCALE:	1" = 10'
DRWN:	HSS
DWG. NO.	4

Figure #4

Form No.: 103

horseshoe farm park existing upstream-normal pool

e:\gstabl7\branch 66\horseshoe farm park upstream slope-normal pool.pl2 Run By: RFS 8/25/2010 04:29PM



GSTABL7 v.2 FSmin=2.865

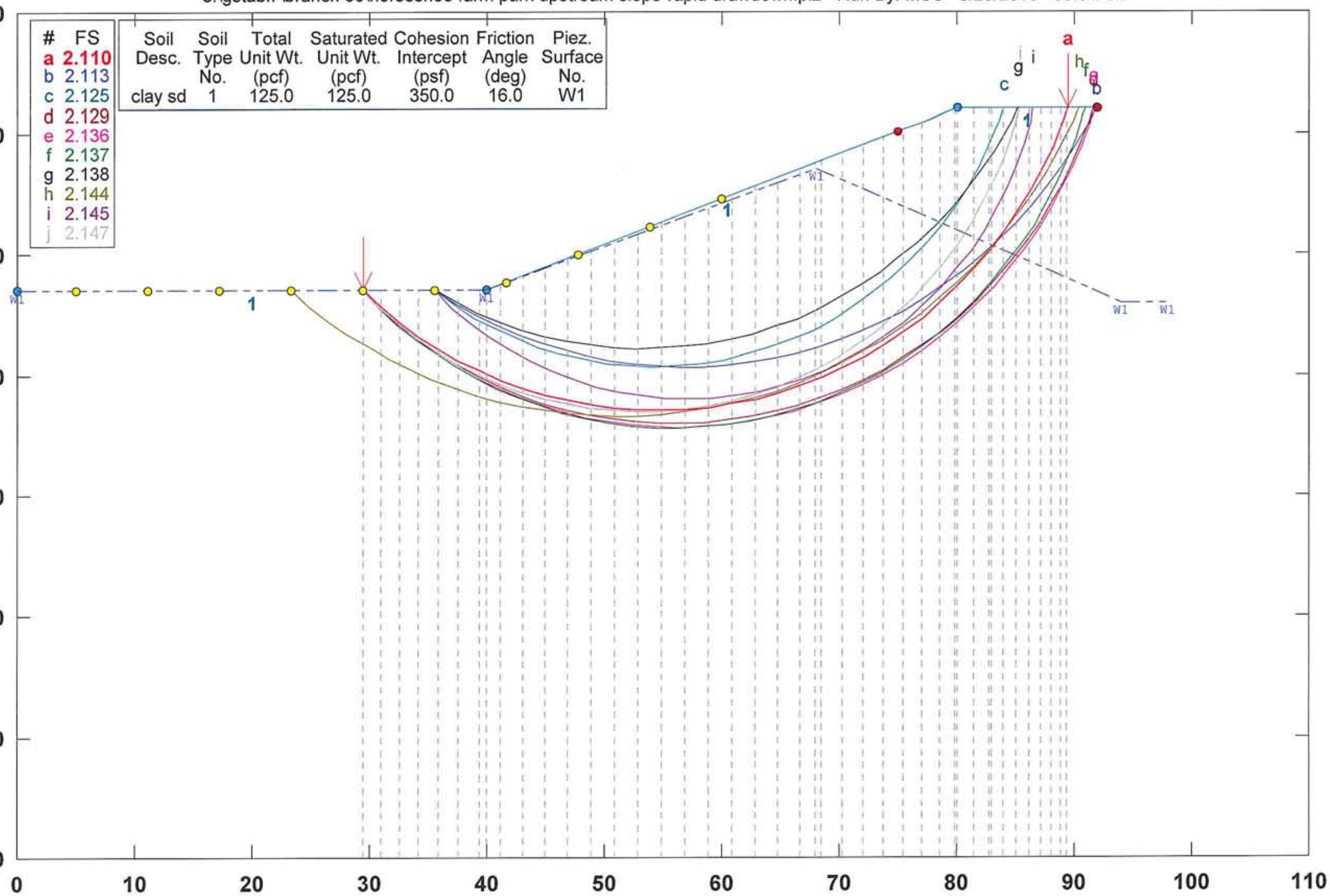
Safety Factors Are Calculated By The Modified Bishop Method

GSTABL7

Figure #5

horseshoe farm park existing upstream-rapid drawdown

e:\gstabl7\branch 66\horseshoe farm park upstream slope-rapid drawdown.pl2 Run By: MSS 8/26/2010 09:01AM



GSTABL7 v.2 FSmin=2.110

Safety Factors Are Calculated By The Modified Bishop Method

GSTABL7

Figure #6

horseshoe farm park existing downstream- normal pool

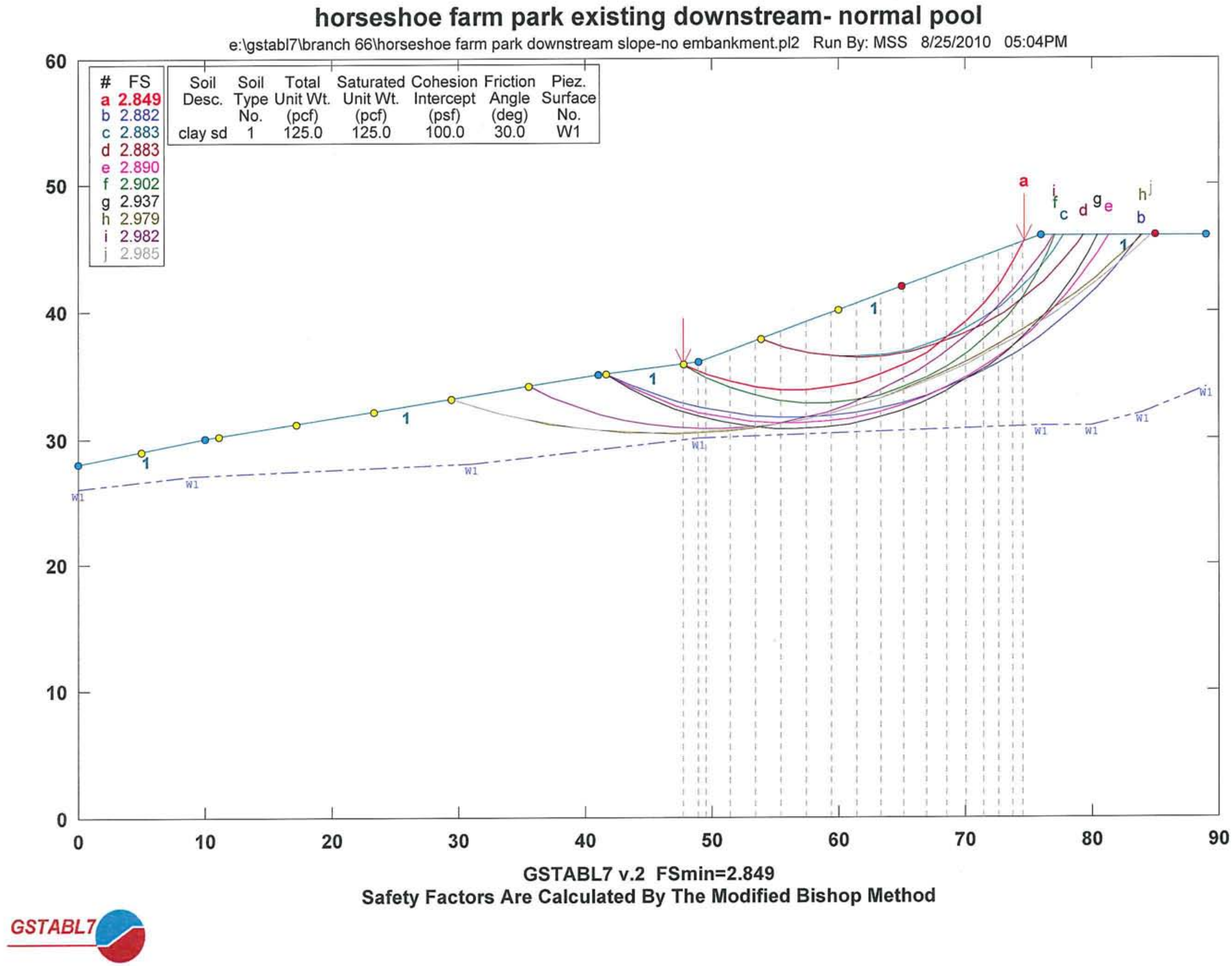
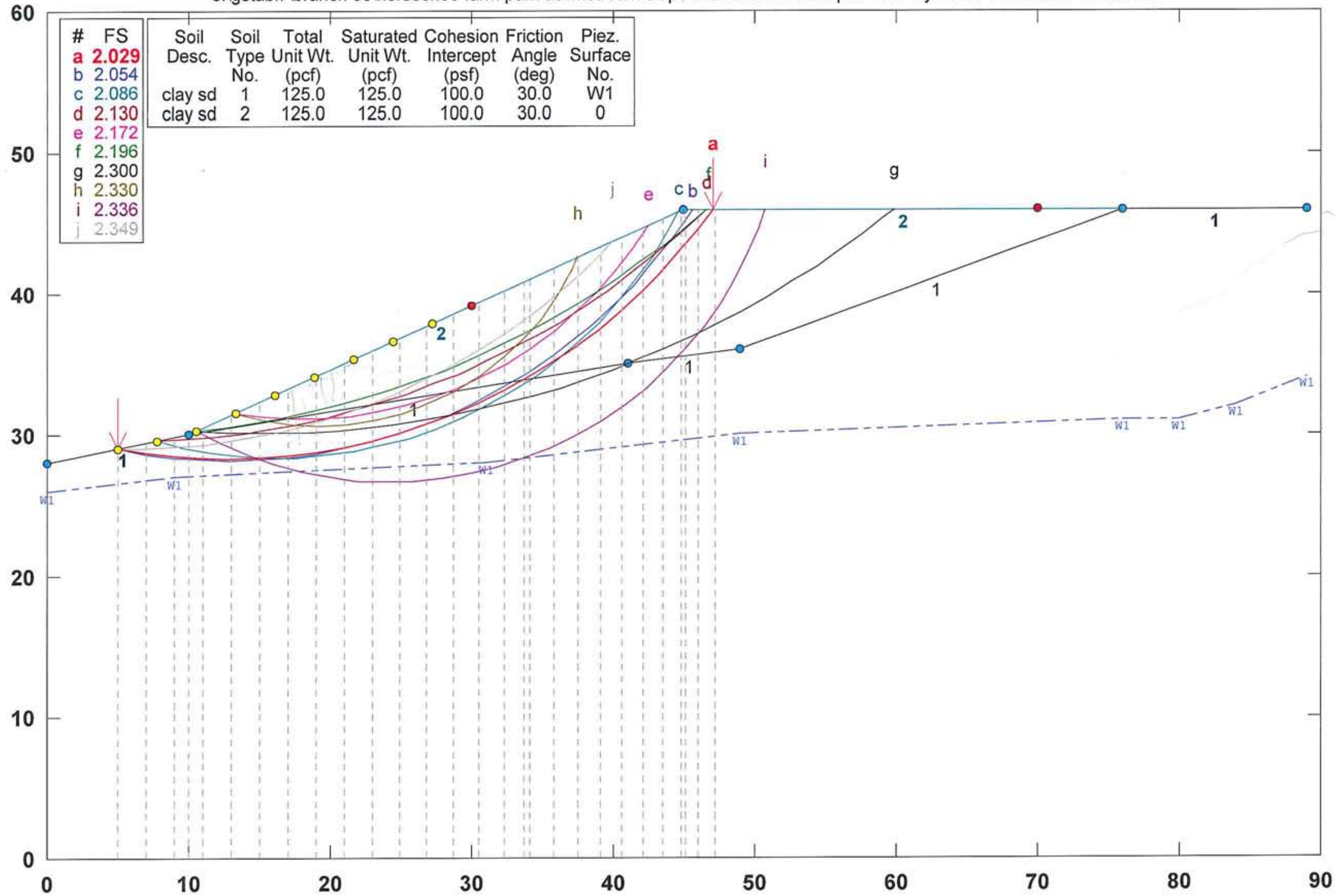


Figure # 7

horseshoe farm park existing downstream- widened embankment

e:\gstabl7\branch 66\horseshoe farm park downstream slope-with embankment.pl2 Run By: RFS 8/25/2010 02:56PM



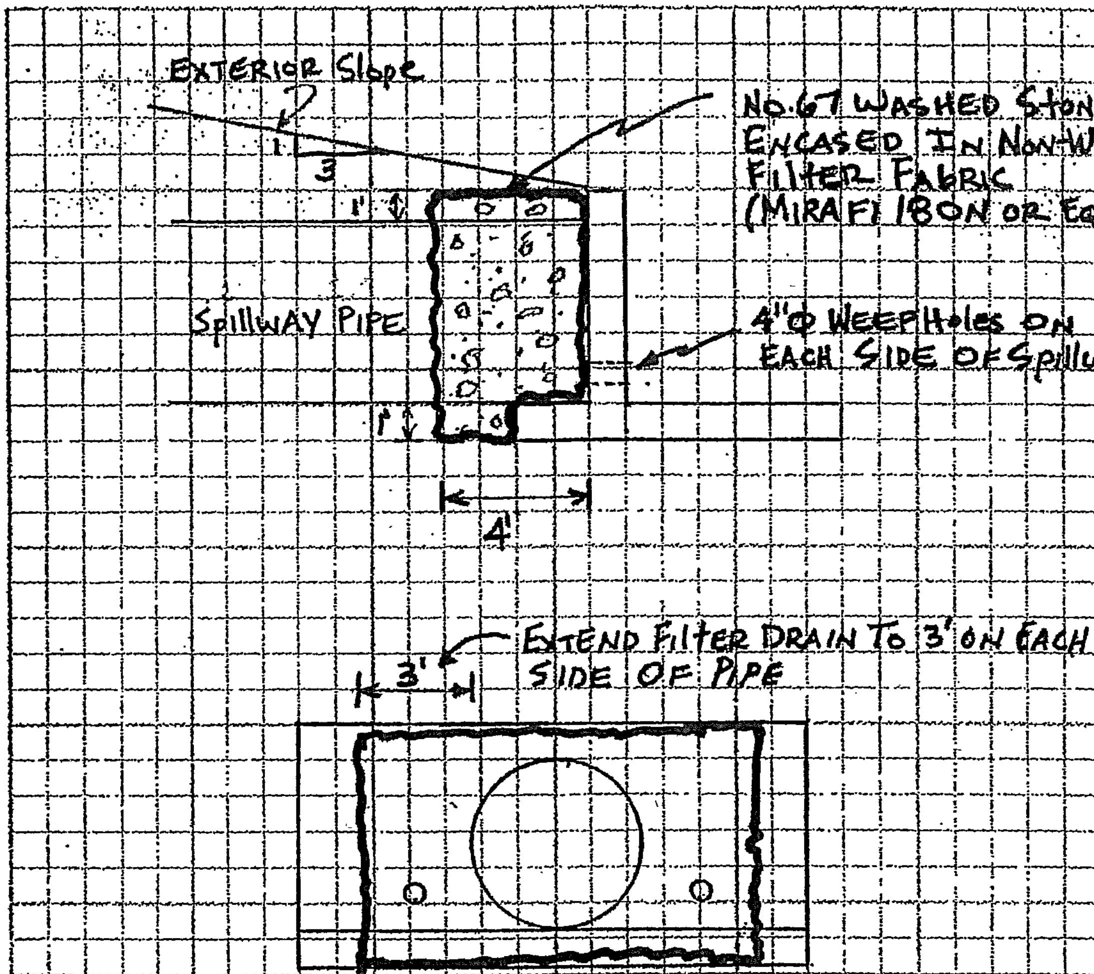
Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
clay sd	1	125.0	125.0	100.0	30.0	W1
clay sd	2	125.0	125.0	100.0	30.0	0

GSTABL7 v.2 FSmin=2.029

Safety Factors Are Calculated By The Modified Bishop Method

GSTABL7

Figure #8



NOTE: RETAINING WALL DESIGN TO BE PROVIDED BY STRUCTURAL ENGINEER OR IN ACCORDANCE WITH NCDOT HEADWALL DETAILS.

TYPICAL SPILLWAY FILTER DETAIL AT DOWNSTREAM HEADWALL

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CLIENT: Lappas & Havener
PROJECT: Horseshoe Farm Park Dam
LOCATION: Raleigh, NC
F&R PROJECT No: 66M-0065
DRAWN BY: M. Sabodish
DATE: August 2010 | SCALE: As Shown | FIGURE No.: 9

APPENDIX II

BORING LOGS

SINCE F&R 1881

UNIFIED SOIL CLASSIFICATION SYSTEM (USCS)					
MAJOR DIVISION					TYPICAL NAMES
	GRAVELS More than 50% of coarse fraction larger than No. 4 sieve	CLEAN GRAVEL (little or no fines)		GW	Well graded gravels
				GP	Poorly graded gravels
		GRAVELS with fines		GM	Silty gravels
				GC	Clayey gravels
	SANDS More than 50% of coarse fraction smaller than No. 4 sieve	CLEAN SAND (little or no fines)		SW	Well graded sands
				SP	Poorly graded sands
		SAND with fines		SM	Silty sands, sand/silt mixtures
				SC	Clayey sands, sand/clay mixtures
	SILTS AND CLAYS Liquid Limit is less than 50			ML	Inorganic silts, sandy and clayey silts with slightly plasticity
				CL	Sandy or silty clays of low to medium plasticity
				OL	Organic silts of low plasticity
	SILTS AND CLAYS Liquid Limit is greater than 50			MH	Inorganic silts, sandy micaceous or clayey elastic silts
				CH	Inorganic clays of high plasticity, fat clays
				OH	Organic clays of medium to high plasticity
HIGHLY ORGANIC SOILS				PT	Peat and other highly organic soils
MISCELLANEOUS MATERIALS					PWR (Partially Weathered Rock)
					Rock
					Asphalt
					ABC Stone
					Concrete
					Surficial Organic Soil

KEY TO SOIL CLASSIFICATION

Correlation of Penetration Resistance with Relative Density and Consistency

Sands and Gravels

No. of Blows, N	Relative Density
0 - 4	Very loose
4 - 10	Loose
10 - 30	Medium dense
30 - 50	Dense
Over 50	Very dense

Silts and Clays

No. of Blows, N	Relative Density
0 - 2	Very soft
2 - 4	Soft
4 - 8	Firm
8 - 15	Stiff
15 - 30	Very stiff
30 - 50	Hard
Over 50	Very hard

Particle Size Identification (Unified Classification System)

Boulders:	Diameter exceeds 8 inches
Cobbles:	3 to 8 inches diameter
Gravel:	**Coarse** - 3/4 to 3 inches diameter **Fine** - 4.76 mm to 3/4 inch diameter
Sand:	**Coarse** - 2.0 mm to 4.76 mm diameter **Medium** - 0.42 mm to 2.0 mm diameter **Fine** - 0.074 mm to 0.42 mm diameter
Silt and Clay:	Less than 0.07 mm (particles cannot be seen with naked eye)

Modifiers

The modifiers provide our estimate of the amount of silt, clay or sand size particles in the soil sample.

Approximate Content	Modifiers
≤ 5%:	Trace
5% to 12%:	Slightly silty, slightly clayey, slightly sandy
12% to 30%:	Silty, clayey, sandy
30% to 50%:	Very silty, very clayey, very sandy

Field Moisture	Description
Saturated:	Usually liquid; very wet, usually from below the groundwater table
Wet:	Semisolid; requires drying to attain optimum moisture
Moist:	Solid; at or near optimum moisture
Dry:	Requires additional water to attain optimum moisture

BORING LOG

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FROEHLING & ROBERTSON, INC.
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Report No.: **66M-0065**　　　　Date: **July 21, 2010**

Client: **Lappas & Havener, PA**

Project: **Horseshoe Farm Park, Raleigh, North Carolina**

Boring No.: **B-1** **(1 of 1)** Total Depth **14.5'** Elev: **207.0ft ±** Location: **See Boring Location Plan**

Type of Boring: **Hand Auger** Started: **7/9/10** Completed: **7/9/10** Driller: **D. Tignor**

Elevation	Depth (feet)	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (feet)	N Value (blows/ ft)	REMARKS
		FILL: Gravel with fines	14-15+	0.0		GROUNDWATER DATA: 24 Hrs.: 13.0' inside HSA
206.0	1.0	Moist, orange-brown fine silty SAND (SM) with wood fragments.	15+	1.0	15+	
205.0	2.0		15+	2.0		
204.0	3.0	Moist, brown fine silty SAND (SM) with wood fragments.	4-4-9	3.0	15+	
203.0	4.0	Moist, orange-gray fine sandy CLAY (CH) with wood fragments.	10-10-13	4.0	15+	
202.0	5.0		9-9-14	5.0	13	
		Moist, orange-gray fine sandy CLAY (CH) with mica and wood fragments.	15+	6.0	23	
		Moist, orange-gray fine clayey fine to medium SAND (SC) with mica and wood fragments.	8-10-11	7.0	23	
			12-14-15	8.0	15+	
			15+	9.0	21	
197.0	10.0	Moist, orange-brown clayey fine to medium SAND (SC) with mica and root fragments.	15+	10.0	29	
196.0	11.0		9-15+	11.0	15+	
195.0	12.0	Moist, dark gray silty fine to medium SAND (SM) with mica.	6-5-4	12.0	15+	
		NATIVE: Moist, orange-gray fine to medium sandy CLAY (CL) with mica.	4-4-7	13.0	15+	
192.5	14.5	Hand auger terminated at 14.5 feet.	4-4-5	14.0	9	
					11	
					9	

BORING_LOG 66M-0065 BORING LOGS.GPJ F&R.GDT 8/23/10

*Number of blows required for a 140 lb automatic hammer dropping 30" to drive 2" O.D., 1.375" I.D. split-spoon sampler in successive 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration Test value, "N".

BORING LOG

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Report No.: **66M-0065** Date: **July 21, 2010**

Client: **Lappas & Havener, PA**

Project: **Horseshoe Farm Park, Raleigh, North Carolina**

Boring No.: **B-2** **(1 of 1)** Total Depth **34.0'** Elev: **207.0ft ±** Location: **See Boring Location Plan**

Type of Boring: **2.25" ID HSA** Started: **7/8/10** Completed: **7/8/10** Driller: **D. Tignor**

Elevation	Depth (feet)	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (feet)	N Value (blows/ ft)	REMARKS
206.7	0.3	FILL: Gravel and fines.	25-10-7	0.0 - 1.5	17	GROUNDWATER DATA: 0 Hrs.: 17.5' inside HSA; 24 Hrs.: 15.5' inside HSA
205.0	2.0	Dry, medium dense, gray silty fine to medium SAND (SM) with fine gravel.	5-3-4	2.0 - 3.5	7	
203.5	3.5	Moist to wet, loose, gray-brown-orange mottled clayey fine to medium SAND (SC), slightly micaceous with wood fragments.	3-3-5	3.5 - 5.0	8	
		Moist to wet, loose to medium dense, gray-brown clayey fine to medium SAND (SC) with root fragments and wood fragments.	4-5-6	6.5 - 8.0	11	
			5-7-6	8.5 - 10.0	13	
			6-7-7	11.5 - 13.0	14	
			5-6-4	13.5 - 15.0	10	
190.5	16.5	Wet, soft, gray-brown fine to medium sandy CLAY (CL) with root fragments.	2-2-1	16.5 - 18.0	3	
188.0	19.0	WOOD	1-7-7	18.5 - 20.0	14	
187.5	19.5	NATIVE: Saturated, medium dense, tan-gray slightly silty fine to coarse SAND (SP).				
185.5	21.5	Moist, medium dense to dense, gray silty fine to medium SAND (SM), micaceous.	6-11-14	21.5 - 23.0	25	
			9-14-18	23.5 - 25.0	32	
178.5	28.5	Moist, very dense, gray silty fine to medium SAND (SM), micaceous.	30-39-50	28.5 - 30.0	89	
			50/5.5"	33.5	50/5.5"	
173.0	34.0	Boring terminated at 34.0 feet.				

*Number of blows required for a 140 lb automatic hammer dropping 30" to drive 2" O.D., 1.375" I.D. split-spoon sampler in successive 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration Test value, "N".

BORING LOG 66M-0065 BORING LOGS.GPJ F&R.GDT 8/23/10

BORING LOG

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Report No.: **66M-0065** Date: **July 21, 2010**

Client: **Lappas & Havener, PA**

Project: **Horseshoe Farm Park, Raleigh, North Carolina**

Boring No.: **B-3** **(1 of 1)** Total Depth **30.0'** Elev: **207.0ft ±** Location: **See Boring Location Plan**

Type of Boring: **2.25" ID HSA** Started: **7/8/10** Completed: **7/8/10** Driller: **D. Tignor**

Elevation	Depth (feet)	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (feet)	N Value (blows/ ft)	REMARKS
206.6	0.4	FILL: Gravel and fines.	30-17-12	0.0 / 1.5	29	GROUNDWATER DATA: 0 Hrs.: 16.5' inside HSA 24 Hrs.: 15.5' inside HSA
205.0	2.0	Dry, medium dense, brown-gray clayey fine to medium SAND (SC) with wood fragments and fine gravel.	5-6-6	2.0 / 3.5	12	
		Moist, medium dense, gray clayey fine to medium SAND (SC) with wood fragments, slightly micaceous.	3-4-7	3.5 / 5.0	11	
200.5	6.5	Moist, loose, gray-dark gray clayey fine to medium SAND (SC) with root and wood fragments.	3-4-5	6.5 / 8.0	9	
			3-5-4	8.5 / 10.0	9	
195.5	11.5	NATIVE: Moist, stiff, light gray fine to medium sandy CLAY (CL).	2-5-6	11.5 / 13.0	11	
193.5	13.5	Moist, medium dense, tan-gray clayey fine to medium SAND (SC).	4-6-8	13.5 / 15.0	14	
190.5	16.5	Moist, loose, brown-gray mottled silty fine SAND (SM), micaceous.	3-4-5	16.5 / 18.0	9	
188.5	18.5	Saturated, loose to medium dense, tan-gray silty fine to medium SAND (SM) with trace clay.	3-4-3	18.5 / 20.0	7	
			5-7-7	21.5 / 23.0	14	
183.5	23.5	Moist, medium dense to very dense, orange-brown silty fine to medium SAND (SM) with trace clay.	7-15-21	23.5 / 25.0	36	
			24-32-37	28.5 / 30.0	69	
177.0	30.0	Boring terminated at 30.0 feet.				

BORING_LOG 66M-0065 BORING LOGS.GPJ F&R.GDT 8/23/10

*Number of blows required for a 140 lb automatic hammer dropping 30" to drive 2" O.D., 1.375" I.D. split-spoon sampler in successive 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration Test value, "N".

BORING LOG

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Report No.: **66M-0065** Date: **July 21, 2010**

Client: **Lappas & Havener, PA**

Project: **Horseshoe Farm Park, Raleigh, North Carolina**

Boring No.: **B-4** **(1 of 1)** Total Depth **20.0'** Elev: **197.0ft ±** Location: **See Boring Location Plan**

Type of Boring: **2.25" ID HSA** Started: **7/9/10** Completed: **7/9/10** Driller: **D. Tignor**

Elevation	Depth (feet)	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (feet)	N Value (blows/ ft)	REMARKS
196.5	0.5	FILL: Surficial Soil	4-4-5	0.0		GROUNDWATER DATA: 0 Hrs.: 8.0' inside HSA 24 Hrs.: 7.0' inside HSA
		Moist, loose, dark brown clayey fine to medium SAND (SC) with root and wood fragments.		1.5	9	
195.0	2.0		11-4-4	2.0		
		Moist, loose, gray-brown silty fine to medium SAND (SM) with wood fragments.			8	
193.5	3.5		4-4-5	3.5		
		NATIVE: Saturated, loose, gray silty fine to medium SAND (SM).		5.0	9	
190.5	6.5	Saturated, medium dense, orange-gray mottled silty fine to medium SAND (SM).	5-12-12	6.5	24	
				8.0		
188.5	8.5	Saturated, very loose, gray silty fine to medium SAND (SM).	3-2-2	8.5	4	
				10.0		
183.5	13.5	Saturated, medium dense, gray silty fine to coarse SAND (SM).	3-9-7	13.5	16	
182.4	14.6	Moist, medium dense, tan-orange slightly clayey silty fine to medium SAND (SM), micaceous.		15.0		
			7-10-11	18.5	21	
177.0	20.0	Boring terminated at 20.0 feet.		20.0		

BORING_LOG 66M-0065 BORING LOGS.GPJ F&R.GDT 8/23/10

*Number of blows required for a 140 lb automatic hammer dropping 30" to drive 2" O.D., 1.375" I.D. split-spoon sampler in successive 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration Test value, "N".

BORING LOG

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Report No.: **66M-0065** Date: **July 21, 2010**

Client: **Lappas & Havener, PA**

Project: **Horseshoe Farm Park, Raleigh, North Carolina**

Boring No.: **B-5** **(1 of 1)** Total Depth **20.0'** Elev: **195.0ft ±** Location: **See Boring Location Plan**

Type of Boring: **2.25" ID HSA** Started: **7/9/10** Completed: **7/9/10** Driller: **D. Tignor**

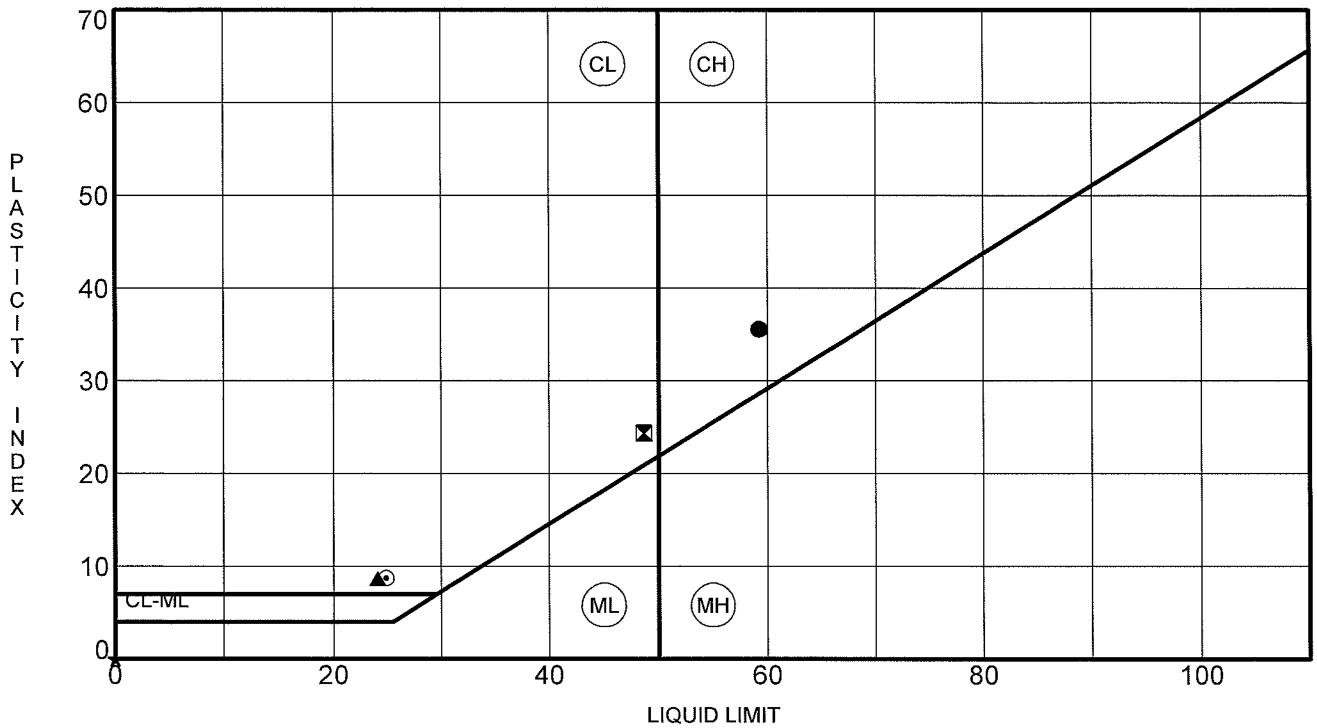
Elevation	Depth (feet)	DESCRIPTION OF MATERIALS (Classification)	* Sample Blows	Sample Depth (feet)	N Value (blows/ ft)	REMARKS
194.5	0.5	NATIVE: Surficial soil	6-24-6	0.0		GROUNDWATER DATA: 0 Hrs.: 9.0' inside HSA 24 Hrs.: 5.0' inside HSA
		Dry, medium dense, tan silty fine SAND (SM) with root fragments.		1.5	30	
			8-5-3	2.0	8	
192.0	3.0	Wet, loose, gray-brown clayey fine SAND (SC).				
191.5	3.5	Saturated, very loose dark brown clayey fine SAND (SC).	3-1-1	3.5	2	
				5.0		
188.5	6.5	Saturated, loose, gray slightly clayey silty fine to medium SAND (SM).	3-4-3	6.5	7	
				8.0		
186.5	8.5	Wet, medium dense, tan-gray slightly clayey silty fine to medium SAND (SM).	3-5-6	8.5	11	
				10.0		
181.5	13.5	Wet, medium dense, orange-tan-gray mottled silty fine to medium SAND (SM).	12-11-10	13.5	21	
				15.0		
176.5	18.5	Moist, dense, orange silty fine to coarse SAND (SM).	10-14-18	18.5	32	
175.0	20.0	Boring terminated at 20.0 feet.		20.0		

*Number of blows required for a 140 lb automatic hammer dropping 30" to drive 2" O.D., 1.375" I.D. split-spoon sampler in successive 6" increments. The sum of the second and third increments of penetration is termed the Standard Penetration Test value, "N".

BORING LOG 66M-0065 BORING LOGS.GPJ F&R.GDT 8/23/10

APPENDIX III

LABORATORY TEST RESULTS



	Boring No.	Depth	LL	PL	PI	Fines	Classification	% Natural Moisture Content
●	B-1	3.0	59	24	35	56.4	Light Grey-Grey-little Brown, SANDY FAT CLAY (CH)	20.1
⧗	B-2	2.0 - 3.5	49	24	25	34.7	Grey-Light Brown, CLAYEY SAND (SC)	17.0
▲	B-3	6.5 - 8.0	24	15	9	33.5	Light Brown-little Grey, CLAYEY SAND (SC)	10.7
★	B-4	3.5 - 5.0	NP	NP	NP	30.2	Tan-Light Grey, SILTY SAND (SM)	12.5
⊙	B-5	3.5 - 5.0	25	16	9	40.1	Grey, CLAYEY SAND (SC)	21.9

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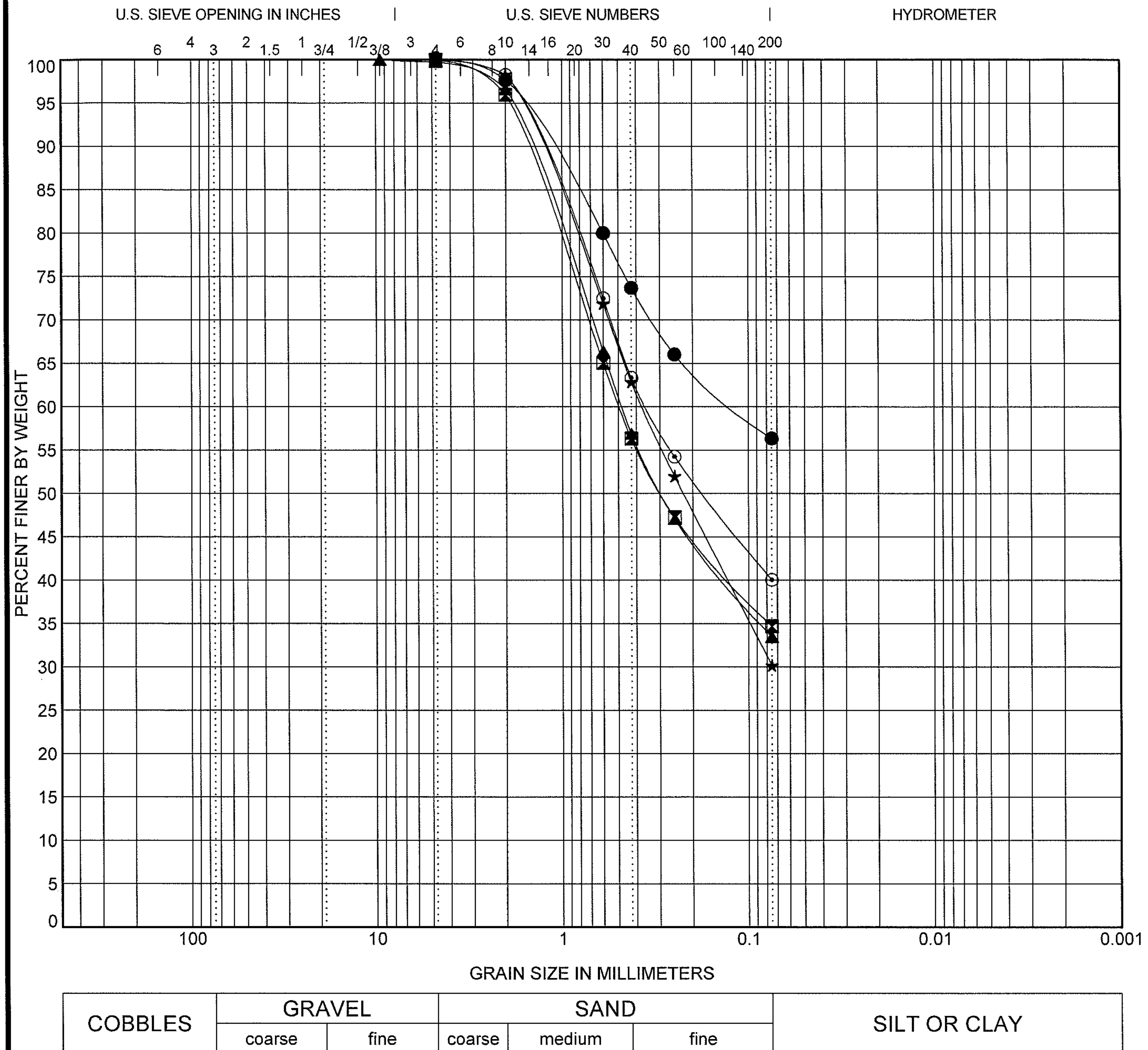
ATTERBERG LIMITS' RESULTS

Report No.: 66M-0065
Client: Lappas & Havener
Project: Horseshoe Farm Park
Location: Raleigh, NC
Date: 07/21/2010



Boring No.		Depth	Classification	LL	PL	PI	Cc	Cu
● B-1	at	3.0	Light Grey-Grey-little Brown, SANDY FAT CLAY (CH)	59	24	35		
⧗ B-2	at	2.0 - 3.5	Grey-Light Brown, CLAYEY SAND (SC) (mica)	49	24	25		
▲ B-3	at	6.5 - 8.0	Light Brown-little Grey, CLAYEY SAND (SC)	24	15	9		
★ B-4	at	3.5 - 5.0	Tan-Light Grey, SILTY SAND (SM)	NP	NP	NP		
⊙ B-5	at	3.5 - 5.0	Grey, CLAYEY SAND (SC)	25	16	9		

Boring No.		Depth	D100	D60	D30	D10	%Gravel	%Sand	%Silt	%Clay
● B-1	at	3.0	4.75	0.118			0.0	43.6	56.4	
⧗ B-2	at	2.0 - 3.5	4.75	0.491			0.0	65.3	34.7	
▲ B-3	at	6.5 - 8.0	9.5	0.476			0.2	66.3	33.5	
★ B-4	at	3.5 - 5.0	4.75	0.369			0.0	69.8	30.2	
⊙ B-5	at	3.5 - 5.0	4.75	0.349			0.0	59.9	40.1	

SINCE 1881

FROEHLING & ROBERTSON, INC.
ENGINEERING • ENVIRONMENTAL • GEOTECHNICAL

GRAIN SIZE DISTRIBUTION

Report No.: 66M-0065
Client: Lappas & Havener
Project: Horseshoe Farm Park
Location: Raleigh, NC
Date: 07/21/2010

US GRAIN SIZE 66M-0065.GPJ F&R.GDT 7/27/10

APPENDIX IV

SLOPE STABILITY ANALYSIS RESULTS

```
                      ***  GSTABL7  ***
               ** GSTABL7 by Garry H. Gregory, P.E. **
   ** Original Version 1.0, January 1996; Current Version 2.003, June 2002 **
             (All Rights Reserved-Unauthorized Use Prohibited)
*********************************************************************************
                    SLOPE STABILITY ANALYSIS SYSTEM
       Modified Bishop, Simplified Janbu, or GLE Method of Slices.
       (Includes Spencer & Morgenstern-Price Type Analysis)
       Including Pier/Pile, Reinforcement, Soil Nail, Tieback,
       Nonlinear Undrained Shear Strength, Curved Phi Envelope,
       Anisotropic Soil, Fiber-Reinforced Soil, Boundary Loads, Water
       Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
*********************************************************************************
    Analysis Run Date:         8/25/2010
    Time of Run:               04:29PM
    Run By:                    RFS
    Input Data Filename:       E:\GStabl7\Branch 66\horseshoe farm park upstream slope-norm
al pool.in
    Output Filename:           E:\GStabl7\Branch 66\horseshoe farm park upstream slope-norm
al pool.OUT
    Unit System:               English
    Plotted Output Filename:   E:\GStabl7\Branch 66\horseshoe fpark upstream slope-normal p
ool.PLT
    PROBLEM DESCRIPTION:  horseshoe farm park
                          existing upstream-normal pool
    BOUNDARY COORDINATES
        3 Top   Boundaries
```

3 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	46.00	40.00	46.00	1
2	40.00	46.00	80.00	62.00	1
3	80.00	62.00	92.00	62.00	1

Default Y-Origin = 0.00(ft)
Default X-Plus Value = 0.00(ft)
Default Y-Plus Value = 0.00(ft)
ISOTROPIC SOIL PARAMETERS
1 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	125.0	125.0	100.0	32.0	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) SPECIFIED
Unit Weight of Water = 62.40 (pcf)
Piezometric Surface No. 1 Specified by 4 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	58.00
2	68.00	58.00
3	80.00	48.00
4	92.00	46.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
10 Surface(s) Initiate(s) From Each Of 10 Points Equally Spaced
Along The Ground Surface Between X = 5.00(ft)
and X = 60.00(ft)
Each Surface Terminates Between X = 75.00(ft)
and X = 92.00(ft)
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y = 0.00(ft)
2.00(ft) Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Evaluated. They Are
Ordered - Most Critical First.
* * Safety Factors Are Calculated By The Modified Bishop Method * *
Total Number of Trial Surfaces Evaluated = 100
Statistical Data On All Valid FS Values:
FS Max = 8.873 FS Min = 2.865 FS Ave = 3.794
Standard Deviation = 0.815 Coefficient of Variation = 21.48 %
Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	41.67	46.67
2	43.65	46.42
3	45.64	46.26
4	47.64	46.19
5	49.64	46.22
6	51.64	46.34
7	53.63	46.55
8	55.61	46.85
9	57.57	47.25
10	59.51	47.73
11	61.42	48.30
12	63.31	48.96
13	65.17	49.71
14	66.99	50.54
15	68.76	51.46
16	70.50	52.45
17	72.18	53.53
18	73.82	54.68
19	75.40	55.91
20	76.92	57.20

21	78.38	58.57
22	79.78	60.00
23	81.11	61.50
24	81.51	62.00

Circle Center At X = 48.07 ; Y = 89.47 ; and Radius = 43.28

Factor of Safety

*** 2.865 ***

Individual data on the 26 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	2.0	129.4	1458.5	1430.0	0.	0.	0.0	0.0	0.0
2	2.0	379.0	1358.8	1455.4	0.	0.	0.0	0.0	0.0
3	2.0	607.4	1255.1	1469.3	0.	0.	0.0	0.0	0.0
4	2.0	812.5	1148.1	1471.7	0.	0.	0.0	0.0	0.0
5	2.0	992.3	1039.0	1462.6	0.	0.	0.0	0.0	0.0
6	2.0	1145.6	928.5	1442.0	0.	0.	0.0	0.0	0.0
7	2.0	1271.3	817.5	1409.9	0.	0.	0.0	0.0	0.0
8	2.0	1368.7	707.1	1366.5	0.	0.	0.0	0.0	0.0
9	1.9	1437.4	598.0	1311.8	0.	0.	0.0	0.0	0.0
10	1.9	1477.6	491.2	1245.8	0.	0.	0.0	0.0	0.0
11	1.9	1489.7	387.3	1168.9	0.	0.	0.0	0.0	0.0
12	1.9	1474.4	287.3	1081.0	0.	0.	0.0	0.0	0.0
13	1.8	1433.0	191.9	982.5	0.	0.	0.0	0.0	0.0
14	1.0	785.4	68.4	512.3	0.	0.	0.0	0.0	0.0
15	0.8	581.6	0.0	273.6	0.	0.	0.0	0.0	0.0
16	1.7	1278.3	0.0	464.9	0.	0.	0.0	0.0	0.0
17	1.7	1169.0	0.0	220.7	0.	0.	0.0	0.0	0.0
18	0.6	419.6	0.0	19.1	0.	0.	0.0	0.0	0.0
19	1.0	622.0	0.0	0.0	0.	0.	0.0	0.0	0.0
20	1.6	898.8	0.0	0.0	0.	0.	0.0	0.0	0.0
21	1.5	743.7	0.0	0.0	0.	0.	0.0	0.0	0.0
22	1.5	579.4	0.0	0.0	0.	0.	0.0	0.0	0.0
23	1.4	409.2	0.0	0.0	0.	0.	0.0	0.0	0.0
24	0.2	50.6	0.0	0.0	0.	0.	0.0	0.0	0.0
25	1.1	155.6	0.0	0.0	0.	0.	0.0	0.0	0.0
26	0.4	12.7	0.0	0.0	0.	0.	0.0	0.0	0.0

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	47.78	49.11
2	49.70	48.54
3	51.64	48.10
4	53.62	47.77
5	55.61	47.58
6	57.61	47.51
7	59.61	47.56
8	61.60	47.74
9	63.57	48.05
10	65.53	48.48
11	67.45	49.04
12	69.33	49.71
13	71.17	50.50
14	72.95	51.41
15	74.67	52.43
16	76.33	53.55
17	77.91	54.78
18	79.41	56.10
19	80.82	57.52
20	82.14	59.02
21	83.36	60.60
22	84.31	62.00

Circle Center At X = 57.73 ; Y = 79.13 ; and Radius = 31.62

Factor of Safety

*** 2.939 ***

Failure Surface Specified By 32 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.56	46.00
2	37.53	45.69
3	39.52	45.44
4	41.51	45.25
5	43.50	45.12
6	45.50	45.05
7	47.50	45.03
8	49.50	45.08
9	51.50	45.19
10	53.49	45.36
11	55.48	45.59
12	57.46	45.87
13	59.43	46.22
14	61.39	46.62
15	63.33	47.09
16	65.26	47.61
17	67.18	48.19
18	69.07	48.82
19	70.95	49.52
20	72.80	50.26
21	74.63	51.07
22	76.44	51.93
23	78.22	52.84
24	79.97	53.80
25	81.70	54.82
26	83.39	55.89
27	85.05	57.00
28	86.67	58.17
29	88.26	59.39
30	89.81	60.65
31	91.32	61.96
32	91.37	62.00

Circle Center At X = 46.89 ; Y = 111.83 ; and Radius = 66.80

Factor of Safety

*** 2.967 ***

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.56	46.00
2	37.34	45.11
3	39.18	44.32
4	41.07	43.65
5	42.99	43.09
6	44.94	42.66
7	46.92	42.34
8	48.91	42.13
9	50.90	42.05
10	52.90	42.09
11	54.90	42.26
12	56.88	42.54
13	58.84	42.94
14	60.77	43.46
15	62.66	44.09
16	64.52	44.84
17	66.33	45.69
18	68.08	46.66
19	69.77	47.73
20	71.39	48.90
21	72.94	50.16
22	74.41	51.52
23	75.79	52.96
24	77.09	54.49
25	78.29	56.09
26	79.39	57.76
27	80.39	59.49

28	81.28	61.28
29	81.59	62.00

Circle Center At X = 51.23 ; Y = 75.15 ; and Radius = 33.10

Factor of Safety

*** 2.991 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.56	46.00
2	37.54	45.79
3	39.54	45.63
4	41.54	45.53
5	43.53	45.48
6	45.53	45.48
7	47.53	45.53
8	49.53	45.65
9	51.52	45.81
10	53.51	46.03
11	55.49	46.30
12	57.47	46.62
13	59.43	47.00
14	61.38	47.43
15	63.33	47.91
16	65.25	48.44
17	67.17	49.03
18	69.06	49.67
19	70.94	50.35
20	72.80	51.09
21	74.64	51.88
22	76.45	52.71
23	78.25	53.60
24	80.02	54.53
25	81.76	55.51
26	83.48	56.54
27	85.17	57.61
28	86.83	58.73
29	88.45	59.89
30	90.05	61.09
31	91.19	62.00

Circle Center At X = 44.42 ; Y = 119.91 ; and Radius = 74.44

Factor of Safety

*** 2.996 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.56	46.00
2	37.31	45.05
3	39.12	44.19
4	40.98	43.44
5	42.87	42.80
6	44.80	42.27
7	46.75	41.85
8	48.73	41.54
9	50.72	41.34
10	52.72	41.25
11	54.72	41.28
12	56.71	41.43
13	58.70	41.68
14	60.66	42.05
15	62.60	42.53
16	64.51	43.12
17	66.39	43.82
18	68.22	44.62
19	70.00	45.53
20	71.73	46.54
21	73.40	47.64
22	75.00	48.84

23	76.54	50.12
24	77.99	51.49
25	79.37	52.94
26	80.66	54.47
27	81.86	56.07
28	82.97	57.73
29	83.99	59.45
30	84.90	61.23
31	85.24	62.00

Circle Center At X = 53.20 ; Y = 76.40 ; and Radius = 35.14
Factor of Safety
*** 3.013 ***
Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	41.67	46.67
2	43.57	46.06
3	45.50	45.54
4	47.46	45.10
5	49.43	44.76
6	51.41	44.51
7	53.40	44.35
8	55.40	44.27
9	57.40	44.29
10	59.40	44.41
11	61.39	44.61
12	63.37	44.90
13	65.33	45.29
14	67.27	45.76
15	69.19	46.32
16	71.08	46.97
17	72.94	47.70
18	74.77	48.52
19	76.56	49.42
20	78.30	50.40
21	79.99	51.46
22	81.64	52.60
23	83.23	53.81
24	84.77	55.09
25	86.24	56.44
26	87.66	57.86
27	89.00	59.33
28	90.28	60.87
29	91.13	62.00

Circle Center At X = 55.95 ; Y = 88.06 ; and Radius = 43.79
Factor of Safety
*** 3.028 ***
Failure Surface Specified By 36 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	29.44	46.00
2	31.29	45.24
3	33.17	44.54
4	35.07	43.93
5	37.00	43.38
6	38.94	42.91
7	40.90	42.52
8	42.88	42.20
9	44.86	41.96
10	46.85	41.80
11	48.85	41.71
12	50.85	41.70
13	52.85	41.77
14	54.85	41.91
15	56.83	42.14
16	58.81	42.44
17	60.77	42.81

18	62.72	43.27
19	64.65	43.79
20	66.56	44.40
21	68.44	45.07
22	70.30	45.82
23	72.12	46.64
24	73.91	47.53
25	75.67	48.48
26	77.39	49.51
27	79.06	50.60
28	80.70	51.75
29	82.28	52.97
30	83.82	54.25
31	85.31	55.59
32	86.74	56.98
33	88.12	58.43
34	89.45	59.93
35	90.71	61.48
36	91.10	62.00

Circle Center At X = 50.08 ; Y = 93.28 ; and Radius = 51.59
Factor of Safety
*** 3.044 ***

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	41.67	46.67
2	43.51	45.89
3	45.39	45.21
4	47.31	44.64
5	49.25	44.17
6	51.22	43.80
7	53.20	43.54
8	55.19	43.39
9	57.19	43.35
10	59.19	43.41
11	61.19	43.58
12	63.17	43.86
13	65.13	44.25
14	67.07	44.74
15	68.98	45.33
16	70.85	46.03
17	72.69	46.82
18	74.48	47.72
19	76.22	48.71
20	77.90	49.79
21	79.52	50.96
22	81.08	52.21
23	82.56	53.55
24	83.98	54.97
25	85.31	56.46
26	86.56	58.02
27	87.73	59.64
28	88.80	61.33
29	89.19	62.00

Circle Center At X = 57.01 ; Y = 80.45 ; and Radius = 37.11
Factor of Safety
*** 3.052 ***

Failure Surface Specified By 36 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	29.44	46.00
2	31.30	45.25
3	33.18	44.57
4	35.08	43.96
5	37.01	43.42
6	38.96	42.96
7	40.92	42.57

8	42.89	42.26
9	44.88	42.02
10	46.87	41.85
11	48.87	41.77
12	50.87	41.75
13	52.87	41.82
14	54.86	41.96
15	56.85	42.17
16	58.83	42.46
17	60.80	42.83
18	62.75	43.27
19	64.68	43.78
20	66.59	44.37
21	68.48	45.03
22	70.34	45.76
23	72.18	46.56
24	73.98	47.42
25	75.75	48.36
26	77.48	49.36
27	79.17	50.43
28	80.82	51.56
29	82.42	52.75
30	83.98	54.01
31	85.49	55.32
32	86.95	56.69
33	88.36	58.11
34	89.71	59.58
35	91.01	61.11
36	91.71	62.00

Circle Center At X = 50.18 ; Y = 94.45 ; and Radius = 52.70

Factor of Safety

*** 3.058 ***

**** END OF GSTABL7 OUTPUT ****

```
                    *** GSTABL7 ***
          ** GSTABL7 by Garry H. Gregory, P.E. **
  ** Original Version 1.0, January 1996; Current Version 2.003, June 2002 **
```


```
*********************************************************************************
              SLOPE STABILITY ANALYSIS SYSTEM
     Modified Bishop, Simplified Janbu, or GLE Method of Slices.
     (Includes Spencer & Morgenstern-Price Type Analysis)
     Including Pier/Pile, Reinforcement, Soil Nail, Tieback,
     Nonlinear Undrained Shear Strength, Curved Phi Envelope,
     Anisotropic Soil, Fiber-Reinforced Soil, Boundary Loads, Water
     Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
*********************************************************************************
    Analysis Run Date:        8/26/2010
    Time of Run:              09:01AM
    Run By:                   MSS
    Input Data Filename:      E:\GStabl7\Branch 66\horseshoe farm park upstream slope-rapi
d drawdown.in
    Output Filename:          E:\GStabl7\Branch 66\horseshoe farm park upstream slope-rapi
d drawdown.OUT
    Unit System:              English
    Plotted Output Filename:  E:\GStabl7\Branch 66\horseshoe fpark upstream slope-rapid dr
awdown.PLT
    PROBLEM DESCRIPTION:  horseshoe farm park
                          existing upstream-rapid drawdown
    BOUNDARY COORDINATES
        3 Top   Boundaries
        3 Total Boundaries
    Boundary     X-Left     Y-Left     X-Right    Y-Right    Soil Type
       No.        (ft)       (ft)       (ft)       (ft)      Below Bnd
        1         0.00      47.00      40.00      47.00          1
        2        40.00      47.00      80.00      62.00          1
        3        80.00      62.00      92.00      62.00          1
    Default Y-Origin = 0.00(ft)
    Default X-Plus Value = 0.00(ft)
    Default Y-Plus Value = 0.00(ft)
   ISOTROPIC SOIL PARAMETERS
     1 Type(s) of Soil
    Soil  Total  Saturated  Cohesion Friction   Pore    Pressure   Piez.
    Type Unit Wt. Unit Wt. Intercept   Angle  Pressure Constant Surface
     No.  (pcf)    (pcf)     (psf)     (deg)   Param.    (psf)     No.
      1   125.0    125.0     350.0     16.0    0.00       0.0      1
    1 PIEZOMETRIC SURFACE(S) SPECIFIED
    Unit Weight of Water =  62.40 (pcf)
    Piezometric Surface No.  1 Specified by  5 Coordinate Points
    Pore Pressure Inclination Factor =  0.50
      Point      X-Water     Y-Water
       No.         (ft)        (ft)
        1          0.00       47.00
        2         40.00       47.00
        3         68.00       57.00
        4         94.00       46.00
        5         98.00       46.00
    A Critical Failure Surface Searching Method, Using A Random
    Technique For Generating Circular Surfaces, Has Been Specified.
     100 Trial Surfaces Have Been Generated.
      10 Surface(s) Initiate(s) From Each Of    10 Points Equally Spaced
    Along The Ground Surface Between  X =    5.00(ft)
                                    and  X =   60.00(ft)
    Each Surface Terminates Between   X =   75.00(ft)
                                  and    X =   92.00(ft)
    Unless Further Limitations Were Imposed, The Minimum Elevation
    At Which A Surface Extends Is  Y =       0.00(ft)
     2.00(ft) Line Segments Define Each Trial Failure Surface.
    Following Are Displayed The Ten Most Critical Of The Trial
          Failure Surfaces Evaluated. They Are
          Ordered - Most Critical First.
          * * Safety Factors Are Calculated By The Modified Bishop Method * *
```

Total Number of Trial Surfaces Evaluated = 100
Statistical Data On All Valid FS Values:
FS Max = 21.242 FS Min = 2.110 FS Ave = 3.345
Standard Deviation = 2.405 Coefficient of Variation = 71.89 %
Failure Surface Specified By 38 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	29.44	47.00
2	30.94	45.67
3	32.51	44.43
4	34.14	43.27
5	35.83	42.21
6	37.58	41.23
7	39.37	40.35
8	41.22	39.58
9	43.10	38.90
10	45.01	38.33
11	46.96	37.86
12	48.93	37.50
13	50.91	37.24
14	52.90	37.09
15	54.90	37.05
16	56.90	37.12
17	58.89	37.30
18	60.87	37.59
19	62.83	37.98
20	64.77	38.48
21	66.68	39.09
22	68.55	39.79
23	70.38	40.60
24	72.16	41.51
25	73.89	42.51
26	75.57	43.60
27	77.18	44.78
28	78.73	46.05
29	80.20	47.40
30	81.60	48.83
31	82.92	50.34
32	84.16	51.91
33	85.31	53.54
34	86.36	55.24
35	87.33	56.99
36	88.20	58.80
37	88.97	60.64
38	89.45	62.00

Circle Center At X = 54.61 ; Y = 73.85 ; and Radius = 36.80
Factor of Safety
*** 2.110 ***
Individual data on the 41 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	1.5	124.1	0.0	82.8	0.	0.	0.0	0.0	0.0
2	1.6	381.6	0.0	243.3	0.	0.	0.0	0.0	0.0
3	1.6	642.3	0.0	393.1	0.	0.	0.0	0.0	0.0
4	1.7	901.2	0.0	531.8	0.	0.	0.0	0.0	0.0
5	1.7	1153.5	0.0	659.1	0.	0.	0.0	0.0	0.0
6	1.8	1394.6	0.0	774.6	0.	0.	0.0	0.0	0.0
7	0.6	529.9	0.0	287.2	0.	0.	0.0	0.0	0.0
8	1.2	1124.8	0.0	574.2	0.	0.	0.0	0.0	0.0
9	1.9	2016.3	0.0	1004.6	0.	0.	0.0	0.0	0.0
10	1.9	2373.0	0.0	1158.1	0.	0.	0.0	0.0	0.0
11	1.9	2710.7	0.0	1300.6	0.	0.	0.0	0.0	0.0
12	2.0	3024.6	0.0	1431.8	0.	0.	0.0	0.0	0.0
13	2.0	3310.7	0.0	1551.2	0.	0.	0.0	0.0	0.0
14	2.0	3565.0	0.0	1658.5	0.	0.	0.0	0.0	0.0

15	2.0	3784.4	0.0	1753.4	0.	0.	0.0	0.0	0.0
16	2.0	3966.1	0.0	1835.6	0.	0.	0.0	0.0	0.0
17	2.0	4108.0	0.0	1904.9	0.	0.	0.0	0.0	0.0
18	2.0	4208.6	0.0	1961.0	0.	0.	0.0	0.0	0.0
19	2.0	4267.0	0.0	2003.8	0.	0.	0.0	0.0	0.0
20	1.9	4283.0	0.0	2033.1	0.	0.	0.0	0.0	0.0
21	1.9	4256.9	0.0	2049.0	0.	0.	0.0	0.0	0.0
22	1.3	2960.2	0.0	1449.7	0.	0.	0.0	0.0	0.0
23	0.5	1229.6	0.0	582.0	0.	0.	0.0	0.0	0.0
24	1.8	4083.2	0.0	1866.3	0.	0.	0.0	0.0	0.0
25	1.8	3939.5	0.0	1679.4	0.	0.	0.0	0.0	0.0
26	1.7	3761.3	0.0	1483.8	0.	0.	0.0	0.0	0.0
27	1.7	3552.2	0.0	1279.9	0.	0.	0.0	0.0	0.0
28	1.6	3315.8	0.0	1068.4	0.	0.	0.0	0.0	0.0
29	1.5	3056.4	0.0	850.0	0.	0.	0.0	0.0	0.0
30	1.3	2406.5	0.0	553.0	0.	0.	0.0	0.0	0.0
31	0.2	371.1	0.0	72.2	0.	0.	0.0	0.0	0.0
32	1.4	2428.3	0.0	394.8	0.	0.	0.0	0.0	0.0
33	1.3	2048.3	0.0	159.5	0.	0.	0.0	0.0	0.0
34	0.2	299.5	0.0	3.4	0.	0.	0.0	0.0	0.0
35	1.0	1381.5	0.0	0.0	0.	0.	0.0	0.0	0.0
36	1.1	1331.9	0.0	0.0	0.	0.	0.0	0.0	0.0
37	1.1	1006.4	0.0	0.0	0.	0.	0.0	0.0	0.0
38	1.0	709.3	0.0	0.0	0.	0.	0.0	0.0	0.0
39	0.9	445.5	0.0	0.0	0.	0.	0.0	0.0	0.0
40	0.8	219.3	0.0	0.0	0.	0.	0.0	0.0	0.0
41	0.5	40.8	0.0	0.0	0.	0.	0.0	0.0	0.0

Failure Surface Specified By 34 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.56	47.00
2	37.26	45.95
3	39.02	45.00
4	40.82	44.13
5	42.66	43.36
6	44.54	42.68
7	46.46	42.09
8	48.40	41.61
9	50.36	41.22
10	52.34	40.94
11	54.33	40.76
12	56.33	40.67
13	58.33	40.69
14	60.33	40.81
15	62.31	41.03
16	64.29	41.36
17	66.24	41.78
18	68.17	42.30
19	70.08	42.92
20	71.94	43.63
21	73.77	44.44
22	75.56	45.34
23	77.30	46.33
24	78.98	47.41
25	80.61	48.57
26	82.18	49.82
27	83.68	51.14
28	85.11	52.53
29	86.47	54.00
30	87.75	55.53
31	88.96	57.13
32	90.08	58.79
33	91.11	60.50
34	91.92	62.00

Circle Center At X = 56.95 ; Y = 79.99 ; and Radius = 39.32

Factor of Safety

*** 2.113 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.56	47.00
2	37.19	45.85
3	38.90	44.80
4	40.67	43.87
5	42.49	43.05
6	44.36	42.35
7	46.28	41.77
8	48.23	41.32
9	50.20	40.99
10	52.19	40.78
11	54.19	40.71
12	56.19	40.76
13	58.18	40.94
14	60.15	41.25
15	62.11	41.68
16	64.03	42.23
17	65.91	42.91
18	67.74	43.71
19	69.52	44.62
20	71.24	45.65
21	72.89	46.78
22	74.46	48.01
23	75.95	49.35
24	77.36	50.77
25	78.67	52.28
26	79.88	53.88
27	80.98	55.54
28	81.98	57.28
29	82.86	59.07
30	83.63	60.92
31	84.00	62.00

Circle Center At X = 54.37 ; Y = 71.99 ; and Radius = 31.28

Factor of Safety

*** 2.125 ***

Failure Surface Specified By 40 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	29.44	47.00
2	30.89	45.62
3	32.41	44.32
4	34.00	43.10
5	35.64	41.97
6	37.35	40.92
7	39.11	39.97
8	40.92	39.12
9	42.77	38.36
10	44.66	37.71
11	46.58	37.15
12	48.53	36.70
13	50.50	36.35
14	52.48	36.11
15	54.48	35.98
16	56.48	35.95
17	58.48	36.03
18	60.47	36.22
19	62.45	36.51
20	64.41	36.91
21	66.34	37.41
22	68.25	38.01
23	70.12	38.72
24	71.95	39.52
25	73.74	40.42
26	75.47	41.42
27	77.15	42.51

```
     28        78.77        43.68
     29        80.32        44.94
     30        81.81        46.28
     31        83.22        47.70
     32        84.55        49.19
     33        85.80        50.75
     34        86.97        52.38
     35        88.05        54.06
     36        89.03        55.80
     37        89.92        57.59
     38        90.72        59.43
     39        91.41        61.30
     40        91.63        62.00
 Circle Center At X =    55.99 ; Y =    73.35 ; and Radius =    37.40
        Factor of Safety
       ***   2.129   ***
 Failure Surface Specified By 40 Coordinate Points
   Point       X-Surf       Y-Surf
    No.         (ft)         (ft)
     1         29.44        47.00
     2         30.87        45.60
     3         32.37        44.28
     4         33.94        43.04
     5         35.57        41.88
     6         37.27        40.82
     7         39.01        39.85
     8         40.81        38.97
     9         42.66        38.19
    10         44.54        37.51
    11         46.45        36.94
    12         48.40        36.47
    13         50.36        36.10
    14         52.34        35.84
    15         54.34        35.69
    16         56.34        35.64
    17         58.34        35.70
    18         60.33        35.87
    19         62.31        36.15
    20         64.27        36.53
    21         66.21        37.02
    22         68.12        37.61
    23         70.00        38.30
    24         71.84        39.10
    25         73.63        39.99
    26         75.37        40.98
    27         77.05        42.05
    28         78.67        43.22
    29         80.23        44.48
    30         81.72        45.81
    31         83.14        47.22
    32         84.47        48.71
    33         85.73        50.27
    34         86.90        51.89
    35         87.98        53.57
    36         88.97        55.31
    37         89.86        57.10
    38         90.65        58.94
    39         91.35        60.81
    40         91.72        62.00
 Circle Center At X =    56.18 ; Y =    72.77 ; and Radius =    37.14
        Factor of Safety
       ***   2.136   ***
 Failure Surface Specified By 40 Coordinate Points
   Point       X-Surf       Y-Surf
    No.         (ft)         (ft)
     1         29.44        47.00
     2         30.86        45.59
```

3	32.35	44.25
4	33.91	43.00
5	35.54	41.84
6	37.22	40.76
7	38.97	39.79
8	40.76	38.91
9	42.61	38.12
10	44.49	37.45
11	46.40	36.87
12	48.35	36.40
13	50.31	36.04
14	52.30	35.79
15	54.29	35.64
16	56.29	35.61
17	58.29	35.68
18	60.28	35.87
19	62.26	36.16
20	64.22	36.56
21	66.15	37.07
22	68.06	37.69
23	69.92	38.40
24	71.75	39.22
25	73.53	40.14
26	75.25	41.15
27	76.92	42.26
28	78.52	43.46
29	80.05	44.74
30	81.51	46.11
31	82.90	47.55
32	84.20	49.06
33	85.42	50.65
34	86.55	52.30
35	87.59	54.01
36	88.53	55.77
37	89.38	57.59
38	90.12	59.44
39	90.76	61.34
40	90.94	62.00

Circle Center At X = 55.91 ; Y = 72.05 ; and Radius = 36.44

Factor of Safety

*** 2.137 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.56	47.00
2	37.31	46.05
3	39.12	45.19
4	40.98	44.44
5	42.87	43.80
6	44.79	43.26
7	46.75	42.83
8	48.72	42.51
9	50.71	42.30
10	52.71	42.21
11	54.71	42.23
12	56.71	42.36
13	58.69	42.60
14	60.66	42.95
15	62.60	43.42
16	64.52	43.99
17	66.40	44.67
18	68.24	45.45
19	70.03	46.34
20	71.77	47.33
21	73.46	48.41
22	75.07	49.58
23	76.62	50.85

24	78.10	52.20
25	79.50	53.63
26	80.81	55.14
27	82.04	56.71
28	83.18	58.36
29	84.22	60.06
30	85.17	61.83
31	85.25	62.00

Circle Center At X = 53.39 ; Y = 77.75 ; and Radius = 35.55

Factor of Safety

*** 2.138 ***

Failure Surface Specified By 41 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	47.00
2	24.88	45.73
3	26.48	44.53
4	28.13	43.40
5	29.83	42.36
6	31.59	41.39
7	33.38	40.51
8	35.22	39.71
9	37.08	39.00
10	38.99	38.38
11	40.91	37.85
12	42.86	37.40
13	44.83	37.05
14	46.82	36.80
15	48.81	36.63
16	50.81	36.56
17	52.81	36.58
18	54.80	36.70
19	56.79	36.90
20	58.77	37.21
21	60.73	37.60
22	62.67	38.08
23	64.59	38.66
24	66.47	39.32
25	68.33	40.07
26	70.15	40.91
27	71.92	41.83
28	73.65	42.83
29	75.33	43.91
30	76.96	45.07
31	78.54	46.31
32	80.05	47.62
33	81.50	48.99
34	82.89	50.44
35	84.20	51.94
36	85.45	53.51
37	86.62	55.13
38	87.71	56.80
39	88.72	58.53
40	89.65	60.30
41	90.45	62.00

Circle Center At X = 51.34 ; Y = 79.34 ; and Radius = 42.78

Factor of Safety

*** 2.144 ***

Failure Surface Specified By 34 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.56	47.00
2	37.01	45.62
3	38.55	44.35
4	40.17	43.17
5	41.86	42.11
6	43.62	41.16

7	45.44	40.33
8	47.31	39.63
9	49.23	39.05
10	51.17	38.60
11	53.15	38.27
12	55.14	38.08
13	57.14	38.03
14	59.14	38.10
15	61.13	38.31
16	63.10	38.65
17	65.04	39.12
18	66.95	39.71
19	68.82	40.44
20	70.63	41.28
21	72.38	42.24
22	74.07	43.32
23	75.68	44.51
24	77.20	45.80
25	78.64	47.19
26	79.99	48.67
27	81.23	50.24
28	82.36	51.88
29	83.39	53.60
30	84.29	55.39
31	85.08	57.22
32	85.74	59.11
33	86.28	61.04
34	86.48	62.00

Circle Center At X = 57.00 ; Y = 68.13 ; and Radius = 30.11

Factor of Safety

*** 2.145 ***

Failure Surface Specified By 37 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	29.44	47.00
2	30.88	45.61
3	32.40	44.31
4	33.99	43.10
5	35.66	41.99
6	37.38	40.98
7	39.17	40.08
8	41.00	39.29
9	42.89	38.61
10	44.80	38.04
11	46.75	37.59
12	48.73	37.26
13	50.71	37.05
14	52.71	36.96
15	54.71	36.99
16	56.71	37.14
17	58.69	37.41
18	60.65	37.80
19	62.58	38.31
20	64.48	38.93
21	66.34	39.67
22	68.15	40.52
23	69.91	41.48
24	71.61	42.54
25	73.24	43.70
26	74.79	44.95
27	76.27	46.30
28	77.66	47.74
29	78.97	49.25
30	80.18	50.84
31	81.29	52.51
32	82.30	54.23
33	83.20	56.02

```
      34         84.00        57.85
      35         84.68        59.73
      36         85.25        61.65
      37         85.33        62.00
  Circle Center At X =    53.21 ; Y =    70.09 ; and Radius =    33.13
         Factor of Safety
        ***    2.147   ***
            **** END OF GSTABL7 OUTPUT ****
```

***** GSTABL7 *****

** GSTABL7 by Garry H. Gregory, P.E. **

** Original Version 1.0, January 1996; Current Version 2.003, June 2002 **

****

SLOPE STABILITY ANALYSIS SYSTEM

Modified Bishop, Simplified Janbu, or GLE Method of Slices.
(Includes Spencer & Morgenstern-Price Type Analysis)
Including Pier/Pile, Reinforcement, Soil Nail, Tieback,
Nonlinear Undrained Shear Strength, Curved Phi Envelope,
Anisotropic Soil, Fiber-Reinforced Soil, Boundary Loads, Water
Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.

****

Analysis Run Date: 8/25/2010
Time of Run: 05:04PM
Run By: MSS
Input Data Filename: E:\GStabl7\Branch 66\horseshoe farm park downstream slope-no embankment.in
Output Filename: E:\GStabl7\Branch 66\horseshoe farm park downstream slope-no embankment.OUT
Unit System: English
Plotted Output Filename: E:\GStabl7\Branch 66\horseshoe fpark downstream slope-no embankment.PLT
PROBLEM DESCRIPTION: horseshoe farm park
existing downstream- normal pool

BOUNDARY COORDINATES
5 Top Boundaries
5 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	28.00	10.00	30.00	1
2	10.00	30.00	41.00	35.00	1
3	41.00	35.00	49.00	36.00	1
4	49.00	36.00	76.00	46.00	1
5	76.00	46.00	89.00	46.00	1

Default Y-Origin = 0.00(ft)
Default X-Plus Value = 0.00(ft)
Default Y-Plus Value = 0.00(ft)

ISOTROPIC SOIL PARAMETERS
1 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	125.0	125.0	100.0	30.0	0.00	0.0	1

1 PIEZOMETRIC SURFACE(S) SPECIFIED
Unit Weight of Water = 62.40 (pcf)
Piezometric Surface No. 1 Specified by 8 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	26.00
2	9.00	27.00
3	31.00	28.00
4	49.00	30.00
5	76.00	31.00
6	80.00	31.00
7	84.00	32.00
8	89.00	34.00

A Critical Failure Surface Searching Method, Using A Random
Technique For Generating Circular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
10 Surface(s) Initiate(s) From Each Of 10 Points Equally Spaced
Along The Ground Surface Between X = 5.00(ft)
and X = 60.00(ft)
Each Surface Terminates Between X = 65.00(ft)
and X = 85.00(ft)
Unless Further Limitations Were Imposed, The Minimum Elevation

At Which A Surface Extends Is Y = 0.00(ft)
2.00(ft) Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Evaluated. They Are
Ordered - Most Critical First.
* * Safety Factors Are Calculated By The Modified Bishop Method * *
Total Number of Trial Surfaces Evaluated = 100
Statistical Data On All Valid FS Values:
FS Max = 17.569 FS Min = 2.849 FS Ave = 3.712
Standard Deviation = 1.562 Coefficient of Variation = 42.09 %
Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	47.78	35.85
2	49.61	35.06
3	51.52	34.46
4	53.48	34.05
5	55.47	33.84
6	57.47	33.83
7	59.46	34.03
8	61.42	34.42
9	63.33	35.01
10	65.17	35.79
11	66.93	36.75
12	68.58	37.88
13	70.10	39.18
14	71.49	40.62
15	72.73	42.19
16	73.80	43.88
17	74.61	45.49

Circle Center At X = 56.53 ; Y = 53.66 ; and Radius = 19.85
Factor of Safety
*** 2.849 ***
Individual data on the 17 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	1.2	51.8	0.0	0.0	0.	0.	0.0	0.0	0.0
2	0.6	71.1	0.0	0.0	0.	0.	0.0	0.0	0.0
3	1.9	435.1	0.0	0.0	0.	0.	0.0	0.0	0.0
4	2.0	745.3	0.0	0.0	0.	0.	0.0	0.0	0.0
5	2.0	1015.2	0.0	0.0	0.	0.	0.0	0.0	0.0
6	2.0	1232.2	0.0	0.0	0.	0.	0.0	0.0	0.0
7	2.0	1386.7	0.0	0.0	0.	0.	0.0	0.0	0.0
8	2.0	1473.1	0.0	0.0	0.	0.	0.0	0.0	0.0
9	1.9	1489.6	0.0	0.0	0.	0.	0.0	0.0	0.0
10	1.8	1438.3	0.0	0.0	0.	0.	0.0	0.0	0.0
11	1.8	1325.2	0.0	0.0	0.	0.	0.0	0.0	0.0
12	1.6	1159.8	0.0	0.0	0.	0.	0.0	0.0	0.0
13	1.5	954.8	0.0	0.0	0.	0.	0.0	0.0	0.0
14	1.4	725.3	0.0	0.0	0.	0.	0.0	0.0	0.0
15	1.2	488.4	0.0	0.0	0.	0.	0.0	0.0	0.0
16	1.1	262.3	0.0	0.0	0.	0.	0.0	0.0	0.0
17	0.8	66.2	0.0	0.0	0.	0.	0.0	0.0	0.0

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	41.67	35.08
2	43.49	34.26
3	45.36	33.55
4	47.27	32.96
5	49.21	32.47
6	51.18	32.11
7	53.16	31.86
8	55.16	31.73
9	57.16	31.71

10	59.15	31.82
11	61.14	32.05
12	63.11	32.39
13	65.06	32.85
14	66.97	33.43
15	68.85	34.12
16	70.68	34.92
17	72.47	35.82
18	74.19	36.83
19	75.85	37.95
20	77.45	39.15
21	78.97	40.46
22	80.40	41.85
23	81.76	43.32
24	83.02	44.87
25	83.84	46.00

Circle Center At X = 56.35 ; Y = 65.31 ; and Radius = 33.60

Factor of Safety

*** 2.882 ***

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	53.89	37.81
2	55.78	37.16
3	57.73	36.72
4	59.72	36.47
5	61.72	36.44
6	63.71	36.60
7	65.67	36.98
8	67.59	37.55
9	69.43	38.32
10	71.19	39.28
11	72.84	40.41
12	74.36	41.71
13	75.74	43.15
14	76.97	44.74
15	77.75	46.00

Circle Center At X = 61.08 ; Y = 55.77 ; and Radius = 19.35

Factor of Safety

*** 2.883 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	53.89	37.81
2	55.79	37.19
3	57.74	36.75
4	59.72	36.49
5	61.72	36.42
6	63.72	36.54
7	65.70	36.84
8	67.64	37.33
9	69.52	38.00
10	71.34	38.83
11	73.07	39.84
12	74.70	41.00
13	76.21	42.31
14	77.59	43.75
15	78.84	45.32
16	79.28	46.00

Circle Center At X = 61.47 ; Y = 57.77 ; and Radius = 21.35

Factor of Safety

*** 2.883 ***

Failure Surface Specified By 24 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	41.67	35.08
2	43.43	34.14

```
     3          45.26       33.32
     4          47.13       32.63
     5          49.05       32.07
     6          51.01       31.65
     7          52.99       31.37
     8          54.98       31.22
     9          56.98       31.21
    10          58.98       31.34
    11          60.96       31.60
    12          62.92       32.01
    13          64.84       32.55
    14          66.73       33.22
    15          68.56       34.02
    16          70.33       34.95
    17          72.04       35.99
    18          73.66       37.16
    19          75.21       38.43
    20          76.66       39.81
    21          78.01       41.28
    22          79.26       42.85
    23          80.39       44.49
    24          81.28       46.00
Circle Center At X =     56.12 ; Y =     59.98 ; and Radius =    28.79
       Factor of Safety
      ***    2.890   ***
Failure Surface Specified By 19 Coordinate Points
  Point       X-Surf      Y-Surf
   No.         (ft)        (ft)
     1          47.78       35.85
     2          49.53       34.88
     3          51.36       34.09
     4          53.27       33.48
     5          55.23       33.07
     6          57.22       32.86
     7          59.22       32.85
     8          61.21       33.04
     9          63.17       33.42
    10          65.08       34.00
    11          66.93       34.77
    12          68.69       35.72
    13          70.35       36.84
    14          71.89       38.12
    15          73.29       39.55
    16          74.54       41.11
    17          75.63       42.78
    18          76.54       44.56
    19          77.11       46.00
Circle Center At X =     58.34 ; Y =     52.82 ; and Radius =    19.99
       Factor of Safety
      ***    2.902   ***
Failure Surface Specified By 24 Coordinate Points
  Point       X-Surf      Y-Surf
   No.         (ft)        (ft)
     1          41.67       35.08
     2          43.39       34.06
     3          45.18       33.18
     4          47.03       32.42
     5          48.94       31.81
     6          50.88       31.34
     7          52.85       31.01
     8          54.84       30.83
     9          56.84       30.80
    10          58.84       30.92
    11          60.82       31.19
    12          62.78       31.60
    13          64.70       32.16
    14          66.57       32.86
```

15	68.39	33.69
16	70.14	34.66
17	71.82	35.75
18	73.40	36.97
19	74.90	38.30
20	76.29	39.74
21	77.57	41.28
22	78.73	42.90
23	79.77	44.61
24	80.48	46.00

Circle Center At X = 56.24 ; Y = 57.71 ; and Radius = 26.91

Factor of Safety

*** 2.937 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	29.44	33.14
2	31.35	32.54
3	33.28	32.02
4	35.23	31.57
5	37.20	31.19
6	39.17	30.89
7	41.16	30.66
8	43.16	30.51
9	45.15	30.43
10	47.15	30.42
11	49.15	30.49
12	51.15	30.64
13	53.14	30.86
14	55.11	31.15
15	57.08	31.52
16	59.03	31.96
17	60.96	32.48
18	62.87	33.06
19	64.76	33.72
20	66.63	34.45
21	68.46	35.24
22	70.26	36.11
23	72.03	37.04
24	73.77	38.04
25	75.46	39.10
26	77.12	40.22
27	78.73	41.41
28	80.29	42.65
29	81.81	43.96
30	83.28	45.32
31	83.96	46.00

Circle Center At X = 46.27 ; Y = 83.81 ; and Radius = 53.40

Factor of Safety

*** 2.979 ***

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	35.56	34.12
2	37.37	33.29
3	39.24	32.56
4	41.14	31.96
5	43.09	31.48
6	45.05	31.12
7	47.04	30.89
8	49.04	30.77
9	51.04	30.79
10	53.03	30.93
11	55.01	31.19
12	56.98	31.58
13	58.91	32.09
14	60.81	32.72

15	62.66	33.47
16	64.47	34.33
17	66.21	35.31
18	67.90	36.39
19	69.51	37.58
20	71.04	38.86
21	72.49	40.24
22	73.85	41.70
23	75.12	43.25
24	76.29	44.87
25	76.99	46.00

Circle Center At X = 49.80 ; Y = 62.68 ; and Radius = 31.91

Factor of Safety

*** 2.982 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	29.44	33.14
2	31.36	32.56
3	33.29	32.05
4	35.24	31.61
5	37.21	31.24
6	39.19	30.95
7	41.18	30.72
8	43.17	30.57
9	45.17	30.49
10	47.17	30.49
11	49.17	30.55
12	51.16	30.69
13	53.15	30.90
14	55.13	31.18
15	57.10	31.54
16	59.05	31.96
17	60.99	32.46
18	62.91	33.03
19	64.81	33.66
20	66.68	34.37
21	68.52	35.14
22	70.34	35.98
23	72.12	36.88
24	73.87	37.85
25	75.59	38.88
26	77.26	39.97
27	78.90	41.12
28	80.49	42.33
29	82.04	43.60
30	83.54	44.93
31	84.67	46.00

Circle Center At X = 46.35 ; Y = 85.57 ; and Radius = 55.09

Factor of Safety

*** 2.985 ***

**** END OF GSTABL7 OUTPUT ****

```
                          ***  GSTABL7  ***
               ** GSTABL7 by Garry H. Gregory, P.E. **
   ** Original Version 1.0, January 1996; Current Version 2.003, June 2002 **
           (All Rights Reserved-Unauthorized Use Prohibited)
*********************************************************************************
                  SLOPE STABILITY ANALYSIS SYSTEM
       Modified Bishop, Simplified Janbu, or GLE Method of Slices.
       (Includes Spencer & Morgenstern-Price Type Analysis)
       Including Pier/Pile, Reinforcement, Soil Nail, Tieback,
       Nonlinear Undrained Shear Strength, Curved Phi Envelope,
       Anisotropic Soil, Fiber-Reinforced Soil, Boundary Loads, Water
       Surfaces, Pseudo-Static & Newmark Earthquake, and Applied Forces.
*********************************************************************************
    Analysis Run Date:        8/25/2010
    Time of Run:              02:56PM
    Run By:                   RFS
    Input Data Filename:      E:\GStabl7\Branch 66\horseshoe farm park downstream slope-wi
th embankment.in
    Output Filename:          E:\GStabl7\Branch 66\horseshoe farm park downstream slope-wi
th embankment.OUT
    Unit System:              English
    Plotted Output Filename:  E:\GStabl7\Branch 66\horseshoe fpark downstream slope-with e
mbankment.PLT
    PROBLEM DESCRIPTION:  horseshoe farm park
                          existing downstream- widened embankment
    BOUNDARY COORDINATES
        4 Top   Boundaries
```

9 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	28.00	10.00	30.00	1
2	10.00	30.00	45.00	46.00	2
3	45.00	46.00	76.00	46.00	2
4	76.00	46.00	89.00	46.00	1
5	0.00	28.00	10.00	30.00	1
6	10.00	30.00	41.00	35.00	1
7	41.00	35.00	49.00	36.00	1
8	49.00	36.00	76.00	46.00	1
9	76.00	46.00	89.00	46.00	1

Default Y-Origin = 0.00(ft)
Default X-Plus Value = 0.00(ft)
Default Y-Plus Value = 0.00(ft)
ISOTROPIC SOIL PARAMETERS
2 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	125.0	125.0	100.0	30.0	0.00	0.0	1
2	125.0	125.0	100.0	30.0	0.00	0.0	0

1 PIEZOMETRIC SURFACE(S) SPECIFIED
Unit Weight of Water = 62.40 (pcf)
Piezometric Surface No. 1 Specified by 8 Coordinate Points
Pore Pressure Inclination Factor = 0.50

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	26.00
2	9.00	27.00
3	31.00	28.00
4	49.00	30.00
5	76.00	31.00
6	80.00	31.00
7	84.00	32.00
8	89.00	34.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.
100 Trial Surfaces Have Been Generated.
10 Surface(s) Initiate(s) From Each Of 10 Points Equally Spaced
Along The Ground Surface Between X = 5.00(ft)
and X = 30.00(ft)
Each Surface Terminates Between X = 30.00(ft)
and X = 70.00(ft)
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y = 0.00(ft)
2.00(ft) Line Segments Define Each Trial Failure Surface.
Following Are Displayed The Ten Most Critical Of The Trial
Failure Surfaces Evaluated. They Are
Ordered - Most Critical First.
* * Safety Factors Are Calculated By The Modified Bishop Method * *
Total Number of Trial Surfaces Evaluated = 100
Statistical Data On All Valid FS Values:
FS Max = 21.638 FS Min = 2.029 FS Ave = 3.638
Standard Deviation = 2.324 Coefficient of Variation = 63.90 %
Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	5.00	29.00
2	6.97	28.68
3	8.96	28.45
4	10.96	28.32
5	12.96	28.28
6	14.96	28.34
7	16.95	28.50
8	18.93	28.74
9	20.91	29.08

10	22.86	29.52
11	24.79	30.04
12	26.69	30.66
13	28.56	31.37
14	30.40	32.16
15	32.19	33.04
16	33.94	34.01
17	35.65	35.05
18	37.30	36.18
19	38.90	37.38
20	40.44	38.66
21	41.91	40.01
22	43.32	41.43
23	44.67	42.91
24	45.94	44.45
25	47.09	46.00

Circle Center At X = 12.74 ; Y = 70.45 ; and Radius = 42.17

Factor of Safety

*** 2.029 ***

Individual data on the 27 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	2.0	88.2	0.0	0.0	0.	0.	0.0	0.0	0.0
2	2.0	255.1	0.0	0.0	0.	0.	0.0	0.0	0.0
3	1.0	191.7	0.0	0.0	0.	0.	0.0	0.0	0.0
4	1.0	223.1	0.0	0.0	0.	0.	0.0	0.0	0.0
5	2.0	647.7	0.0	0.0	0.	0.	0.0	0.0	0.0
6	2.0	873.3	0.0	0.0	0.	0.	0.0	0.0	0.0
7	2.0	1072.5	0.0	0.0	0.	0.	0.0	0.0	0.0
8	2.0	1243.4	0.0	0.0	0.	0.	0.0	0.0	0.0
9	2.0	1385.0	0.0	0.0	0.	0.	0.0	0.0	0.0
10	2.0	1496.4	0.0	0.0	0.	0.	0.0	0.0	0.0
11	1.9	1577.2	0.0	0.0	0.	0.	0.0	0.0	0.0
12	1.9	1627.5	0.0	0.0	0.	0.	0.0	0.0	0.0
13	1.9	1647.6	0.0	0.0	0.	0.	0.0	0.0	0.0
14	1.8	1638.5	0.0	0.0	0.	0.	0.0	0.0	0.0
15	1.8	1601.4	0.0	0.0	0.	0.	0.0	0.0	0.0
16	1.4	1217.6	0.0	0.0	0.	0.	0.0	0.0	0.0
17	0.4	320.3	0.0	0.0	0.	0.	0.0	0.0	0.0
18	1.7	1450.1	0.0	0.0	0.	0.	0.0	0.0	0.0
19	1.7	1340.4	0.0	0.0	0.	0.	0.0	0.0	0.0
20	1.6	1211.3	0.0	0.0	0.	0.	0.0	0.0	0.0
21	1.5	1066.0	0.0	0.0	0.	0.	0.0	0.0	0.0
22	1.5	907.6	0.0	0.0	0.	0.	0.0	0.0	0.0
23	1.4	739.6	0.0	0.0	0.	0.	0.0	0.0	0.0
24	1.3	565.8	0.0	0.0	0.	0.	0.0	0.0	0.0
25	0.3	117.2	0.0	0.0	0.	0.	0.0	0.0	0.0
26	0.9	247.7	0.0	0.0	0.	0.	0.0	0.0	0.0
27	1.2	111.3	0.0	0.0	0.	0.	0.0	0.0	0.0

Failure Surface Specified By 25 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	5.00	29.00
2	6.97	28.64
3	8.95	28.38
4	10.94	28.23
5	12.94	28.18
6	14.94	28.23
7	16.94	28.38
8	18.92	28.64
9	20.89	29.00
10	22.84	29.46
11	24.76	30.02
12	26.64	30.67
13	28.50	31.43

14	30.31	32.27
15	32.07	33.21
16	33.79	34.24
17	35.45	35.36
18	37.05	36.56
19	38.58	37.84
20	40.05	39.20
21	41.45	40.63
22	42.77	42.14
23	44.01	43.70
24	45.17	45.33
25	45.59	46.00

Circle Center At X = 12.95 ; Y = 67.01 ; and Radius = 38.83

Factor of Safety

*** 2.054 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	7.78	29.56
2	9.72	29.08
3	11.69	28.72
4	13.67	28.49
5	15.67	28.38
6	17.67	28.40
7	19.67	28.55
8	21.65	28.82
9	23.61	29.22
10	25.54	29.74
11	27.43	30.38
12	29.28	31.14
13	31.08	32.02
14	32.82	33.00
15	34.50	34.10
16	36.10	35.29
17	37.62	36.59
18	39.06	37.98
19	40.40	39.46
20	41.66	41.02
21	42.81	42.66
22	43.85	44.36
23	44.63	45.83

Circle Center At X = 16.34 ; Y = 60.04 ; and Radius = 31.66

Factor of Safety

*** 2.086 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	7.78	29.56
2	9.78	29.65
3	11.77	29.82
4	13.76	30.05
5	15.73	30.35
6	17.70	30.72
7	19.65	31.15
8	21.59	31.66
9	23.50	32.23
10	25.40	32.86
11	27.27	33.56
12	29.12	34.32
13	30.95	35.15
14	32.74	36.03
15	34.50	36.98
16	36.23	37.99
17	37.92	39.06
18	39.57	40.18
19	41.19	41.36
20	42.76	42.59

21	44.29	43.88
22	45.78	45.22
23	46.58	46.00

Circle Center At X = 5.97 ; Y = 87.86 ; and Radius = 58.33
Factor of Safety
*** 2.130 ***

Failure Surface Specified By 19 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	13.33	31.52
2	15.32	31.26
3	17.31	31.14
4	19.31	31.16
5	21.31	31.32
6	23.28	31.61
7	25.24	32.04
8	27.15	32.61
9	29.03	33.31
10	30.85	34.14
11	32.60	35.10
12	34.29	36.17
13	35.90	37.36
14	37.42	38.66
15	38.85	40.06
16	40.17	41.56
17	41.39	43.15
18	42.49	44.82
19	42.52	44.87

Circle Center At X = 18.06 ; Y = 59.78 ; and Radius = 28.65
Factor of Safety
*** 2.172 ***

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	10.56	30.25
2	12.54	30.49
3	14.52	30.78
4	16.49	31.14
5	18.44	31.56
6	20.39	32.03
7	22.31	32.57
8	24.22	33.16
9	26.11	33.82
10	27.98	34.53
11	29.83	35.30
12	31.65	36.13
13	33.44	37.01
14	35.21	37.95
15	36.95	38.94
16	38.65	39.98
17	40.33	41.08
18	41.96	42.23
19	43.56	43.42
20	45.13	44.67
21	46.65	45.97
22	46.69	46.00

Circle Center At X = 3.98 ; Y = 94.69 ; and Radius = 64.77
Factor of Safety
*** 2.196 ***

Failure Surface Specified By 28 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	10.56	30.25
2	12.55	30.15
3	14.55	30.11
4	16.55	30.12
5	18.55	30.19

6	20.55	30.31
7	22.54	30.49
8	24.53	30.73
9	26.50	31.02
10	28.47	31.37
11	30.43	31.77
12	32.38	32.23
13	34.31	32.75
14	36.23	33.31
15	38.13	33.93
16	40.01	34.61
17	41.88	35.34
18	43.72	36.12
19	45.54	36.95
20	47.33	37.83
21	49.10	38.76
22	50.84	39.74
23	52.56	40.77
24	54.24	41.85
25	55.90	42.98
26	57.52	44.15
27	59.10	45.37
28	59.88	46.00

Circle Center At X = 15.14 ; Y = 101.02 ; and Radius = 70.92

Factor of Safety

*** 2.300 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	13.33	31.52
2	15.27	31.03
3	17.25	30.73
4	19.25	30.63
5	21.24	30.73
6	23.22	31.03
7	25.16	31.53
8	27.04	32.22
9	28.84	33.09
10	30.54	34.13
11	32.13	35.34
12	33.59	36.71
13	34.91	38.21
14	36.07	39.84
15	37.07	41.58
16	37.51	42.58

Circle Center At X = 19.24 ; Y = 50.57 ; and Radius = 19.95

Factor of Safety

*** 2.330 ***

Failure Surface Specified By 26 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	10.56	30.25
2	12.33	29.33
3	14.17	28.54
4	16.06	27.89
5	17.99	27.37
6	19.95	26.99
7	21.94	26.75
8	23.94	26.66
9	25.94	26.71
10	27.93	26.90
11	29.90	27.23
12	31.84	27.71
13	33.75	28.32
14	35.60	29.07
15	37.40	29.94
16	39.13	30.95

17	40.78	32.08
18	42.35	33.32
19	43.82	34.67
20	45.19	36.12
21	46.46	37.67
22	47.61	39.31
23	48.64	41.02
24	49.55	42.80
25	50.33	44.65
26	50.79	46.00

Circle Center At X = 24.26 ; Y = 54.52 ; and Radius = 27.86

Factor of Safety

*** 2.336 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	5.00	29.00
2	7.00	29.01
3	9.00	29.10
4	10.99	29.28
5	12.97	29.54
6	14.94	29.88
7	16.90	30.31
8	18.83	30.82
9	20.74	31.42
10	22.62	32.09
11	24.47	32.85
12	26.29	33.68
13	28.08	34.59
14	29.82	35.57
15	31.52	36.63
16	33.17	37.75
17	34.77	38.95
18	36.32	40.21
19	37.82	41.54
20	39.25	42.93
21	39.99	43.71

Circle Center At X = 5.83 ; Y = 76.03 ; and Radius = 47.04

Factor of Safety

*** 2.349 ***

**** END OF GSTABL7 OUTPUT ****