CLEAN HARBORS
GRASSY MOUNTAIN FACILITY

LANDFILL CELLS 8 THROUGH 13
DESIGN ENGINEERING REPORT

(HAL Project No.: 064.85.100)

AUGUST 2018 Rev 1

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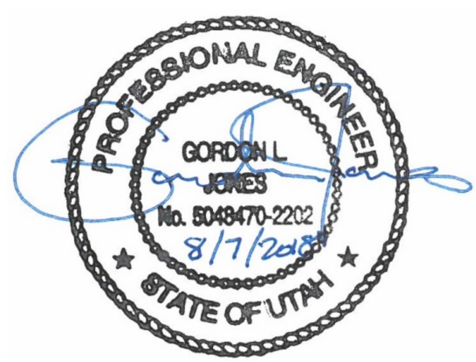

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HANSEN ALLEN & LUCE INC
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CHAPTER 1 - INTRODUCTION

BACKGROUND

Clean Harbors, Grassy Mountain Facility, is proposing six new RCRA/TSCA landfill cells (designated Landfill Cells 8 through 13) to be located primarily in the east-central area of Section 16 (all within Section 16), Township 1 North, Range 12 West, Salt Lake Base and Meridian (see the design drawings in Appendix A). Landfill Cell 8, 10, and 12 will be located to the east of existing Landfill Cell 7 and Landfill Cells 9, 11, and 13 will be located adjacent to the south side of Landfill Cells 8, 10, and 12. All of the proposed landfill cells will be located in the previous land treatment area that was previously cleaned and has been closed. Clean Harbors plans to place RCRA and TSCA waste materials that have been approved for the facility in Landfill Cells 8 through 13.

Scope of Services

The scope of services for this project included the following:
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1. Design of Landfill Cells 8 through 13 to meet the design requirements for hazardous waste landfills as defined in Utah Administrative Code R315-264-300 through R315-264-309.
2. Design of Landfill Cells 8 through 13 to meet the design requirements for chemical waste landfills as defined in 40CFR 761.75 of the Code of Federal Regulations and in Utah Administrative Code R315-264-301 of the Utah Department of Environmental Quality "Environmental Quality, Waste Management and Radiation Control, Waste Management" rules for PCB Containing Waste.
3. Design of Landfill Cells 8 through 13 in accordance with the requirements of Module VI Hazardous Waste Landfills in the Grassy Mountain Facility Permit.
4. Provide a closure and post-closure care plan for Landfill Cells 8 through 13 with cost estimates in accordance with applicable sections of Utah Administrative Code R315-264-110 to 112, R315-264-310 and Attachment 7 (Closure and Post-Closure Plan) in the Grassy Mountain Permit.

This Design Engineering Report for Landfill Cells 8 through 13 is prepared to address current federal and state regulations pertaining to hazardous waste landfills and their closures, and chemical waste landfills. The following sections are presented in this report: 1) Landfill Cell Design, 2) Action Leakage Rate (ALR), 3) Storm Water Management, 4) Closure and Post-Closure Care, and 5) Construction Quality Assurance.

Permit design drawings for Landfill Cells 8 through 13 are included in Appendix A. A geotechnical investigation for Landfill Cells 8 through 13 was completed by Applied Geotechnical Engineering Consultants (AGEC) of Salt Lake City, Utah and is included in Appendix B. The design calculations for the HDPE geomembrane liners are presented in Appendix C. Design calculations for the Leachate Collection and Removal Systems (LCRS) and the Leak Detection Collection and Removal System (LDCRS) are presented in Appendix D. HDPE leachate withdrawal pipe design calculations are presented in Appendix E. Storm water management calculations are presented in Appendix F. Calculations for erosion protection are presented in Appendix G, and closure / post-closure cost calculations are presented in Appendix H.

CHAPTER 2 – LANDFILL CELLS DESIGN

GENERAL LAYOUT AND DESIGN

Measured east/west, proposed Landfill Cell 8 is 755.75 feet and Landfill Cells 9 through 13 are each 764.75 each and Landfill Cells 8 through 13 are 830 feet each in the north/south direction as measured to the top inside edge of the liner systems (or within the lined containment area). The containment area of Landfill Cell 8 is about 14.32 acres and the containment area of each of the Landfill Cells 9 through 13 is about 14.50 acres resulting in a total containment area of 86.82 acres for the six landfill cells combined. The design elevation for the top of the perimeter embankments is 4267 feet (all elevations referred to hereafter are implied to be measured in feet) and the peak elevation of each closure cap of about 4306.17 (at the top of the stone mulch (gravel) erosion protective layer. This provides a design waste capacity of about 785,300 cy for Landfill Cell 8 and about 793,800 cy for Landfill Cells 9 through 13. The total design waste capacity for Landfill Cells 8 through 13 combined is about 4,754,300 cy. Interior embankment slopes are designed to be 3 horizontal to 1 vertical (3H:1V). This includes exterior embankment slopes that form the interior slope for adjacent cells. The exterior embankment slopes around the perimeter of the combined landfill cell footprint is designed to be 2.5 horizontal to 1 vertical (2.5H:1V).

The landfill cells are designed with two composite liner systems consisting of a top liner system and a bottom liner system. Leachate collection and removal systems (LCRS) are designed above the top and bottom composite liner systems. Each cell is divided into four areas or leachate collection system areas with sumps and leachate removal systems in each of the four areas.

A leachate collection and removal system (LCRS) is designed above the top liner system for collection and removal of the majority of leachate that will be generated in the landfill cells. A leak detection, collection and removal system (LDCRS) is designed above the bottom liner system (between the top and bottom liner systems) for collection and removal of leachate that may leak through a breach in the top liner system. Leachate from the LCRS and LDCRS will collect in sumps located at low points on the floor within each quarter division of the cells. Each sump is designed with a leachate withdrawal pipe into which pumps will be inserted for removal of leachate that collects in the sumps. The planar surfaces of the floor have design slopes of 2.3% in the north/south and in the east/west directions providing a resultant design slope at a 45 degree angle toward the sumps of 3.25%. Applying settlement estimates presented in the Geotechnical Investigation Report included in Appendix B, the minimum post-settlement slopes for the planar surfaces of the floor will be approximately 1.4% in the north/south direction (along the line formed by the valley in the sump drainage area), 1.7% in the east/west direction (perpendicular to the line formed by the valley in each sump drainage area, and 2.3% for the resultant slope on a 45 degree angle toward the sumps.

The top sump and the bottom sump for the six proposed landfill cells are designed with consistent elevations. The lowest points on the liner surface within the top and bottom sumps are 4240.59 and 4239.08, respectively. The lowest elevation at the bottom of the subgrade to the compacted clay liner is 4235.80.

Two feet of protective soil cover material is designed above the top liner and LCRS to provide a protection and buffer between waste material placed in the cells and the liner and LCRS. The protective soil cover material will either consist of native soils or imported soils.

The final perimeter slopes around the closure caps are designed to be 3 horizontal to 1 vertical (3H:1V). The top cap slopes of 5 percent continue above the perimeter slopes to the center peak of each closure cap. The top slopes intersect to form ridge lines extending from the corners to the center point of the closure caps where peak design elevations of 4306.17 feet are provided on the erosion protective layer for each closure cap.

Storm water is managed by drainage ditches, pipes, manholes, inlet and outlet structures, and ponds. All closure cap slopes and exterior embankment slopes of the landfill cells are designed with a layer of stone mulch material for erosion protection.

Permit design drawings showing the configuration of the landfill cells including closure caps, details of the liner systems, leachate collection and removal systems, leak detection, collection and removal systems, and storm water management are provided in Appendix A. The drawings also provide general access locations for the landfill cells. Ramps to the access the cells will be constructed and moved as operationally needed during construction and operation of the different landfill cells.

The cells and their closure caps are designed to meet or exceed all the requirements for RCRA (hazardous waste) and TSCA (chemical waste) landfills as presented in Utah Administrative Code R315-264-300 through R315-264-309, Utah Administrative Code R315-315-7, 40 CFR 264.761.75 with the exception of 40 CFR 761.75(b)(3). This states that the bottom of the landfill liner system shall be at least fifty feet from the historic high water table. In the past, EPA Region 8 granted a waiver for this requirement (as allowed by 40 CFR 761.75(c)(4)) by designing the TSCA cells (chemical waste cells) with a double liner system consisting of primary liner and a secondary composite liner. The double liner systems consisting of top composite and bottom composite liner systems, with leachate collection systems above each liner system, meets the standards for issuing the waiver in the past. All the landfill cells have been designed to have a minimum separation of about 5.5 feet between the lowest design elevation on top of the compacted clay liner and the historic high groundwater elevation. All other requirements for RCRA (hazardous waste) landfills meet or exceed the requirements for TSCA (chemical) landfills. Therefore, reference is provided to requirements for RCRA landfill cells throughout this report.

GEOTECHNICAL INVESTIGATION

A geotechnical investigation for Landfill Cells 8 through 13 was completed by Applied Geotechnical Engineering Consultants (AGEC) of Salt Lake City, Utah. The geotechnical investigation report is provided in its entirety in Appendix B. Results and recommendations provided in the geotechnical investigation report will be referenced in various sections of this report. Some of the results and recommendations resulting from the geotechnical investigation are presented below.

1. The natural subsurface soils encountered at the site are suitable for support of the proposed embankment and landfill disposal cells.
2. Exterior slopes of 2.5 horizontal to 1 vertical may be used for embankment construction. Interior slopes of 3 horizontal to 1 vertical may be used.

3. The natural on-site silty clay and silty sand to sandy silt materials are suitable for construction of the proposed embankment. The upper mud flat soils are suitable for the clay liner.
4. Settlement analysis was performed for the proposed landfill cells considering the construction and closure of each sequential cell. Settlement at proposed embankments is estimated to be on the order of 105 inches in the center of common cell embankments and about 72 inches in the center of outside (non-common) embankments. Embankment settlement may be on the order of 20 percent less near the corners of the cells versus the center of the embankments. Settlement in the central part of the cells, below the peak of the waste mound, is estimated to be on the order of 140 inches. The time rate for project settlement to occur is 50 percent in 7 years, 70 percent in 15 years, and 90 percent in 22 years.
5. Some soils at the site are susceptible to liquefaction. Settlement from liquefaction is estimated to be on the order of ½ to 4½ inches for the design seismic event. Settlement from liquefaction is small compared to the expected settlement from consolidation and would be within acceptable tolerances for a landfill.
6. At the time borings were completed the water levels within the borings were measured to be approximately between elevation 4231 and 4232. A free water level at elevation 4234 was used for stability analyses.
7. A seismic load coefficient equal to the peak horizontal ground acceleration (PGA) of 0.18 was used for the seismic analysis based on a bedrock peak horizontal ground acceleration (PGA) of 0.15g for a seismic event with a 90 percent probability of not being exceeded in a 250 year period.
8. The safety factor for overall long-term stability under static conditions for the typical embankment sections is 2.1 and 2.0 for the section adjacent to the runoff control pond north of the office/lab area.
9. The safety factor for overall long-term stability under seismic conditions for the typical embankment sections is 1.3 and 1.1 for the section adjacent to the runoff control pond north of the office/lab area.
10. Deformations of 2½ inches and 3½ inches are anticipated under seismic conditions for the typical landfill profile and for the profile adjacent to the runoff control pond north of the office/lab area, respectively.
11. Stability at the end of construction is expected to have a safety factor of 2.0 or higher under static conditions at the rate of construction typically experienced at the facility.
12. The long term stability of the closure cap under static conditions has a safety factor of 2.1 and a safety factor of 1.3 under seismic conditions.
13. The embankment meets the minimum safety factor requirements under static conditions and the anticipated deformation under seismic conditions is on the order of 2½ to 3½ inches, which should be within acceptable limits.
14. The protective soil cover should not be placed any higher than 10 vertical feet above cover and waste materials placed across the landfill in order to provide a safety factor of 1.5 against sliding.
15. Stability calculations show the interior access ramps have safety factors greater than 1.5 under static conditions and greater than 1.3 under seismic conditions.
16. The 3 horizontal to 1 vertical slopes around the perimeter of the closure caps and the 5 percent slopes across the top surface of the closure caps have safety factors against sliding greater than 1.5 under static conditions and greater than 1.3 under seismic conditions.
17. The natural soils will support the proposed construction (landfill cells) and will result in suitable safety factors against bearing capacity type failures.
18. The compacted clay liner has an allowable bearing capacity of 1,500 pounds per square foot under static conditions and 2,000 pounds per square foot under impact loading

conditions. This is based on previous work completed at the site and assumes safety factors of 3 and 2.25 based on the ultimate bearing capacity of 4,500 pounds per square foot.

19. The allowable bearing capacity (q_{all}) of the protective soil cover materials under static conditions is: $q_{all} = 250(B) + 600(d)$ where B is the load width in feet and d is the depth of embedment in feet. The allowable bearing capacity of the protective soil cover under temporary conditions may be increased to: $q_{all} = 375(B) + 900(d)$.
20. Construction considerations include the following:
    a. Foundations are to be prepared by removing disturbed soils, vegetation, debris, and any backfill material not meeting compaction criteria.
    b. Construct embankments with a mixture of clay, silt, or sand soils local to the area. Compact materials to 95 percent of the maximum dry density as determined by ASTM D-698 with the moisture content near optimum.
    c. Place fill in uniform lifts no more than 8 inches thick for areas compacted using heavy equipment and no more than 4 inches thick in areas where hand operated compaction equipment is used.
    d. Place and compact graded gravel over exterior embankment surfaces similar to materials used on previous projects.
    e. Construct the compacted clay liner with local materials similar to the CL, CL-ML, and ML materials used on previous projects and using procedures, equipment, etc. established from construction of previous test fills. Test fills should be constructed should there be any variations to materials, procedures, equipment, etc. established during previous test fill construction. Clay surfaces should be kept moist to prevent surface cracking.

LANDFILL DESIGN AND OPERATING REQUIREMENTS

Utah Administrative Code R315-264-301

Proposed Landfill Cells 8-13 will be new landfill units and must meet the design requirements provided under Utah Administrative Code R315-264-301(c). The liner systems within new landfill cells must also meet the design requirements listed in paragraphs 40CFR 264.301(a)(1)(i), (ii), & (iii) and Utah Administrative Code R315-264-301(a)(1)(i), (ii), &(iii) as listed below.

1) Have a liner that is:
    a) Designed, constructed, and installed to prevent any migration of wastes out of the landfill to adjacent subsurface soil or groundwater or surface water;
    b) Constructed of materials that prevent wastes from passing into the liner;
    c) Constructed of materials that have appropriate chemical properties and sufficient strength and thickness to prevent failure due to:
        i) Pressure gradients (including static head and external hydrogeologic forces),
        ii) Physical contact with the waste or leachate to which they are exposed,
        iii) Climatic conditions,
        iv) Stress of installation, and
        v) Stress of daily operation;
    d) Placed upon a foundation or base capable of providing:
        i) Support,
        ii) Resistance to pressure gradients above and below to prevent failure from:
            (1) Settlement,
            (2) Compression, or
            (3) Uplift;

   e) Installed to cover all surrounding earth likely to be in contact with waste or leachate.
2) Have a leachate collection and removal system immediately above each liner that is:
   a) Designed, constructed, maintained, and operated to collect and remove leachate from the landfill,
   b) Constructed of materials that are:
      i) Chemically resistant to the waste managed in the landfill and leachate expected to be generated;
      ii) Of sufficient strength and thickness to prevent collapse under pressures from overlying wastes, waste cover materials, and equipment;
      iii) Designed and operated to function without clogging.

Each requirement listed above will be addressed in the following sections for Lining System Design, Liner System Foundation, and Extent of Liner System Installation.

LINER SYSTEM DESIGN

Utah Administrative Code R315-264-301(a)(1)(i)

The liner systems for the landfill cells must include, at minimum, a top liner system and a bottom composite liner system. The top liner system must be designed and constructed of materials to prevent the migration of hazardous constituents into the liner (e.g., a geomembrane). The bottom liner must consist of a composite system with an upper component designed and constructed to prevent migration of hazardous constituents into the liner (e.g., a geomembrane) and a lower component must be designed and constructed to minimize migration of hazardous constituents if a breach occurs in the upper component. The lower component must be constructed of at least 3 feet of compacted soil material with a hydraulic conductivity of no more than 1×10^{-7} cm/sec.

The liner systems meet the criteria presented above and in the previous section under the title "Landfill Design and Operating Requirements." The following sections provide design considerations in analyzing the above requirements for conditions expected to be encountered in Landfill Cells 8 through 13. Supporting calculations associated with design of the liner systems are provided in Appendix C.

Liner System Components

<u>Top Liner System</u>. The top liner system is designed as a composite system consisting of three components on the floor and 10 feet up the interior side slopes and two components the rest of the distance up the interior side slopes. An 80-mil HDPE geomembrane provides the upper component which extends across the floor and up the interior slopes of the landfill cells. The middle and bottom components on the floor and 10 feet up the interior side slopes consists of a geosynthetic clay liner (GCL) and a bottom 80-mil HDPE geomembrane. The two components the rest of the distance up the interior side slopes consists of a single 80-mil HDPE geomembrane and a GCL. The upper 80-mil HDPE geomembrane provides an impermeable barrier to prevent migration of hazardous constituents into the liner and provides a barrier on which the top leachate collection system is placed. Clean Harbors is providing the added GCL and the lower 80-mil HDPE geomembrane components described above for extra protection (beyond regulatory requirements) against leachate migration through the liner system.

The GCL directly below the upper geomembrane provides a sealing or plugging component should a breach occur in the upper geomembrane. Leachate that migrates through a breach in the upper geomembrane will contact the bentonite material within the GCL causing the bentonite to hydrate and expand or swell. Confining pressures resulting from the normal loading of overlying soil and waste materials restricts the ability of the bentonite to swell. As the bentonite tries to swell under the confining pressures, the void spaces within the bentonite layer of the GCL seal more tightly, thus causing a tighter seal to form at the location of the breach. Hydrated bentonite will also squeeze into the breach in the top geomembrane and will form a “bentonite plug” which aids in sealing process and in restricting movement of leachate through the top liner system.

Providing an 80-mil HDPE geomembrane below the GCL creates a lower barrier between the GCL and the underlying leachate collection-leak detection system (LCLDS) located above the bottom liner system. This barrier prevents migration of bentonite materials from the overlying GCL into the LCLDS. The lower geomembrane also provides an added barrier against migration of leachate through the top liner system.

Bottom Liner System. The bottom liner system is designed as a composite system consisting of a 60-mil HDPE geomembrane upper component and a 3-foot thick compacted clay liner with a maximum hydraulic conductivity of 1×10^{-7} cm/sec as the lower component. This system meets the regulatory requirements for the bottom liner system. The geomembrane provides and impermeable barrier to prevent migration of hazardous constituents into the liner. The compacted clay liner is designed to minimize migration of hazardous constituents if a breach occurs in the geomembrane. Clay soil for the compacted clay liner will be obtained from the mud flat area west or south of the facility or from the clay that was used for the clay liner system in Cell A. These clays have been used successfully with previous landfill construction projects in meeting the minimum hydraulic conductivity requirement.

Pressure Gradients

External and internal pressure gradients that may be exerted on the liner systems typically result from the overburden load caused by soil and waste materials placed above the liners in the landfill cells, static head from leachate and storm water inside the landfill cells, and from uplift forces caused by the presence of groundwater or gases that may accumulate below the liner systems.

Overburden Loads. Normal forces from overburden loads caused by soil and waste materials placed in the landfill cells are expected to exert significant pressures on the liner systems. These forces may result in localized displacement of the clay liner soils that can cause the geomembrane to become stressed as it conforms to these localized movements. Forces from overburden loads can also result in failure of the geomembrane liners to bridge gaps when placed in direct contact with underlying geonet materials. Both scenarios can result in the yield strength of the geomembrane to be exceeded.

Clay Liner Displacement. The maximum overburden load on the clay liner is approximately 6,380 lbs/ft^2 when the landfill cells are filled to capacity. Results from the geotechnical investigation show the allowable bearing capacity of the clay liner, with a safety factory of 3, to be about 1,500 lbs/ft^2 (the ultimate bearing capacity is 4,500 lbs/ft^2). While maximum overburden load exceeds the allowable bearing capacity of the clay liner, the mechanism of failure when the bearing capacity of the clay liner is exceeded is displacement of the clay liner material similar to a rut that can form in soil material when a vehicular loading is applied. This type of failure can only occur if there are adjacent areas where confining forces (or pressures) are sufficiently low that clay can be displaced into those areas. In other words, the applied pressure tending to cause failure and displacement of the clay liner must exceed the confining pressure (or pressure resisting clay liner displacement) by at least as much as the bearing capacity of the clay.

Waste placement within the landfill cells occurs in lifts that are relatively uniform resulting in relatively uniform overburden loads across the clay liner surface. Therefore the applied and confining (resisting) pressures will be sufficient to prevent localized displacement of the underlying clay liner material.

Potential clay liner displacement from live loads caused by equipment and vehicles operating above the liner systems will be discussed later in sections of this report on resistance to construction and installation stresses, and resistance to stresses of daily operation. Equipment and vehicle operation will occur during protective soil cover and waste placement activities.

Bridging Gaps in the Geonet. The small gap (approximately 0.5-inch) formed between the ribs in the geonet has formed the basis for completing a gap analysis on previous landfill projects at the Grassy Mountain Facility. Previous project designs placed bottom lining system directly over compacted clay liner providing a continuous support system to the bottom geomembrane. However, other lining systems were placed directly over leachate systems comprised of geonet materials and were exposed to the gaps between the geonet ribs. The methodology used to evaluate the ability of the geomembrane materials to bridge the gap in the geonet was presented in a paper entitled "Design of Geotextiles Associated with Geomembranes" by J. P. Giroud, which is presented in a publication entitled, "Geotextiles and Geomembranes Definitions, Properties and Design Selected Papers, Revisions and Comments, Third Edition, Industrial Fabrics Association International, 1985, St. Paul, Minnesota. On all previous projects, each gap analysis completed showed the geomembrane materials to have sufficient strength properties to bridge the gap in the underlying geonet under the loading conditions anticipated within the landfill cells.

Design conditions within Landfill Cells 8 through 13 provide a continuous support system to the geomembrane materials at all levels rather than the geomembrane materials directly bridging the gap in the geonet materials. The bottom lining system is provided with continuous support from the underlying compacted clay liner. The bottom geomembrane in the top lining system is provided with continuous support from the non-woven geotextile that provides the upper and lower boundaries to the double sided geocomposite, and the upper geomembrane in the top lining system is provided continuous support from the GCL. Therefore, no significant gaps are expected to be bridged by the geomembrane materials.

Static Head. Static head is a result of liquids creating pressure head above the liner systems. The geomembrane (impermeable) portions of the top and bottom liner systems consist of 80-mil and 60-mil high density polyethylene (HDPE) geomembrane. Federal and State regulations require the landfill cells to be operated to limit the hydraulic head on the liner systems to less than one foot. Therefore, the static head will result in very low hydrostatic forces (a hydrostatic pressure of about 62.4 lbs/ft^2) above the liner systems. Since the geomembrane materials are provided with continuous support from underlying materials, all hydrostatic forces are transferred through the materials to the underlying compacted clay liner which has an allowable bearing capacity of 1,500 lbs/ft^2 using a safety factor of 3. The geomembrane materials are therefore provided with sufficient structural support and strength to resist forces from static head that may occur above the lining systems.

Hydrogeologic Forces. Hydrogeologic forces, or uplift pressures resulting from the accumulation of gases or liquids beneath the liner systems are also normal stresses that can act on the geomembrane liners. However, the effect of uplift pressure on the liner system in a landfill cell (with solid waste deposited and compacted therein) is significantly different from the effect of uplift pressures on a liner system within a surface impoundment filled with a liquid that can be displaced if the uplift pressures are significant enough. Uplift forces in a landfill cell will not be significant enough to displace the overburden consisting of soil and solid waste materials. An analysis of a free-body diagram at the surfaces a geomembrane liner at rest would indicate that the force applied to the geomembrane from the top would be countered by an equivalent reaction from the forces of the subgrade material on the bottom of the geomembrane. Any force created by uplift pressures would not be added to the reaction force from the subgrade soil, but would be a component of the reaction force by replacing an equivalent amount of the reaction force from the subgrade soil, since the combined forces from beneath must equal the force from overburden above the geomembrane. In order for uplift pressures on the liner to totally replace the reactions of the subgrade soil, displace the overburden materials, and cause damage to the geomembrane liner, uplift pressures would have to exceed approximately 6,400 lbs/ft^2 (or the equivalent of approximately 100 feet of hydraulic head) which is not anticipated

The existence of liquid below the liner systems provides the only opportunity for development of hydrostatic pressures to create uplift forces on the liner systems. Possible sources for liquid below the liner systems are groundwater, storm water flowing below the liner systems, or from leachate migrating through the composite liner systems. Even if groundwater levels rise as high as the existing ground surface (about 7 feet above the historic high groundwater elevations) there would not be sufficient hydrostatic pressure to damage the liner systems. Surface water flowing below the liner systems from within the anchor trenches is possible, however, water migrating through the top liner system will be conveyed to the leak detection sump through the leak detection system and will be removed with very little hydrostatic pressure below the top liner system, and flow below the bottom liner system will be very restricted because of the contact between the geomembrane and the compacted clay liner. The greatest hydrostatic pressure possible below the bottom liner system is if liquid builds up from the lowest elevation of the bottom liner system (4238.58) to the top elevation of the cell embankments (4267). Although this scenario is unlikely to occur, it would result a maximum of 28.42 feet of head which is much less than the hydrostatic pressure necessary to displace or damage the liner system.

Chemical Compatibility

High Density Polyethylene geomembrane has been used extensively to line landfills and containment systems in the hazardous waste and chemical industries. These materials have also been used successfully to line the RCRA and TSCA waste landfills at the Grassy Mountain Facility for over 3 decades. Many studies have been conducted by government and private entities during this time regarding the compatibility of various geomembrane materials.

USPCI (former owner of the Grassy Mountain Facility) also previously demonstrated chemical compatibility with RCRA wastes disposed at the Grassy Mountain Facility. The testing procedures used and data obtained regarding chemical compatibility were also previously submitted by USPCI to the Utah Division of Solid and Hazardous Waste.

Any waste materials received for disposal that vary from those historically received at the facility and from those previously demonstrated by industry to be compatible with HDPE geomembrane materials will be tested to ensure compatibility in accordance with one of the Waste Analysis Plans. Waste analysis plans are provided in Attachment II-WAP RCRA-TSCA Waste Analysis Plan of the facility Permit. Materials that show to be incompatible with the HDPE geomembrane liners will not be placed in the landfill cells.

Resistance to Climatic Conditions

Climatic conditions that may adversely affect the geomembrane liner systems are temperature extremes and ultraviolet (UV) radiation exposure. The geomembrane materials proposed for the lining systems in Landfill Cells 8 through 13 consist of high density polyethylene (HDPE). Historically these materials have been successfully used at the Grassy Mountain Facility in landfill applications and their closures. The uppermost liner systems in several of the facilities have been exposed to climatic conditions for more than two decades and continue to remain serviceable.

Temperature Extremes. Results from laboratory testing show that temperature extremes affect the physical properties of the HDPE geomembrane materials. As stated in GSI White Paper #28 on "Cold Temperature and Freeze-Thaw Cycling Behavior of Geomembranes and Their Seams" (Geosynthetics Institute, Jun 17, 2013), polymetric materials in particular, will somewhat soften and increase in flexibility under high temperatures and will conversely somewhat harden and decrease in flexibility under cold temperatures. The focus of the white paper referenced is on cold temperature behavior of the various geomembranes, including HDPE. The primary source of information presented in White Paper #28 is from a joint study completed by the U.S. EPA and the U.S. Bureau of Reclamation.

General property behaviors of HDPE geomembrane in cold temperatures are:

- Tensile strength increases with decreasing temperature.
- Elongation decreases with decreasing temperature.
- The material becames more brittle with decreasing temperature.

The study referenced in White Paper #28 included subjecting the geomembrane to 200 and 500 repeated freeze-thaw cycles and then conducting tensile, shear, and peal tests on the materials and their seams at temperatures of -20°C (-4°F) and +20°C (68°F). Conclusions reached about the effects of freeze-thaw cycles on the tensile, shear, and peal strengths of the material are:

- Tensile Strength – The results show no change in either peak strength or peak elongation.
- Shear Strength – The results show no change in strength.
- Peel strength – the results show no change in strength.

Laboratory tests are currently being conducted on HDPE geomembrane under various environmental conditions. Preliminary results are presented for varying temperatures in a paper entitled "Ageing of HDPE Geomembrane Exposed to Air, Water and Leachate" (Rowe, R.K., Rimal, S., and Sangam, H., November 21, 2008). The purpose of the testing is to provide an estimate of the life expectancy of HDPE geomembrane materials as they are exposed to the stated environmental conditions.

Three stages of degradation typically occur when the geomembrane materials are exposed to the different environmental conditions. During stage 1 the geomembrane material experiences antioxidant depletion. Then there is a transition period (stage 2) between depletion of antioxidants and physical aging (stage 3) when reduction of strength related properties occur. The material is assumed to have reached the end of its service life when the physical aging process has reduced strength related properties to half the original (or newly manufactured) values.

Testing has been conducted on the HDPE geomembrane material for 8 to 10 years and is still in progress. Preliminary findings from the tests are as follows:

- Temperature is shown to have a critical effect on the service life of geomembranes when immersed in air, water, and leachate. The higher the temperature, the greater the reduction in the anticipated service life.
- The likely service life of geomembrane immersed in leachate is likely to exceed 700 years and will probably be on the order of 1000 years (or longer) at 20°C (68°F).
- The likely service life of geomembrane immersed in leachate is more than 150 years and is likely 225 to 375 years at 35°C (95°F).
- The service life in a liner configuration (as installed in a landfill condition) may be expected to be longer than when immersed in leachate.
- Results in the referenced paper show the geomembrane service life is longest when immersed in air, and longer when immersed in water than when immersed in leachate. It should be noted that the service life projections are based on immersed geomembrane. When installed in a landfill application, the geomembrane is only exposed to the leachate on one side and to soil or air on the other side. Therefore, the service life will be longer in a landfill application.

The worst case exposure condition of the HDPE geomembrane at the Grassy Mountain Facility will be in the sumps. The upper surface of the geomembrane components of the liner systems will potentially be immersed in leachate and the bottom surface will be exposed to geotextile (associated with GCL and drainage geocomposite) and compacted clay liner. It is expected that the geomembrane components in Landfill Cells 8-13 will have a longer service life than the completely submerged conditions presented.

A study was conducted for the USEPA Office of Research and Development by Science Applications International Corporation, Inc. entitled "Composition of Leachates from Actual Hazardous Waste Sites." The study was focused on determining the chemical composition of hazardous waste landfill leachates from 13 sites located at different regions of the United States. Temperatures were recorded in the field at the time each leachate sample was collected and the resulting temperature range was 19.9°C to 32°C (68°F to 90°F) with a mean of 26.7°C (80°F).

Assuming the temperature to be 32°C, or the high of the range from the testing completed, and exposure to leachate on only one side of the geomembrane, the service life is likely to exceed 375 years. Based on the information presented, it is expected that the HDPE geomembrane will meet the strength requirements for the temperature and environmental conditions anticipated at the facility.

Ultraviolet (UV) Radiation Exposure. Ultraviolet radiation exposure causes deterioration which changes mechanical properties and limits serviceable life of plastic polymers. The various manufacturers of HDPE geomembranes used in lining waste facilities add 2%-3% carbon black content to the materials during the manufacturing process. The Geosynthetics Research Institute at Drexel University has an ongoing study (GRI White Paper #6, Geomembrane Lifetime Prediction: Unexposed and Exposed Conditions) regarding the life expectancy of geoembrane materials. The study began for geomembranes under exposed conditions in 2005 using a fluorescent UV light source to accelerate the weathering process of the material. Their correlation studies between field performance and fluorescent UV light exposure showed an acceleration factor of 6.8. After 6 years of accelerated exposure the HDPE geomembrane with 2-3% carbon black continued to retain 80-85% of its strength. The lifetime expectancy for geomembrane materials is generally accepted to be until the strength reduction has reached 50%, or its half-life. As of the February 8, 2011 revision to the published study, exposed HDPE geomembrane in dry and arid climates (which is the type of climate exposure at Grassy Mountain) has an exposed lifetime prediction greater than 36 years. The testing for the study is ongoing and is expected to be updated periodically.

The entire floor area and much of the interior sideslope areas within the landfill cells will be covered with protective soil cover material at the time of construction. Thus, the exposure time of these areas to UV light will be less than a year. The remaining portions of the sideslope areas will be covered during filling and closure of each landfill cell, which is expected to be less than 36 years. Deterioration from exposure to UV light is non-existent when all areas of the geomembrane are covered and the landfill is closed.

Resistance to Construction and Installation Stresses

Installation Related Stresses. Installation of the geomembrane materials will be completed by a contractor with significant experience in installing HDPE geomembranes. The only vehicular equipment that will be allowed to operate directly on the geomembrane materials during installation will be low ground pressure type ATV's and only after evaluation and approval. The manufacturer's installation specifications and the requirements of the Grassy Mountain Facility Construction Quality Assurance Plan will also be followed to obtain approvals and to provide documentation and certifications associated with the quality of the materials used and the quality of installation completed.

With the exception of cold weather deployment, the geomembrane liner systems should be installed to provide slack at each seam equal to one percent of the panel width. This slack should be provided to reduce the potential of stress cracking at the seams that can develop as the geomembrane materials contract (developing high tensile stresses) during cold temperature extremes.

Other Construction Related Stresses. Other construction related stresses occur as a result of equipment loadings during placement of the 2 feet of protective soil cover material above the liner systems. The protective soil cover provides a separation and protective barrier between waste materials containing debris and underlying geomembrane liners. Materials used for protective soil cover may consist of on-site soils or imported soils.

Equipment loadings cause normal stresses on the liner systems that transfer to the underlying subgrade soils. Should equipment loadings exceed the bearing capacity of subgrade soils, the subgrade soils can become displaced causing depressions or "ruts" below the liner systems. Stresses can then develop in the geomembrane materials as they are pushed into the depressions in the soil subgrade.

The ability of the liner systems to resist construction related stresses is dependent on the integrity of the subgrade soils and the ability of the subgrade soils to resist loads from above. Calculations presented in Appendix C provide typical evaluations that have been conducted to determine the safety factor of soil sub-grade materials against failure for various types of construction equipment that may be used during protective soil cover placement. Additional equipment has been evaluated and approved following CQA Plan procedures during prior construction projects at the Grassy Mountain Facility. The list of additional equipment is included in Appendix C and should be allowed for use based on the constraints provided for each equipment type. Other equipment may also be evaluated and added to the list of approved equipment after evaluation and approval by the Engineer (following CQA Plan procedures) to ensure the equipment does not exceed the allowable bearing capacity of the underlying soils. The following are results from typical evaluations completed for several types of equipment provided in Appendix C, including associated construction constraints developed for the equipment analyzed.

1) The following is a partial list of equipment that has been evaluated and may be used on 2 feet of protective soil cover thickness while placing and spreading the protective soil cover above the liner systems in the bottom of the landfill cells.

    a. Track-Type Tractors of equivalent or improved loading characteristics (i.e. weight, center of gravity, etc.) to the Caterpillar D6 Track-Type Tractor.

    b. Wheel-Type Rubber Tire Dozer Tractors of equivalent or improved loading characteristics (i.e. weight, center of gravity, etc.) to the Caterpillar 824B or 824C Wheel-Type Rubber Tire Dozer Tractor.

    c. Track-Type Front End Loaders of equivalent or improved loading characteristics (i.e. weight, center of gravity, etc.) to the Caterpillar 977L Track Front End Loader with a three and one quarter yard bucket.

    d. Wheel-Type Rubber Tire Front End Loaders of equivalent or improved loading characteristics (i.e. weight, center of gravity, etc.) to the Caterpillar 966C Wheel Front End Loader with a three and one quarter yard bucket.

    e. Motor Graders of equivalent or improved loading characteristics (i.e. weight, center of gravity, etc.) to the Caterpillar 14G Motor Grader.

    f. Track-Type Excavator/Backhoes of equivalent or improved loading characteristics (i.e. weight, center of gravity, etc.) to the Caterpillar 235 Track-Type Excavator/Backhoe.

2) Track type tractors or front-end loaders used to place and spread the protective soil cover in the bottom of the cells must push the soil out in front of the equipment to maintain a minimum cover of two feet between the liner and the tracks of the vehicle.

3) Wheel type tractors must maintain a minimum cover of two feet between the liner and the wheels of the vehicle.

4) Trucks that do not exceed the maximum highway wheel loads specified by AASHTO for a HS-20 truck may be used to haul and place protective soil cover material in the cells. The minimum cover that must be maintained over areas traversed by trucks (with HS-20 loading) hauling the soil into the cell for placement is 2.5 feet for single rear-axle loading and 2.0 feet for double rear-axle loading.

5) The two-foot protective soil cover on top of the liner materials on the inside slopes of the cells will not exceed a vertical height of 10 feet above the level of the cover or waste materials placed inside the cells. The protective soil cover material will be placed in lifts as the cells are filled with waste using equipment to reach from the bottom of side slopes up and/or from the top of side slopes down. No machinery will be allowed on the side slopes while placing the protective soil cover.

Stress to the liner systems due to deformation of the subgrade materials can be avoided by assuring that normal loadings above the liner systems are approximately within the allowable bearing capacity of the subgrade materials. According to AGEC (see Exhibit B), the allowable bearing capacity of the compacted clay liner subgrade to the liner systems is 1,500 pounds per square foot for live and dead loads and 2,000 pounds per square foot for impact loads (using an ultimate bearing capacity of 4,500 pounds per square foot and assuming safety factors of 3 and 2.5, respectively). All equipment approved for use during placement of the protective soil cover materials was approved based on the bearing capacity restrictions provided by AGEC. As long as the bearing capacity of the compacted clay liner subgrade is not exceeded, there will be no resulting ruts and depressions or any corresponding stresses to the liner system materials from normal loadings. The strength and elongation properties of the geomembrane materials provide some additional safety factor against failure as long as the yield strength of the material is not exceeded. Therefore, the factor of safety against failure of the liner system materials is greater than the safety factors resulting from equipment evaluations.

Equipment operation should be restricted to avoid sharp and pivoting turns, and high speed turns, that can result in displacement of protective soil cover materials and that can induce high tangential stresses that transfer to the liner system.

Resistance to Stresses of Daily Operation

Stresses from daily operations occur as a result of equipment loadings during placement of waste materials above the protective soil cover and, thus, placed above the liner systems. The ability of the liner system materials to resist normal forces from equipment loadings during waste placement is dependent on the loadings not exceeding the bearing capacity of the soils providing the subgrade to the lining systems. Exceeding the bearing capacity of subgrade soils causes ruts and depressions to form into which the liner system materials can be pressed. The geomembrane materials become stressed when the materials are deformed as they are pressed into the depressions.

All equipment evaluated and approved for use to place protective soil cover material can also be used for waste placement provided the same operational constraints are applied. Additional equipment historically used during placement of waste material at the facility was also analyzed to determine the ability of the subgrade soils (the compacted clay liner) to resist the equipment loadings.

1. Results from the analysis and operational constraints developed for equipment historically used at the facility include the following:

    a. The Caterpillar 977L Track Front End Loader with a 5 cy bucket.

    b. Trucks hauling wastes having the AASHTO HS-20 designated loading.

2) The minimum cover requirements above the top liner system for the Caterpillar 977L front-end loader with a 5 cy bucket shall be 3.5 feet. The cover minimum cover includes the total thickness of the protective soil cover and the waste material combined.

3) Trucks used in hauling and placing waste (having the AASHTO HS-20 loading) within the cell shall have a total minimum cover of 2.5 feet for single axle loading and 2.0 feet for double axle loading.

4) Other equipment that is not included herein for construction and daily operations may also be used after it has been analyzed by the Engineer to determine the minimum cover thickness that must be maintained between the liner systems and the equipment. The minimum cover thickness must be maintained as designated for each piece of equipment approved.

Equipment that has been evaluated and presented in this report with corresponding operational constraints (including equipment provided in Appendix C) include sufficient safety factor against exceeding the bearing capacity of the subgrade soils that depressions or ruts in the subgrade soils should not occur. Therefore, the liner system materials will be subjected to minimal stresses resulting from depressions in the subgrade soils and will have sufficient strength against those stresses. The strength and elongation properties of the geomembrane materials provide some additional safety factor against failure as long as the yield strength of the material is not exceeded. Therefore, the factor of safety against failure of the liner system materials is greater than the safety factors resulting from equipment evaluations.

Equipment operation above the liner systems should be restricted to avoid sharp and pivoting turns, and high speed turns that can result in displacement of protective soil cover materials and that can induce high tangential stresses that transfer to the liner systems.

LINER SYSTEM FOUNDATION

Utah Administrative Code R315-264-301(a)(1)(ii)

The foundation must be capable of resisting pressure gradients above and below the liner and prevent failure of the liner systems due to settlement, compression, or uplift. Supporting calculations are provided in the geotechnical investigation report provided in Appendix B and in the liner system calculations provided in Appendix C.

Resist Pressure Gradients

<u>Above the Lining Systems.</u> The geomembrane lining systems are directly supported by the compacted clay liner that forms the lowest layer of the bottom composite liner system. The compacted clay liner has an ultimate bearing capacity of 4,500 lbs/ft^2 resulting in an allowable bearing capacity of 1,500 lbs/ft^2 (assuming safety factor of 3.0). A maximum normal loading of approximately 6,400 lbs/ft^2 will be applied to the lining system from the overburden materials after closure of the landfill cells. The normal loading is a result of protective soil cover, waste, and closure cap materials. Compacted clay liner materials will support a localized load approaching 4,500 lbs/ft^2 (using ultimate bearing capacity) prior to being displaced. With a localized overburden load of 6,400 lbs/ft^2, the area immediately surrounding the localized load would require an over burden load less than approximately 1,900 lbs/ft^2 (or the difference between the normal loading and the ultimate bearing capacity of the clay liner) for the compacted clay liner to become displaced. This represents a difference in waste thickness of about 37 feet (using a waste density of 120 lbs/ft^3).

Placement of the waste materials occurs in relatively uniform lifts (typically less than 15 feet in height) that result in little spatial variation in lift thickness and, therefore, little spatial variation in the normal loading above the lining systems. No displacement of the clay liner is expected since there will not be sufficient variation on overburden loads to cause displacement to occur.

<u>Below the Lining Systems.</u> Pressure gradients below the liner systems typically result from the presence of liquids that may accumulate below the liner systems. As previously discussed, under "Pressure Gradients-Hydrogeologic Forces," pressure gradients that might occur under extreme conditions are not sufficient to displace overburden materials and are, therefore, not sufficient to displace or damage the lining systems.

Prevent Failure to Settlement, Compression, or Uplift

Settlement. Results from the geotechnical investigation provide long term settlement estimates and differential settlement estimates for the embankments and the floor area of the landfill cells. Settlement estimates are primarily a result of consolidation (or compression) within the foundation soils. Settlement below the cell embankments may be up to about 105 inches for common embankments between landfill cells and 72 inches for outside embankments that are not common between cells. Settlement below the floor in the central part of the cells (below the highest point of the closure cap, is estimated between 122 to 134 inches and may be on the order of about 140 inches. The maximum differential settlement between the low and high points of the floors is about 36 inches with areas below the high points (near the center to the cell floors and below the high point of the closure caps) settling more than the areas below low points (near the sumps).

Stresses in the liner systems resulting from differential settlement occur where settlement of a lower point on a slope settles more than a point that is on the slope causing the slope length to increase. As slope lengths increase, the lining system materials elongate to conform to the longer slope. Settlement estimates show the toe of the embankment slopes to settle about 40 inches more than the top of the cell embankments. This differential settlement will require the liner, which is anchored at the top of the embankment, to elongate about 1.24 percent along the inside slope of the cell, thereby creating tensile stresses within the liner.

Laboratory tests conducted by Gundle Lining Systems (currently GSE) are presented in their Laboratory Report #443. Results of the tests show that the HDPE geomembrane materials increase in strength with decreasing temperatures and the percent elongation at yield decreases with decreasing temperatures from 15% at 20°C (68°F) and 6.7% at -50°C (-58°F). The safety factor against overstressing the geomembrane materials by exceeding the percent elongation at yield is 12.1 or higher at temperatures at or above 20°C and between 12.1 and 5.4 at temperatures between 20°C and -50°C. Safety factors presented show the geomembrane materials have physical properties necessary to resist stresses associated with settlement since temperatures below -50°C are not expected.

Compression. Other than settlement issues discussed above, compressive forces can result in displacement of soils forming the subgrade to the geomembrane materials and the inability of the geomembrane materials to bridge gaps typically present between the ridges of the geonet material used for the leachate collection and removal system. These concerns were addressed in pervious sections of this report under Liner System Design and specifically discussed in the paragraphs on Pressure Gradients, Resistance to Construction and Installation Stresses, and Resistance to Stresses of Daily Operation. Information presented in the other sections of this report show that the landfill cells and liner systems are designed to resist compression forces exerted on the liner systems.

Uplift. Uplift forces may result from localize displacement of soils forming the subgrade to the geomembrane materials, slope failures on the interior side slopes of the cells below the geomembrane materials, and accumulation of gases or liquids below the liner systems.

Resistance to uplift forces caused by displacement of the compacted clay liner material is included in the section of this report under Liner System Design and specifically discussed in the paragraphs on Pressure Gradients, Resistance to Construction and Installation Stresses, and Resistance to Stresses of Daily Operation. Information presented in these other sections of this report show that the landfill cells and liner systems are designed to resist uplift forces associated with clay liner displacement.

According to the geotechnical investigation completed by AGEC, there is a safety factor against failure of the interior embankment slopes of 2.1 under long-term static conditions and 1.3 under seismic conditions. Therefore, slope failure is not expected to cause any uplift forces on the geomembrane liner systems.

Uplift pressure resulting from the accumulation of gases or liquids beneath the liner is discussed in a previous section "Liner System Design" of this report. Information regarding these uplift forces is specifically presented under the subsection on Pressure Gradients and in the paragraph on Hydrogeologic Forces. The landfill cells and liner systems are designed to resist the uplift forces from potential gas and liquid accumulations.

EXTENT OF LINER SYSTEM INSTALLATION

Utah Administrative Code R315-264-301(a)(1)(iii)

The landfill cells are designed and will be constructed entirely of raised embankments to provide complete containment of waste materials placed within the raised embankments. The liner systems are designed and will be constructed to cover the entire waste containment area within the raised embankments of the landfill cells. All areas of the landfill cells likely to be in contact with waste materials will be covered with the liner systems.

LEACHATE COLLECTION AND REMOVAL SYSTEM (LCRS)

Utah Administrative Code R315-264-301(c)(2)

A leachate collection and removal system must be designed, constructed, maintained, and operated to collect and remove leachate from the landfill, and to ensure that the leachate depth over the liner does not exceed one foot. The materials must be chemically resistant to the waste managed in the landfill and the leachate expected to be generated and sufficiently strong to prevent collapse under the pressure of overlying waste and cover materials. It must also be designed and operated to function without clogging through the scheduled closure of the landfill. Supporting calculations for the LCRS are included in Appendix D.

Leachate Depth

A detailed discussion regarding design of the leachate collection and removal system is provided later under the heading "Lining, Leachate Collection and Removal, and Leak Detection Systems Designs". As presented in the referenced discussion, the leachate collection and removal system is designed with sufficient capacity to collect and convey leachate to the top sumps and maintain less than one foot of depth on the top lining system.

Chemical Compatibility

The leachate collection and removal system is designed to consist of geocomposite which is comprised of geonet and non-woven geotextile. Geonets and geotextiles, made primarily of high density polyethylene and polypropylene, have been approved and used extensively in the landfill industry to provide drainage layers and to filter overlying soils from entering the drainage layers. These materials have also been used successfully to line the RCRA and TSCA waste landfills at the Grassy Mountain Facility for over 3 decades. Many studies have been conducted by government and private entities during this time regarding the compatibility of the various materials used in geomembranes and geocomposites. Results from these studies are provided in chemical compatibility charts and other reports provided by the entities completing the studies. USPCI (former owner of the Grassy Mountain Facility) has also previously demonstrated chemical compatibility with RCRA wastes disposed at the Grassy Mountain Facility. The testing procedures used and data obtained regarding chemical compatibility were previously submitted by USPCI to the Utah Division of Solid and Hazardous Waste.

Any waste materials received for disposal that vary from those historically received at the facility and from those previously demonstrated by industry to be compatible with the geocomposite materials will be tested to ensure compatibility in accordance with one of the Waste Analysis Plans. Waste analysis plans are provided in Attachment II-WAP RCRA-TSCA Waste Analysis Plan of the facility Permit. Materials that show to be incompatible with the geocomposite materials will not be placed in the landfill cells.

Manufacturer's published specifications for geocomposites typically provide transmissivity results from testing conducted at 10,000 lbs/ft^2. This exceeds the normal loading expected in the landfill cells after filling and closure are complete. Therefore, the geocomposite is expected to have the strength necessary to support the normal loading anticipated in the landfill cells and maintain the properties necessary for the leachate collection and removal system.

EXEMPTIONS FROM DESIGN REQUIREMENTS

Utah Administrative Code R315-264-301(b)

No exemptions are being requested from design requirements in 40CFR 264 or R315-264.

LINING SYSTEM, LEACHATE COLLECTION AND REMOVAL SYSTEM, AND LEAK DETECTION SYSTEM DESIGNS

Utah Administrative Code R315-264-301(c)

Federal and State Regulations require that landfills be designed and constructed with two or more liner systems and a leachate collection and removal system above the top liner system and between each liner system. The lowermost leachate collection and removal system is also considered to be the leak detection system.

Landfill Cells 8 through 13 are designed with two liner systems, a leachate collection and removal system above the top liner system and a leak detection system between the liner systems, or above the bottom liner system. The leachate collection and removal system (LCRS) above the top liner system consists of a double sided geocomposite (a geonet sandwiched between two non-woven geotextiles). The top liner system consists of a composite system (including geosynthetic clay liner sandwiched between two synthetic 80-mil HDPE geomembranes) across the floor and 10 feet up the interior sideslopes and a single 80-mil HDPE geomembrane above a geosynthetic clay liner from 10 feet up the interior sideslopes to the top inside crest of the landfill cell embankments. The leak detection system will consist of a double sided geocomposite. The bottom composite liner system consists of a of 60-mil HDPE geomembrane overlying a minimum three-foot thick compacted clay liner (CCL).

The floor of each landfill cell is divided into four sections that slope to a sump area located at the low point of each of the four floor sections. Leachate that enters the leachate collection and removal system, or the leak detection system will drain to the sumps where the leachate is collected and removed by pumping. Design drawings presented in Appendix A show the configuration of the liner systems, the leachate collection and removal systems, and the leak detection systems. Supporting calculations for design of the liner systems are provided in

Appendix C and supporting calculations for design of the leachate collection and removal systems and the leak detection systems are provided in Appendix D.

Liner Systems

Utah Administrative Code R315-264-301(c)(1)(i)-(ii)

Top Liner System. The top liner system is designed as a composite system consisting of three components on the floor and 10 feet up the interior side slopes and two components the rest of the distance up the interior side slopes. An 80-mil HDPE geomembrane provides the upper component which extends across the floor and up the interior slopes of the landfill cells. The middle and bottom components on the floor and 10 feet up the interior side slopes consists of a geosynthetic clay liner (GCL) and a bottom 80-mil HDPE geomembrane. The two components the rest of the distance up the interior side slopes consists of a single 80-mil HDPE geomembrane and a GCL. The upper 80-mil HDPE geomembrane provides an impermeable barrier to prevent migration of hazardous constituents into the liner and provides a barrier on which the top leachate collection system is placed. Clean Harbors is providing the added GCL and the lower 80-mil HDPE geomembrane components described above for extra protection (beyond regulatory requirements) against leachate migration through the liner system. As presented earlier in this report, the geomembrane liner has material properties and strength sufficient to prevent failure from pressure gradients, physical contact with the liquids to which it will be exposed, climatic conditions, installation stresses, and stresses from daily operation. The foundation materials to the liner system provide support necessary to resist pressure gradients, and to prevent failure from settlement, compression, and uplift. The liner system will also cover all earth materials likely to be in contact with the waste or leachate that will be placed in the landfill cell.

Bottom Composite Liner System. The bottom composite liner system consists of a 60-mil HDPE geomembrane placed directly over and in contact with a 3-foot thick compacted clay liner. The geomembrane meets the same criteria in materials and strength as stated above for the top liner system. The compacted clay liner is designed to meet a minimum permeability of 1×10^{-7} cm/sec as required by federal and state regulations.

The compacted clay liner will be processed and compacted generally using the same borrow source areas and methodologies that have historically been used at the site for clay liner construction. The methodology used is provided in the construction quality assurance plan for the facility. The geotechnical investigation report prepared by AGEC (provided in appendix B) includes recommended procedures for mining, processing, placement, compaction, and maintenance of the compacted clay liner.

Leachate Collection and Removal System (LCRS)

Utah Administrative Code R315-264-301(c)(2) & ((3)(iii)-(iv)

The landfill cells are divided into four separate sump drainage areas and the floor of each sump drainage area consists of two planar surfaces that slope toward each other (in the east/west direction) at a 2.3% slope and parallel to each other (in the north/south direction) at a 2.3% slope. Slopes of 2.3% were provided to leave a resulting slope greater than 1% after projected differential settlement occurs. The two slopes form a resultant slope for the planar surfaces of 3.25% (at an angle of 45 degrees from the 2.3% slopes) toward the sumps located at the low point of each sump drainage area. A valley is formed at the line of intersection between the two planar surfaces that has a slope of 2.3% toward the sumps. After settlement occurs, the resulting minimum slopes will be 1.7% toward the valley between the two planar surfaces, 1.4% parallel to and along the valley, and a resultant of 2.3%.

The leachate collection and removal system (LCRS) is located on the floor area of the cells above the top liner system and is provided with the slopes and configuration described in the previous paragraph. The LCRS is designed as a double-sided geocomposite consisting of 8 oz. non-woven geotextile on both sides of the geonet. A 4-inch diameter HDPE perforated pipe will also be placed along the valley within each sump drainage area to collect leachate that concentrates along the valley and convey the leachate to the sumps for removal.

U.S. Environmental Protection Agency's "Hydrologic Evaluation of Landfill Performance (HELP)" computer model was used to estimate the design leachate rate for the leachate collection system. Input date for the HELP model and calculated results from the model are provided in Appendix D. The following tables provide a summary of the results generated by the HELP model for the following four scenarios: 1) the cells with only protective soil cover and no waste; 2) the cells with 10 feet of waste; 3) the cells with 30 feet of waste; and, 4) the cells with 48 feet of waste above the protective soil cover. Sump drainage areas used to calculate leachate volumes are 154,869 square feet and 158,586 square feet for Landfill Cell 8 and for Landfill Cells 9-13, respectively. Since calculated leachate volumes generated in Landfill Cells 9-13 are slightly higher than those generated in Landfill Cell 8, design of the leachate collection and removal system will be based on the leachate volumes for Landfill Cells 9-13.

TABLE 2.1 - AVERAGE ANNUAL AND AVERAGE DAY LEACHATE RATES LANDFILL CELL 8

Waste height	Average Annual Leachate Rates			Average Day Leachate Rates	
(ft)	(in)	(cf/sump)	(gal/sump)	(cf/sump)	(gal/sump)
0	1.33143	17,179.8	128,505	47.1	352
10	1.43115	18,466.5	138,129	50.6	378
30	1.04327	13,461.6	100,693	36.9	276
48	0.69773	9,003.0	67,342	24.7	184

Average Day Leachate Rates are calculated from the Average Annual Leachate Rates

TABLE 2.2 - AVERAGE ANNUAL AND AVERAGE DAY LEACHATE RATES LANDFILL CELLS 9-13

Waste height	Average Annual Leachate Rates			Average Day Leachate Rates	
(ft)	(in)	(cf/sump)	(gal/sump)	(cf/sump)	(gal/sump)
0	1.33143	17,595.5	131,614	48.2	361
10	1.43115	18,913.4	141,472	51.8	388
30	1.04327	13,787.3	103,129	37.8	283
48	0.69773	9,220.9	68,972	25.3	189

Average Day Leachate Rates are calculated from the Average Annual Leachate Rates

TABLE 2.3 - PEAK DAY LEACHATE RATES
FOR LANDFILL CELL 8

Waste height	Peak Day Leachate Rates		
(ft)	(in)	(cf/sump)	(gal/sump)
0	0.13165	1,739.8	13,014
10	0.01934	255.6	1,912
30	0.01646	217.5	1,627
48	0.01546	204.3	1,528

TABLE 2.4 - PEAK DAY LEACHATE RATES
FOR LANDFILL CELLS 9-13

Waste height	Peak Day Leachate Rates		
(ft)	(in)	(cf/sump)	(gal/sump)
0	0.13165	1,739.8	13,014
10	0.01934	255.6	1,912
30	0.01646	217.5	1,627
48	0.01546	204.3	1,528

A peak day flowrate of 2.87 ft^3/ft-day was calculated using the highest peak day leachate rate (0.13165 inch/day), the longest flow path within the geocomposite (262 feet), and a flow width of 1-foot within the geocomposite. Applying a safety factor of 4.5 to the peak day flowrate (accounting for creep deformation of the geonet, biological clogging, and chemical clogging) results in a design leachate flow rate of 12.915 ft^3/ft-day. The geocomposite should have a minimum transmissivity of $6.0x10^{-4}$ m^2/sec to provide sufficient capacity to convey the design leachate flowrate within the leachate collection system to the leachate collection pipe and to the sumps. The conditions under which the geocomposite must meet the minimum transmissivity include a minimum normal loading of 6,400 lbs/ft^2, a gradient of 3.25%, a layer of soil for the upper boundary, and HDPE geomembrane for the lower boundary. Double sided geocomposite tests results showing a minimum transmissivity of $6.0x10^{-4}$ m^2/sec under more conservative testing conditions is acceptable.

The total drainage area contributing leachate flow to the 4-inch diameter HDPE perforated leachate collection pipe is 89,110 ft^2. Multiplying the peak day leachate rate (0.13165 inch/day) by the drainage area results in a flow rate of 5.1 gpm through each leachate collection pipe. A design flowrate of 23 gpm for the leachate collection pipe results when a safety factor of 4.5 is applied to the leachate flow rate. A slope of 0.12% (much less than the anticipated slope of 1.4% after differential settlement occurs) is required for a 4-inch diameter HDPE pipe to convey 23 gpm to the sumps assuming the pipe flows at 80% capacity to maintain gravity flow. Therefore, the leachate collection pipes have sufficient capacity to convey the peak day leachate rate to the sumps.

Leachate collected within the sumps will be removed using leachate pumps that will be installed in the sumps through leachate withdrawal pipes that extend from the sumps to the top of the embankment slopes directly above the sumps. The leachate collection sumps have a capacity of about 1,280 gallons at 1 foot of leachate depth above the lowest point in the sumps, 3,650 gallons prior to the leachate backing up onto the floor area outside the sumps (at the lowest point around the top perimeter of the sumps), and 4,380 gallons at full sump capacity (the total capacity in pore spaces of the rock and leachate withdrawal pipe within the leachate collection sumps at the highest elevation around the top perimeter of the sumps), and a total leachate storage capacity within the leachate collection sumps, the leachate withdrawal pipe, the geocomposite (leachate collection system), and the overlying protective soil cover (to 1-foot of depth above the lowest point around the top perimeter of the sumps) of about 8,190 gallons.

The average frequency that leachate may be pumped from the sumps depends on the rate at which leachate enters the sumps and the depth to which leachate is allowed to pond within the sumps to accommodate pumping operations. Based on average daily leachate rates projected using the HELP model (189 to 388 gallons per sump), the estimated pumping frequency will be between 3 and 7 days assuming a limiting leachate depth of 1 foot above the lowest point in the sumps. The estimated pumping frequency will increase to 10 to 19 days if the leachate depth in the sumps is allowed to reach the lowest point around the perimeter of the sumps (prior to backing up into the leachate collection system outside the sumps). There may, however, be precipitation events when waste placement within a cell is beginning and much of the protective soil cover on the floor area is still exposed. Assuming no waste, or very little waste, the peak day leachate rate obtained from the HELP model over the drainage area contributing to each sump is 12,706 gallons, which exceeds the total leachate storage capacity. Should a peak day condition occur, pumping will be required until leachate generated within the sumps slows to allow less frequent pumping to occur. When the waste level within the cells is about 10 feet the peak day leachate rate is only expected to be about 1,912 gallons and gradually gets lower as the waste level within the cells gets higher. Also, during dry periods of little to no precipitation, the leachate generation rate will be very low and the pumping frequency may be less than projected by the HELP model. The above information is intended to provide an estimate of conditions that may be experienced and provide a baseline frequency for leachate removal. The actual pumping frequency will be determined operationally based on recorded volumes as leachate is removed from the sumps.

As presented earlier in this report, the geocomposite has material properties chemically resistant to the waste materials and leachate expected to be present in the landfill cells, and strength sufficient to prevent collapse under the pressures exerted by overlying waste and cover materials. The safety factor of 4.5 applied to the design provides for creep deformation and the potential for biological and chemical clogging.

Leak Detection System (Bottom Leachate Collection and Removal System)

Utah Administrative Code R315-264-301(c)(3)(i)-(v)

The leak detection system must be capable of detecting, collecting, and removing leaks of hazardous constituents at the earliest practicable time through all areas of the top liner system likely to be exposed to waste or leachate during the active life and post-closure care period. The HELP model was used to determine potential leakage rates based on a good quality installation of the geomembrane materials with 1 defect per acre and 1 pinhole per acre. The following tables provide the estimated leakage rates for Landfill Cells 8-13 based on the HELP model assumptions. The sump drainage areas of Landfill Cells 9-13 are slightly larger than the sump drainage areas for Landfill Cell 8 resulting in higher leakage volume estimates. Therefore, leakage volume estimates for Landfill Cells 9-13 were also conservatively used for Landfill Cell 8. HELP model parameters and results and supporting calculations for the leak detection system are included in Appendix D.

TABLE 2.5 – AVERAGE ANNUAL LEAKAGE RATES FOR LANDFILL CELL 8

Waste height	Average Annual Leakage Rates			Average Day Leakage Rates	
(ft)	(in)	(cf/sump)	(gal/sump)	(cf/sump)	(gal/sump)
0	0.44601	5,755.0	43,047	15.8	118
10	0.46899	6,051.5	45,265	16.6	124
30	0.35085	4,527.1	33,863	12.4	93
48	0.24477	3,158.3	23,624	8.7	65

TABLE 2.6 - AVERAGE ANNUAL LEAKAGE RATES FOR LANDFILL CELLS 9-13

Waste height	Average Annual Leakage Rates			Average Day Leakage Rates	
(ft)	(in)	(cf/sump)	(gal/sump)	(cf/sump)	(gal/sump)
0	0.44601	5,894.2	44,089	16.1	121
10	0.46899	6,197.9	46,361	17.0	127
30	0.35085	4,636.7	34,682	12.7	95
48	0.24477	3,234.8	24,196	8.9	66

TABLE 2.7 – PEAK DAY LEAKAGE RATES FOR LANDFILL CELL 8

Waste height	Peak Day Leachate Rates		
(ft)	(in)	(cf/sump)	(gal/sump)
0	0.13165	1,698.7	12,706
10	0.01934	249.5	1,867
30	0.01646	212.4	1,589
48	0.01546	199.5	1,492

TABLE 2.8 – PEAK DAY LEAKAGE RATES FOR LANDFILL CELLS 9-13

Waste height	Peak Day Leachate Rates		
(ft)	(in)	(cf/sump)	(gal/sump)
0	0.13165	1,739.8	13,014
10	0.01934	255.6	1,912
30	0.01646	217.5	1,627
48	0.01546	204.3	1,528

Each of the landfill cells are divided into four sections or sump drainage areas with sumps located at the low points of the floor in each of the four sections. The leak detection system is located between the geomembrane components of the bottom and top liner systems throughout the entire lined area of the landfill cells. Leachate that leaks through the top liner system enters the leak detection system and is conveyed within the leak detection system to the sumps where the leachate is collected for leak detection and removal.

The floor within each sump drainage area is divided into two planar sections that are designed at slopes of 2.3% toward each other to form a valley along their line of intersection. The valley and the two planar sections of the floor also slope at a 2.3% slope toward the sumps. The resultant design slope of each of the planar floor sections is 3.25% which is at a 45 degree angle in the general direction toward the sumps. After projected differential settlement occurs, the minimum slope of the planar slopes directly toward (or perpendicular to) the valley formed by the intersection of the floor sections is about 1.7%. The minimum slope of the valley and the planar floor sections parallel to the valley after projected differential settlement is about 1.4% and the minimum resultant slope after projected differential settlement is about 2.3%.

The leak detection system consisting of a geocomposite, with a minimum transmissivity of 2.7×10^{-4} m^2/sec, will be installed between the top and bottom liner systems. This exceeds the minimum transmissivity requirements (3×10^{-5} m^2/sec) for geonets/geocomposites in the federal and state regulations.

As presented earlier in this report, the geocomposite has material properties chemically resistant to the waste materials and leachate expected to be present in the landfill cells, and strength sufficient to prevent collapse under the pressures exerted by overlying waste and cover materials. The amount of flow within the leak detection system is expected to follow flow paths that are downgradient from leaks that may be present in the top liner system. Should any clogging occur, flow paths will naturally widen to allow flow to the sump for quick detection of leaks and removal of leachate that enters the sumps.

The leak detection sump will consist of ¾-inch rounded washed rock which is assumed to have a porosity of 32%. The total sump capacity within the pore spaces of the rock is estimated to be 2,318 gallons. The pump for the leak detection system should have a minimum capacity of 7.5 gallons per minute. Assuming 4 hours of operation per day, the pump will have the capacity to remove 1,800 gallons of leachate per day (slightly higher than the maximum ALR) in the four hours of operation. Therefore the leak detection sump will have sufficient capacity within the void spaces of the rock and the pump will have sufficient capacity for collection and removal of leachate minimal potential for liquids backing up into the drainage system.

Leak Detection System Operation
Utah Administrative Code R315-264-301(c)(4) & (5)

Attachment II-3 of the Grassy Mountain Facility Permit requires inspections to occur at a minimum every 7 days for the presence of leachate in and for the proper functioning of the leak detection system. The inspection schedule provided should result in proper collection and removal of leachate within the leak detection system to maintain a leachate depth of less than one foot on the bottom liner system and to minimize the potential for liquids backing up into the drainage system. If leakage rates are sufficient to require more frequent inspection and removal of leachate from the leak detection system, the inspection schedule should be adjusted accordingly.

Should ground water elevations rise sufficiently to make contact with the bottom liner system, contact will most likely be limited to the lower portion of the bottom sumps since the floor area outside the sumps is above the existing ground surface elevation which is above the historic ground water elevation. If ground groundwater rises high enough to enter the leak detection system, it will need to flow through the compacted clay liner and must be exposed to a hole in the bottom geomembrane. Since groundwater will flow very slowly through the compacted clay liner and a very small area of the bottom geomembrane will be exposed to groundwater, effects of groundwater on the leak detection system will be negligible.

ALTERNATIVE DESIGNS, WAIVERS, AND EXEMPTIONS
Utah Administrative Code R315-264-301(d)-(f)

No alternative designs, waivers, or exemptions are requested regarding the design standards for the landfill cells.

RUN-ON CONTROL SYSTEM
Utah Administrative Code R315-264-301(g)

The landfill cells are constructed with raised embankments designed to be approximately 25 feet or more above the existing ground surface. The raise embankments will prevent storm water flows from surrounding areas from entering the active area the landfill cells.

Closures of adjacent landfill cells are designed to collect and convey storm water off the top areas of the closure caps and to bottom outside toe of the cell embankments. Raised embankments of active landfill cells will prevent storm water from entering active areas of those cells once storm water from adjacent closure caps is conveyed to the bottom outside toe of the cell embankments.

Erosion Protection

Erosion protection of embankments and closure caps outside the active areas of the landfill cells is a part of run-on control and for long term protection of the embankments and closure caps. On-site observations show that erosion of the exterior embankment slopes and closure caps of the existing landfill cells at the Grassy Mountain Facility has generally been effectively controlled by the placement of a gravel layer (stone mulch or gravel armor plating) on the embankment slopes and closure cap surfaces. All outside slopes and top surfaces of the raised embankments and all surfaces of the closure caps are designed to receive a six-inch thick layer of stone mulch.

Use of the stone mulch material is in keeping with procedures for controlling erosion on steep side slopes of embankments or cuts as proposed by the Federal Highway Administration in the National Cooperative Highway Research Project NCHRP Report 221 "Erosion Control During Highway Construction Manual on Principles and Practices," (Israelsen, et. al., 1980). The principles presented in this manual were developed for the Transportation Research Board by personnel of the Utah Water Research Laboratory, College of Engineering, Utah State University in Logan, Utah. These same principles, but specific to Utah, were published by the Utah Water Research Laboratory in a report entitled, "Erosion and Sedimentation in Utah: A guide for Control," (Israelsen, et. al., 1984).

The above referenced documents identify a procedure for designing a "stone mulch" to provide erosion control on steep embankment slopes. The stone mulch (gravel armor plating) material used historically at the facility and proposed for use on Landfill Cells 8-13 meets the criteria for the stone mulch proposed in the documents. The design procedure identifies a required thickness for the stone mulch in order to maintain soil loss at less than 1 ton per acre per year during a designated recurrence interval. A 100-year recurrence interval was selected for the erosion control design of the landfill cells. EPA guidance recommends controlling erosion to a level of less than 2 tons/acre/year (EPA, 1991). Calculations with accompanying assumptions and design procedures used in this analysis are presented in Appendix G. The procedure recommends a minimum stone mulch thickness of less than one inch on the exterior embankment slopes and for stone mulch on the top of the closure caps. A minimum six-inch thickness will be placed on the top surface and side slopes of the embankments and on all closure cap surfaces. This provides at least six times the required thickness of stone mulch resulting from the calculations.

Observations have been conducted to evaluate the effectiveness of the four-inch thick layer of stone mulch placed for erosion protection on previous projects. With the exception of some localized occurrences, the stone mulch appears to be effective for controlling erosion. The thickness was increased to 6-inches in order to provide additional protection.

RUN-OFF MANAGEMENT SYSTEM

Utah Administrative Code R315-264-301(h)

Run-off from the active areas of the landfill cells, within the lined area, will be contained within the active area of the landfill by maintaining containment areas within the landfills, including depressions in the waste, ditches around the inside perimeter of the cell embankments (outside perimeter of waste placed in the landfill cells), and other methods of sufficient capacity to contain the estimated 1.23 acre-feet of run-off. Should containment of run-off be completely provided within a perimeter containment ditch, the ditch should be maintained by keeping the top level of the protective soil cover 3 feet below the top of the cell embankments and grading the waste material so that the bottom tow of the waste mound intersects the top inside edge of the protective soil cover. Run-off containment will be maintained until landfill cell closure occurs. Calculations associated with run-off containment volume and a perimeter containment ditch are provided in Appendix F.

STORM WATER HOLDING FACILITIES MANAGEMENT

Utah Administrative Code R315-264-301(i)

Run-On Containment Facilities

Run-on containment facilities associated with Landfill Cells 8-13 include the following:

- An existing pond located east of the northeast corner of Landfill Cell 12 (north of the office and laboratory area) that will be enlarged during construction of the landfill cells and their closures;
- An existing temporary pond located southeast of Landfill Cell 8 that will be abandoned when Landfill Cell 9 is constructed;
- An existing pond located east of the southwest corner of the facility property;
- A pond that will be located west of Landfill Cell 9 (between Landfill Cell 9 and the proposed Surface Impoundment A);
- A pond that will be located south of the southeast corner of Landfill Cell 13 when the temporary pond located southeast of Landfill Cell 8 is abandoned.

In addition to the ponds, the dike system around the area of the former land treatment area (previously cleaned and closed) provide for containment of run-on water from the area discharged from the south side Landfill Cells 9, 11, and 13 closure caps, the south side of the exterior embankment slopes of the proposed landfill cells, and the open area south of the proposed landfill cells and Surface Impoundment A. The facility may do additional grading, road construction, and construction of drainage swales and channels south of the proposed cells that will convey run-on water to specific locations for containment in order to accommodate facility operations.

Storm water should be removed from ponds and other containment facilities in order to maintain the design storage volume for these facilities. Water from the run-on containment ponds is assumed to be clean since the water was not generated from active waste disposal areas of the facility. This water can be used for general facility dust control, wheel washing, construction, etc.

Run-Off Containment Facilities

The capacity of the run-off containment areas within the landfill cells should be maintained by removing storm water in these areas. The water removed from run-off containment areas can be used for dust control within the landfill cells and may be removed and treated similar to leachate water.

CHAPTER 3 – STORM WATER MANAGEMENT

GENERAL DESCRIPTION OF STORM WATER MANAGEMENT SYSTEM

Storm water management at the Grassy Mountain Facility provides for the control of surface water drainage resulting from precipitation events on and around the landfill cells and surface impoundments. A portion of the precipitation that falls on the site will infiltrate directly into the ground, a portion will evaporate, some will adhere directly to vegetation, soil, and gravel surfaces, and some will run off and be directed towards collection points or drainage ditches, and then conveyed to containment ponds or retained in containment areas. Run-off management will include systems capable of collecting and containing the volume of storm water runoff from within active waste containment areas of the landfill cells and surface impoundments. Run-on management will consist of systems designed to collect, convey, and contain storm water runoff from non-contaminated areas outside active waste containment areas. These areas include the tops and exterior slopes of landfill cell and surface impoundment embankments, landfill cell closure caps, ground surfaces surrounding landfill cells and surface impoundments, containment dikes, conveyance facilities, and containment ponds.

It should be noted that use of the single, non-hyphenated word "runoff" is applied as a general term to all storm water that generates flows and volumes of water used for design of the run-off and run-on systems. Design of run-off and run-on storm water management systems are required to collect, convey and contain runoff water resulting from a 25-year, 24-hour storm event. Clean Harbors has conservatively chosen to design the systems based on a 100-year, 24-hour storm event.

Due to the flatness of the terrain on which the Grassy Mountain Facility is located; storm water control facilities are needed to minimize accumulation of storm water along the exterior toes of embankment slopes and in low lying areas around the facility that may be a nuisance to facility operations. The existing storm water containment ponds at the facility provide a destination point for storm water to collect inside the containment dike systems inside the facility property. Existing conveyance ditches have been designed to collect and convey uncontaminated storm water to the storm water containment ponds. Design of run-off and run-on storm water management systems in this report is specific to Landfill Cells 8-13 and facilities affected by storm water runoff from those cells and there closures. This report does not discuss storm water management for other areas of the Grassy Mountain Facility.

HYDROLOGY

Hydrologic calculations were completed for the Landfill Cells 8-13 to determine peak flows and volumes for design purposes. The Soil Conservation Service (SCS) curve number methodology was used in conjunction with the Army Corps of Engineers HEC-HMS hydrology model to predict the peak flows and volumes.

Run-Off Management System

The run-off management system inside Landfill Cells 8-13 the landfill includes maintaining sufficient storage capacity inside of these facilities (while open and operating) to totally contain precipitation from the 100-year, 24-hour precipitation event. A discussion regarding containment of precipitation inside the landfill cells is provided in Chapter 2 under the section titled "Run-off Management System."

Run-On Management System

The run-on management system is designed to collect, convey, and contain storm water runoff from landfill cell closure caps and embankments in a way that will protect the integrity of the landfill cells. This is accomplished by sloped surfaces, berms, pipes, open channels, and ponds as presented in the permit drawings provided in Appendix A. Supporting calculations are provided in Appendix F.

Methodology. Delineation of the sub-basins for Landfill Cells 8 through 13, shown in the figure included in Appendix F, was based on the landfill cell design discussed in Chapter 2. Each sub-basin is designed to drain runoff water directly off of closure caps and cell embankments or to direct flows to downspout and storm water pipes that convey runoff off the closure caps and cell embankments. Additional storm water facilities will then collect storm water discharged from the cells and convey the storm water to containment areas in the facility.

Curve numbers are generally determined based on the hydrologic soil type, soil vegetative cover, and other surface conditions. The hydrologic soil type is a general indication of the soil's infiltration capacity. Soils are assigned a hydrologic soil type of A, B, C or D by the Natural Resource Conservation Service (NRCS). Soils of hydrologic soil type A have the highest infiltration rate, and therefore produce the least amount of runoff. Soils of hydrologic soil type D have the lowest infiltration rate, and therefore produce the highest amount of runoff. Cover conditions are usually combined with the hydrologic soil type to produce a curve number based on Table 2-2d of Technical Release 55 "Urban Hydrology of Small Watersheds" (TR-55). In order to remain consistent with previous hydrologic calculations for design and permitting of previous cells, a curve number of 83 was selected for the model.

The lag times (T_L), defined as the time to the hydrograph peak, were calculated by using the time of concerntration (T_C) and the equation $T_L = 0.6T_C$. The time of concentration was calculated using the criteria found in Worksheet 3 in TR-55 with a minimum lag time of 3.6 minutes being applied to sub-basins where the calculated value was less than 3.6 minutes. Lag times for the delineated sub-basins are provided in Appendix F.

The SCS Type II Distribution was used with the 100-year 24-hour storm, exceeding the requirement of R315-264-251(g). The rainfall amount was taken from the Point Precipitation Frequency Estimates from NOAA Atlas 14, based on a location defined at the center of the study area. The value of the 100-year 24-year precipitation event is 1.85 inches.

Peak Design Flows. The hydrologic parameters presented above were used in the HEC-HMS model to generate peak design flows for each of the subbasins defined for the cells and their closures and for the downspout and other storm drainage piping located at along the landfill cell embankments.

HYDRAULICS

The peak flow rates based on the hydrologic modelling discussed above provided the basis for the design of the drainage conveyances. Hydraulic capacity for channels and pipes was determined using Manning's equation. Should channel or pipe capacities be exceeded and cause temporary flooding of roads and other facility areas in extreme precipitation events, the raised embankments of the landfill cells will prevent the run-on storm water from entering the active waste disposal areas. Water from extreme events then is limited to be nuisance water for facility operations.

Storm Drainage Channels

An existing channel along the north sides of Landfill Cells 8, 10, and 12 currently receives storm water runoff from portions of Cells 3, 4, 5, and 6 and conveys the water to the pond located east of Landfill Cell 12. An existing 24-inch diameter storm drainage pipe is currently provided to convey the peak design flow (16 cfs) from the channel to the containment pond.

The projected peak flow (29 cfs) from the northeast quarter of Cell 7 and from the north sides of Cells 8, 10, and 12 (resulting from the HEC-HMS model) will combine with the current peak flow (16 cfs) and will convey the storm water through the channel to the east containment pond. Pipes conveying runoff from the Cells 8, 10, and 12 will discharge into the channel through energy dissipation outlet structures. The channel is formed by the outside embankment slopes of Landfill Cells 4, 5, and 6 on the north side and the access road to Landfill Cells 8, 10, and 12 on the south side. The channel has a bottom slope of 0.1 percent and will behave much like a series of retention ponds behind each monitoring well mound that extends to the north from the access road. At a flow depth of 2 feet, storm water will flow past the monitoring well mounds at about 3 fps and will flow in the wider portions of the channel at less than 1 fps.

Replacing the existing 24-inch diameter storm drainage pipe with three 24-inch diameter pipes will provide the added capacity to convey the peak flow of 45 cfs from the channel into the containment pond with a head water depth of about 2.3 feet. The pipes should be installed at the time the closure cap for Landfill Cell 8, 10, or 12 is constructed and the invert of the pipes should be installed a minimum of 3 feet below the road surface, or nearby monitoring well pads. The depth may also be provided by constructing the access road and setting other facilities to a height that is 3 feet above the bottom of the channel at the pipe inlet, by installing a concrete inlet box that allows the channel bottom to drop suddenly to the invert of the pipes, or by providing a slope in the channel near the inlet to the pipes and providing concrete, rip rap, or some other form of erosion protection for the steeper slope.

A proposed channel on the east side of Cells 12 and 13 will convey runoff from parts of Cells 10, 11, 12, and 13 to a containment pond south of Cell 13. Pipes conveying runoff from the top of the landfill cells and their closure caps will discharge into the channel through energy dissipation outlet structures. The channel is 13 feet wide and has a projected peak flow of 29 cfs. The first reach of the channel is designed with a slope of 0.1% bottom slope resulting in a calculated flow depth of 1 foot and flow velocity is 1.7 fps which is a non-eroding velocity. The second reach of the channel is the pond inlet and is designed with a bottom slope of 2.6%. The calculated velocity is 5.1 fps (an eroding velocity) and 6 inches of rock erosion protection (D_{50} = 3 inches) is needed.

There are two inlet channels to the proposed pond west of Landfill Cell 9 that convey storm water from the storm drainage downspout pipes on the west side of Cell 9 to the pond. The north inlet channel has a bottom width of 10 feet, a bottom slope of 2.1%, and a projected peak flow rate of 25 cfs. The calculated flow depth is 0.4 foot resulting in an erosive velocity of 4.8 fps requiring 6 inches of rock erosion protection (D_{50} = 3 inches). The south inlet channel has a bottom width of 10 feet, a bottom slope of 1.5%, and a projected peak flow rate of 5 cfs. The calculated flow depth is 0.2 foot resulting in a non-erosive velocity of 2.4 fps requiring no erosion protection.

Storm Drainage Pipes

Hydrologic calculations for runoff described above were used to determine the design flows for the downspouts pipes to convey storm water off the closure caps and off the top of the common cell embankments. The downspout pipes are designed with a diameter of 18 inches to convey to peak storm water flow of 2.4 cfs off the closure caps, to provide ease of cleaning, and to reduce the potential of plugging. The steep slope of the downspout pipes provides for inlet control conditions and a head water depth of 0.65 foot for the 2.4 cfs to enter the downspouts. The height of the berms at the corners of the closure caps is approximately 2.5 feet above the downspout inverts resulting in about 1.8 feet of freeboard.

Embankments between the closure caps are designed to be graded at a 1% slope toward manholes with grated inlets. Storm water will enter the manholes through the grated inlets and will then be conveyed through 18-inch diameter and 24-inch diameter drainage pipes to the bottom of the outside embankments of the cells. The storm drainage pipes along the top of the east/west common embankments are designed at a slope of 0.5% and have sufficient capacity to receive and convey the combined projected peak flows from the closure caps and tops of the common cell embankments to the bottom of the east and west bottom toes of the cell embankments. Storm water will discharge from the pipes through energy dissipation structures to storm drainage channels or graded surfaces that will convey the storm water to containment ponds and containment areas within the berm system surrounding the facility.

As presented earlier with the north storm drainage channel, three 24-inch diameter culverts will be installed under the access road to convey storm water from the north drainage channel to the east containment pond. The culverts have the capacity to convey the projected peak flow of 45 cfs to the pond with 2.3 feet of head water depth. The inlet to the culverts will be installed at a depth that is at least 3 feet below the surface of the access road and the nearest monitoring well pad. This will provide a minimum 0.7 foot of freeboard to the road surface and monitoring well pads.

RUNOFF VOLUME AND STORM WATER CONTAINMENT

Runoff volumes were determined through the hydrology methods described above. Runoff from the 100-year 24-hour precipitation event will be wholly contained in three containment ponds located on the site. Supporting calculations are provided in Appendix F.

The east containment pond currently is located south of Cell B6 and will be east of Cell 12 and has a current capacity of 9.0 acre feet for containment of storm water from portions of Cells 3, 4, 5, and B6, from Cells X, Y, and Z, and from facility areas and roads around those cells.. The east containment pond will be expanded to accommodate additional an additional 1.74 acre feet (a total minimum capacity of 10.74 acre feet) for storm water that will be received from the north half of Cells 8, 10, and 12, and the northeast quarter of Cell 7 as seen in appendix F. Expanding the existing pond an additional 208.5 feet will provide the capacity needed.

The west containment pond will be located west of Cell 9 and south of Cell 7. The containment pond will receive storm water from portions of Cells 7, 8, 9, 10, and 11, the proposed Surface

Impoundment B embankments and some of the surrounding areas. The west containment pond will be provided with a minimum capacity of 3.0 acre feet. A pond that has equivalent floor dimensions of 130 feet x 295 feet and a depth of 4 feet will provide the required capacity. This will provide a water depth of 3 feet and allow for 1 foot of freeboard.

The south containment pond will be located south of Cell 13 and will receive storm water from portions of Cells 10, 11, 12, and 13 and some of the surrounding area. The south containment pond will be provided with a minimum capacity of 3.37 acre feet. A pond that has equivalent dimension of 212 feet x 212 feet and a depth of 4 feet will provide the required capacity. This will provide a water depth of 3 feet and allow for 1 foot of freeboard.

The complete area to the west, south, and east of the proposed landfill cells is also within the berm system for the former land treatment area that has been cleaned and closed. The south and west ponds are also within the berm system. Therefore, the south and west ponds have an added containment system and any storm water from areas within the berm system will naturally be contained on the facility. The facility will provide drainage and containment areas as needed to control nuisance water and to facilitate facility operations.

CHAPTER 4 –ACTION LEAKAGE RATE (ALR)

Utah Administrative Code R315-264-301(a) & (b)

The Action Leakage Rate (ALR) is defined as the maximum design flow rate that the leak detection system can convey, store, and remove without the fluid head on the bottom liner exceeding one foot. The ALR must include an adequate safety margin to allow for uncertainties in the design, (e.g., slope, hydraulic conductivity or geonet transmissivity, thickness of drainage material), construction, operation, and location of the leak detection system, waste and leachate characteristics, likelihood and amounts of other sources of liquids in the leak detection system, and proposed response actions, e.g., the action leakage rate must consider decreases in the flow capacity of the system over time resulting from siltation and clogging, rib layover, and creep of synthetic components of the system, overburden pressures, etc. Calculations associated with the ALR are included in Appendix D.

Evaluations associated with the ALR were completed using average day and peak day leakage rates generated by EPA's HELP model for a good liner installation, 1 hole per acre, and 1 defect per acre. The leakage rates generated by the HELP model were multiplied by the maximum area contributing flow to the valley side of the sumps (89,237 ft^2) to obtain the volume of leakage per day to the sumps. The following tables provide the estimated leachate rates.

TABLE 4.1 - AVERAGE DAY LEAKAGE RATE TO THE VALLEY SIDE OF THE SUMPS

Waste height	Average Annual Leakage Rates			Average Day Leakage Rates	
(ft)	(in)	(cf/sump)	(gal/sump)	(cf/sump)	(gal/sump)
0	0.44601	3,316.7	24,809	9.3	70
10	0.46899	3,487.6	26,087	9.6	72
30	0.35085	2,609.1	19,516	7.1	54
48	0.24477	1,820.2	13,615	5.0	37

TABLE 4.2 – PEAK DAY LEAKAGE RATE TO THE VALLEY SIDE OF THE SUMPS

Waste height	Peak Day Leakage Rates		
(ft)	(in)	(cf/sump)	(gal/sump)
0	0.00818	60.8	455
10	0.00309	23.0	172
30	0.00274	20.4	152
48	0.00268	19.9	149

CONVEYANCE SYSTEM

The conveyance system will consist of a double-sided geocomposite with a minimum transmissivity of 2.7 x 10^{-4} m^2/sec. Details of the design of the conveyance system are provided in Chapter 2 – Landfill Cells Design under the heading "Lining System, Leachate Collection and Removal System, and Leak Detection System Designs."

Areas that control the capacity of the conveyance system are in the valley formed by the two planar surface of the floor in each sump drainage area and the point of entry for leachate collected within the valley into the leak detection (bottom) sumps. The highest concentration of flow within the conveyance system will be in the valley of the system where the flow enters the sumps.

The top perimeter of the 3 horizontal to 1 vertical slopes into the sumps is about 40 feet square and the sump has a depth of 2.0 feet from the floor of the bottom sumps to the top lining system forming the floor of the top (leachate collection) sumps. The side of the sumps where the valley of the floor intersects the sumps is about 40 feet long (about 20 feet on each side of the valley).

A double-sided geocomposite with and transmissivity of 2.7 x 10^{-4} m^2/sec will require 18 feet of geocomposite width to convey the estimated peak day flowrate of 455 gallons per day from the floor valley into the sump. Only 3 feet of geocomposite width will be required to convey the average day flow of 72 gallons per minute into the sumps.

The entire perimeter around the top of the sumps is 118 feet in length. Double-sided geocomposite with a transmissivity of 2.7 x 10^{-4} m^2/sec and a gradient of 1.4% has a capacity to convey 26.2 gallons per day per foot of width (gpd/ft). Multiplying the 26.2 gpd/ft by 118 feet of length around the sumps, and then applying a safety factor of 4.5 to the geocomposite, results in a maximum flow capacity from the leak detection system into the sumps of 688 gpd. Since the maximum sump drainage area for Landfill Cells 8-13 is 3.64 acres, the maximum flow capacity of the system is 189 gpd/acre. This is greater than the projected leakage rate from the HELP model of 455 gallons per day for each sump. The system, therefore, has sufficient capacity to convey the projected leakage rate into the bottom sumps.

BOTTOM (LEAK DETECTION) SUMP

A stage capacity calculation for the bottom (leak detection) sump where leachate that enters the leak detection system will be collected for removal is provided in Appendix D. The sump will be filled with ¾-inch rounded washed rock with a total leachate storage capacity within the pore spaces in the rock of 2,318 gallons (assuming a porosity of 32%). Therefore, the sumps have sufficient capacity to collect and store over 3 days of the maximum system capacity into the sumps equivalent to 688 gpd/sump. The leachate storage capacity of the leak detection system is also sufficient to store 5 days of the projected peak day leakage rate (455 gpd/sump) and 32 days of the average day leakage rate (72 gpd/sump) from the HELP model.

However, since the pumps will not operate automatically and Clean Harbors' proposed plan for inspection and pumping the LDCRS is once each week, the limiting ALR for the system becomes the weekly operational inspection and pumping plan. If the ALR is exceeded at an inspection and pumping frequency of once each week, the frequency will be increased and the ALR adjusted accordingly until other limiting factors for the ALR are reached (system capacity, storage capacity, etc.). The maximum ALR for the proposed weekly inspection and pumping plan, must be based on the amount of leachate which will fill the void volume within the sump and the drainage layer (i.e. geocomposite) while maintaining a maximum liquid depth of one foot on the bottom liner system outside the sumps. The allowable ALR for each sump for a 7 day inspection and pumping frequency is 91 gallons per acre per day (2,318 gallons divided by 7 days divided by 3.64 acres tributary to a sump). Should Clean Harbors decide to increase the inspection and pumping of the secondary sumps, the ALR value can increase according to the values provided in Table 4.3. The values provided in Table 4.3 are based on the largest sump drainage area of 3.64 acres in Landfill Cells 9-13.

TABLE 4.3 – ALR BASED ON LEAK DETECTION SUMP CAPACITY AND INSPECTION AND PUMPING FREQUENCY

Frequency for Inspecting and Pumping From the Sumps	Resulting Action Leakage Rate (ALR) (sump drainage area = 3.64 acres)	
(days)	(gpd/acre)	(gpd/sump)
4	189	688
5	152	555
6	127	463
7	108	396

After an inspection and pumping frequency of four days, the system capacity controls the ALR at 688 gpd/sump or 189 gpd/acre. Therefore, the highest ALR that can be allowed for Landfill Cells 8-13 is 189 gpd/acre.

This analysis has been conducted in accordance with the suggestions and requirements of the January 29, 1992 Federal Register "Part II Environmental Protection Agency 40 CFR Parts 260, 264, 265, 270, and 271 Liners and Leak Detection Systems for Hazardous Waste Land Disposal Units; Final Rule" (Federal Register, Volume 57, No. 19, Wednesday, January 29, 1992, Rules and Regulations).

LEACHATE REMOVAL (PUMP)

Leachate collected in the sump from the leak detection system will be removed by a pump that will be lowered into the sump through a 18-inch diameter HDPE leachate withdrawal pipe (DR-17). The pump will have the capacity to pump a minimum of 3 gpm of leachate into a mobile containment vessel. A minimum pump capacity of 3 gpm will provide removal of 720 gallons of leachate within a 4-hour time period. A leachate removal rate of 720 gpd per sump drainage area results in an ALR of 198 gpd/acre. This meets the maximum ALR of 189 gpd/acre corresponding to the system capacity. A pumping rate exceeding 3 gpm and a corresponding pumping time that is shorter than 4 hours is acceptable.

CONTROLLING ALR AND RESPONSES FOR EXCEEDANCE

At a 7-day frequency for inspection and pumping, the ALR is 108 gpd/acre (396 gpd per sump drainage area). The action plan when this ALR is exceeded is to increase the frequency of inspection and pumping to 6 days.

At a 6-day frequency for inspection and pumping, the ALR is 127 gpd/acre (463 gpd per sump drainage area). The action plan when this ALR is exceeded is to increase the frequency of inspection and pumping to 5 days.

At a 5-day frequency for inspection and pumping, the ALR is 152 gpd/acre (555 gpd per sump drainage area). The action plan when this ALR is exceeded is to increase the frequency of inspection and pumping to 4 days.

At a 4-day frequency for inspection and pumping, the ALR is 189 gpd/acre (688 gpd per sump drainage area). The action plan for exceeding this ALR is to repair the leaks, grade the waste and install an additional liner system in that sump drainage area, closure of that area of the landfill, or prepare another written plan that is acceptable to the Director of the Utah Division of Waste Management and Radiation Control.

CHAPTER 5 –CLOSURE PLAN AND POST CLOSURE CARE

Utah Administrative Code R315-310 for closure requirements
Utah Administrative Code R315-117 through 120, and 310 (as applicable) for Post Closure Care Requirements

CLOSURE PLAN

Final closures for landfills must be designed and constructed to provide long-term minimization of migration of liquids through the closed landfill, function with minimal maintenance, promote drainage and minimize erosion or abrasion of the cover, accommodate settling and subsidence so that the cover's integrity is maintained, and have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present. Landfill Cells 8-13 are generally designed with identical closures including slopes and closure system components and are designed to meet the regulatory requirements presented.

General Description

Landfill Cells 8 has a closure cap footprint of 649,108 square feet (about 14.90 acres) and Landfill Cells 9-13 each have a footprint of 656,710 square feet (about 15.08 acres) providing a cover system over the entire waste placement area of the landfill cells. Each closure cap is designed with 3 horizontal to 1 vertical slopes around their perimeter (around the perimeter of the waste mound) that extend from the top of the cell embankments to a height of between about 23 feet (at each of the four corners) and about 26 feet (at the middle of each side) above the top of the cell embankments. The top surface of the closure caps consist of 5 percent slopes that extend from the top of the 3 horizontal to 1 vertical slopes to the center of the closure caps. The highest point at the center of the closure caps is designed to be about 39 feet above the top of the cell embankments.

A 2-foot high berm is provided around the top of the 3 horizontal to 1 vertical perimeter slopes. The berm is designed to contain precipitation runoff from the 5 percent slopes and direct the runoff to the four corners where the runoff is conveyed off the closure caps, through storm drainage pipes, to the ground surface at the bottom of the cell embankments.

The closure cover system above the 3 horizontal to 1 vertical slopes consists of compacted clay cap material (with a minimum thickness of 2 feet) meeting a permeability of 1 x 10^{-7} cm/sec., a 60-mil HDPE geomembrane, a 2-foot thick compacted clay protective layer, and 6 inches of stone mulch. The closure cover system above the top 5 percent slopes consists of a 6-inch soil layer, a geosynthetic clay liner (GCL), a 60-mil geomembrane, a double-sided geocomposite, 2 feet of protective soil cover, and 6 inches of stone mulch.

Minimize Migration of Liquids

Migration of liquids through the closure cap is minimized by providing slopes and storm drainage systems designed to prevent ponding of storm water on the surface and on the lining system of the closure cap.

Minimize Maintenance

Closure cap maintenance needs arise most commonly as a result of settlement, erosion, breaching or blocking of storm drainage facilities, and localized areas where soils and erosion protection materials are displaced.

Settlement. Settlement projections are included in the geotechnical investigation report completed by AGEC and provided in Appendix B. Compression of the foundation soils below the landfill cells (from the weight of overburden materials) is the primary cause of settlement. Settlement occurs from placement of soil materials to construct the cells, as waste material is placed, and as the closure caps are constructed.

Differential settlement is a result of differences in the overburden load from one point to another, and the timing of material placement causing the overburden loads. Since the height of overburden will occur at the center of the cells which will also be the area where the last of the waste within the cells will be placed, the greatest differential settlement will be from the outside edges to the center of the closure caps. Results of the differential settlement discussed will be flattening of the closure cap slopes, but also some shortening of the slope lengths.

The 5% slopes designed for the top surface of the Landfill Cells 8-13 closure caps are similar to the slopes used on previous closures at the Grassy Mountain Facility. According to the geotechnical report, 50 percent of the settlement occurs in about 7 years, 70 percent occurs in about 15 years, and 90 percent occurs in about 22 years. Landfill Cells 1, 2, and 3 were closed in 1990 and 1991 (about 26 years ago) and Landfill Cells 4 and 5 were closed in 2011 (about 6 years ago). Landfill Cells 1-5 closure caps were constructed with 5% top slopes and all closure caps continue to provide positive drainage of surface runoff to the storm drainage pipes that convey the storm water to the ground surface at the bottom of the landfill cell embankments. The closure caps for Landfill Cells 8-13 should also continue to provide positive drainage of storm water from the top of the closure caps.

There is a potential of developing tension and, therefore, stresses in the lining materials as a result of differential settlement. However, tensile forces will only develop if slope length increase across the closure caps. Longer slopes will only develop if the lower areas of the slopes settle more than the higher areas of the slopes. As previously stated, the upper areas of the slopes are projected to settle more than the lower areas of the slopes which will result in a shortening of slope lengths. No stresses are, therefore, expected to develop in the lining system as a result of differential settlement.

Erosion. Erosion protection is provided in the design by placing 6 inches of stone mulch over all closure cap surfaces that will be exposed to precipitation. Stone mulch has successfully been used at the Grassy Mountain Facility on previous landfill and landfill closure projects.

Breaching or Blocking of Storm Drainage Facilities. A 60-mil geomembrane is provided in the design on the inside slope of the berms around the perimeter of the top closure cap surfaces. The geomembrane is provided to protect the berms from saturating and from washing out during storm events.

Displacement of Soil and Erosion Protection Materials. Results from the geotechnical investigation report (provided in Appendix B) shows the closure caps have acceptable safety factors against displacement of soil materials. The erosion protection calculations in

Appendix G show that the stone mulch is only required to be 1 inch thick to protect the soils from erosion. The design provides for 6 inches of stone mulch which is 2 inches more than has been placed on the surfaces of previous landfill cells and their closure caps. Based on observations made, the stone mulch has shown to be adequate for erosion protection on the previous landfill cells and their closures.

Promote Drainage and Minimize Erosion

Drainage from the top surface of the closure caps is provided by the sloping surfaces and perimeter berms that direct surface runoff to storm drainage piping located at the four corners of each closure cap. The storm drainage piping will then convey the runoff water to the ground surface at the bottom of the landfill cell embankments. Drainage of storm water from the 3 horizontal to 1 vertical slopes around the perimeter of the closure caps will flow down the slopes and combine with runoff from the top of the landfill cell embankments. Runoff water on top of embankments that are between cells will be directed to manhole inlets to a storm drain piping system. Water will then be conveyed through the storm drain pipes to the bottom of the landfill cell embankments and will discharge through energy dissipation structures (baffled outlets) to the existing ground surface and to storm drainage channels.

A double-sided geocomposite is designed immediately above the closure lining system to intercept storm water that percolates through the stone mulch and protective soil cover and convey the water to the outer edges of the closure caps. Water conveyed through the double-sided geocomposite will discharge into the stone mulch on the 3 horizontal to 1 vertical slopes around the outer perimeter of the closure caps, and then to the outside bottom toe of the closure caps. Storm water that discharges from the closure caps to the top of embankments common with other cells will be conveyed to a storm drainage system that will convey storm water to the ground surface at the bottom of the landfill cell embankments. Storm water that discharges to the top of embankments uncommon with other cells will flow to the outside embankment slopes and down the slopes to the ground surface at the bottom of the landfill cell embankment.

Erosion protection for all surfaces of the closure caps is provided by a 6-inch thick layer of stone mulch. Calculations provided in Appendix G show that the required thickness of stone mulch less than 1 inch to reduce soil loss to 1 ton per acre per year. Due to the difficulty in placing a 1-inch thickness of stone mulch, and to provide greater erosion protection, 6 inches of stone mulch will be placed. Observations of previously constructed closure caps also demonstrate the effectiveness of the stone mulch material in providing for erosion protection.

Accommodate Settling and Subsidence

The effects of settlement and subsidence on the closure cap are accommodated by the slopes designed for the closure caps. As presented previously, slopes after settlement and subsidence will continue to provide positive drainage of storm water. Slope lengths will also be shortened instead of lengthened from settlement and subsidence which will prevent inducing stresses in the lining system.

Permeability

The closure caps are provided with a composite lining system consisting of a 60-mil geomembrane and an underlying geosynthetic clay liner (GCL) over the entire top area of the closure caps (areas with 5% slopes) and a 60-mil HDPE geomembrane above the compacted clay liner on the 3 horizontal to 1 vertical perimeter slopes. Therefore, the liner system meets the permeability requirements of the bottom liner system for the landfill cells.

Closure Certification

Certification of closure will be provided upon closure of each landfill cell. The certification will state that closure has been completed in accordance with the specifications and the approved closure plan, and it will be signed by the owner or operator and a qualified Professional Engineer. This certification will be submitted to the Director of the Division of Waste Management and Radiation Control within 60 days after completion of construction for the final closure of each landfill cell.

POST-CLOSURE CARE

Post-closure care will consist of the groundwater monitoring, inspection and maintenance of the closure caps and landfill cells, monitoring and pumping leachate from the leachate collection and removal systems, and monitoring and pumping leachate from the leak detection systems. Post-closure activities will occur based on the scheduled frequencies established in the facility's closure plan included with the facility's permit. The post-closure care period will be for a period of thirty (30) years from the time certification has been obtained that the cell has been closed in accordance with the closure plan.

COSTS OF CLOSURE AND POST-CLOSURE CARE

The calculations of closure and post-closure care cost are provided in Appendix H.

Closure

The cost for closure of each of the landfill cells is estimated to be about $3,340,000 for a total closure cost for all of the proposed landfill cells of $20,040,000. This includes the complete closure cap and storm drainage specific to each closure cap (storm drainage from the top of the closure cap to the manholes at the top of the cell embankments). The cost of shared storm drainage facilities was averaged between the six cells.

Post-Closure Care

The post-closure care cost is based on 30 years of groundwater monitoring, inspection and maintenance of the closure caps and landfill cells, monitoring and pumping leachate from the leachate collection and removal systems, and monitoring and pumping leachate from the leak detection systems on the scheduled frequencies established in the facility's closure plan. The cost also includes removal and abandonment of the groundwater monitoring wells at the end of the thirty-year post-closure care period. The estimated cost for post-closure care is $391,200 for each of the landfill cells for a total estimated post-closure care cost for all the proposed landfill cells of $2,347,200.

CHAPTER 6 –CONSTRUCTION QUALITY ASSURANCE

Utah Administrative Code R315-264-19

SURFACE IMPOUNDMENT CONSTRUCTION

The Construction Quality Assurance Plan for Surface Impoundments, Landfills, and Landfill Closures (CQA Plan) provided in Attachment VI-2, Appendix A of the Grassy Mountain Facility Permit covers all aspects that will be required for construction of the landfill cells and their closure caps. The closure plan will be amended and revised, as needed, to meet changing regulatory requirements, future designs, and future facility needs. All amendments and revisions must receive approval by the Director of the Utah Division of Water Management and Radiation Control prior to implementation.

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APPENDIX A

Landfill Cells 8 - 13
Permit Drawings

CleanHarbors®
ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY

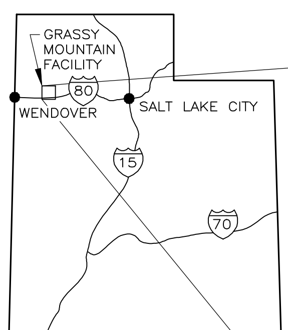
LANDFILL CELLS 8-13

PERMIT DRAWINGS

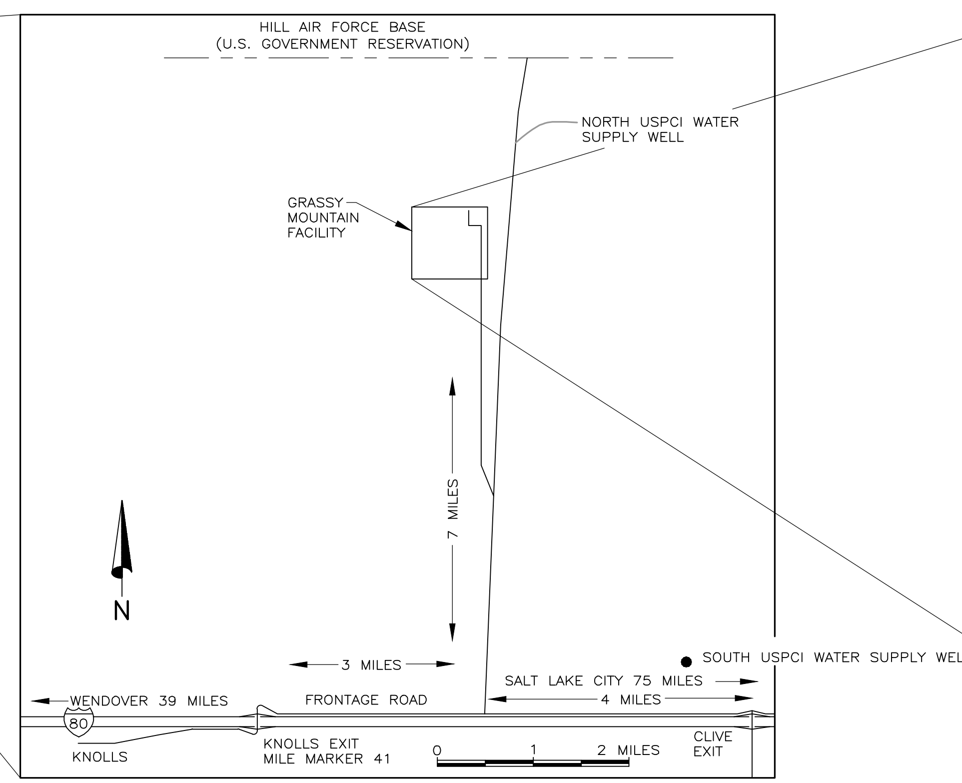
AUGUST 2018 REV 1

FACILITY LOCATION
KNOLLS, UTAH
Phone: (435) 884-8900

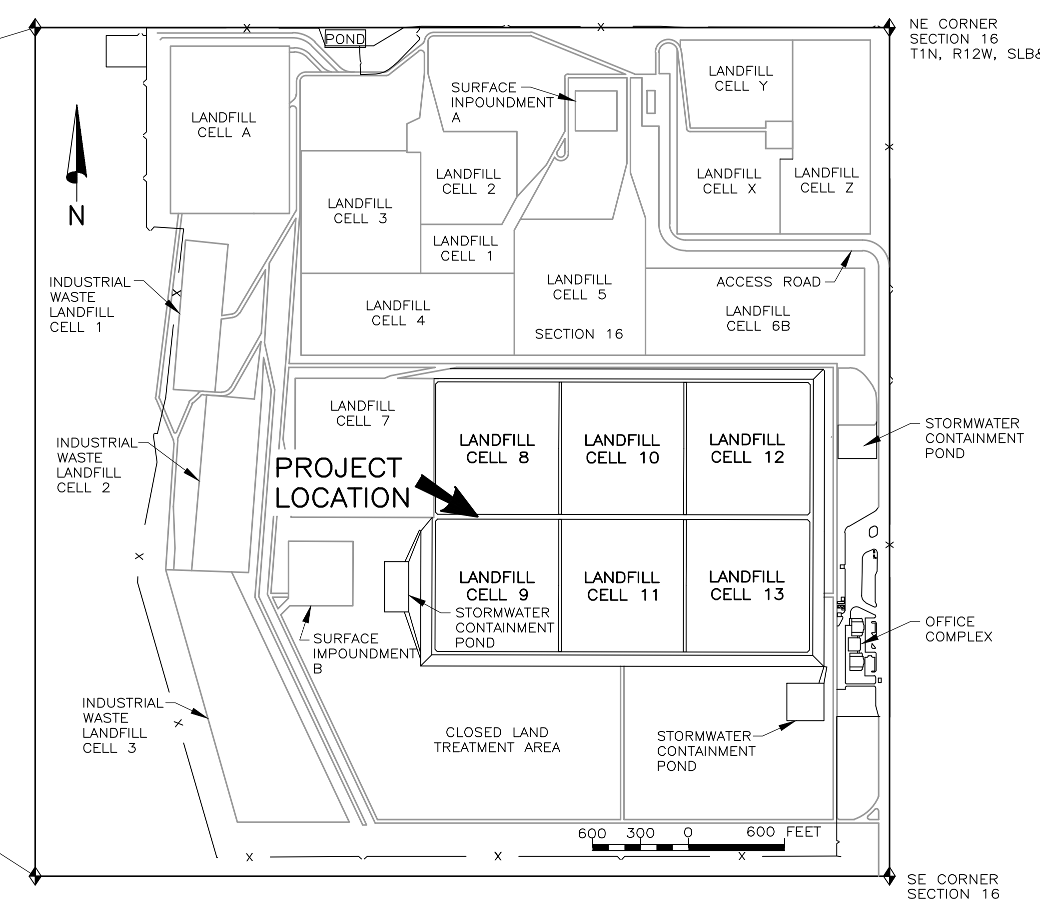
REGIONAL HEADQUARTERS
42 LONGWATER DRIVE
NORWELL, MA 02061
Phone: (781) 792-5000



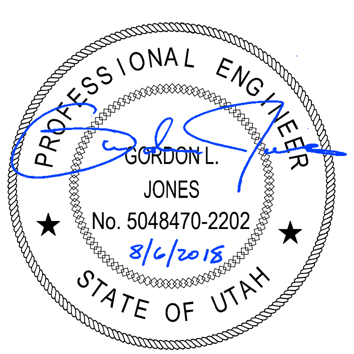
STATE OF UTAH



VICINITY MAP



PROJECT LOCATION



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FILE DATE: 8.6.2018 10:40:54 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

CONSULTANTS ENGINEERS
Salt Lake City Utah

7/95

GENERAL NOTES

1. COORDINATES AND ELEVATIONS PROVIDED ARE BASED ON SITE SPECIFIC COORDINATE SYSTEM AND DATUM CONTROL ESTABLISHED AT THE EAST ¼ CORNER OF SECTION 16, T1N, R2W (N 0.00, E 0.00, EL. 4238.66). ELEVATIONS ARE APPROXIMATE FEET ABOVE MEAN SEA LEVEL.
2. ALL ELEVATIONS PROVIDED ARE BASED ON ORIGINAL EMBANKMENT DESIGN AND CONSTRUCTION ELEVATIONS. ADJUSTMENTS SHALL BE MADE PRIOR TO CLOSURE TO ACCOUNT FOR SETTLEMENT.

LINING SYSTEM SUBGRADES & SOIL FILL

1. ALL SURFACES PROVIDING SUBGRADES FOR LINING SYSTEMS SHALL BE PROOF ROLLED FOR SOFT AND/OR YIELDING SURFACES. SOFT AND/OR YIELDING SURFACES SHALL BE COMPACTED TO PROVIDE A FIRM SUBGRADE FOR LINING SYSTEMS.
2. ALL CLAY LINER MATERIALS SHALL BE COMPACTED TO 95% OF ASTM D-698 AT A MOISTURE CONTENT TYPICALLY BETWEEN MINUS 2% AND PLUS 4% OF OPTIMUM. ALL CLAY LINER SHALL MEET THE REQUIRED PERMEABILITY OF 1 X 10-7 CM/SEC.
3. THE SUB-GRADE FOR THE GEOSYNTHETIC MATERIALS SHALL BE FREE OF PROTRUDING ROCKS AND DEBRIS THAT MAY POTENTIALLY CAUSE DAMAGE TO THE GEOSYNTHETIC MATERIALS. THE SUBGRADE SHALL ALSO BE ROLLED WITH A SMOOTH DRUM ROLLER TO LEAVE THE SURFACE SMOOTH.
4. ALL FILL MATERIALS REQUIRING COMPACTION SHALL BE COMPACTED TO 95% OF ASTM D-698.
5. PIPE BACKFILL AND ANCHOR TRENCH BACKFILL SHALL BE COMPACTED TO 90% OF ASTM D-698.
6. COMPACTED CLAY SOIL ON ABOVE THE HDPE LINER THE PERIMETER SLOPES OF THE CLOSURE CAP HAS NO PERMEABILITY REQUIREMENT AND SHALL BE COMPACTED TO 95% OF ASDM D-698.

GENERAL GEOSYNTHETICS

1. MANUFACTURER'S CERTIFICATIONS SHALL BE PROVIDED FOR ALL RAW AND MANUFACTURED MATERIALS. CERTIFICATIONS SHALL BE IN ACCORDANCE WITH THE MANUFACTURER'S MATERIAL SPECIFICATIONS AND PROJECT CQA PLAN CRITERIA AND SHALL INCLUDE ALL TEST DATA FOR MATERIALS DELIVERED AND MEET THE MINIMUM TEST FREQUENCIES DESIGNATED IN THE MANUFACTURER'S QUALITY ASSURANCE MANUALS AND SPECIFICATIONS AND THE CQA PLAN.
2. ALL GEOSYNTHETIC MATERIALS SHALL BE LOADED, TRANSPORTED, OFF-LOADED, STORED, AND HANDLED IN ACCORDANCE WITH MANUFACTURER RECOMMENDATIONS.
3. AT A MINIMUM, ALL GEOSYNTHETIC MATERIALS SHALL BE INSTALLED IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS AND INSTALLATION GUIDES AND IN ACCORDANCE WITH THE PROJECT SPECIFICATIONS AND CQA PLAN.

GEOSYNTHETIC CLAY LINER (GCL)

1. ALL GCL MATERIALS SHALL BE NEEDLE PUNCH REINFORCED.
2. GCL SHALL BE DEPLOYED WITH NON-WOVEN GEOTEXTILE SIDE UP.
3. ALL DEPLOYED GCL MATERIALS SHALL BE COVERED BY THE END OF EACH WORK DAY TO MINIMIZE EVAPORATION OF MOISTURE WITHIN THE BENTONITE AND TO PROTECT THE GCL MATERIALS FROM EXPOSURE TO RAINY AND SNOWY WEATHER.
4. SEAMING SHALL BE IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS, THE PROJECT SPECIFICATIONS, AND THE CQA PLAN.
5. GCL MATERIALS THAT ARE MANUFACTURED TO PROVIDE SELF-SEALING SEAMS AND DO NOT REQUIRE A BENTONITE BEAD SHALL RECEIVE A BENTONITE BEAD WHEN THE SELF-SEALING DESIGN IS COMPROMISED ON THE ENDS OF PANELS AND WHERE THE SELF-SEALING GROOVE (IF PART OF THE SELF-SEALING DESIGN) HAS BEEN REMOVED FROM PARTIAL WIDTH ROLLS.
6. GCL MATERIALS THAT HAVE NOT BEEN MANUFACTURED TO PROVIDE SELF SEALING SEAMS SHALL RECEIVE A BENTONITE BEAD TO PROVIDE THE SEAM SEAL IN ACCORDANCE WITH MANUFACTURER'S RECOMMENDATIONS.

GEOMEMBRANE LINER

1. ALL GEOMEMBRANE MATERIALS SHALL BE TEXTURED ON BOTH SIDES.
2. NO GEOMEMBRANE MATERIALS SHALL BE DEPLOYED IN SUB-FREEZING TEMPERATURES UNLESS APPROVED BY OWNER WITH AN APPROVED COLD WEATHER DEPLOYMENT PLAN.
3. NO SEAMING SHALL BE ALLOWED IN SUB-FREEZING TEMPERATURES WITHOUT OWNER APPROVAL OF AN APPROPRIATE COLD WEATHER SEAMING PLAN AND ONLY AFTER PROPER DEMONSTRATION OF PRE-QUALIFIED TEST SEAMS.
4. FIELD TESTING AND QUALITY CONTROL SHALL FOLLOW, AT A MINIMUM, THE REQUIREMENTS PROVIDED IN THE MOST RECENT VERSION MANUFACTURERS INSTALLATION PROCEDURES, AND/OR THE PROJECT SPECIFICATIONS AND CQA PLAN, WHICHEVER IS MOST STRINGENT.

GEOCOMPOSITE

1. GEOCOMPOSITE SHALL HAVE A TRANSMISSIVITY OF 6.0 X 10^{-4} M^2/SEC.
2. DOUBLE-SIDED GEOCOMPOSITE SHALL CONSIST OF 8 OZ. NON-WOVEN GEOTEXTILE BONDED TO BOTH SIDES OF GEONET.
3. GEOMEMBRANE MATERIALS SHALL BE CLEANED OF DIRT AND DEBRIS PRIOR TO DEPLOYMENT OF GEOCOMPOSITE.
4. GEOCOMPOSITE SHALL BE FASTENED OR SECURED WITH HEAT BONDING, SEWING OR OTHER APPROVED METHOD, BETWEEN GEOTEXTILE FABRIC MATERIALS ALONG THE ENTIRE LENGTH OF THE SEAMS.
5. OVERLAPS OF SEAMS SHALL BE, AT A MINIMUM, THE DIMENSIONS RECOMMENDED BY THE MANUFACTURES.

PROTECTIVE SOIL COVER

1. CARE SHALL BE EXERCISED DURING PLACEMENT OF PROTECTIVE SOIL COVER MATERIALS. A MINIMUM COVER THICKNESS AS DESIGNATED IN THE PROJECT SPECIFICATIONS AND/OR THE CQA PLAN SHALL BE MAINTAINED AT ALL TIMES BETWEEN THE TIRES OR TRACKS OF EQUIPMENT AND THE UNDERLYING GEOSYNTHETIC MATERIALS.
2. NO SHARP, ABRUPT, OR PIVOTING TURNS SHALL BE ALLOWED BY EQUIPMENT USED ABOVE THE PROTECTIVE SOIL COVER THAT MAY CAUSE SOIL DISPLACEMENT AND DAMAGE TO UNDERLYING GEOSYNTHETIC MATERIALS.
3. ANY WAVES OR WRINKLES THAT BEGIN TO FORM SHALL BE TRAPPED BY PLACING SUFFICIENT PROTECTIVE SOIL COVER BEYOND THE WAVES OR WRINKLES TO HOLD THEM IN PLACE AND KEEP THEM FROM COMBINING INTO LARGER WAVES OR WRINKLES.

GRAVEL ARMOR PLATING (STONE MULCH)

1. STONE MULCH SHALL BE PLACED TO A MINIMUM THICKNESS OF 6 INCHES ON ALL SURFACES.
2. MINIMUM D50 SIZE FOR STONE MULCH SHALL BE 1.0 INCH AND SHALL BE VERIFIED BY TESTING.

STORM DRAINAGE SYSTEM

1. ALL MANHOLES, LIDS, AND RINGS AND COVERS SHALL BE RATED FOR H20 LOADINGS.
2. RINGS AND COVERS AND GRATED COVERS SHALL PROVIDE A MINIMUM OPENING FOR ACCESS OF 30 INCHES.
3. GRATED COVERS SHALL BE USED FOR EMBANKMENT DRAINAGE DITCH INLETS
4. A 10' X 10' CONCRETE APRON SHALL BE PLACED AROUND ALL MANHOLE COVERS.
5. RIPRAP APRON AT CONCRETE BAFFLED OUTLETS TO EXTEND A MINIMUM DISTANCE OF 5 FEET, TO BE 12 INCHES THICK, AND HAVE A D_{50}=3".

CLOSURE GCL COMPATIBILITY

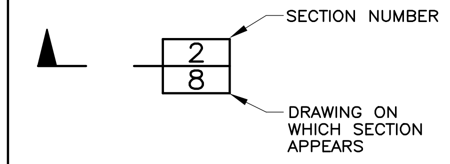
1. BORROW SOURCES FOR 6-INCH THICK SAND LAYER AND 2-FOOT THICK PROTECTIVE SOIL COVER LAYERS TO BE APPROVED BASED ON THE FOLLOWING TESTS USING LIQUID OBTAINED FROM SYNTHETIC LEACHATE PRODUCED USING BORROW SOURCE SOILS: 1. SCREENING CLAY PORTION OF GEOSYNTHETIC CLAY LINER FOR CHEMICAL COMPATIBILITY TO LIQUIDS (ASTM D6141); TESTING RESULTS SHALL DEMONSTRATE THAT THE MAXIMUM HYDRAULIC CONDUCTIVITY OF GCL SHALL MEET AN EQUIVALENCY OF A 2-FOOT THICK COMPACTED CLAY LINER WITH A HYDRAULIC CONDUCTIVITY OF 1X10-7 CM/SEC.

INDEX OF DRAWINGS

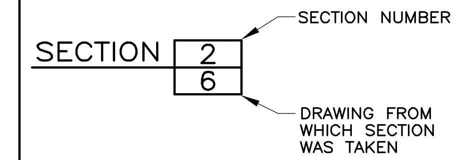
SECTION & DETAIL IDENTIFICATION

SECTION IDENTIFICATION

SECTION CUT ON DRAWING NO. 6 AND SHOWN ON DRAWING NO. 8
ON DRAWING NO. 6 THIS SECTION IS REFERENCED AS:

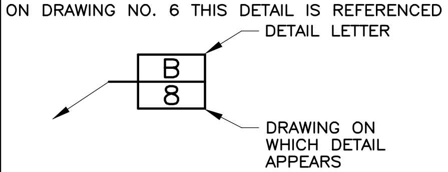


ON DRAWING NO. 8, THIS SECTION IS IDENTIFIED AS:

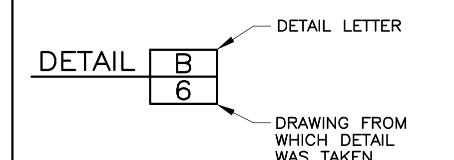


DETAIL IDENTIFICATION

DETAIL CALL-OUT ON DRAWING NO. 6 AND SHOWN ON DRAWING NO. 8
ON DRAWING NO. 6 THIS DETAIL IS REFERENCED AS:



ON DRAWING NO. 8, THIS DETAIL IS IDENTIFIED AS:



NOTES:
1. IF SECTION AND DETAILS ARE SHOWN ON THE SAME DRAWING AS SECTION CUTS AND SECTION OR DETAIL CALL-OUTS DRAWING NUMBER IS REPLACED BY A LINE.
2. DETAIL LETTERS "I" AND "O" NOT USED.

TABLE OF ABBREVIATIONS

●	=	AIR GAS VENT	MH	=	MANHOLE
@	=	AT	MIN.	=	MINIMUM
AVG.	=	AVERAGE	N.	=	NORTH
C.C.	=	CENTER TO CENTER	N.T.S.	=	NOT TO SCALE
℄	=	CENTER LINE	O.C.	=	ON CENTER
CLR.	=	CLEARANCE	PC	=	POINT OF CURVE
CONT.	=	CONTINUOUS	PI	=	POINT OF INTERSECTION
CPP	=	CORRUGATED POLYETHYLENE PIPE	PSI	=	POUND PER SQUARE INCH
DIA.	=	DIAMETER	PT	=	POINT OF TANGENT
DWG	=	DRAWING	REINF	=	REINFORCEMENT
E.	=	EAST	SDR	=	STANDARD DIMENSIONAL RATIO
EF	=	EACH FACE	SF	=	SQUARE FEET
EL.	=	ELEVATION	SQ.	=	SQUARE
E.W.	=	EACH WAY	STA.	=	STATION
FL	=	FLOW LINE	TL	=	TOP OF LINER
HDPE	=	HIGH DENSITY POLYETHYLENE	T.O.C.	=	TOP OF CONCRETE
ID	=	INSIDE DIAMETER	TYP.	=	TYPICAL
MAX.	=	MAXIMUM	UBC	=	UNTREATED BASE COURSE

FILE NAME: PROJECTS\064 - CLEAN HARBORS\85.100 - CELL 8 AND 9 DESIGN\CAD\WORKING\G-2 INDEX SHEET__R1.DWG (CAH)
FILE DATE: 8.6.2018 11:01:16

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER No. 5048470-2202 GORDON L. JONES 8/6/2018 STATE OF UTAH
PROJECT ENGINEER

DESIGNED	KCS	3				
DRAFTED	CAH	2				
CHECKED	GLJ	1				
DATE	AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

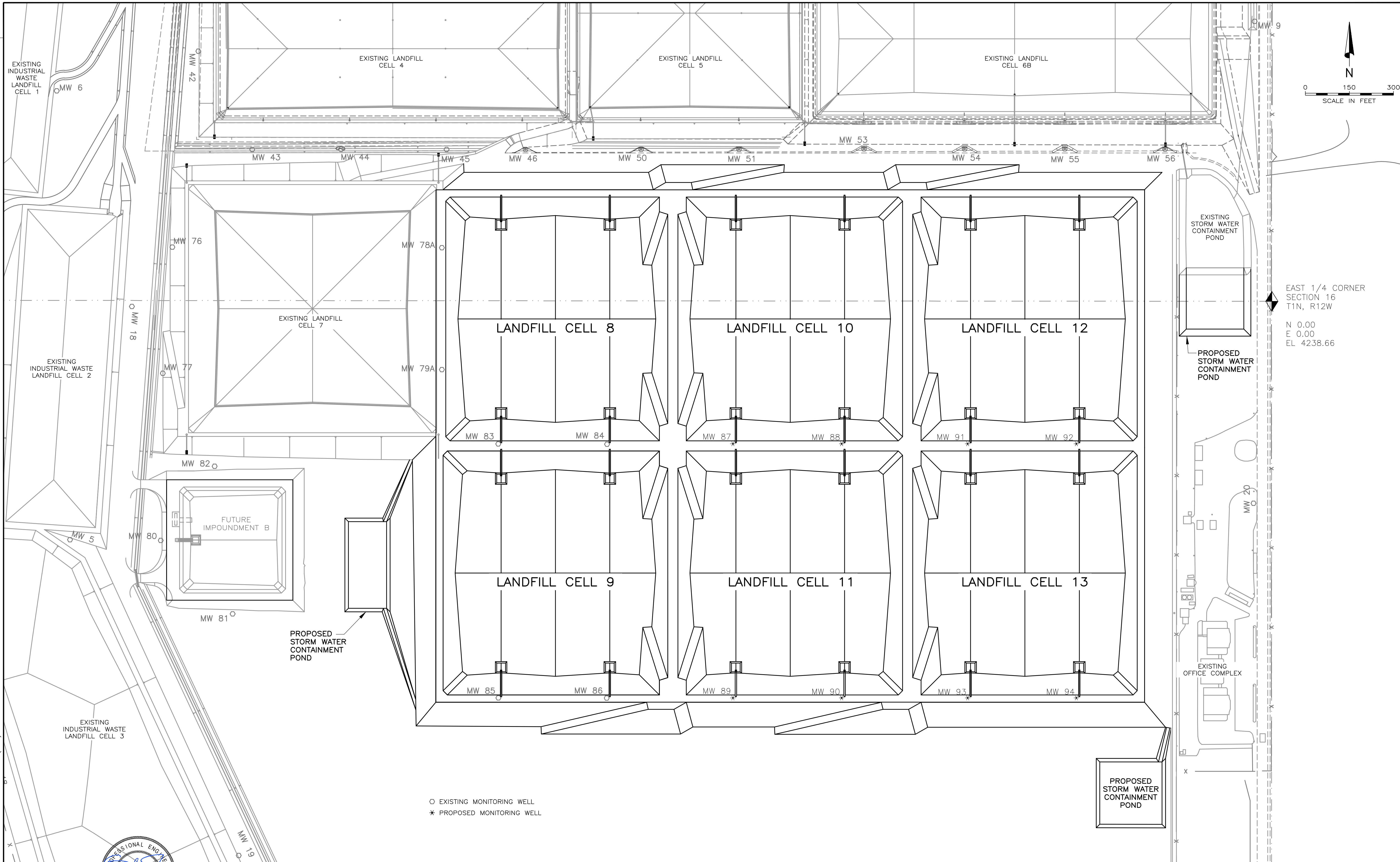
SCALE: NOT TO SCALE

CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8-13
GENERAL
GENERAL NOTES, LEGEND & INDEX OF DRAWINGS

SHEET G-2
064.85.100

10/07



FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\G-3 OVERALL SITE PLAN__R1.DWG
FILE DATE: 8.6.2018 11:02:53 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE NOT TO SCALE

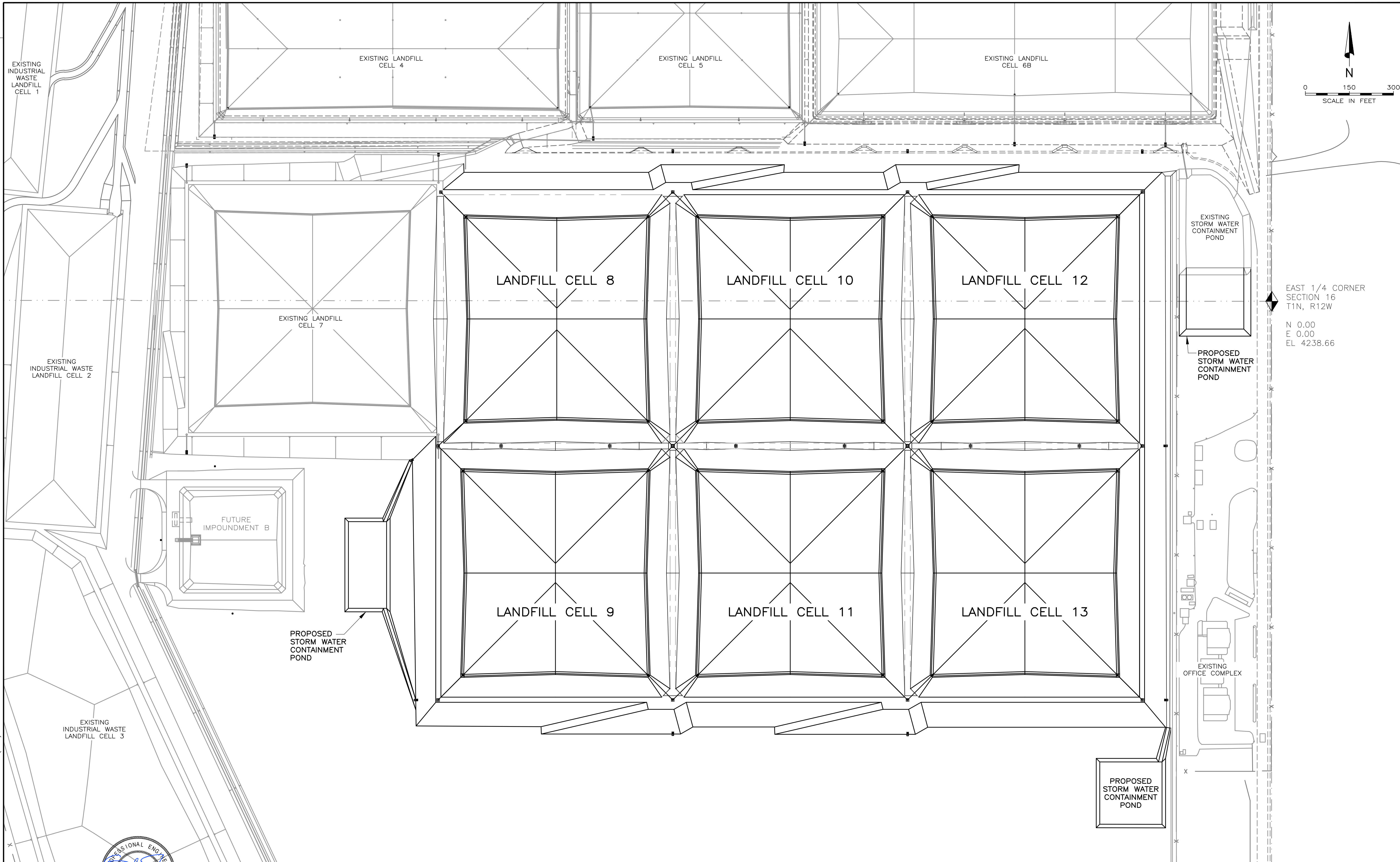
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13
GENERAL
OVERALL FLOOR PLAN

SHEET G–3

064.85.100

10/07



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FILE DATE: 8.6.2018 11:03:57 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3			
DRAFTED CAH	2			
CHECKED GLJ	1			
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

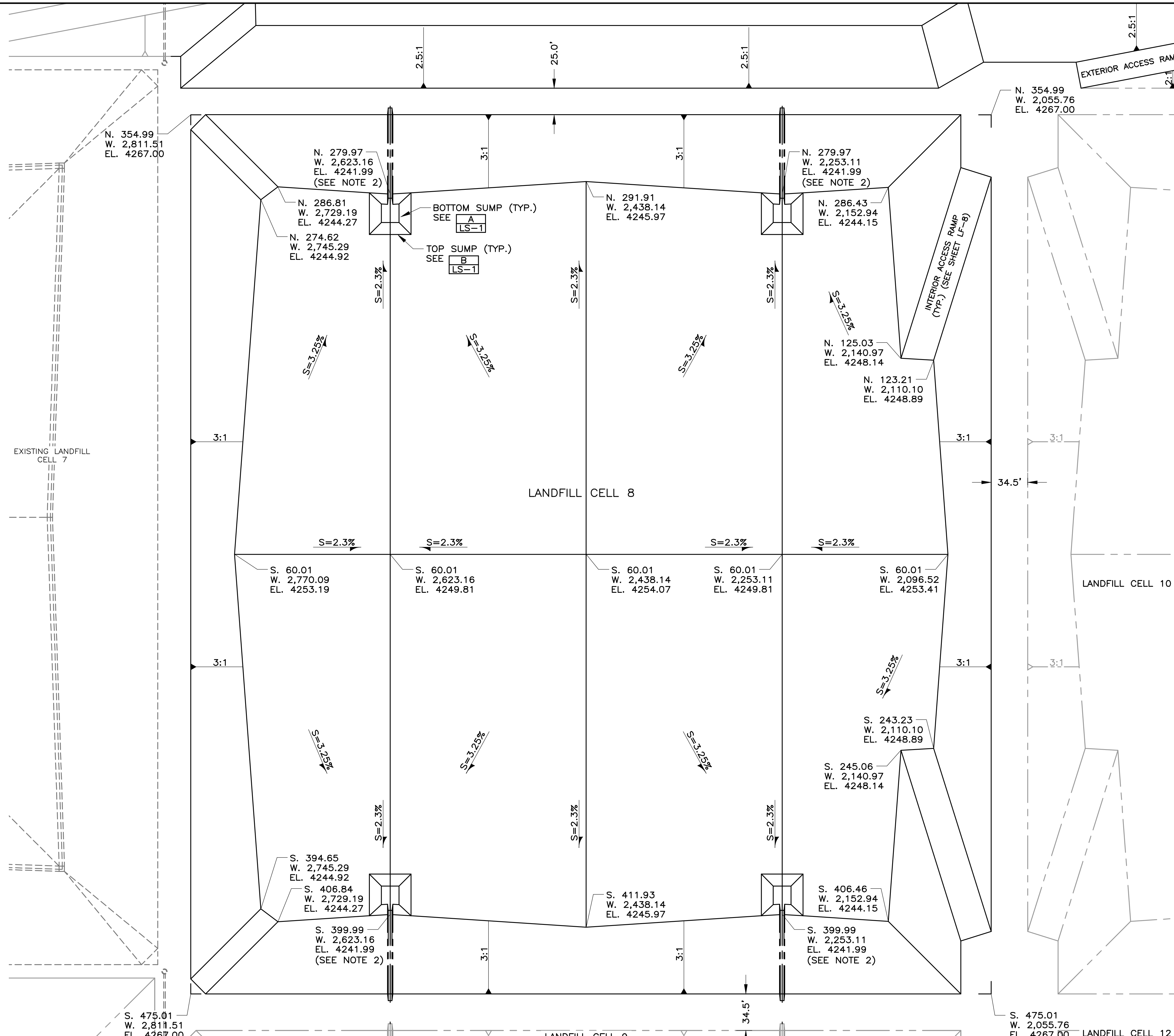
SCALE: NOT TO SCALE

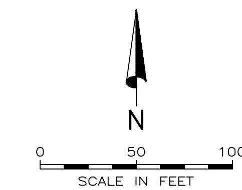
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13
GENERAL
OVERALL CLOSURE PLAN

SHEET G–4
064.85.100

10/07





NOTES:

1. COORDINATES & ELEVATIONS ARE TOP OF COMPACTED CLAY LINER.
2. SUMP REFERENCE POINT SEE SHEET LS-1 FOR SUMP PLAN.
3. ALL LINES SHOWING THE INSIDE OF LANDFILL CELLS ARE DEPICTING TOP OF CLAY SURFACE.

FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\LF-1 CELL 8 PLAN VIEW_R1.DWG
FILE DATE: 8.6.2018 11:32:47 (CAH)

HANSEN ALLEN & LUCE inc ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE: NOT TO SCALE

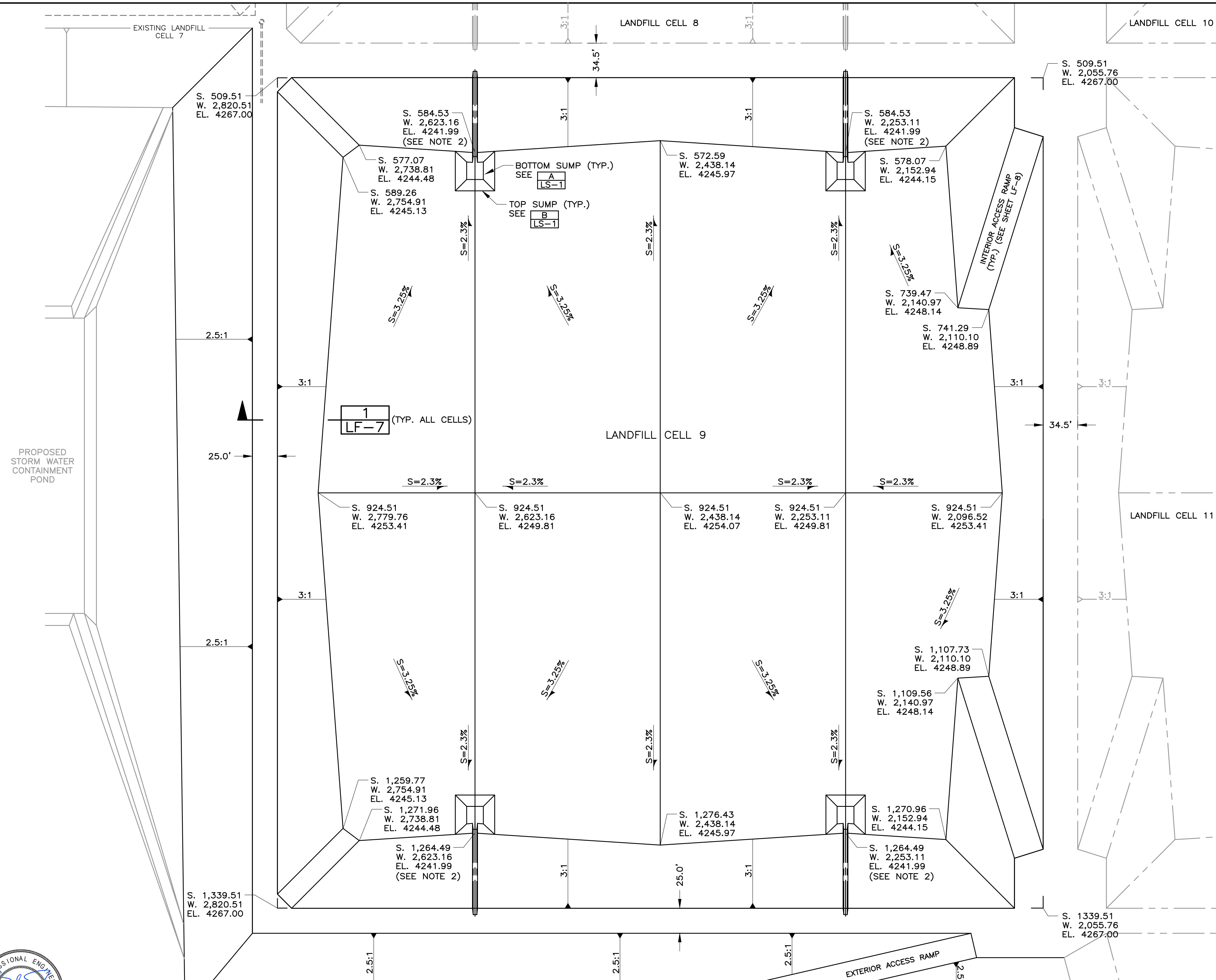
CleanHarbors ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13
LANDFILL
PLAN VIEW CELL 8

SHEET LF–1

064.85.100

10/07



N

0 50 100
SCALE IN FEET

NOTES:

1. COORDINATES & ELEVATIONS ARE TOP OF COMPACTED CLAY LINER.
2. SUMP REFERENCE POINT SEE SHEET LS-1 FOR SUMP PLAN.
3. ALL LINES SHOWING THE INSIDE OF LANDFILL CELLS ARE DEPICTING TOP OF CLAY SURFACE.

FILE NAME: PROJECTS\064 - CLEAN HARBORS\85.100 - CELL 8 AND 9 DESIGN\CAD\WORKING\LF-2 CELL 9 PLAN VIEW__R1.DWG
FILE DATE: 8.6.2018 11:33:47 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH
PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE: NOT TO SCALE

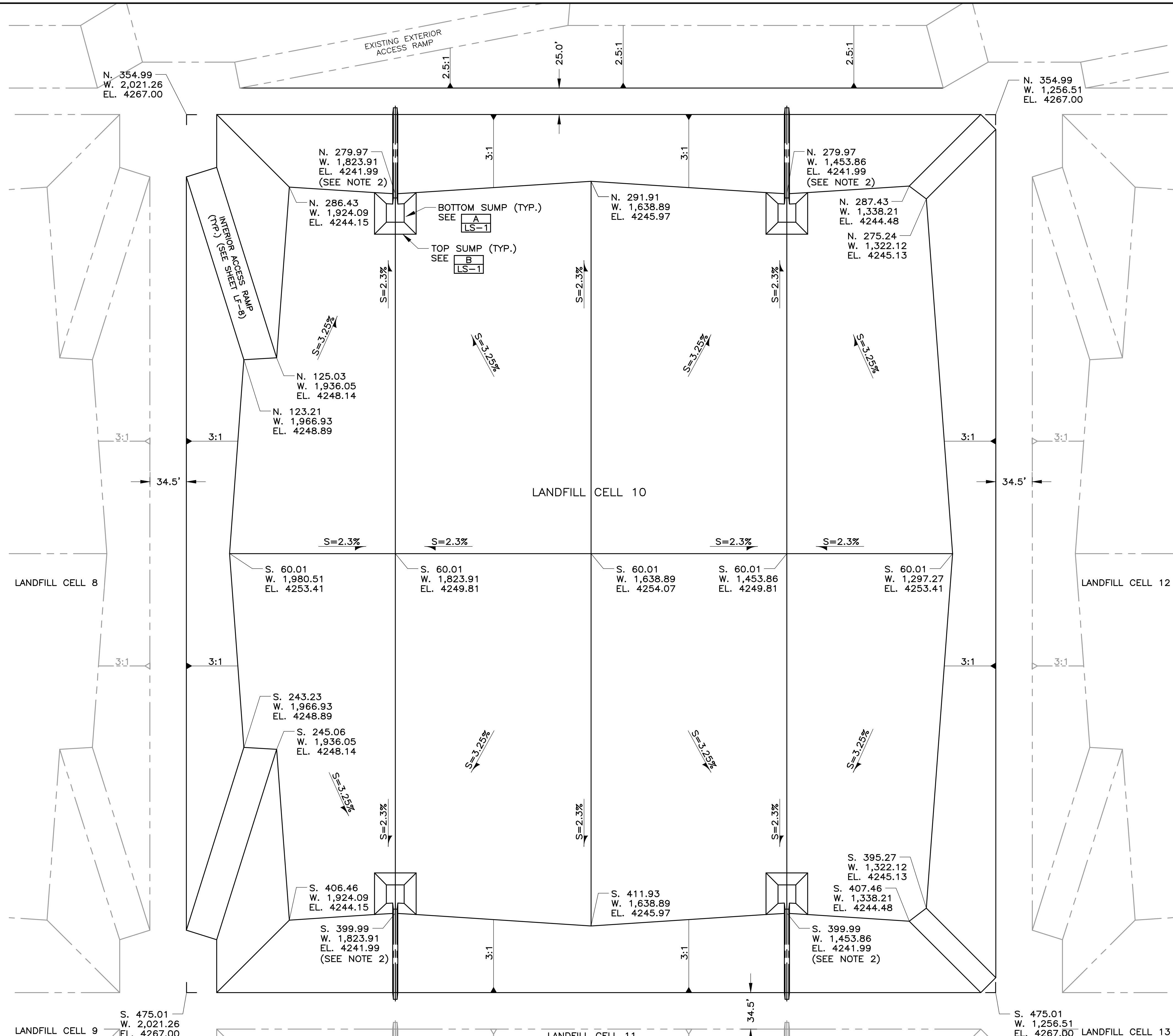
CleanHarbors ENVIRONMENTAL SERVICES, INC.

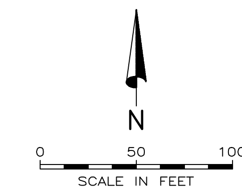
GRASSY MOUNTAIN FACILITY CELLS 8-13
LANDFILL
PLAN VIEW CELL 9

SHEET LF-2

064.85.100

10/07





NOTES:

1. COORDINATES & ELEVATIONS ARE TOP OF COMPACTED CLAY LINER.
2. SUMP REFERENCE POINT SEE SHEET LS-1 FOR SUMP PLAN.
3. ALL LINES SHOWING THE INSIDE OF LANDFILL CELLS ARE DEPICTING TOP OF CLAY SURFACE.

FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\LF-3 CELL 10 PLAN VIEW__R1.DWG
FILE DATE: 8.6.2018 11:34:33 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3					
DRAFTED CAH	2					
CHECKED GLJ	1					
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.	

SCALE: NOT TO SCALE

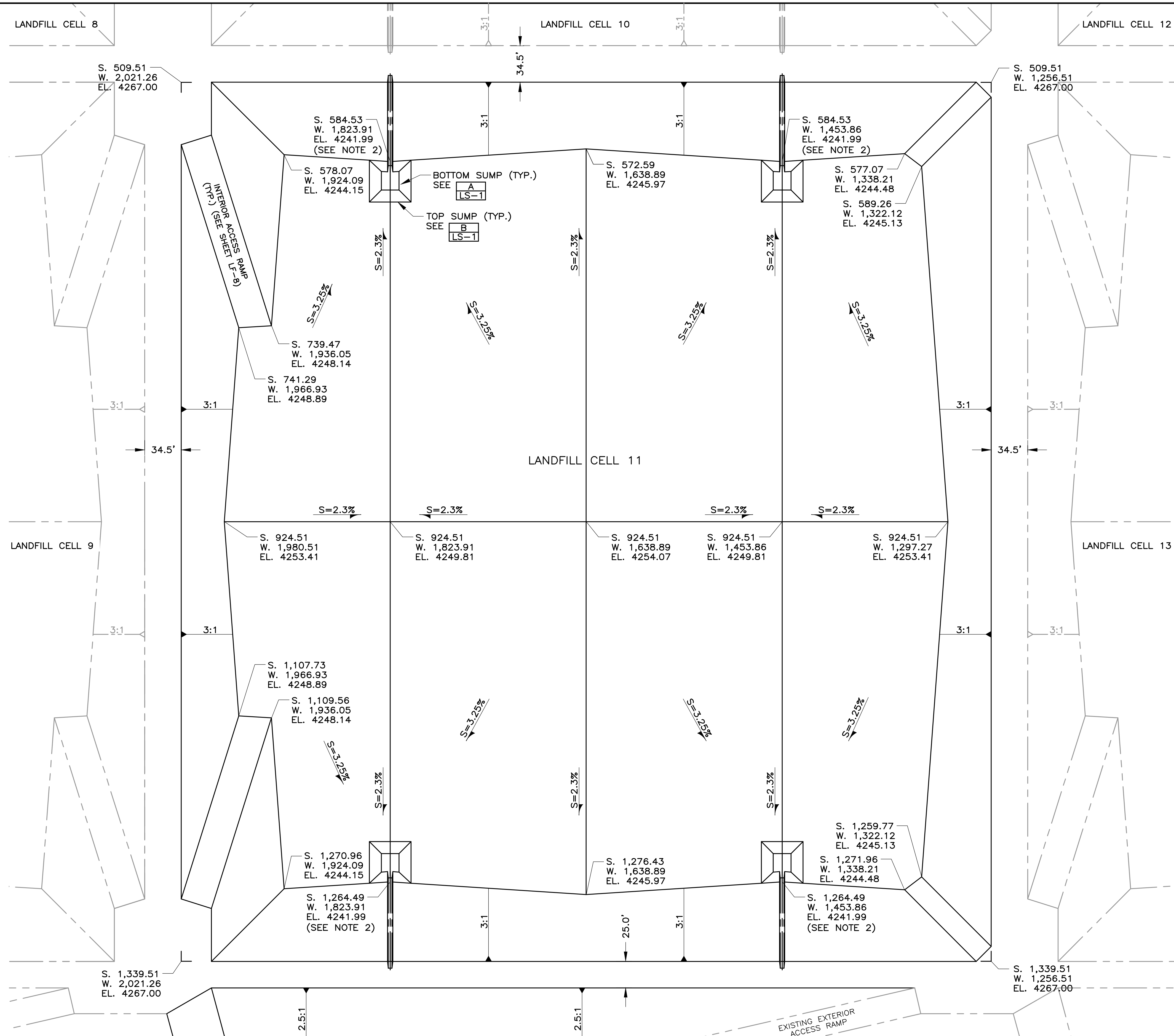
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

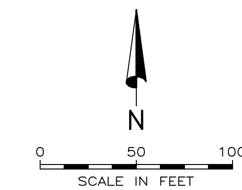
GRASSY MOUNTAIN FACILITY CELLS 8–13
LANDFILL
PLAN VIEW CELL 10

SHEET LF–3

064.85.100

10/07





NOTES:

1. COORDINATES & ELEVATIONS ARE TOP OF COMPACTED CLAY LINER.
2. SUMP REFERENCE POINT SEE SHEET LS-1 FOR SUMP PLAN.
3. ALL LINES SHOWING THE INSIDE OF LANDFILL CELLS ARE DEPICTING TOP OF CLAY SURFACE.

FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\LF-4 CELL 11 PLAN VIEW__R1.DWG
FILE DATE: 8.6.2018 11:35:36 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED	KCS	3				
DRAFTED	CAH	2				
CHECKED	GLJ	1				
DATE	AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE: NOT TO SCALE

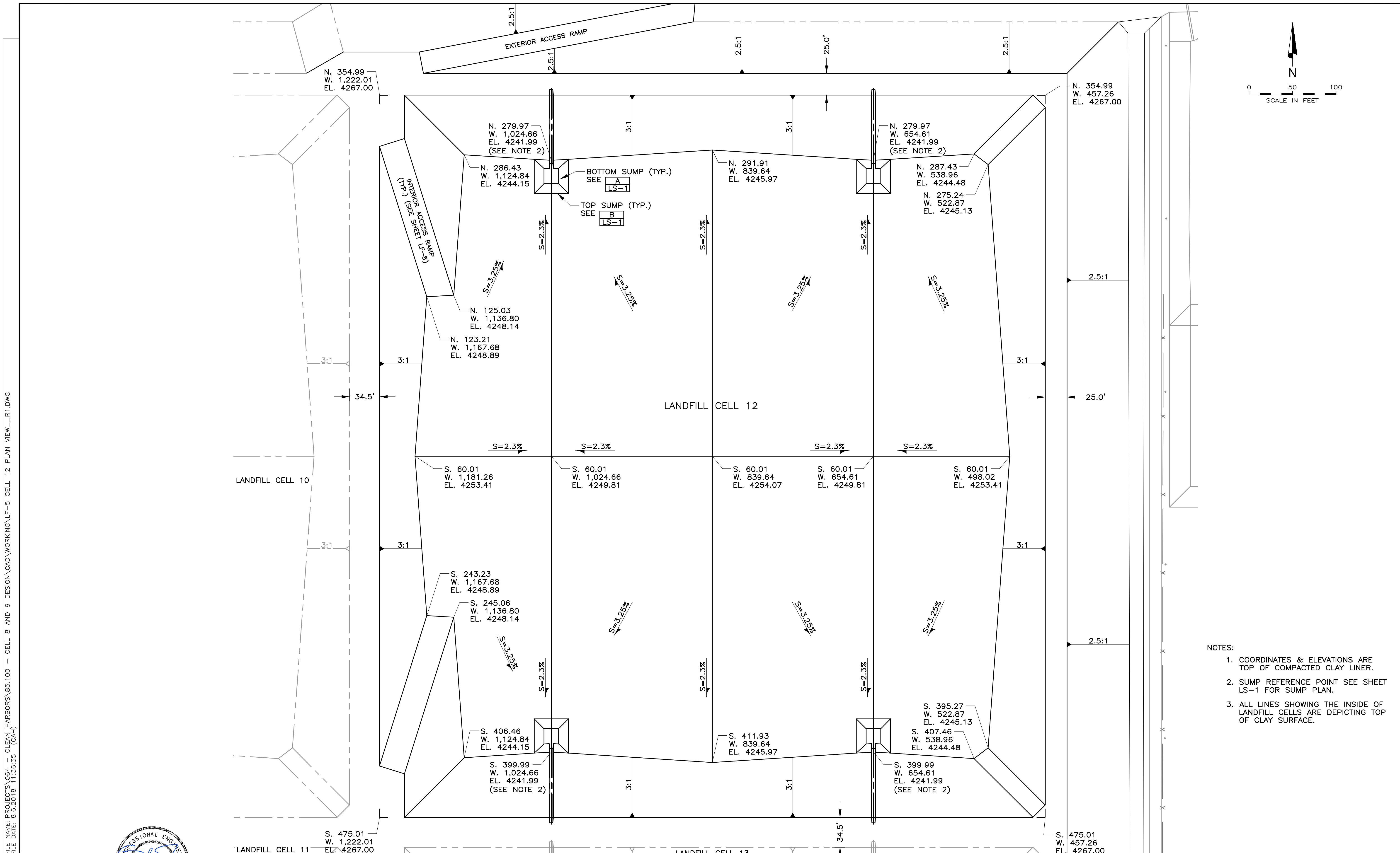
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13
LANDFILL
PLAN VIEW CELL 11

SHEET LF–4

064.85.100

10/07



NOTES:

1. COORDINATES & ELEVATIONS ARE TOP OF COMPACTED CLAY LINER.
2. SUMP REFERENCE POINT SEE SHEET LS–1 FOR SUMP PLAN.
3. ALL LINES SHOWING THE INSIDE OF LANDFILL CELLS ARE DEPICTING TOP OF CLAY SURFACE.

HANSEN ALLEN & LUCE INC ENGINEERS	PROFESSIONAL ENGINEER No. 5048470-2202 GORDON L. JONES 8/6/2018 STATE OF UTAH — PROJECT ENGINEER	DESIGNED KCS	3			
		DRAFTED CAH	2			
		CHECKED GLJ	1			
		DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY / APVD.

SCALE: NOT TO SCALE

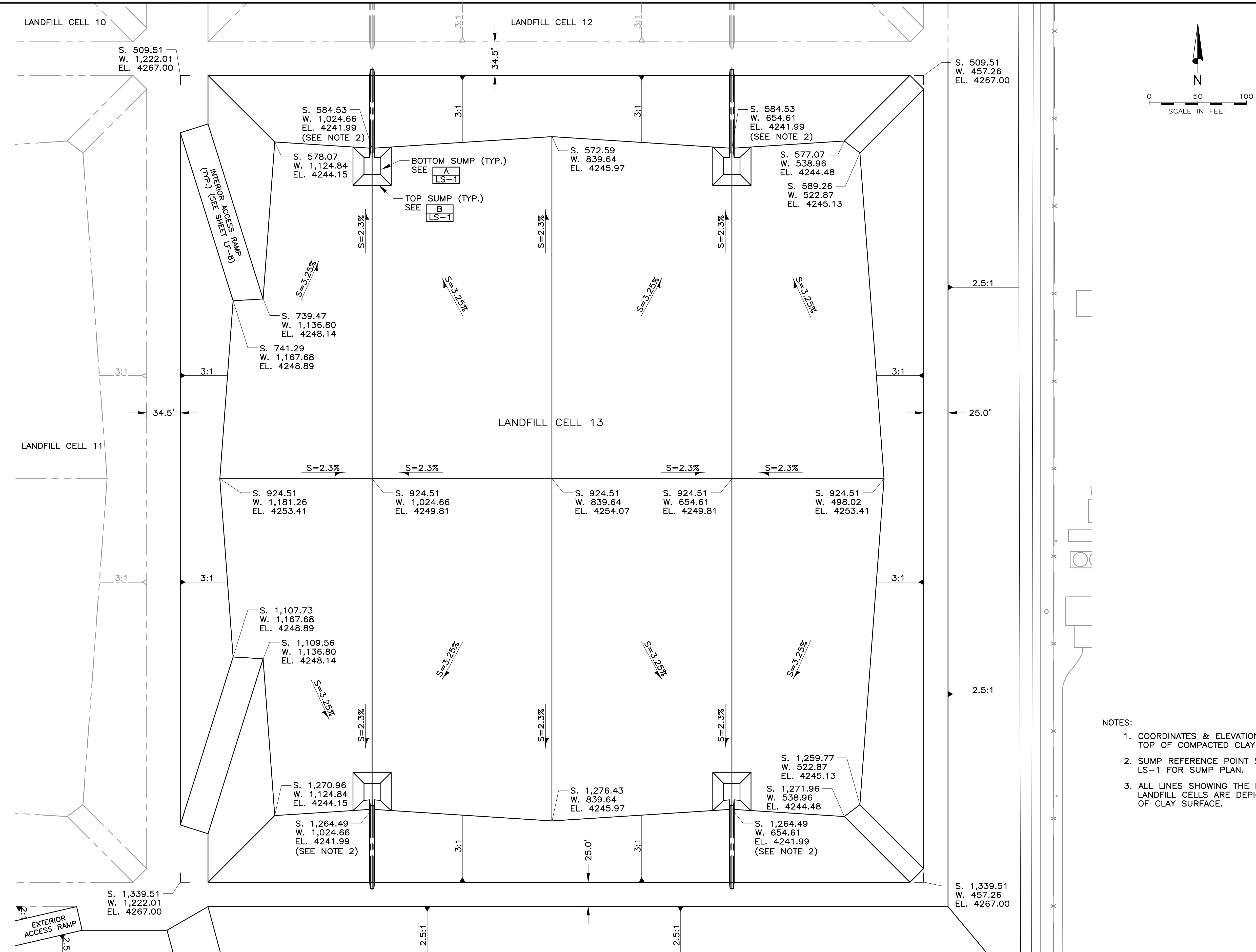
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13
LANDFILL
PLAN VIEW CELL 12

SHEET LF–5

064.85.100

10/07



NOTES:

1. COORDINATES & ELEVATIONS ARE TOP OF COMPACTED CLAY LINER.
2. SUMP REFERENCE POINT SEE SHEET LS-1 FOR SUMP PLAN.
3. ALL LINES SHOWING THE INSIDE OF LANDFILL CELLS ARE DEPICTING TOP OF CLAY SURFACE.

FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\LF-6 CELL 13 PLAN VIEW__R1.DWG
FILE DATE: 8.6.2018 11:37:47 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE NOT TO SCALE

CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13
LANDFILL
PLAN VIEW CELL 13

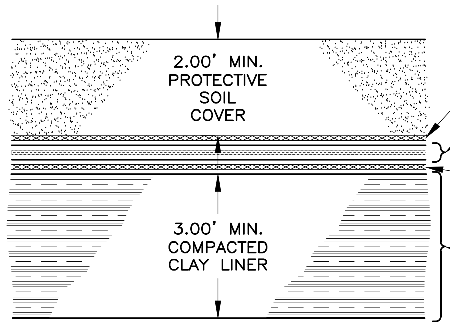
SHEET LF–6

064.85.100

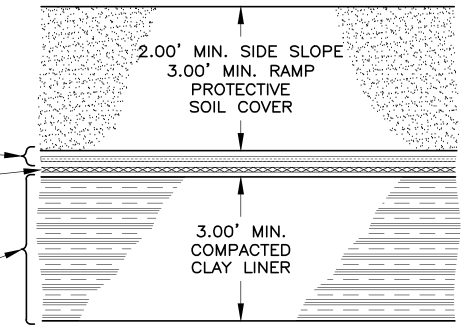
10/07

NOTES:

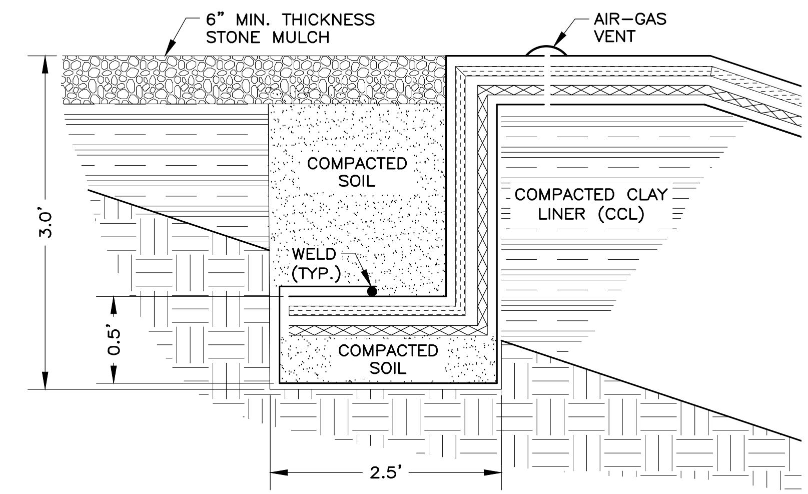
1. TOP LEACHATE COLLECTION SYSTEM CONSISTS OF DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   8 OZ. NON-WOVEN GEOTEXTILE / GEONET / 8 OZ. NON-WOVEN GEOTEXTILE } MIN. GEOCOMPOSITE TRANSMISSIVITY OF 6.0×10^{-4} M^2/SEC, TYP.)
2. TOP COMPOSITE LINER SYSTEM ON THE FLOOR AND TO A DISTANCE OF 10 FEET UP THE INTERIOR SLOPES CONSISTS OF:
   80-MIL HDPE GEOMEMBRANE (TEXTURED)
   GEOSYNTHETIC CLAY LINER (GCL)
   80-MIL HDPE GEOMEMBRANE (TEXTURED)
3. TOP LINER SYSTEM ON THE INTERIOR SIDESLOPES FROM A DISTANCE OF 10 FEET UP THE SLOPES TO THE ANCHOR TRENCH AT THE TOP OF THE SLOPES CONSISTS OF:
   80-MIL HDPE GEOMEMBRANE (TEXTURED)
   GEOSYNTHETIC CLAY LINER (GCL)
4. BOTTOM LEACHATE COLLECTION / LEAK DETECTION SYSTEM CONSISTS OF DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   8 OZ. NON-WOVEN GEOTEXTILE / GEONET / 8 OZ. NON-WOVEN GEOTEXTILE } MIN. GEOCOMPOSITE TRANSMISSIVITY OF 2.7×10^{-4} M^2/SEC, TYP.)
5. BOTTOM COMPOSITE LINER SYSTEM CONSISTS OF:
   60-MIL HDPE GEOMEMBRANE (TEXTURED)
   COMPACTED CLAY LINER (CCL)
6. PROTECTIVE SOIL COVER PLACED ON THE INTERIOR SLOPES SHALL ONLY BE PLACED TO A VERTICAL HEIGHT OF 10-FEET ABOVE THE LEVEL OF THE COVER ON WASTE MATERIALS IN THE LANDFILL CELLS.
7. PROTECTIVE SOIL COVER ON RAMP TO CONSIST OF 18 INCHES OF COMPACTED SOIL (95% ASTM D-698) AND 18 INCHES OF ROAD BASE AGGREGATE AS SHOWN ON SHEET LF-8.
8. PROTECTIVE SOIL COVER ON FLOOR EXTENDING A DISTANCE OF 20 FEET FROM THE BASE OF THE RAMP TO CONSIST OF 12 INCHES OF COMPACTED SOIL (95% ASTM D-698) AND 12 INCHES OF ROAD BASE AGGREGATE AS SHOWN ON SHEET LF-8.



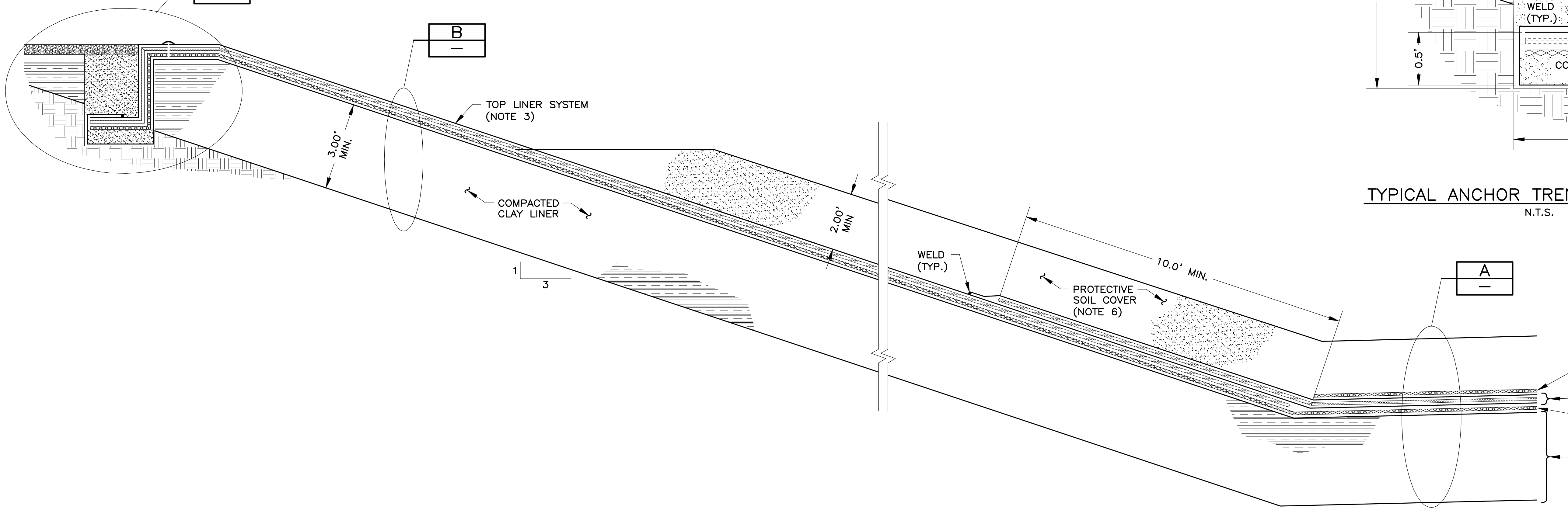
FLOOR LINER SYSTEM DETAIL A/– A/LF-8
N.T.S.



SIDESLOPE LINER SYSTEM DETAIL B/– B/LF-8
N.T.S.



TYPICAL ANCHOR TRENCH DETAIL C/–
N.T.S.



TYPICAL SIDESLOPE LINER SYSTEM DETAILS 1/LF-2
N.T.S.

FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\LF-7 DETAILS__R1.DWG
FILE DATE: 8.6.2018 11:38:39 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH
PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

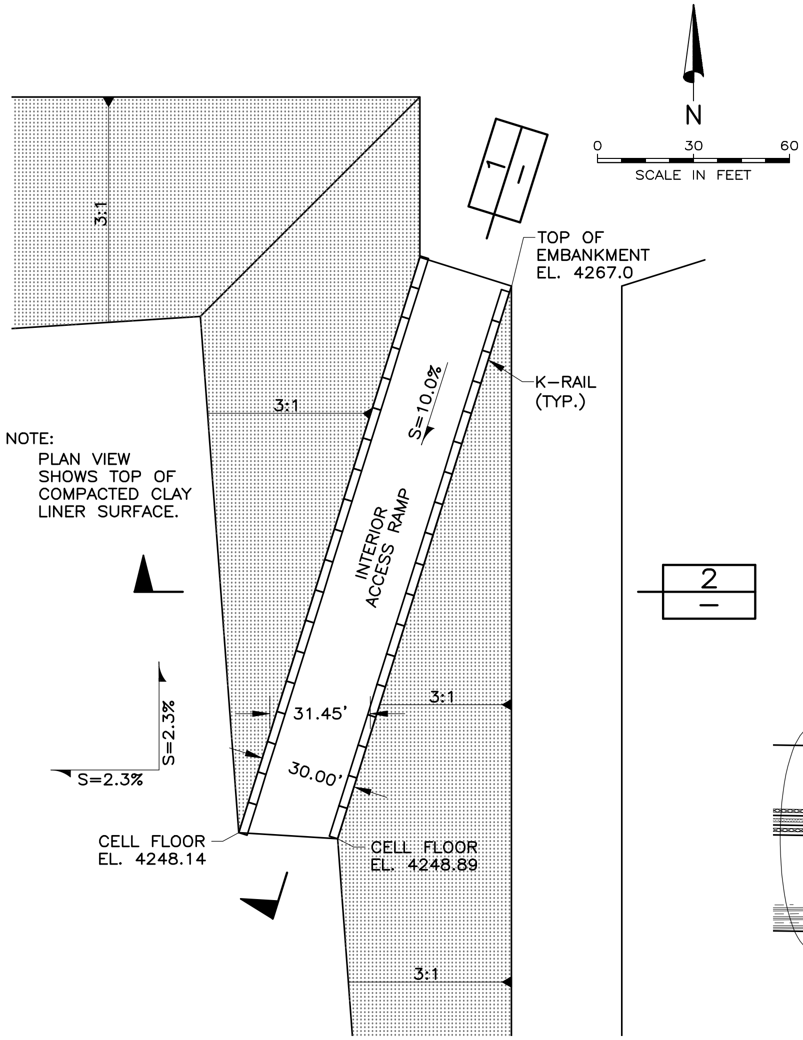
SCALE AS SHOWN

CleanHarbors ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8-13
LANDFILL
DETAILS

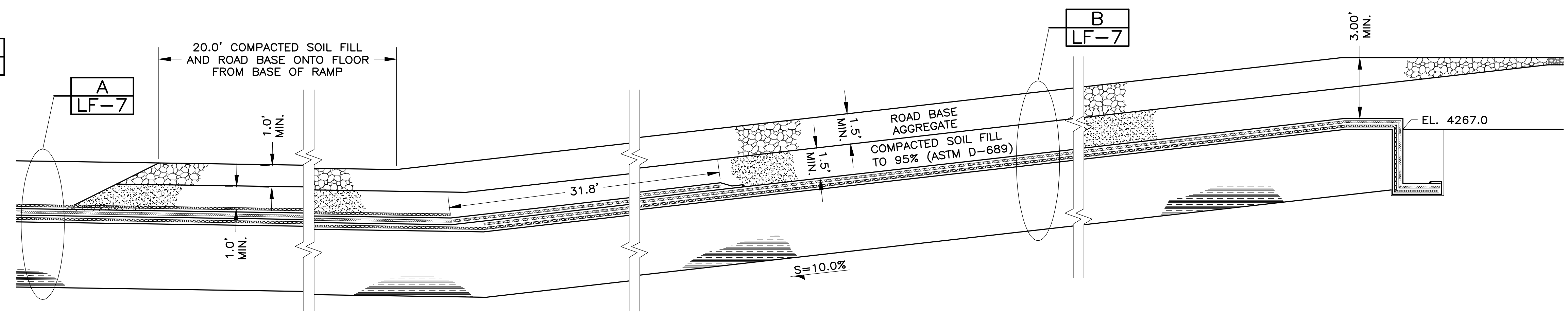
SHEET LF-7
064.85.100

10/07



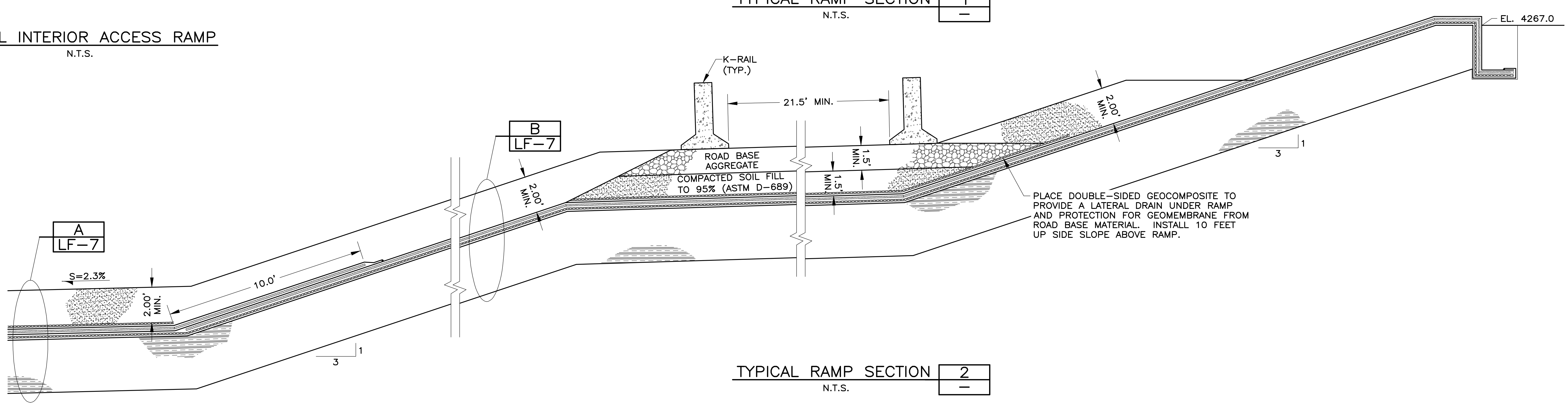
TYPICAL INTERIOR ACCESS RAMP

N.T.S.



TYPICAL RAMP SECTION 1 / —

N.T.S.



TYPICAL RAMP SECTION 2 / —

N.T.S.

FILE NAME: PROJECTS\064 - CLEAN HARBORS\85.100 - CELL 8 AND 9 DESIGN\CAD\WORKING\LF-8 RAMP SECTIONS__R1.DWG
FILE DATE: 8.6.2018 11:39:28 (CAH)

HANSEN ALLEN & LUCE inc ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE: AS SHOWN

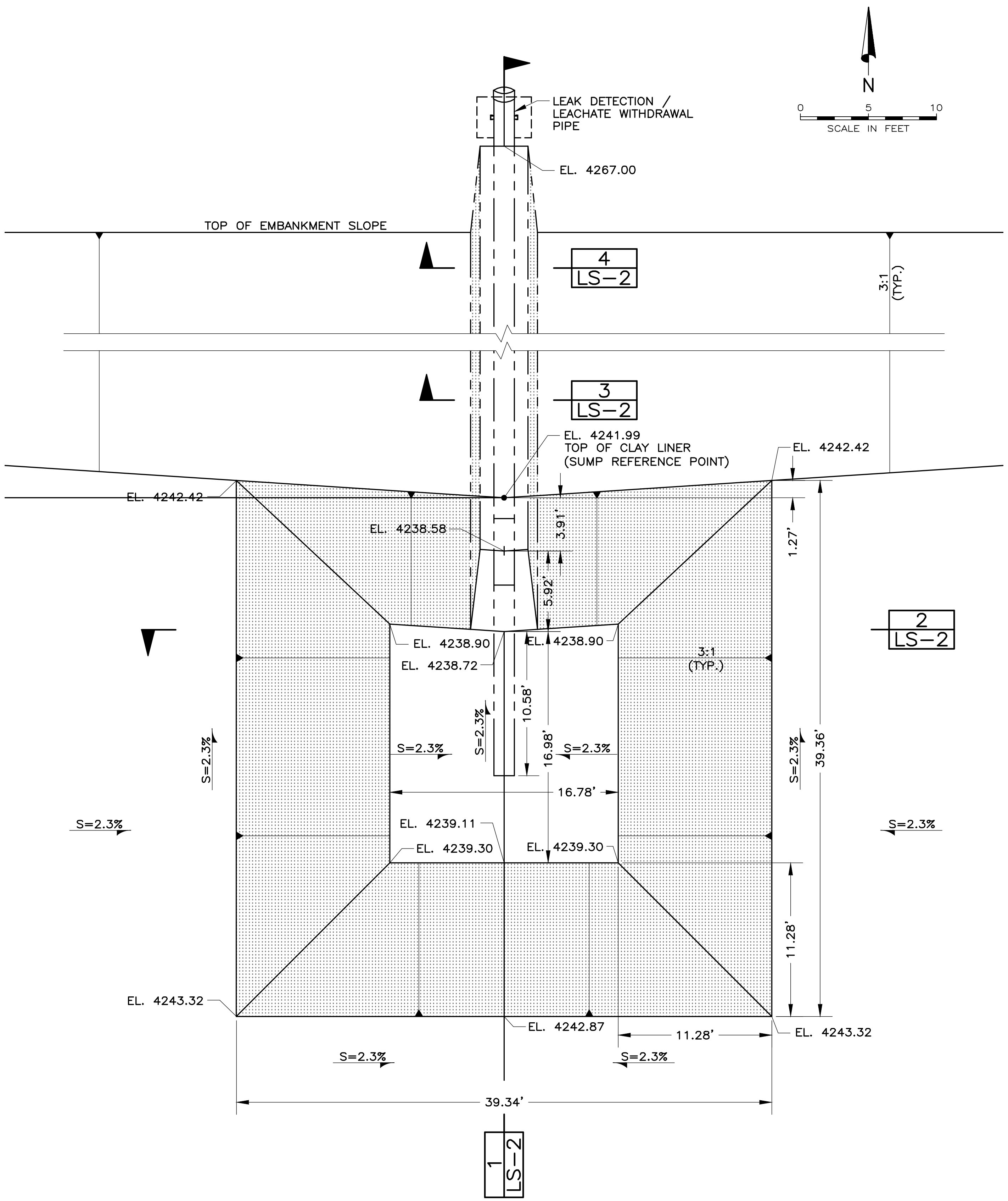
CleanHarbors ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8-13
LANDFILL
TYPICAL ACCESS RAMPS

SHEET LF-8

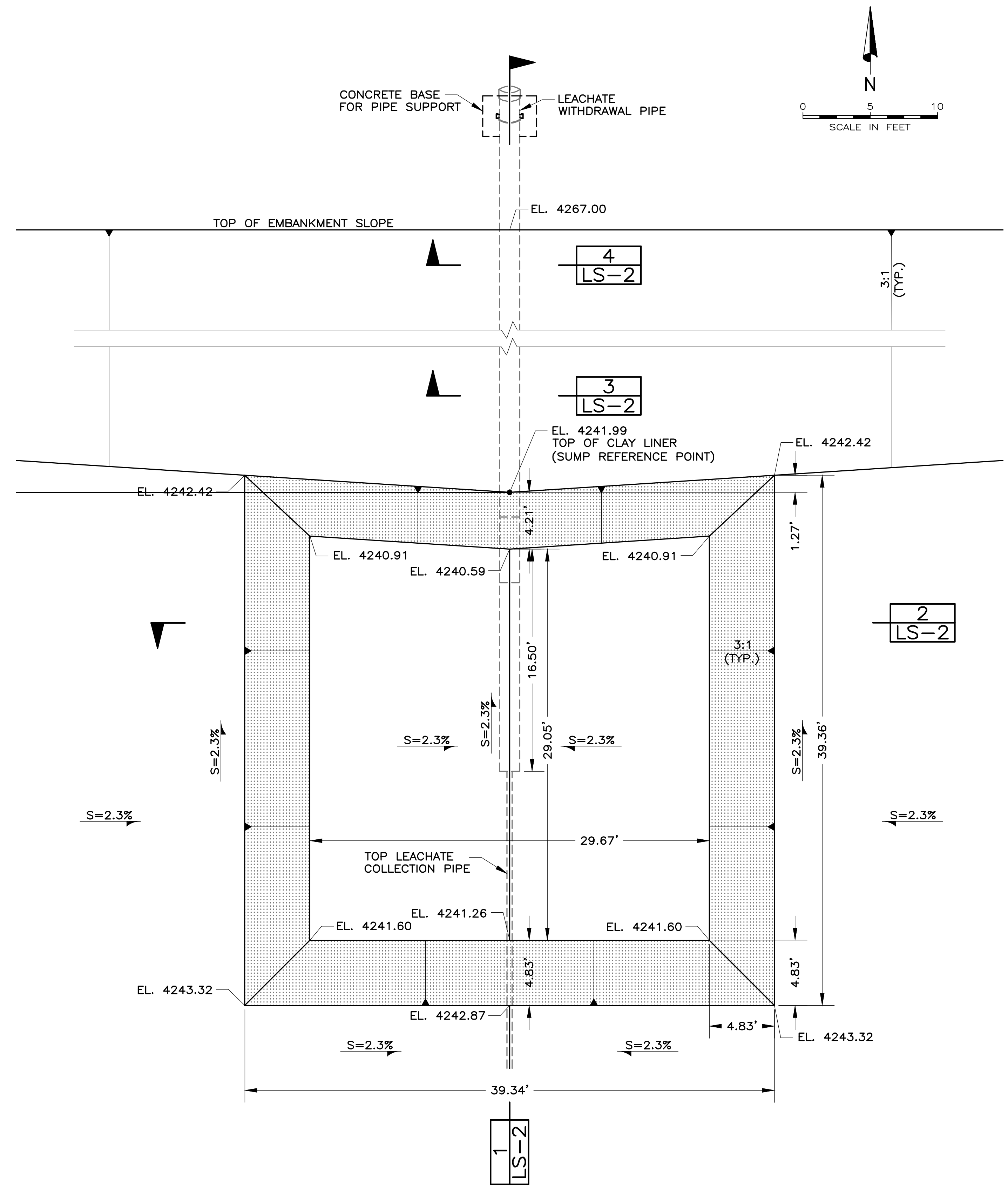
064.85.100

10/07



TYPICAL BOTTOM (LEAK DETECTION) SUMP
N.T.S.

A LF-1 | A LF-2 | A LF-3 | A LF-4 | A LF-5 | A LF-6



TYPICAL TOP (LEACHATE COLLECTION) SUMP
N.T.S.

B LF-1 | B LF-2 | B LF-3 | B LF-4 | B LF-5 | B LF-6

FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\LS-1 SUMP PLANS__R1.DWG
FILE DATE: 8.6.2018 11:40:41 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH
PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

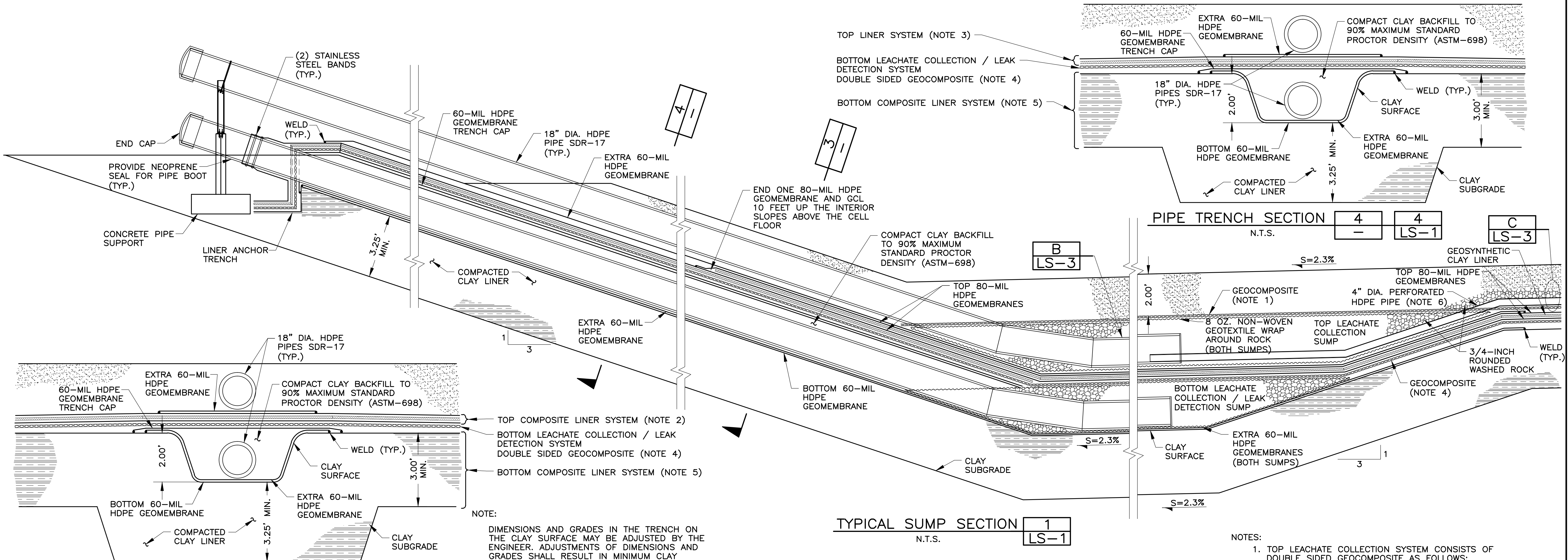
SCALE: NOT TO SCALE

CleanHarbors ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13
LCRS
SUMP PLANS

SHEET LS–1
064.85.100

10/07



PIPE TRENCH SECTION 4/– 4/LS-1

N.T.S.

TYPICAL SUMP SECTION 1/LS-1

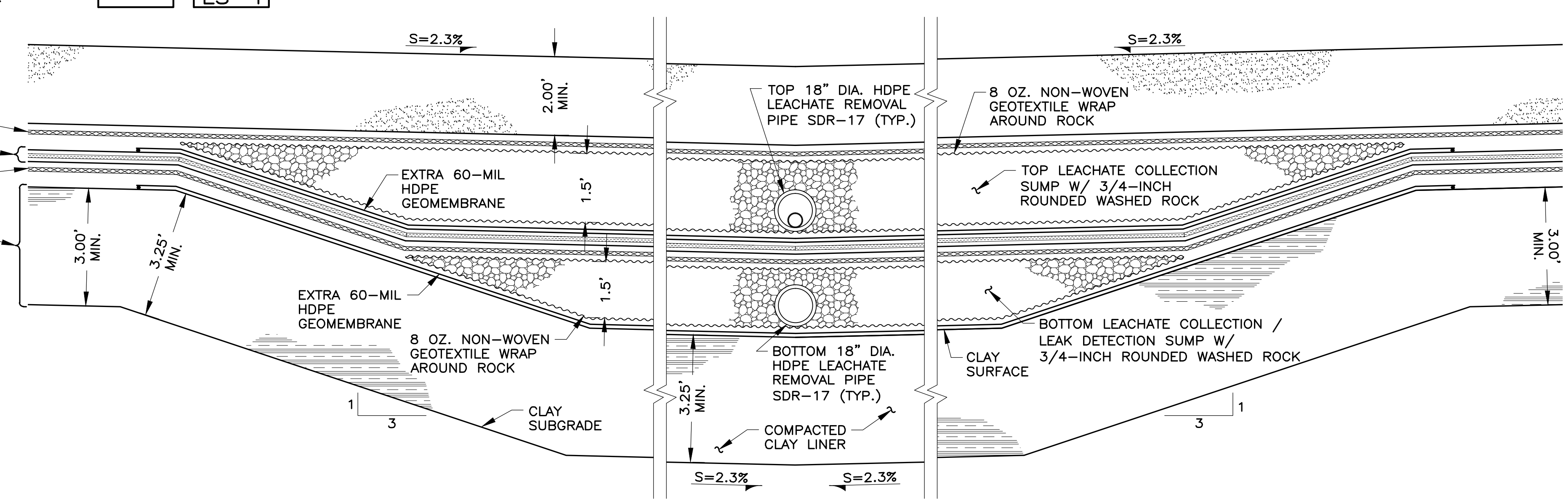
N.T.S.

NOTE:

DIMENSIONS AND GRADES IN THE TRENCH ON THE CLAY SURFACE MAY BE ADJUSTED BY THE ENGINEER. ADJUSTMENTS OF DIMENSIONS AND GRADES SHALL RESULT IN MINIMUM CLAY THICKNESS AS DESIGNATED ON THIS SECTION.

PIPE TRENCH SECTION 3/– 3/LS-1

N.T.S.



TYPICAL SUMP SECTION 2/LS-1

N.T.S.

NOTES:

1. TOP LEACHATE COLLECTION SYSTEM CONSISTS OF DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   - 8 OZ. NON-WOVEN GEOTEXTILE
   - GEONET
   - 8 OZ. NON-WOVEN GEOTEXTILE

   MIN. GEOCOMPOSITE TRANSMISSIVITY OF 6.0×10^{-4} M^2/SEC, TYP.)
2. TOP COMPOSITE LINER SYSTEM ON THE FLOOR AND TO A DISTANCE OF 10 FEET UP THE INTERIOR SLOPES CONSISTS OF:
   - 80-MIL HDPE GEOMEMBRANE (TEXTURED)
   - GEOSYNTHETIC CLAY LINER (GCL)
   - 80-MIL HDPE GEOMEMBRANE (TEXTURED)
3. TOP LINER SYSTEM ON THE INTERIOR SIDESLOPES FROM A DISTANCE OF 10 FEET UP THE SLOPES TO THE ANCHOR TRENCH AT THE TOP OF THE SLOPES CONSISTS OF:
   - 80-MIL HDPE GEOMEMBRANE (TEXTURED)
   - GEOSYNTHETIC CLAY LINER (GCL)
4. BOTTOM LEACHATE COLLECTION / LEAK DETECTION SYSTEM CONSISTS OF DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   - 8 OZ. NON-WOVEN GEOTEXTILE
   - GEONET
   - 8 OZ. NON-WOVEN GEOTEXTILE

   MIN. GEOCOMPOSITE TRANSMISSIVITY OF 2.7×10^{-4} M^2/SEC, TYP.)
5. BOTTOM COMPOSITE LINER SYSTEM CONSISTS OF:
   - 60-MIL HDPE GEOMEMBRANE (TEXTURED)
   - COMPACTED CLAY LINER (CCL)
6. EXTEND 4" DIA. PERFORATED HDPE PIPE THE FULL LENGTH OF THE VALLEY EXTENDING ACROSS THE CELL FLOOR FROM THE SUMPS.

FILE NAME: PROJECTS\064 - CLEAN HARBORS\85.100 - CELL 8 AND 9 DESIGN\CAD\WORKING\LS-2 SUMP SECTIONS__R1.DWG
FILE DATE: 8.6.2018 11:44:55 (CAH)

10/07

HANSEN ALLEN & LUCE INC ENGINEERS	PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH — PROJECT ENGINEER	DESIGNED KCS	3			
		DRAFTED CAH	2			
		CHECKED GLJ	1			
		DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY / APVD.

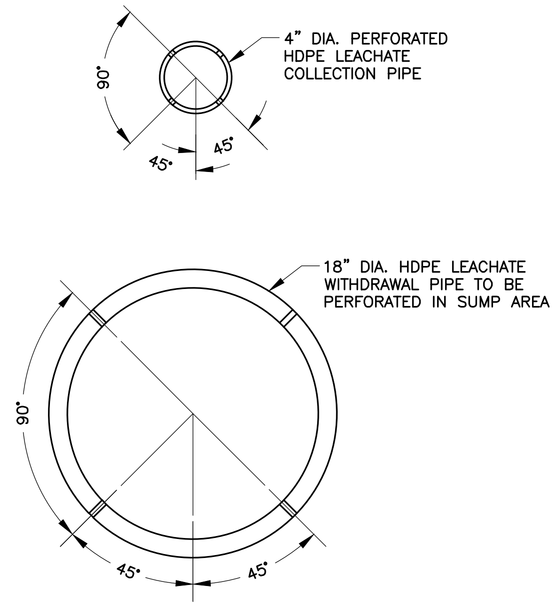
SCALE: AS SHOWN

CleanHarbors ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8-13
LCRS
SUMP SECTIONS

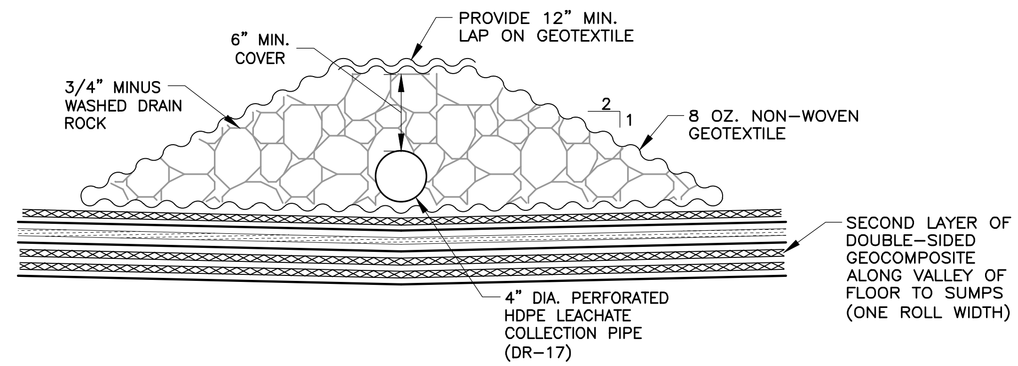
SHEET LS-2

064.85.100



PERFORATION DETAIL | A / –

N.T.S.

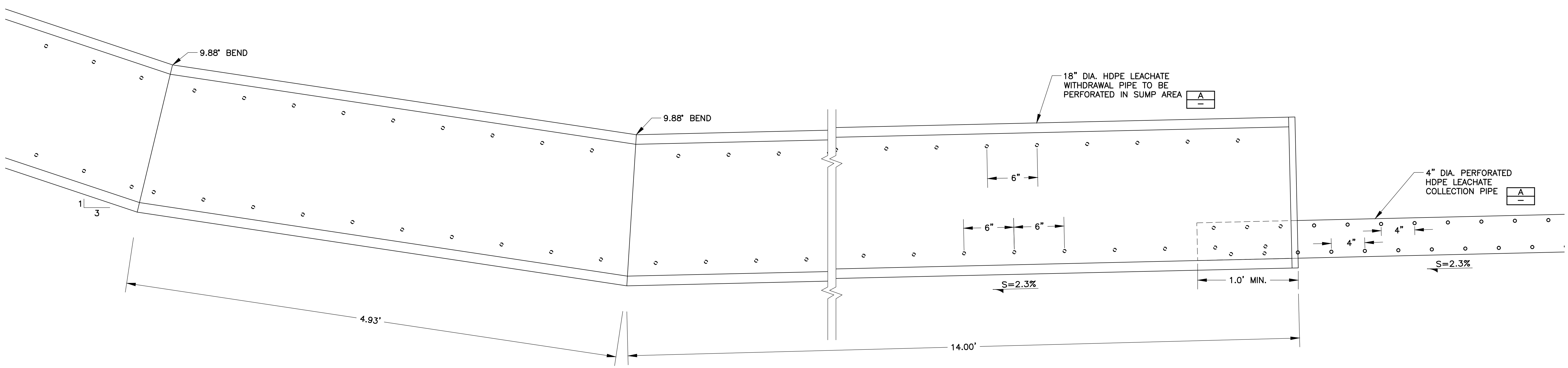


TYPICAL LEACHATE CONVEYANCE PIPE WRAP DETAIL | C / LS-2

N.T.S.

NOTES:

1. 3/4" MINUS WASHED DRAIN ROCK TO BE PLACED AROUND PERFORATED HDPE LEACHATE COLLECTION. A MINIMUM COVER OF 6 INCHES TO BE PROVIDED OVER PIPES.
2. PERFORATED HDPE PIPE TO EXTEND ENTIRE LENGTH OF THE VALLEY OF EACH SUMP DRAINAGE AREA.
3. 18-INCH AND 4-INCH DIA. PERFORATED HDPE PIPES TO RECEIVE 4 ROWS OF 3/8-INCH DIA. PERFORATIONS STAGGERRED AS SHOWN. PERFORATIONS IN 18-INCH DIA. HDPE PIPE ONLY REQUIRED FOR THE PORTION OF THE PIPE WITHIN THE SUMPS. PERFORATIONS IN THE 4-INCH DIA. HDPE PIPE TO BE ALONG THE FULL LENGTH OF THE PIPE.



HDPE PIPE "TIE-IN" DETAIL | B / LS-2

N.T.S.

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FILE DATE: 8.6.2018 11:45:47 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3					
DRAFTED CAH	2					
CHECKED GLJ	1					
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.	

SCALE: AS SHOWN

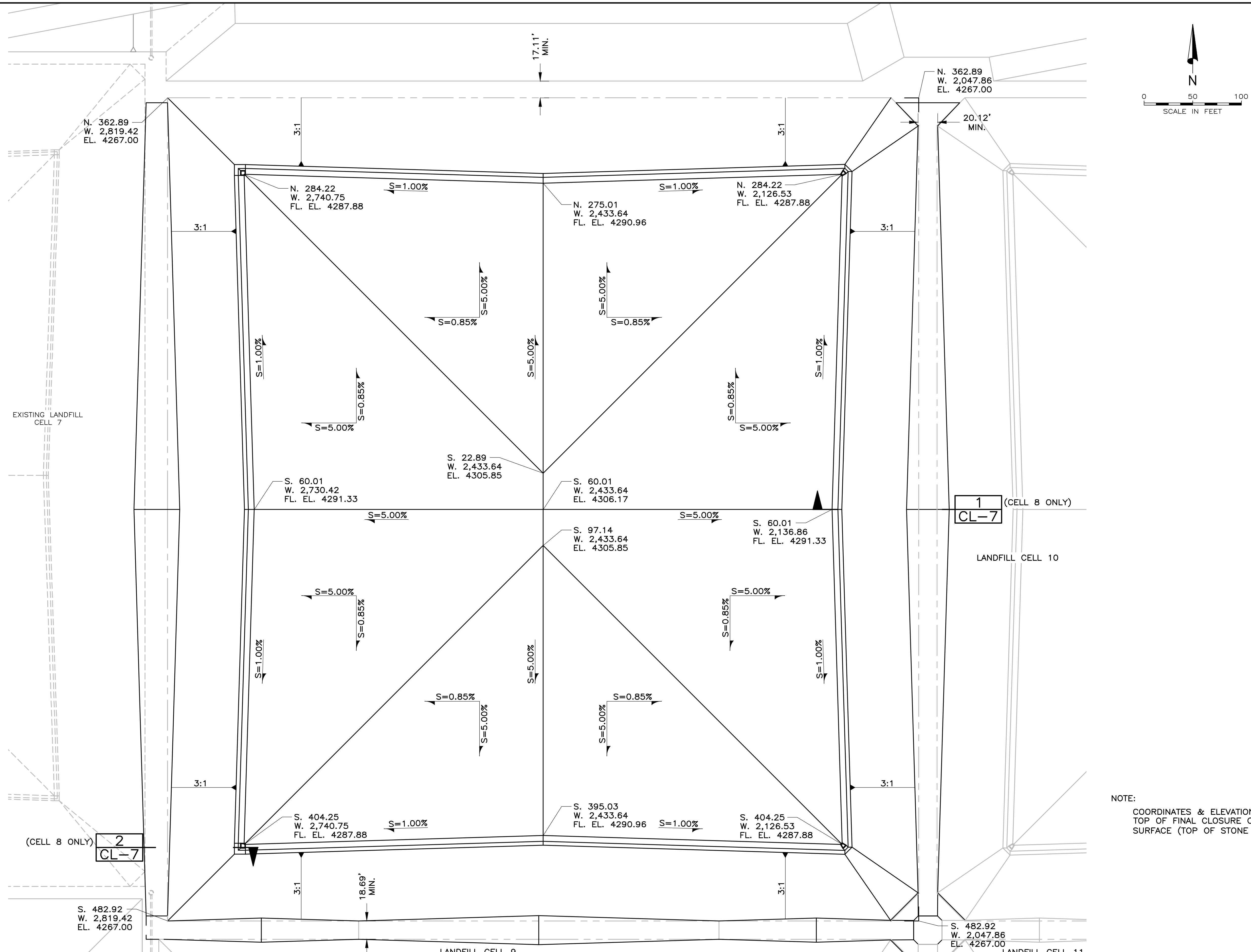
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8-13
LCRS
LCRS DETAILS

SHEET LS-3

064.85.100

10/07



NOTE:

COORDINATES & ELEVATIONS ARE TOP OF FINAL CLOSURE CAP SURFACE (TOP OF STONE MULCH).

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FILE DATE: 8.6.2018 11:47:04 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH
PROJECT ENGINEER

DESIGNED	KCS	3				
DRAFTED	CAH	2				
CHECKED	GLJ	1				
DATE	AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

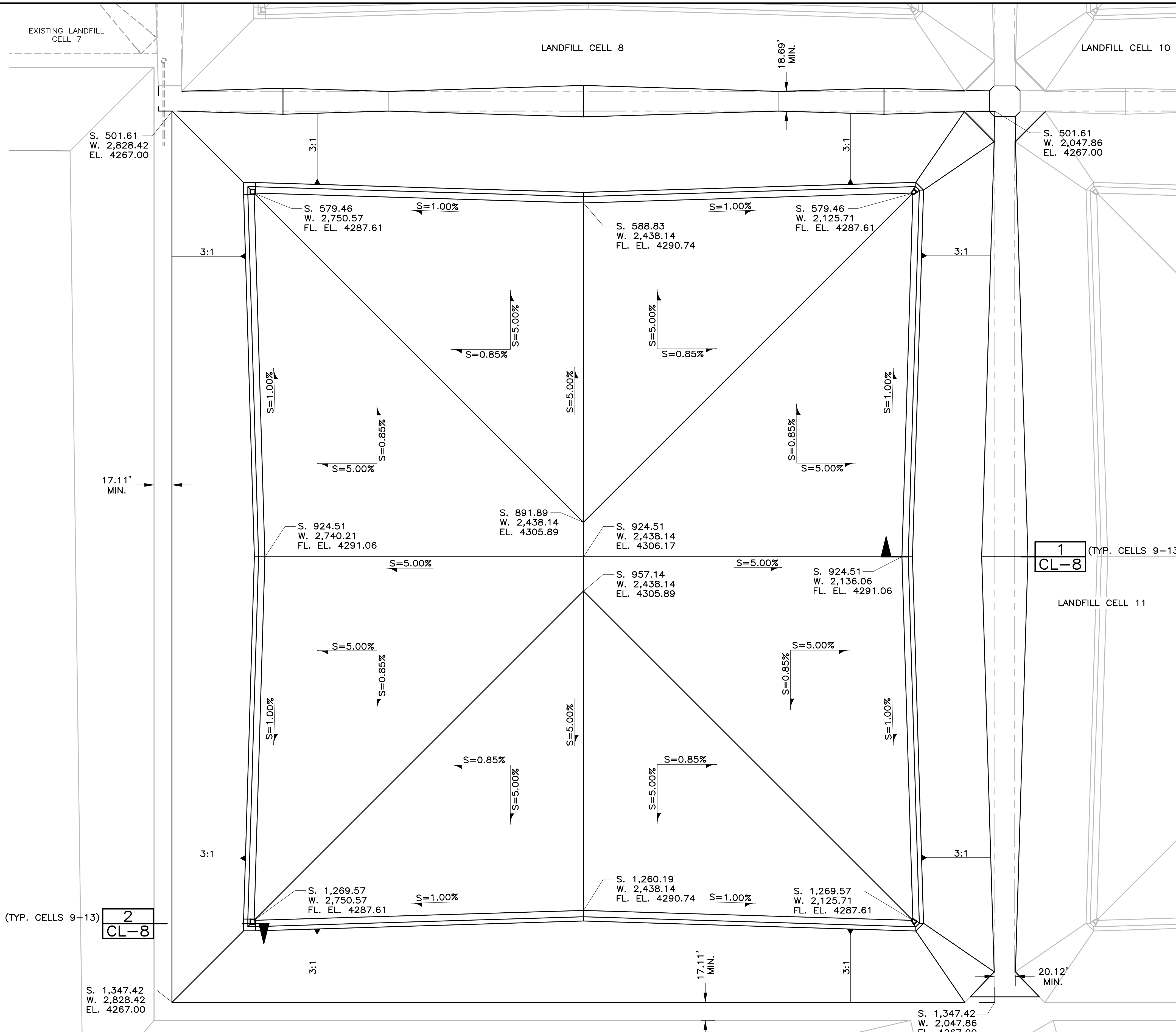
SCALE
NOT TO SCALE

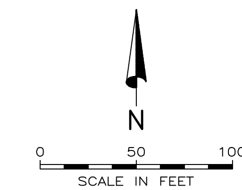
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13
CLOSURE
PLAN VIEW CELL 8

SHEET
CL–1
064.85.100

10/07





NOTE:

COORDINATES & ELEVATIONS ARE TOP OF FINAL CLOSURE CAP SURFACE (TOP OF STONE MULCH).

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FILE DATE: 8.6.2018 11:50:50 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3			
DRAFTED CAH	2			
CHECKED GLJ	1			
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE: NOT TO SCALE

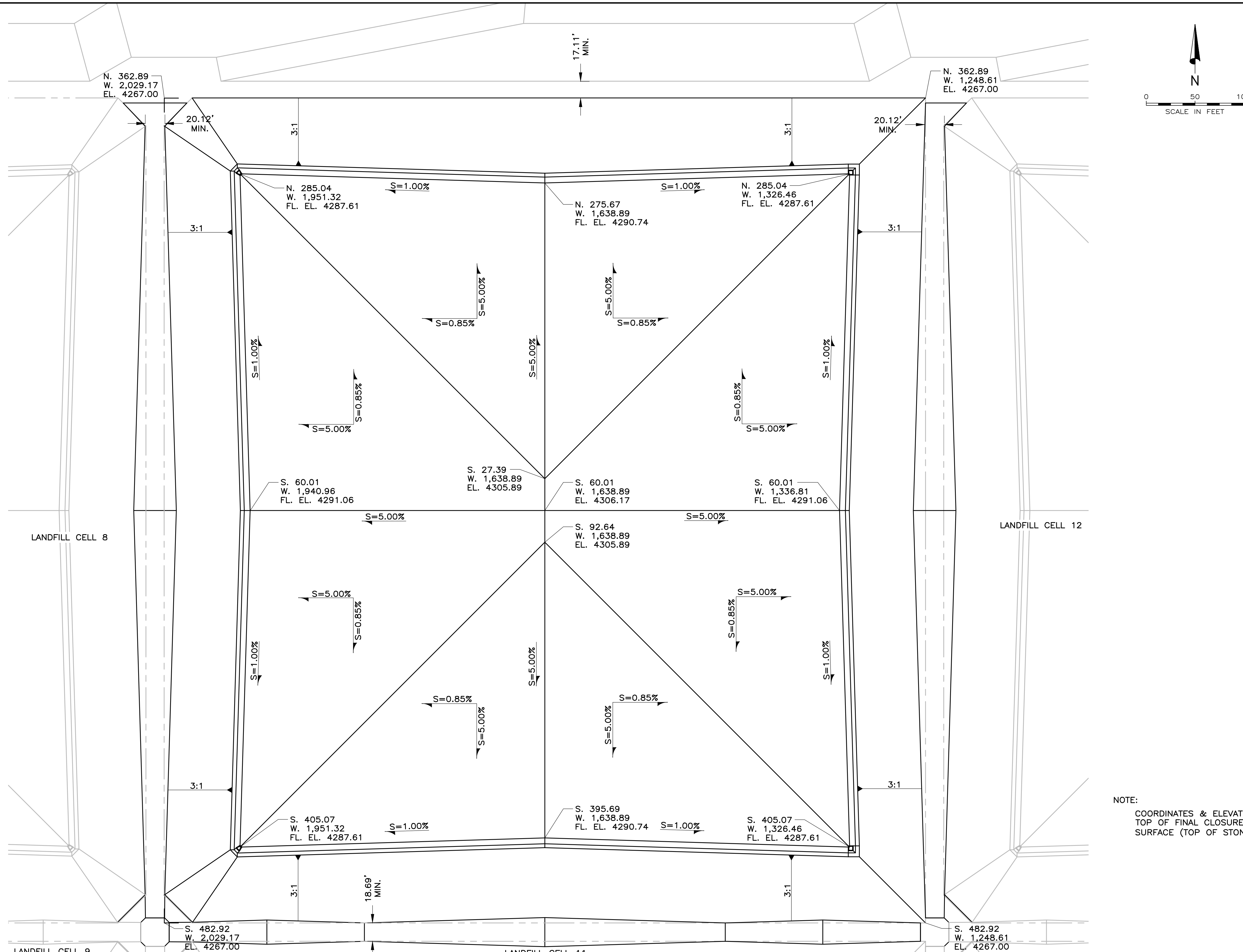
CleanHarbors ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8-13 CLOSURE
PLAN VIEW CELL 9

SHEET CL-2

064.85.100

10/07



NOTE:

COORDINATES & ELEVATIONS ARE TOP OF FINAL CLOSURE CAP SURFACE (TOP OF STONE MULCH).

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FILE DATE: 8.6.2018 11:51:43 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH
PROJECT ENGINEER

DESIGNED	KCS	3			
DRAFTED	CAH	2			
CHECKED	GLJ	1			
DATE	AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY / APVD.

SCALE: NOT TO SCALE

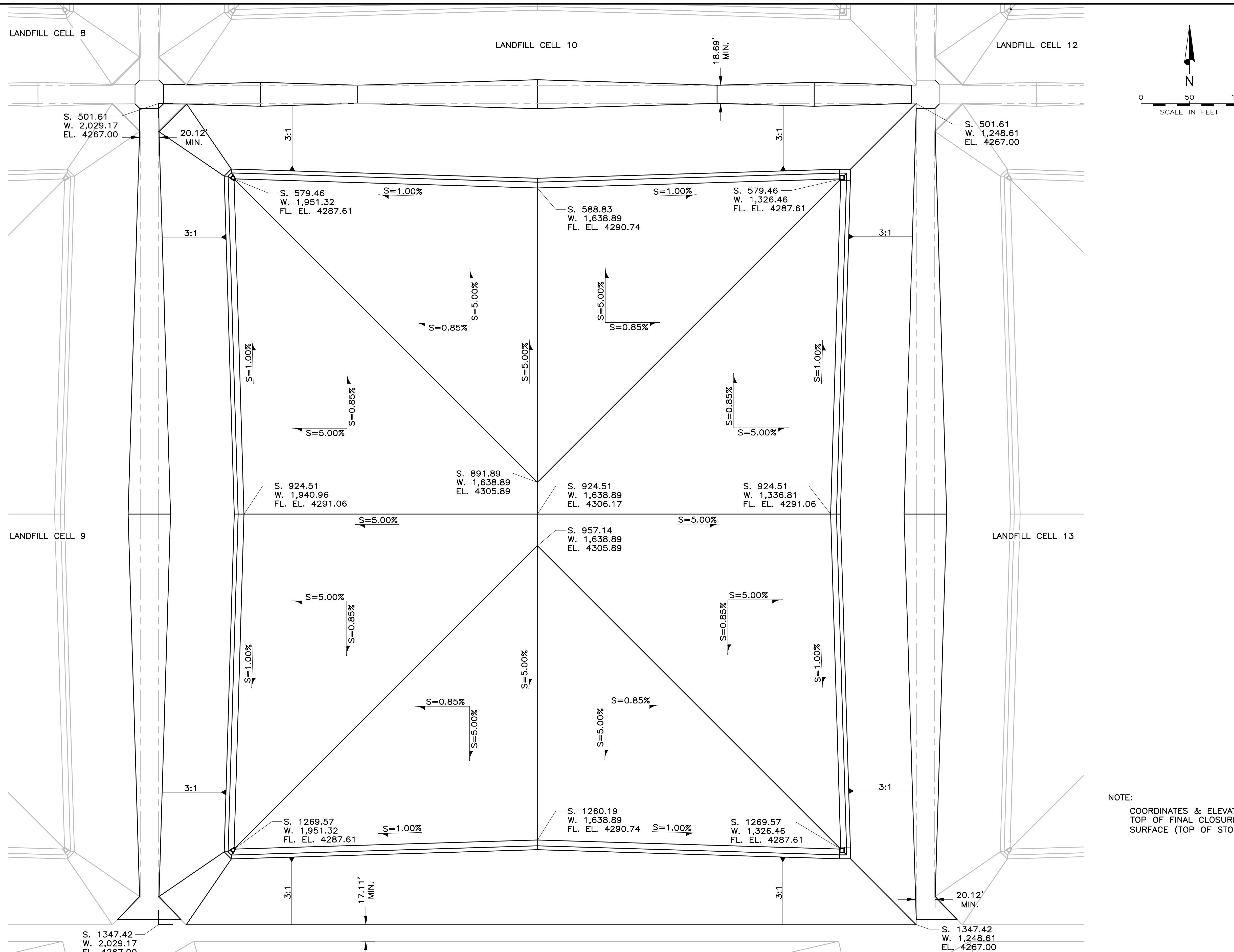
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13
CLOSURE
PLAN VIEW CELL 10

SHEET CL-3

064.85.100

10/07



NOTE:

COORDINATES & ELEVATIONS ARE TOP OF FINAL CLOSURE CAP SURFACE (TOP OF STONE MULCH).

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FILE DATE: 8.6.2018 11:52:45 (CAH)

HANSEN ALLEN & LUCE inc ENGINEERS

PROFESSIONAL ENGINEER No. 5048470-2202 GORDON L. JONES 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3					
DRAFTED CAH	2					
CHECKED GLJ	1					
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.	

SCALE: NOT TO SCALE

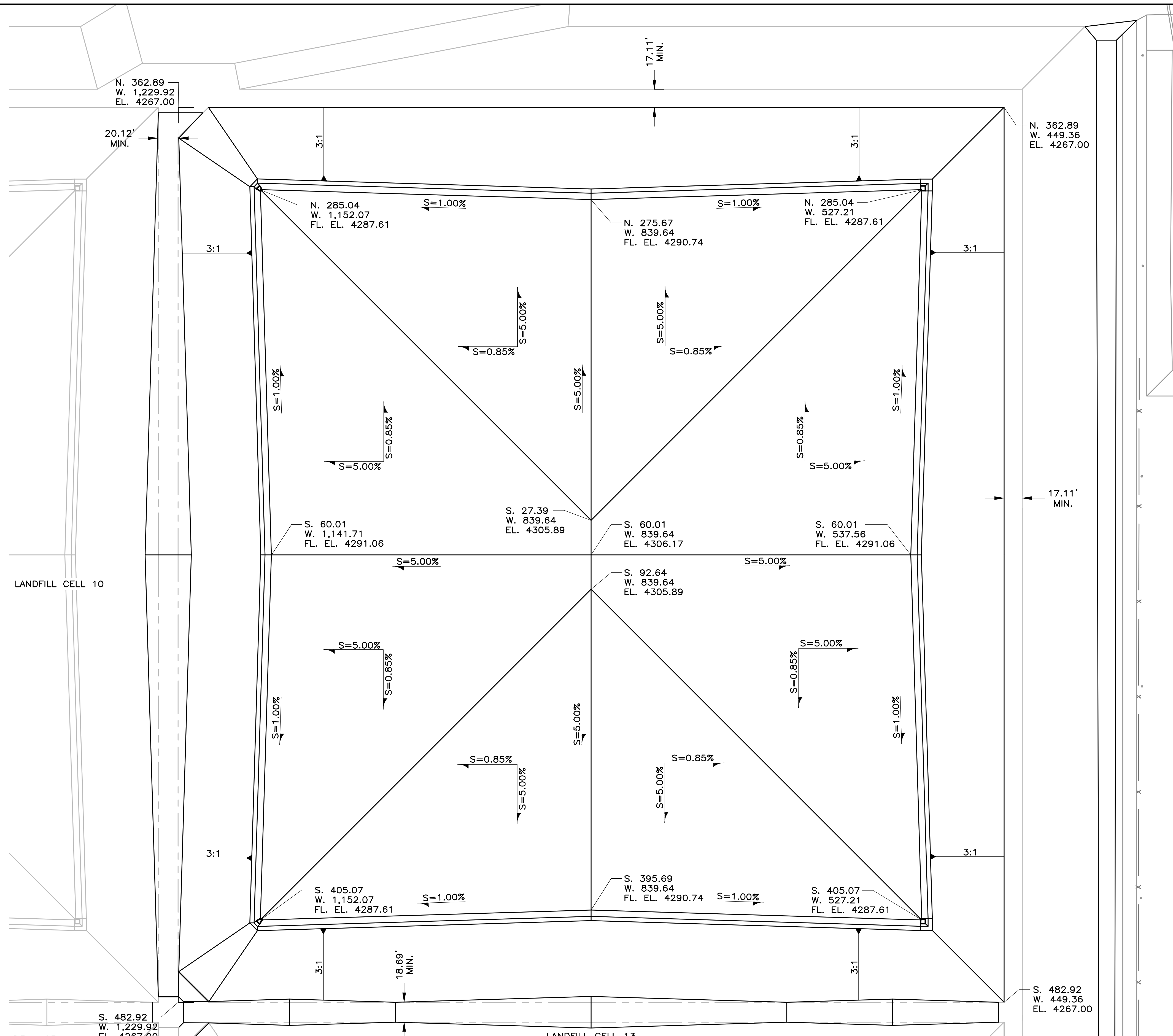
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

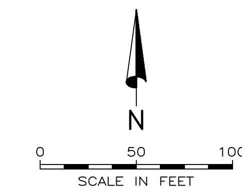
GRASSY MOUNTAIN FACILITY CELLS 8–13
CLOSURE
PLAN VIEW CELL 11

SHEET CL–4

064.85.100

10/07





NOTE:
COORDINATES & ELEVATIONS ARE TOP OF FINAL CLOSURE CAP SURFACE (TOP OF STONE MULCH).

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FILE DATE: 8.6.2018 11:53:48 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH
PROJECT ENGINEER

DESIGNED KCS	3					
DRAFTED CAH	2					
CHECKED GLJ	1					
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.	

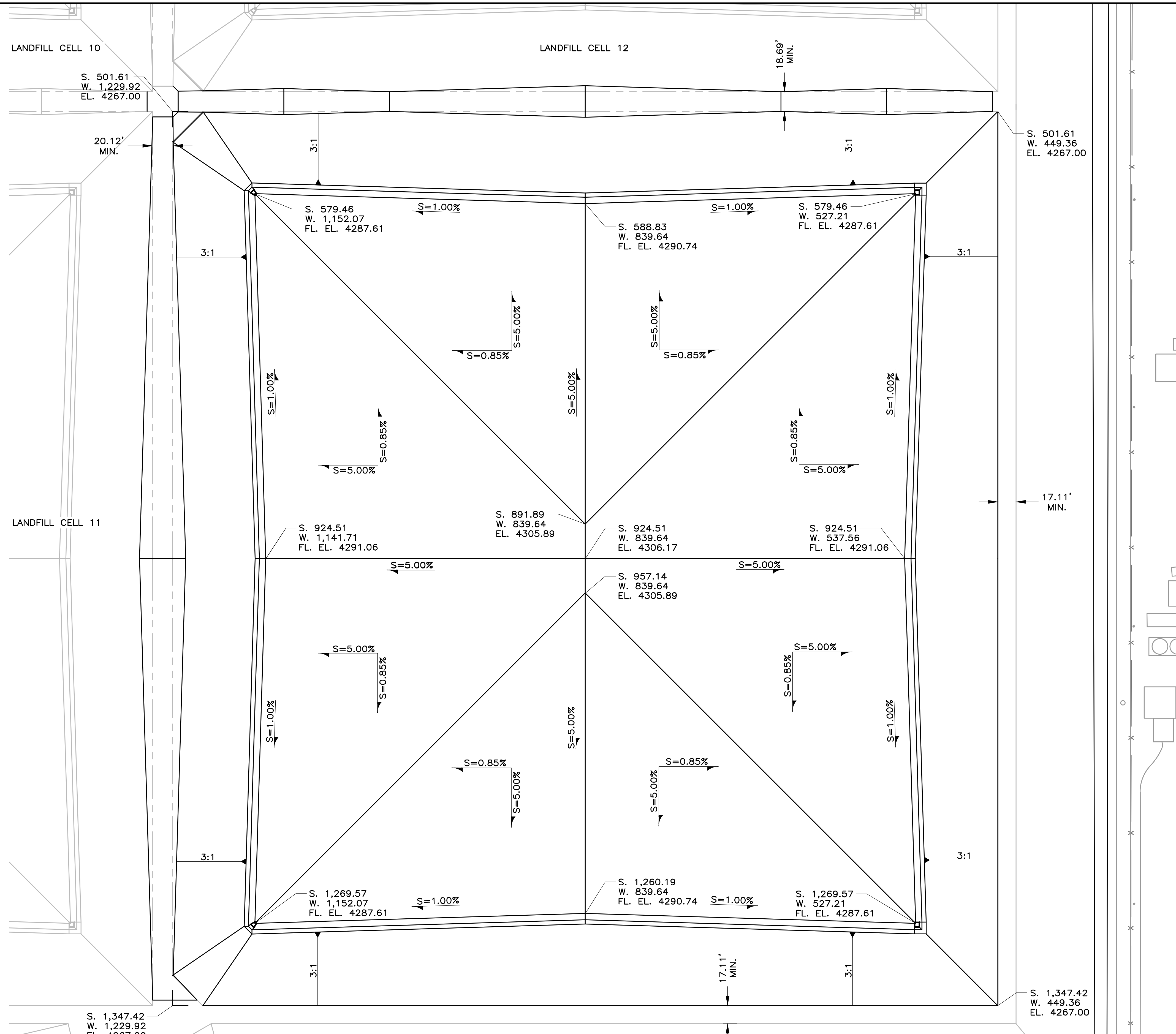
SCALE
NOT TO SCALE

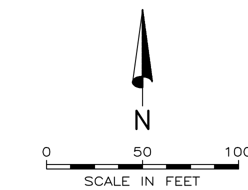
CleanHarbors ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13
CLOSURE
PLAN VIEW CELL 12

SHEET
CL–5
064.85.100

10/07





NOTE:

COORDINATES & ELEVATIONS ARE TOP OF FINAL CLOSURE CAP SURFACE (TOP OF STONE MULCH).

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FILE DATE: 8.6.2018 11:54:59 (CAH)

HANSEN ALLEN & LUCE inc ENGINEERS

PROFESSIONAL ENGINEER No. 5048470-2202 GORDON L. JONES 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE: NOT TO SCALE

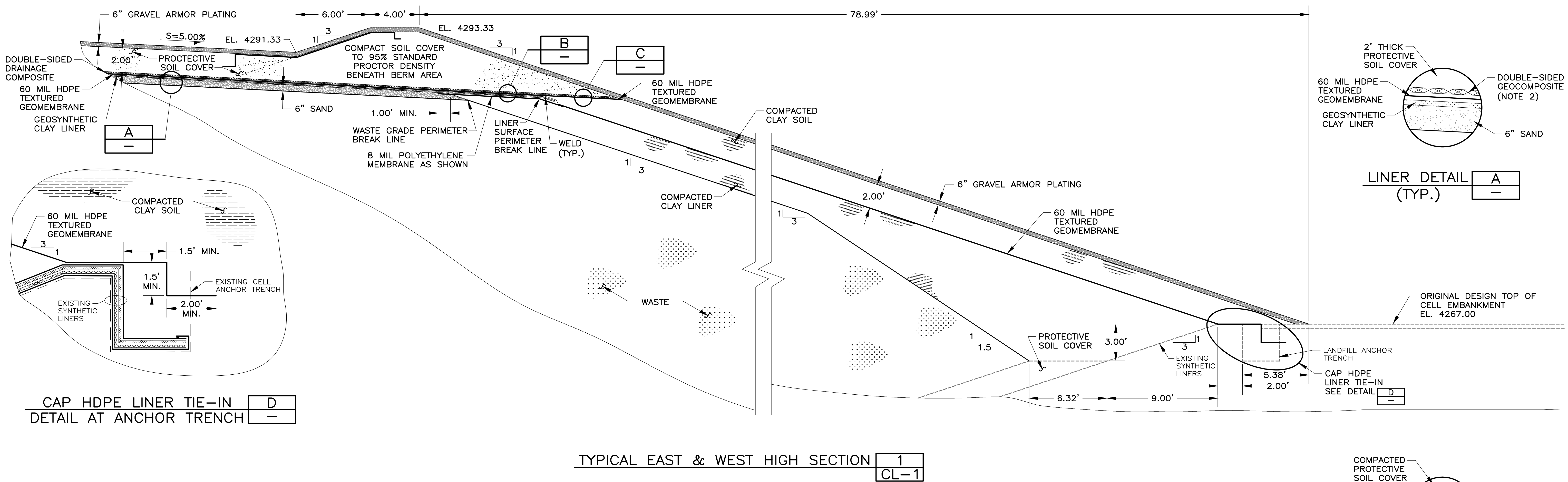
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

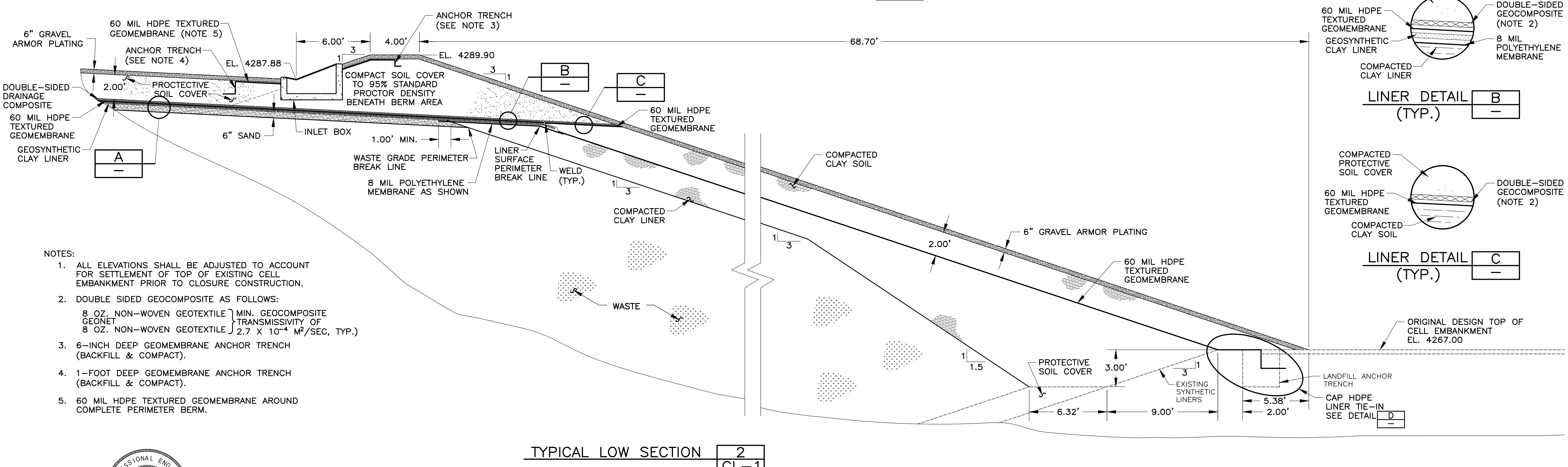
GRASSY MOUNTAIN FACILITY CELLS 8–13
CLOSURE
PLAN VIEW CELL 13

SHEET CL–6

064.85.100

10/07





NOTES:

1. ALL ELEVATIONS SHALL BE ADJUSTED TO ACCOUNT FOR SETTLEMENT OF TOP OF EXISTING CELL EMBANKMENT PRIOR TO CLOSURE CONSTRUCTION.
2. DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   8 OZ. NON–WOVEN GEOTEXTILE / GEONET / 8 OZ. NON–WOVEN GEOTEXTILE } MIN. GEOCOMPOSITE TRANSMISSIVITY OF 2.7×10^{-4} M²/SEC, TYP.)
3. 6–INCH DEEP GEOMEMBRANE ANCHOR TRENCH (BACKFILL & COMPACT).
4. 1–FOOT DEEP GEOMEMBRANE ANCHOR TRENCH (BACKFILL & COMPACT).
5. 60 MIL HDPE TEXTURED GEOMEMBRANE AROUND COMPLETE PERIMETER BERM.

FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\CL–7 HIGH LOW SECTIONS 8__R1.DWG
FILE DATE: 8.6.2018 11:55:53 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER No. 5048470-2202 GORDON L. JONES 8/6/2018 STATE OF UTAH
PROJECT ENGINEER

DESIGNED	KCS	3				
DRAFTED	CAH	2				
CHECKED	GLJ	1				
DATE	AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE: NOT TO SCALE

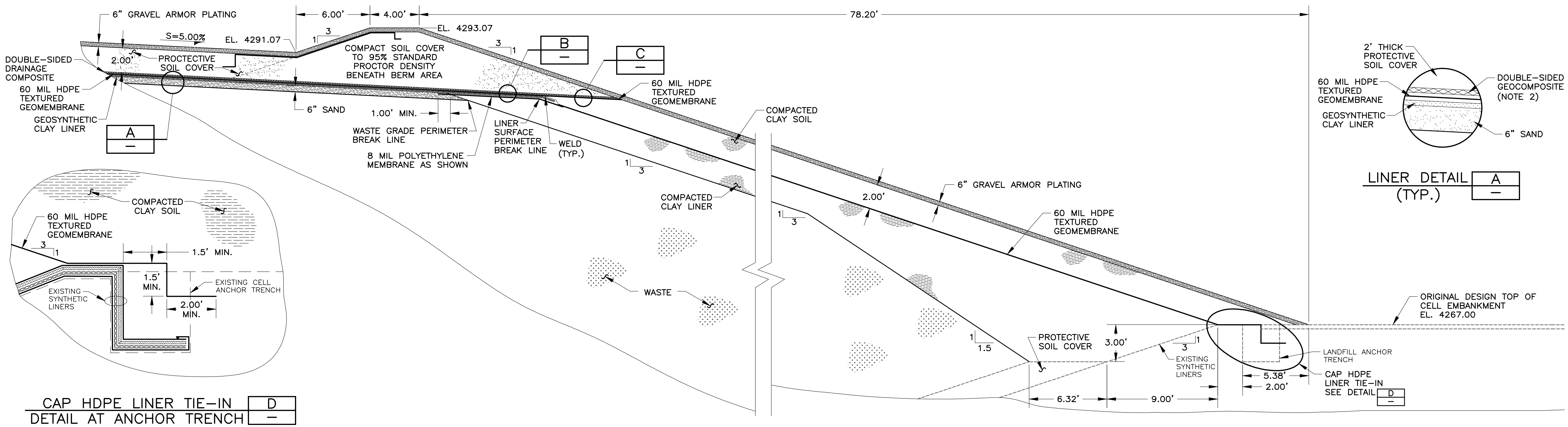
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13 CLOSURE
HIGH–LOW SECTIONS CELL 8

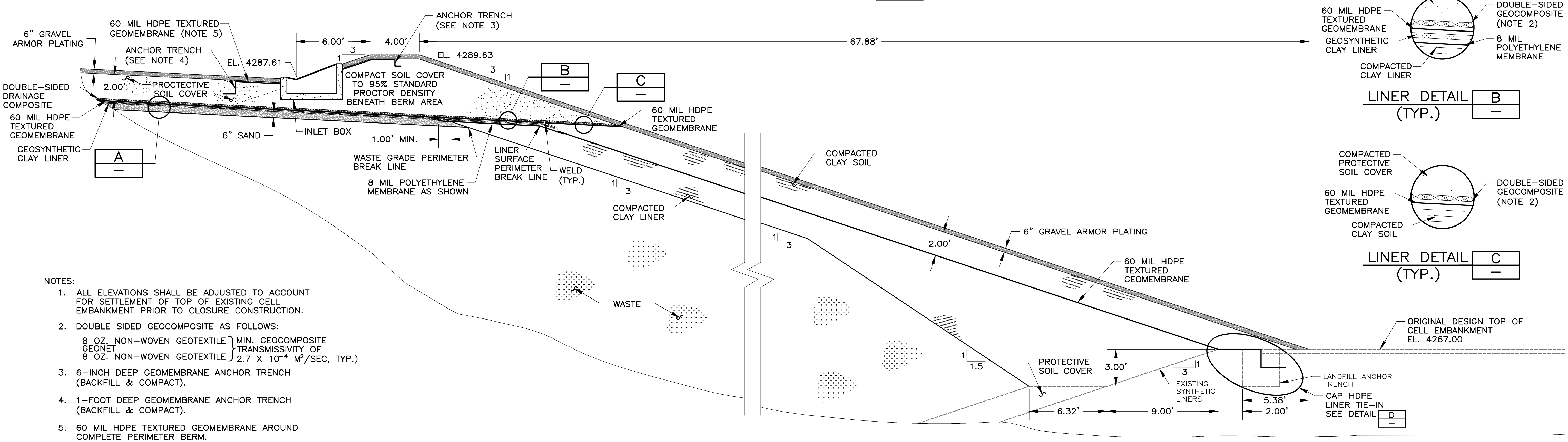
SHEET CL–7

064.85.100

10/07



TYPICAL EAST & WEST HIGH SECTION 1 CL-2



NOTES:

1. ALL ELEVATIONS SHALL BE ADJUSTED TO ACCOUNT FOR SETTLEMENT OF TOP OF EXISTING CELL EMBANKMENT PRIOR TO CLOSURE CONSTRUCTION.
2. DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   8 OZ. NON-WOVEN GEOTEXTILE / GEONET / 8 OZ. NON-WOVEN GEOTEXTILE } MIN. GEOCOMPOSITE TRANSMISSIVITY OF 2.7×10^{-4} M^2/SEC, TYP.)
3. 6-INCH DEEP GEOMEMBRANE ANCHOR TRENCH (BACKFILL & COMPACT).
4. 1-FOOT DEEP GEOMEMBRANE ANCHOR TRENCH (BACKFILL & COMPACT).
5. 60 MIL HDPE TEXTURED GEOMEMBRANE AROUND COMPLETE PERIMETER BERM.

TYPICAL LOW SECTION 2 CL-2

FILE NAME: PROJECTS\064 - CLEAN HARBORS\85.100 - CELL 8 AND 9 DESIGN\CAD\WORKING\CL-8 HIGH LOW SECTIONS 9-13__R1.DWG
FILE DATE: 8.6.2018 11:56:51 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER No. 5048470-2202 GORDON L. JONES 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3					
DRAFTED CAH	2					
CHECKED GLJ	1					
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.	

SCALE NOT TO SCALE

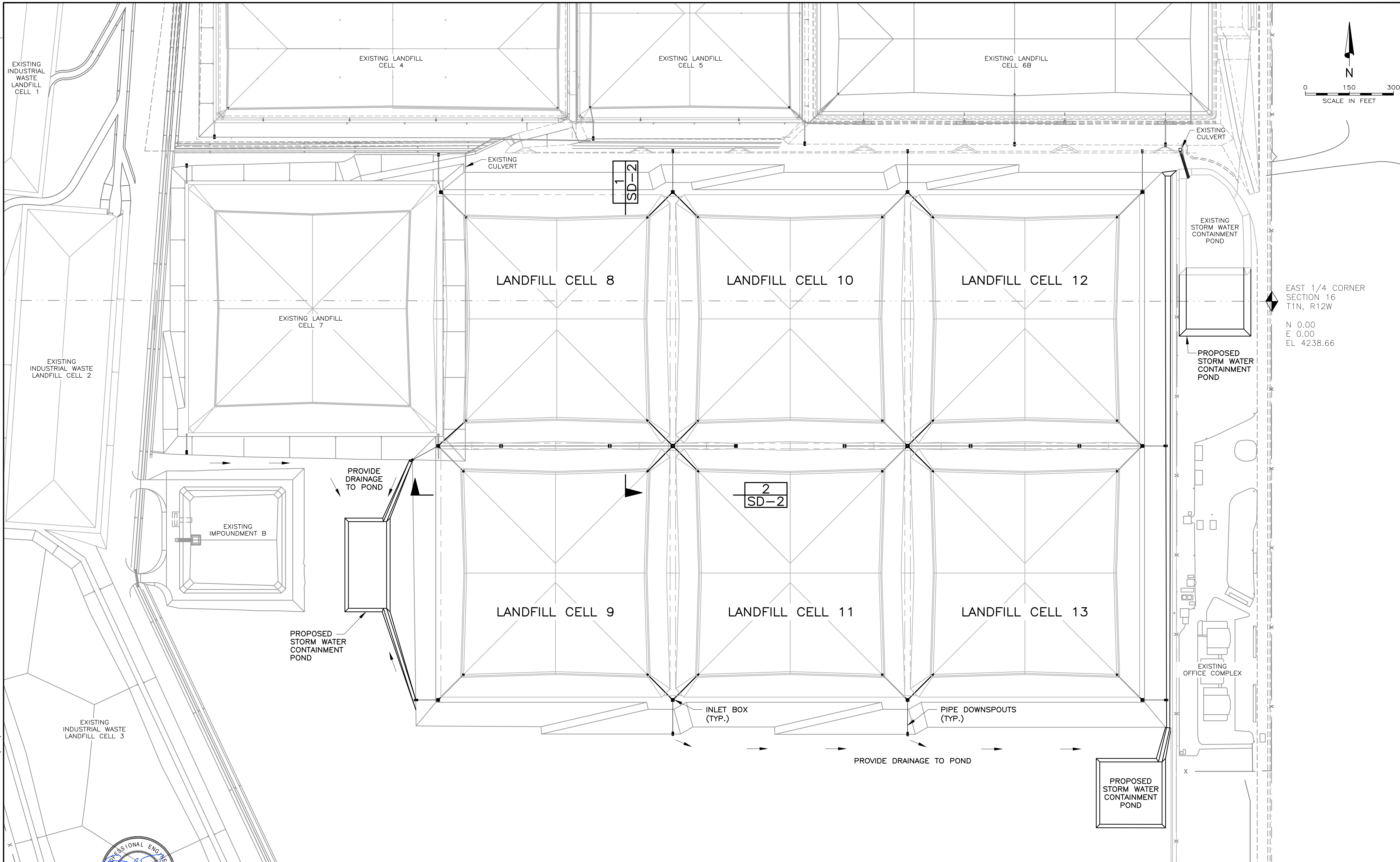
CleanHarbors ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8-13 CLOSURE
HIGH-LOW SECTIONS CELLS 9-13

SHEET CL-8

064.85.100

10/07



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FILE DATE: 8.6.2018 11:57:49 (CAH)

HANSEN ALLEN & LUCE inc ENGINEERS

PROFESSIONAL ENGINEER — GORDON L. JONES — No. 5048470-2202 — 8/6/2018 — STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE: NOT TO SCALE

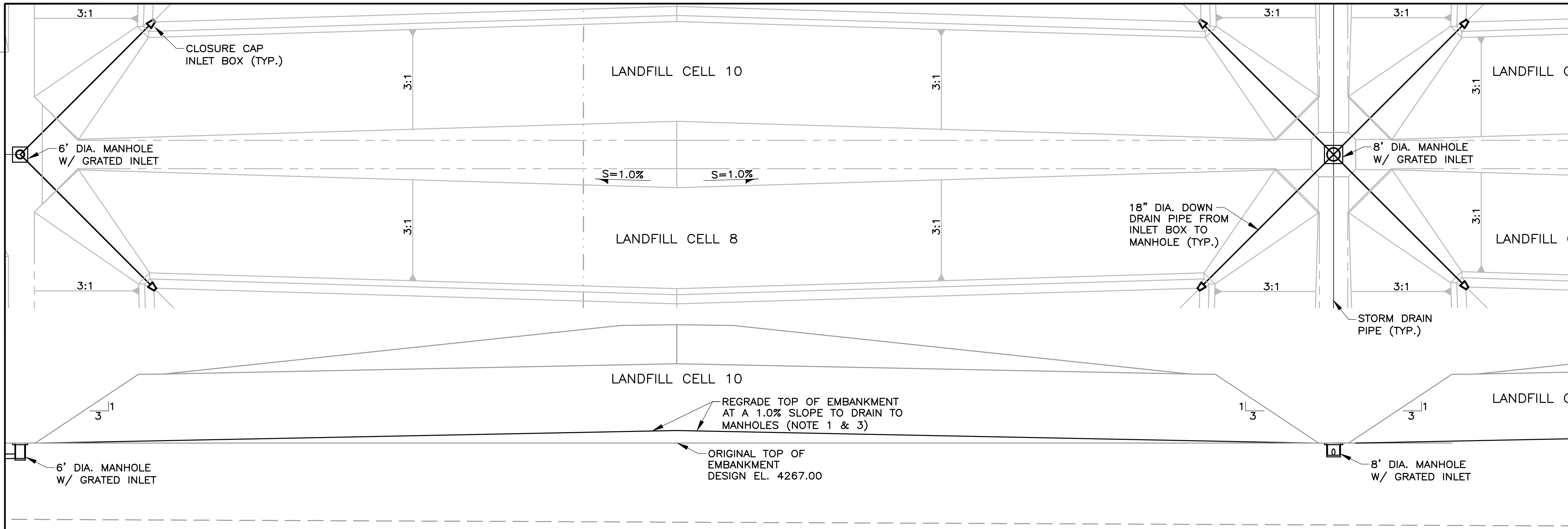
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8-13
STORM DRAIN
DRAINAGE PLAN

SHEET SD-1

064.85.100

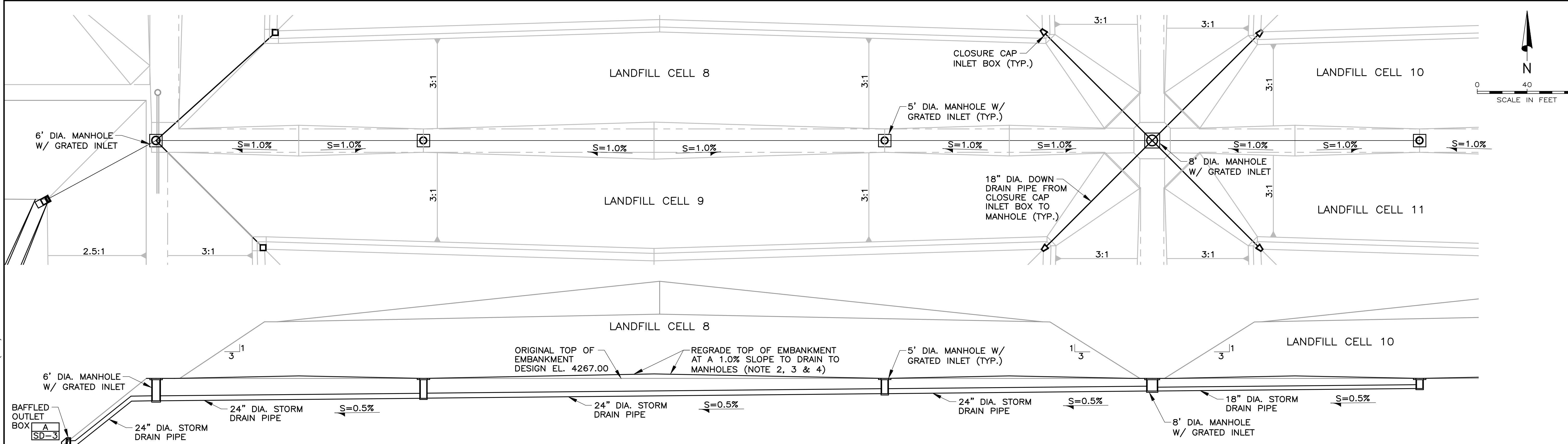
10/07



NORTH & SOUTH SECTION 1 SD−1

NOTES:

1. TOP OF EMBANKMENT GRADING ON THE NORTH & SOUTH SECTION IS REPRESENTATIVE OF NORTH & SOUTH GRADING BETWEEN ALL CLOSURE CAPS.
2. GRADING AND STORM DRAIN PIPING ON EAST & WEST SECTION IS REPRESENTATIVE OF THE GRADING AND PIPING BETWEEN CELLS 10 & 11 AND 12 & 13.
3. GRADE TOP OF EMBANKMENT AT 1% SLOPE TOWARD MANHOLES UPON COMPLETION OF ADJACENT CLOSURE CAPS.
4. STORM DRAINAGE PIPE AND MANHOLES TO BE INSTALLED AT TIME OF CLOSURE WHEN ADJACENT LANDFILLS ARE MOSTLY FILLED AND DIFFERENTIAL SETTLEMENT HAS MOSTLY OCCURRED.



EAST & WEST SECTION 2 SD−1

FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\SD-2 SECTIONS__R1.DWG
FILE DATE: 8.6.2018 11:58:43 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER No. 5048470-2202 GORDON L. JONES 8/6/2018 STATE OF UTAH
PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

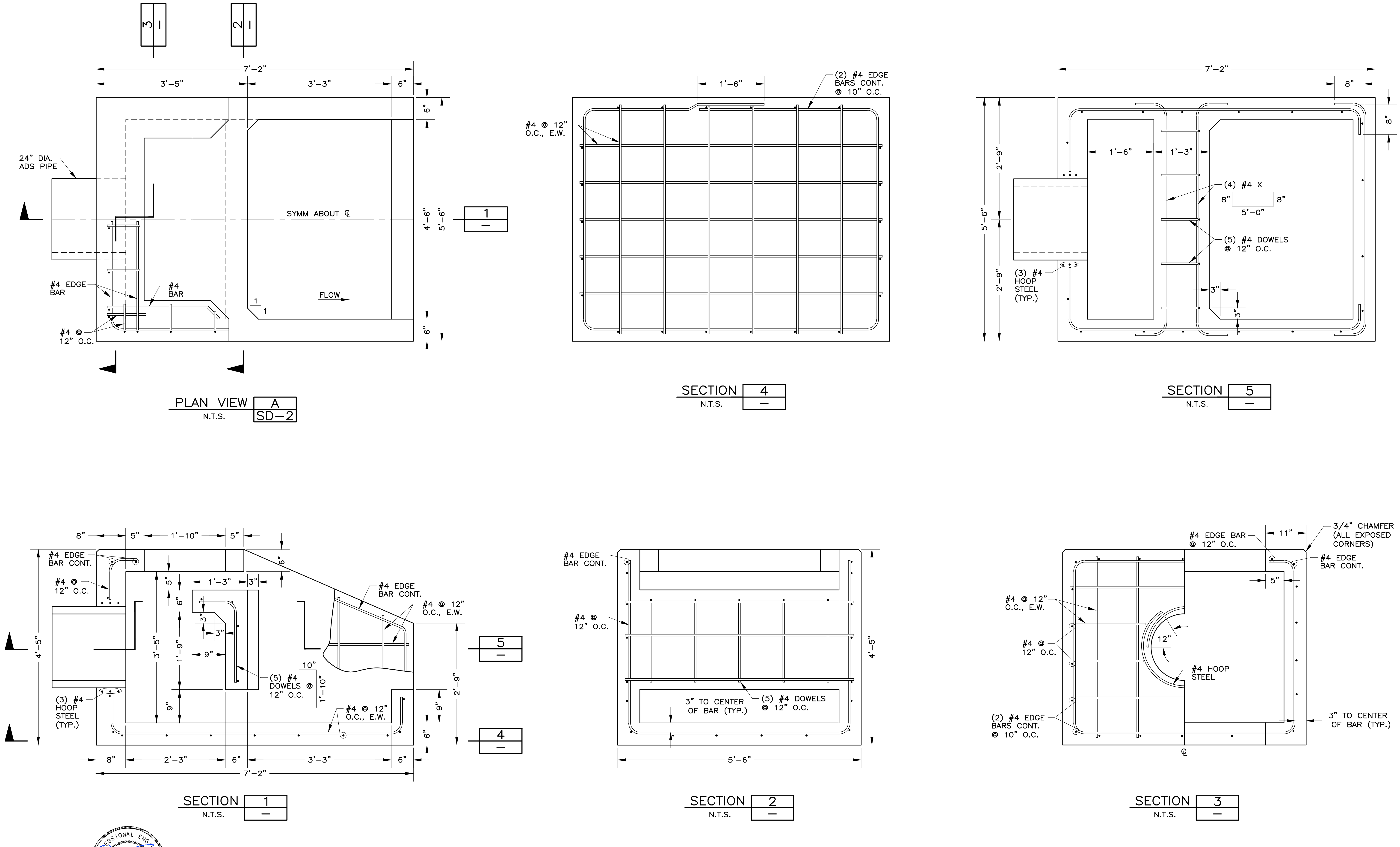
SCALE AS SHOWN

CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8−13
STORM DRAIN
DRAINAGE SECTIONS

SHEET SD−2
064.85.100

10/07



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FILE DATE: 8.6.2018 12:00:00 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 8/6/2018 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE AUGUST 2018 REV 1	NO.	DATE	REVISIONS	BY	APVD.

SCALE

CleanHarbors ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8-13
STORM DRAIN
BAFFLED OUTLET BOX

SHEET SD-3

064.85.100

10/07

APPENDIX B

Geotechnical Investigation
Cells 8 - 13
Grassy Mountain Facility
Tooele County, Utah

Prepared for:

Clean Harbors
2027 Independence Parkway
LaPorte, Texas 77571

Prepared by:

Applied Geotechnical Engineering Consultants, Inc.
Salt Lake City, Utah

Applied GeoTech

GEOTECHNICAL INVESTIGATION

CELLS 8 - 13

GRASSY MOUNTAIN FACILITY

TOOELE COUNTY, UTAH

PREPARED FOR:

CLEAN HARBORS
2027 INDEPENDENCE PARKWAY
LAPORTE, TEXAS 77571

ATTENTION: FAIZUR KHAN

PROJECT NO. 1160276 NOVEMBER 16, 2017

600 West Sandy Parkway • Sandy, Utah 84070 • (801) 566-6399 • FAX (801) 566-6493

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FIGURES

APPENDIX

EXECUTIVE SUMMARY

1. In our professional opinion, the natural soils at the site are suitable for support of the proposed embankment and landfill disposal cells.

2. Exterior slopes of 2.5 horizontal to 1 vertical may be used for embankment construction. Interior slopes of 3 horizontal to 1 vertical may be used.

3. The natural on-site silty clay and silty sand to sandy silt materials are suitable for construction of the proposed embankment. The upper mud flat soils are suitable for the clay liner.

4. Stability analysis was performed for the proposed landfill configuration based on subsurface conditions encountered in explorations, laboratory testing and our understanding of the strengths of materials at the site. The results of the analysis indicate suitable safety factors for the proposed landfill cells.

5. Settlement analysis was performed for the proposed landfill cells considering the construction and closure of each sequential cell. Settlement at proposed embankments is established to be on the order of 105 inches and on the order of 140 inches in the central part of the cells after waste placement. Settlement profiles are presented in Appendix G.

6. Information obtained during the study and recommendations for geotechnical aspects of the proposed construction including subgrade preparation, materials and compaction are included in the report.

SCOPE

This report presents the results of a geotechnical study for the proposed Landfill Cells 8 through 13 at the Grassy Mountain Facility in Tooele County, Utah. The site is located in the east-central portion of Section 16, Township 1 North, Range 12 West, Salt Lake Base and Meridian in Tooele County, Utah. Our services are provided in general accordance with proposals dated June 4, 2016 and April 4, 2017.

Geotechnical investigations have been conducted at the Grassy Mountain Facility for Landfill Cells 1 through 7, A, X, Y and Z, along with Industrial Waste Cells 2 and 3. Geotechnical investigations have also been conducted for the other facilities at the Grassy Mountain Facility, which are included within Section 16. The previous geotechnical investigations conducted for Landfill Cells 1 through 5, X and Y were conducted by Chen and Associates, Inc. and Chen-Northern, Inc. The Cell 6, 7 and Z investigations were conducted by Applied Geotechnical Engineering Consultants, Inc. The Cell A investigation was conducted by Kleinfelder. Subsurface exploration and laboratory testing were previously conducted in the land treatment area, in which the proposed surface impoundment is located.

A report was provided previously by AGEC for Surface Impoundment B and is dated April 12, 2017 under Project No. 1160276A.

This report has been prepared to summarize the data obtained, to present our conclusions and recommendations based on the subsurface conditions encountered and the proposed construction for Cells 8 through 13. Construction considerations related to the geotechnical engineering aspects of the facility are included.

SITE CONDITIONS

The Grassy Mountain Facility consists of landfill cells and an office/laboratory complex.

The ground surface in the area of the proposed landfill cells is relatively flat and has a gentle downward slope to the east.

The site of the future landfill cells consists of an area that was previously a portion of the land treatment area used to spread and treat contaminated hydrocarbons. This process has since been abandoned and the contaminated soil removed.

Landfill Cell 7 is located along the west end of the north portion of the future landfill cell area. Landfill Cells 4, 5 and 6 are located along the north side. There is a storm water containment pond to the east at the north end of the area that extends to a depth of approximately 7 feet below the adjacent ground surface and has 3 horizontal to 1 vertical side slopes. The former land treatment area extends to the south and to the west of the south portion of the area. There is an office building and parking area for the facility on the east side of the south end of the proposed landfill cells.

Vegetation at the site consists of grass and weeds.

FIELD STUDY

The subsoil conditions in the area proposed for Landfill Cells 8 through 13 have been investigated during this and during previous studies. The locations of borings drilled and cone penetration tests performed in the area of the proposed Landfill Cells 8 through 13 and the proposed surface impoundment are shown on Figure 1. Listed below is a summary of the explorations in the area of proposed Landfill Cells 8 through 13 and the proposed surface impoundment including the dates of the explorations and project numbers.

Boring or CPT	Date of Exploration	Project Number
Borings L-2, L-6, L-8, L-10, L-12, L-14, L-15, L-17 and L-19	April 1992	AGEC #20591
CPTs L-3, L-5, L-7, L-9, L-11, L-13, L-14, L-16, L-18 and L-20	April 1992	AGEC #20591
CPTs L-32, L-33 and L-34	August 1995	AGEC #45995
Borings B-1A, B-2A, B-3A, B-1B, B-2B, B-3B and B-4B	August 2016	(this study)

Borings L-2, L-6, L-8, L-10, L-12, L-14, L-15, L-17 and L-19 were drilled using 8-inch diameter hollow stem auger. Locations of cone penetration test soundings designated by X's on Figure 1, were obtained using standard cone penetration test equipment. Borings B-1A, B-2A, B-3A, B-1B, B-2B, B-3B and B-4B were drilled using direct-push methods.

Borings were logged and samples obtained by engineers from AGEC. Logs for Borings B-1A, B-2A, B-3A, B-1B, B-2B, B-3B and B-4B are presented on Figures 2 through 7 with Legend and Notes on Figure 8. Logs of the other borings designated with "L" are included in Appendix A-1. The results of CPT soundings are included in Appendix A-2.

Water levels were measured several weeks after drilling Borings B-1A, B-2A and B-3A and B-1B through B-4B. Following the water level measurements, the borings were abandoned by introducing bentonite grout into the bottom of the boring and pumping grout to fill the boring. The following notes relate to the abandonment of these borings:

Boring Number	Boring Depth (feet)	Date Grouted	Theoretical Volume (ft^3)	Approximate Volume of Grout Placed (ft^3)	Notes
B-1A	40	9/7/2016	3.1	4½	Grout placed with tremie pipe
B-2A	40	9/7/2016	3.1	4½	Grout placed with tremie pipe
B-3A	100	10/11/2016	7.7	11½	Grout placed with tremie pipe
B-1B	100	10/11/2016	7.7	11½	Grout placed with tremie pipe
B-2B	100	10/11/2016	7.7	9½	Grout placed with tremie pipe
B-3B	100	10/13/2016	34.9	35	Boring re-drilled with 8-inch HSA. Grout placed through auger with tremie pipe
B-4B	100	10/11/2016	7.7	9½	Grout placed with tremie pipe

Notes:

1. Grout was pumped through a tremie pipe in each boring until grout was observed at the surface of the bore hole. Additional grout was pumped in stages as the tremie pipe was removed.

2. The initial portion of the bentonite grout was diluted by the groundwater in the bore hole as the grout displaced the water to the surface. Several additional cubic feet of grout were pumped in each boring, as needed, to ensure that undiluted grout extended to the ground surface. This resulted in a larger grout volume pumped than the theoretical volume.

Borings and CPT soundings from previous studies at the site were backfilled with bentonite at the time of the earlier studies.

LABORATORY TESTING

Laboratory testing was conducted (during this study and previous studies) for the land treatment area to identify the engineering characteristics of the soil obtained from the exploratory borings. Laboratory testing conducted during the study includes natural moisture content, natural dry density, Atterberg Limits, grain size distribution, strength and consolidation. The test results are shown on Figures 9 through 24 and summarized on Table I . Results of laboratory testing from previous studies in the area and adjacent areas are included in Appendix A-3.

Samples obtained from the exploratory borings were examined and classified in the laboratory by the project engineer.

A discussion of the laboratory testing procedures is presented below. The testing procedures are primarily those of the American Society for Testing and Materials (ASTM).

Index Properties - The Unified Soil Classification System (ASTM D-2487) was used to classify the soil. This system is based on index property tests including the determination of natural water content (ASTM D-2216), liquid and plastic limits (ASTM D-4318) and grain-size distribution (ASTM D-422). Results of the moisture content, dry density, Atterberg Limits and percentage of soil passing the No. 200 sieve are presented on Table I.

Consolidation - Consolidation tests (ASTM D 2435) were performed during this and earlier investigations. Consolidation test samples were prepared and placed in a consolidometer ring between porous disks. An initial seating load of 250 or 500 pounds per square foot (psf) was placed on the sample. The sample was then loaded to 1,000 psf, saturated with water and the percent of change in sample thickness was measured with a dial gauge. Additional load increments were applied to the sample as indicated on the consolidation test results. In some cases, the loads were reduced to measure the rebound portion of the consolidation curve. Results of consolidation tests are presented on Figures 9 through 21.

Uniaxial Compressive Strength - Unconfined compressive strength testing was conducted on samples of soil (ASTM D-2166). Each sample was prepared by cutting the ends of the specimen parallel to each other and at right angles to the longitudinal axis of the soil sample. The load was applied continuously and without shock to produce a constant range of deformation until failure occurred. The axial deformation during the tests is recorded. Results of the unconfined compressive strength testing are included on Table I and on the boring logs.

Triaxial Compression - Triaxial compression tests were conducted in general accordance with ASTM D-4767. Samples were prepared by trimming the ends perpendicular to the sample axis and placing it in a latex membrane. The prepared sample was placed in the triaxial cell and was saturated using back pressure saturation. Testing consisted of applying consolidation loads of 1, 2 and 4 ksf and loading the samples to near failure for each load (staged test) or beyond failure for each load (unique point test). Sample strains, loads and pore pressures were monitored throughout each test. Test results are shown on Figures 22, 23 and 24.

SUBSURFACE CONDITIONS

Subsurface conditions at the site were determined by drilling exploratory borings and performing cone penetration tests. Since the subsurface soils consist of multiple layers of silt, sand and clay, the cone penetration tests provided a more detailed subsurface profile.

Based on the explorations, the subsoil profile generally consists of approximately 19 feet of clay to sandy clay overlying interlayered sand, silt and clay. The interlayered sand, silt and clay extends to the maximum depth investigated, which was approximately 250 feet.

Deeper exploration near the proposed cell indicates layers and lenses of clay and sand to a depth of at least 300 feet. A seismic reflection study conducted at the facility indicates a reflective layer at a depth of approximately 520 feet. This reflective layer could be materials that are more consolidated than the upper soils.

Using the reflection study results and more recent shear wave velocities, we have estimated that dense gravels would be encountered at a depth of approximately 380 feet below the ground surface in the area of Cells 8 to 13. We have estimated that bedrock would be encountered at a depth of approximately 600 feet.

The natural clay was found to be interlayered with thin sand and silt layers. Consistency of the clay ranged from very soft to hard. Moisture content of the clay ranged from slightly moist near the ground surface to wet at the water level and deeper. Color ranged from light to olive brown and gray.

The interlayered clay and silty sand had a consistency and density ranging from soft to medium stiff and very loose to medium dense. The soil contains occasional cemented layers. The soil is very moist to wet and olive brown to gray color.

The engineering characteristics of the soils were tested during this and earlier investigations. These parameters have been reviewed and are incorporated into our analysis to estimate the behavior of the soil for the proposed landfill cells.

SUBSURFACE WATER

Water was encountered in all of the borings and cone penetration test holes at the time of the investigations. Water levels measured within the borings are shown on the logs. From the borings, the water level is estimated to be between approximate elevation 4231 and 4232 feet.

PROPOSED CONSTRUCTION

Plans provided show Landfill Cells 8 through 13 each having dimensions similar to Landfill Cell 7 and sharing common embankments (see Figure 1). Each cell will have plan dimensions on the order of 800 feet by 800 feet. Profiles provided show exterior embankment slopes of 2½ horizontal to 1 vertical and interior slopes of 3 horizontal to 1 vertical. The top of the embankments are shown at elevation 4267 feet, which is the same as the design elevation of Landfill Cell 7 and approximately 29 feet above the original ground surface. Embankment crest widths are shown at 20 feet. The lowest points in the interior of the cell will be at the floor sumps which will have elevations of approximately 4242 at the top of the clay liner. Ramps will provide access to the cells at slopes of 10 percent.

The waste mounding is shown with a 3 horizontal to 1 vertical slope from the top of the embankment to approximately elevation 4293 feet. Above the 3 horizontal to 1 vertical slope, the cell cap slopes up at 5 percent to a maximum elevation of 4306 feet. A copy of the profiles provided and considered in the geotechnical analysis including details of the planned liner systems and entry ramps are included in Appendix B.

SEISMICITY AND LIQUEFACTION

A. Seismicity

A bedrock peak horizontal ground acceleration (PGA) of 0.15g was used for our seismic analysis considering a seismic event with a 90 percent probability of not being exceeded in a 250 year period (Petersen et al., 2008). Soil response to the bedrock acceleration was evaluated using the computer program "SHAKE". The results of this analysis are included in Appendix H. Based on the results of the soil response analysis, a horizontal seismic load coefficient equal to the PGA of 0.18g was used for our analysis.

B. Liquefaction

The liquefaction hazard at the site was evaluated based on cone penetration (CPT) soundings conducted at the site in 1992 and 1995. The results of the analysis indicate that some soil layers at the site are susceptible to liquefaction during the design seismic event.

Settlement resulting from liquefaction was analyzed based on available CPT data from the locations indicated on Figure 1. The printouts of the analysis and supporting documents are included in Appendix I.

The liquefaction assessment indicates the following settlement due to liquefaction from a seismic event having a 90 percent probability of not being exceeded in 250 years.

CPT	Liquefaction-Induced Settlement (inches)
L-1	3½
L-3	1½
L-5	1
L-7	1½
L-9	1½
L-11	4½
L-13	1½
L-14	1½
L-16	3
L-18	2
L-20	3½
L31	½
L32	½
L33	½
L34	½

Based on our analysis, we estimate that settlement from liquefaction will be on the order of ½ to 4½ inches for the design seismic event. It is our opinion that the settlement resulting from liquefaction is small compared to the expected settlement from consolidation and would be within acceptable tolerances for a landfill.

STABILITY

Static and dynamic (pseudostatic) analysis of the landfill cells, closure caps and critical interfaces were conducted using the configurations presented in Appendix B.

A. Soil Profile

The soil profile used in the stability analysis was defined from the information obtained from cone penetration tests, exploratory borings and laboratory test results. Material types consist of lean clay to sandy lean clay from the ground surface down to a depth of 19 feet and interlayered silty sand and sandy lean clay below 19 feet.

B. Moisture Conditions

Free water was measured during the field exploratory program at an elevation of approximately 4231 to 4232 feet. The free water level was assumed to be at an elevation of approximately 4234 for the stability analyses. This level is not necessarily the high water level, but was used as a conservative level in the analysis.

The potential of water entering the embankment would be limited to surface infiltration from the exterior portion of the embankment. The interior portion of the embankment will be covered with clay and impervious synthetic liners. With this condition, the embankment was evaluated assuming drained conditions. The natural soils were evaluated for both an undrained and drained condition.

C. Tension Cracking

The potential of tension cracking within the embankment was evaluated assuming that fine-grained soil will be used to construct embankments. Calculations indicate with the stiff, upper, natural soils, the critical height of embankment above which tension cracking would begin is 36 feet. Based on this information and the settlement behavior of embankments on soft foundation soils, tension cracking is not expected to occur and will therefore not influence the stability of the proposed embankment. Calculations for tension crack estimates are presented in Appendix D.

D. Seismic Considerations

Based on the results of a soil response analysis, a PGA of 0.18g was used at the ground surface for stability analysis. This PGA value was used for the seismic coefficient in the pseudostatic stability analysis. This is a conservative approach, since a seismic coefficient on the order of one-half of PGA for pseudostatic stability analysis provides a more representative result. Simplified deformation analysis was performed where the safety factor obtained from the pseudostatic analysis was near or below 1.3. The simplified deformation analysis was performed using methods presented by Bray and Travasarou (2007).

E. Strength Parameters

1. Soil Strength

Strength parameters for use in the stability analysis were determined from the field and laboratory test results conducted for this and previous studies. The testing consisted of unconfined compressive strength tests, triaxial compression tests, direct shear tests, pocket penetrometer tests and Torvane tests. Based on these results, a profile of strength parameters versus depth was developed. The strength parameters are presented in Appendix C.

Strength parameters for the embankment fill and clay liner materials were reviewed from previous investigations. The strength parameters used in this investigation are consistent with those used during earlier investigations. Verification testing of embankment material placed in Landfill Cell No. 2 has been conducted and indicates that the strength parameters used for the stability analysis are conservative.

2. Waste Strength

We have assumed the waste to have a cohesive strength of 100 psf and a friction angle of 25 degrees, which is consistent with the values previously used for evaluation of the existing landfill cells at the site.

Based on a discussion with the landfill operator we understand that the waste placed in Landfill Cells 6 and 7 has consisted of the following:

Waste Material	Fraction
Soil Type Waste	60 to 70 percent
Steel (Pipe, Drums etc.)	15 to 20 percent
Wood, Paper, Plastics etc.	15 to 20 percent

We understand that waste has been placed with a Caterpillar D7 dozer and compacted with a Caterpillar 825 sheepsfoot compactor.

The waste characteristics for hazardous waste landfills are difficult to establish. However, information related to municipal solid waste landfills has indicated a cohesive strength of 300 psf and friction angle of 36 degrees may be typical for waste landfills of similar composition (Bray et al., 2009). In our professional opinion, it is likely that the hazardous waste materials described as having been placed in Landfill Cells 6 and 7 have strength properties similar to or greater than municipal solid waste. Therefore, the strength parameters used in stability analysis should be conservative.

F. End of Construction

With the silty sand to sandy silt used for embankment construction, the strength parameters for both end-of-construction and long term conditions for the embankment were assumed to be in a drained condition, thus, both friction and cohesive strength parameters of the material were used to resist sliding.

During construction of Landfill Cell 2, pore pressures were measured in the foundation soils at shallow depths to determine excess pore pressure build-up and rate of dissipation. During placement of the embankment, it was observed that the pore pressure increase in the foundation soils was small with respect to fill load placed. The excess pore pressures dissipated fairly rapidly. Based on this, the stability of the embankment and cell during construction and filling is adequate.

G. Stability Calculations and Results

A slope stability analysis computer program, Slide 7.0, developed by Rocscience, was used for the analysis except for the interface stability analysis, which was performed using hand calculations. The Spencer method was selected for the analysis. Factors of safety were calculated for the overall landfill cell profile where the failure was allowed to extend through the cell and into the subsurface soil. A typical profile was evaluated as well as a profile for Cell 13 adjacent to the runoff pond.

Overall Stability - Long Term Static - Stability calculations provide a safety factor under long-term static conditions of 2.1 for the typical section and 2.0 for the section adjacent to the runoff control pond. The stability calculation printouts are presented in Appendices E-1 and E-2.

Overall Stability - Long Term Seismic - For the seismic long term condition, the safety factor is calculated to be 1.3 for the typical section and 1.1 for the section adjacent to the runoff control pond (east side of Cell 13). Stability calculation printouts are presented in Appendices E-3 and E-4.

Simplified deformation analysis based on Bray and Travasarou (2007) indicates deformation of 2½ and 3½ inches under seismic conditions for the typical landfill profile and the profile adjacent to the runoff pond, respectively. Small amounts of deformation are predicted based on this analysis, even though the design PGA does not exceed the yield acceleration due to the method being based on spectraL accelerations. Calculations for the simplified deformation analysis are presented in Appendix E-5.

Stability End of Embankment Construction - Based on past experience at the site, it is our professional opinion that the safety factor during placement of the embankment and storage of waste materials will not drop below 2.0 under static conditions.

Closure Cap - Long Term Static - Stability calculations indicate a safety factor of 2.1 for the closure cap under the static condition. Stability calculation printouts are presented in Appendix E-6.

Closure Cap - Long Term Seismic - Stability calculations indicate a safety factor of 1.3 for the closure cap under the seismic condition. Stability calculation printouts are presented in Appendix E-7.

Recommended minimum factors of safety are dependent on the uncertainty of soil strength parameters and the cost of consequences of slope failure. The Environmental Protection Agency recommends use of a minimum safety factor under static conditions of 1.5 for a slope, where the cost of repair is comparable to the cost of construction and if there is no danger to human life or other valuable property if the slope fails with large uncertainty of strength parameters. The corresponding recommended minimum factor of safety under seismic conditions is 1.3.

Based on the subsoils encountered, laboratory test results, stability analysis and given loading conditions, the embankment and landfill cell meet the minimum safety factors under static conditions. Under seismic conditions, analysis indicates that the anticipated deformation of the landfill cells would be relatively small, on the order of 2½ to 3½ inches, which should be within acceptable limits.

H. Interface Stability

1. Soil Protective Cover

Interface stability for the soil protective cover over the landfill liner system was considered. With the use of a welded geocomposite drainage layer, the critical interface in the liner system is between the soil cover and the textured HDPE liner. Based on our experience at the site, a friction angle of 23.8 degrees was used for this interface. To maintain a safety factor of 1.5 against sliding, the height of the soil cover should not extend higher than 10 feet vertically up the slope until materials are placed in the cell sufficient to resist the sliding. Calculations for the soil protective cover interface are presented in Appendix E-8.

2. Entry Ramp

The entrance ramp will be constructed along the interior slope, beginning in a corner of each cell. The ramps will slope at a 10 horizontal to 1 vertical. Soil protective cover material will be placed above the liner materials with a thickness of 3 feet to support traffic into the landfill cell. The soil protective cover will slope down at a 3 horizontal to 1 vertical at the edge of the ramp. The ramp will be 31.5 feet wide. See the ramp details provided in Appendix B. Included within the materials on the ramp from the top down, will be the soil protective cover, textured HDPE, double-sided geocomposite, textured HDPE, and compacted clay liner. With the use of a welded geocomposite drainage layer, the critical interface in the liner system for the ramp is between the soil cover and the textured HDPE liner. Based on our experience at the site, a friction angle of 23.8 degrees was used for this interface. The stability analysis for the ramp indicates static and seismic safety factors of greater than 1.5 and 1.3, respectively. Interface stability calculations for the ramp are presented in Appendix E-9.

3. Closure Cap

The 3 horizontal to 1 vertical slope around the perimeter of the closure cap was considered. The critical interface for this slope is between the compacted clay and textured HDPE. The strength of the clay is assumed to be the controlling strength at the interface between compacted clay and textured HDPE. Safety factors of greater than 1.5 and 1.3 for static and seismic conditions, respectively, were obtained.

The slope of the closure cap above the 3 horizontal to 1 vertical slope is 5 percent. A double-sided geocomposite is planned for use in the closure cap above the 3 horizontal to 1 vertical slope. The critical interface is between the textured HDPE and double-sided geocomposite. Safety factors greater than 1.5 and 1.3 for static and seismic conditions, respectively, are obtained. Calculations are presented in Appendix E-10.

BEARING CAPACITY

Soil bearing capacity with respect to the proposed landfill cell was evaluated. The stability calculations, summarized in the previous section, also models a bearing capacity type failure. A bearing capacity type failure is defined as the lack of strength within the foundation soils for support of the proposed construction. Typically, the bearing capacity of an embankment is evaluated by conducting stability analyses.

Classical bearing capacity calculations have been conducted to determined the bearing capacity of the natural soils with respect to the proposed embankment construction and under the loading conditions resulting from the completed disposal cell. A safety factor of greater than 3 with regards to classical bearing capacity is calculated for the embankment alone, at the level of the softest clay material. In these calculations, it was assumed that the soft clay extends to great depth.

Based on the calculations for bearing capacity and the information obtained during the slope stability evaluation, it is our professional opinion that the natural soils will support the proposed construction and will result in suitable safety factors against bearing capacity type failures. Attached in Appendix F are the classic bearing capacity calculations performed with regards to the proposed embankment and cell.

Bearing capacity of the clay liner was evaluated to determine the loads that can safely be supported by the clay. The analysis indicates that the clay can support an allowable load of 1,500 pounds per square foot under static conditions. Under impact loading conditions, a bearing capacity of 2,000 pounds per square foot may be used.

Bearing capacity of the soil protective cover material was evaluated to determine the loads that can safely be supported by the cover material. Calculations indicate a static allowable bearing capacity to be:

$$q_{all} = 250\ (B) + 600\ (d)$$

Where q_{all} = allowable bearing pressure (psf)

B = load width (feet)

d = depth of embedment (feet)

Under temporary loading conditions the q_{all} values may be increased to:

$$q_{all} = 375\ (B) + 900\ (d)$$

Bearing capacity calculations are included in Appendix F.

SETTLEMENT

Prior to construction of Landfill Cell X, Cell Z and the stabilization facility, settlement platforms were installed on the original ground surface. Measurements were taken for up to 3 years during and after construction. From these measurements, the time rate of settlement has been estimated along with settlement magnitudes.

In addition to the monitoring described above, elevations of the tops of embankments for Landfill Cells 4, 5, 6B, 7 and Z have been measured over many years. Prior to estimating the settlement for the proposed landfill cells, we obtained these measurements from Hansen, Allen and Luce and used this information to calibrate our model used to predict settlement at the site. Based on the difference between embankment design elevations and the most recent survey information provided, the tops of the embankments of Landfill Cells 5, 6B, 7 and Z have settled on the order of 65 to 75 inches and additional settlement is anticipated to result in settlement being on the order of 65 to 90 inches for the tops of these existing embankments. The magnitude of this settlement is influenced by the load of the embankment fill at the point that was surveyed as well as adjacent loads such as adjacent embankments and landfill waste.

A settlement model was used to estimate settlement for the landfill cells. The model is based on the evaluation of measured settlement at the site as discussed above. Subsurface conditions obtained from explorations and laboratory test results and previous settlement monitoring were also considered in development of this model.

Settlement profiles are presented in Appendix G. Seven cross sections were analyzed and estimated settlement profiles are presented to provide information for planning of the proposed landfill cells. Cross sections are cut through the high portion of the landfill cells, along the shared embankment and through sumps.

Calculations indicate that settlement below the proposed embankments could be up to approximately 105 inches near the center of the cells where there are waste cells adjacent to both sides of the embankments. The embankment settlement is estimated to be on the order of 72 inches at the center of cells where there is a landfill cell on only one side of the embankment. The past survey data would suggest that the embankment settlement may be on the order of 20 percent less near the corners of the cells versus the central part of the embankment. Settlement in the central part of the cells below the mounded waste is estimated to be on the order of 140 inches.

Time rate of settlement, as measured indicate the following percentage of settlement with respect to the time period required for settlement to occur. This time rate is based on the past settlement measured at the top of embankments over time with projected future settlement.

Time (years)	Percentage of Settlement
7	50 percent
15	70 percent
22	90 percent

CONSTRUCTION CONSIDERATIONS

Based on the subsurface investigation, the proposed embankment materials, and our experience in the area, the following considerations are presented for design and construction of the proposed landfill disposal cells.

A. Foundation Preparation

Foundation preparation should consist of removing disturbed soils in the proposed landfill cell foundation. Any vegetation or debris that is within the areas to receive fill should be removed. Positive measures should be taken to remove any backfill material in the foundation area that does not meet the compaction criteria.

B. Embankment Construction

1. Materials

   The embankment may be constructed with a mixture of clay, silt or sand soils.

Materials for construction of the embankment are likely available from the surrounding area. If material from areas other than the dunes is used in the embankments, we should be notified to evaluate the potential effect on the stability of the embankments.

2. Compaction

Fill within the embankment should be placed and compacted to at least 95 percent of the maximum dry density as determined by ASTM D-698. The moisture content of the fill should be close to optimum to facilitate the compaction process. Ideally, the moisture content would be within 2 percent of the optimum moisture content.

Fill should be placed in uniform lifts not more than 8 inches thick for compaction. Compaction should be accomplished with heavy compaction equipment. Lifts compacted by hand operated equipment should be no more than 4 inches in thickness.

Based on previous experience at the Grassy Mountain Facility, the first few lifts of embankment material are difficult to compact within specification. Typically, it has been found that the material is moisture sensitive in respect to compaction. Once the moisture of the fill is near optimum and relatively uniform, compaction is more easily obtained. This difficulty has also been encountered as embankments are constructed of fill materials obtained from near the ground surface in the borrow areas. These materials have typically been very dry and very difficult to moisture condition prior to placement and compaction.

3. Erosion Protection

The exterior portions of the embankment should be protected to reduce erosion. Erosion on existing embankments at the site has been reduced by placement and compaction of a graded gravel material. Consideration should be given to using similar material for the exterior portion of the proposed embankments.

4. Construction Quality Control

Construction should be observed and fill tested by a representative of the soils engineer to verify that the material type, densities and moisture contents meet project specifications.

C. Compacted Clay Liner

We understand that the proposed landfill cell will be provided with a low permeable soil liner at least 3 feet thick. Synthetic liners will be placed above the soil liner. A 2-foot thick soil cover will be placed above the synthetic liners.

1. Materials

Clay may be obtained from near the site. Laboratory and field tests conducted during previous investigations indicate that the permeability of the remolded clay ranges from $2x10^{-8}$ to $1x10^{-6}$ cm/sec. The slower permeabilities were obtained on samples remolded at moisture contents above the optimum moisture content. The faster permeabilities were obtained on samples remolded below the optimum moisture content.

The soil used for liner on previous projects is classified as CL, CL-ML and ML based on the Unified Soil Classification System. The percent passing the No. 200 sieve has ranged from 85 to 99. The liquid limits have ranged from 22 to 49 with plasticity indexes from 5 to 25. The soil used for the soil liner have been tested. They had permeabilities of less than $1x10^{-7}$ cm/sec, which is the permeability required by regulation.

Previous liner construction at the site has been accomplished by mining clay from the mud flats and allowing the clay to dry to within a few percentage points of optimum. To consistently achieve the required low permeability, a deflocculent should be added to the clay and the clay should be disced and kneaded with a sheepsfoot compactor while it is drying.

2. <u>Placement and Compaction</u>

Placement and compaction procedures need to be defined to obtain the desired permeability. Many test fills have been constructed and tested. We recommend that a test fill be constructed in the field to determine the construction technique, density and moisture contents required to consistently obtain the permeability required by regulation if other equipment or contractors are considered for the project. Commercial additives have been used in the past to achieve the permeability using on-site clay soils. Previous liners have been constructed using the on-site clay soils mixed with 3 pounds of sodium hexametaphosphate for every 50 cubic feet of loose clay, or 3-1/2 pounds of sodium tripolyphosphate per 50 cubic feet of loose clay. Permeability tests conducted on the compacted clay have found permeabilities to be less than $1x10^{-7}$ cm/sec.

To prevent surface cracking, positive measures should be taken to keep the surface of the clay liner moist.

LIMITATIONS

This report has been prepared in accordance with generally accepted soil and foundation engineering practices in this area for the use of the client for design purposes. The conclusions and recommendations submitted in this report are based on the data obtained from the exploratory borings drilled and cone penetration tests conducted at the locations indicated on Figure 1. Subsurface information obtained for other areas of the site have been added to this information. The nature and extent of variations between exploratory locations may not become evident until excavation is performed. If during construction, soil and groundwater conditions appear to be different from those described herein, this office should be advised at once so that re-evaluation of the recommendations may be made.

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

PROFESSIONAL ENGINEER
11/16/17
JAY R.
MCQUIVEY
No. 177892-2202
STATE OF UTAH

Jay R. McQuivey, P.E.

Reviewed by Douglas R. Hawkes, P.E., P.G.

James E. Nordquist by bw

Reviewed by James E. Nordquist, P.E., G.E.

JRM/bw

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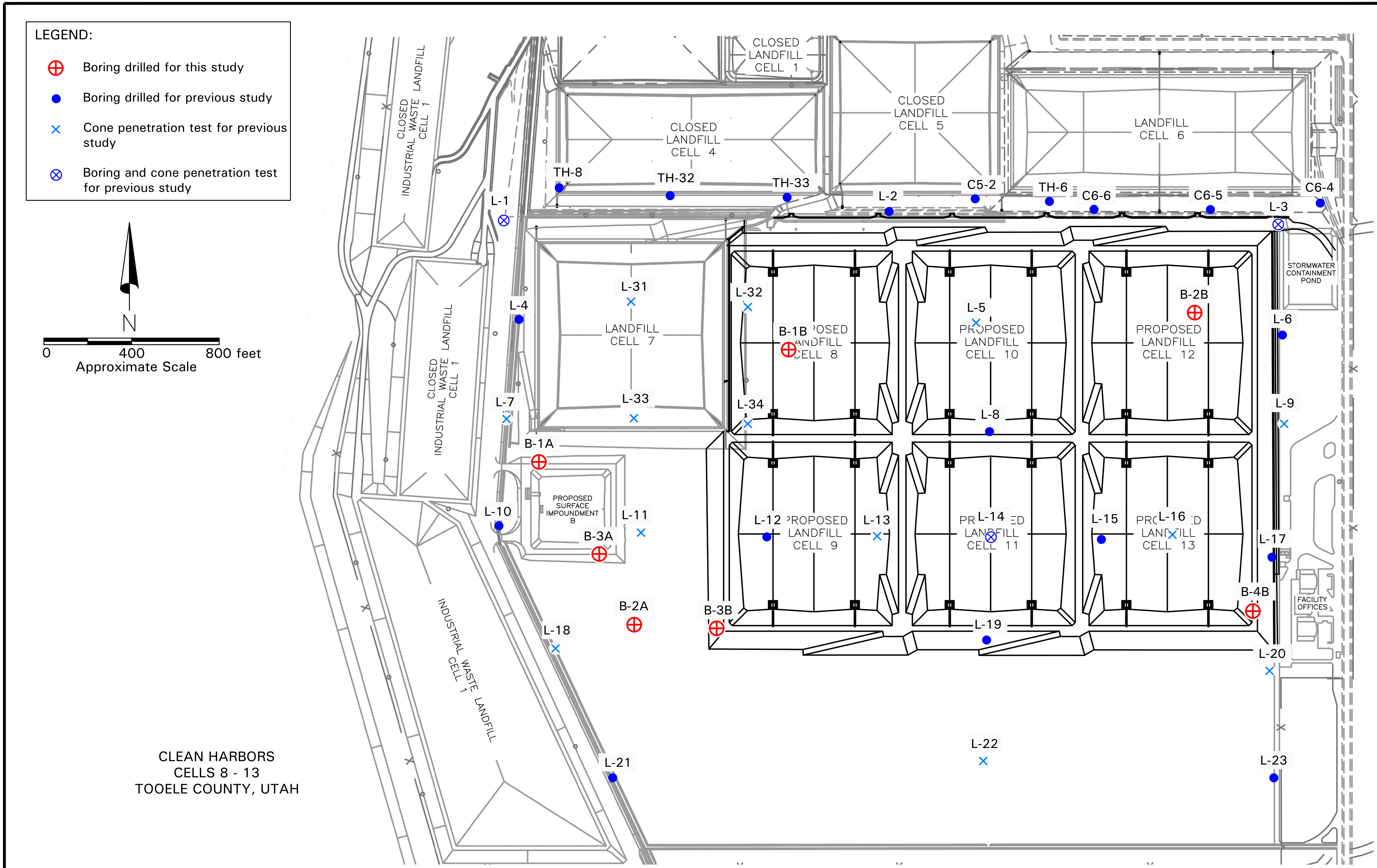
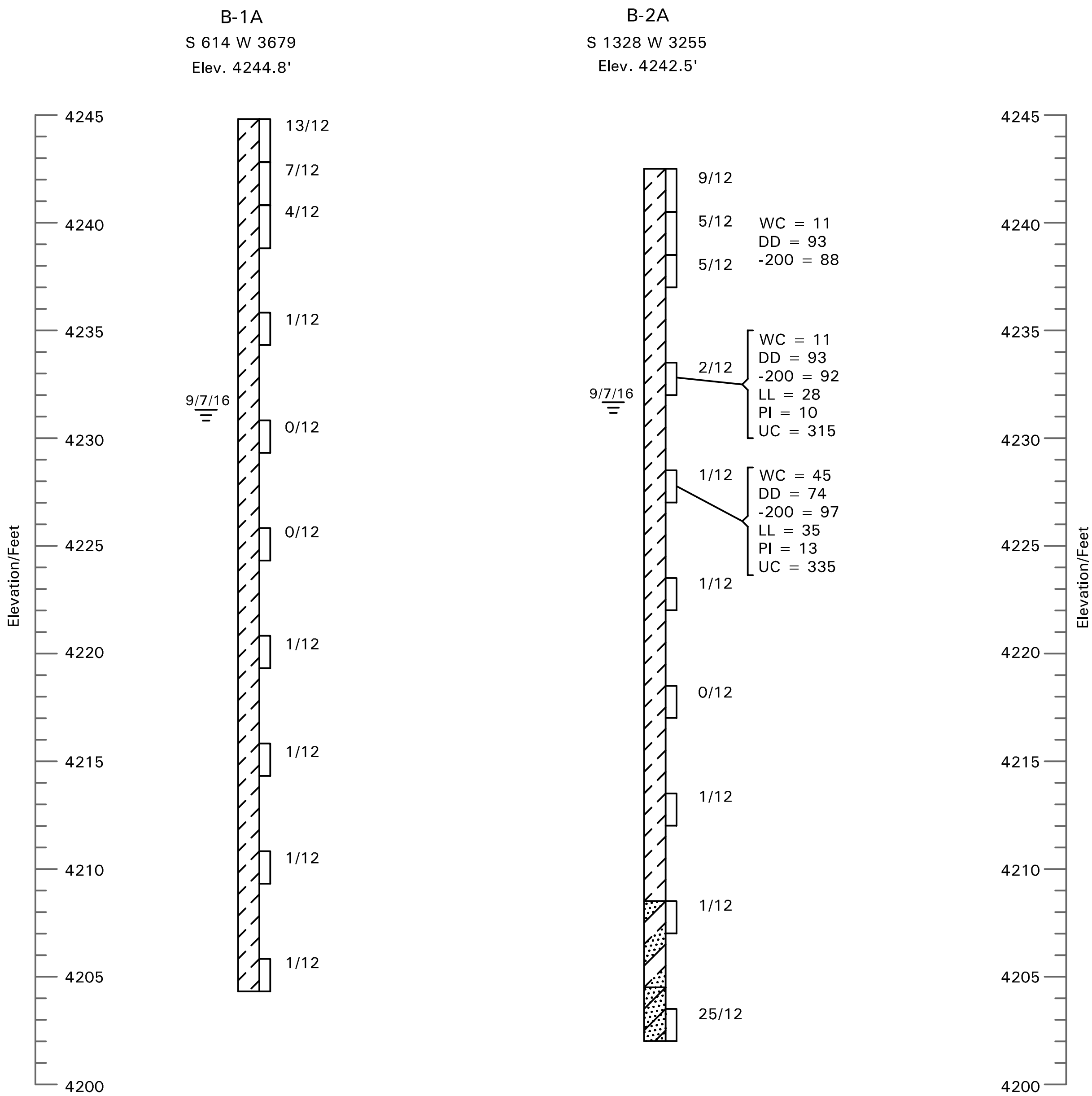
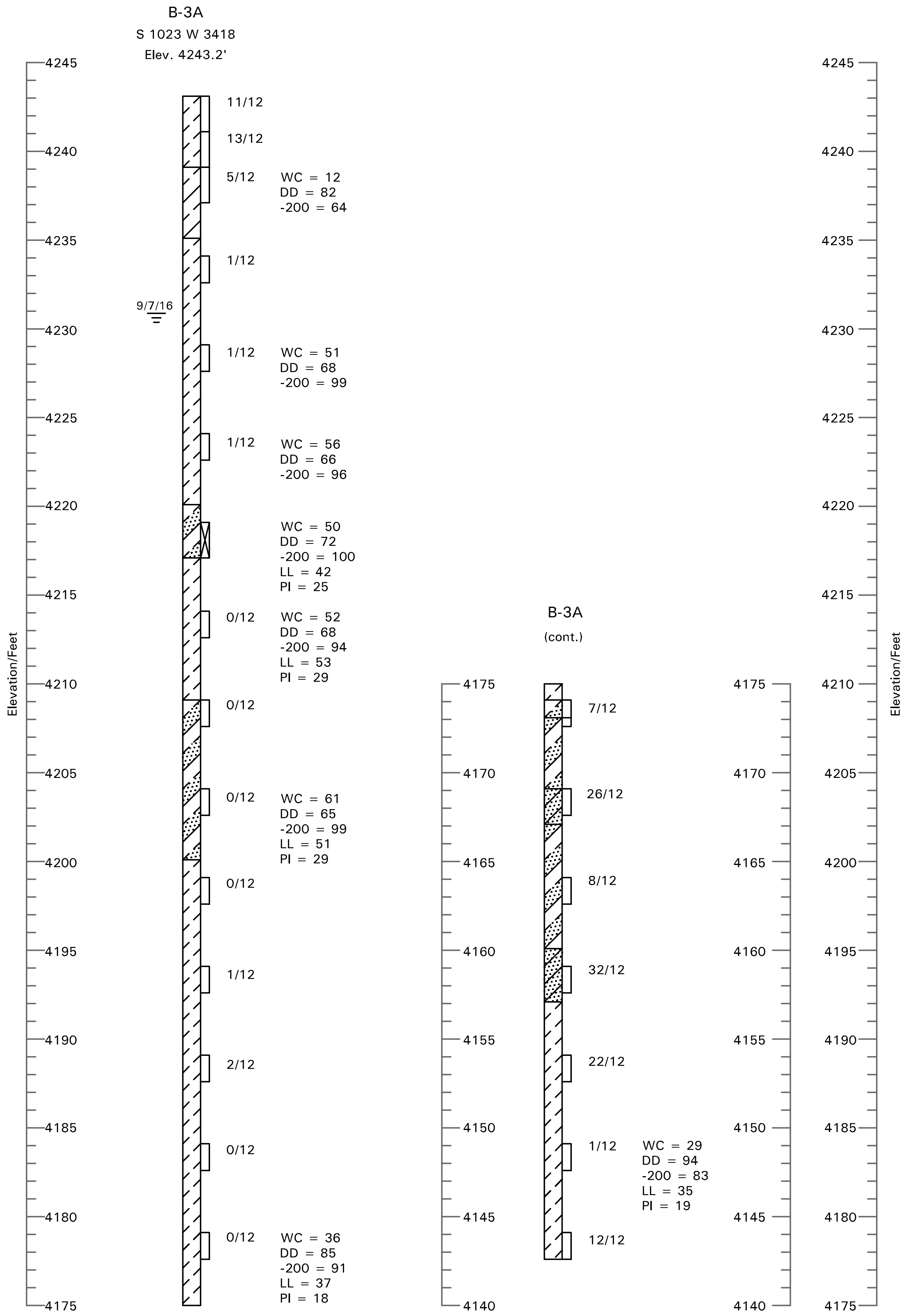


1160276	AGEC	Exploratory Boring Locations	Figure 1



Approximate Vertical Scale 1" = 8'

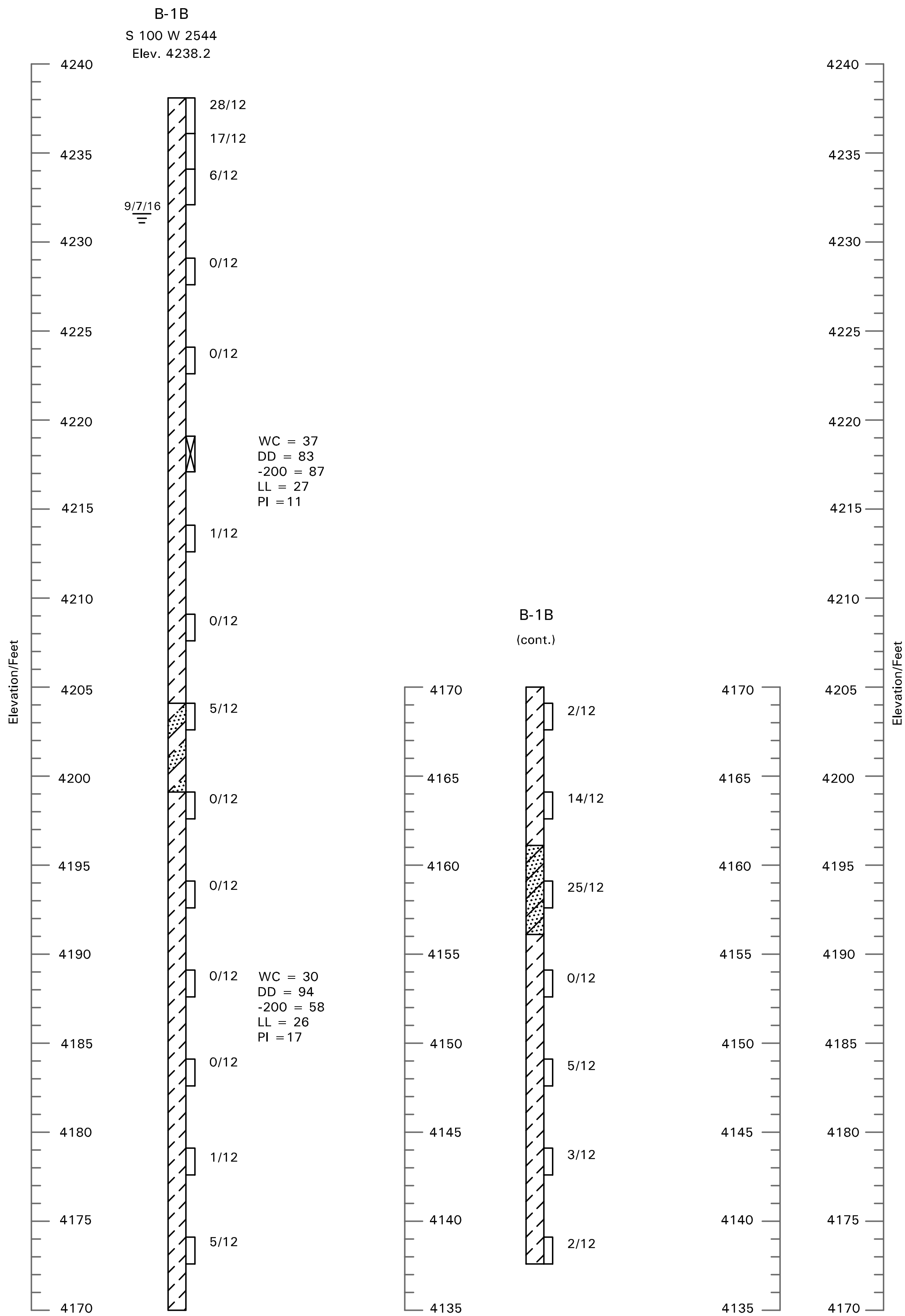
See Figure 8 for legend and notes.



Approximate Vertical Scale 1" = 8'

See Figure 8 for legend and notes.

1160276	AGEC	Exploratory Boring B-3A Log	Figure 3



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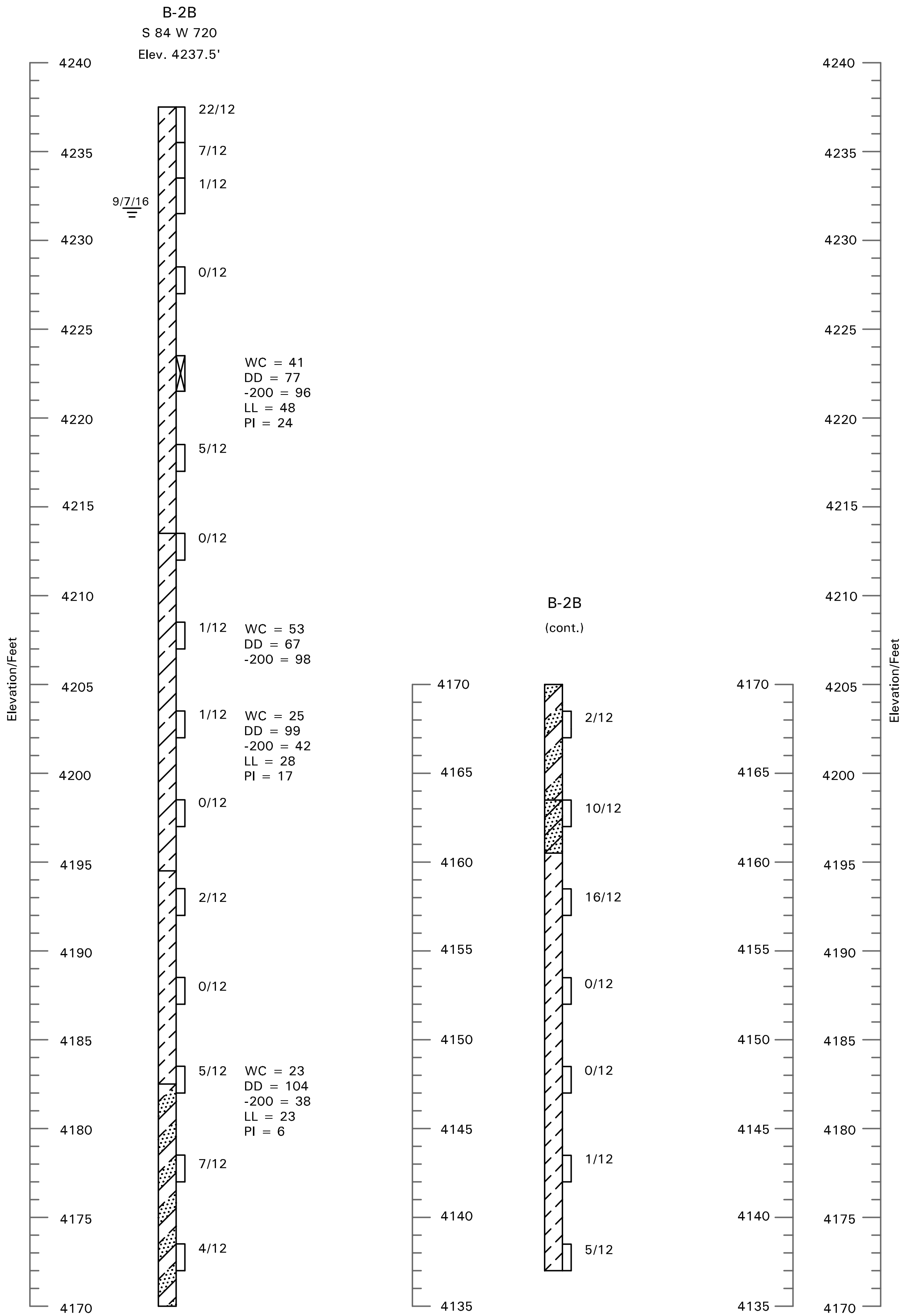
See Figure 8 for legend and notes.

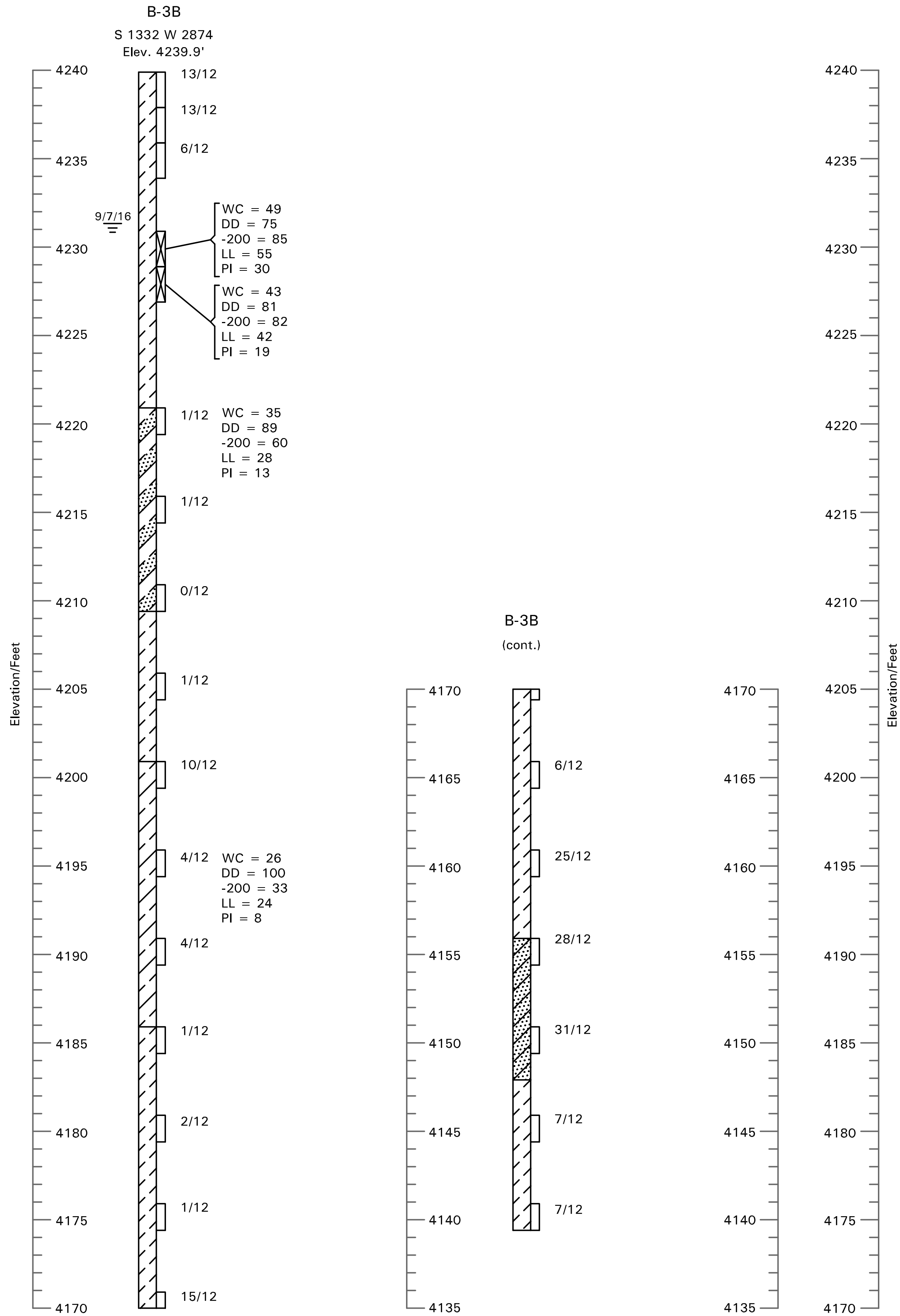
1160276	AGEC	Exploratory Boring B-1B Log	Figure 4



Approximate Vertical Scale 1" = 8'

See Figure 8 for legend and notes.

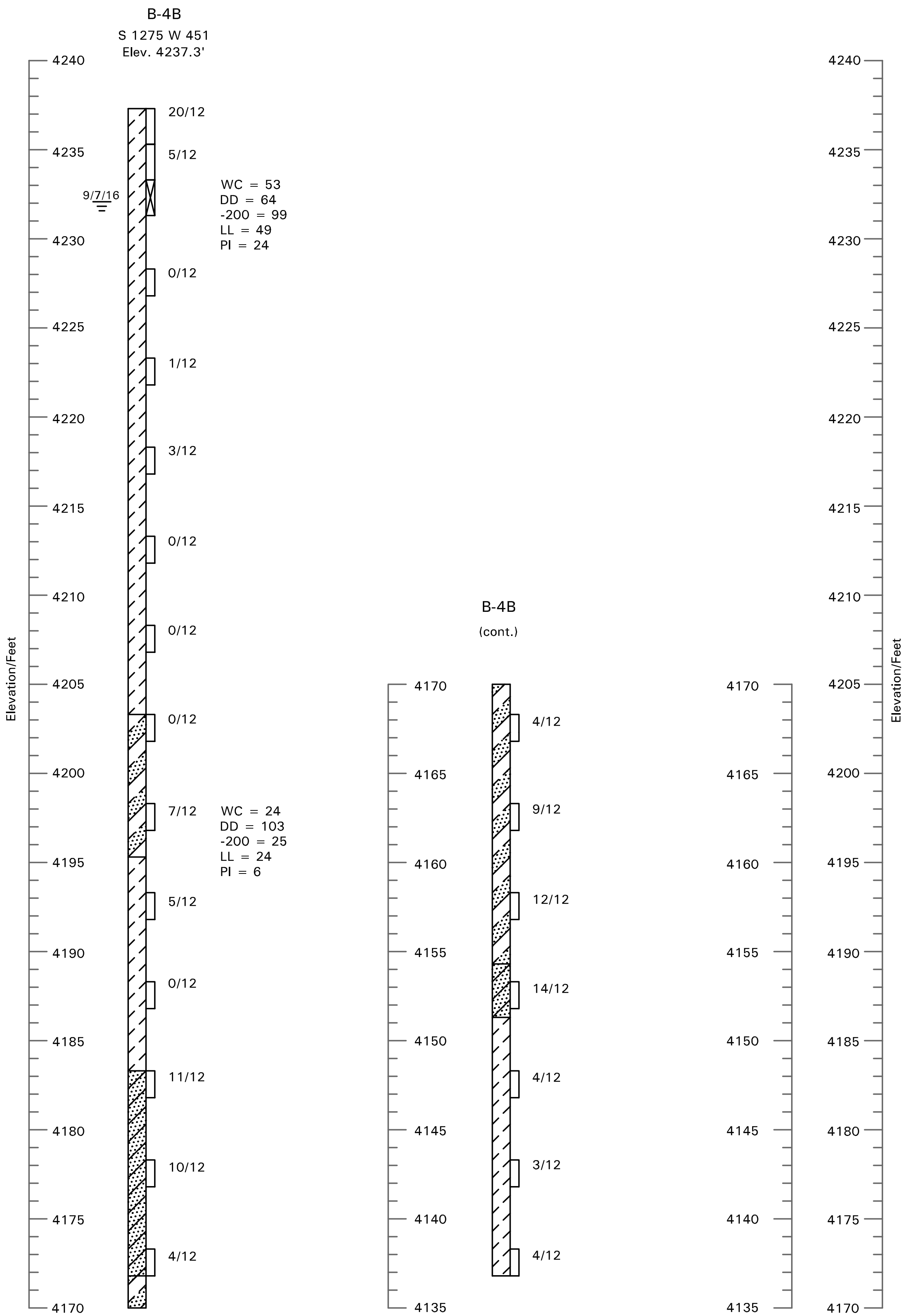
1160276	AGEC	Exploratory Boring B-2B Log	Figure 5



Approximate Vertical Scale 1" = 8'

See Figure 8 for legend and notes.

1160276	AGEC	Exploratory Boring B-3B Log	Figure 6



Approximate Vertical Scale 1" = 8'

See Figure 8 for legend and notes.

1160276	AGEC	Exploratory Boring B-4B Log	Figure 7

LEGEND:

Lean Clay (CL); thin silt and sand layers, occasional cemented layers, small to moderate amount of sand, slightly moist to wet, very hard in the upper 3 to 5 feet, very soft to medium stiff at depth, slightly moist to wet, light brown to gray, sulfurous odor.

Lean Clay and Silt (CL/ML); interlayered, small to moderate amount of sand, silty sand and clayey sand layers, stiff, wet, gray.

Lean Clay and Silty Sand (CL/SM); interlayered, sandy silt layers, soft to medium stiff, medium dense, wet, gray, sulfurous odor.

Silty Sand (SM); clay and sandy silt layers, medium dense, wet, gray to dark gray, sulfurous odor.

10/12 California Drive sample taken. The symbol 10/12 indicates that 10 blows from a 140 pound automatic hammer falling 30 inches were required to drive the sampler 12 inches.

Indicates a Shelby tube sample was taken.

9/7/16 Indicates the depth to free water and the date the measurement was taken.

NOTES:

1. The borings were drilled on August 2 through 10, 2016 using direct push methods.

2. Locations of the borings were measured approximately by pacing from features shown on the site plan provided.

3. Elevations of the borings were surveyed by Hansen Allen and Luce.

4. The boring locations and elevations should be considered accurate only to the degree implied by the method used.

5. The lines between materials shown on the boring logs represent the approximate boundaries between material types and the transitions may be gradual.

6. Water level readings shown on the logs were made at the time and under the conditions indicated. Fluctuations in the water level will occur with time.

7. WC = Water Content (%);
DD = Dry Density (pcf);
+4 = Percent Retained on the No. 4 Sieve;
-200 = Percent Passing the No. 200 Sieve;
LL = Liquid Limit (%);
PI = Plasticity Index (%);
UC = Unconfined Compressive Strength (psf).

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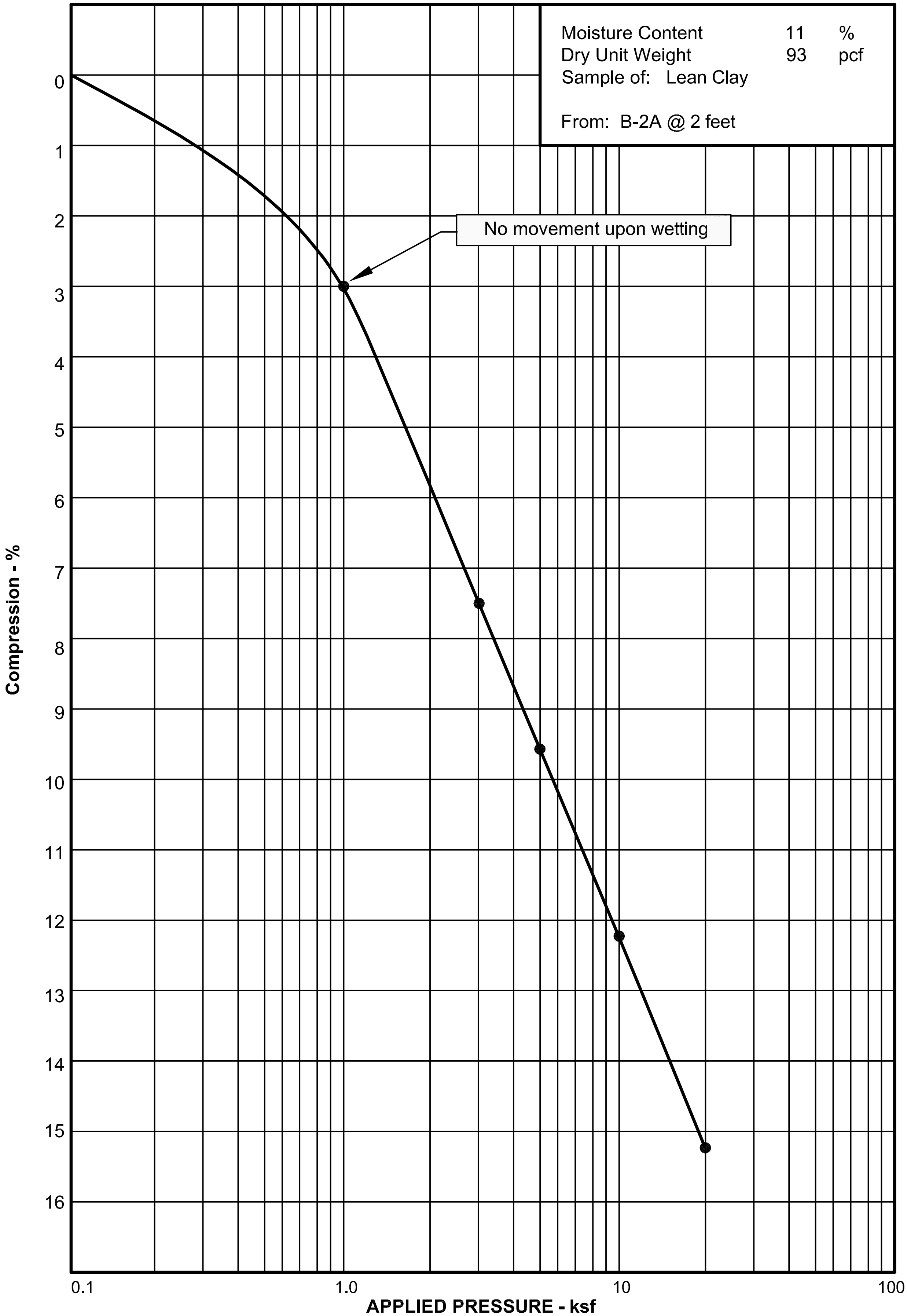
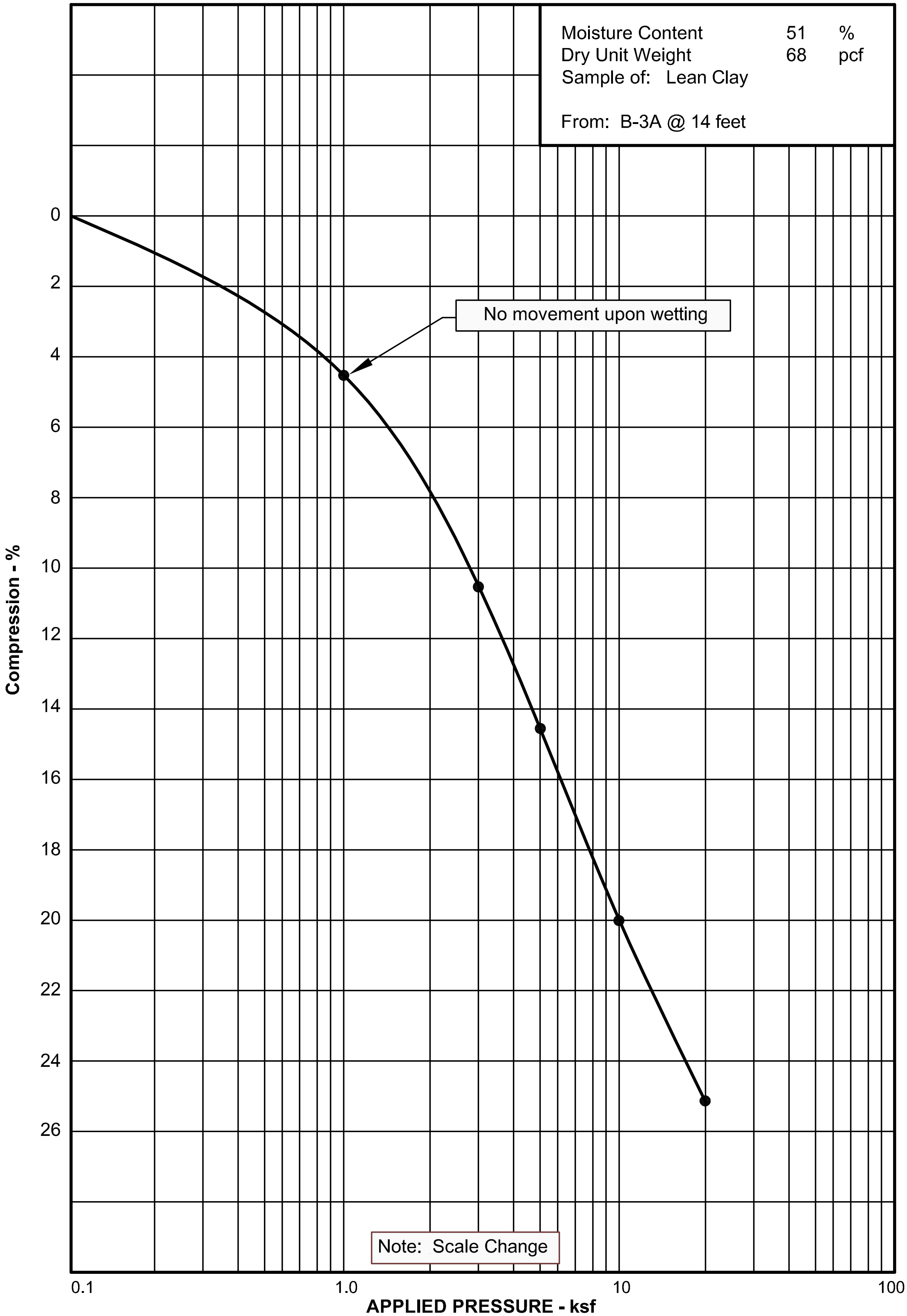


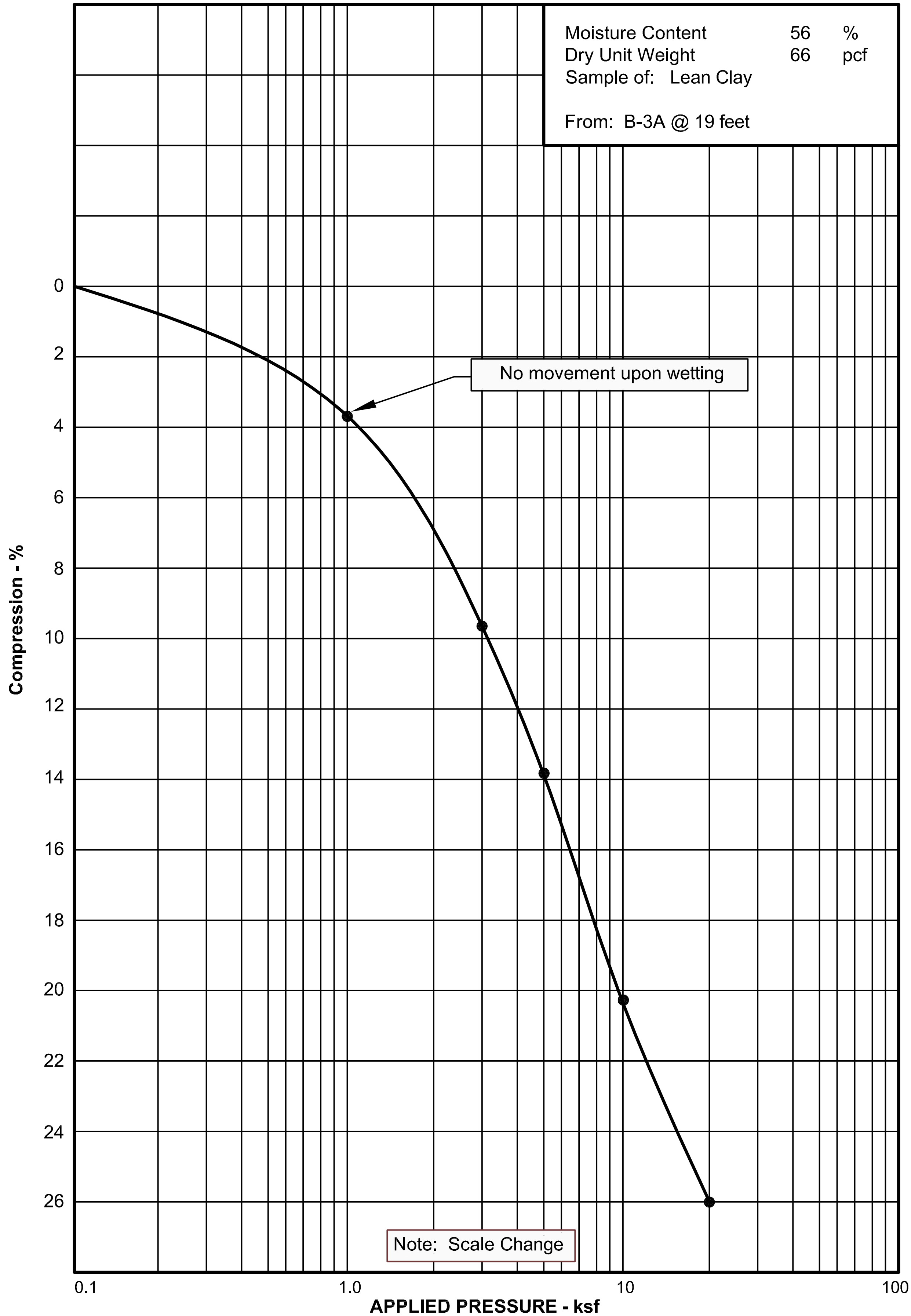
Project No. 1160276 CONSOLIDATION TEST RESULTS Figure 9

Applied Geotechnical Engineering Consultants, Inc.

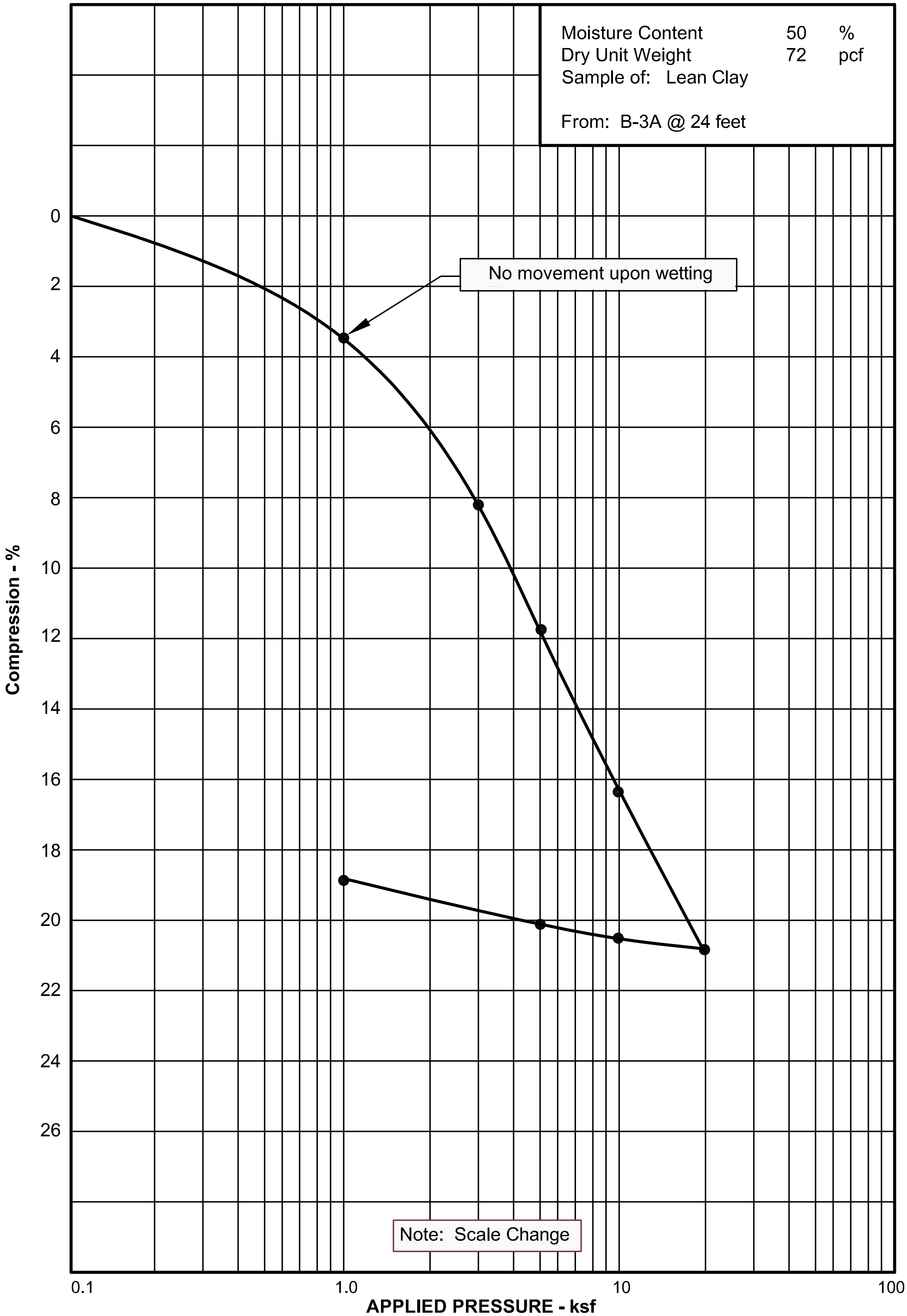


Project No. 1160276 **CONSOLIDATION TEST RESULTS** **Figure 10**

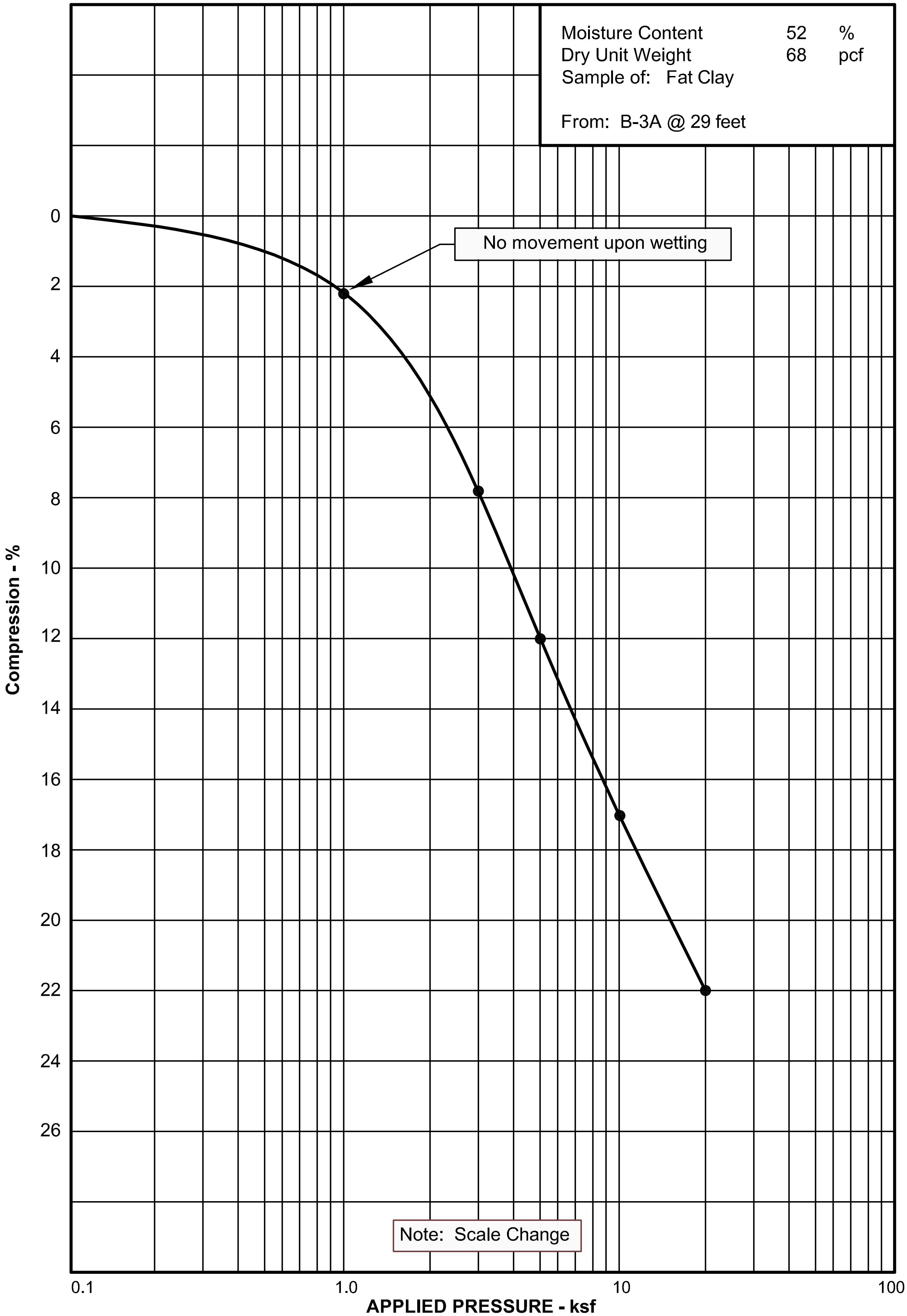
Applied Geotechnical Engineering Consultants, Inc.



Project No. 1160276 **CONSOLIDATION TEST RESULTS** **Figure 11**

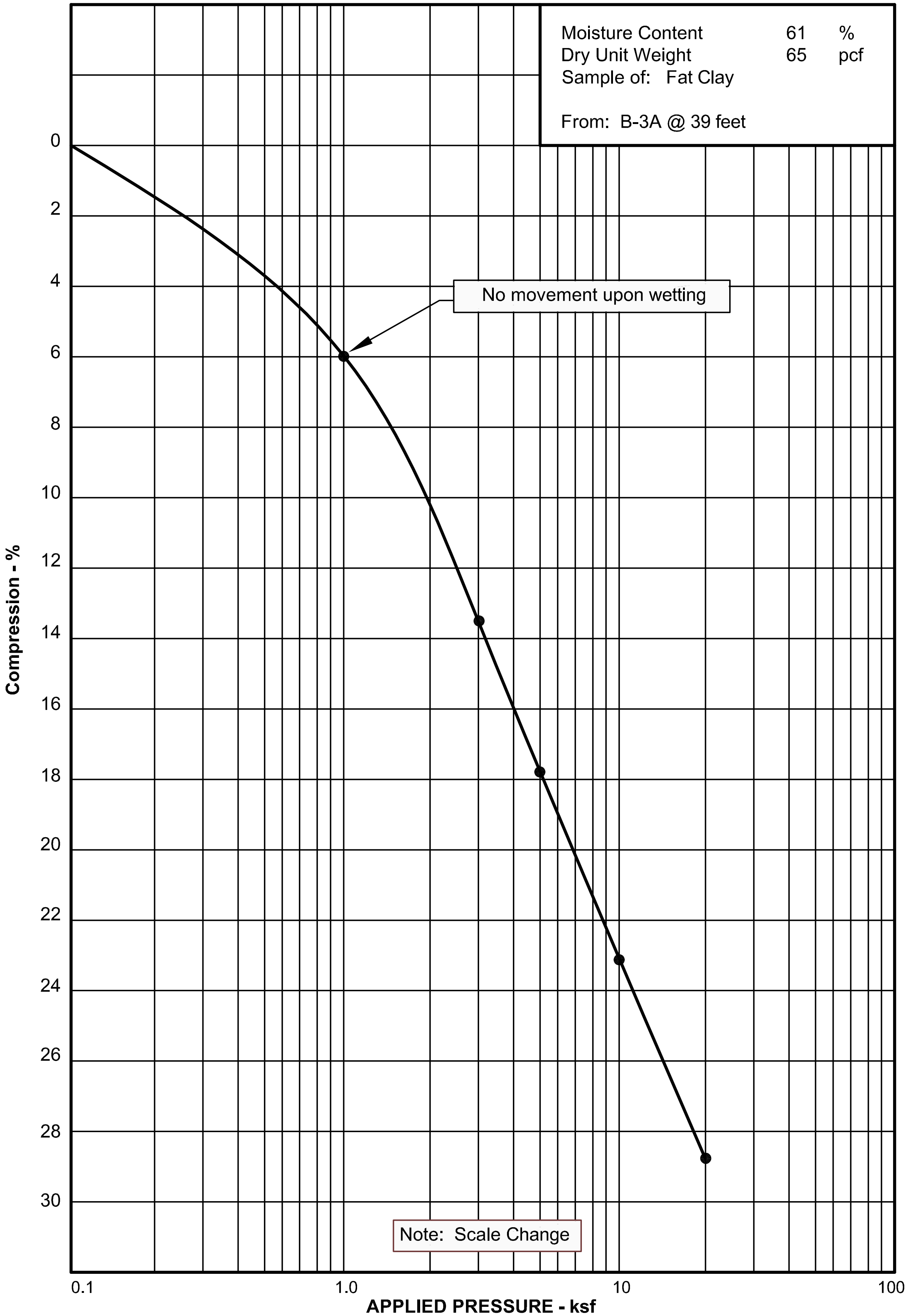

Moisture Content 50 %
Dry Unit Weight 72 pcf
Sample of: Lean Clay
From: B-3A @ 24 feet
No movement upon wetting
Note: Scale Change
Compression - %
0
2
4
6
8
10
12
14
16
18
20
22
24
26
0.1
1.0
10
100
APPLIED PRESSURE - ksf

Applied Geotechnical Engineering Consultants, Inc.



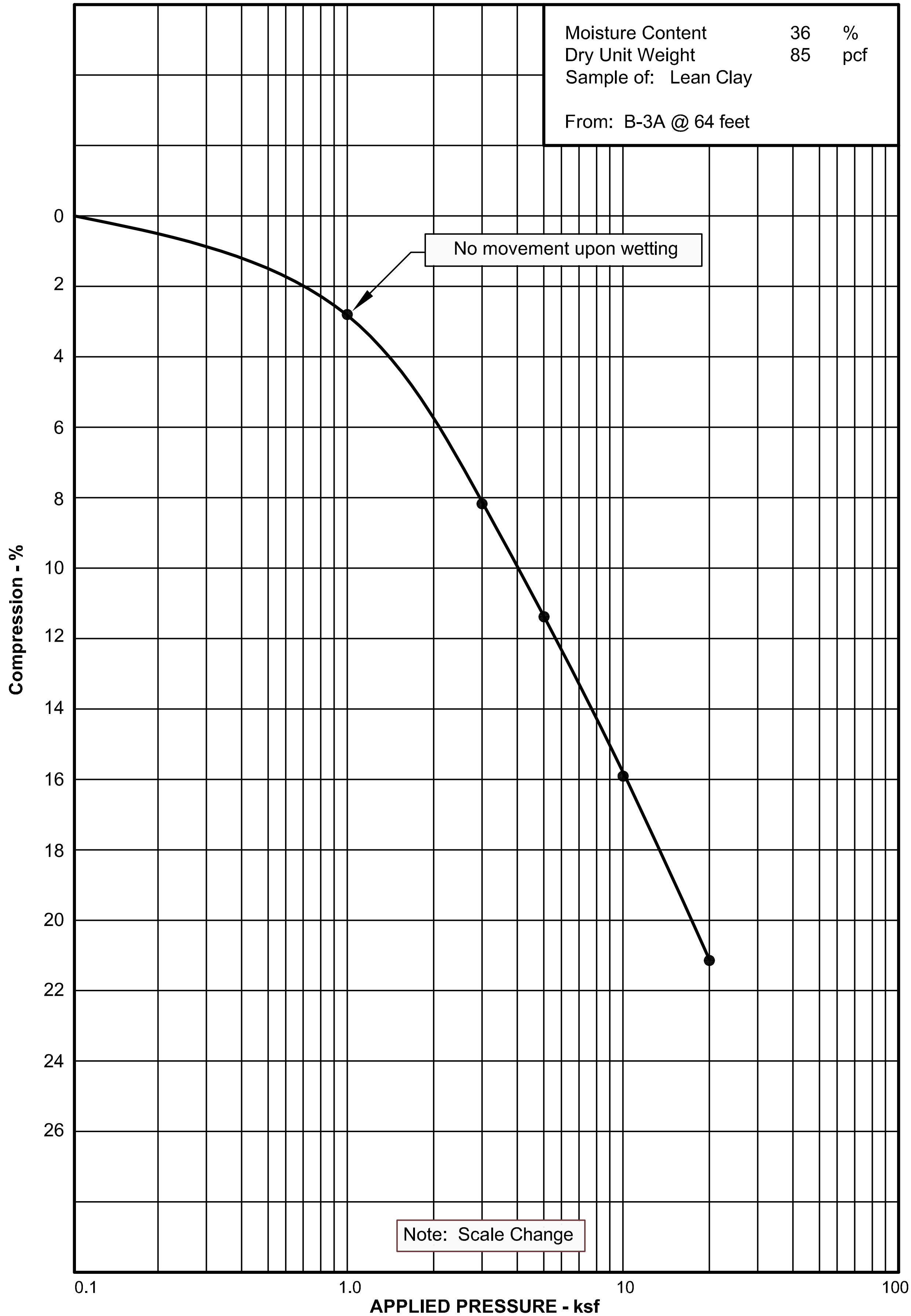
Project No. 1160276 **CONSOLIDATION TEST RESULTS** Figure 13

Applied Geotechnical Engineering Consultants, Inc.



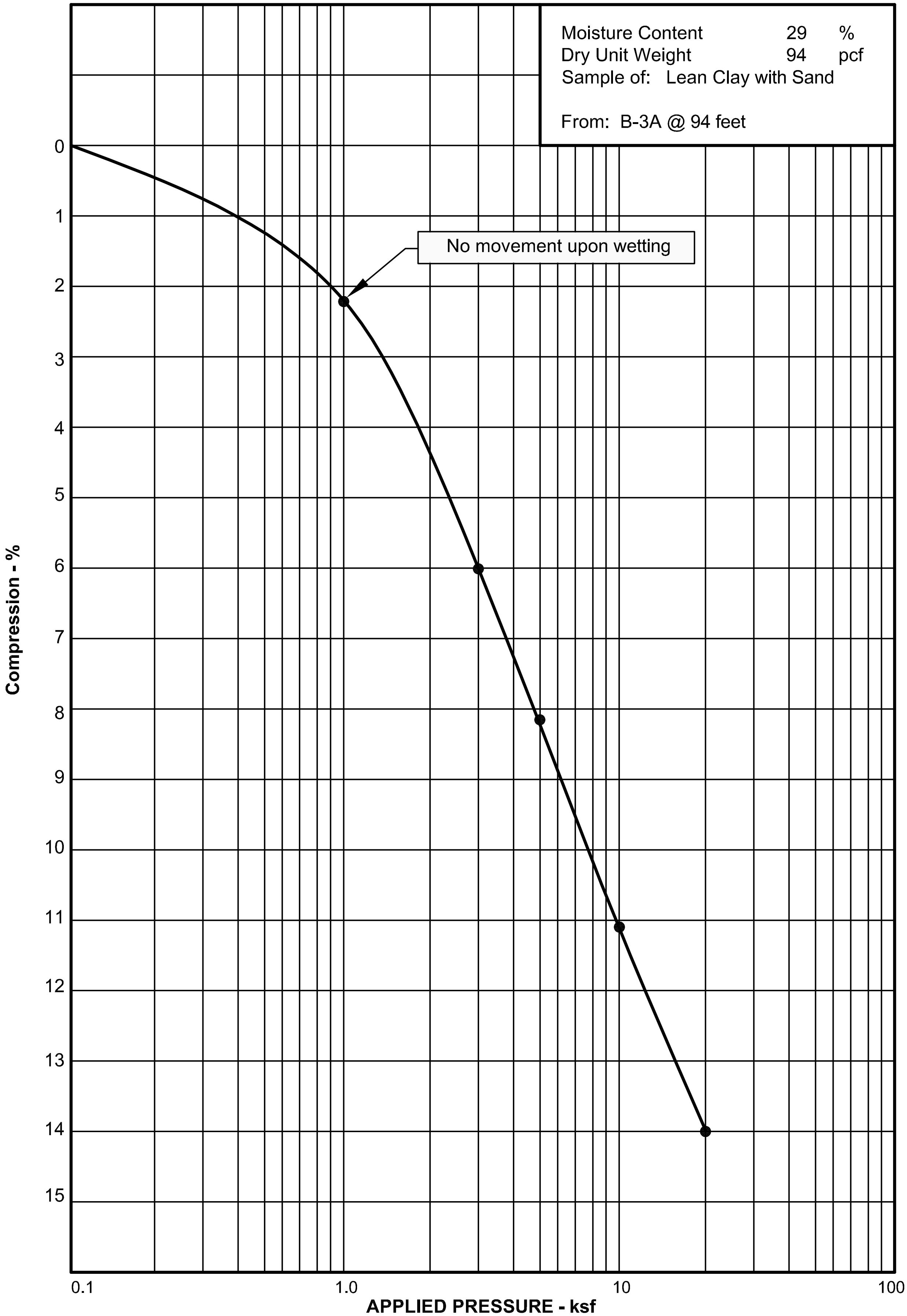
Project No. 1160276 CONSOLIDATION TEST RESULTS Figure 14

Applied Geotechnical Engineering Consultants, Inc.

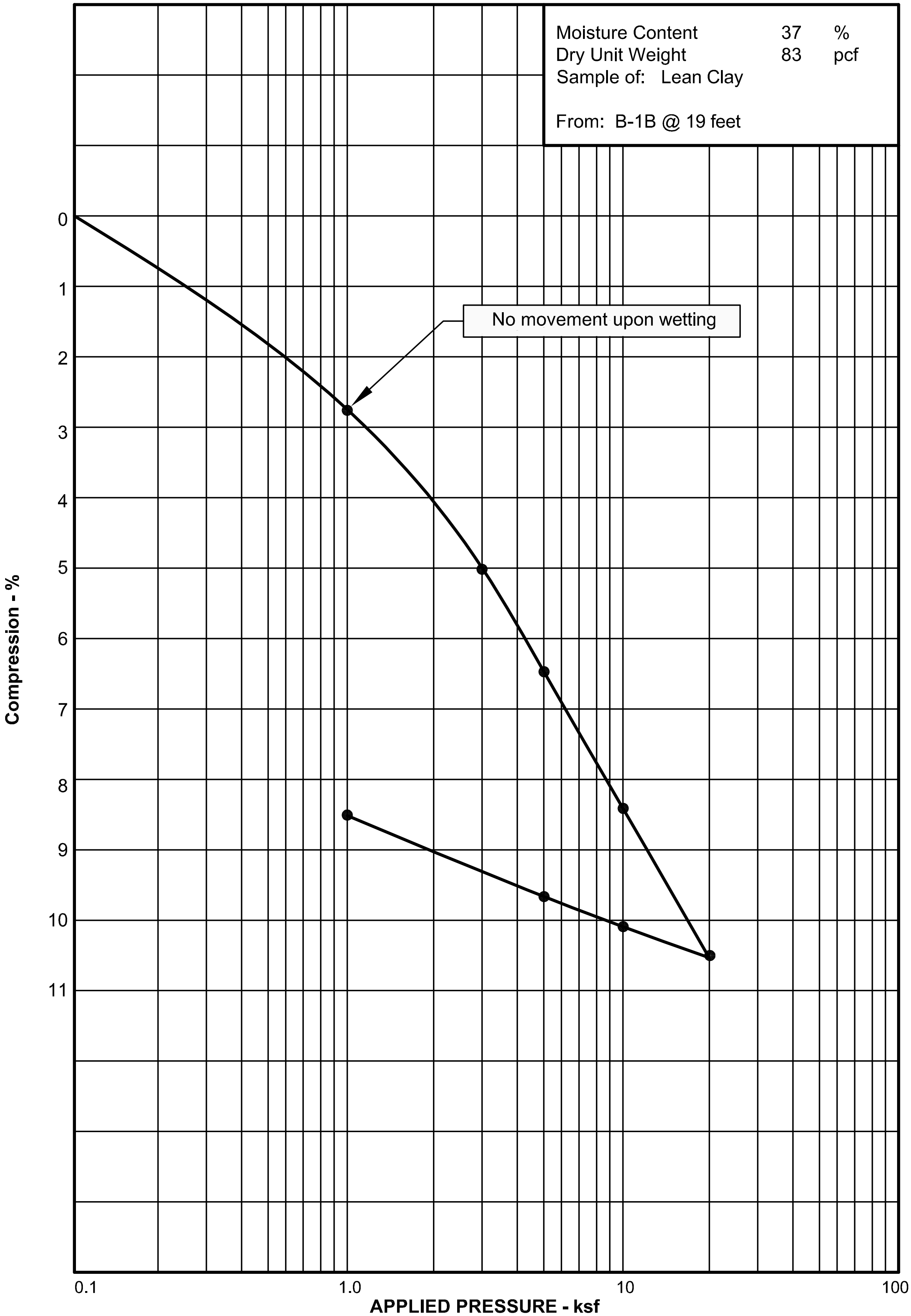


Project No. 1160276 **CONSOLIDATION TEST RESULTS** **Figure 15**

Applied Geotechnical Engineering Consultants, Inc.

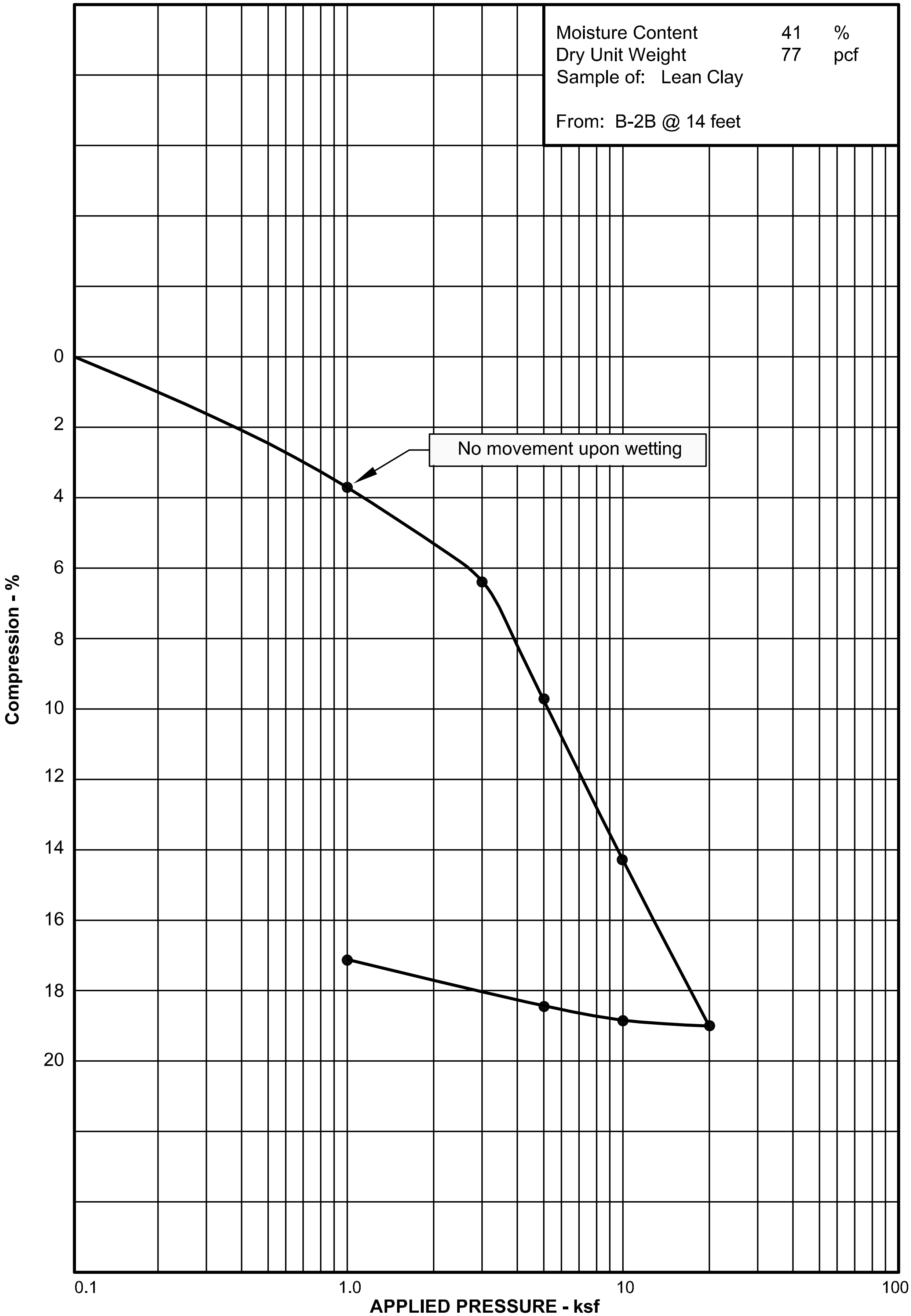


Applied Geotechnical Engineering Consultants, Inc.



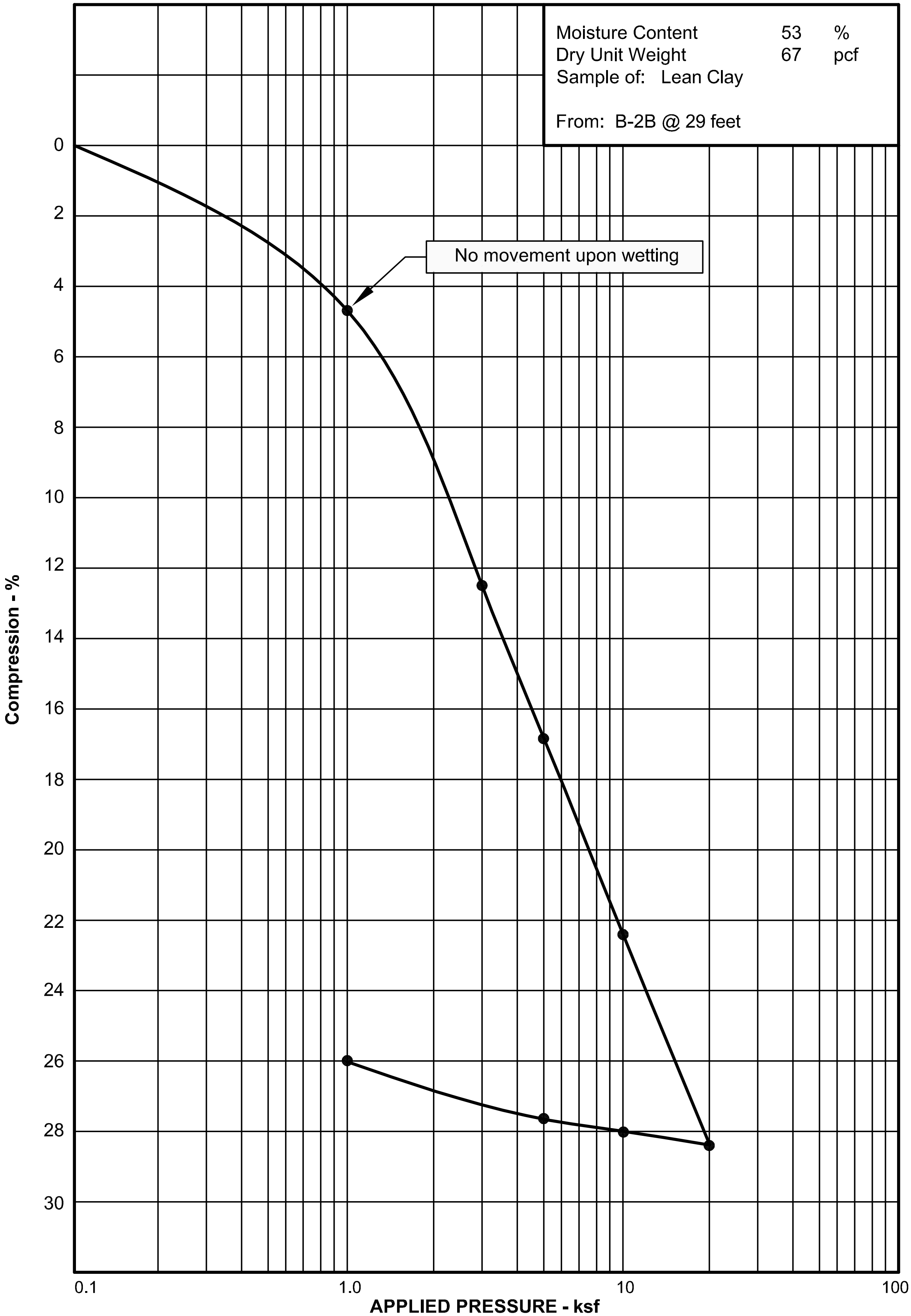
Project No. 1160276 **CONSOLIDATION TEST RESULTS** **Figure 17**

Applied Geotechnical Engineering Consultants, Inc.



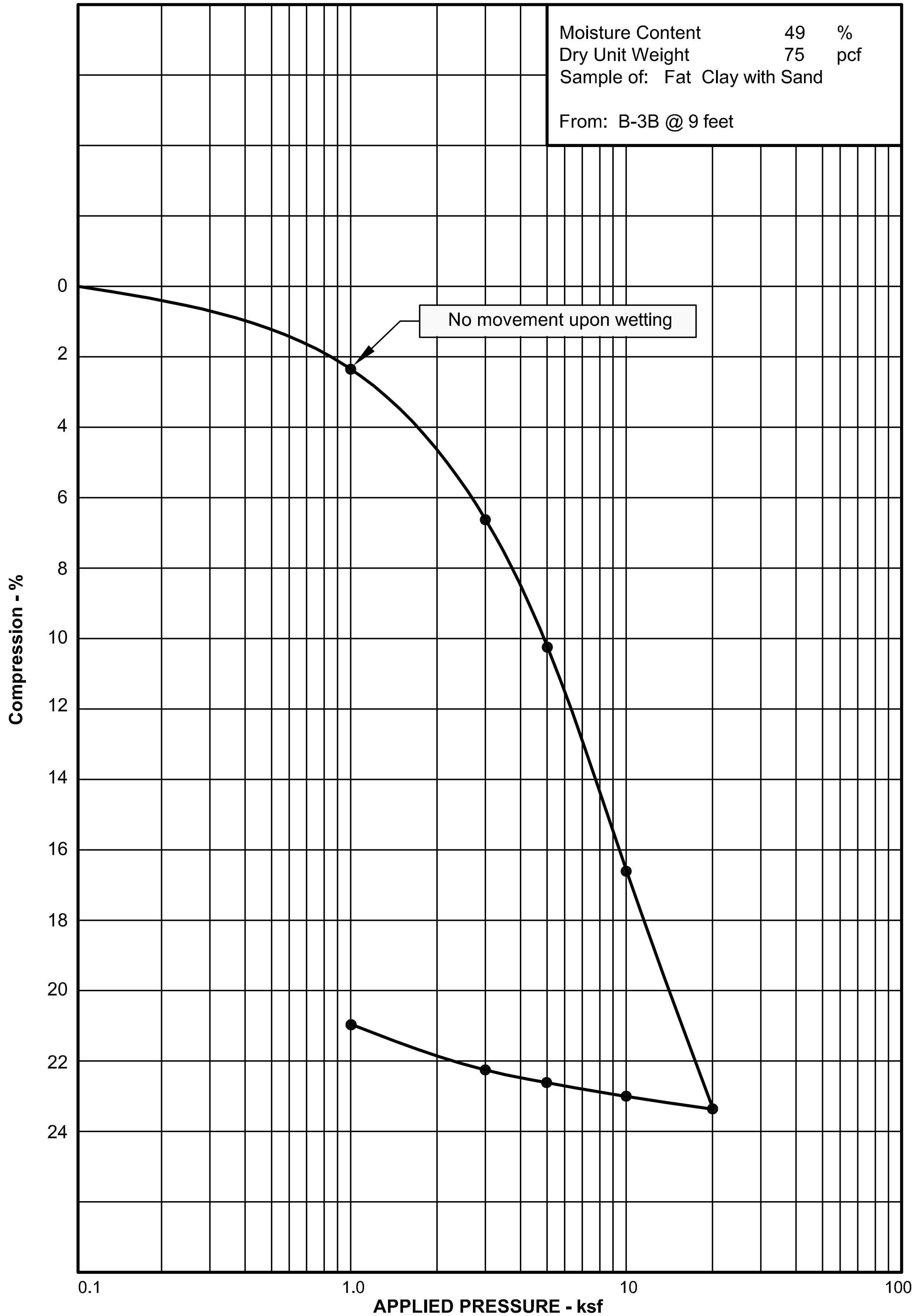
Project No. 1160276 **CONSOLIDATION TEST RESULTS** **Figure 18**

Applied Geotechnical Engineering Consultants, Inc.



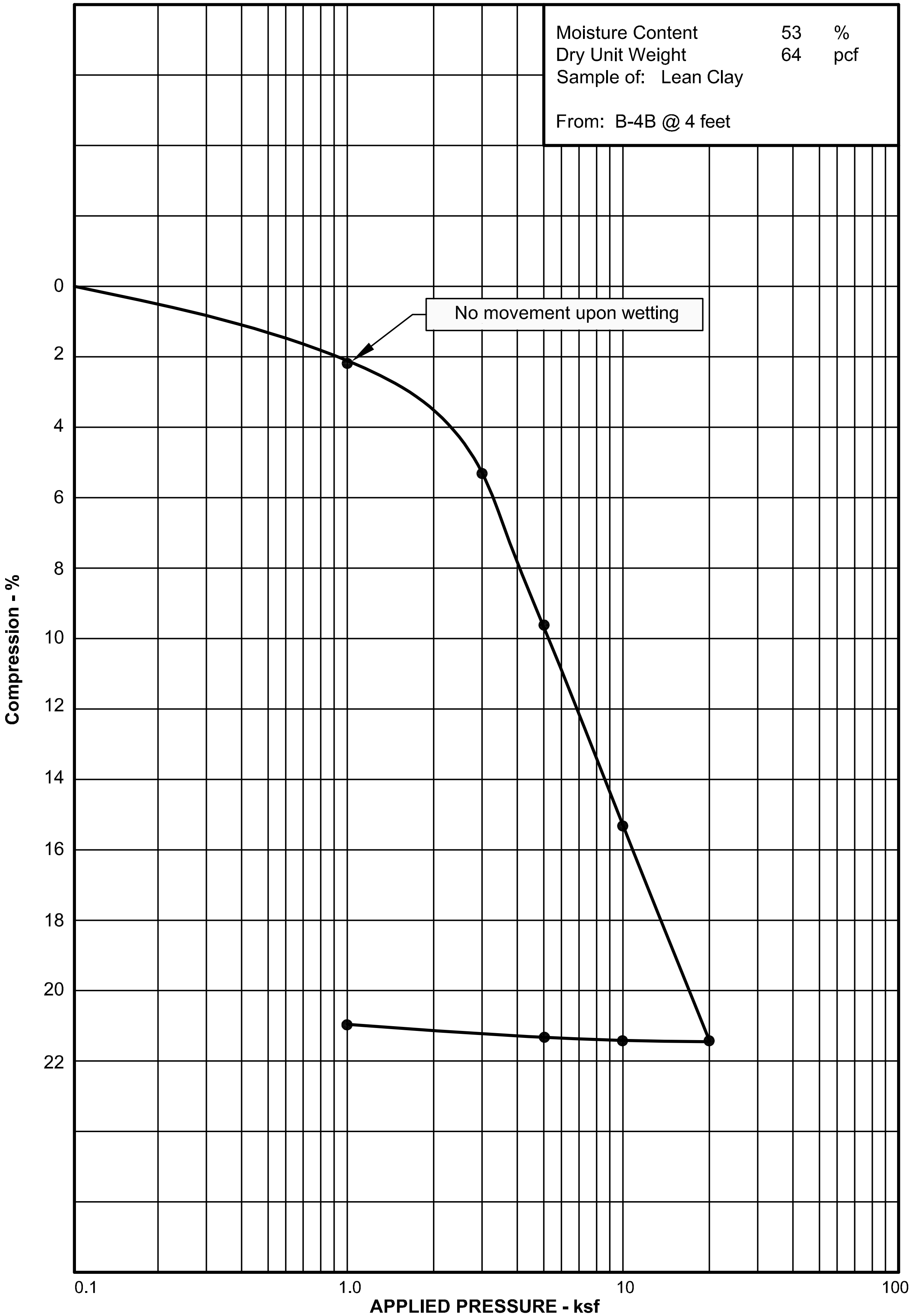
Project No. 1160276 **CONSOLIDATION TEST RESULTS** **Figure 19**

Applied Geotechnical Engineering Consultants, Inc.



Project No. 1160276 **CONSOLIDATION TEST RESULTS** **Figure 20**

Applied Geotechnical Engineering Consultants, Inc.



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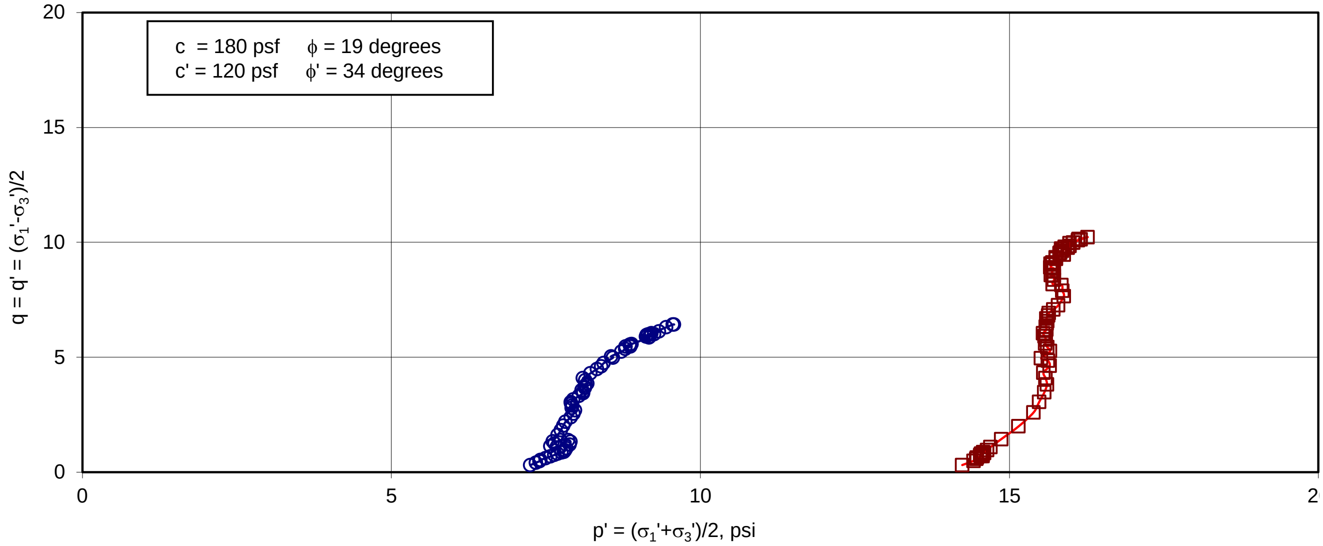
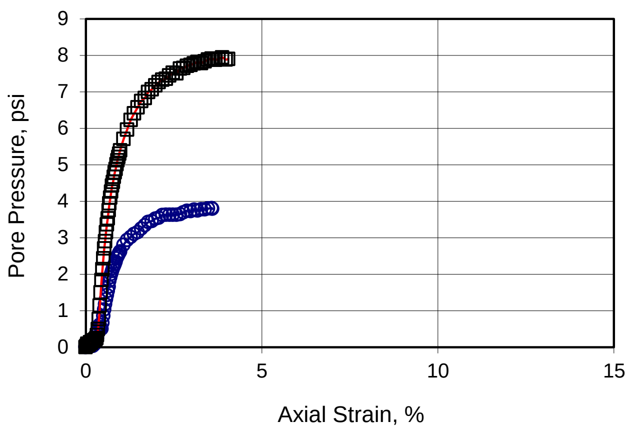
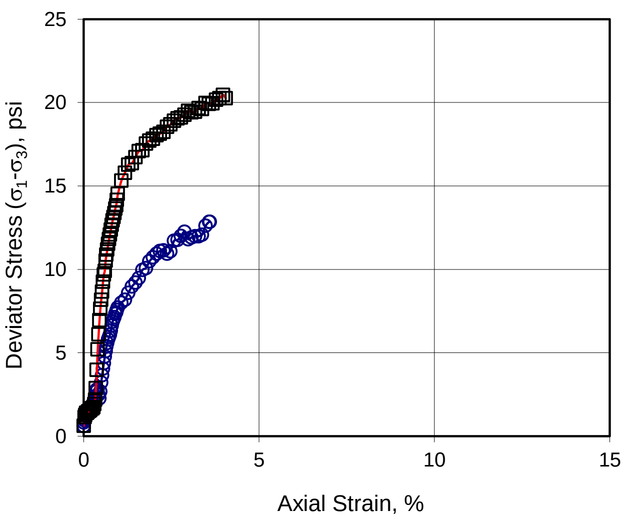






Test No. (Symbol)	○	□	△
Sample Type	Undisturbed		
Length, in.	5.14	4.97	
Diameter, in.	2.33	NM	
Dry Density, pcf	73.3	NM	
Moisture Content, %	48.8	NM	
Consolidation Pressure, psi	6.9	13.93	
"B" Parameter	97	NA	
Total Confining Stress (σ_3), psi	6.9	13.9	
Total Axial Stress (σ_1), psi	18.8	33.4	
Deviator Stress (σ_1-σ_3), psi	11.8	19.5	
Effective Lateral Stress (σ_3'), psi	3.2	6.2	
Effective Axial Stress (σ_1'), psi	15.0	25.7	
Pore Pressure (μ), psi	3.7	7.7	
Strain, %	3.0	3.0	

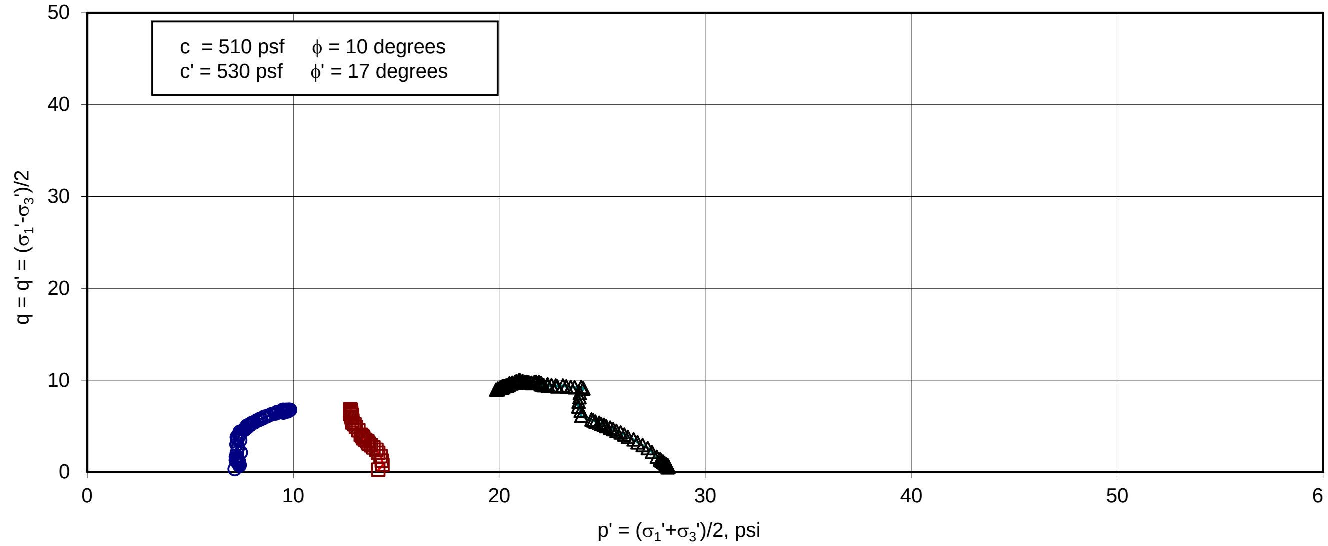
Remarks	Multistage Triaxial Shear Test
Consolidated Undrained (CU) Test	
with pore pressure measurements.	
Sample saturated with back pressure saturation.	
Strength values based on conditions at approximately	
3% strain.	

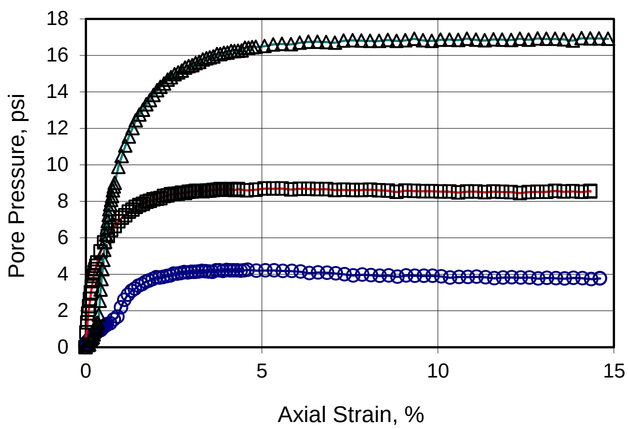
Sample Index Properties	
Ave. Natural Dry Density, pcf	73
Ave. Natural Moisture Content, %	49
Liquid Limit, %	48
Plasticity Index, %	24
Percent Gravel	0
Percent Sand	0
Percent Passing No. 200 Sieve	96
USCS Classification	
Lean Clay	

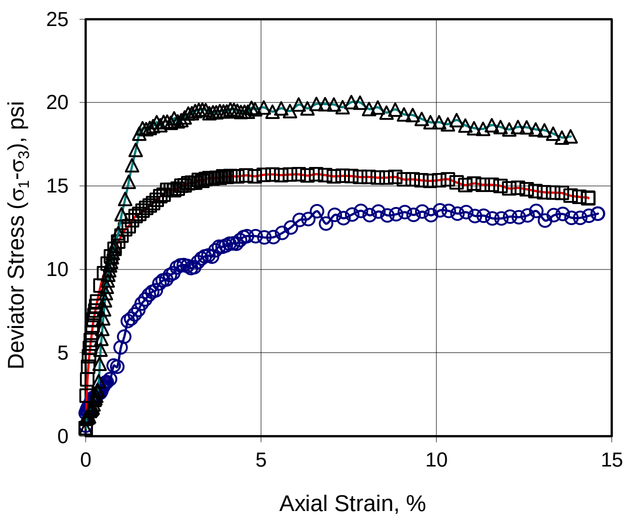
Test Description: Multi-Stage Triaxial Compression Test
Test Sample Location: B-2B at 14' to 16'
Project Name: Grass Mountain

Project No. 1160276 **Triaxial Compression Test** Figure 22

Applied Geotechnical Engineering Consultants, Inc.







Test No. (Symbol)	○	□	△
Sample Type	Undisturbed		
Length, in.	4.89	4.95	4.57
Diameter, in.	2.50	2.49	2.50
Dry Density, pcf	78.6	80.0	78.0
Moisture Content, %	41.9	43.1	42.0
Consolidation Pressure, psi	6.94	13.9	27.8
"B" Parameter	96	97	98
Total Confining Stress (σ_3), psi	6.9	13.9	27.8
Total Axial Stress (σ_1), psi	18.8	29.6	47.5
Deviator Stress (σ_1-σ_3), psi	11.9	15.7	19.7
Effective Lateral Stress (σ_3'), psi	2.7	5.2	11.3
Effective Axial Stress (σ_1'), psi	14.6	20.9	31.0
Pore Pressure (μ), psi	4.2	8.7	16.5
Strain, %	5.1	5.1	5.1

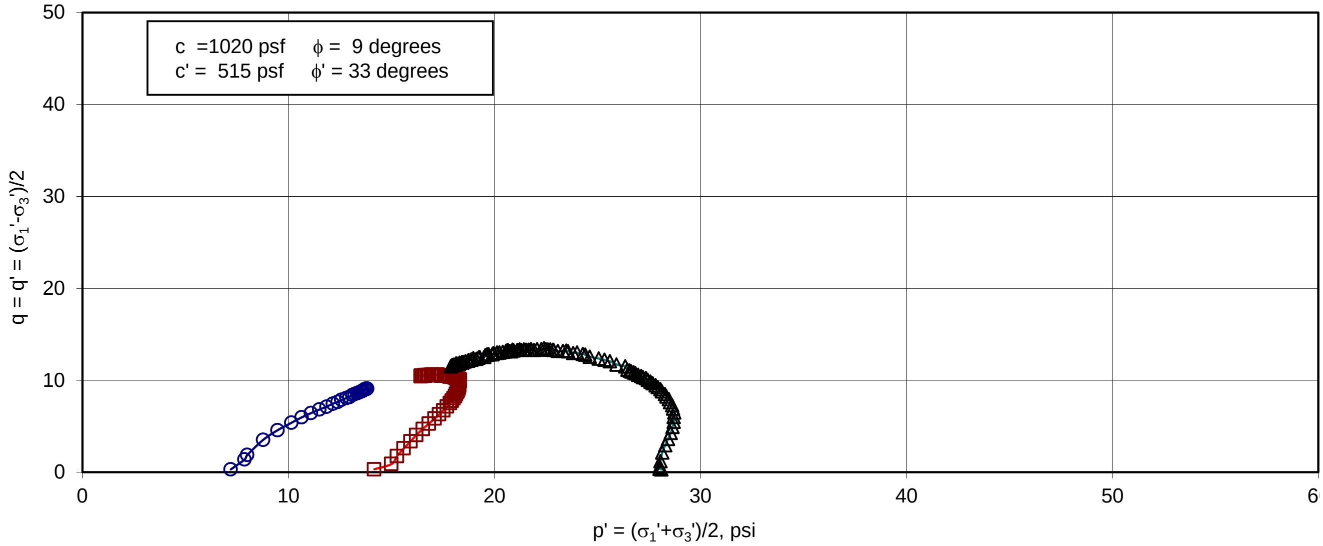
Remarks	Multi-Point Test
Consolidated Undrained (CU) Triaxial Shear Test	
With Pore Pressure Measurements.	
Sample saturated with back pressure saturation.	
Strength envelopes given for conditions at 5.1% strain.	

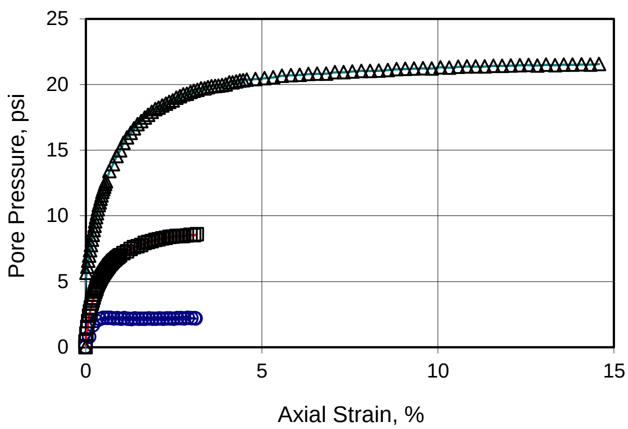
Sample Index Properties	
Ave. Natural Dry Density, pcf	79
Ave. Natural Moisture Content, %	42
Liquid Limit, %	42
Plasticity Index, %	19
Percent Gravel	0
Percent Sand	8
Percent Passing No. 200 Sieve	82
USCS Classification	
Lean Clay with Sand	

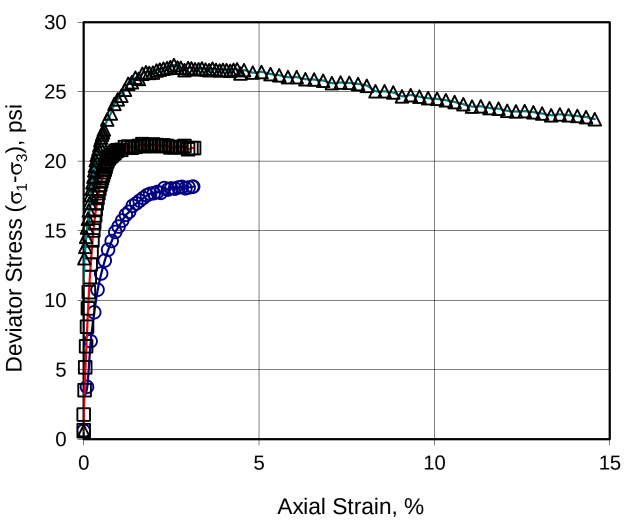
Test Description: Multi-Point Triaxial Compression Test
Test Sample Location: B-3B at 11' to 13'
Project Name: Grassy Mountain

Project No. 1160276 **Triaxial Compression Test** Figure 23

Applied Geotechnical Engineering Consultants, Inc.







Test No. (Symbol)	○	□	△
Sample Type	Undisturbed		
Length, in.	5.75		
Diameter, in.	2.38	NM	NM
Dry Density, pcf	58.7	NM	NM
Moisture Content, %	64.2	NM	NM
Consolidation Pressure, psi	6.9	14.6	27.8
"B" Parameter	96	NA	NA
Total Confining Stress (σ_3), psi	6.9	14.6	27.8
Total Axial Stress (σ_1), psi	25.0	25.4	54.5
Deviator Stress (σ_1-σ_3), psi	18.1	20.9	26.7
Effective Lateral Stress (σ_3'), psi	4.7	6.0	8.4
Effective Axial Stress (σ_1'), psi	22.8	26.9	35.1
Pore Pressure (μ), psi	2.2	8.6	19.4
Strain, %	3.0	3.0	3.0

Remarks: Multistage Triaxial Shear Test
Consolidated Undrained (CU) Test
with pore pressure measurements.
Sample saturated with back pressure saturation.
Strength values based on conditions at approximately
3% strain.

Sample Index Properties	
Ave. Natural Dry Density, pcf	59
Ave. Natural Moisture Content, %	64
Liquid Limit, %	49
Plasticity Index, %	24
Percent Gravel	0
Percent Sand	1
Percent Passing No. 200 Sieve	99
USCS Classification	Lean Clay

Test Description: Multi-Stage Triaxial Compression Test
Test Sample Location: B-4B at 4' to 6'
Project Name: Grass Mountain

Project No. 1160276 **Triaxial Compression Test** Figure 24

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

PROJECT NUMBER 1160276

SAMPLE LOCATION		NATURAL MOISTURE CONTENT (%)	NATURAL DRY DENSITY (PCF)	GRADATION			ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	WATER SOLUBLE SULFATE (%)	SAMPLE CLASSIFICATION
BORING	DEPTH (FEET)			GRAVEL (%)	SAND (%)	SILT/ CLAY (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)			
B-2A	2	11	93			88					Lean Clay
	9	24	93			92	28	10	315		Lean Clay
	14	45	74			97	35	13	335		Lean Clay
B-3A	4	12	82			64					Sandy Lean Clay/Silt
	14	51	68			99					Lean Clay
	19	56	66			96					Lean Clay
	24	50	72			100	42	25			Lean Clay
	29	52	68			94	53	29			Fat Clay
	39	61	65			99	51	29			Fat Clay
	64	36	85			91	37	18			Lean Clay
	94	29	94			83	35	19			Lean Clay with Sand
B-1B	19	37	83			87	27	11			Lean Clay
	49	30	94			58	26	17			Sandy Lean Clay
B-2B	14	41	77			96	48	24			Lean Clay
	29	53	67			98					Lean Clay
	34	25	99			42	27	16			Lean Clay/Silty Sand
	54	23	104			38	23	6			Lean Clay/Silty Sand

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

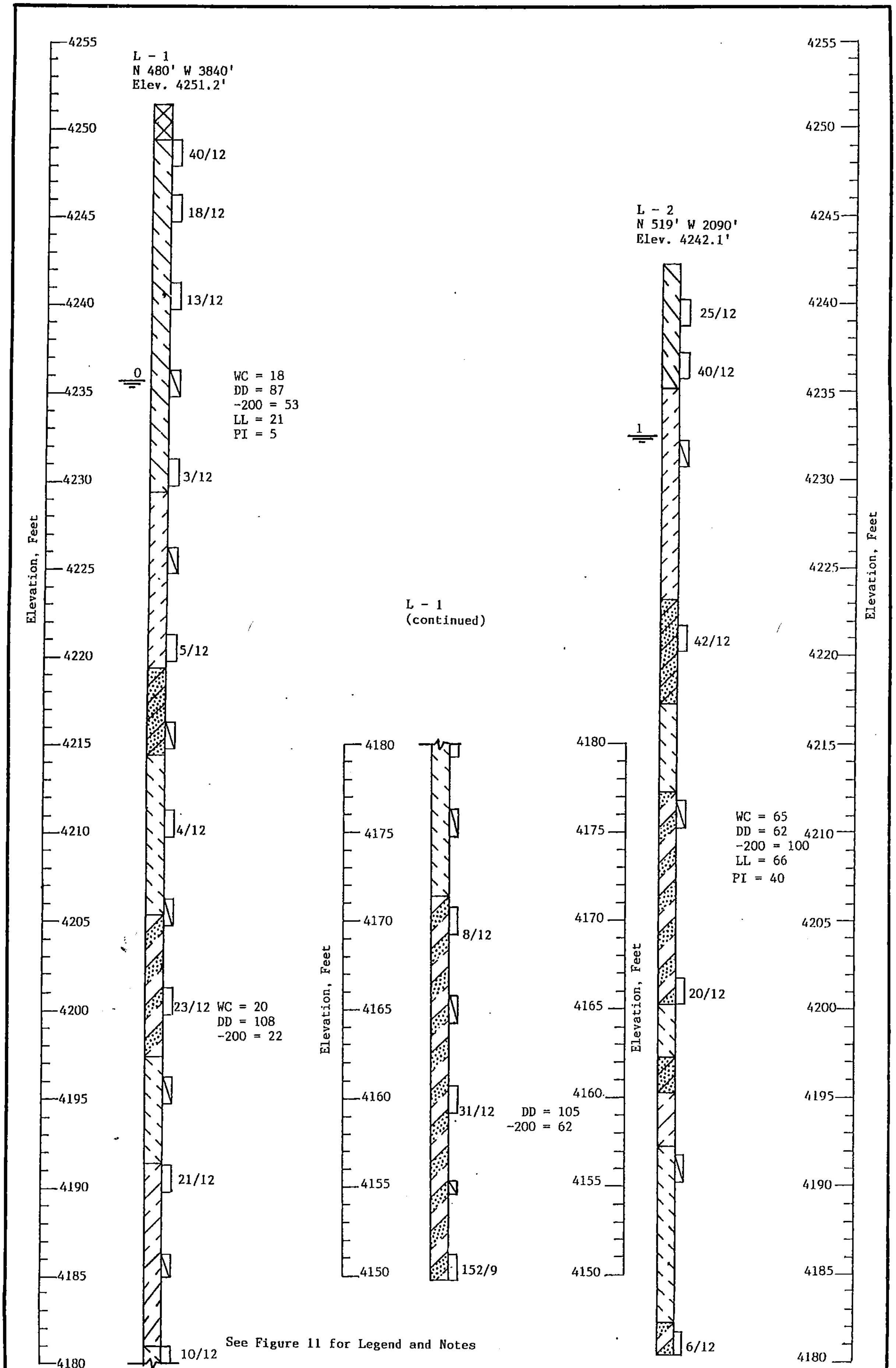
PROJECT NUMBER 1160276

SAMPLE LOCATION		NATURAL MOISTURE CONTENT (%)	NATURAL DRY DENSITY (PCF)	GRADATION			ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	WATER SOLUBLE SULFATE (%)	SAMPLE CLASSIFICATION
BORING	DEPTH (FEET)			GRAVEL (%)	SAND (%)	SILT/ CLAY (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)			
B-3B	9	49	75			85	55	30			Fat Clay with Sand
	11	43	81			82	42	19			Lean Clay with Sand
	19	35	89			60	28	13			Lean Clay/Silty Sand
	44	26	100			33	24	8			Lean Clay/Silty Sand
B-4B	4	53	64			99	49	24			Lean Clay
	39	24	103			25	24	6			Lean Clay/Silty Sand

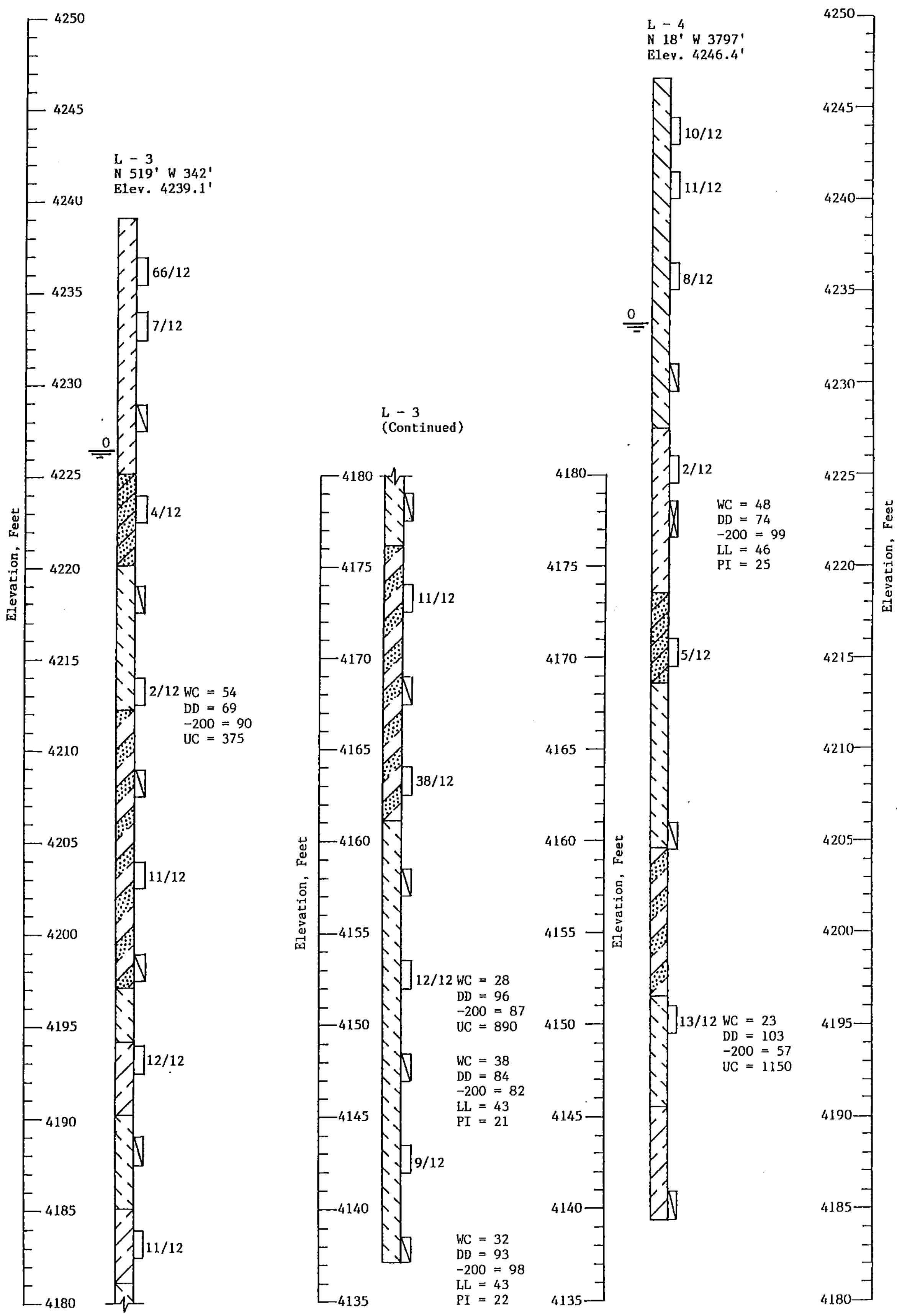
APPENDIX A-1

BORING LOGS

PREVIOUS STUDIES

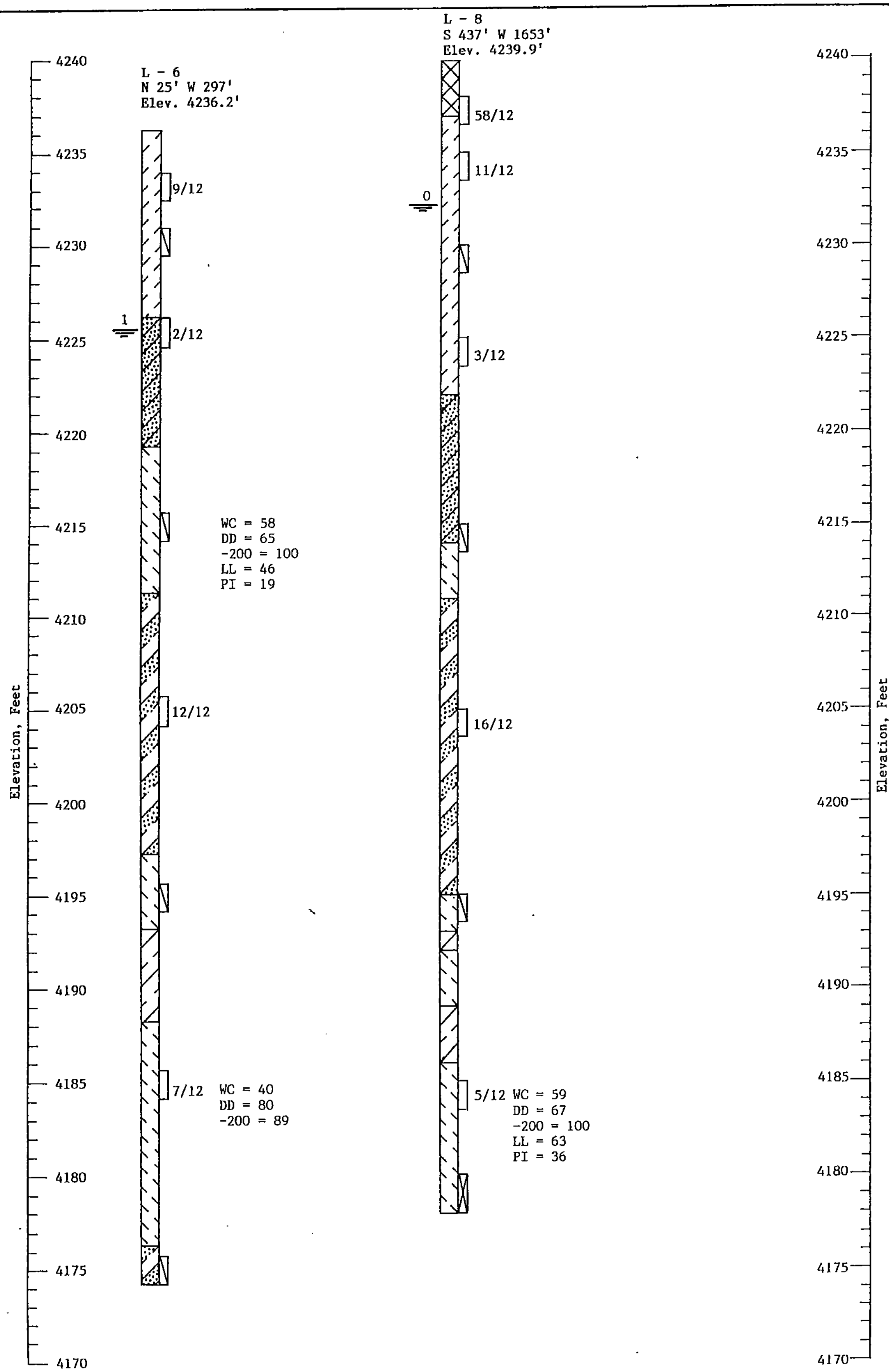


20591	A G E C	LOGS OF EXPLORATORY BORINGS	FIGURE 2



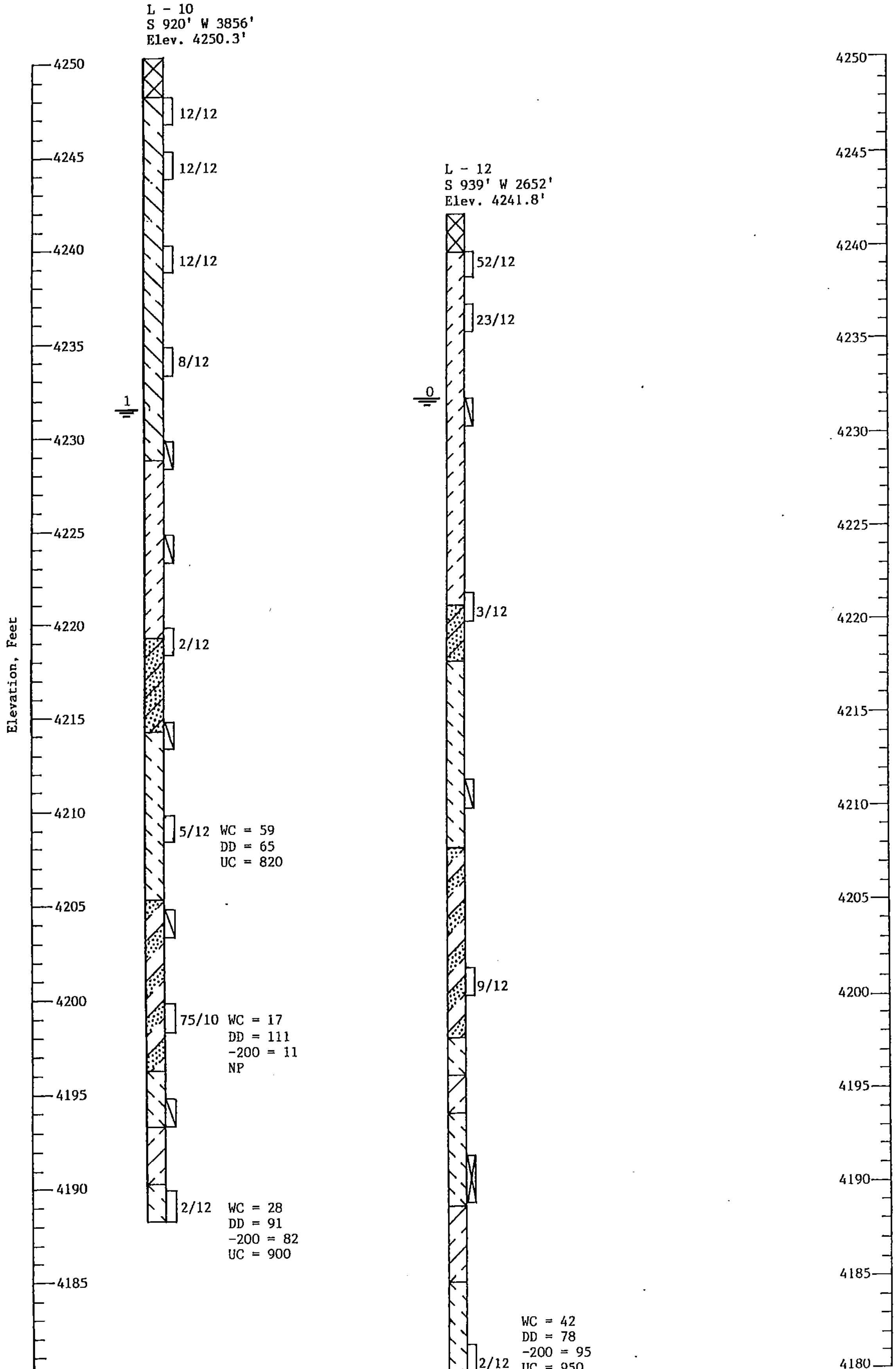
See Figure 11 for Legend and Notes.

20491	A G E C	LOGS OF EXPLORATORY BORINGS	FIGURE 3



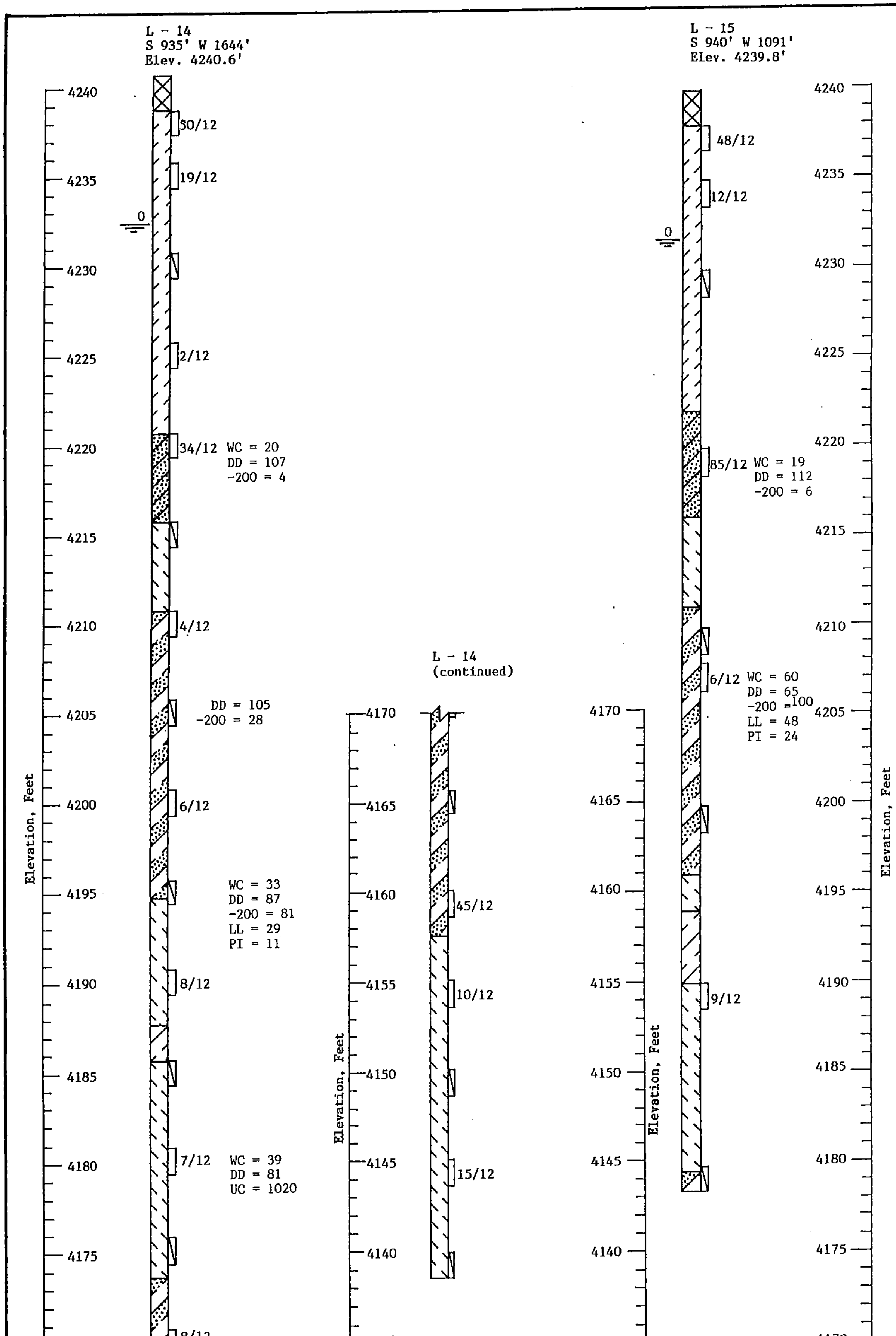
See Figure 11 for Legend and Notes

20501	A G E C	LOGS OF EXPLORATORY BORINGS	FIGURE 4



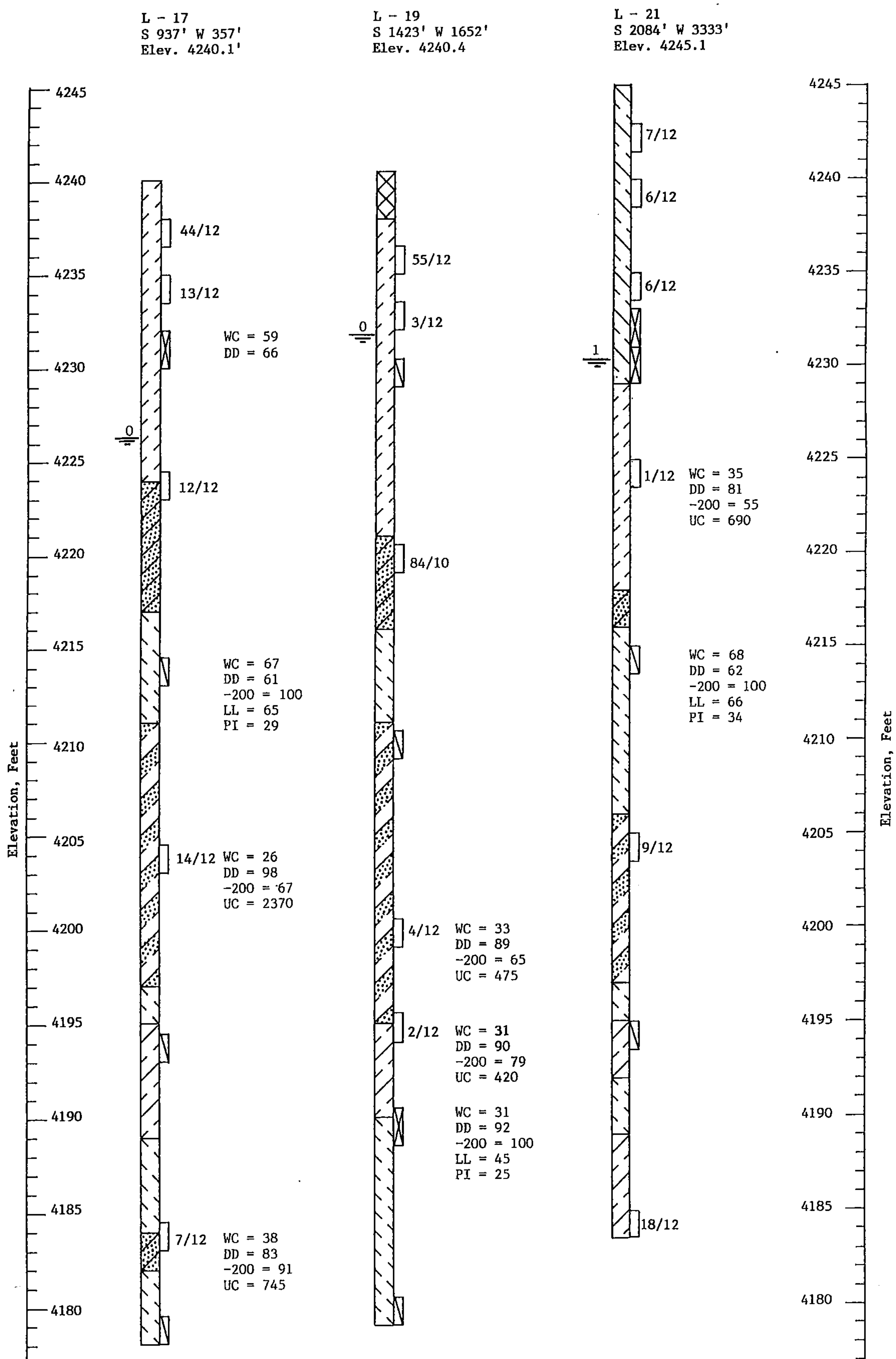
See Figure 11 for Legend and Notes

20491	A G E C	LOGS OF EXPLORATORY BORINGS	FIGURE 5



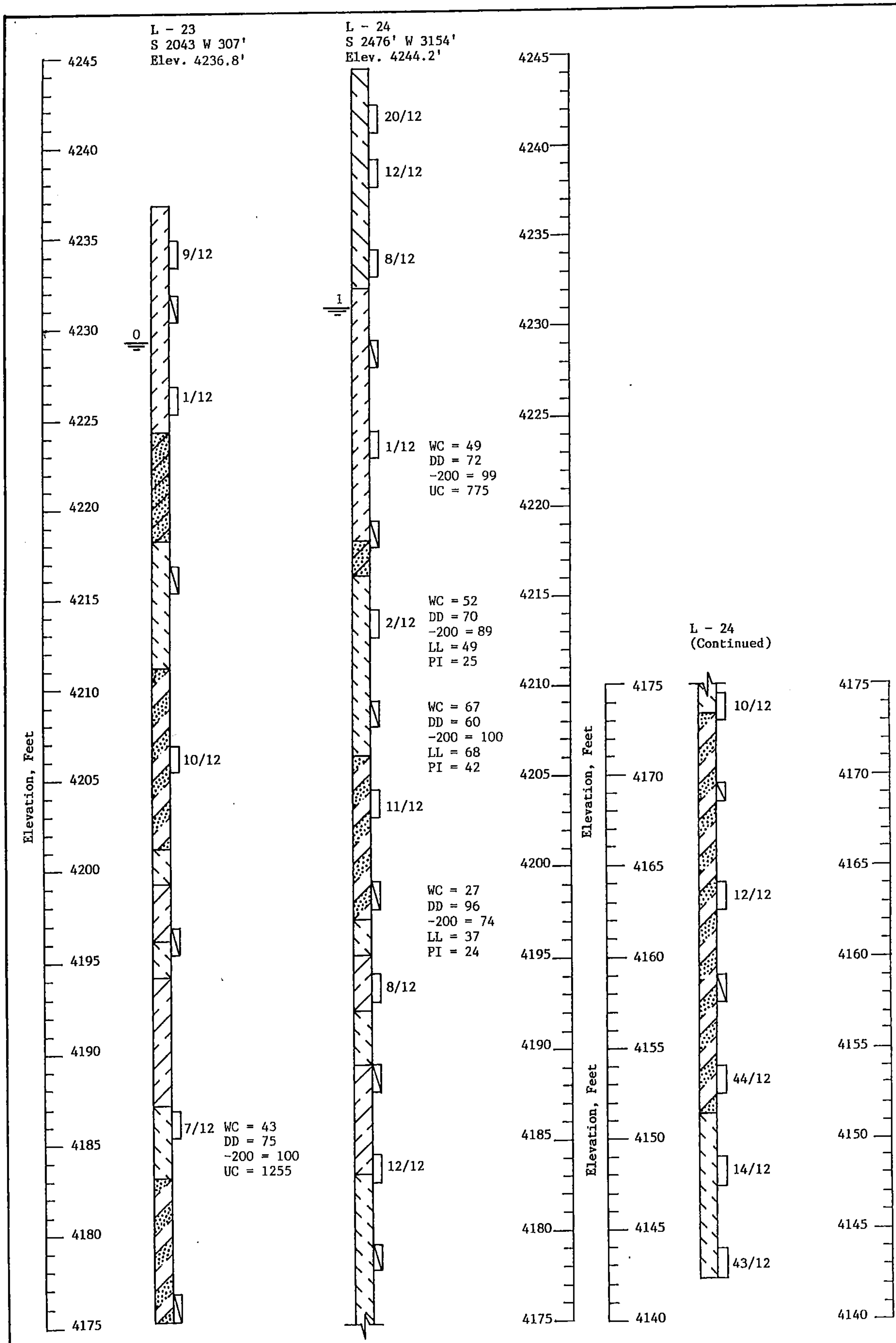
See Figure 11 for Legend and Notes

20591	A G E C	LOGS OF EXPLORATORY BORINGS	FIGURE 6



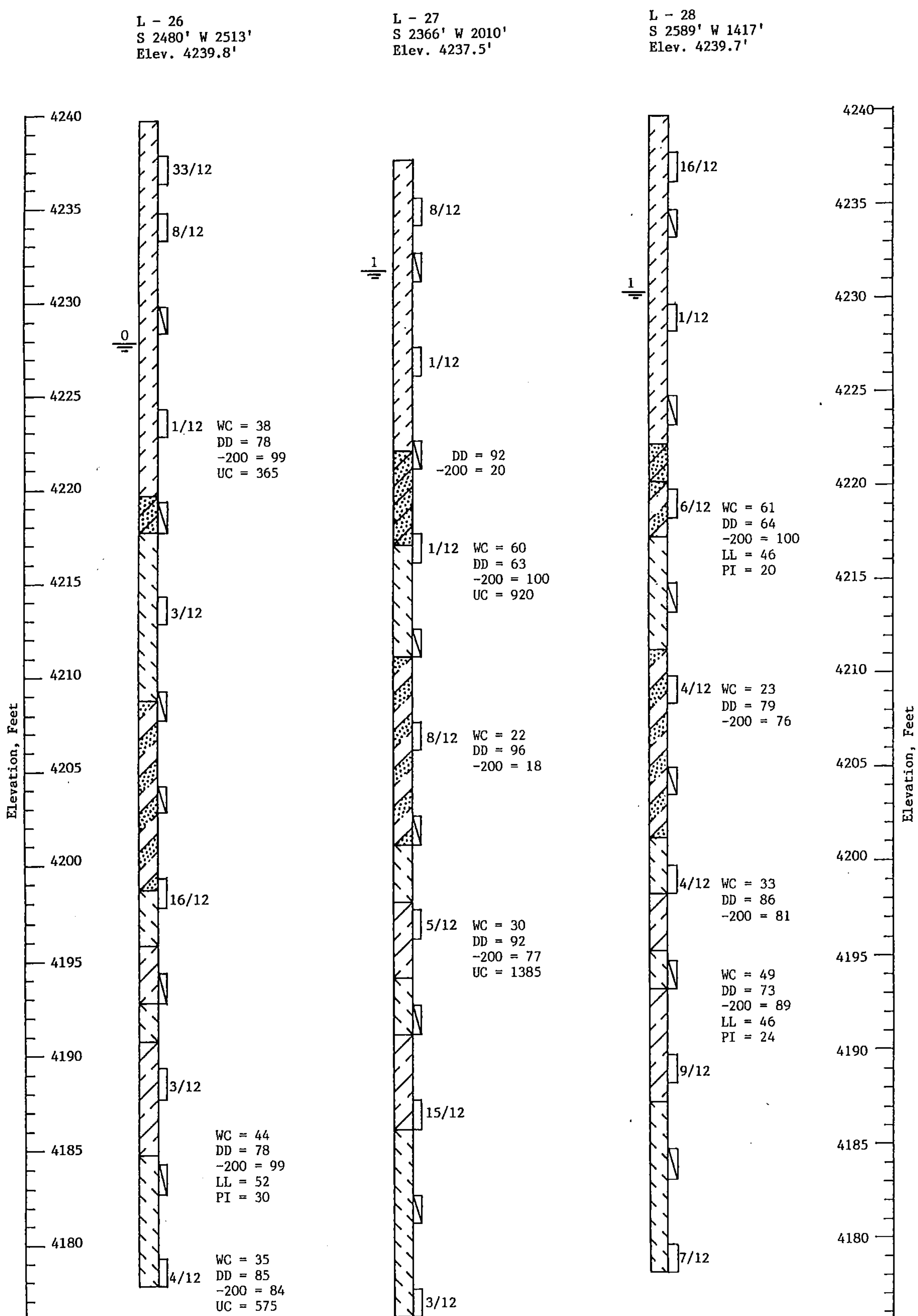
See Figure 11 for Legend and Notes

20591	A G E C	LOGS OF EXPLORATORY BORINGS	FIGURE 7



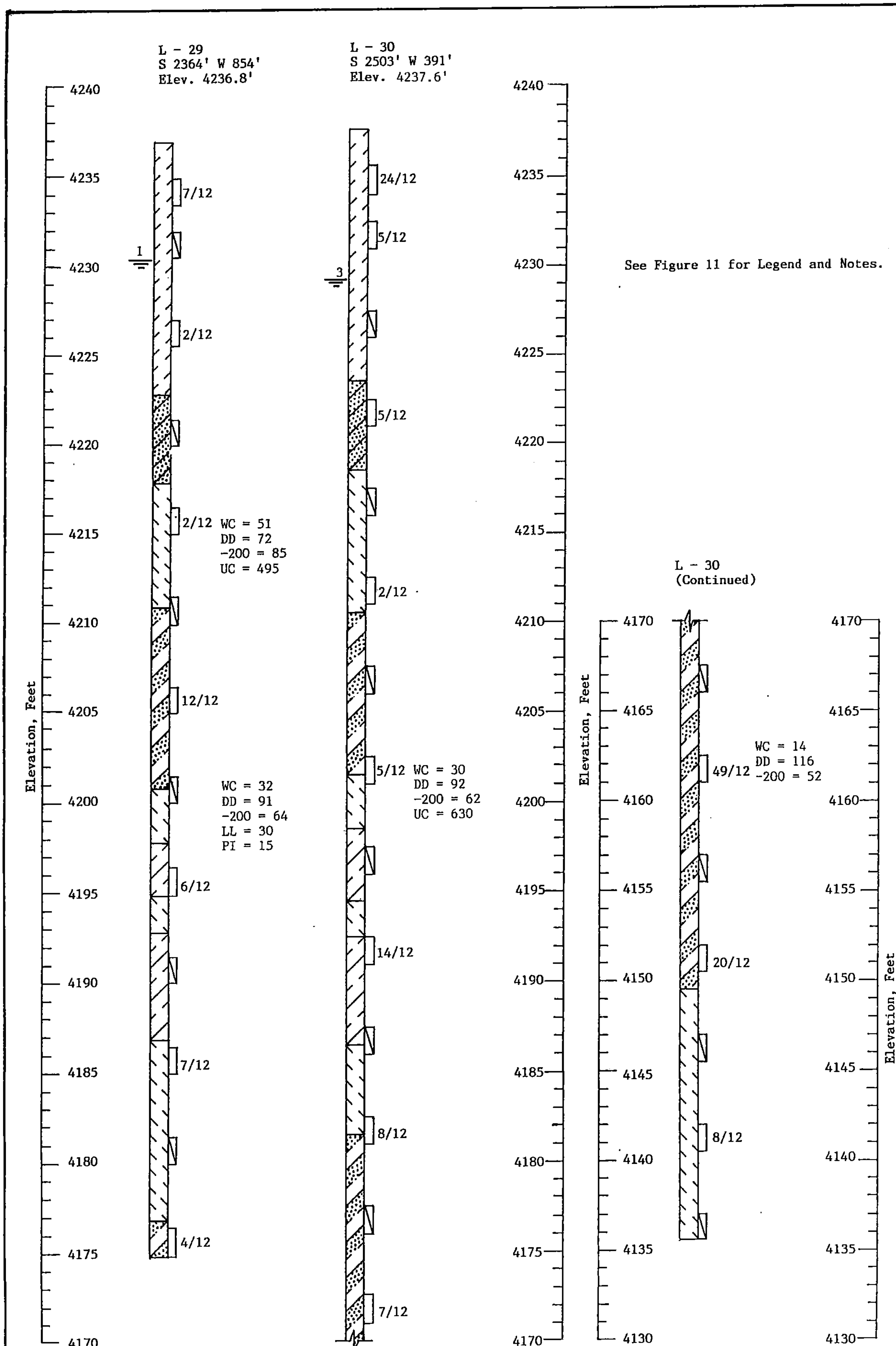
See Figure 11 for Legend and Notes

20591	A G E C	LOGS OF EXPLORATORY BORINGS	FIGURE 8



See Figure 11 for Legend and Notes

20591	A G E C	LOGS OF EXPLORATORY BORINGS	FIGURE 9



20501 | A G E C | LOGS OF EXPLORATORY BORINGS | FIGURE 10

NOTES:

1. Exploratory borings were drilled on March 30, 1992 through May 12, 1992 with 8-inch diamter hollowstem auger.

2. Locations and elevations of exploratory borings were surveyed by Sorenson once drilling was completed.

3. The exploratory boring locations and elevations should be considered accurate only to the degree implied by the method used.

4. The lines between the materials shown on the boring logs represent the approximate boundaries between material types and the transitions may be gradual.

5. Water level readings shown on the logs were made at the time and under the conditions indicated. Fluctuations in the water level may occur with time.

6. WC = Water Content (%);
   DD = Dry Density (pcf);
   -200 = Percent Passing No. 200 Sieve;
   LL = Liquid Limit (%);
   PI = Plasticity Index (%);
   NP = Nonplastic;
   UC = Unconfined Compressive Strength (psf).

7. All borings were backfilled with bentonite.

LEGEND:

Fill; sandy lean clay, slightly moist to moist, light gray brown.

Lean Clay (CL); slightly moist to wet, very hard in upper 3 - 5 feet grading to very stiff to medium stiff with depth, slightly moist to wet with depth, light brown to light gray brown.

Lean Clay (CL); thin silt and sand layers, occasional cemented layers, very soft to stiff, very moist to wet, light brown to gray, sulfurous odor.

Interlayered Sandy Silt and Sandy Lean Clay (ML-CL); silty sand and clayey sand layers, very hard to very soft with depth, moist to wet, light brown, sulfates.

Interlayered Sandy Silt and Lean Clay (ML-CL); occasional thin silty sand layers, medium to very stiff, very moist to wet, light brown to gray, sulfurous odor.

Interlayered Silty Sand and Lean clay (SM-CL); sandy silt layers, medium to very dense, medium to very stiff, very moist to wet, light brown to gray, sulfurous odor.

Silty Sand (SM); clay and sandy silt layers, medium to very dense, wet, gray to dark gray, sulfurous odor.

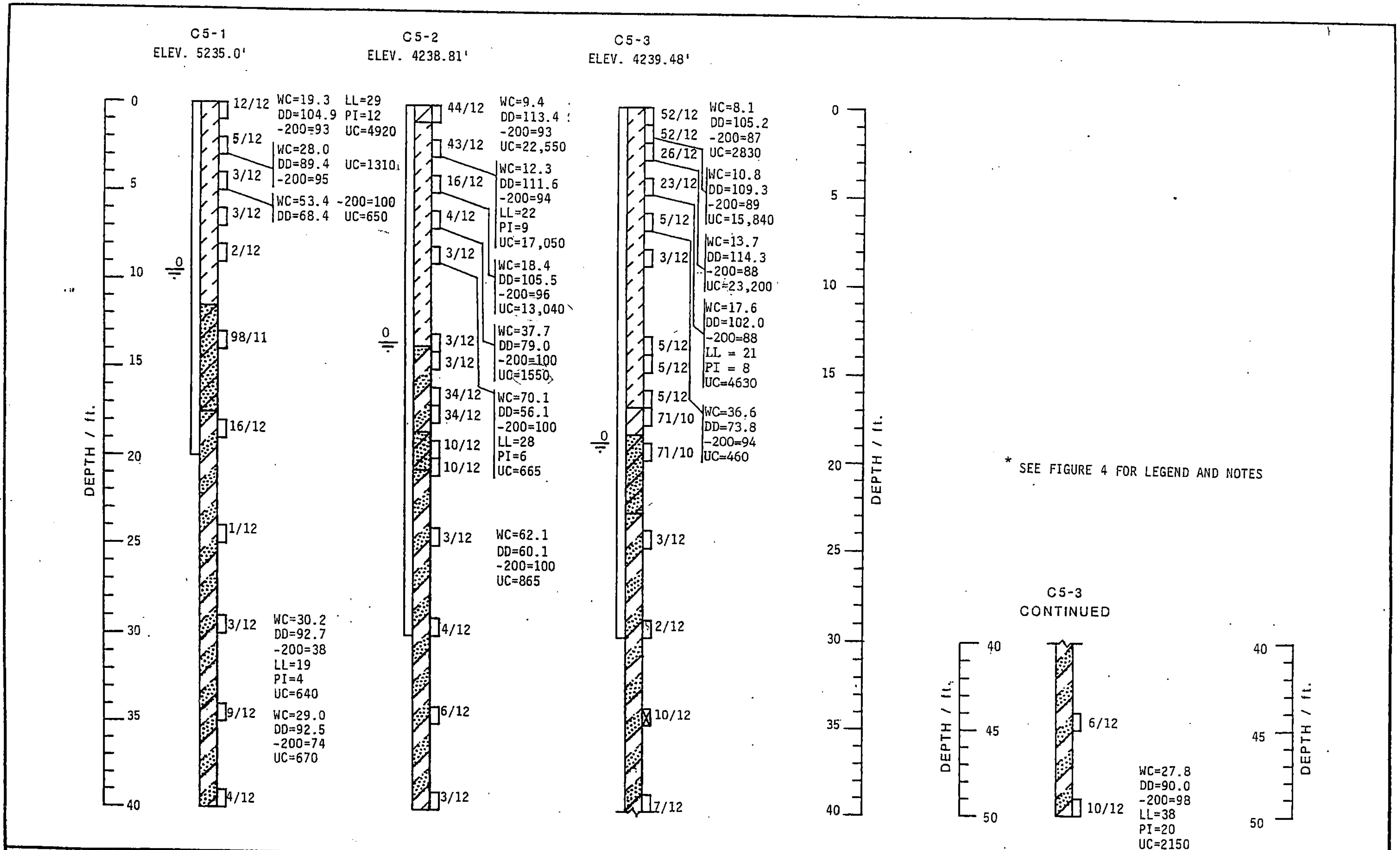
10/12 California Drive Sample. The symbol 10/12 indicates that 10 blows from a 140 pound hammer falling 30 inches were required to drive the sampler 12 inches.

Indicates 2½ inch inside diameter sampler used. The sampler was pushed not driven with a hammer.

Indicates a Shelby tube sample was taken.

1 Indicates depth to free water and the number of days after drilling the measurement was taken.

20591	AGEC	Legend and Notes of Exploratory Borings	Figure 11



#546089 | Chen-Northern, Inc. | LOGS OF BORINGS | Figure 2

NOTES

1. Exploratory borings for this investigation were drilled on August 15 & 16, 1989 with with a 7-inch diameter continuous flight hollow stem power auger.
2. Locations of exploratory borings were measured approximately by pacing from features shown on the site plan provided.
3. Elevations of exploratory borings were provided by others.
4. The exploratory boring locations should be considered accurate only to the degree implied by the method used.
5. The lines between the materials shown on the boring logs represent the approximate boundaries between material types and the transitions may be gradual.
6. Water level readings shown on the logs were made at the time and under the conditions indicated. Fluctuations in the water level may occur with time.
7. WC = Water Content (%);
   DD = Dry Density (pcf);
   -200 = Percent Passing No. 200 Sieve;
   LL = Liquid Limit (%);
   PI = Plasticity Index (%);
   UC = Unconfined Compressive Strength (psf);
8. Borings drilled for earlier investigations were drilled on the following dates and previously reported under the listed project numbers.

Borings	Dates Drilled	Project Number
B-1, B-3, B-4, B-6	April, 1984	520484
TH-7	June, 1984	527584
TH-33	June, 1986	522486

LEGEND

EMBANKMENT FILL, sandy clay to silty sand, very stiff or medium to very dense, slightly moist to moist, light brown.

CLAY (CL), interlayered with sand and silt, soft to very stiff, occasional cemented layers, dry to wet, buff to light brown changing to olive-blueish brown w/depth, black streaks.

SILT (ML), interlayered with clay and sand, medium to very stiff, occasional cemented layers, dry to very moist, light brown.

CLAY, sandy to sand, silty (CL-SM), interlayered, soft to very stiff, on loose to very dense, occasional cemented layers, very moist to wet, olive brown to grey to blueish green.

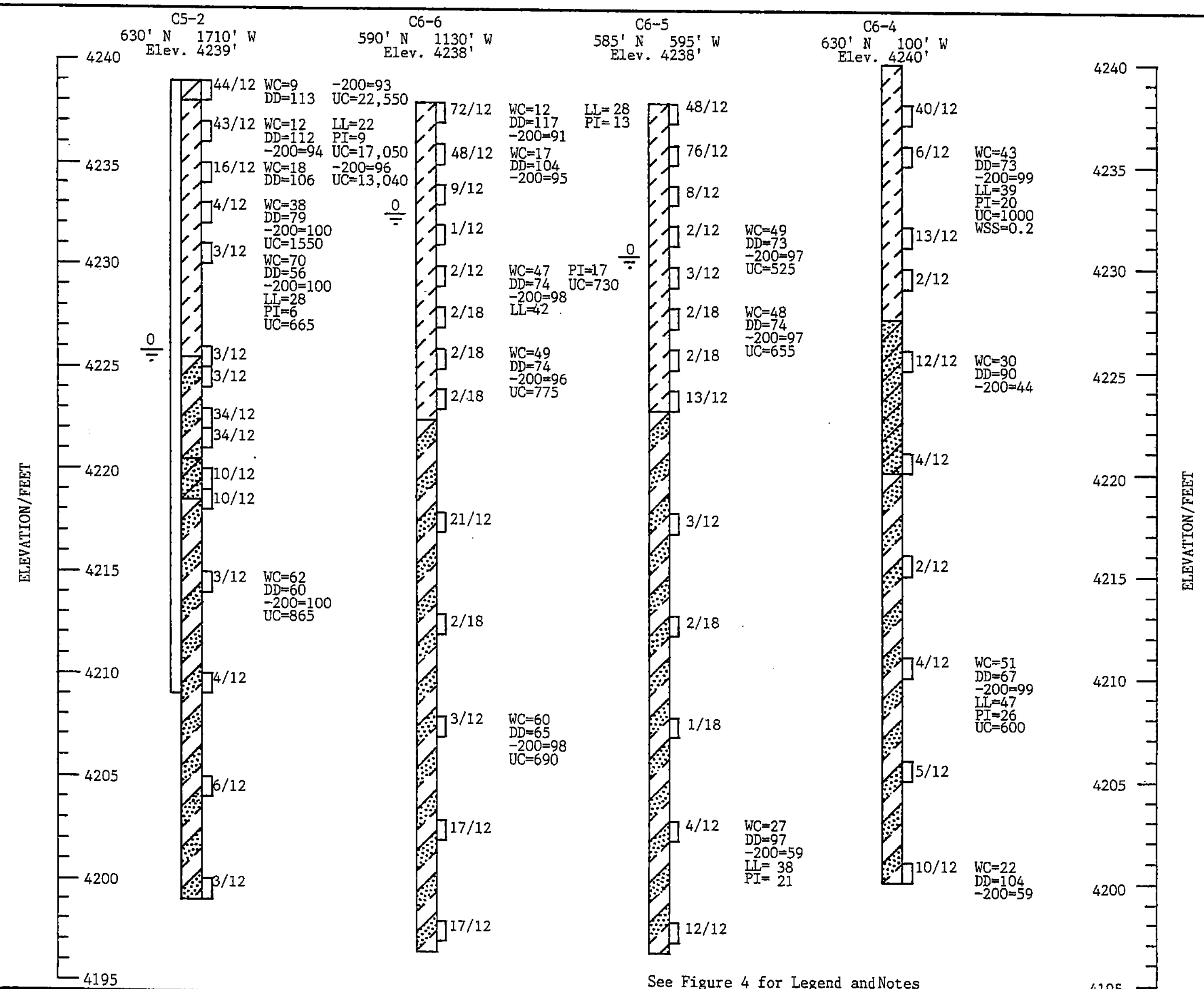
SAND (SM), silty, loose to very dense, wet, olive-blueish brown.

10/12 CALIFORNIA DRIVE SAMPLE. The symbol 10/12 indicates that 10 blows of a 140 pound hammer falling 30 inches were required to drive the sampler 12 inches.

SHELBY TUBE SAMPLE.

Indicates slotted 1½ inch P.V.C. pipe installed in boring to the depth shown.

0 Indicated depth to free water and number of days after drilling that measurement was taken.



See Figure 4 for Legend and Notes

11791	A G E C	LOGS OF BORINGS, INCLUDING SELECTED BORINGS FROM PREVIOUS INVESTIGATIONS	FIGURE 3

NOTES:

1. Exploratory borings for this project (C6-5, 6 & 7) were drilled on March 5, 1991 with 7-inch diameter continuous flight hollow stem power augers.

2. Locations of borings were measured approximately by taping from features shown on the site plan provided.

3. Elevations of borings were determined by interpolating between contours shown on the site plan provided. The boring locations and elevations should be considered accurate only to the degree implied by the method used.

4. The lines between the materials shown on the boring logs represent the approximate boundaries between material types, and the transitions may be gradual.

5. Water level readings shown on the logs were made at the time and under the conditions indicated. Fluctuations in the water level may occur with time.

6. WC = Water Content (%);
   DD = Dry Density (pcf);
   -200 = Percent Passing the No. 200 Sieve;
   LL = Liquid Limit (%);
   PI = Plasticity Index (%);
   UC = Unconfined Compressive Strength (psf);
   WSS = Water Soluble Sulfate (%).

7. All borings were backfilled with bentonite.

8. Borings drilled for earlier investigations were drilled on the following dates and previously reported under the listed project numbers.

Boring	Date Drilled	Project Number
C5-1, 2	August 1989	CNI #546089
C6-1, 2, 3 & 4	September 1989	CNI #560589
TH-1	June 1984	CAI #542184

NOTE: CAI indicates Chen & Associates, Inc.
CNI indicates Chen-Northern, Inc.

LEGEND:

Clay (CL); interlayered with fine sand and silt layers, upper 3-5 feet of upper clays are very hard, changing to very soft to medium stiff with depth, occasional cemented layers, slightly moist to wet, buff to light brown, olive brown, black streaks.

Clay and Silty Sand (CL-SM); interlayered with silt, primarily soft to medium stiff with occasional cemented layers (very loose to loose, occasionally medium dense in sandy deposits), very moist to wet, olive brown to gray to bluish green, to buff.

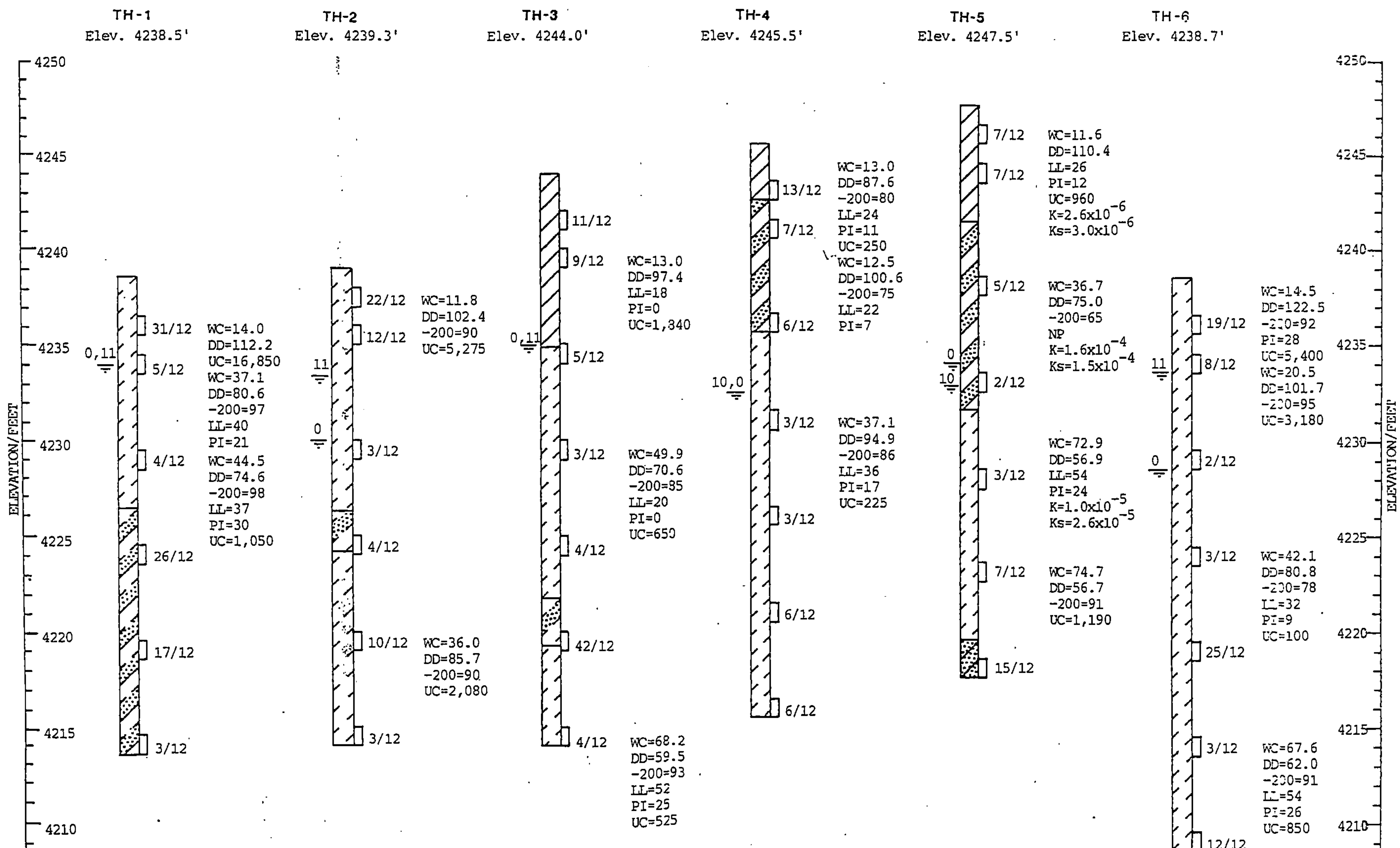
Silty Sand (SM); loose to medium dense, wet, olive-bluish brown, cemented layers.

10/12 California Drive Sample. The symbol 10/12 indicates that 10 blows of a 140 pound hammer falling 30 inches were required to drive the sampler 12 inches.

Indicates PVC pipe placed in boring to depth shown.

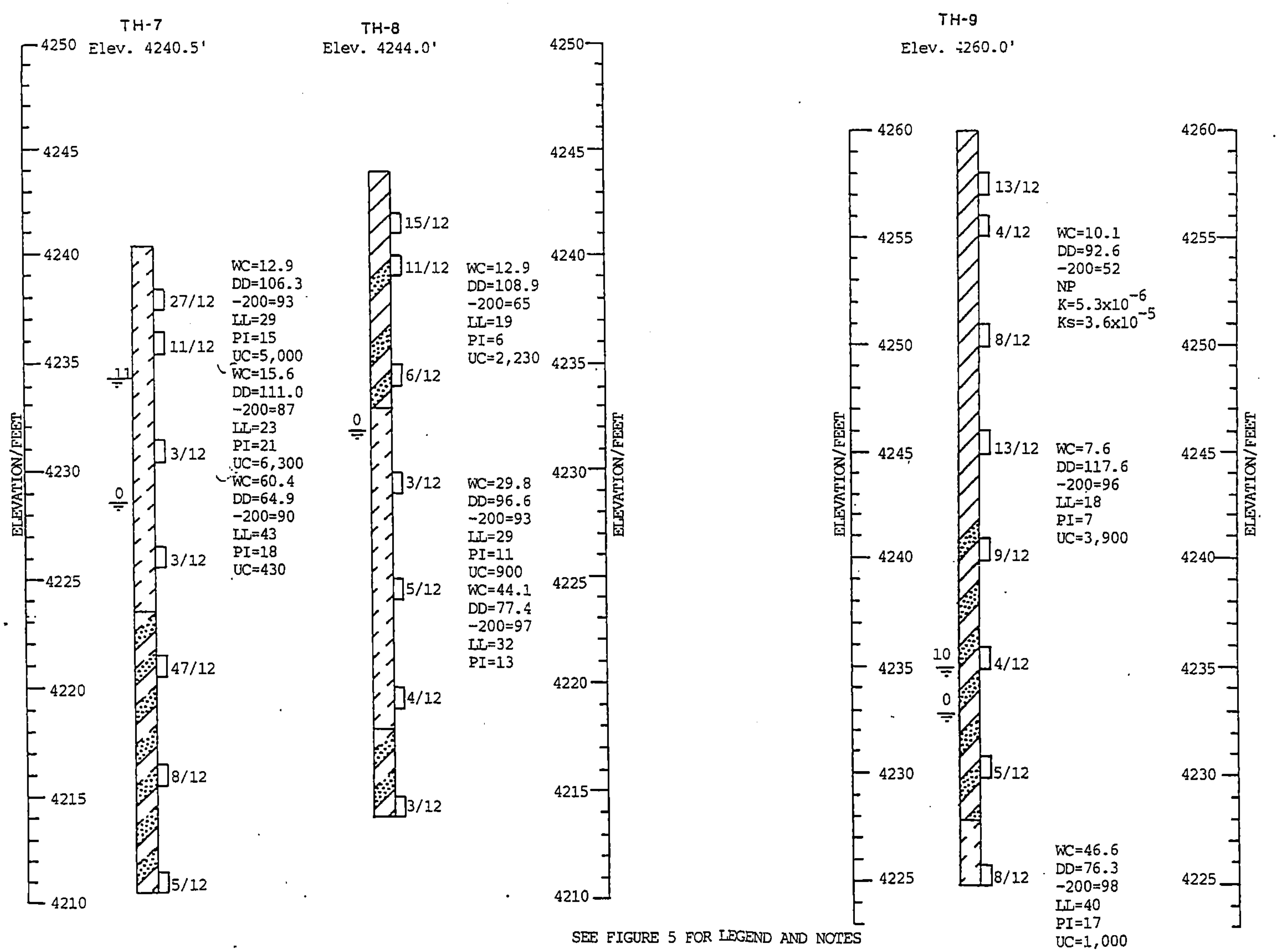
0 Indicates depth to free water and number of days after drilling that measurement was taken.

11791 | A G E C | LEGEND AND NOTES OF BORINGS | FIGURE 4



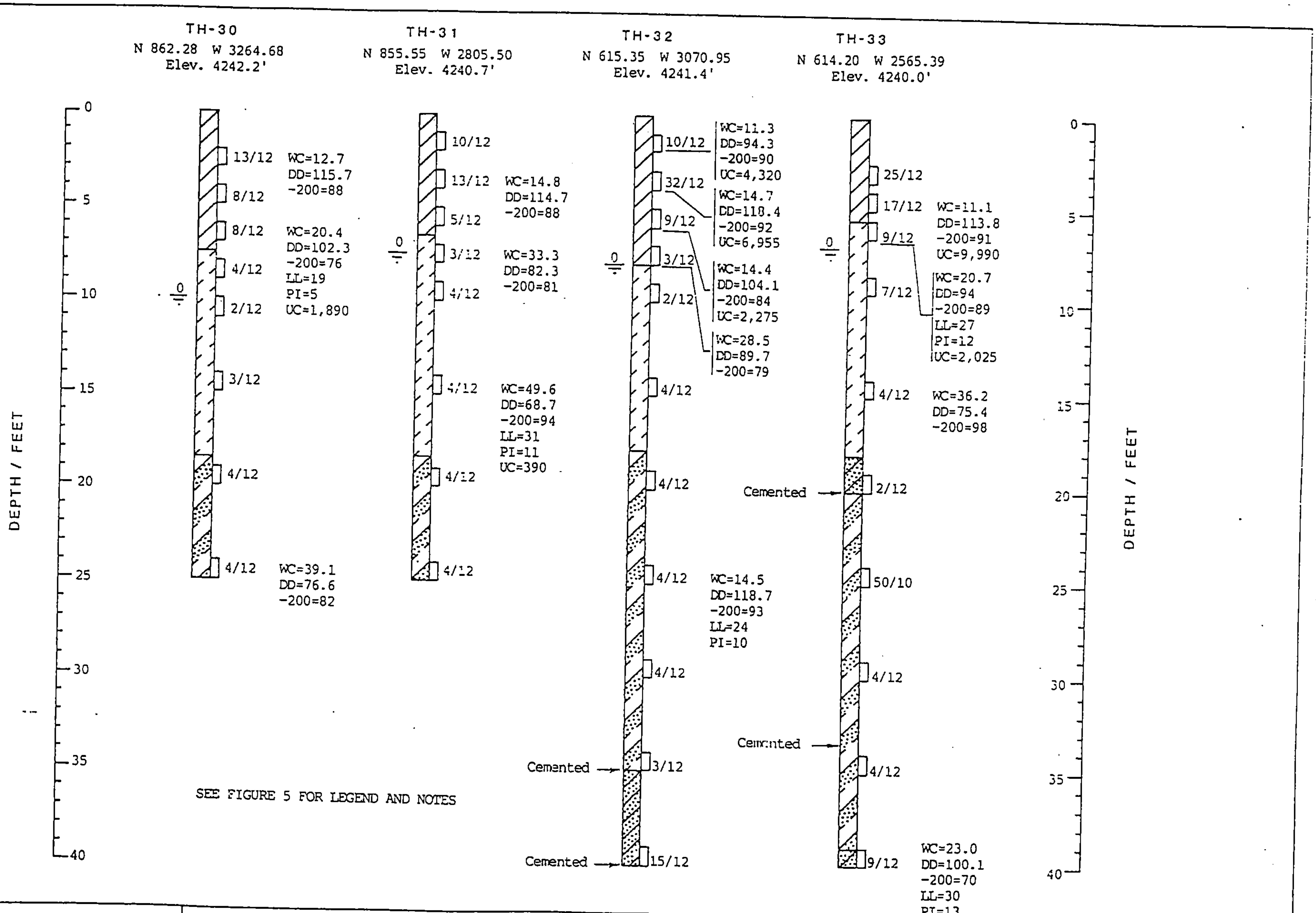
SEE FIGURE 5 FOR LEGEND AND NOTES

527584	chen and associates, inc.	LOGS OF EXPLORATORY TEST HOLES	Figure 3



SEE FIGURE 5 FOR LEGEND AND NOTES

527584	chen and associates, inc.	LOGS OF EXPLORATORY TEST HOLES	Figure 4



522486	Chen & Associates	LOGS OF EXPLORATORY BORINGS	Figure 3

APPENDIX A-2

CONE PENETRATION

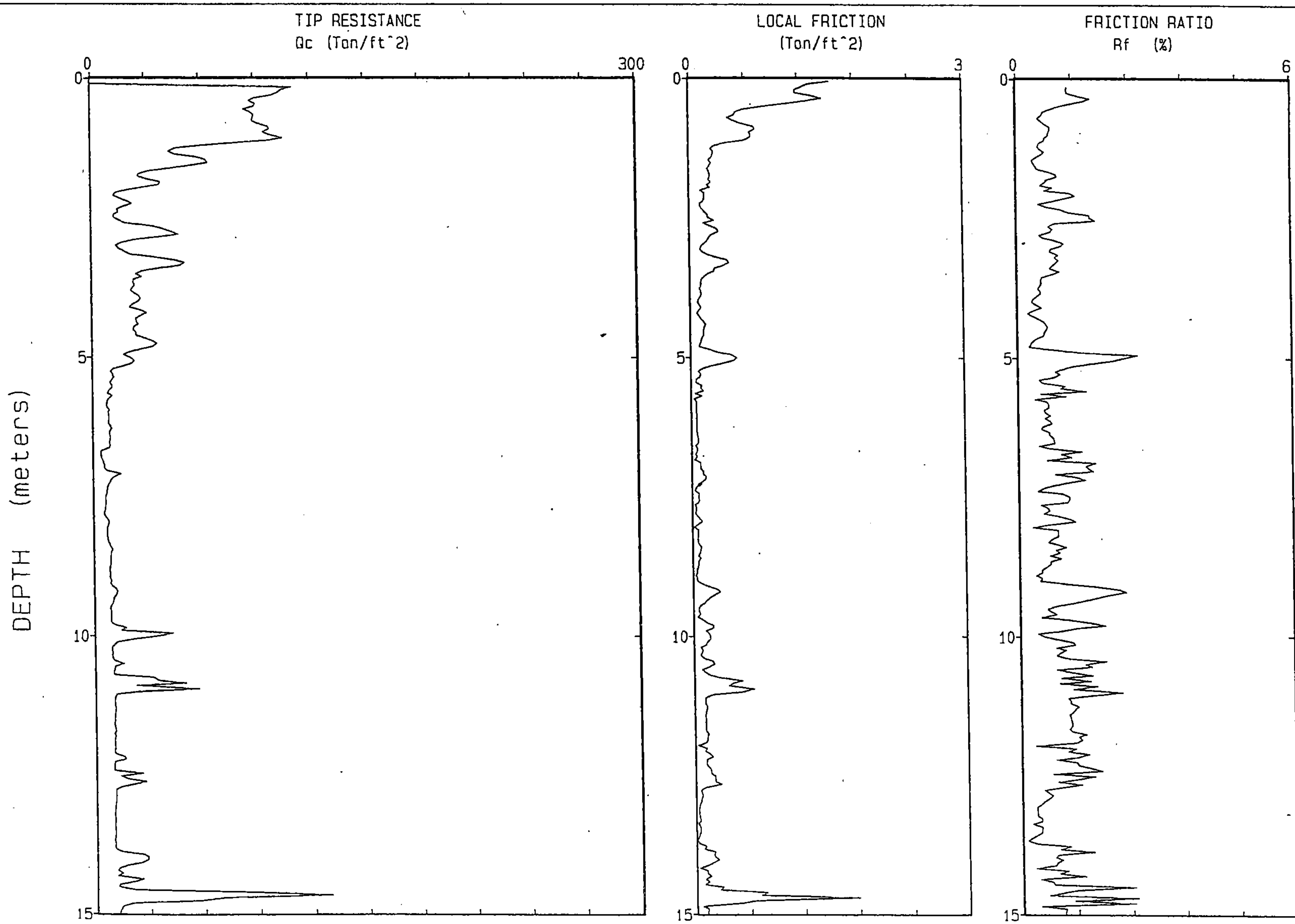
TEST RESULTS

AGEC

Engineer : JM
Location : CL-1

CPT Date : 02/01/92 14:05
Cone Used : H215

Page No: 1 / 2
Job No. : 20591



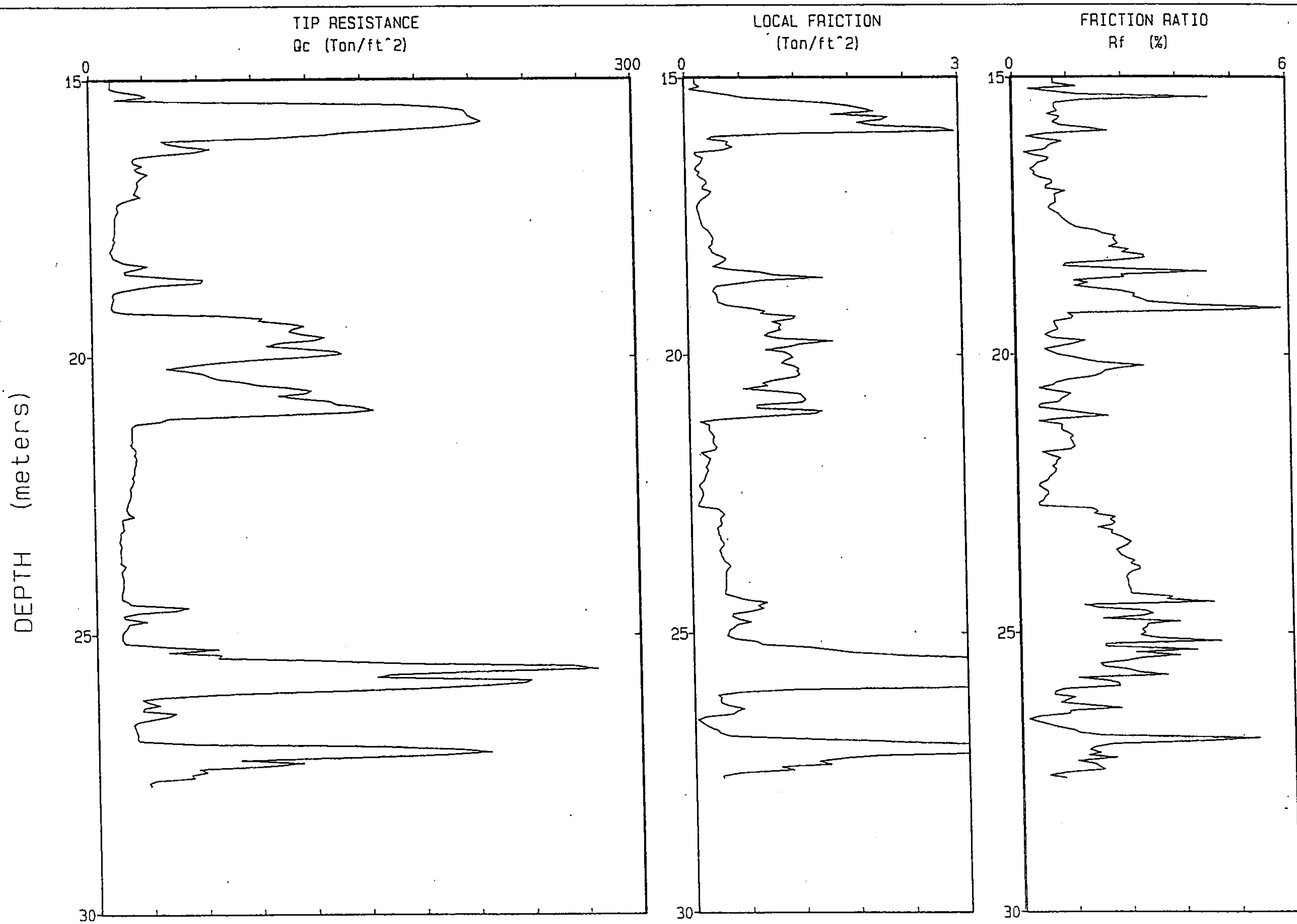
Depth Increment : .05 m

AGEC

Engineer : JM
Location : CL-1

CPT Date : 02/01/92 14:05
Cone Used : H215

Page No: 2 / 2
Job No. : 20591

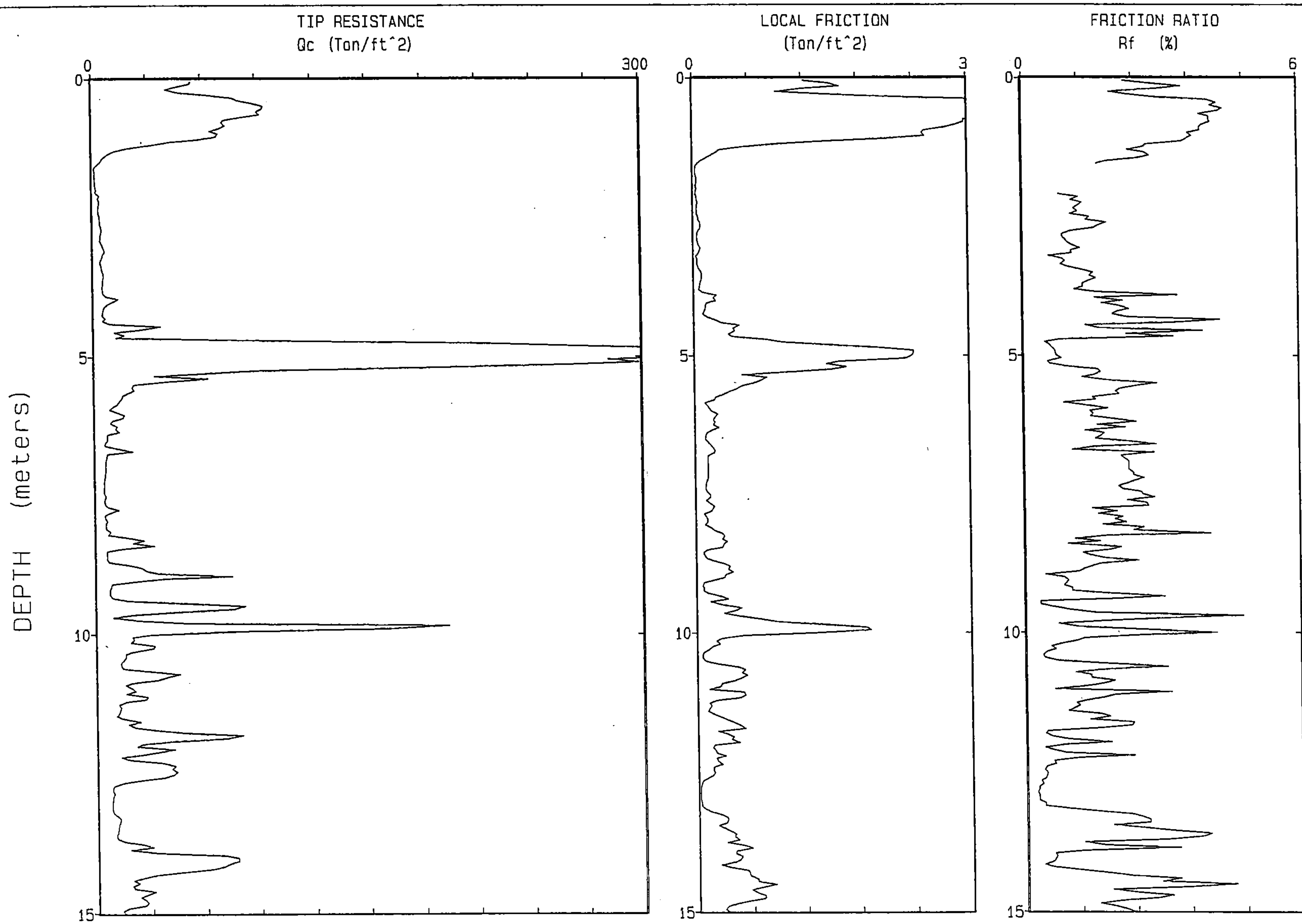


Depth Increment : .05 m

AGEC

Engineer : JM | CPT Date : 04/07/92 13:02 | Page No: 1 / 2

Location : C-L3 | Cone Used : H215 | Job No. : 20591



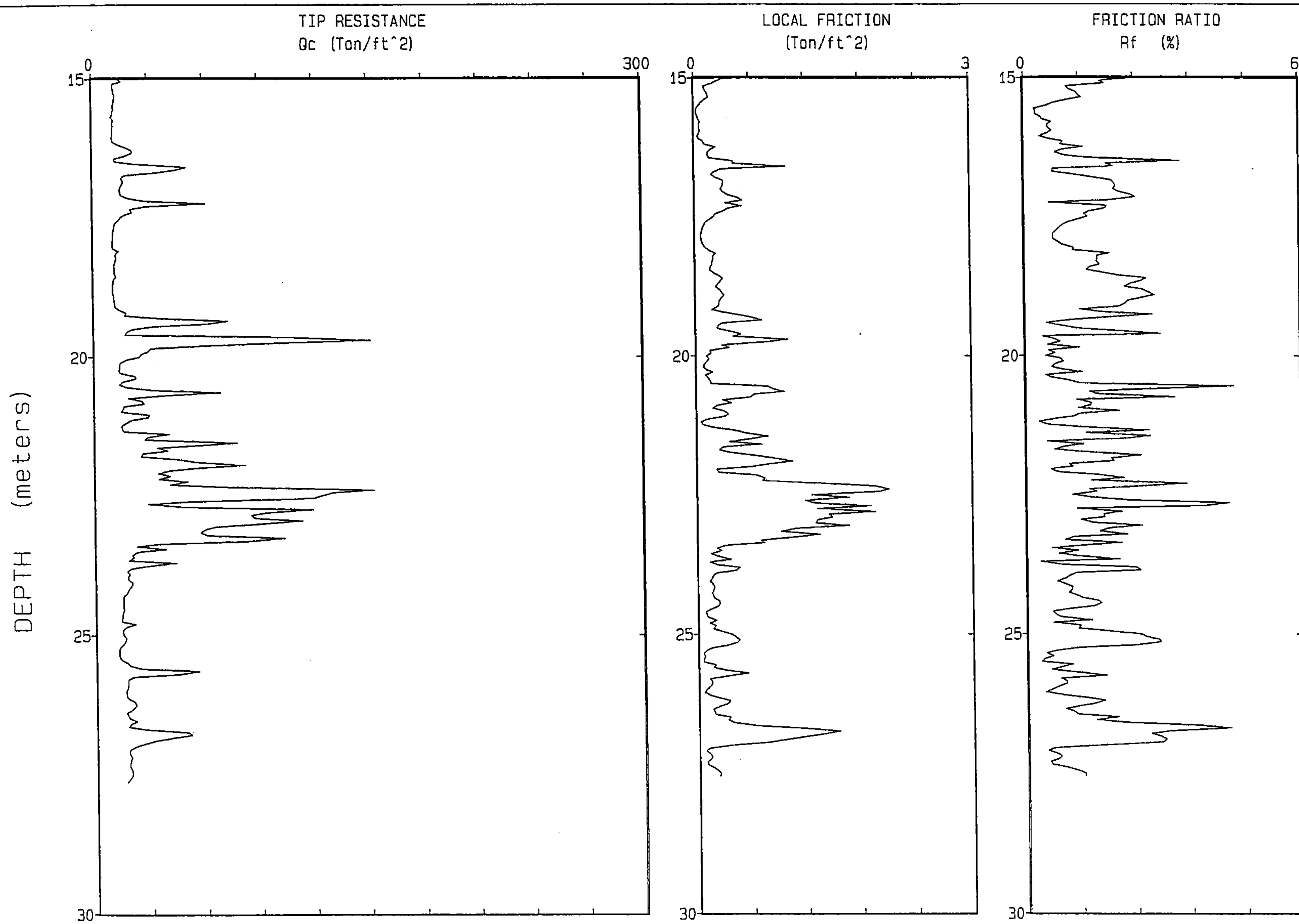
Depth Increment : .05 m

AGEC

Engineer : JM
Location : C-L3

CPT Date : 04/07/92 13:02
Cone Used : H215

Page No: 2 / 2
Job No. : 20591

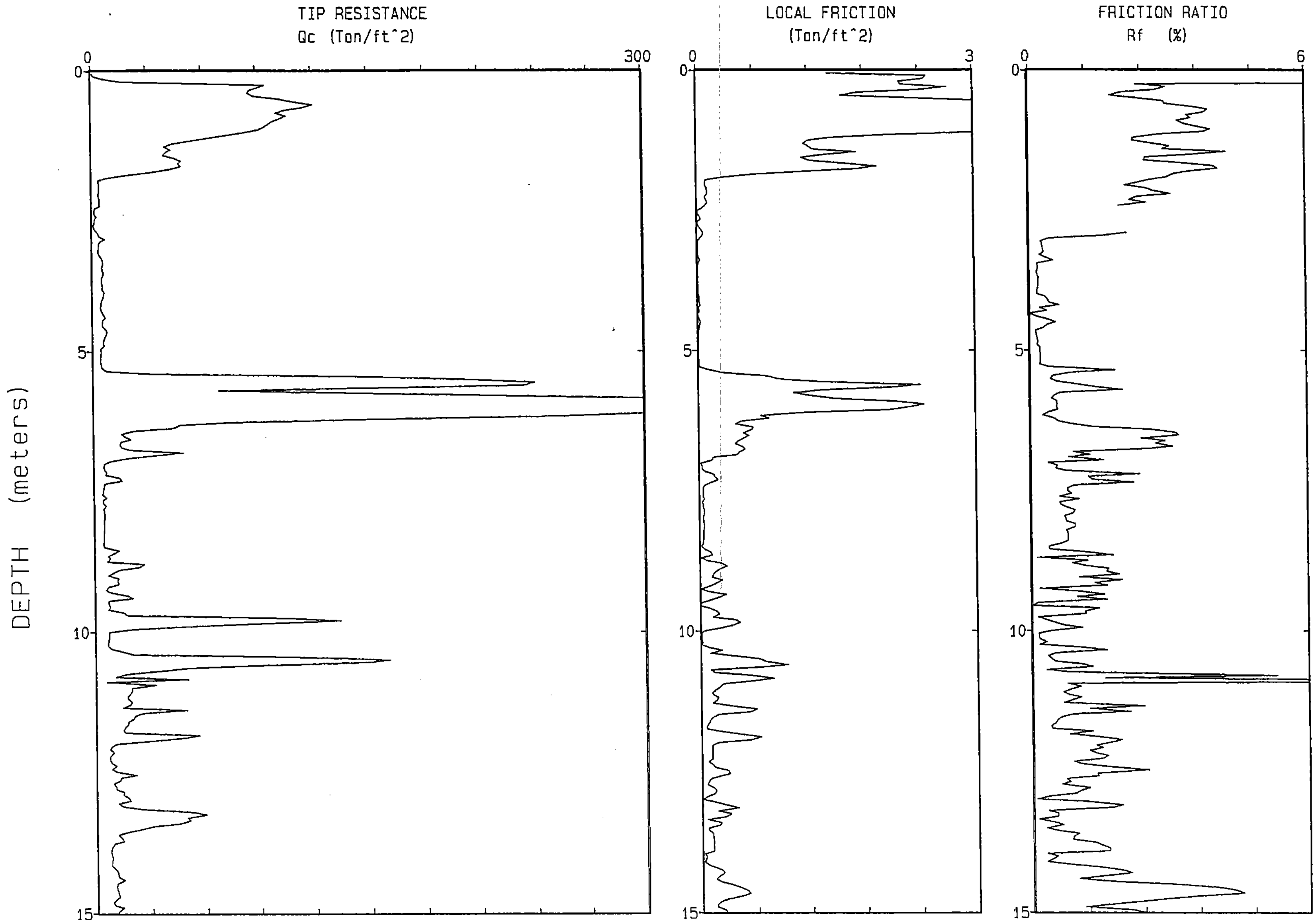


Depth Increment : .05 m

AGEC

Engineer : JM | CPT Date : 04/29/92 13:47 | Page No: 1 / 2

Location : C-L5 | Cone Used : H215 | Job No. : 20591

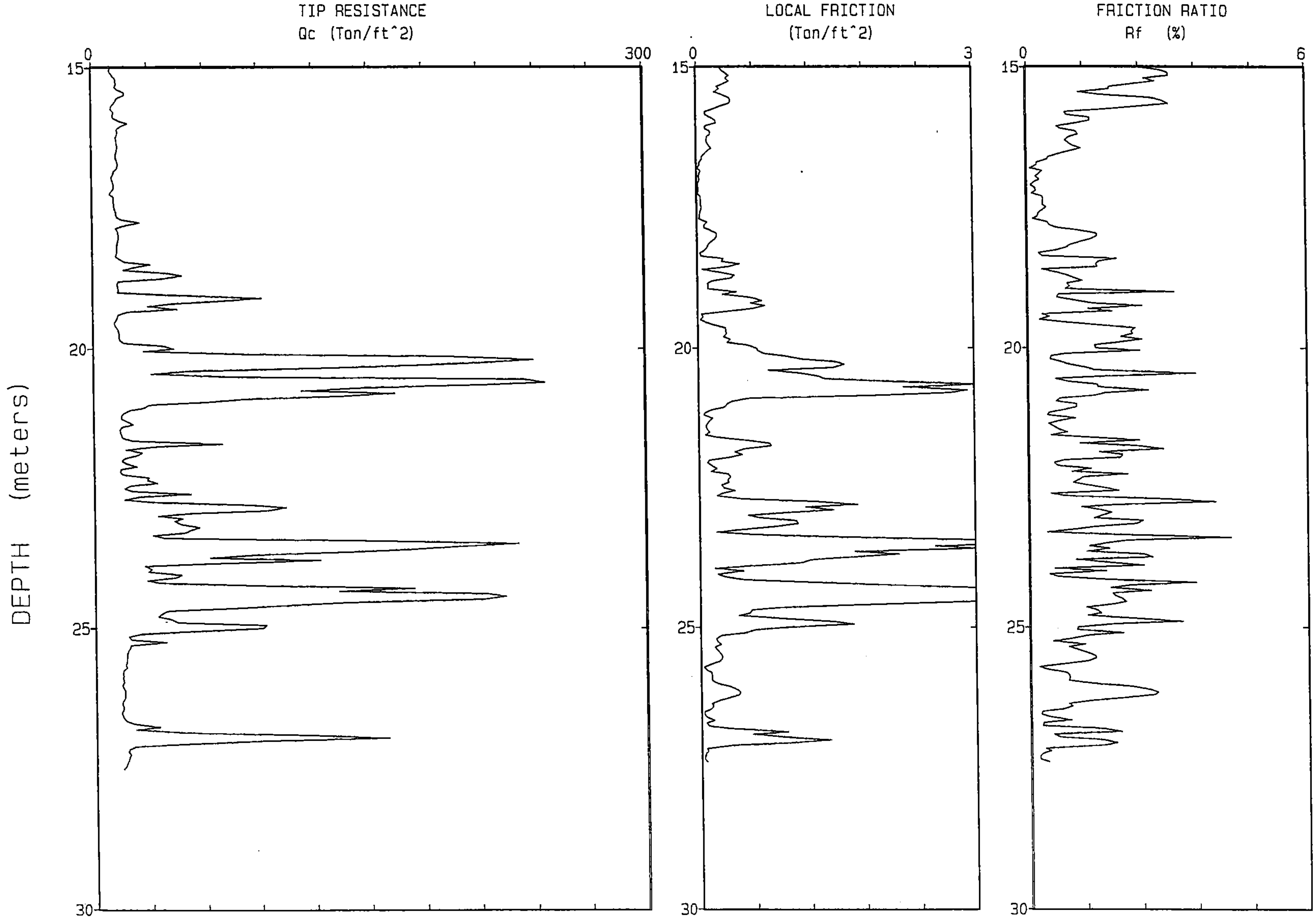


Depth Increment : .05 m

AGEC

Engineer : JM | CPT Date : 04/29/92 13:47 | Page No: 2 / 2

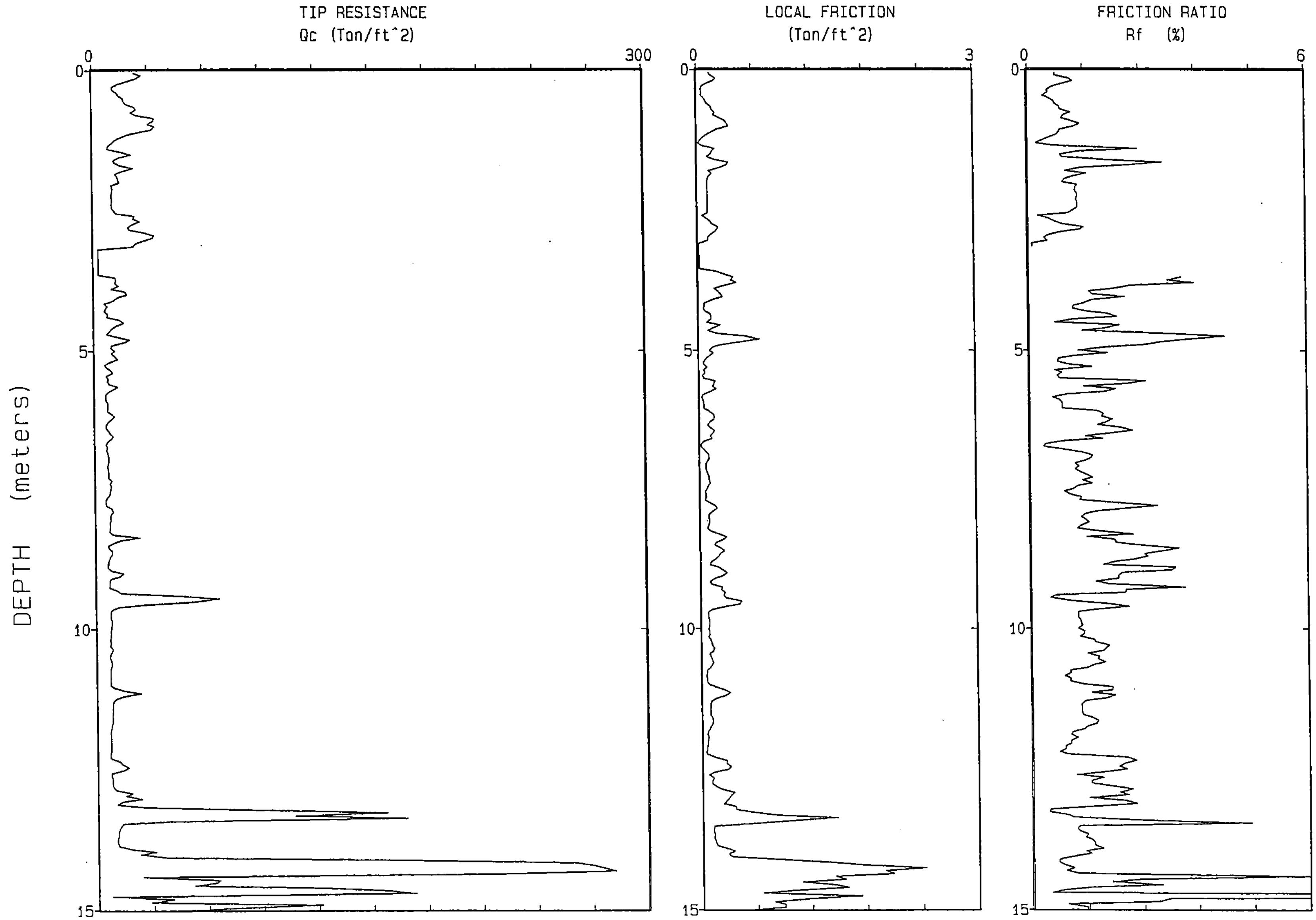
Location : C-L5 | Cone Used : H215 | Job No. : 20591



Depth Increment : .05 m

AGEC

Engineer : JM	CPT Date : 04/27/92 09:22	Page No: 1 / 2
Location : C-L7	Cone Used : H215	Job No. : 20591

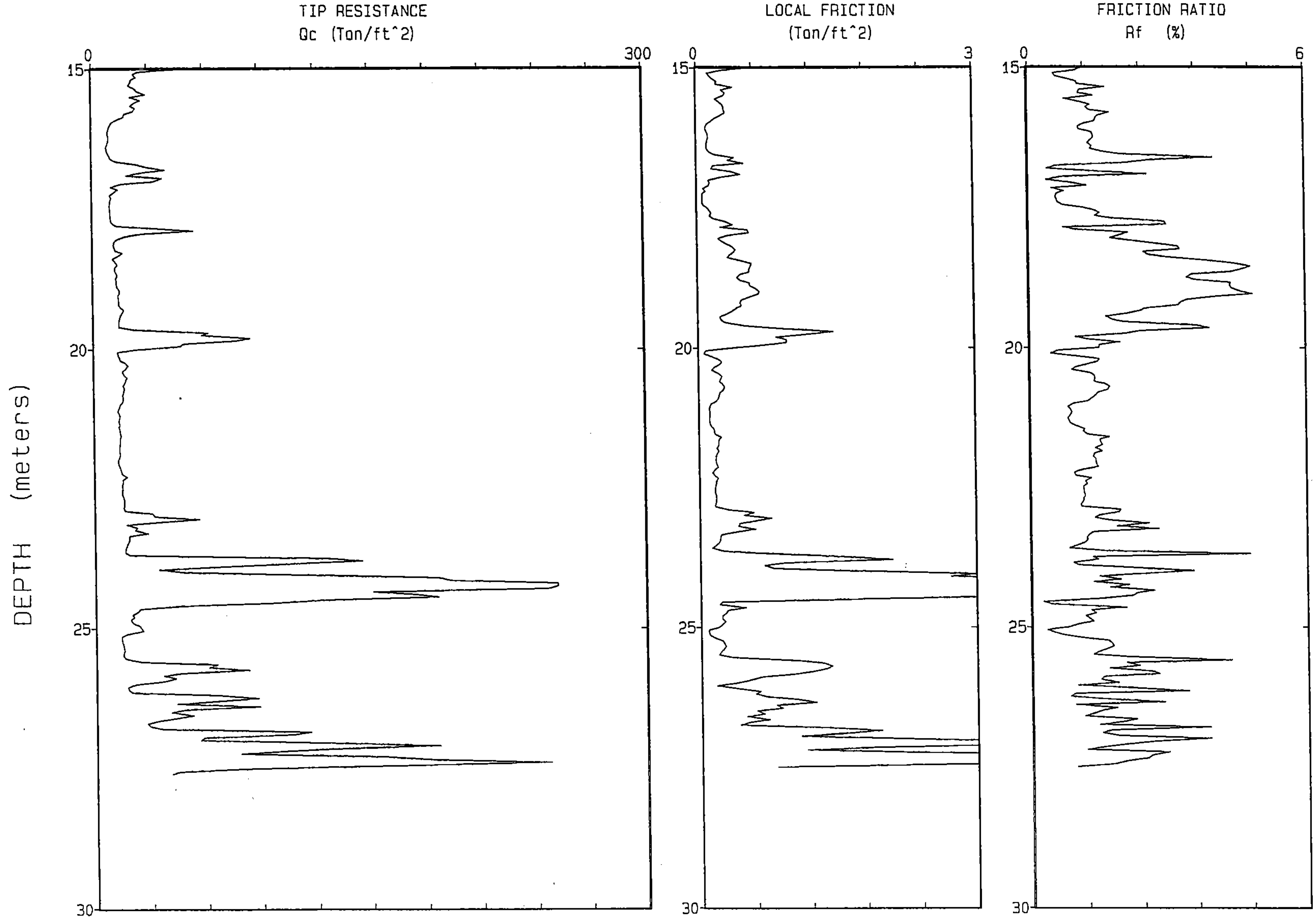


Depth Increment : .05 m

AGEC

Engineer : JM | CPT Date : 04/27/92 09:22 | Page No: 2 / 2

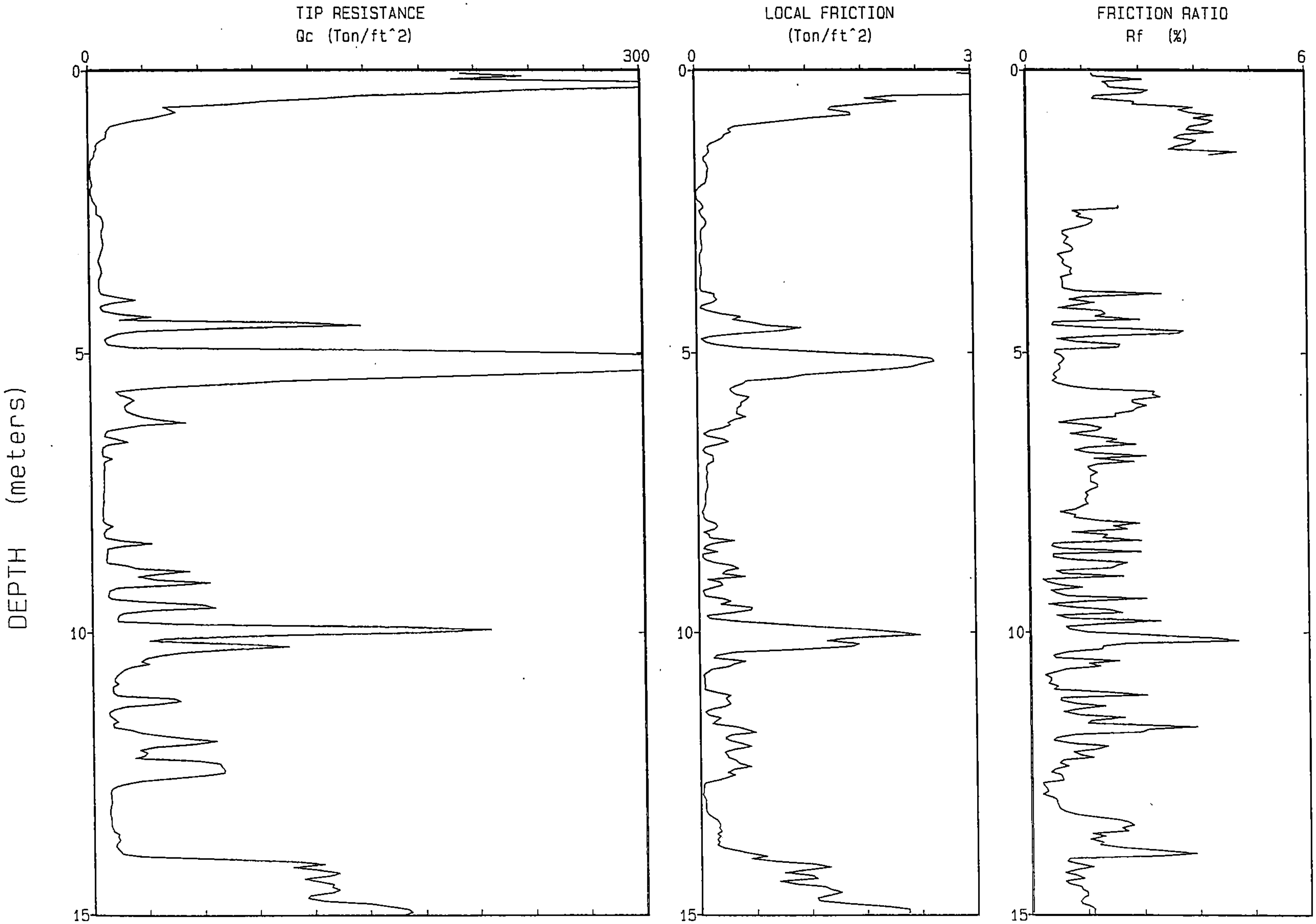
Location : C-L7 | Cone Used : H215 | Job No. : 20591



Depth Increment : .05 m

AGEC

Engineer : JM | CPT Date : 04/30/92 10:21 | Page No: 1 / 2
Location : C-L9 | Cone Used : H215 | Job No. : 20591

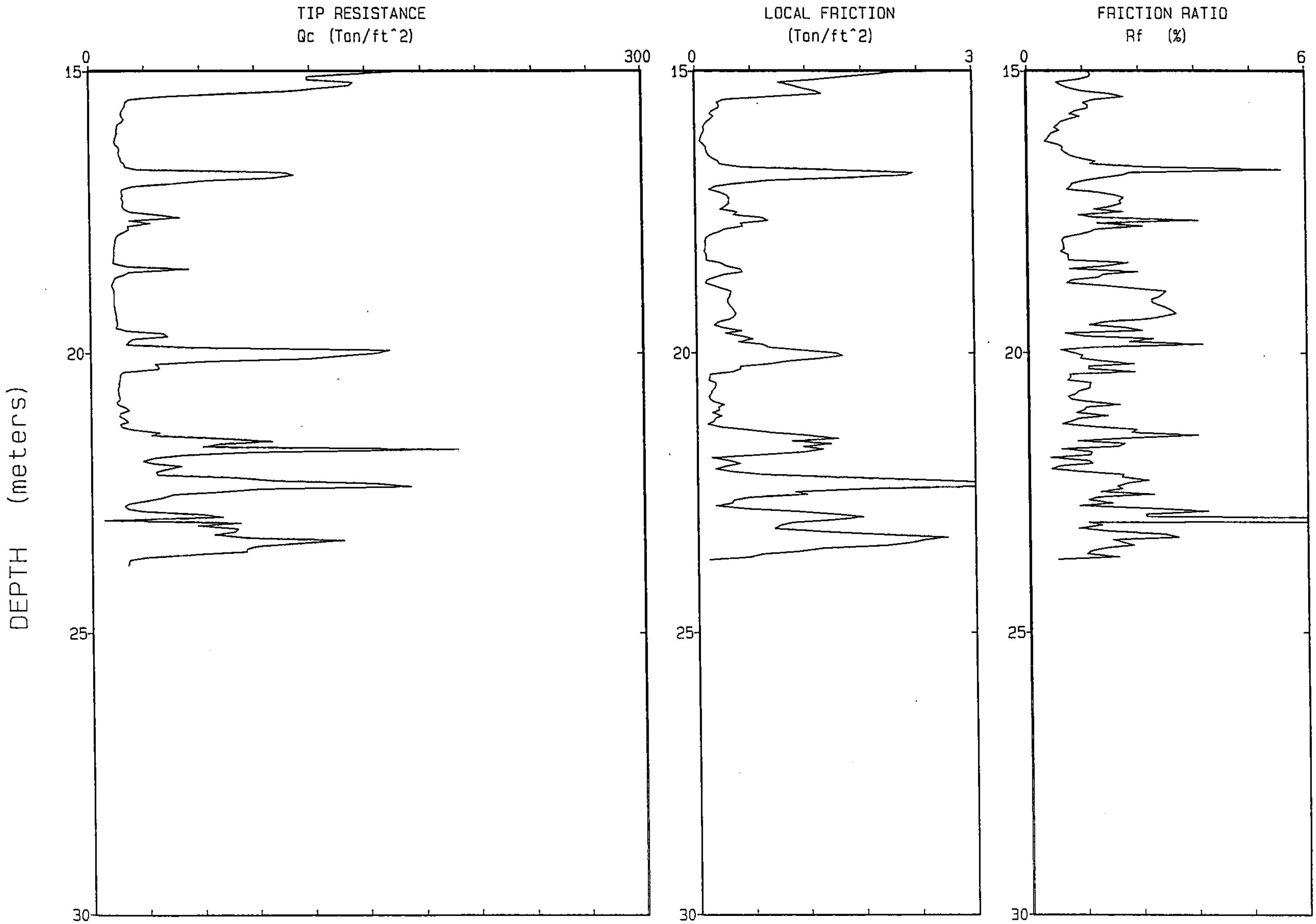


Depth Increment : .05 m

AGEC

Engineer : JM | CPT Date : 04/30/92 10:21 | Page No: 2 / 2

Location : C-L9 | Cone Used : H215 | Job No. : 20591



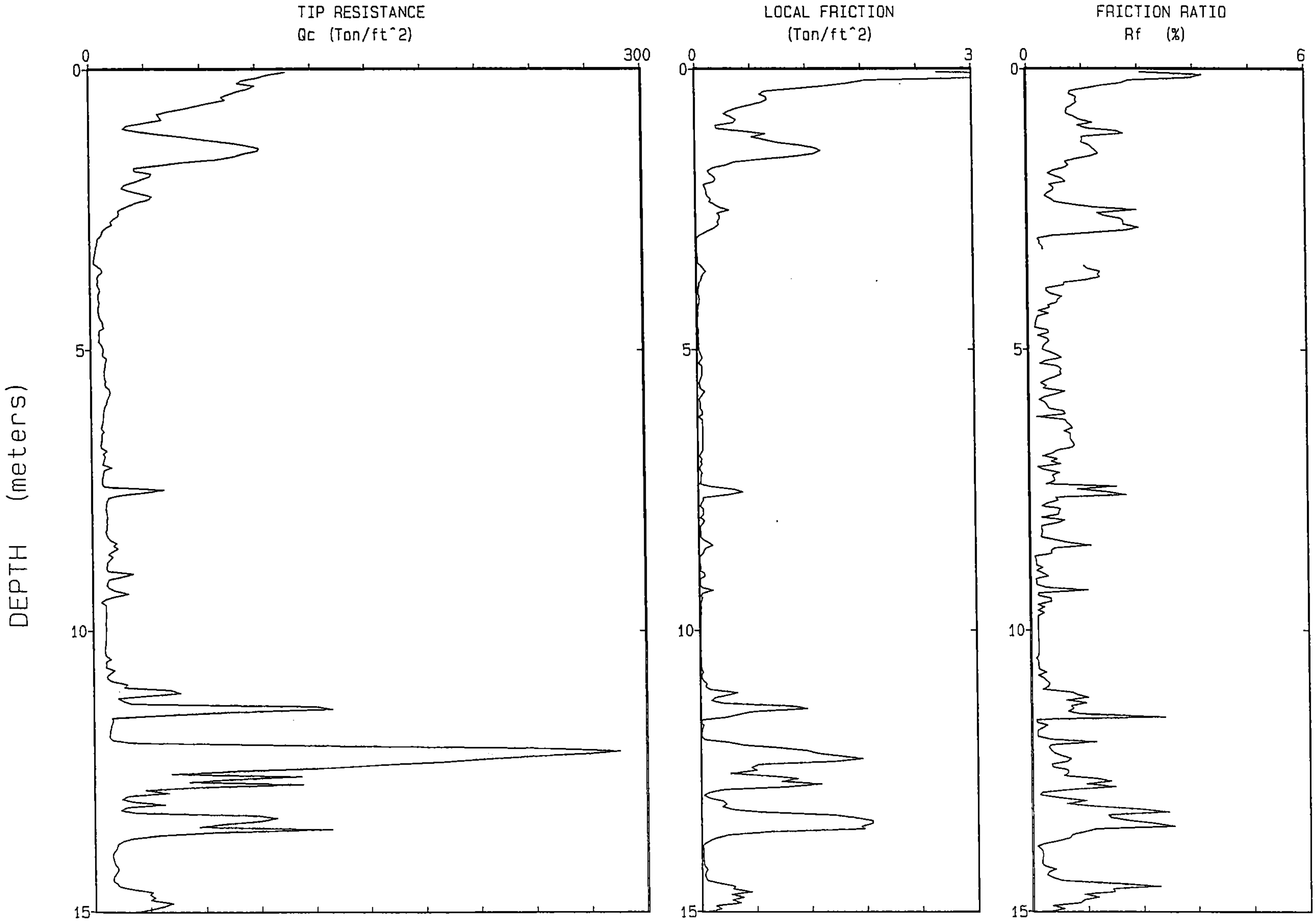
Depth Increment : .05 m

AGEC

Engineer : JM
Location : C-L11

CPT Date : 04/27/92 11:34
Cone Used : H215

Page No: 1 / 2
Job No. : 20591

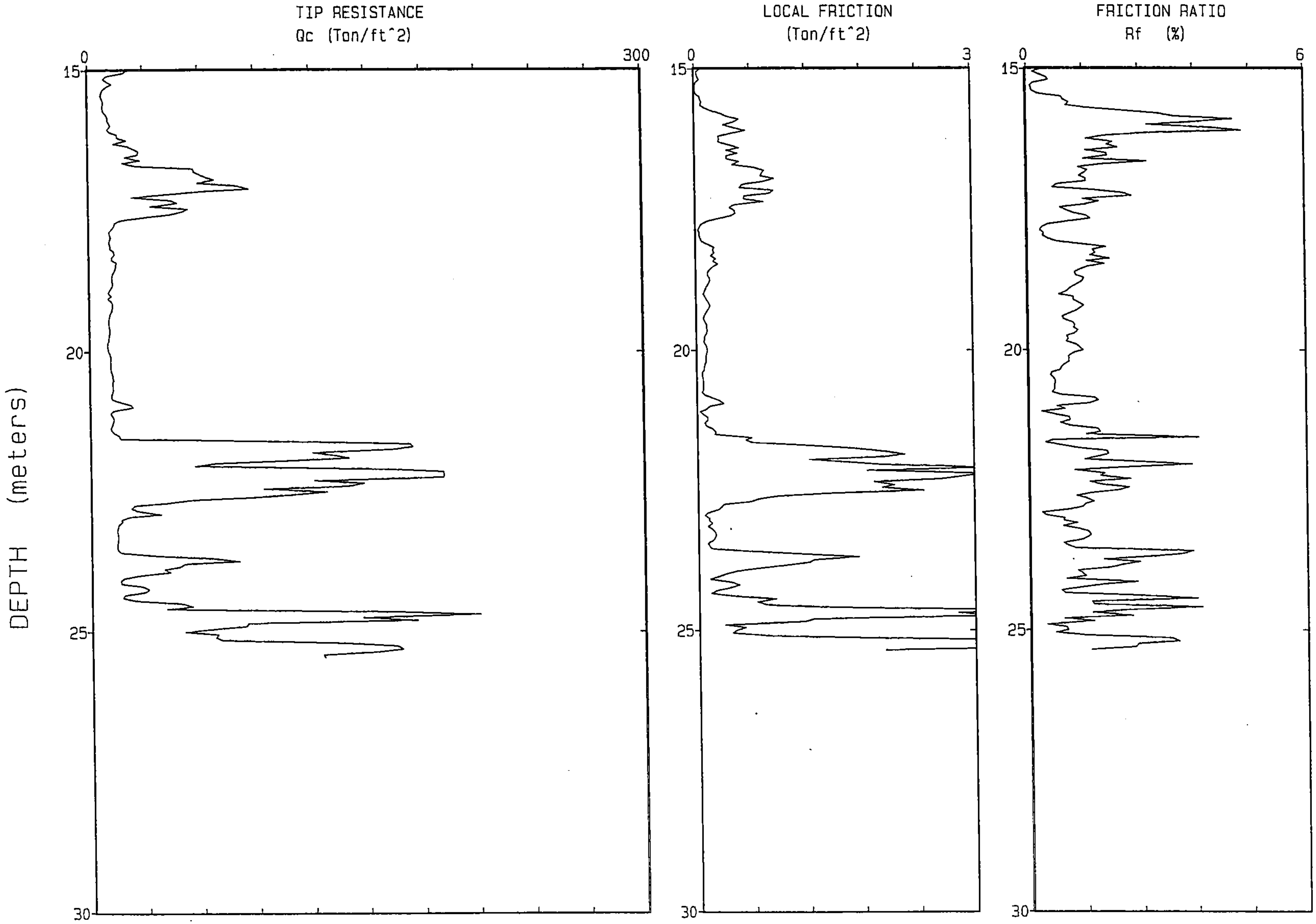


Depth Increment : .05 m

AGEC

Engineer : JM | CPT Date : 04/27/92 11:34 | Page No: 2 / 2

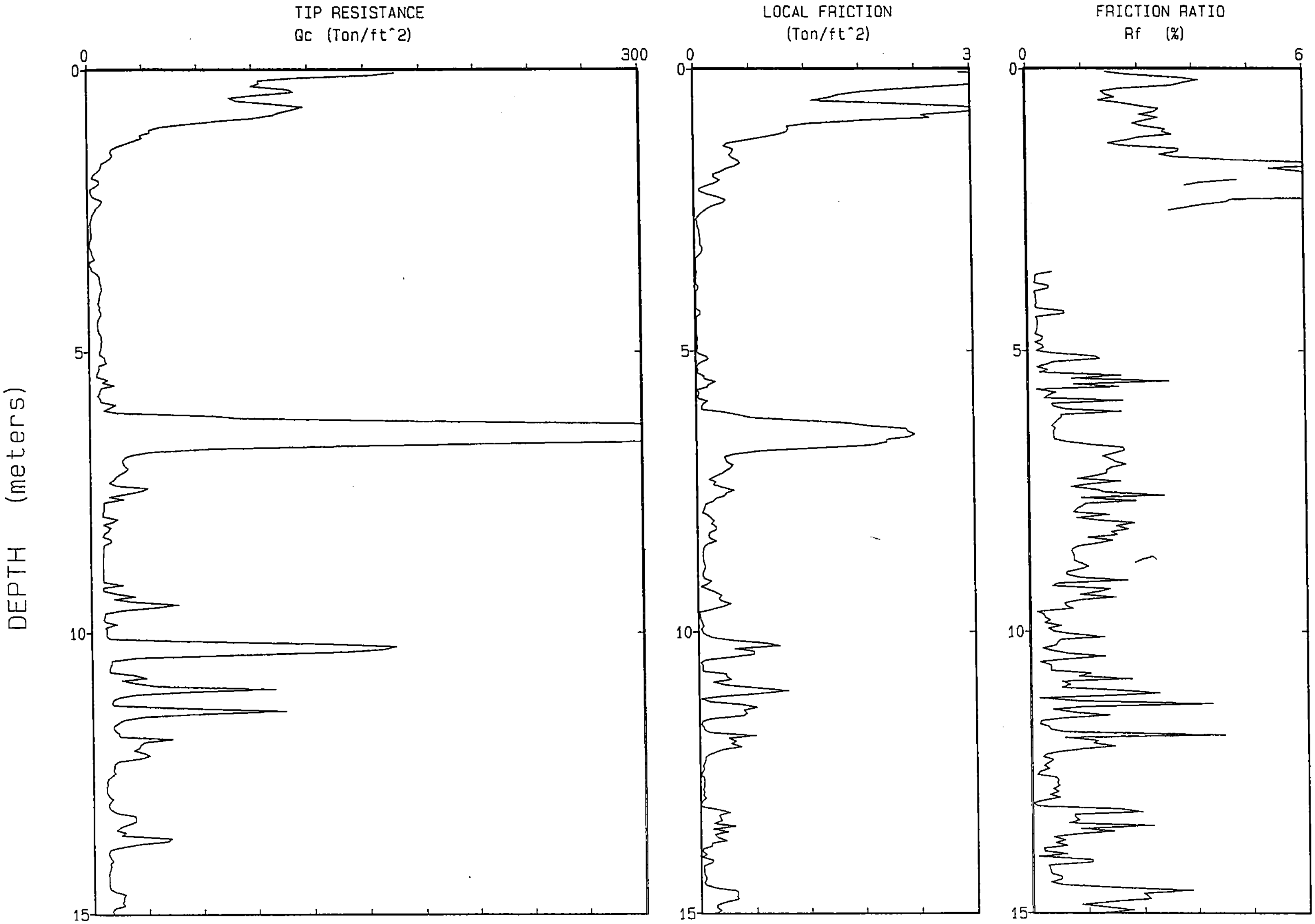
Location : C-L11 | Cone Used : H215 | Job No. : 20591



Depth Increment : .05 m

AGEC

Engineer : JM	CPT Date : 04/27/92 15:04	Page No: 1 / 2
Location : C-L13	Cone Used : H215	Job No. : 20591

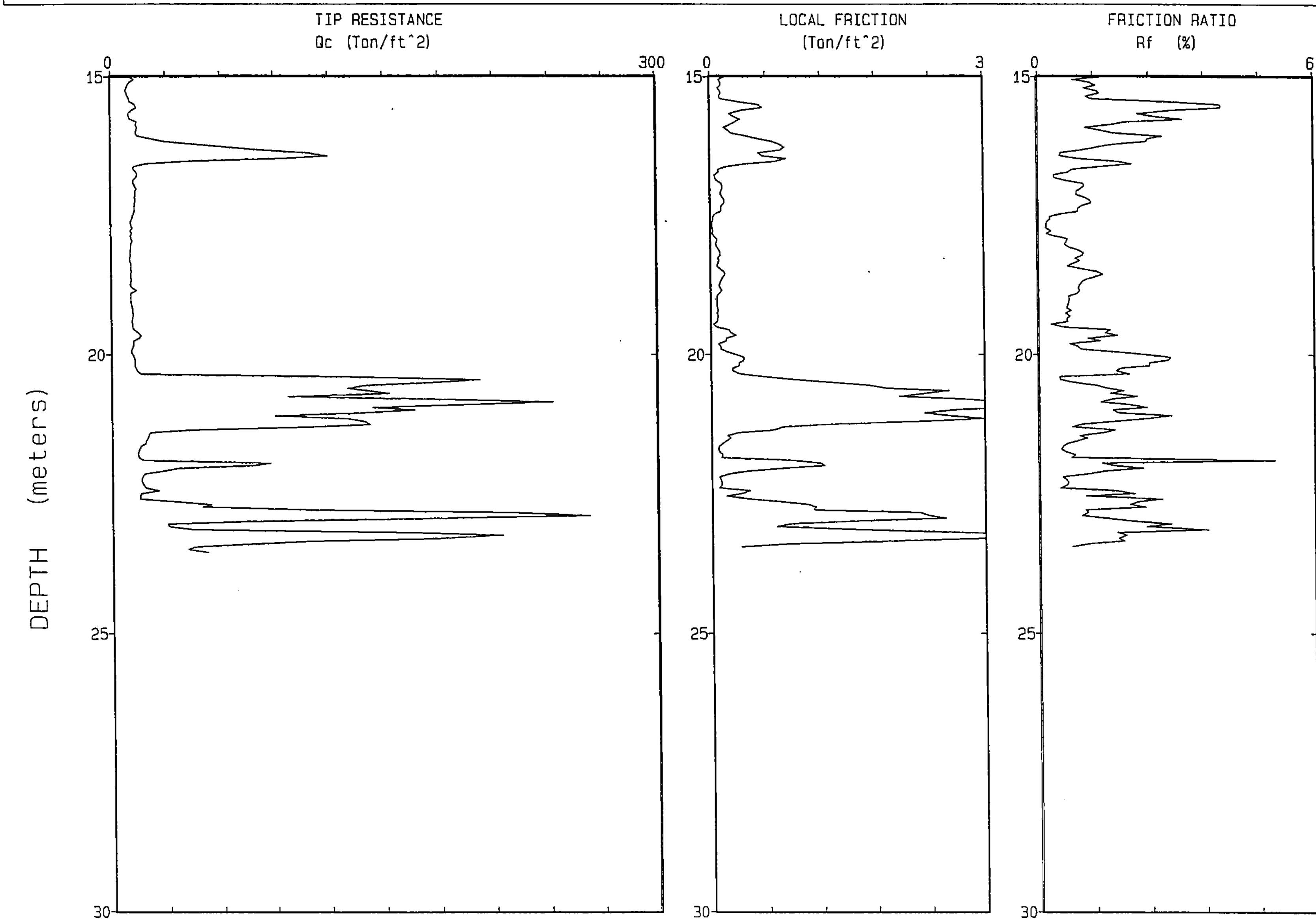


Depth Increment : .05 m

AGEC

Engineer : JM — CPT Date : 04/27/92 15:04 — Page No: 2 / 2

Location : C-L13 — Cone Used : H215 — Job No. : 20591

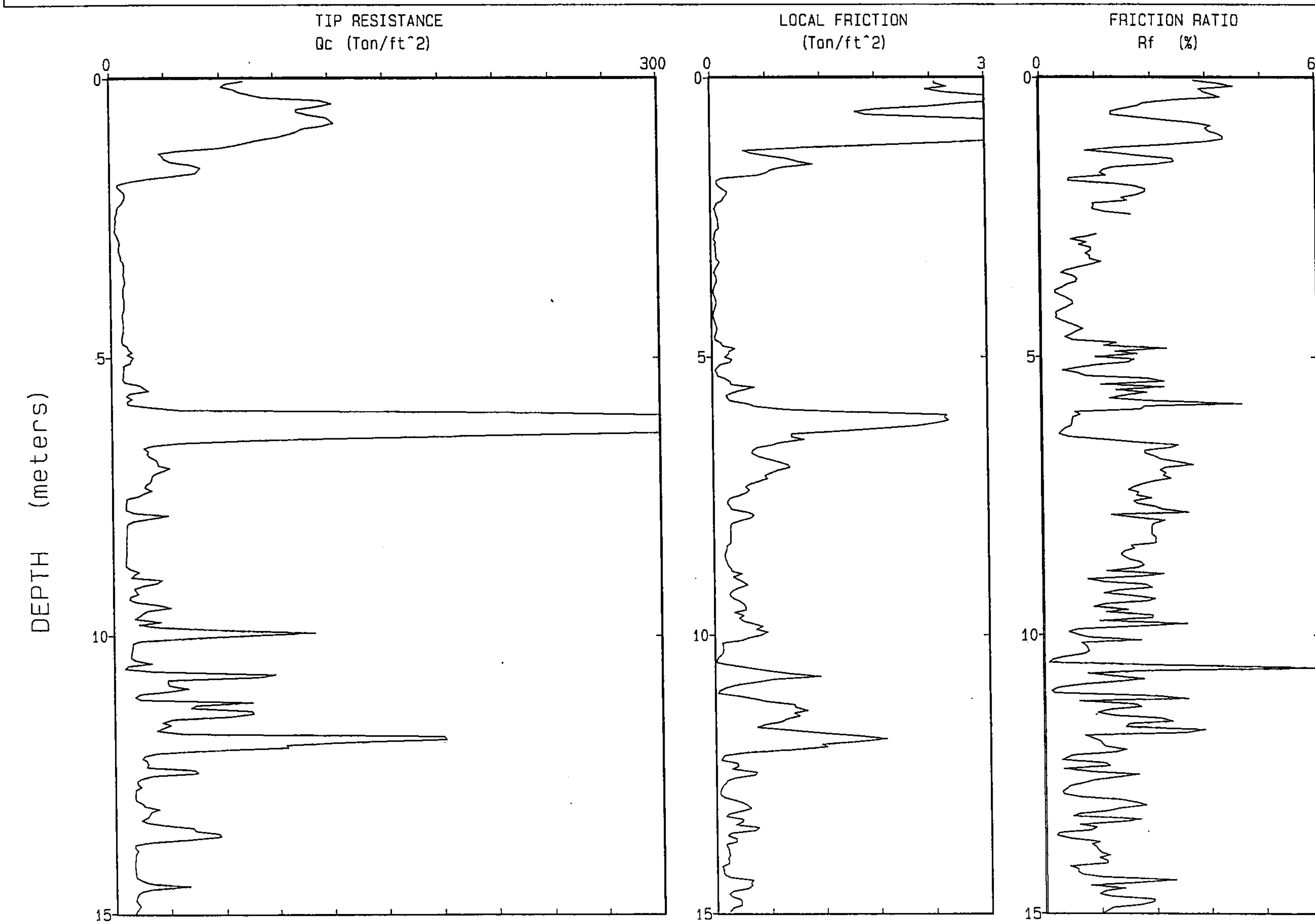


Depth Increment : .05 m

AGEC

Engineer : JM   CPT Date : 04/10/92 11:03   Page No: 1 / 2

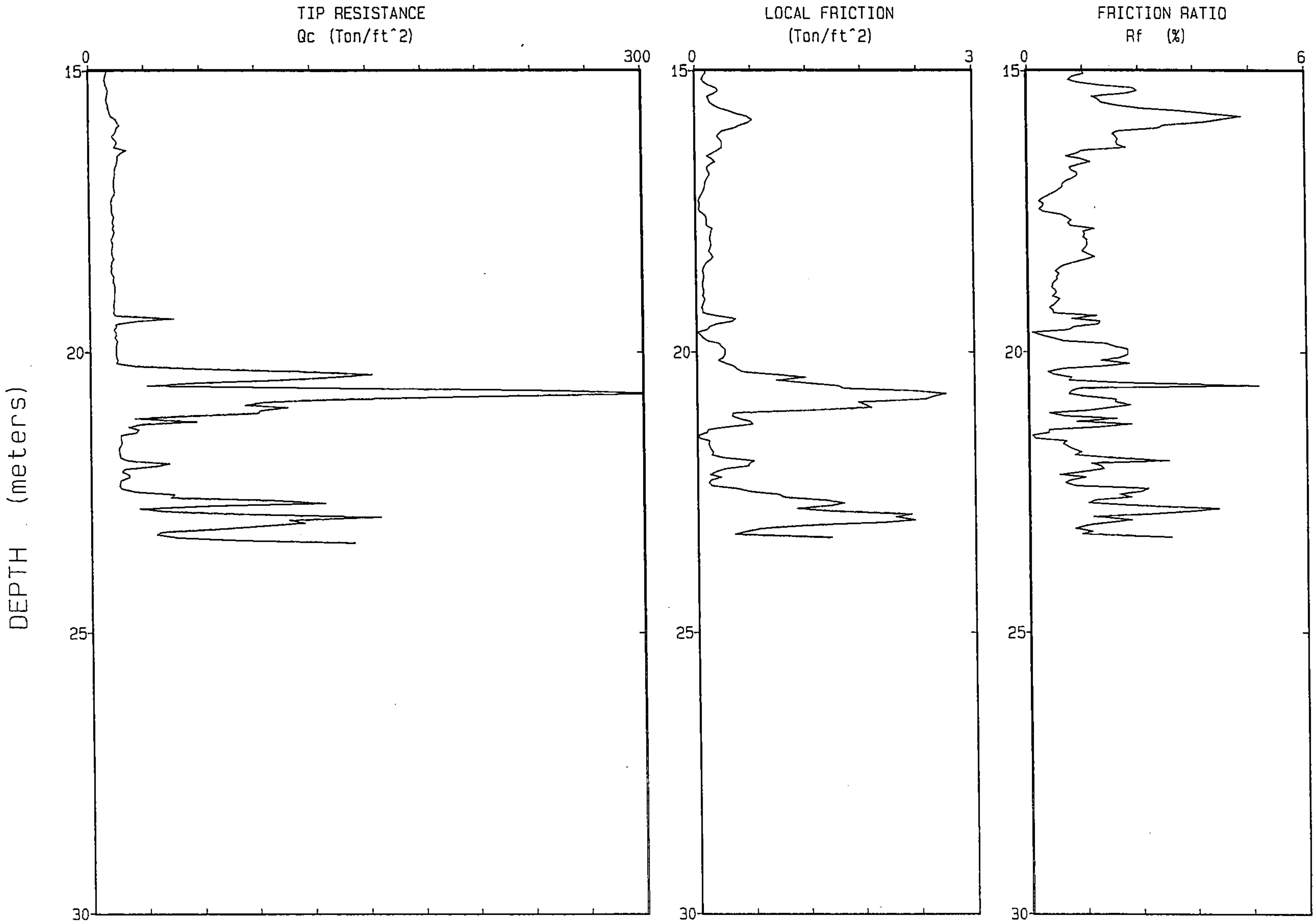
Location : C-L14   Cone Used : H215   Job No. : 20591



Depth Increment : .05 m

AGEC

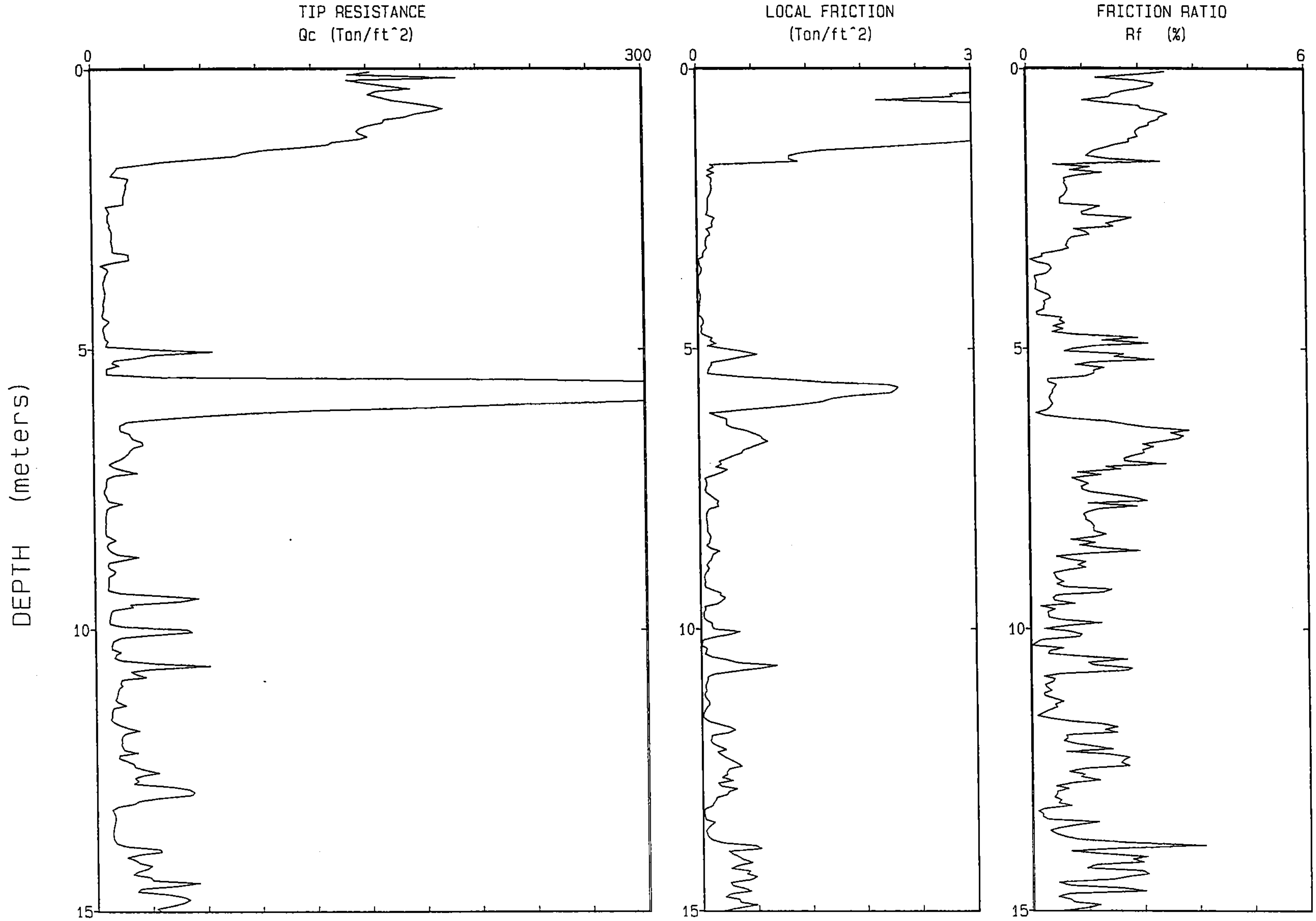
Engineer : JM | CPT Date : 04/10/92 11:03 | Page No: 2 / 2
Location : C-L14 | Cone Used : H215 | Job No. : 20591



Depth Increment : .05 m

AGEC

Engineer :	JM	CPT Date :	04/27/92 15:04	Page No:	1 / 2
Location :	C-L16	Cone Used :	H215	Job No. :	20591

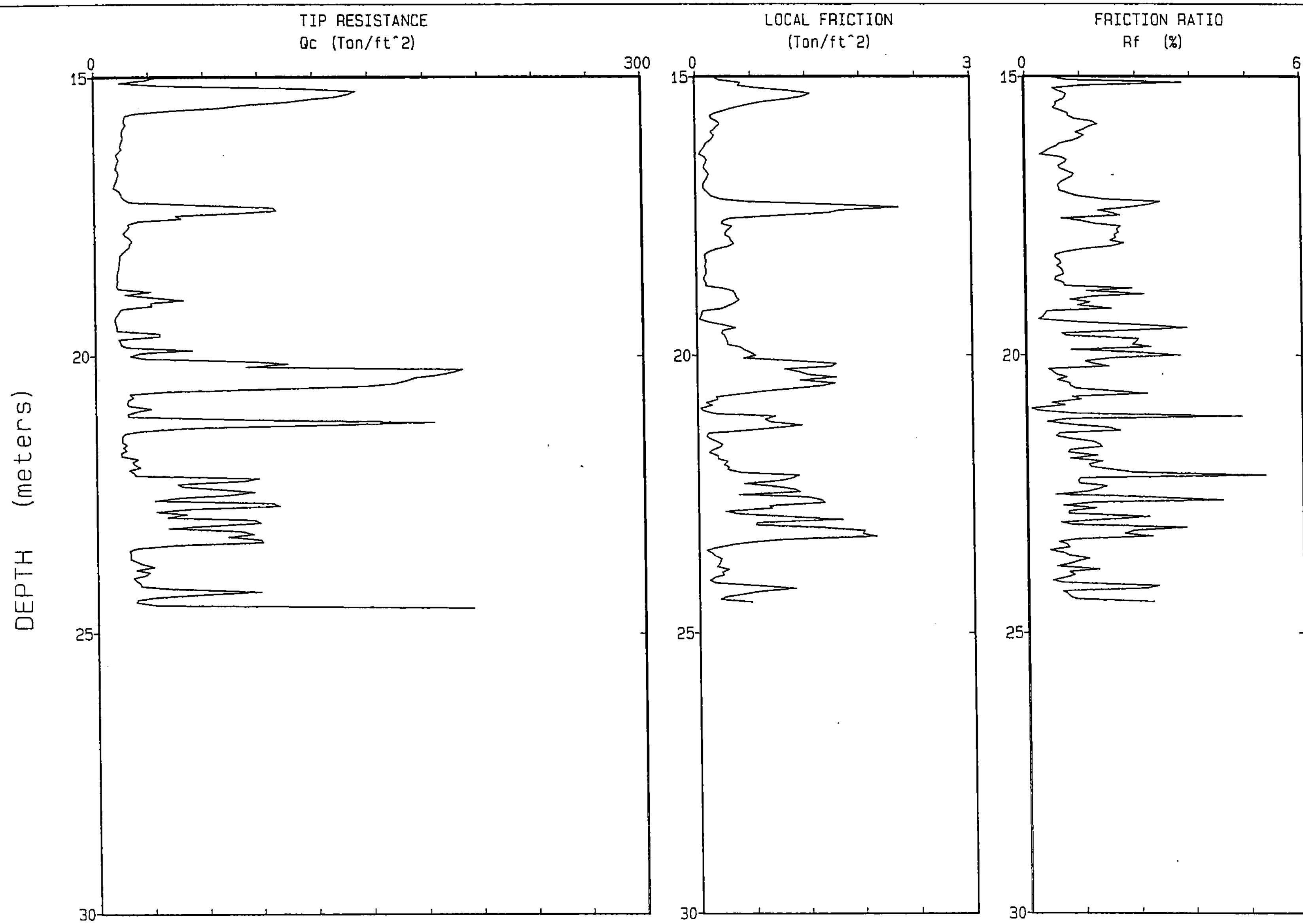


Depth Increment : .05 m

AGEC

Engineer : JM | CPT Date : 04/27/92 15:04 | Page No: 2 / 2

Location : C-L16 | Cone Used : H215 | Job No. : 20591

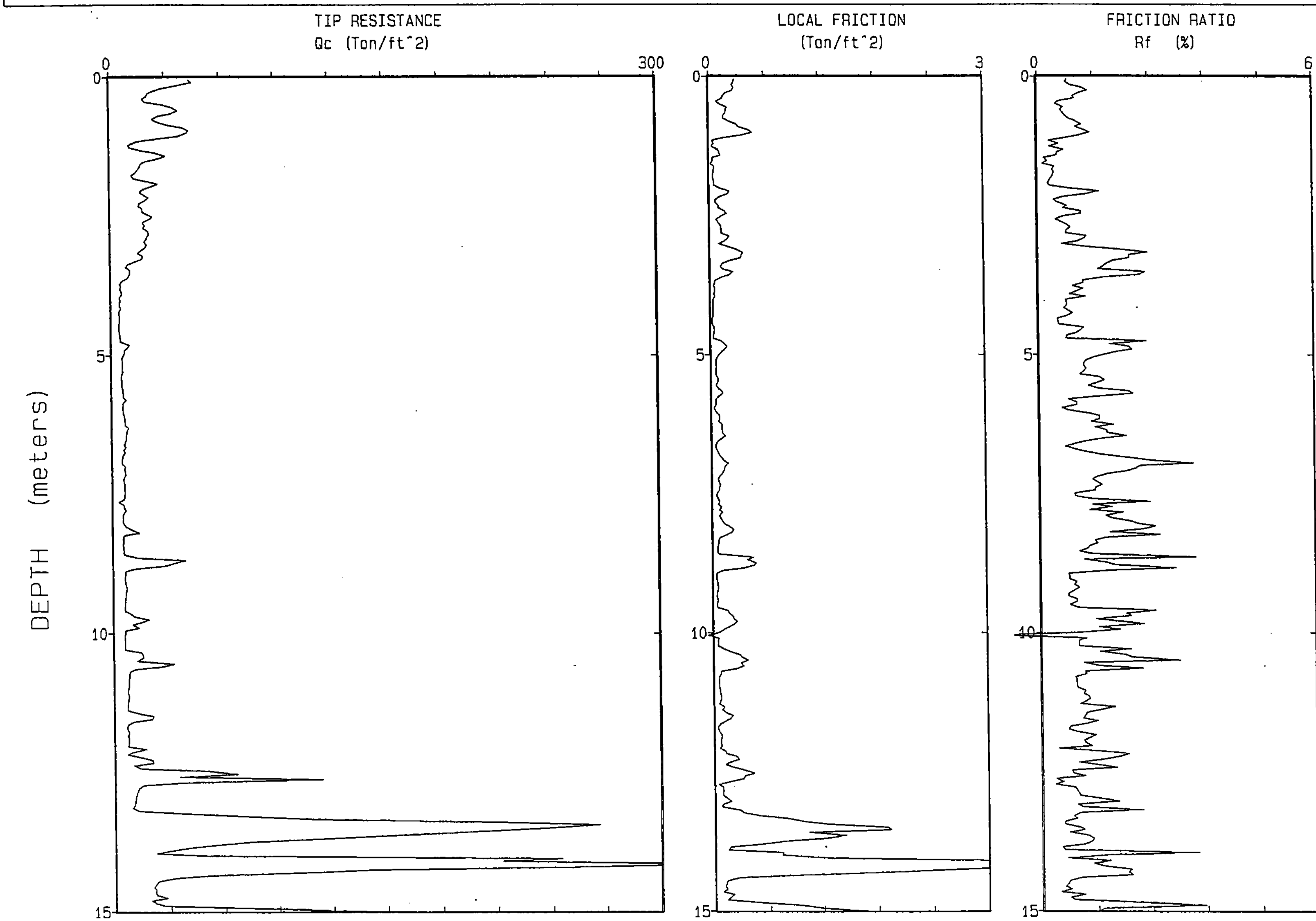


Depth Increment : .05 m

AGEC

Engineer : JM | CPT Date : 07/23/92 11:05 | Page No: 1 / 2

Location : C-L18 | Cone Used : H215 | Job No. : 20591

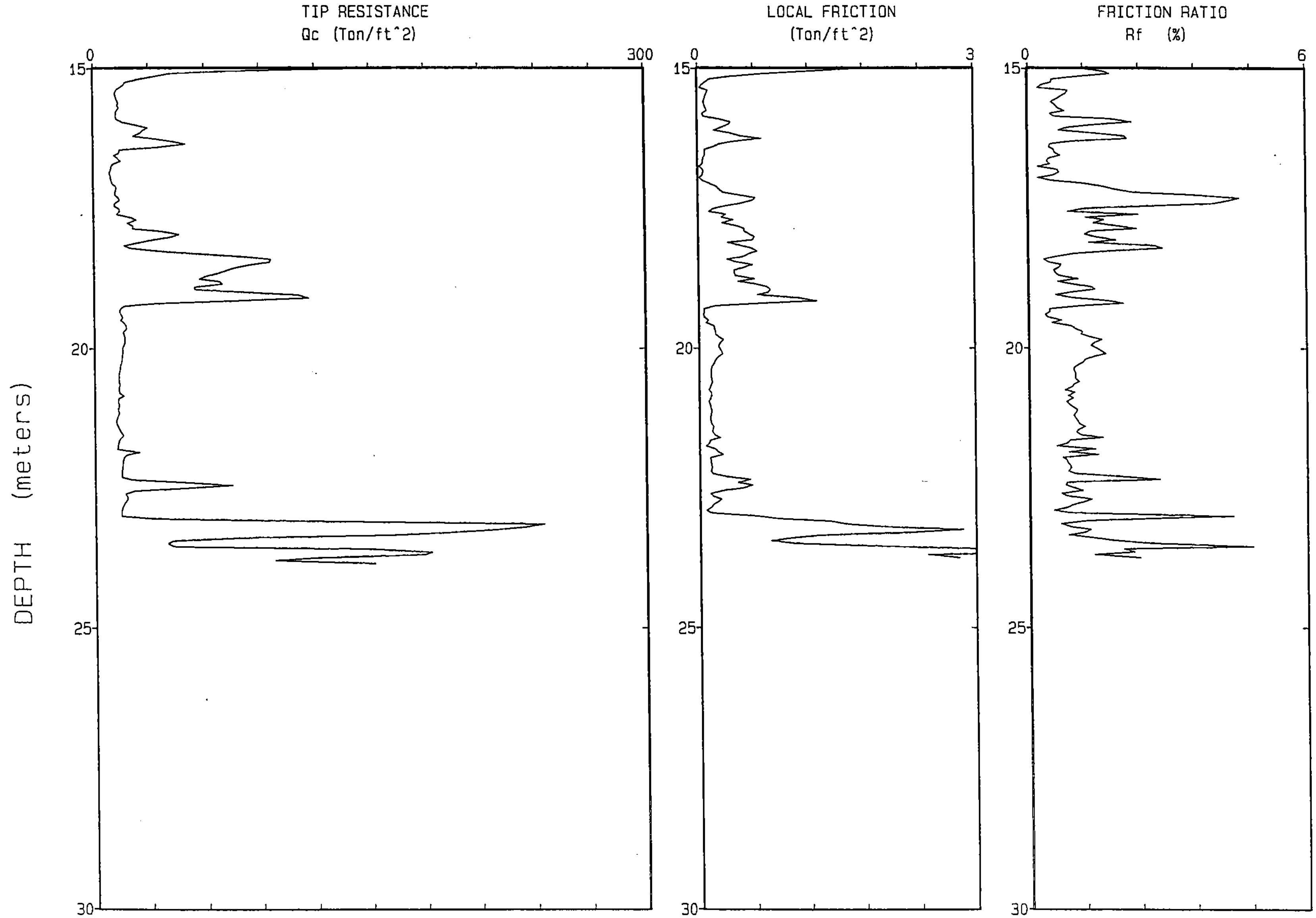


Depth Increment : .05 m

AGEC

Engineer : JM   CPT Date : 07/23/92 11:05   Page No: 2 / 2

Location : C-L18   Cone Used : H215   Job No. : 20591

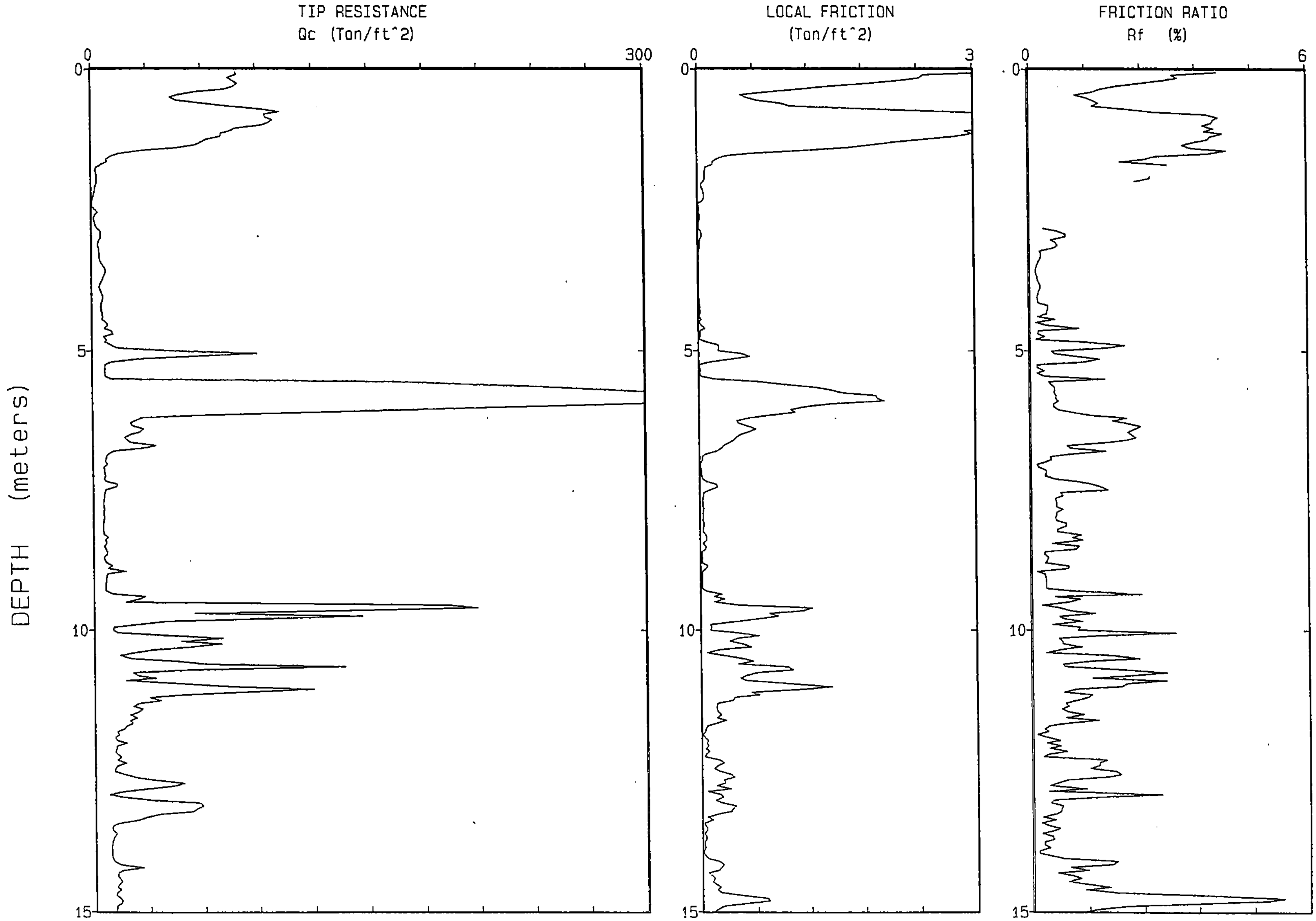


Depth Increment : .05 m

AGEC

Engineer : JM　　CPT Date : 04/28/92 14:04　　Page No: 1 / 2

Location : C-L20　　Cone Used : H215　　Job No. : 20591



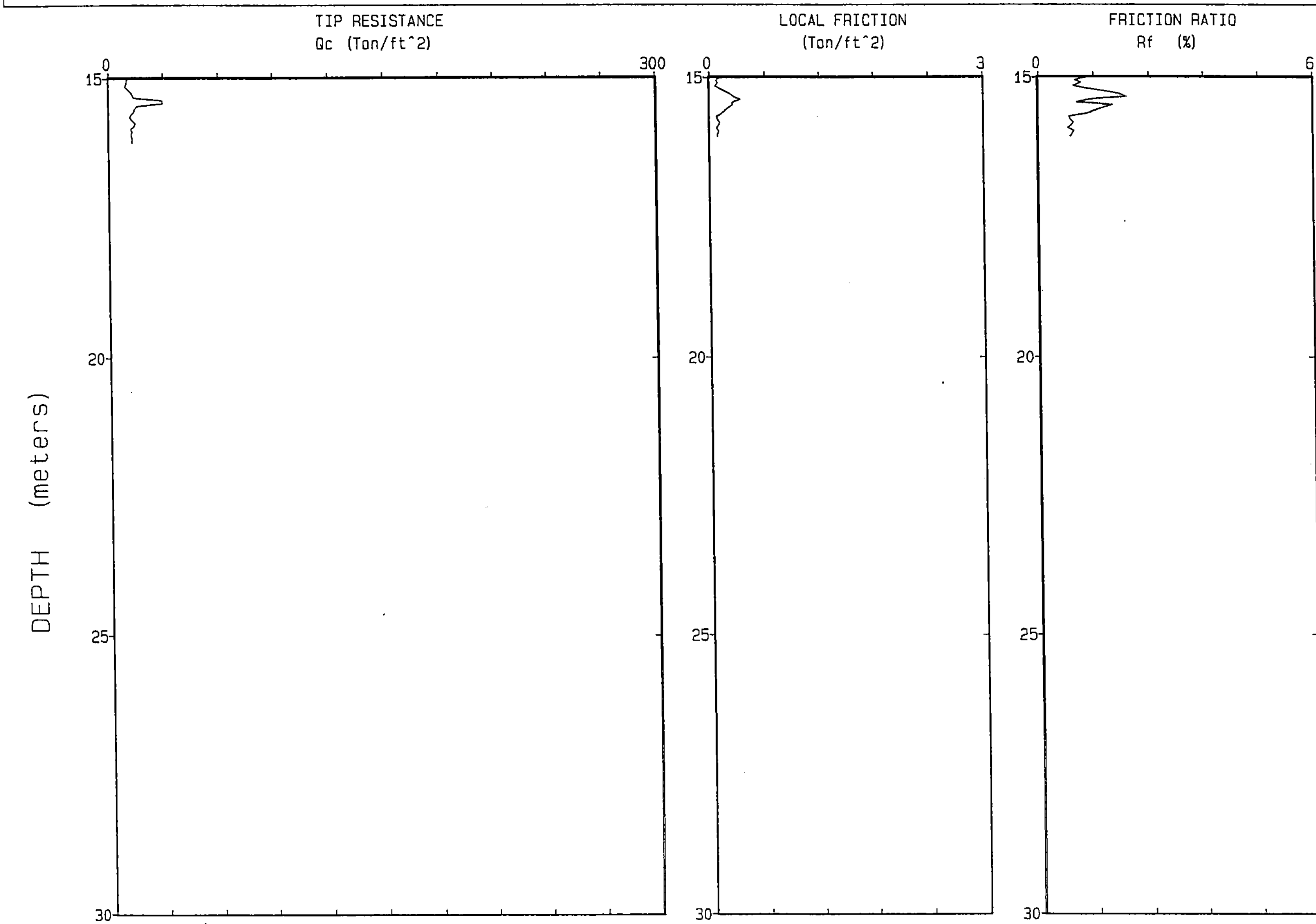
Depth Increment : .05 m

AGEC

Engineer : JM
Location : C-L20

CPT Date : 04/28/92 14:04
Cone Used : H215

Job No. : 20591



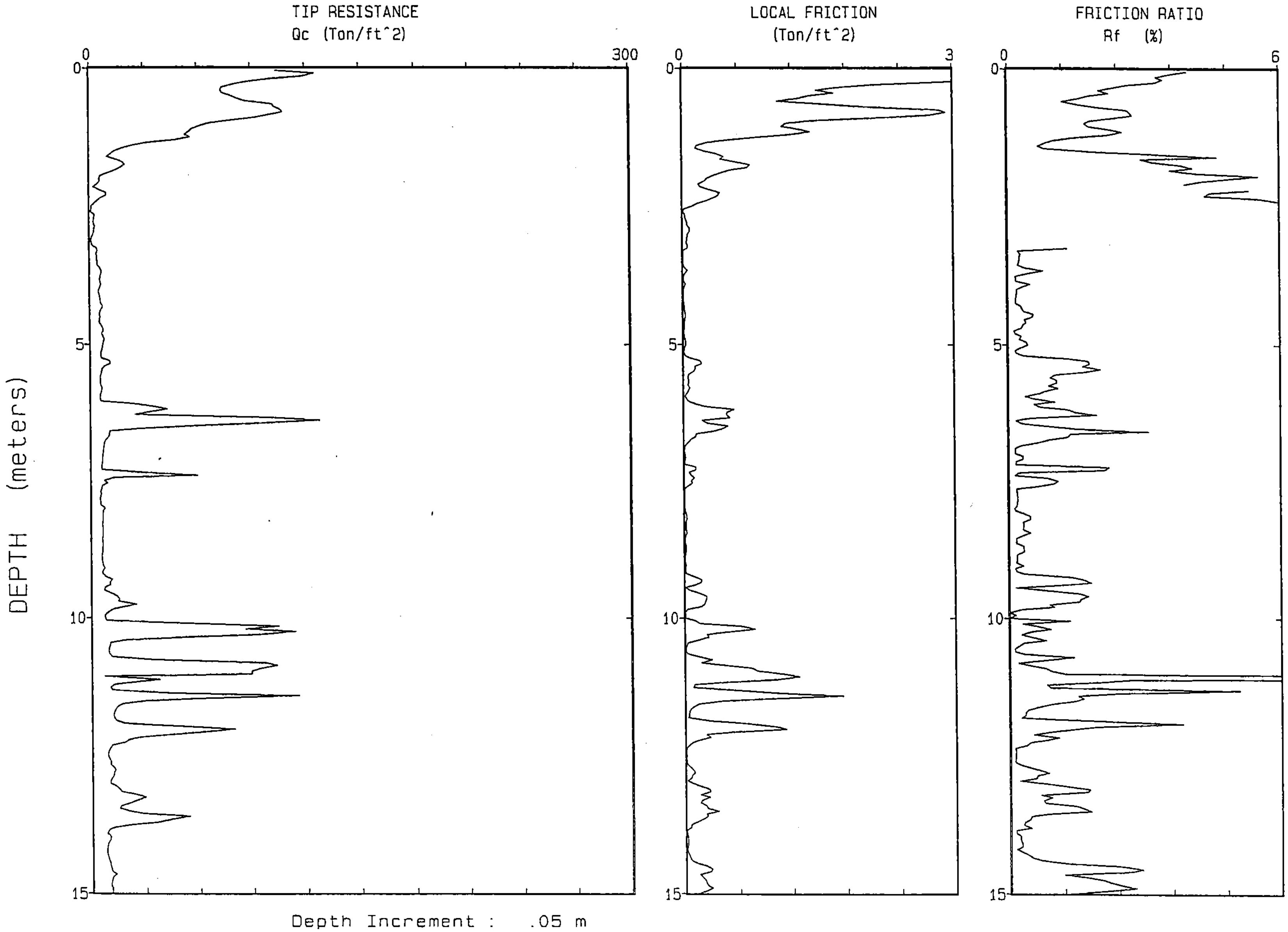
Depth Increment : .05 m

AGEC

Engineer : JM
Location : C-L22

CPT Date : 04/29/92 10:22
Cone Used : H215

Page No: 1 / 2
Job No. : 20591

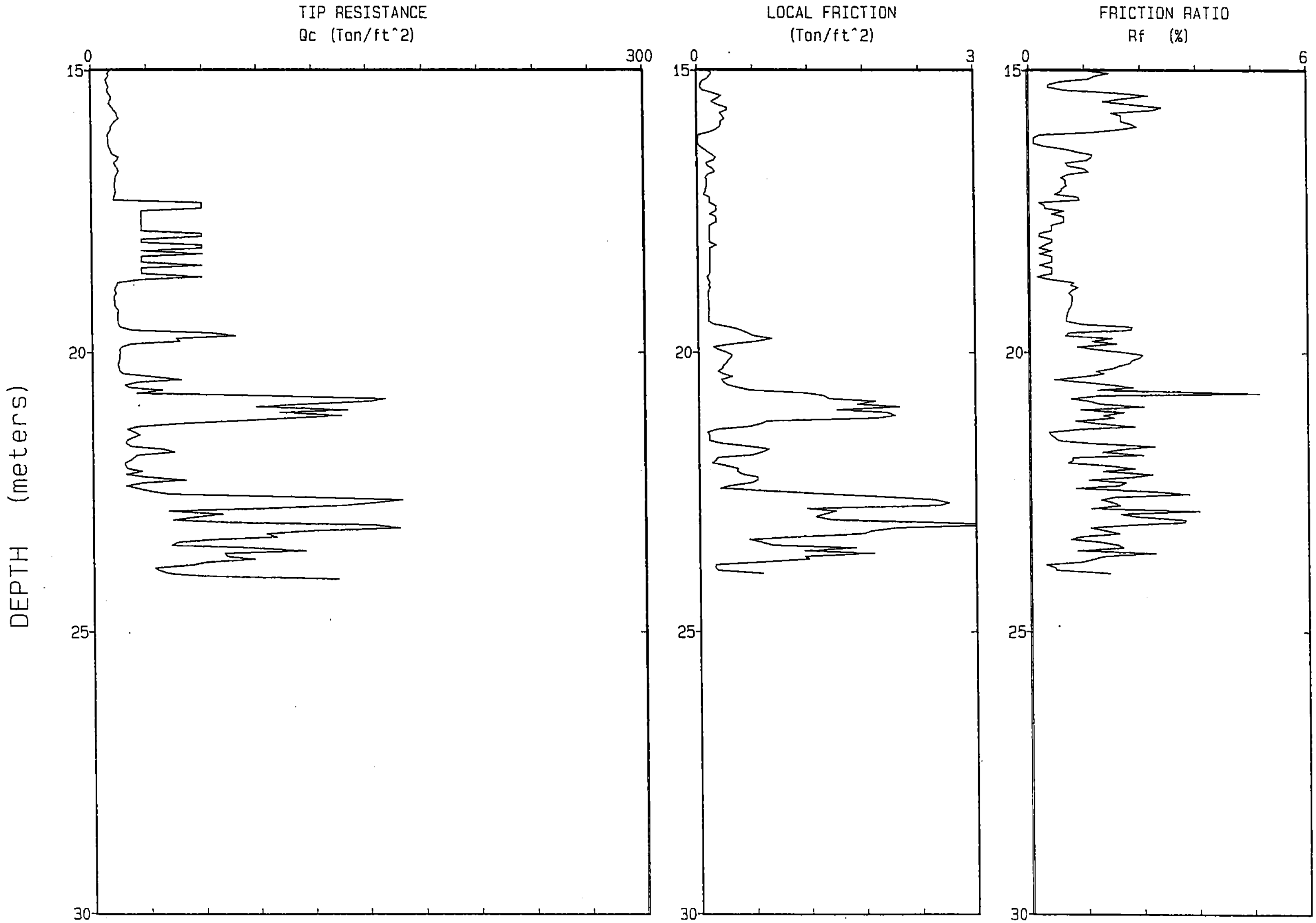


AGEC

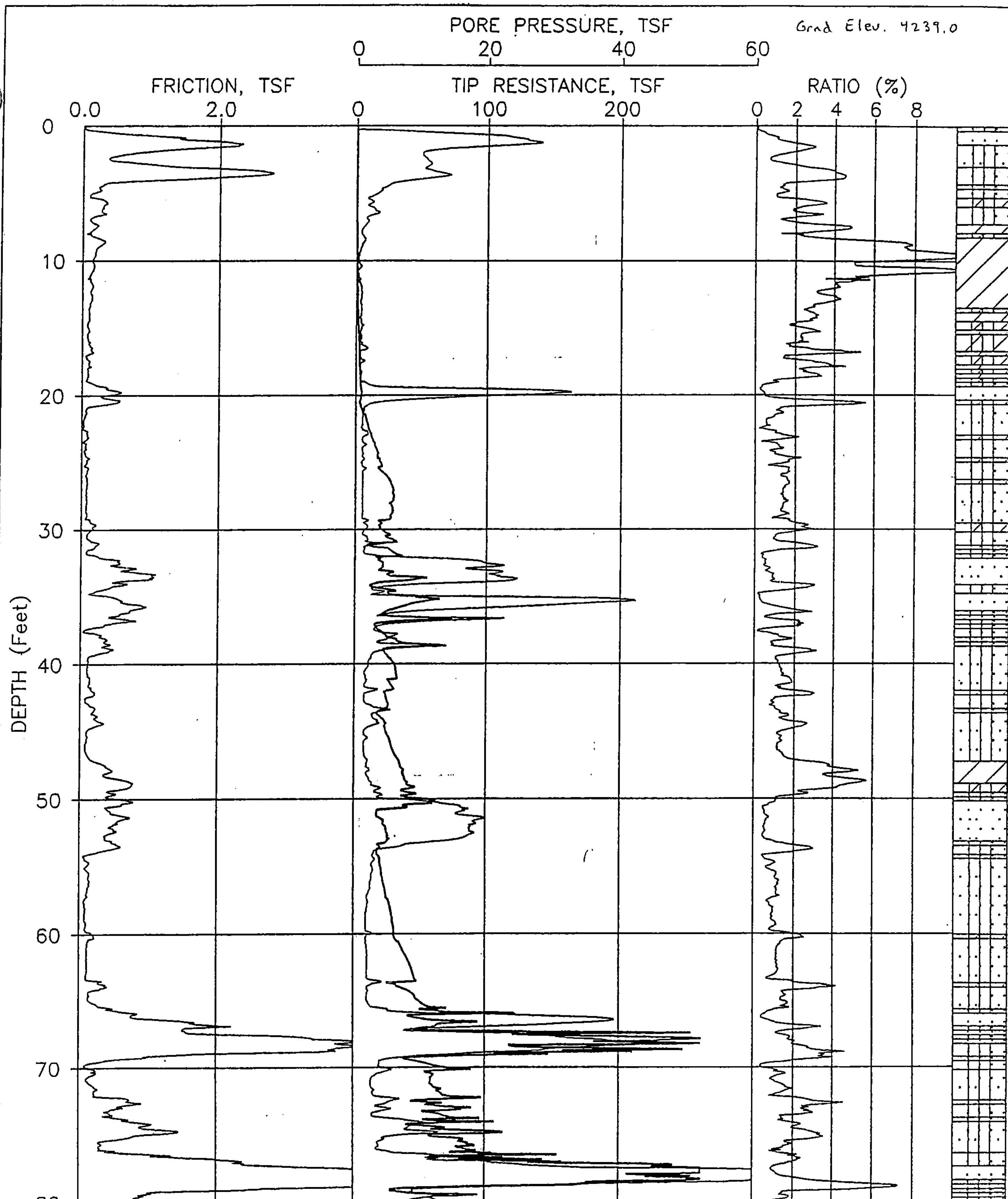
Engineer : JM
Location : C-L22

CPT Date : 04/29/92 10:22
Cone Used : H215

Job No. : 20591



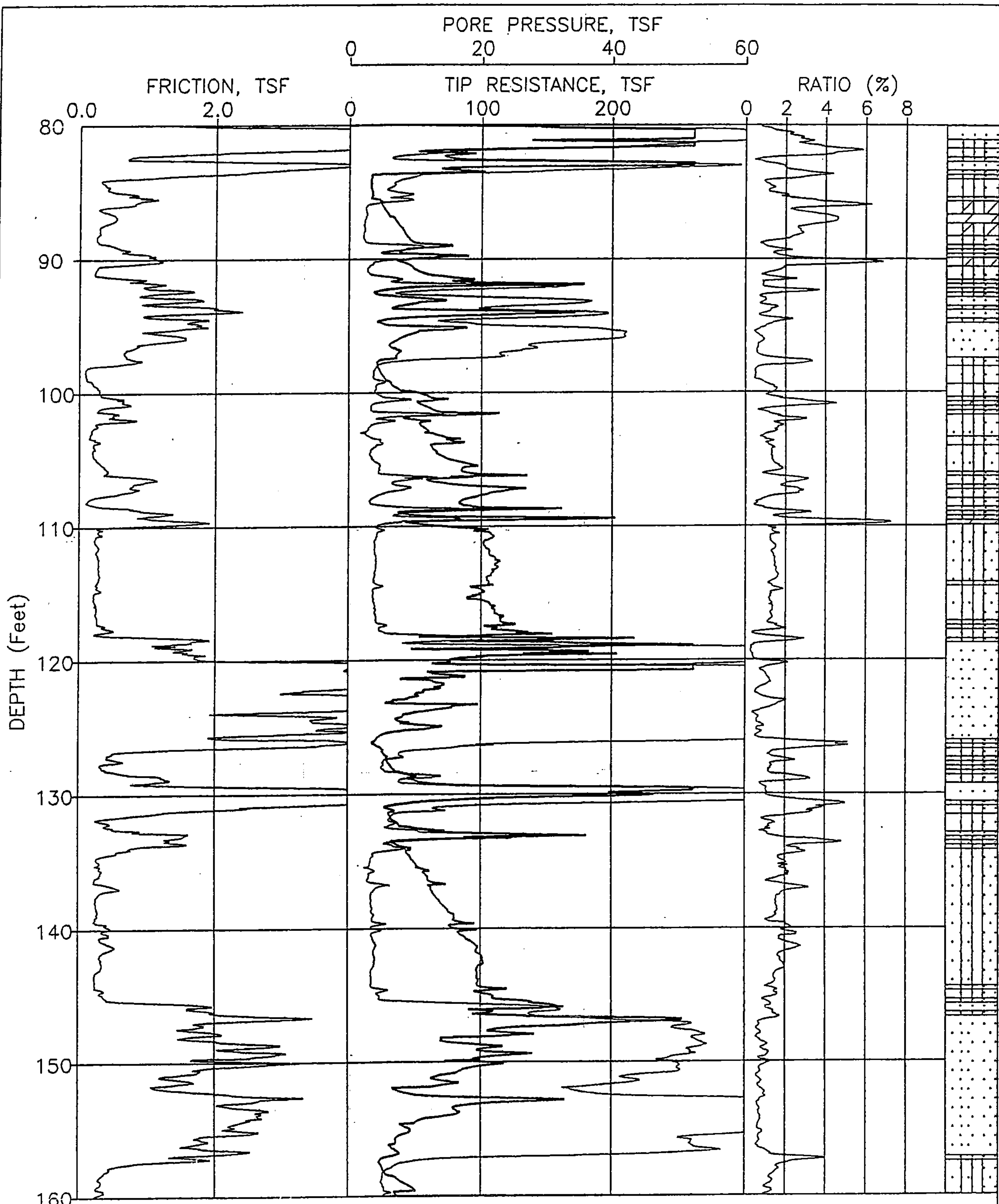
Depth Increment : .05 m



JOB NUMBER: 95-0110 CPT NUMBER: CPT-L32 DATE: 08-17-1995

ELEVATION: 4239.04 CONE NUMBER:F7.5CKEW852 PLATE: 1 OF 4

FUGRO GEOSCIENCES,INC

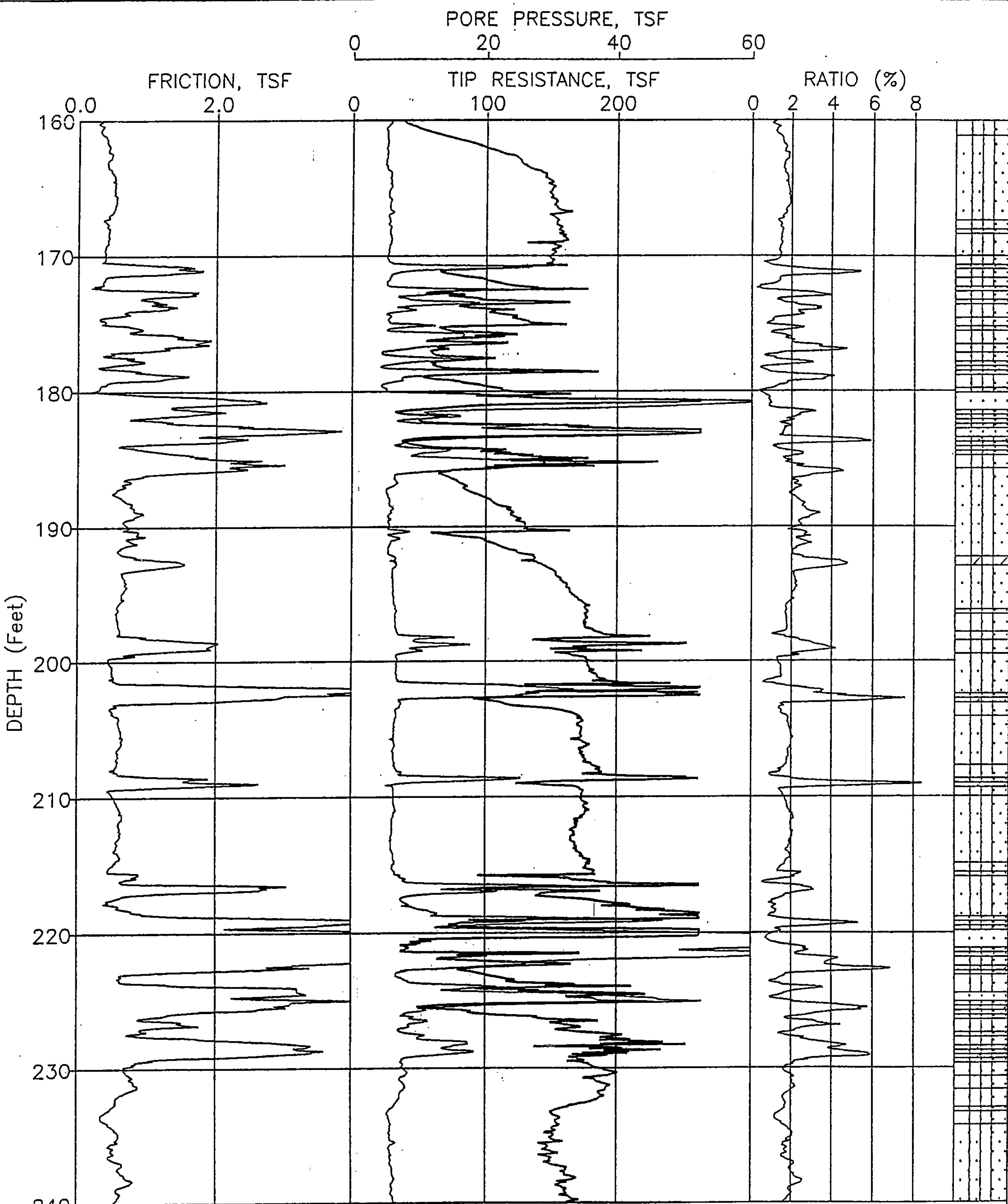


JOB NUMBER: 95-0110
ELEVATION: 4239.04

CPT NUMBER: CPT-L32
CONE NUMBER:F7.5CKEW852

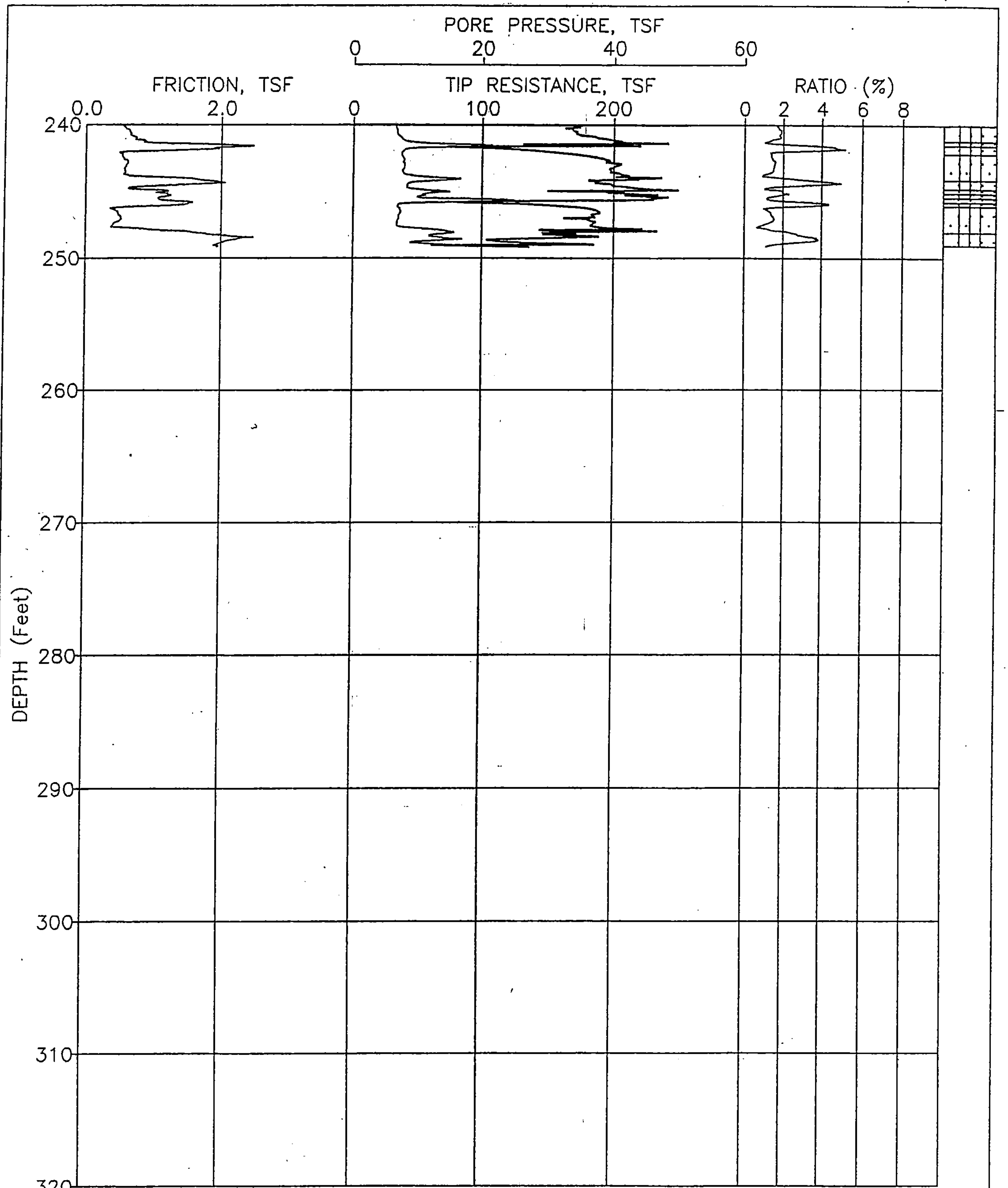
DATE: 08-17-1995
PLATE: 2 OF 4

FUGRO GEOSCIENCES,INC



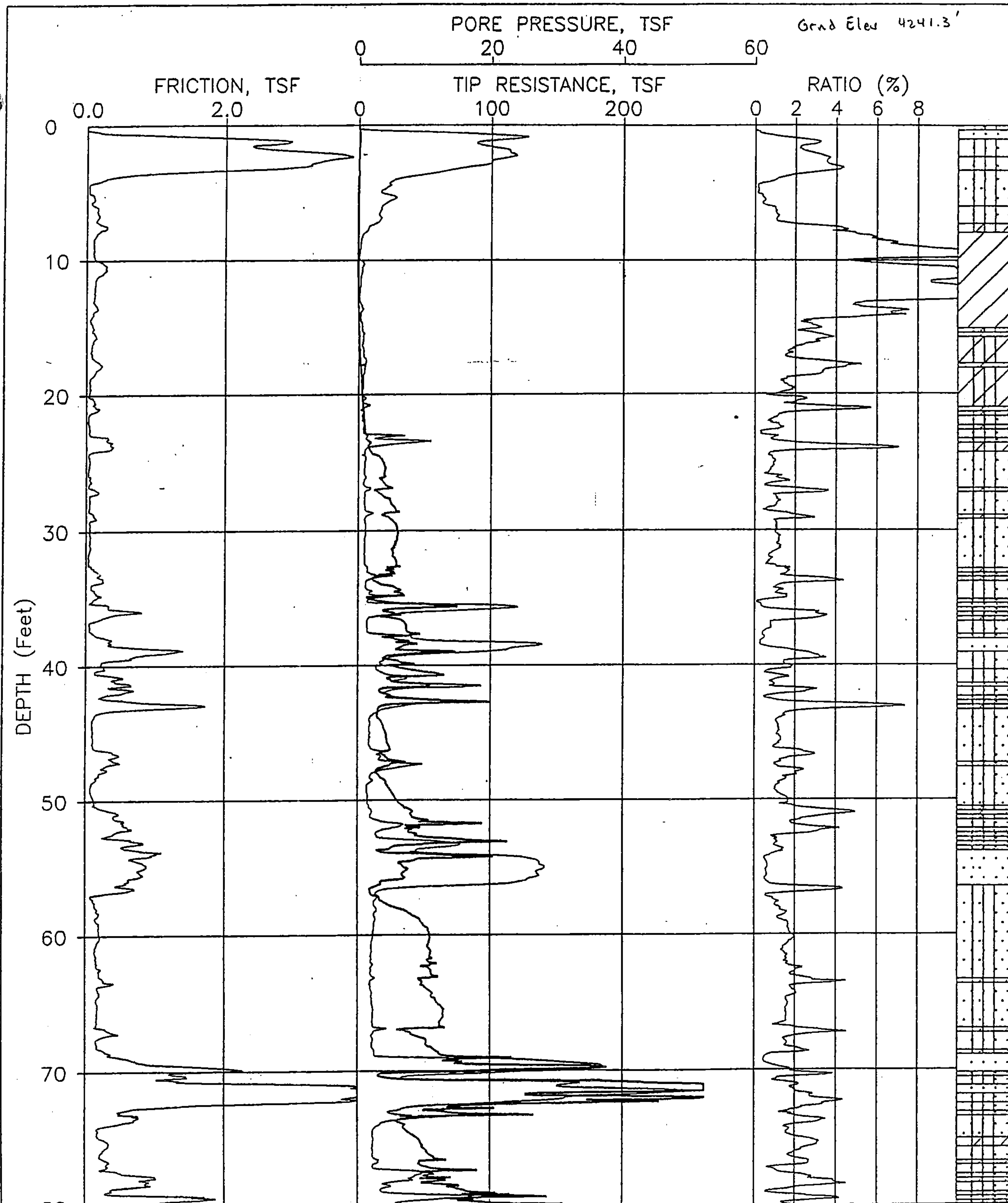
JOB NUMBER: 95-0110
ELEVATION: 4239.04
CPT NUMBER: CPT-L32
CONE NUMBER:F7.5CKEW852
DATE: 08-17-1995
PLATE: 3 OF 4

FUGRO GEOSCIENCES,INC



JOB NUMBER: 95-0110 CPT NUMBER: CPT-L32 DATE: 08-17-1995
ELEVATION: 4239.04 CONE NUMBER:F7.5CKEW852 PLATE: 4 OF 4

FUGRO GEOSCIENCES,INC

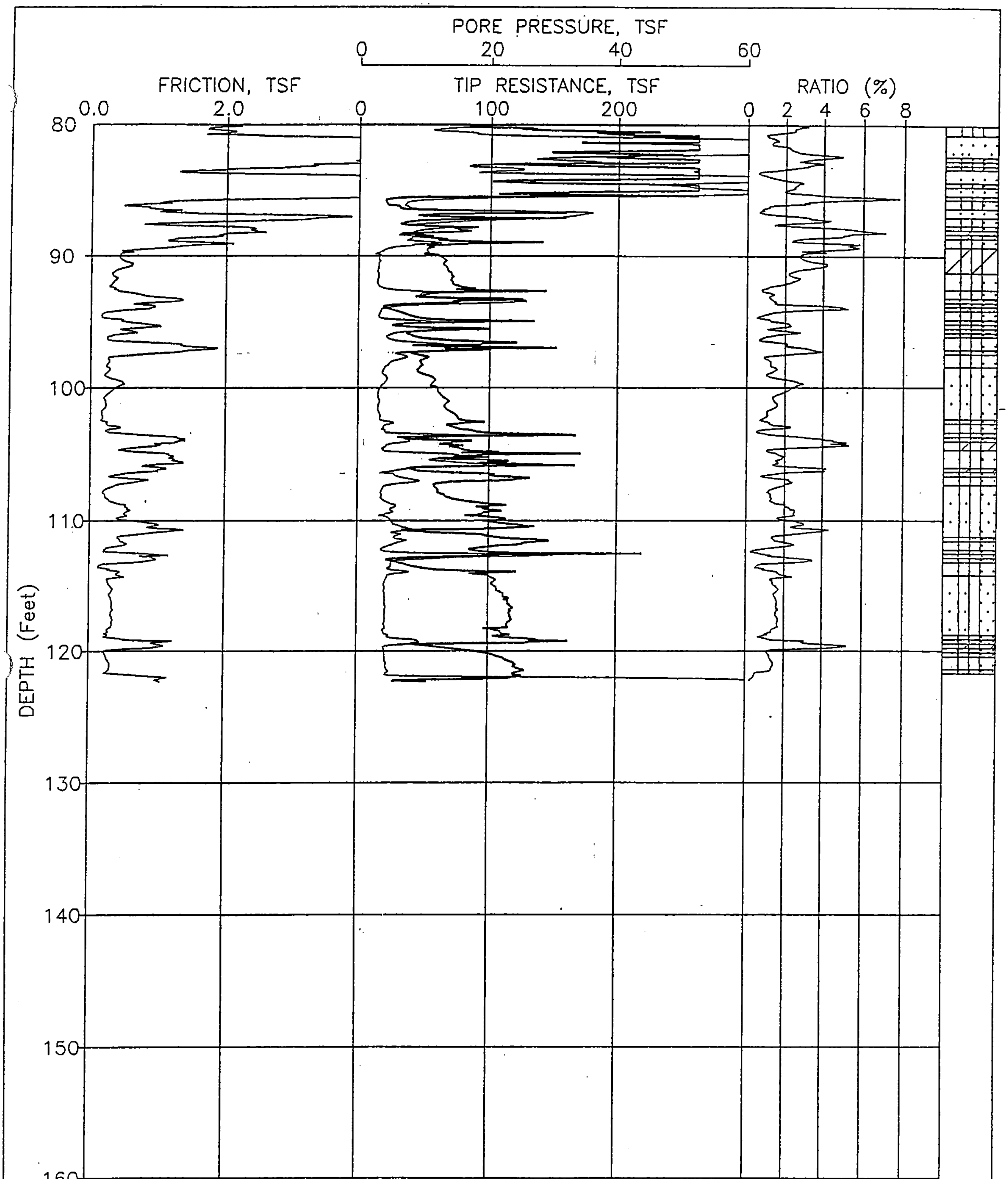


JOB NUMBER: 95-0110
ELEVATION: 0.00

CPT NUMBER: CPT-L33
CONE NUMBER:F7.5CKEW852

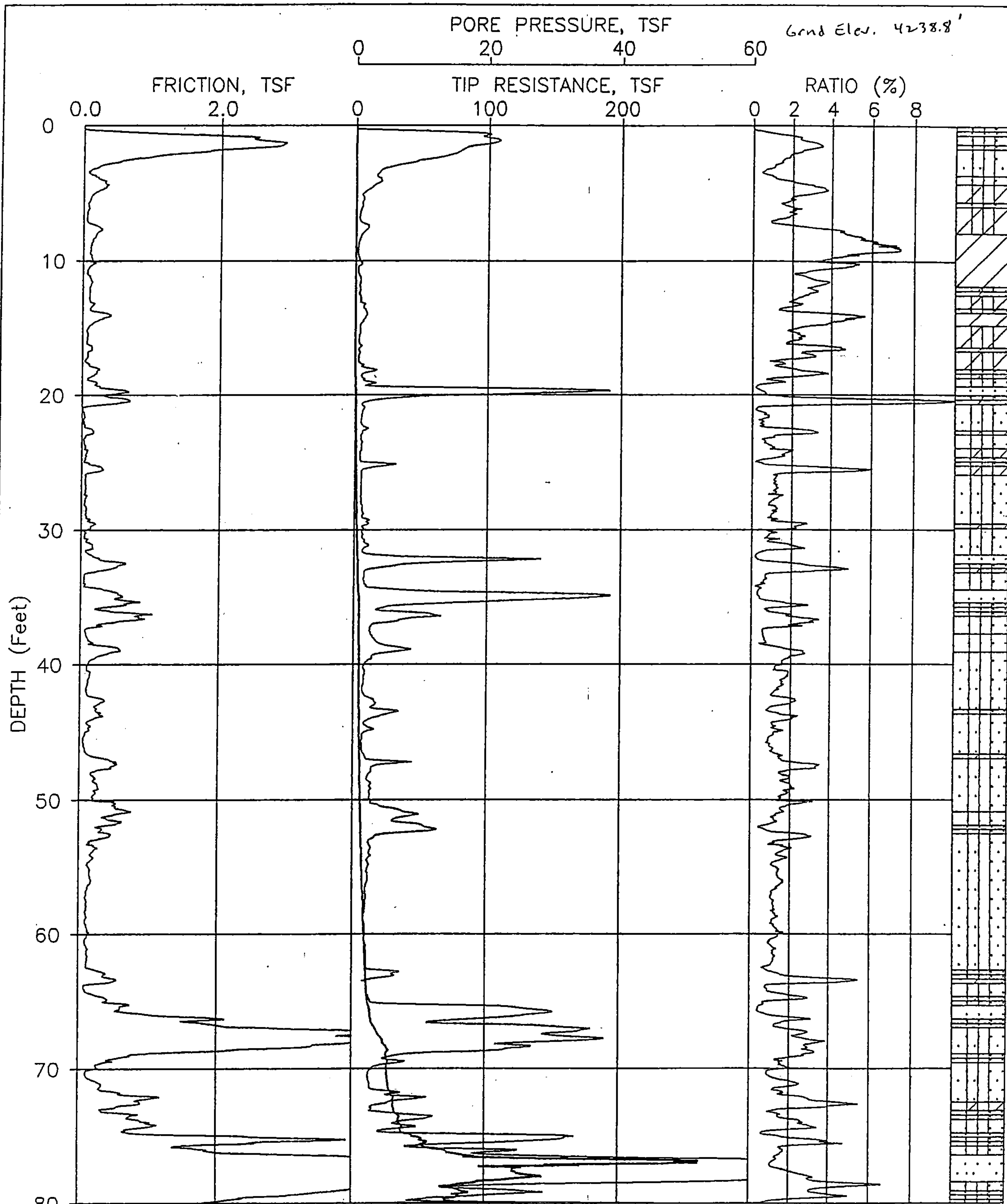
DATE: 08-17-1995
PLATE: 1 OF 2

FUGRO GEOSCIENCES,INC



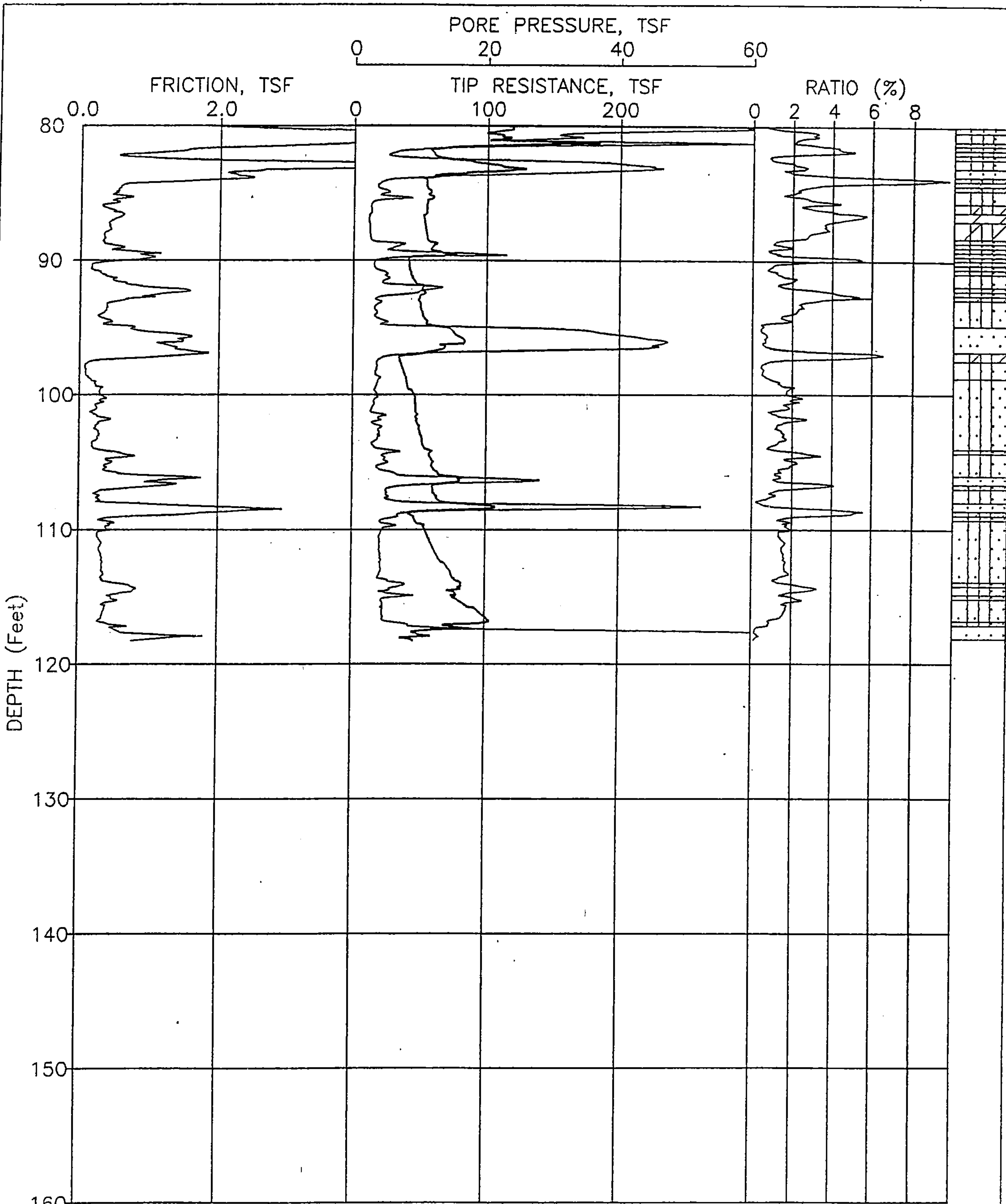
JOB NUMBER: 95-0110 CPT NUMBER: CPT-L33 DATE: 08-17-1995

ELEVATION: 0.00 CONE NUMBER:F7.5CKEW852 PLATE: 2 OF 2



JOB NUMBER: 95-0110
ELEVATION: 0.00
CPT NUMBER: CPT-L34
CONE NUMBER:F7.5CKEW852
DATE: 08-18-1995
PLATE: 1 OF 2

FUGRO GEOSCIENCES,INC



JOB NUMBER: 95-0110 CPT NUMBER: CPT-L34 DATE: 08-18-1995

ELEVATION: 0.00 CONE NUMBER:F7.5CKEW852 PLATE: 2 OF 2

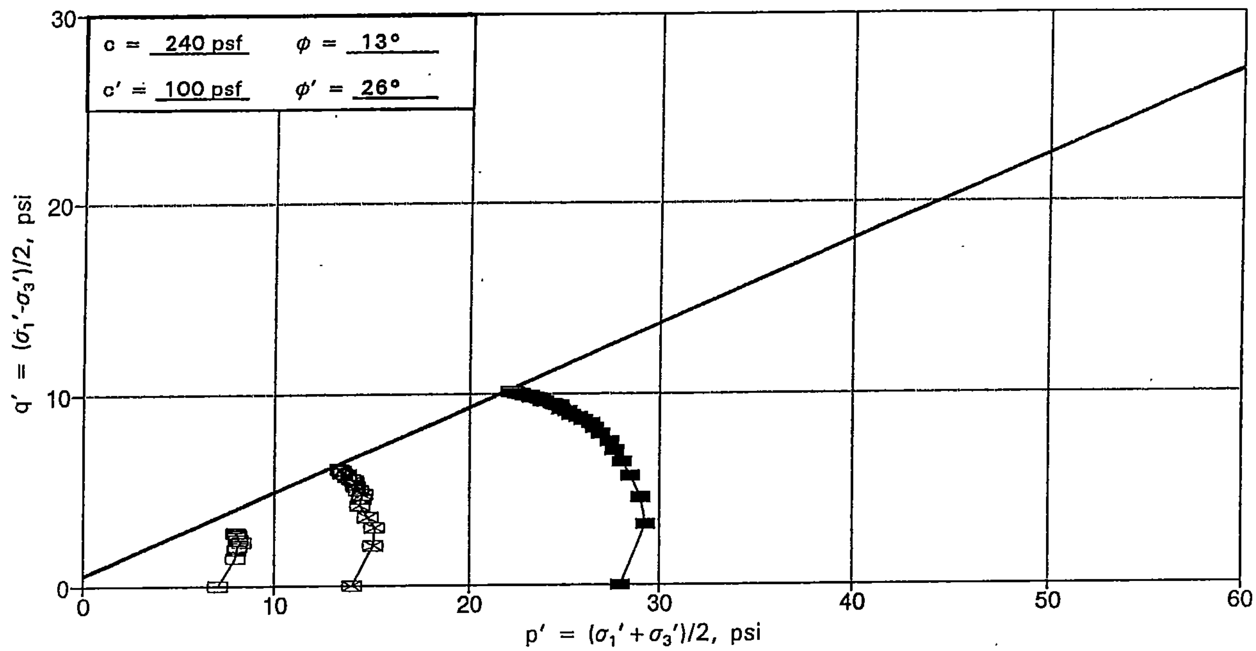
FUGRO GEOSCIENCES,INC

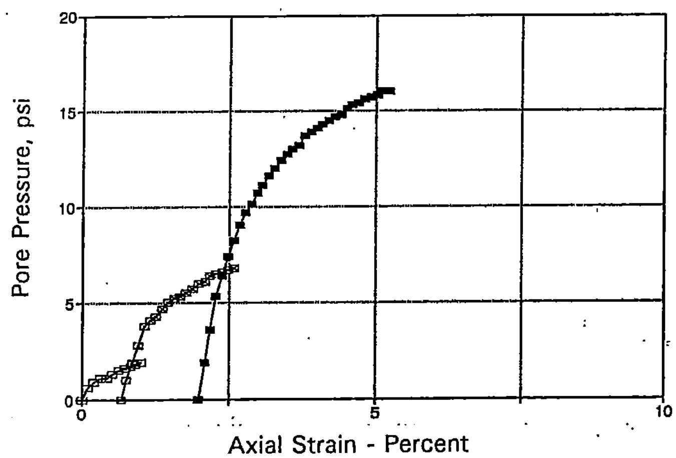
APPENDIX A-3

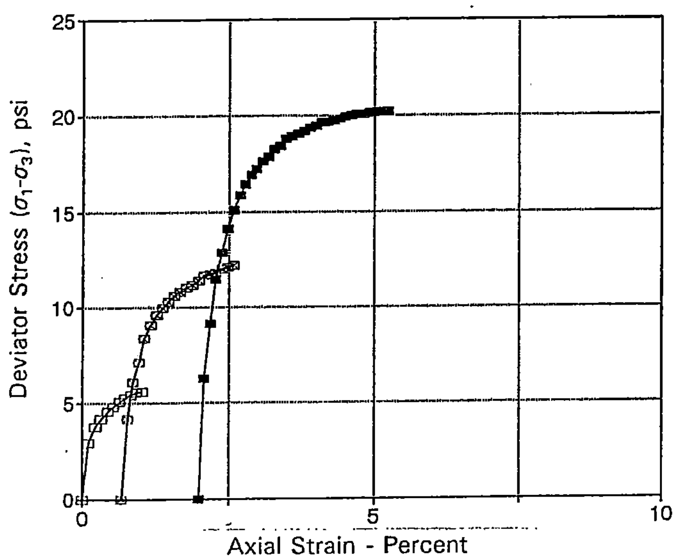
LABORATORY TEST RESULTS

PREVIOUS STUDIES

Applied Geotechnical Engineering Consultants, Inc.







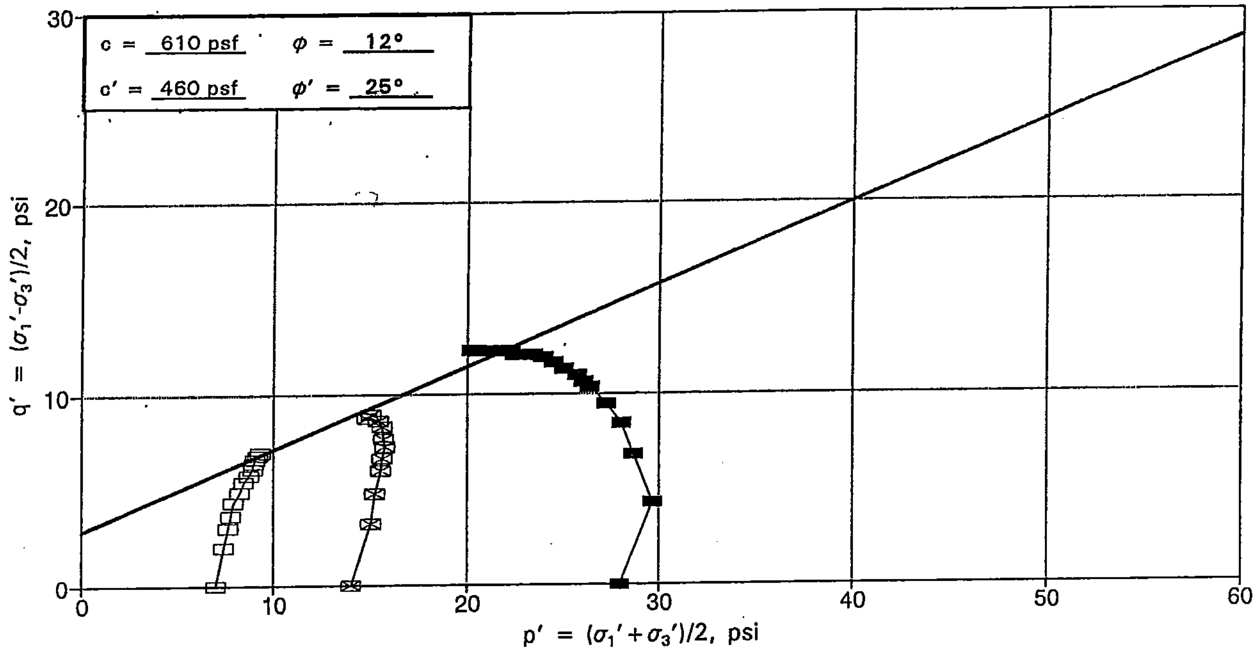
Test No.(Symbol)	1(□)	2(⊠)	3(■)
Sample Type	Undisturbed		
Length, in.	4.9		
Diameter, in.	2.39		
Dry Density, pcf	65		
Moisture Content, %	62		
Consol. Pressure, psi	7	14	28
"B" Parameter	1.0	0.97	0.86
Total Conf. Stress(σ_3), psi	7	14	28
Total Axial Stress(σ_1), psi	12.6	26.2	48.2
Deviator Stress(σ_1-σ_3), psi	5.6	12.2	20.2
Eff. Lateral Stress(σ_3'), psi	5.1	7.2	12.0
Eff. Axial Stress(σ_1'), psi	10.7	19.4	32.2
Pore Pressure(μ), psi	1.9	6.8	16.0
Strain(ϵ), %	1.0	2.6	5.2
Remarks	Staged, consolidated, undrained test with pore pressure measurement.		

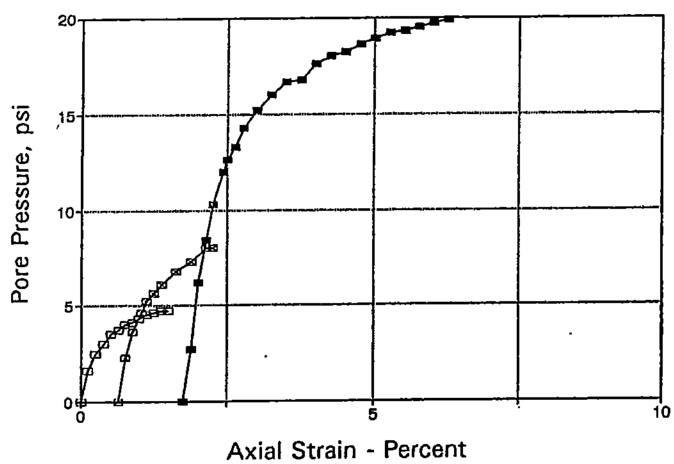
Sample Index Properties	
Natural Dry Density, pcf	65
Natural Moisture Content, %	62
Liquid Limit, %	66
Plasticity Index, %	40
Percent Gravel	-
Percent Sand	-
Percent Passing No. 200 Sieve	100

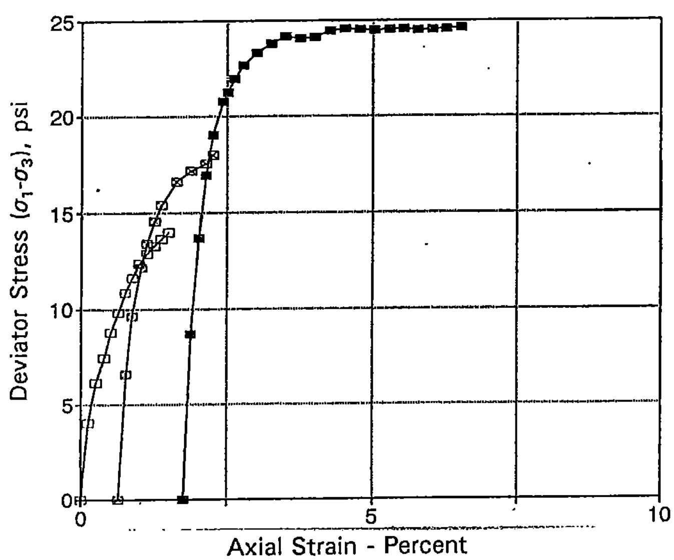
Sample Description Fat Clay (CH) From L-2 @ 30-1/2 feet

Project No. 20591 TRIAXIAL COMPRESSION TEST RESULTS Figure 12

Applied Geotechnical Engineering Consultants, Inc.







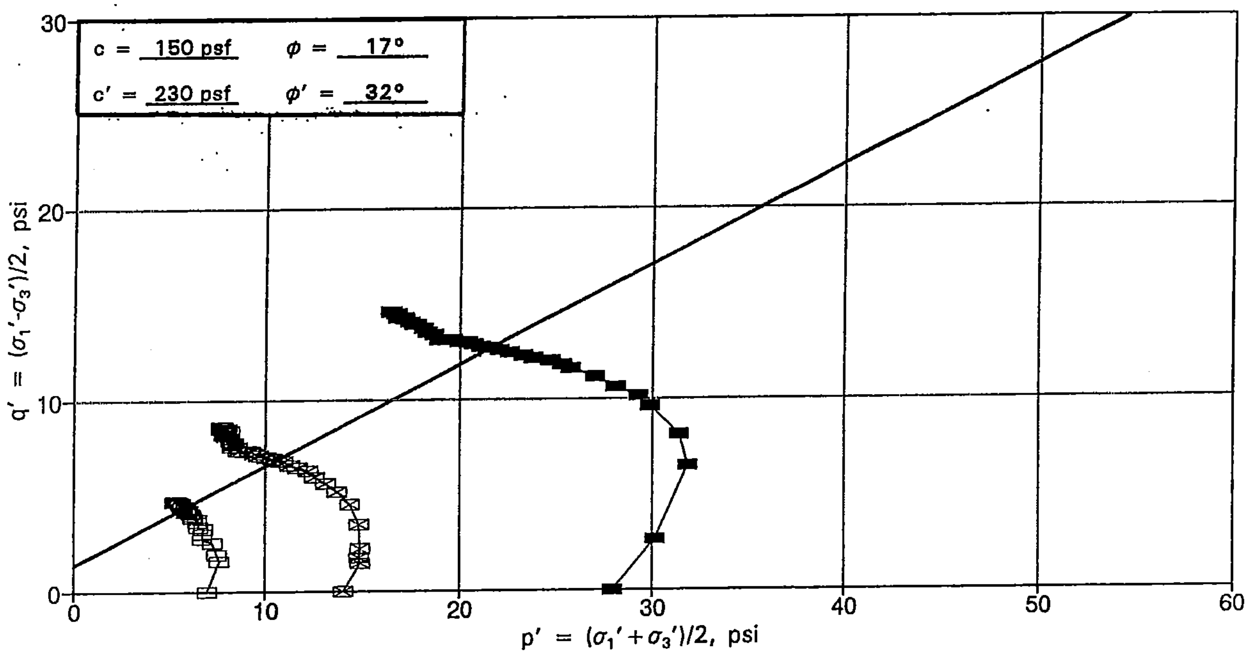
Test No.(Symbol)	1(□)	2(⊠)	3(■)
Sample Type	Undisturbed		
Length, in.	4.0		
Diameter, in.	1.93		
Dry Density, pcf	74		
Moisture Content, %	48		
Consol. Pressure, psi	7	14	28
"B" Parameter	0.99	0.96	0.91
Total Conf. Stress(σ_3), psi	7	14	28
Total Axial Stress(σ_1), psi	21.0	32.0	52.6
Deviator Stress(σ_1-σ_3), psi	14.0	18.0	24.6
Eff. Lateral Stress(σ_3'), psi	2.3	6.0	7.9
Eff. Axial Stress(σ_1'), psi	16.3	24.0	32.5
Pore Pressure(u), psi	4.7	8.0	20.1
Strain(ϵ), %	1.5	2.3	6.5
Remarks	Staged, consolidated, undrained test with pore pressure measurement.		

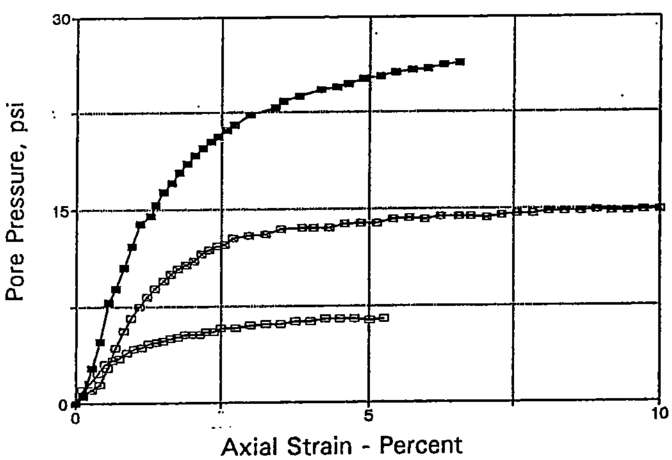
Sample Index Properties	
Natural Dry Density, pcf	74
Natural Moisture Content, %	48
Liquid Limit, %	46
Plasticity Index, %	25
Percent Gravel	-
Percent Sand	-
Percent Passing No. 200 Sieve	99

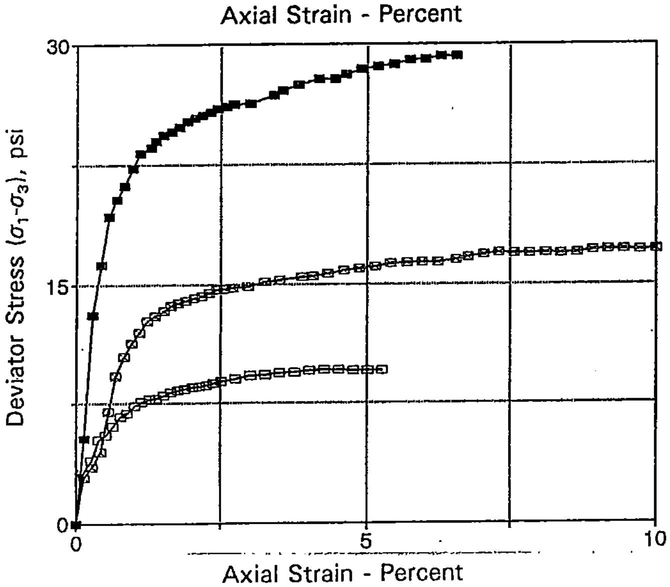
Sample Description Lean Clay (CL) From L-4 @ 23 feet

Project No. 20591 TRIAXIAL COMPRESSION TEST RESULTS Figure 13

Applied Geotechnical Engineering Consultants, Inc.







Test No.(Symbol)	1(□)	2(⊠)	3(■)
Sample Type	Undisturbed		
Length, in.	4.00	3.71	3.71
Diameter, in.	1.93	1.93	1.93
Dry Density, pcf	65	64	65
Moisture Content, %	58	61	60
Consol. Pressure, psi	7	14	28
"B" Parameter	1.0	0.95	0.95
Total Conf. Stress(σ_3), psi	7	14	28
Total Axial Stress(σ_1), psi	15.5	28.1	53.4
Deviator Stress(σ_1-σ_3), psi	8.5	14.1	25.4
Eff. Lateral Stress(σ_3'), psi	1.7	3.0	8.9
Eff. Axial Stress(σ_1'), psi	10.2	17.1	34.3
Pore Pressure(μ), psi	5.3	11.0	19.1
Strain(ϵ), %	2.0	2.0	2.0
Remarks	Consolidated, undrained test with pore pressure measurement.		

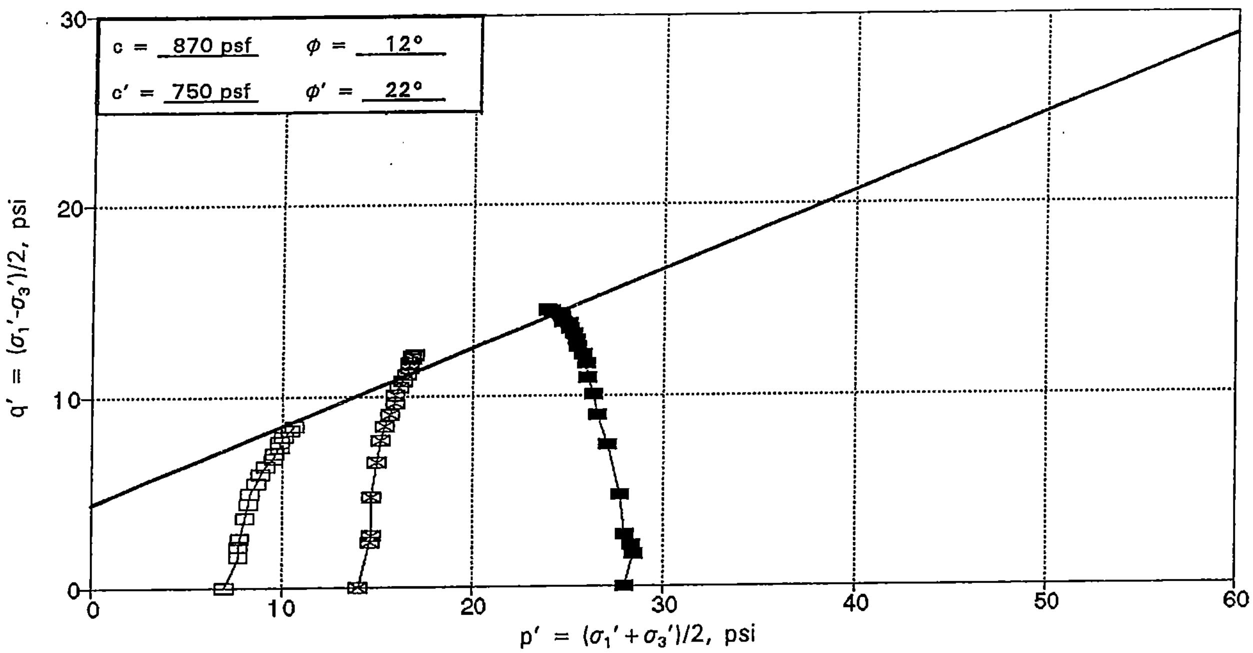
Sample Index Properties			
Natural Dry Density, pcf	65	64	65
Nat. Moisture Content, %	58	61	60
Liquid Limit, %	46	46	48
Plasticity Index, %	19	20	24
Percent Gravel	-	-	-
Percent Sand	-	-	-
% Passing No. 200 Sieve	100	100	100

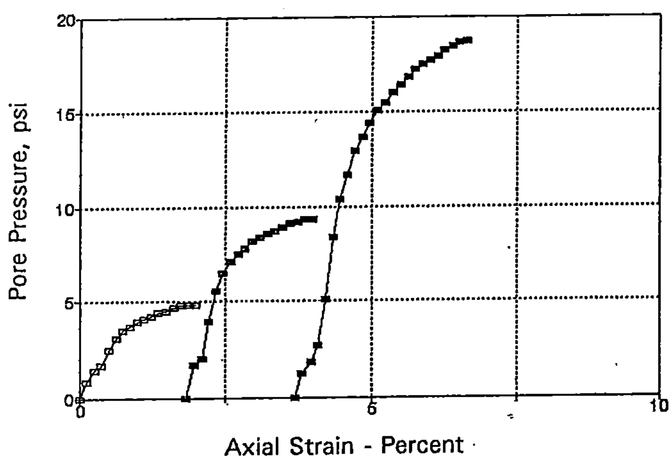
Sample Description Lean Clay (CL)

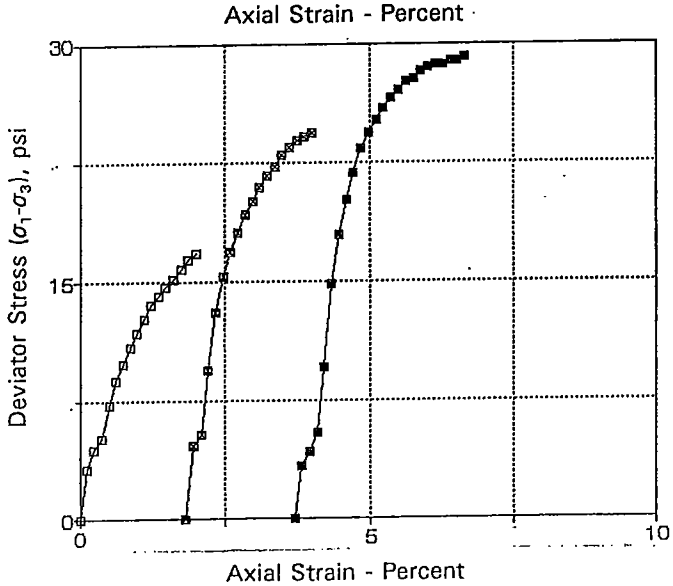
Sample 1 From L-6 @ 20-1/2 feet
2 L-28 @ 20 feet
3 L-15 @ 32 feet

Project No. 20591 TRIAXIAL COMPRESSION TEST RESULTS Figure 14

Applied Geotechnical Engineering Consultants, Inc.







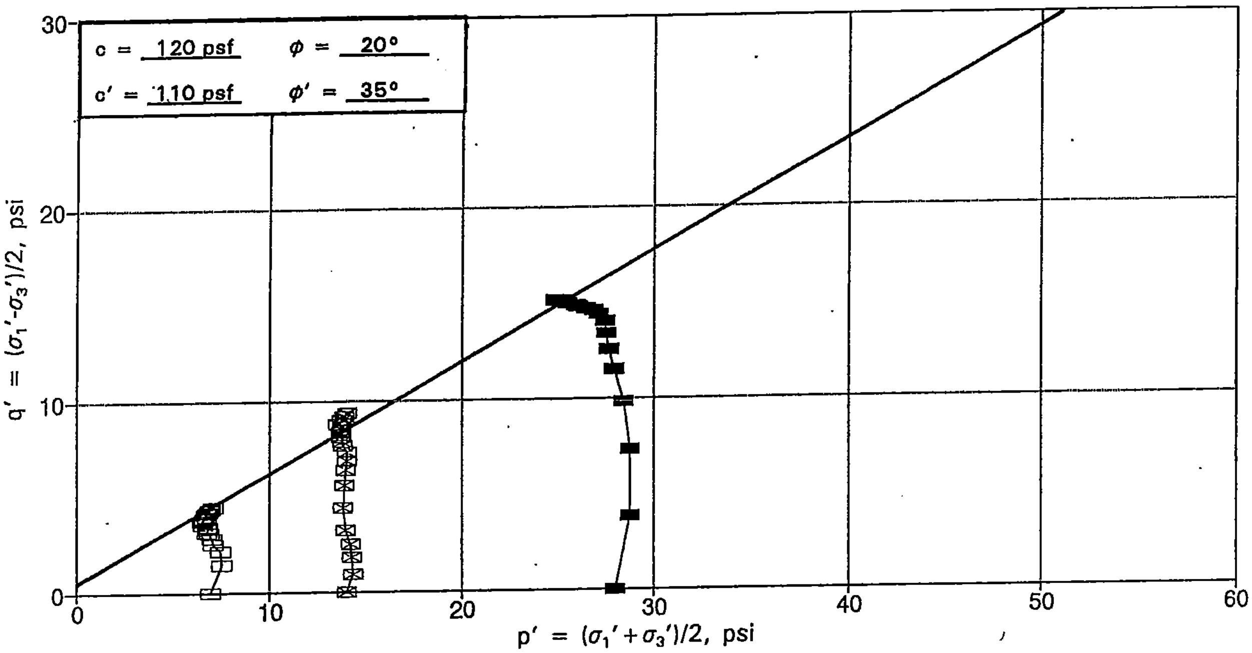
Test No.(Symbol)	1(□)	2(⊠)	3(■)
Sample Type	Undisturbed		
Length, in.	4.0		
Diameter, in.	1.93		
Dry Density, pcf	67		
Moisture Content, %	59		
Consol. Pressure, psi	7	14	28
"B" Parameter	0.97	0.95	0.94
Total Conf. Stress(σ_3), psi	7	14	28
Total Axial Stress(σ_1), psi	23.8	38.1	55.7
Deviator Stress(σ_1-σ_3), psi	16.8	24.1	27.7
Eff. Lateral Stress(σ_3'), psi	2.2	4.7	10.8
Eff. Axial Stress(σ_1'), psi	19.0	28.8	38.5
Pore Pressure(μ), psi	4.8	9.3	17.2
Strain(ϵ), %	2.0	3.9	5.8
Remarks	Staged, consolidated, undrained test with pore pressure measurement.		

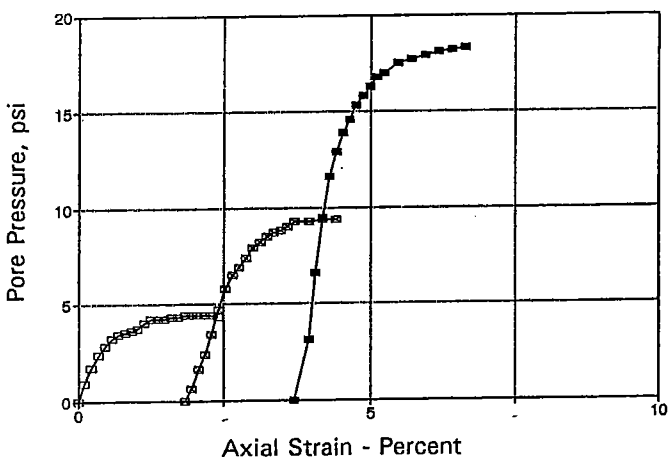
Sample Index Properties	
Natural Dry Density, pcf	67
Natural Moisture Content, %	59
Liquid Limit, %	63
Plasticity Index, %	36
Percent Gravel	-
Percent Sand	-
Percent Passing No. 200 Sieve	100

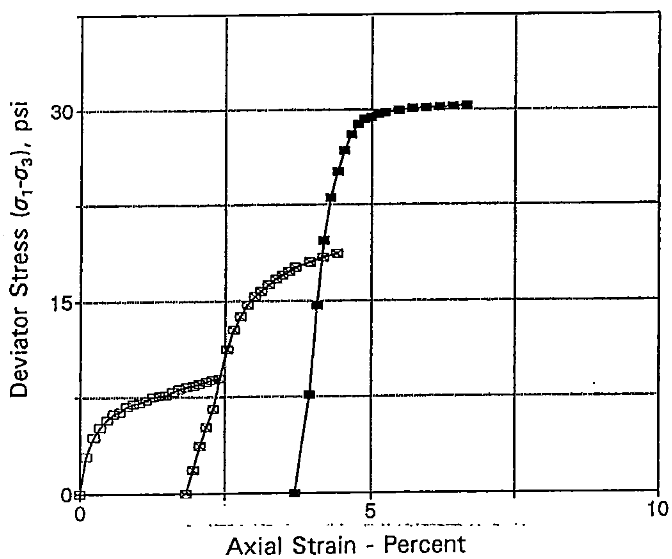
Sample Description Fat Clay (CH) From L-8 @ 60 Feet

Project No. 20591 TRIAXIAL COMPRESSION TEST RESULTS Figure 15

Applied Geotechnical Engineering Consultants, Inc.







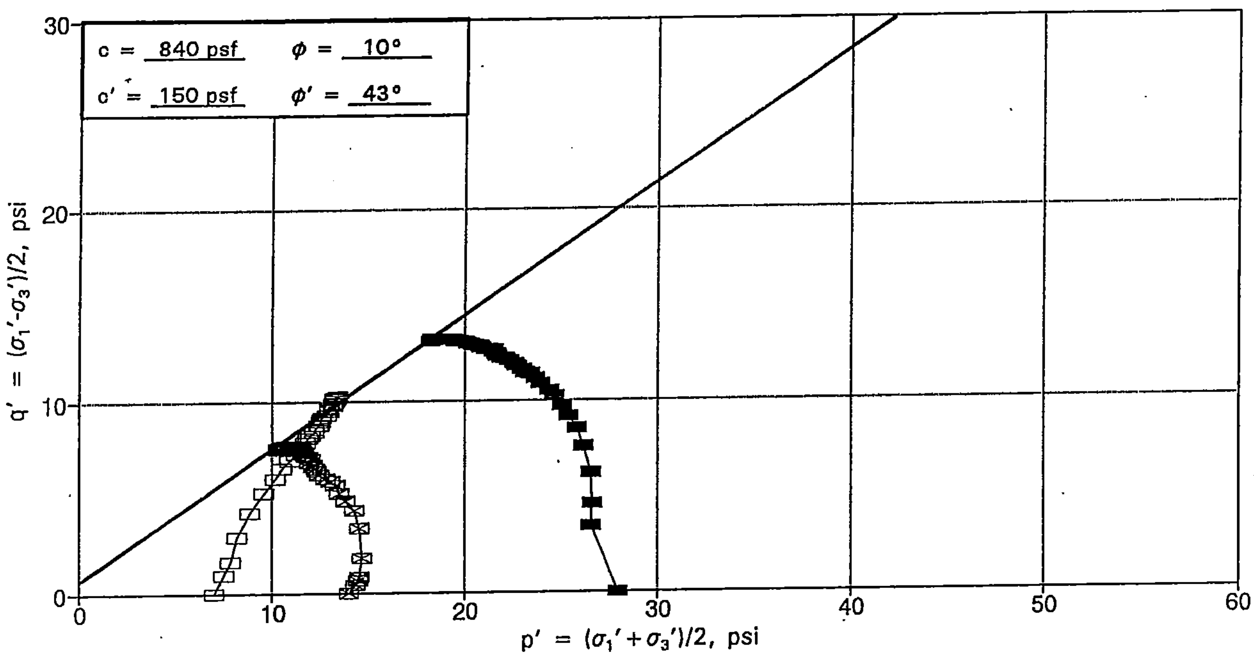
Test No.(Symbol)	1(□)	2(⊠)	3(■)
Sample Type	Undisturbed		
Length, in.	4.37		
Diameter, in.	2.42		
Dry Density, pcf	87		
Moisture Content, %	33		
Consol. Pressure, psi	7	14	28
"B" Parameter	0.97	0.96	0.92
Total Conf. Stress(σ_3), psi	7	14	28
Total Axial Stress(σ_1), psi	15.5	32.0	58.1
Deviator Stress(σ_1-σ_3), psi	8.5	18.0	30.1
Eff. Lateral Stress(σ_3'), psi	2.6	4.7	10.3
Eff. Axial Stress(σ_1'), psi	11.1	22.7	40.4
Pore Pressure(μ), psi	4.4	9.3	17.7
Strain(ϵ), %	2.1	3.9	5.7
Remarks	Staged, consolidated, undrained test with pore pressure measurement.		

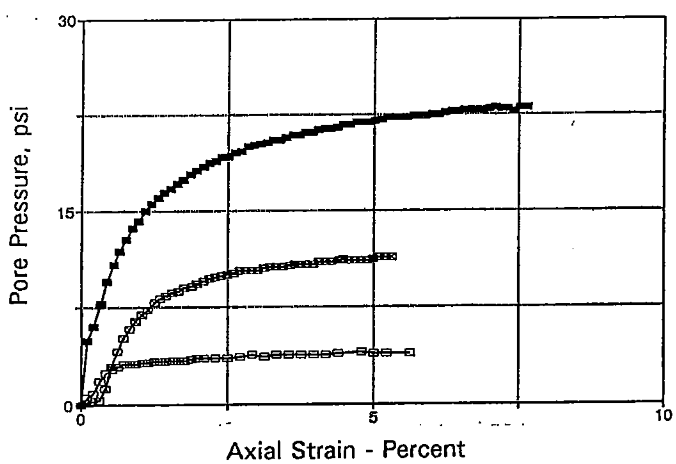
Sample Index Properties	
Natural Dry Density, pcf	87
Natural Moisture Content, %	33
Liquid Limit, %	29
Plasticity Index, %	11
Percent Gravel	-
Percent Sand	-
Percent Passing No. 200 Sieve	81

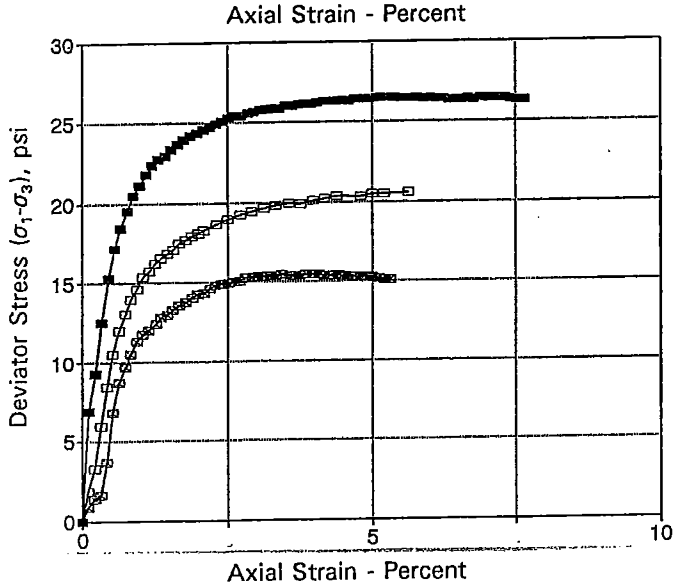
Sample Description Lean Clay with Sand (CL) From L-14 @ 45 feet

Project No. 20591 TRIAXIAL COMPRESSION TEST RESULTS Figure 16

Applied Geotechnical Engineering Consultants, Inc.







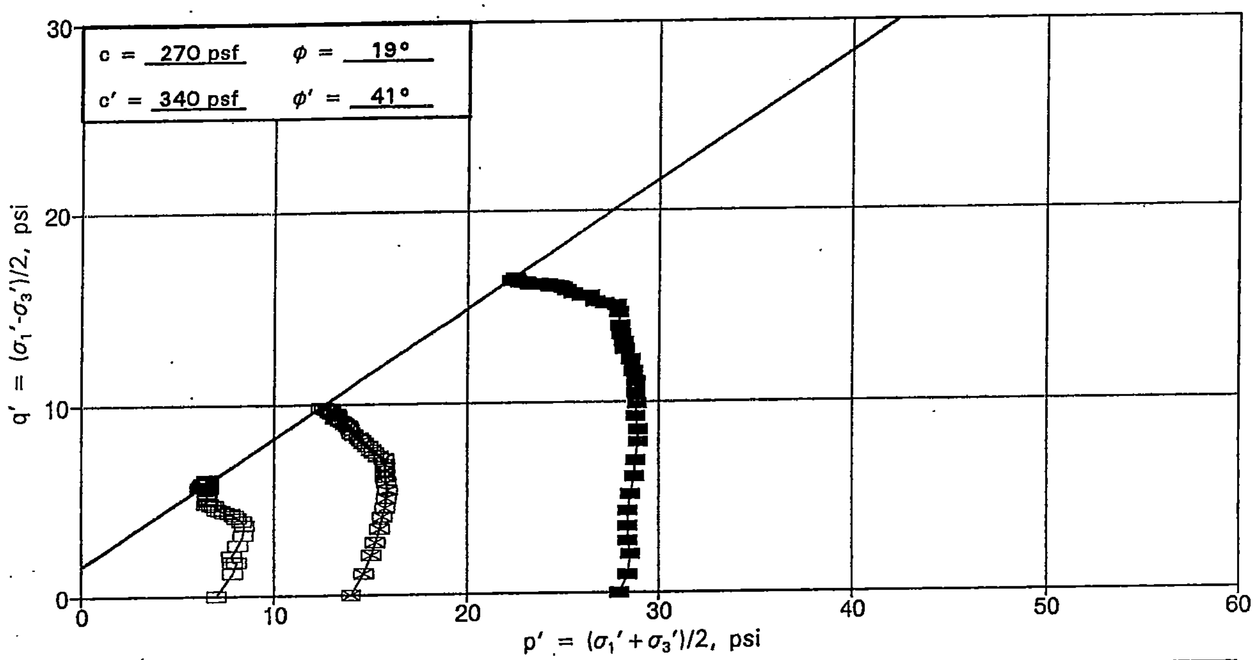
Test No.(Symbol)	1(□)	2(⊠)	3(■)
Sample Type	Undisturbed		
Length, in.	4.80	4.81	4.58
Diameter, in.	2.42	2.42	2.42
Dry Density, pcf		66	
Moisture Content, %		59	
Consol. Pressure, psi	7	14	28
"B" Parameter	0.92	0.96	0.95
Total Conf. Stress(σ_3), psi	7	14	28
Total Axial Stress(σ_1), psi	27.6	29.1	54.3
Deviator Stress(σ_1-σ_3), psi	20.6	15.1	26.3
Eff. Lateral Stress(σ_3'), psi	3.1	2.7	5.0
Eff. Axial Stress(σ_1'), psi	23.7	17.8	31.3
Pore Pressure(μ), psi	3.9	11.3	23.0
Strain(ϵ), %	5.6	5.3	7.6
Remarks	Consolidated, undrained test with pore pressure measurement.		

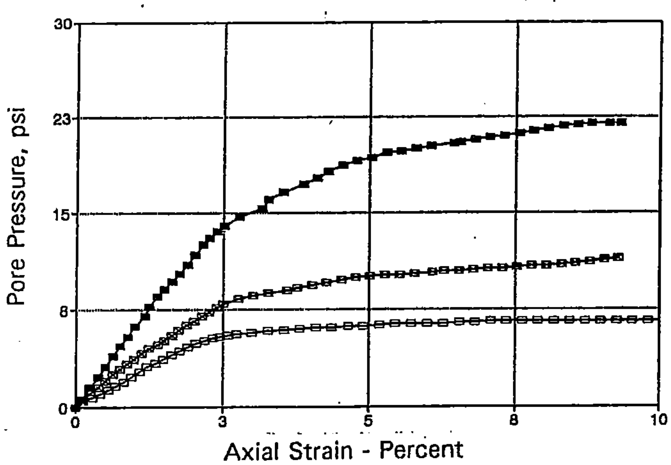
Sample Index Properties	
Natural Dry Density, pcf	66
Natural Moisture Content, %	59
Liquid Limit, %	
Plasticity Index, %	
Percent Gravel	-
Percent Sand	-
Percent Passing No. 200 Sieve	

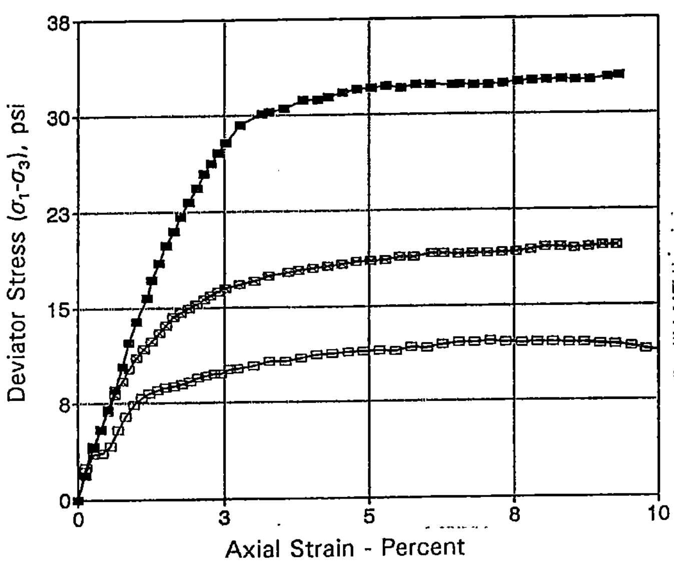
Sample Description Lean Clay (CL)   From L-17 @ 8 feet

Project No. 20591   TRIAXIAL COMPRESSION TEST RESULTS   Figure 17

Applied Geotechnical Engineering Consultants, Inc.







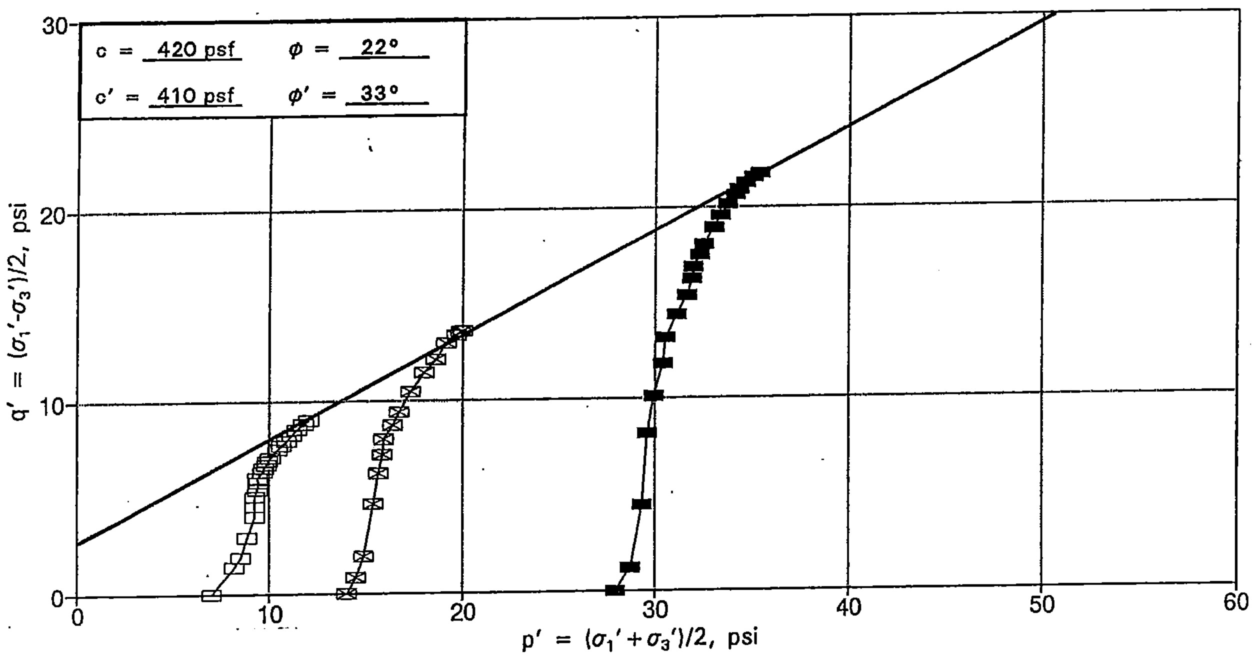
Test No.(Symbol)	1(□)	2(⊠)	3(■)
Sample Type	Undisturbed		
Length, in.	3.68	4.0	4.0
Diameter, in.	1.93	1.93	1.93
Dry Density, pcf	61	62	70
Moisture Content, %	67	68	52
Consol. Pressure, psi	7	14	28
"B" Parameter	0.92	0.95	0.95
Total Conf. Stress(σ_3), psi	7	14	28
Total Axial Stress(σ_1), psi	18.9	33.7	60.9
Deviator Stress(σ_1-σ_3), psi	11.9	19.7	32.9
Eff. Lateral Stress(σ_3'), psi	0.4	2.6	6.0
Eff. Axial Stress(σ_1'), psi	12.3	22.3	38.9
Pore Pressure(μ), psi	6.6	11.4	22.0
Strain(ϵ), %	9.3	9.3	9.3
Remarks	Consolidated, undrained test with pore pressure measurement.		

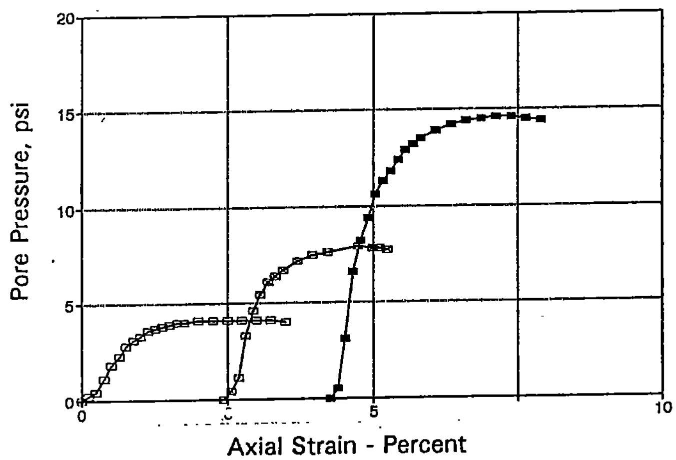
Sample Index Properties			
Natural Dry Density, pcf	61	62	70
Natural Moisture Content, %	67	68	52
Liquid Limit, %	65	66	49
Plasticity Index, %	29	34	25
Percent Gravel			
Percent Sand			
Percent Passing No. 200 Sieve	100	100	89

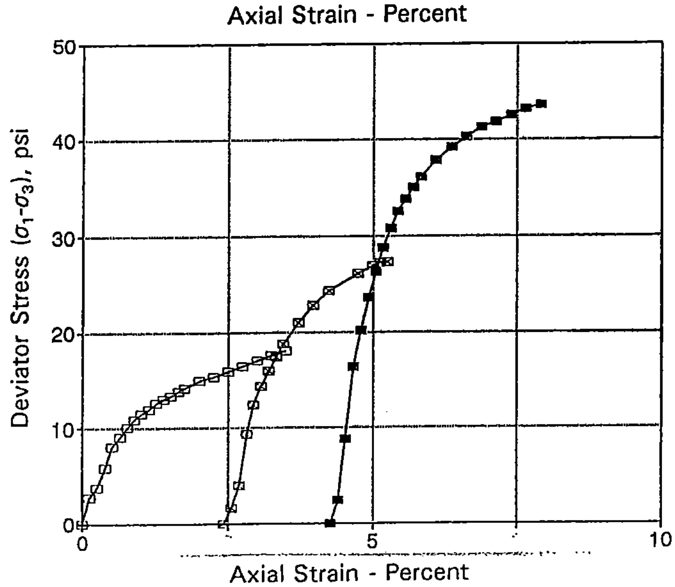
Sample Description		Sample	From
	Lean Clay (CL)	1	L-17 @ 25½ feet
	Fat Clay (CH)	2	L-21 @ 30 feet
	Fat Clay (CH)	3	L-24 @ 30 feet

Project No. 20591 **TRIAXIAL COMPRESSION TEST RESULTS** Figure 18

Applied Geotechnical Engineering Consultants, Inc.







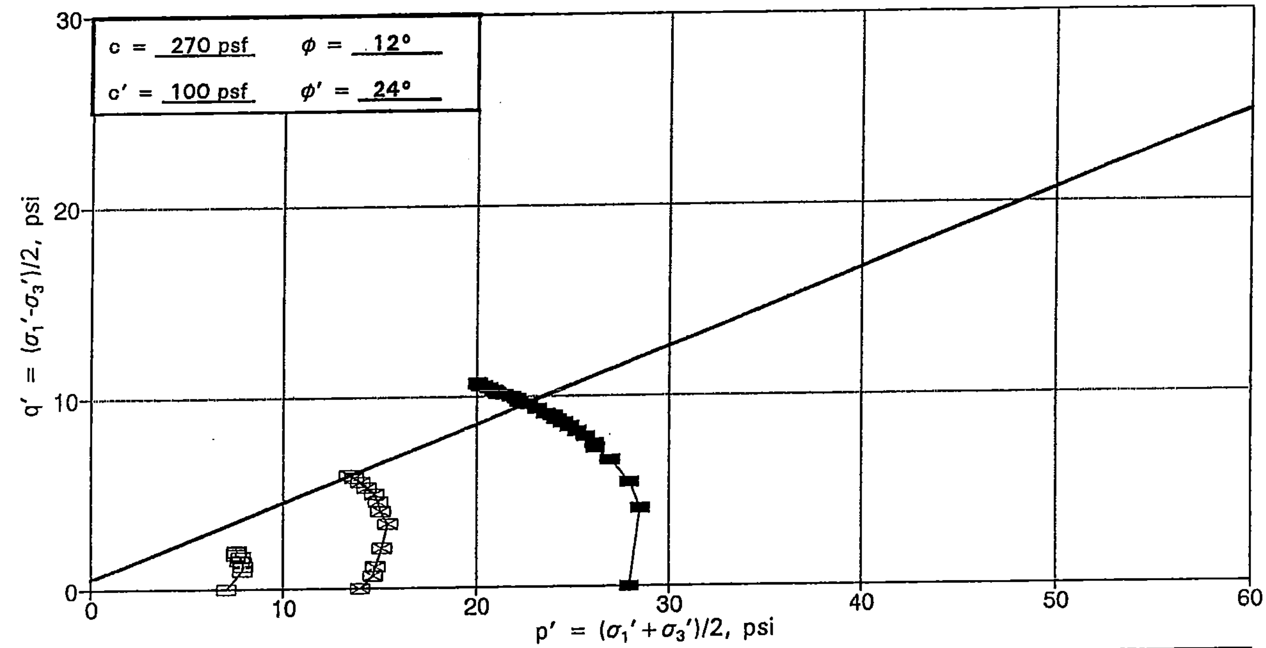
Test No.(Symbol)	1(□)	2(⊠)	3(■)
Sample Type	Undisturbed		
Length, in.	4.0		
Diameter, in.	1.93		
Dry Density, pcf	92		
Moisture Content, %	31		
Consol. Pressure, psi	7	14	28
"B" Parameter	0.96	0.94	0.91
Total Conf. Stress(σ_3), psi	7	14	28
Total Axial Stress(σ_1), psi	25.0	41.3	71.6
Deviator Stress(σ_1-σ_3), psi	18.0	27.3	43.6
Eff. Lateral Stress(σ_3'), psi	3.0	6.3	13.6
Eff. Axial Stress(σ_1'), psi	21.0	33.6	57.2
Pore Pressure(u), psi	4.0	7.7	14.4
Strain(ϵ), %	3.5	5.3	7.9
Remarks	Staged, consolidated, undrained test with pore pressure measurement.		

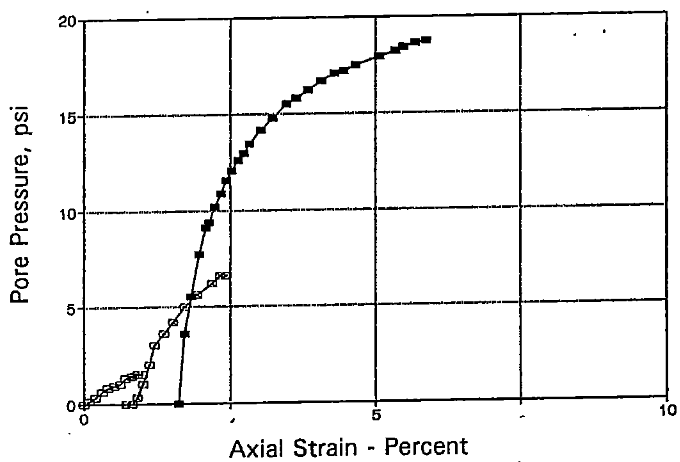
Sample Index Properties	
Natural Dry Density, pcf	92
Natural Moisture Content, %	31
Liquid Limit, %	45
Plasticity Index, %	25
Percent Gravel	-
Percent Sand	-
Percent Passing No. 200 Sieve	100

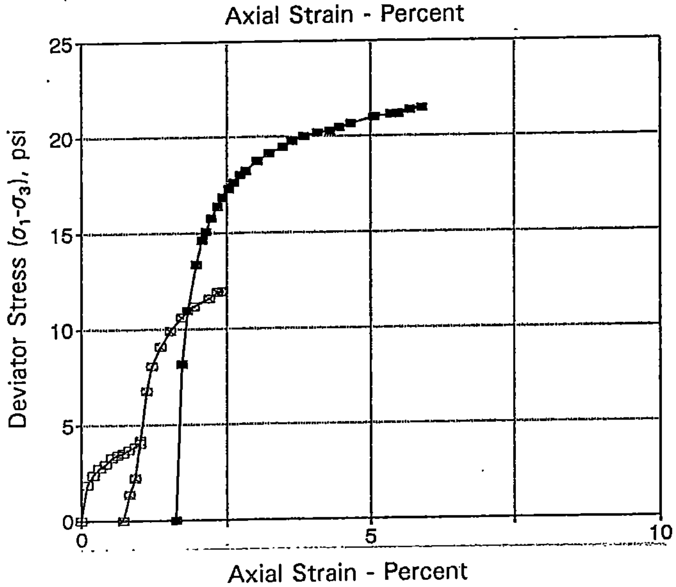
Sample Description Lean Clay (CL) From L-19 @ 50 feet

Project No. 20591 TRIAXIAL COMPRESSION TEST RESULTS Figure 19

Applied Geotechnical Engineering Consultants, Inc.







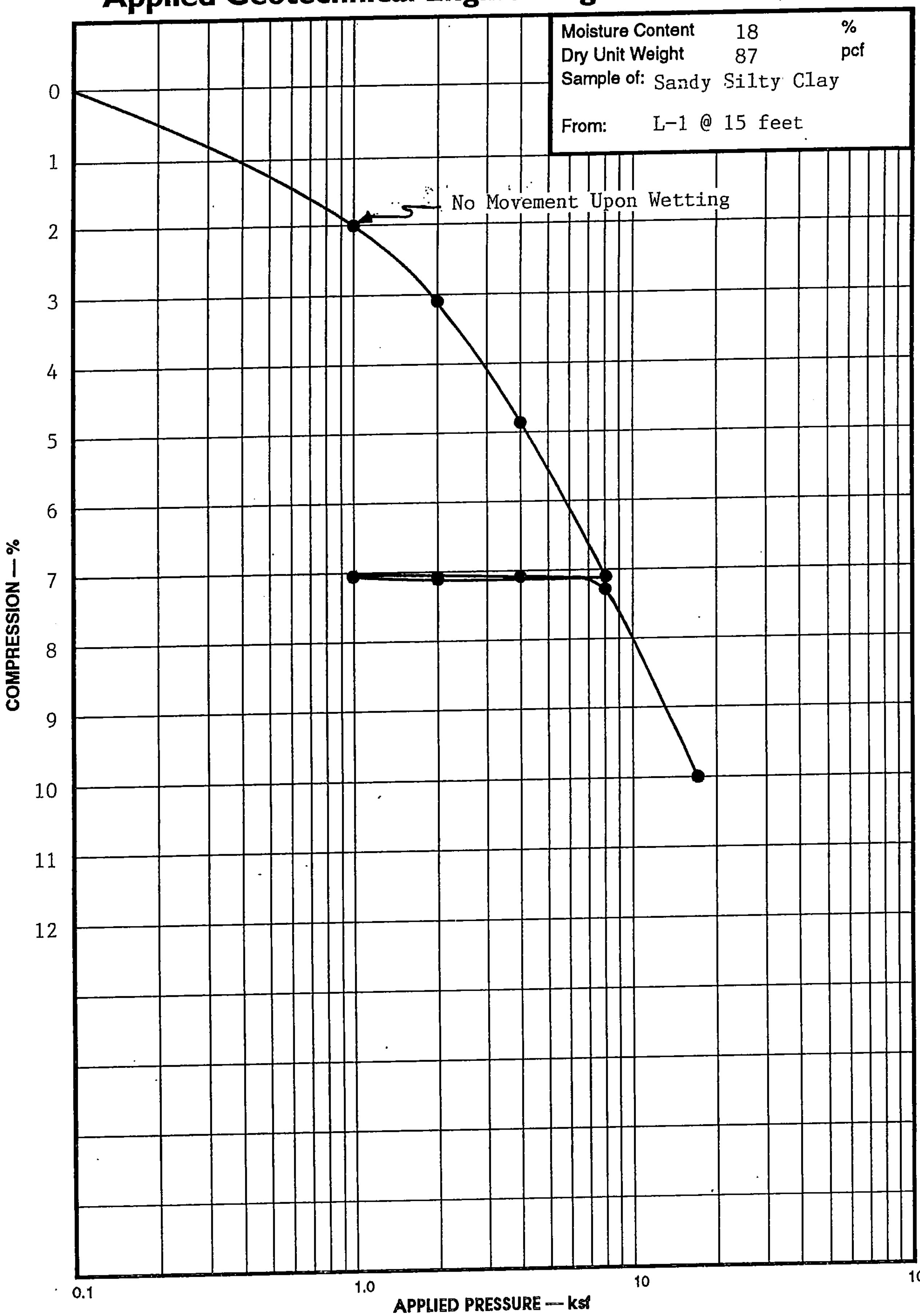
Test No.(Symbol)	1(□)	2(⊠)	3(■)
Sample Type	Undisturbed		
Length, in.	4.96		
Diameter, in.	2.42		
Dry Density, pcf	60		
Moisture Content, %	67		
Consol. Pressure, psi	7	14	28
"B" Parameter	0.95	0.90	0.98
Total Conf. Stress(σ_3), psi	7	14	28
Total Axial Stress(σ_1), psi	11.0	24.6	45.6
Deviator Stress(σ_1-σ_3), psi	4.0	10.6	17.6
Eff. Lateral Stress(σ_3'), psi	5.5	9.0	15.4
Eff. Axial Stress(σ_1'), psi	9.5	19.6	33.0
Pore Pressure(μ), psi	1.5	5.0	12.6
Strain(ϵ), %	1.0	1.7	2.6
Remarks	Staged, consolidated, undrained test with pore pressure measurement.		

Sample Index Properties	
Natural Dry Density, pcf	60
Natural Moisture Content, %	67
Liquid Limit, %	68
Plasticity Index, %	42
Percent Gravel	-
Percent Sand	-
Percent Passing No. 200 Sieve	100

Sample Description Fat Clay (CH) From L-24 @ 35 feet

Project No. 20591 TRIAXIAL COMPRESSION TEST RESULTS Figure 20

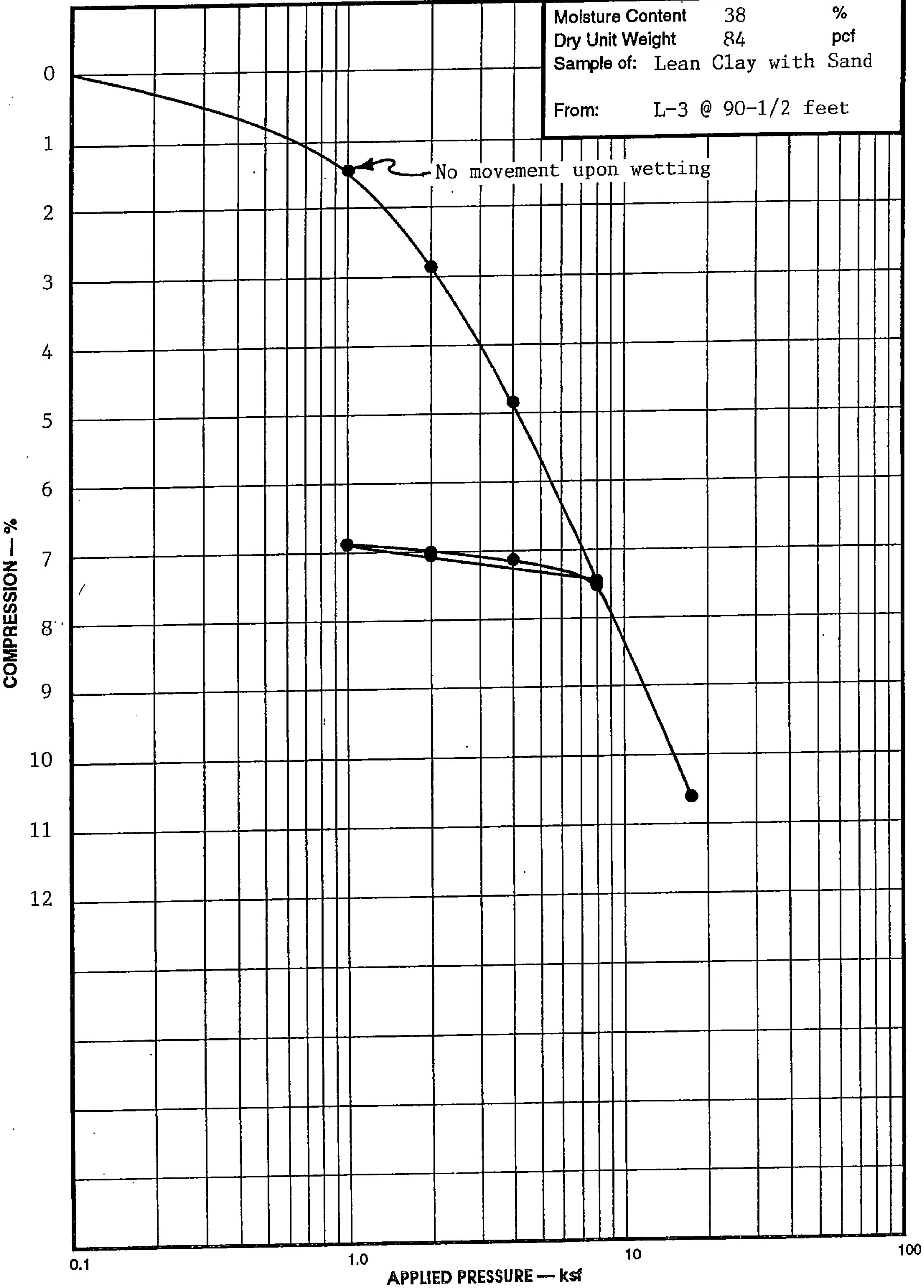
Applied Geotechnical Engineering Consultants, Inc.



Project No. 20591 **CONSOLIDATION TEST RESULTS** Figure 21

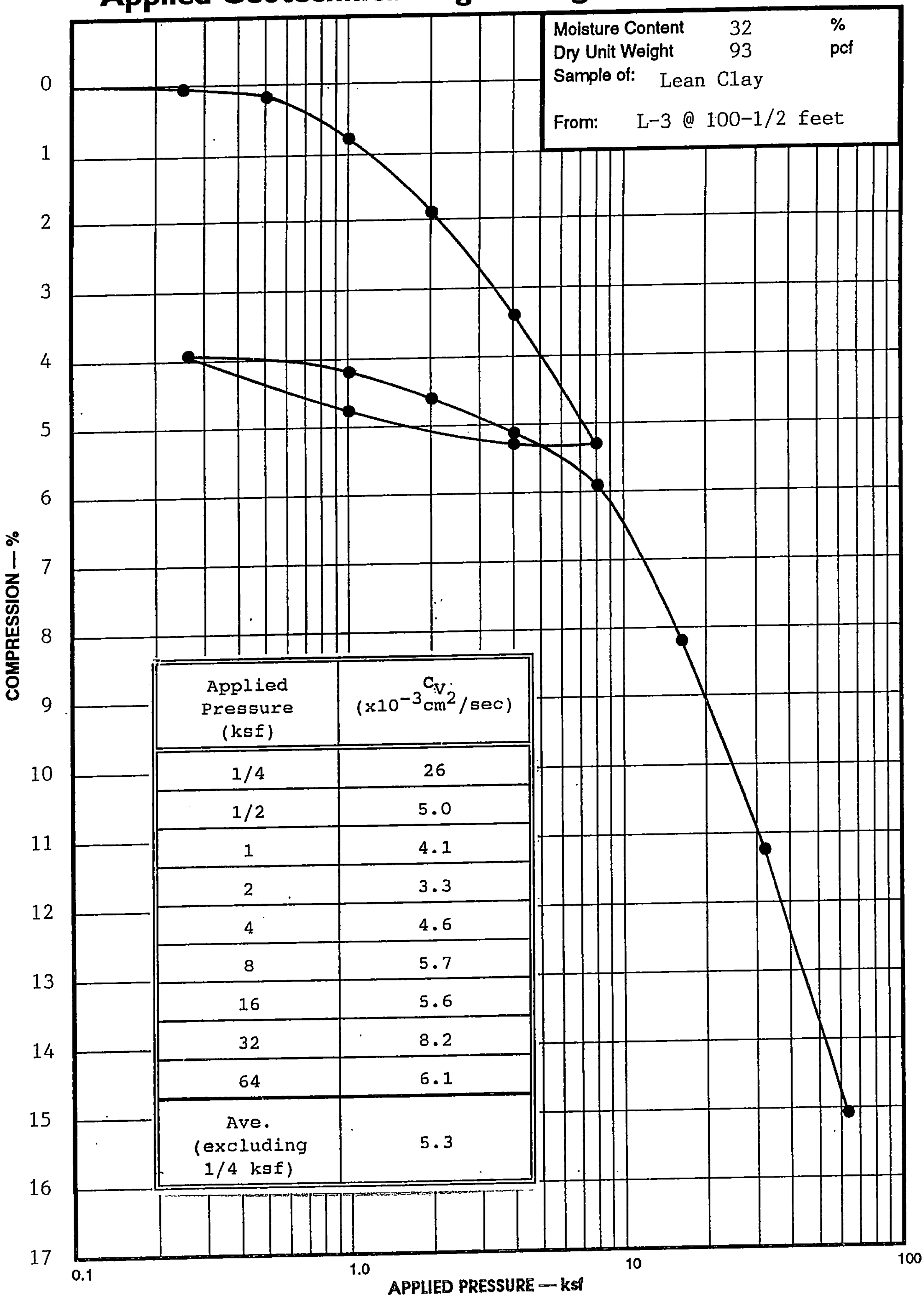
Applied Geotechnical Engineering Consultants, Inc.

Moisture Content	38	%
Dry Unit Weight	84	pcf
Sample of:	Lean Clay with Sand	
From:	L-3 @ 90-1/2 feet	



Project No. 20591 **CONSOLIDATION TEST RESULTS** Figure 22

Applied Geotechnical Engineering Consultants, Inc.

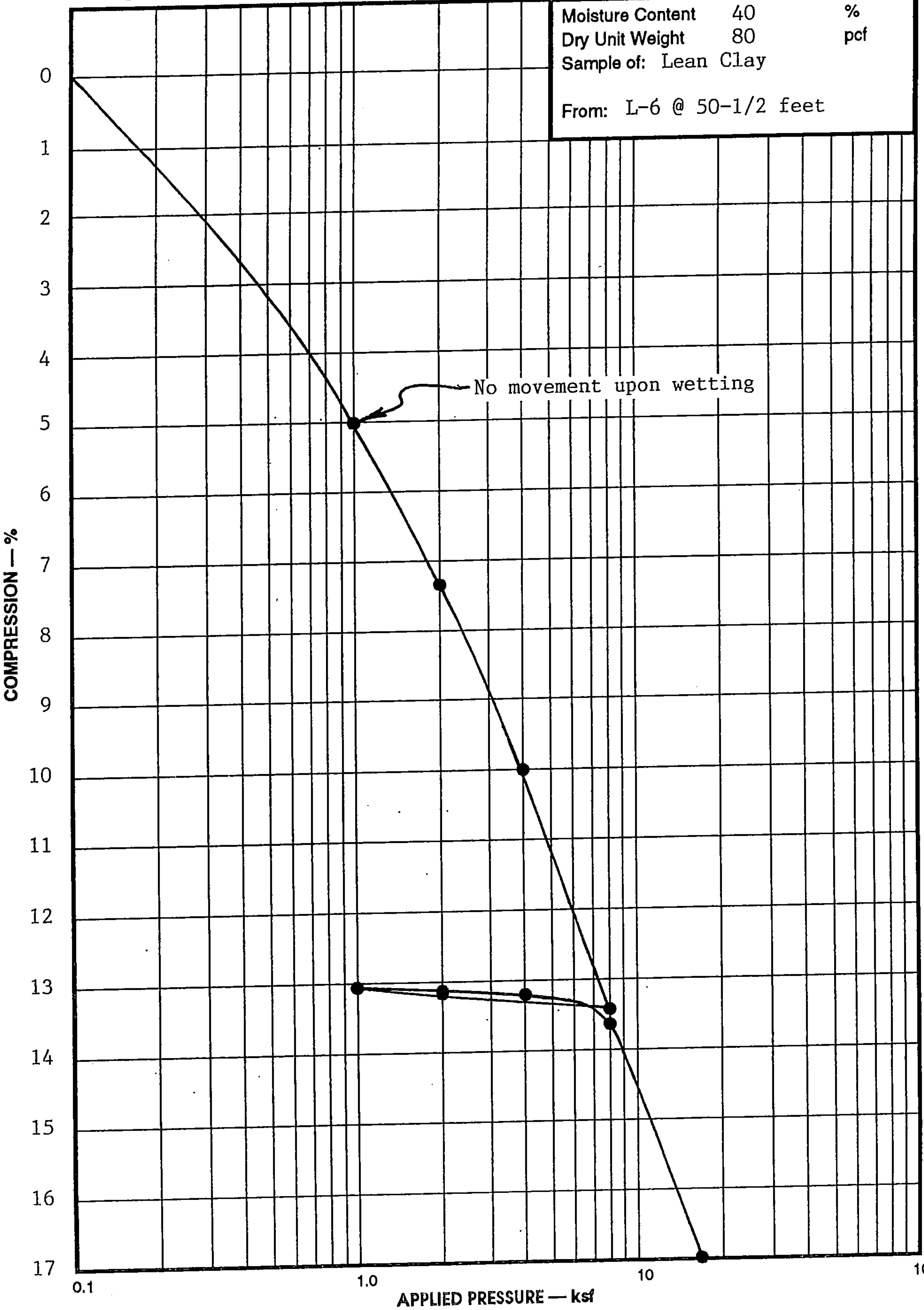


Applied Pressure (ksf)	c_v ($\times 10^{-3}$ cm^2/sec)
1/4	26
1/2	5.0
1	4.1
2	3.3
4	4.6
8	5.7
16	5.6
32	8.2
64	6.1
Ave. (excluding 1/4 ksf)	5.3

Project No. 20591 **CONSOLIDATION TEST RESULTS** Figure 23

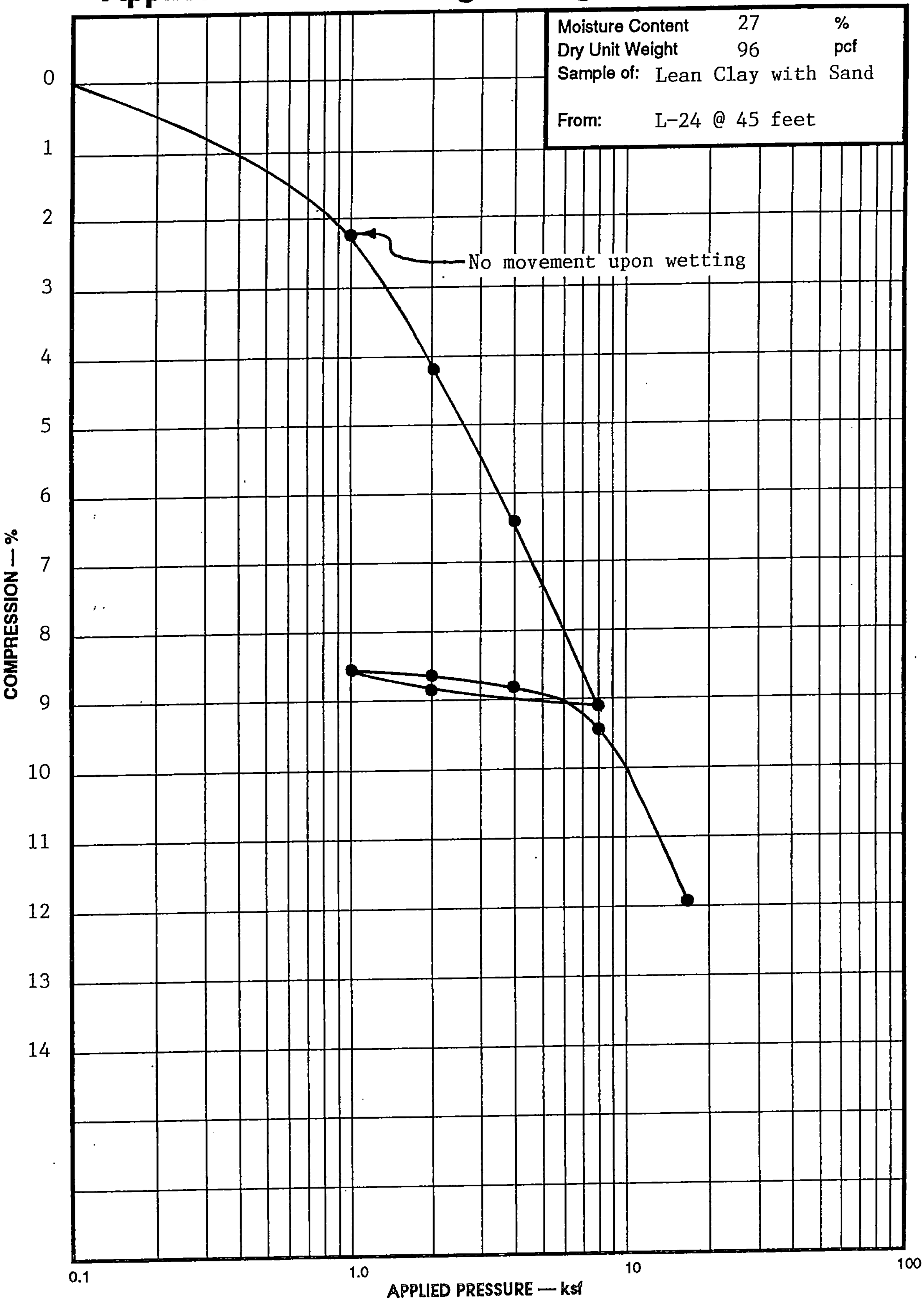
Applied Geotechnical Engineering Consultants, Inc.

Moisture Content	40	%
Dry Unit Weight	80	pcf
Sample of:	Lean Clay	
From:	L-6 @ 50-1/2 feet	



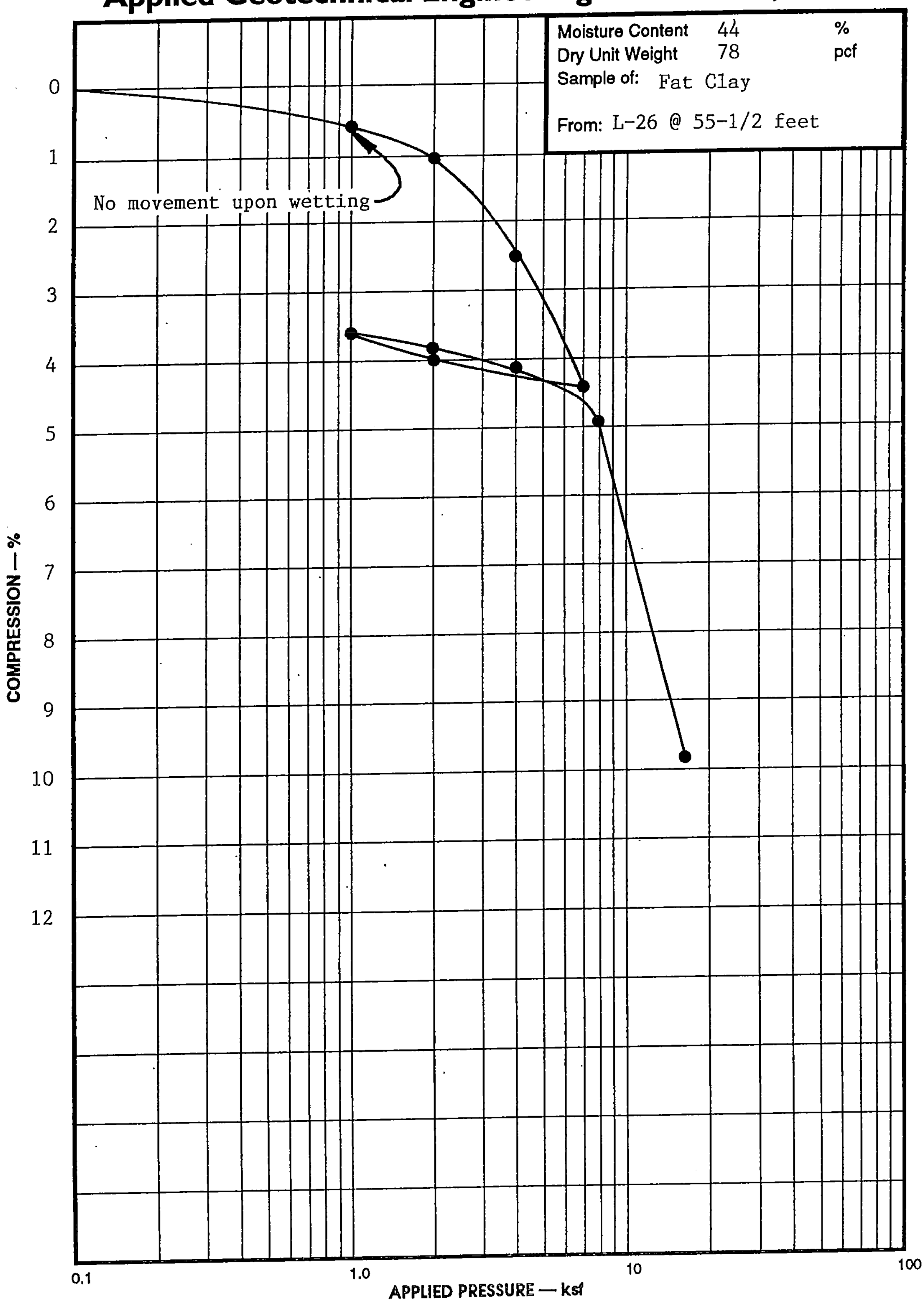
Project No. 20591 **CONSOLIDATION TEST RESULTS** Figure 24

Applied Geotechnical Engineering Consultants, Inc.



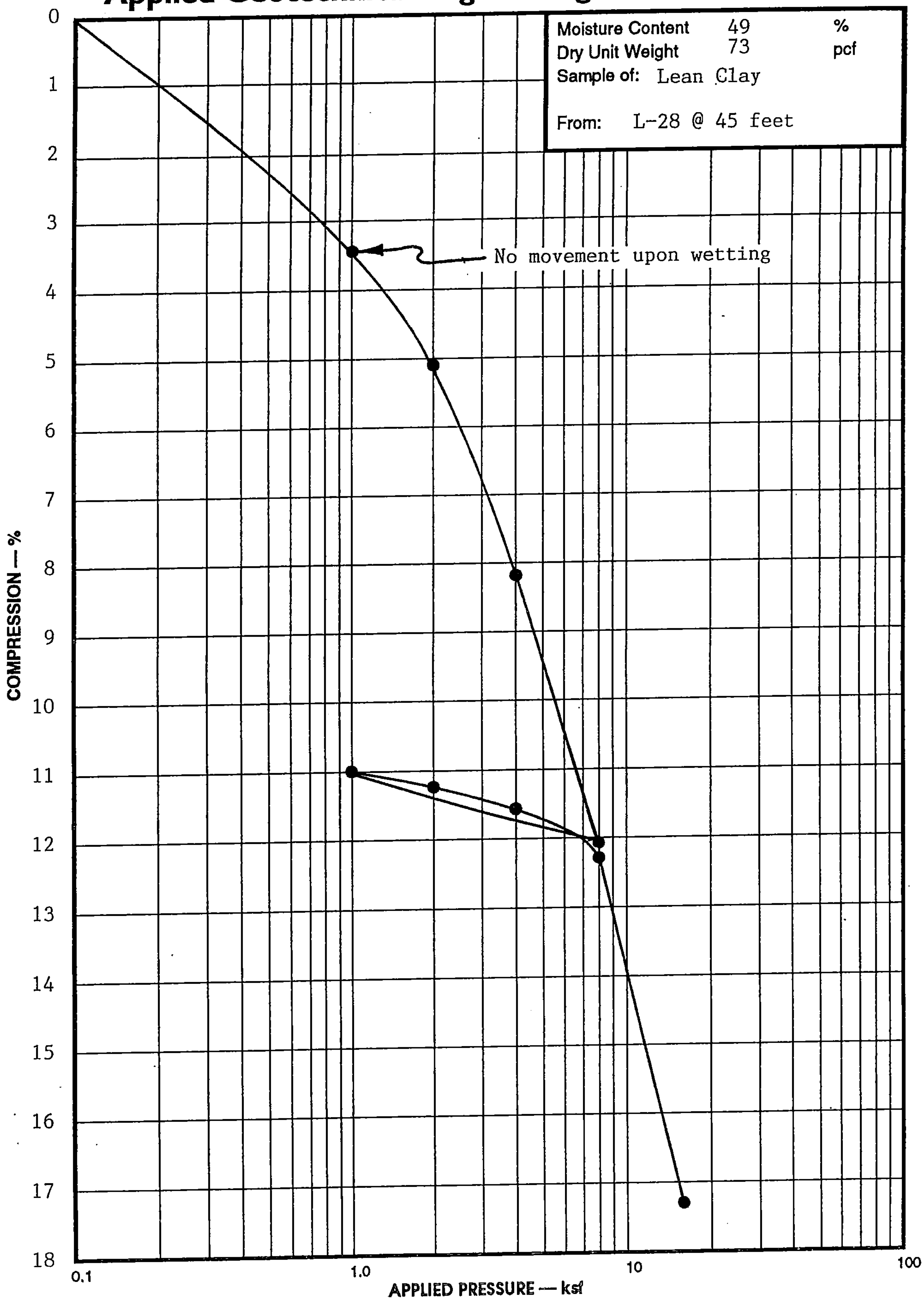
Project No. 20591 **CONSOLIDATION TEST RESULTS** Figure 25

Applied Geotechnical Engineering Consultants, Inc.



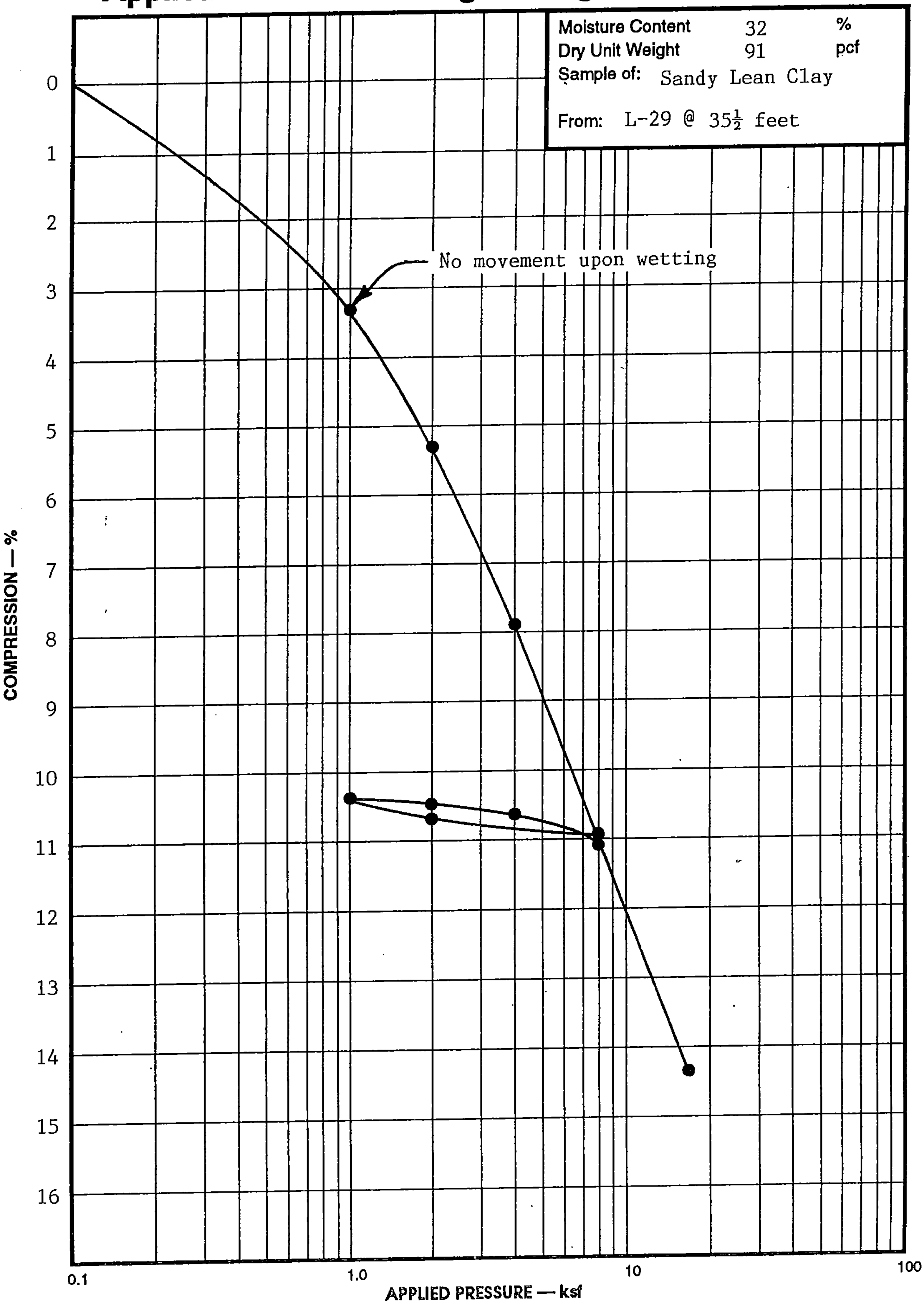
Project No. 20591 **CONSOLIDATION TEST RESULTS** Figure 26

Applied Geotechnical Engineering Consultants, Inc.



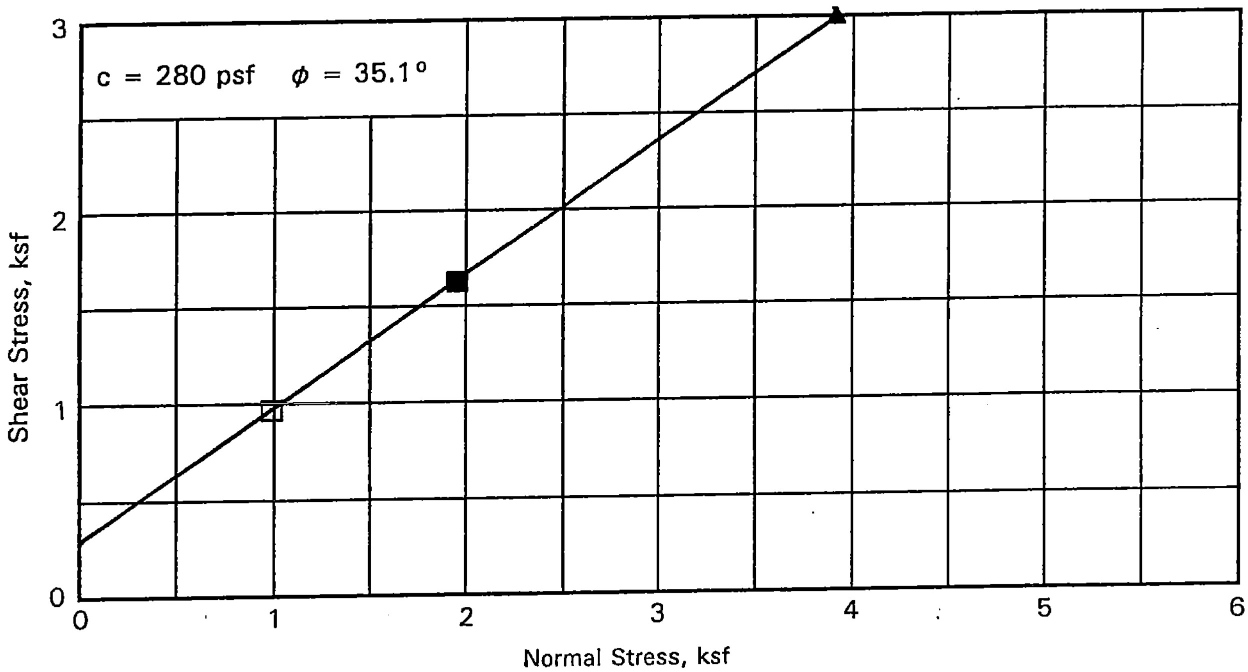
Project No. 20591 **CONSOLIDATION TEST RESULTS** Figure 27

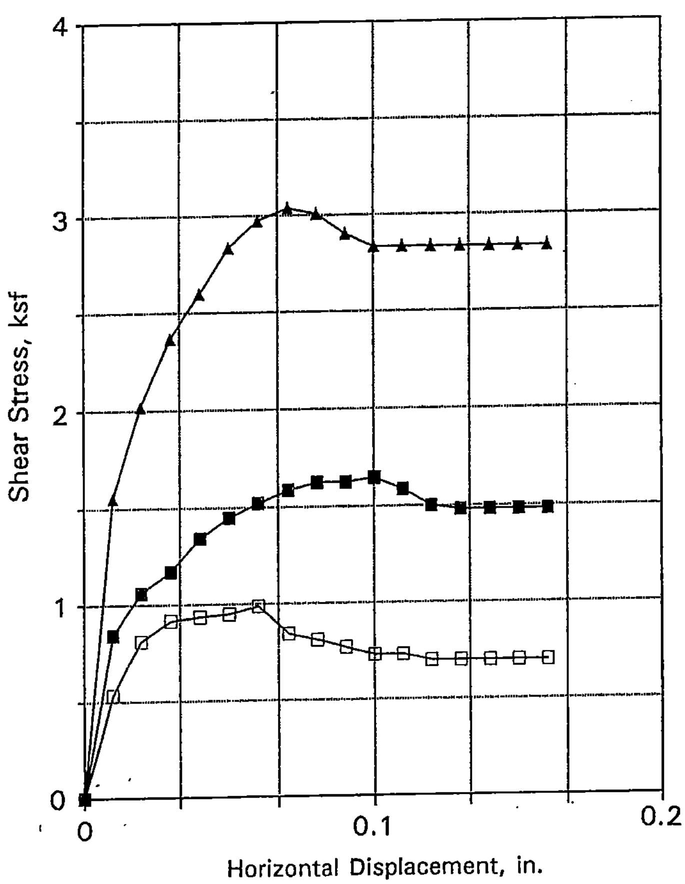
Applied Geotechnical Engineering Consultants, Inc.



Project No. 20591 **CONSOLIDATION TEST RESULTS** Figure 28

Applied Geotechnical Engineering Consultants, Inc.





Test No.(Symbol)	1(□)	2(■)	3(▲)
Sample Type	Undisturbed		
Length, in.	1.0		
Diameter, in.	1.93		
Dry Density, pcf	104	106	104
Moisture Content, %	24	28	26
Consolidation Load,	0.98	1.95	3.91
Normal Load, ksf	0.98	1.95	3.91
Shear Stress, ksf	0.98	1.62	3.04
Remarks	Strain rate, 0.05 in/min		
	Sample wetted before test		

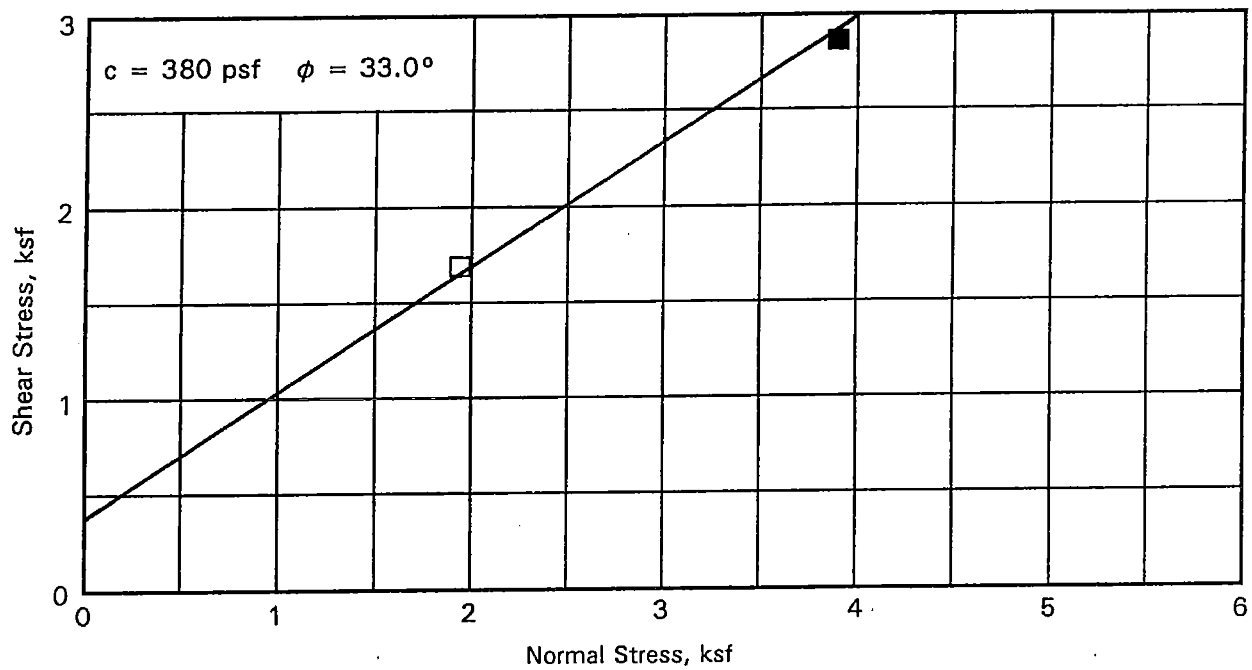
Sample Index Properties	
Natural Dry Density, pcf	
Natural Moisture Content, %	
Liquid Limit, %	
Plasticity Index, %	
Percent Gravel	
Percent Sand	
Percent Passing No. 200 Sieve	62

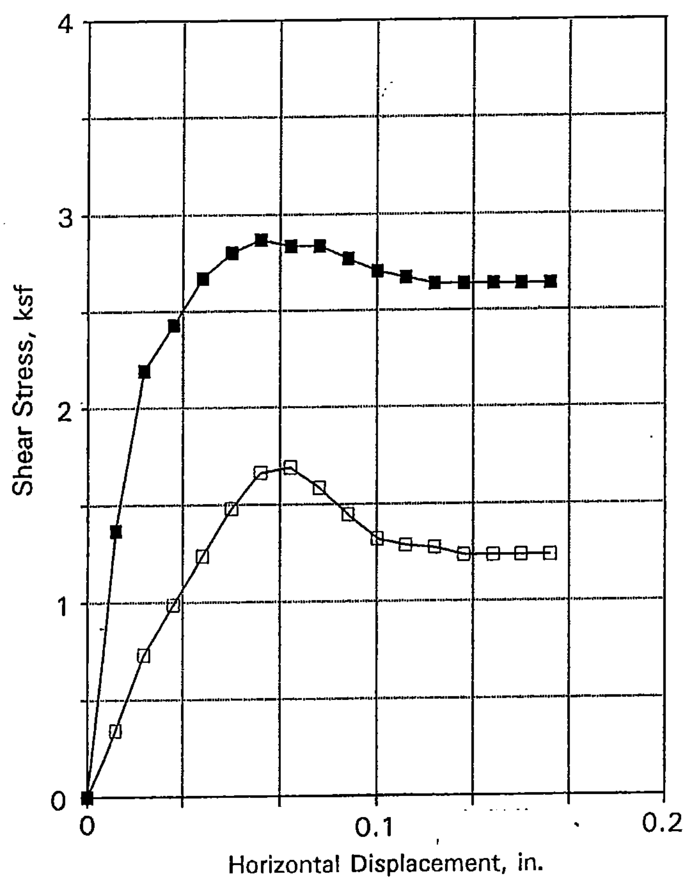
Type of Test Consolidated, Undrained

Sample Description Sandy Silt (ML)   From L-1 @ 95 Feet

Project No. 20591   DIRECT SHEAR TEST RESULTS   Figure 29

Applied Geotechnical Engineering Consultants, Inc.





Test No.(Symbol)	1(□)	2(■)
Sample Type	Undisturbed	
Length, in.	1.0	
Diameter, in.	1.93	
Dry Density, pcf	100	105
Moisture Content, %	24	24
Consolidation Load, ksf	1.95	3.91
Normal Load, ksf	1.95	3.91
Shear Stress, ksf	1.69	2.87
Remarks	Strain rate, 0.05 in/min	
	Sample wetted before test	

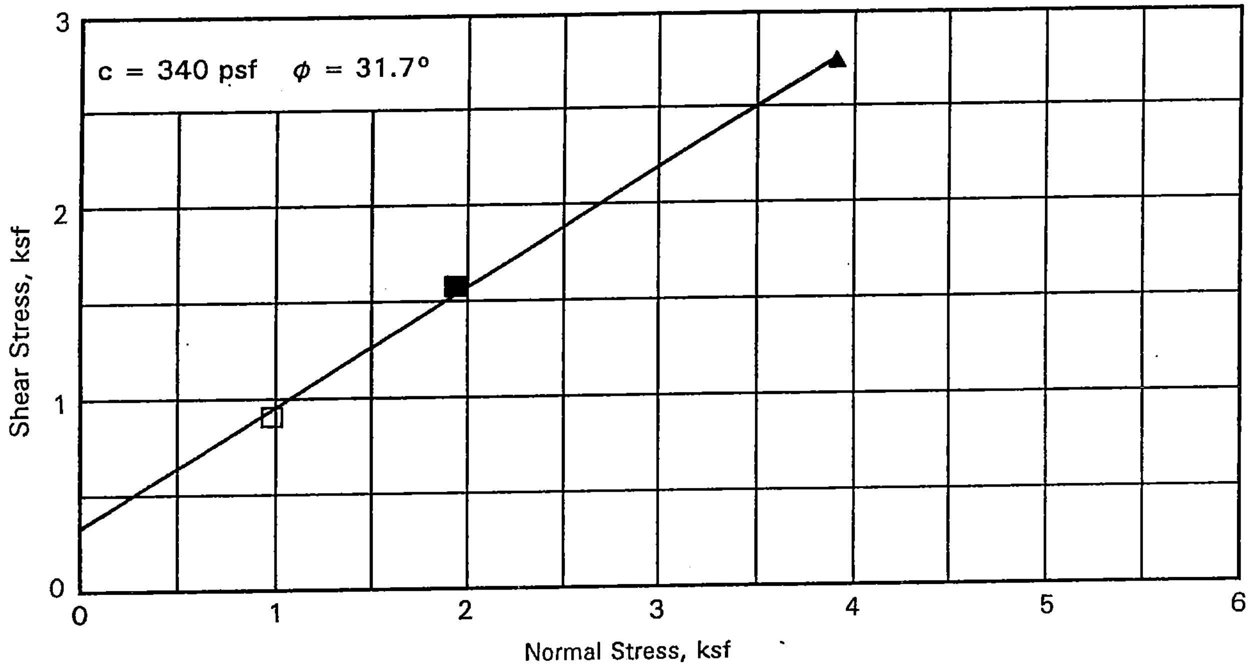
Sample Index Properties	
Natural Dry Density, pcf	
Natural Moisture Content, %	
Liquid Limit, %	
Plasticity Index, %	
Percent Gravel	
Percent Sand	
Percent Passing No. 200 Sieve	28

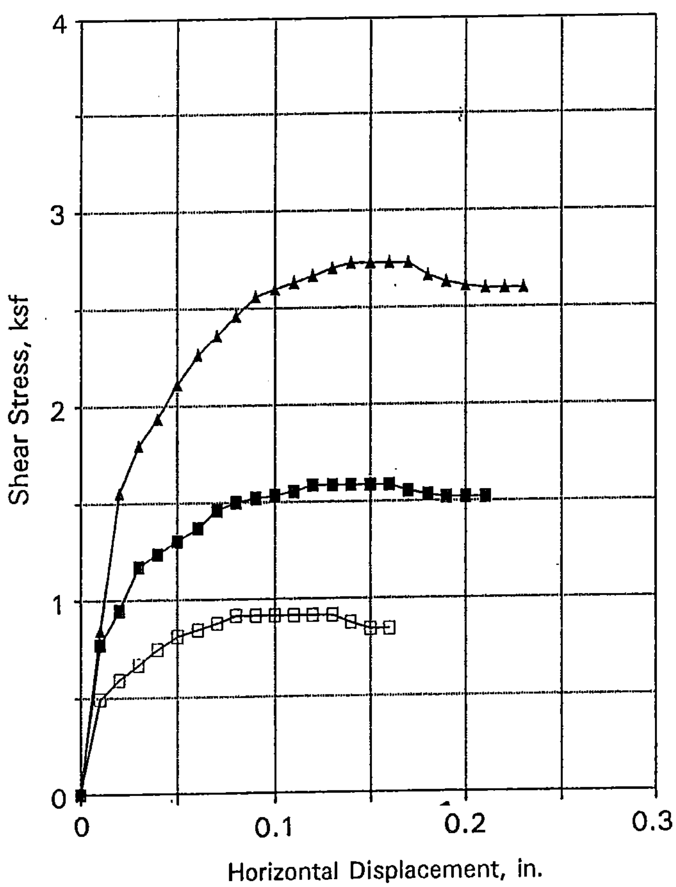
Type of Test Consolidated, Undrained

Sample Description Silty Sand (SM) From L-14 @ 35 Feet

Project No. 20591 DIRECT SHEAR TEST RESULTS Figure 30

Applied Geotechnical Engineering Consultants, Inc.





Test No.(Symbol)	1(□)	2(■)	3(▲)
Sample Type	Undisturbed		
Length, in.	0.75		
Diameter, in.	1.93		
Dry Density, pcf	88	90	98
Moisture Content, %	30	35	29
Consolidation Load,	0.98	1.95	3.91
Normal Load, ksf	0.98	1.95	3.91
Shear Stress, ksf	0.91	1.58	2.73
Remarks	Strain rate, 0.05 in/min		
	Sample wetted before test		

Sample Index Properties	
Natural Dry Density, pcf	
Natural Moisture Content, %	
Liquid Limit, %	
Plasticity Index, %	
Percent Gravel	
Percent Sand	
Percent Passing No. 200 Sieve	20

Type of Test Consolidated, Undrained

Sample Description Silty Sand (SM) From L-27 @ 15 Feet

Project No. 20591 DIRECT SHEAR TEST RESULTS Figure 31

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.
TABLE I - SUMMARY OF LABORATORY TEST RESULTS

PROJECT NUMBER 20591

SAMPLE LOCATION		NATURAL MOISTURE CONTENT (%)	NATURAL DRY DENSITY (PCF)	GRADATION			ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	SAMPLE CLASSIFICATION
BORING	DEPTH (FEET)			GRAVEL (%)	SAND (%)	SILT/ CLAY (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)		
L-1	15	18	87			53	21	5		Sandy Silty Clay
	50	20	108			22				Silty Sand
	95		105			62				Sandy Silt
L-2	30½	65	62			100	66	40		Fat Clay
L-3	25	54	69			90			375	Lean Clay
	85½	28	96			87			890	Lean Clay
	90½	38	84			82	43	21		Lean Clay with Sand
	100½	32	93			98	43	22		Lean Clay
L-4	23	48	74			99	46	25		Lean Clay
	50½	23	103			57			1,150	Sandy Lean Clay
L-6	20½	58	65			100	46	19		Lean Clay
	50½	40	80			89				Lean Clay
L-8	60	59	67			100	63	36		Fat Clay
L-10	40½	59	65						820	Lean Clay with Sand
	50½	17	111			11		NP		Poorly-graded Sand with Silt
	60½	28	91			82			900	Lean Clay with Sand
L-12	60	42	78			95			950	Lean Clay

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.
TABLE I - SUMMARY OF LABORATORY TEST RESULTS

PROJECT NUMBER 20591

SAMPLE LOCATION		NATURAL MOISTURE CONTENT (%)	NATURAL DRY DENSITY (PCF)	GRADATION			ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	SAMPLE CLASSIFICATION
BORING	DEPTH (FEET)			GRAVEL (%)	SAND (%)	SILT/CLAY (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)		
L-14	20	20	107			4				Poorly-graded Sand
	35		105			28				Silty Sand
	45	33	87			81	29	11		Lean Clay with Sand
	60	39	81						1,020	Lean Clay
L-15	20	19	112			6				Poorly-graded Sand with Silt
	32	60	65			100	48	24		Lean Clay
L-17	8	59	66							Lean Clay
	25½	67	61			100	65	29		Fat Clay
	35½	26	98			67			2,370	Sandy Lean Clay
	55½	38	83			91			745	Lean Clay
L-19	40	33	89			65			475	Sandy Silt and Lean Clay
	45	31	90			79			420	Sandy Silt and Lean Clay
	50	31	92			100	45	25		Lean Clay
L-21	20	35	81			55			690	Sandy Lean Clay
	30	68	62			100	66	34		Fat Clay
L-23	50	43	75			100			1,255	Lean Clay
L-24	20	49	72			99			775	Lean Clay
	30	52	70			89	49	25		Lean Clay

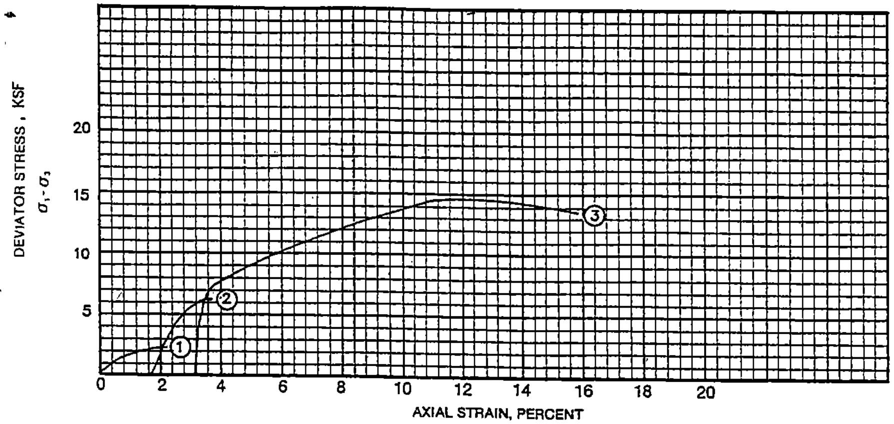
APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.
TABLE I - SUMMARY OF LABORATORY TEST RESULTS

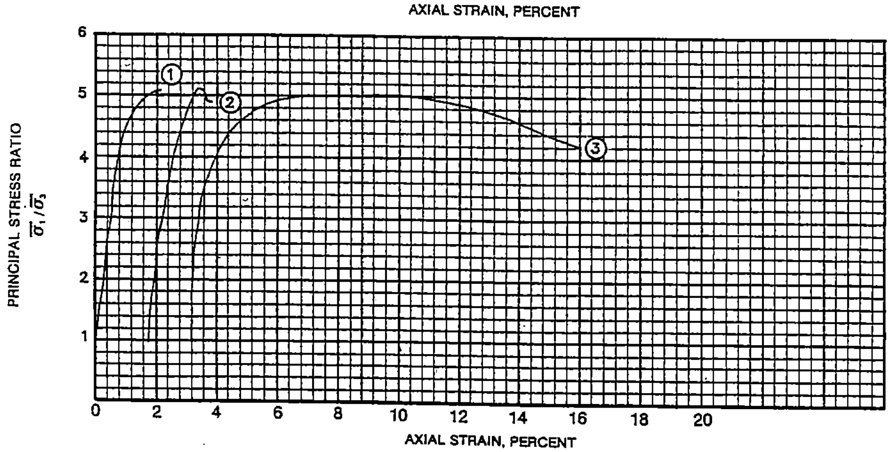
PROJECT NUMBER 20591

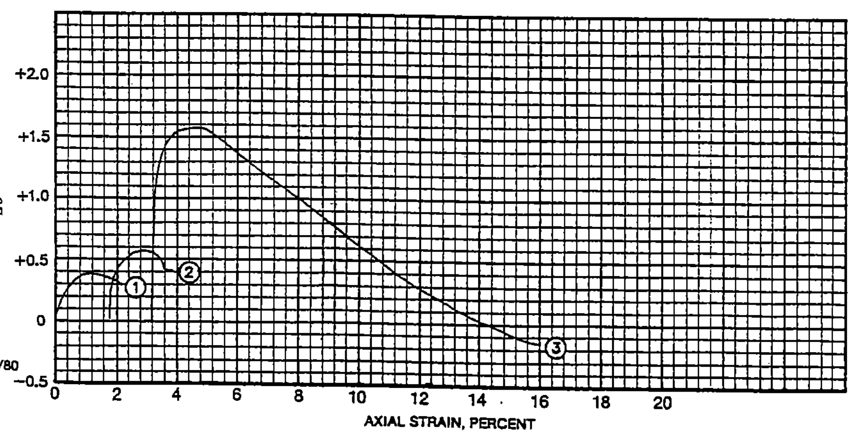
SAMPLE LOCATION		NATURAL MOISTURE CONTENT (%)	NATURAL DRY DENSITY (PCF)	GRADATION			ATTERBERG LIMITS		UNCONFINED COMPRESSIVE STRENGTH (PSF)	SAMPLE CLASSIFICATION
BORING	DEPTH (FEET)			GRAVEL (%)	SAND (%)	SILT/ CLAY (%)	LIQUID LIMIT (%)	PLASTICITY INDEX (%)		
L-24	35	67	60			100	68	42		Fat Clay
	45	27	96			74	37	24		Lean Clay with Sand
L-26	15½	38	78			99			365	Lean Clay
	55½	44	78			99	52	30		Fat Clay
	60½	35	85			84			575	Lean Clay with Sand
L-27	15		92			20				Silty Sand
	20	60	63			100			920	Lean Clay
	30	22	96	21	61	18				Silty Sand
	40	30	92			77			1,385	Lean Clay with Sand
L-28	20	61	64			100	46	20		Lean Clay
	30	23	79			76				Lean Clay with Sand
	40	33	86			81				Lean Clay with Sand
	45	49	73			89	46	24		Lean Clay
L-29	20½	51	72			85			495	Lean Clay with Sand
	35½	32	91			64	30	15		Sandy Lean Clay
L-30	35	30	92			62			630	Sandy Lean Clay
	75	14	116			52				Sandy Silt

SHEAR STRENGTH OF SOIL IN TRIAXIAL COMPRESSION

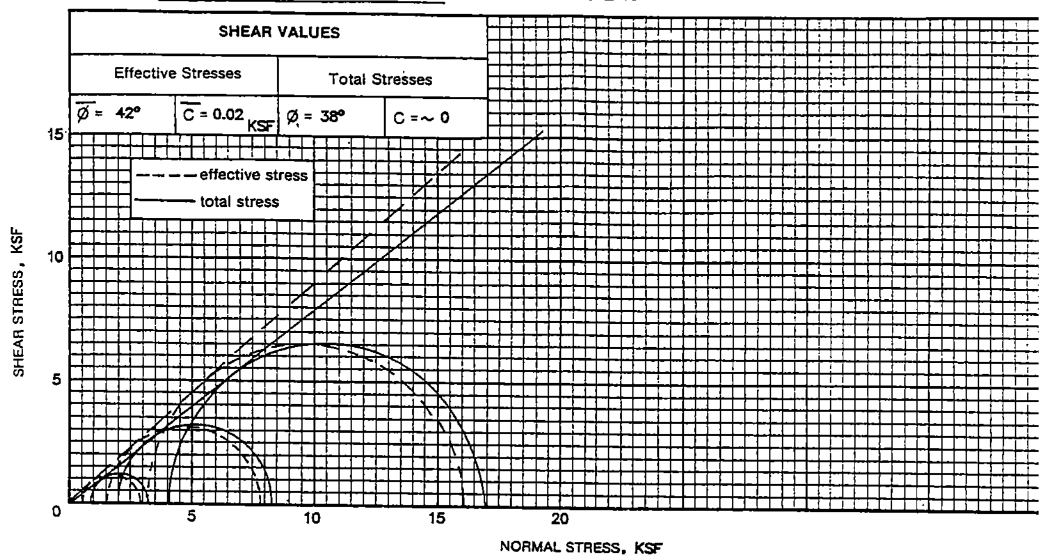
Job No. 11791 -
Date 3-15-91
Type of Test MULTI-STAGED; SATURATED, CONSOLIDATED, UNDRAINED WITH PORE PRESSURE MEASUREMENTS







CA-6/80



Stage Number	Specimen Location: Boring Number	Depth (Ft)	Initial Specimen Data: Sample Type	Length (in)	Diameter (in)	Dry Density (P.C.F.)	Moisture Content (%)	Soil Description
1	C6-7	0	Cal. liner	3.788	1.928	116.7	13.7	SLIGHTLY SANDY CLAY *
2	C6-7	0	Cal. liner	–	–	–	–	SLIGHTLY SANDY CLAY *
3	C6-7	0	Cal. liner	–	–	–	–	SLIGHTLY SANDY CLAY *

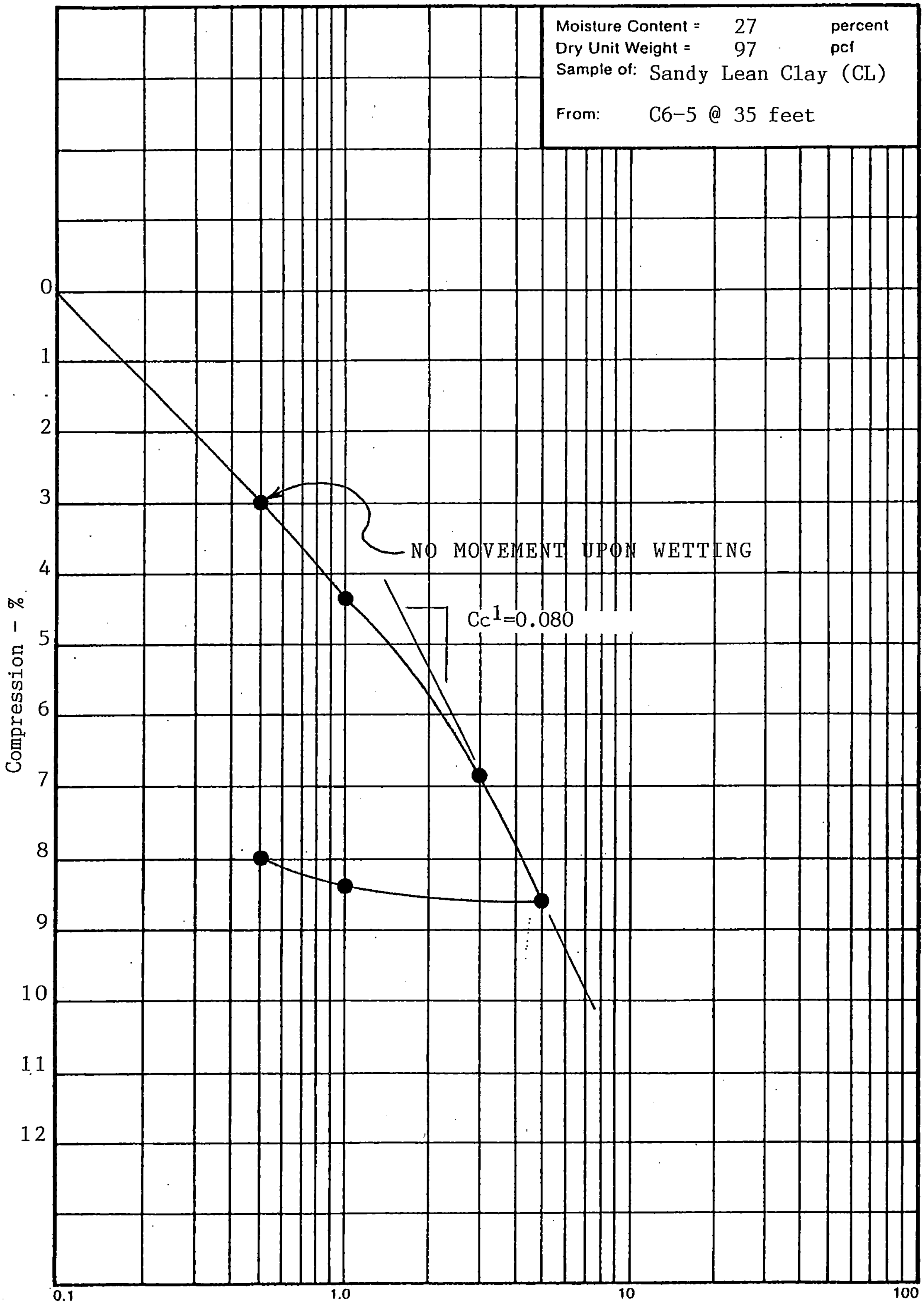
Stage Number	"B" Parameter	Test Values at Failure–Maximum Principal Stress Ratio: Total Confining Stress σ_3	Total Axial Stress σ_1	Deviator Stress $\sigma_1-\sigma_3$	Effective Lateral Stress $\bar{\sigma}_3$	Effective Axial Stress $\bar{\sigma}_1$	Pore Pressure μ	Δ Percent Strain ϵ%	Remarks
1	0.96	0.86	3.14	2.28	0.56	2.84	0.30	2.2	UNITS IN KSF
2	–	2.02	8.27	6.25	1.53	7.78	0.49	1.6	UNITS IN KSF
3	–	4.03	16.80	12.77	3.17	15.94	0.86	5.5	UNITS IN KSF

Remarks:

* Percent passing no. 200 sieve = 88%

Fig. A-1

Applied Geotechnical Engineering Consultants

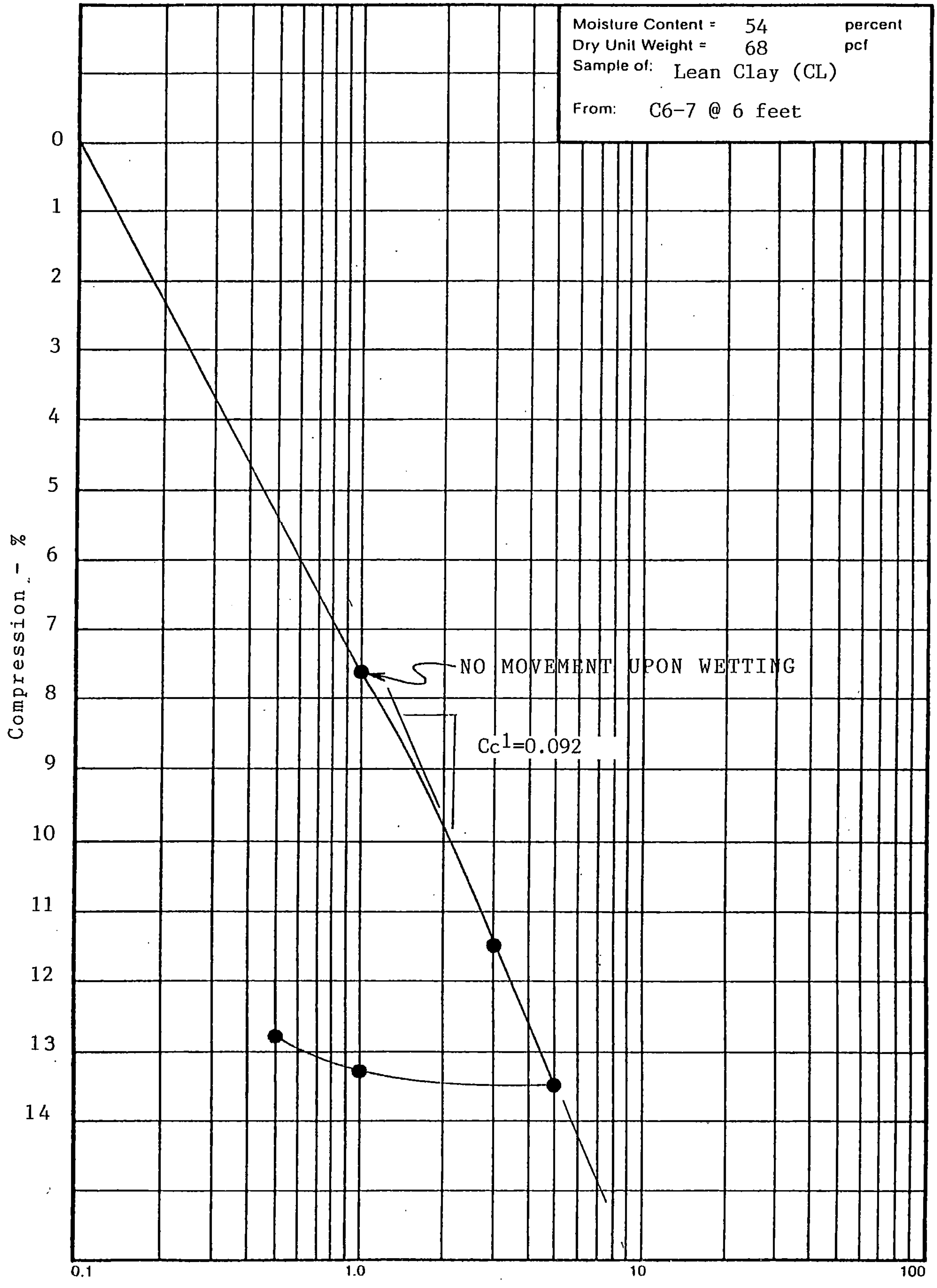


Job No. 11791

SWELL-CONSOLIDATION TEST RESULTS

Fig. A-2

Applied Geotechnical Engineering Consultants

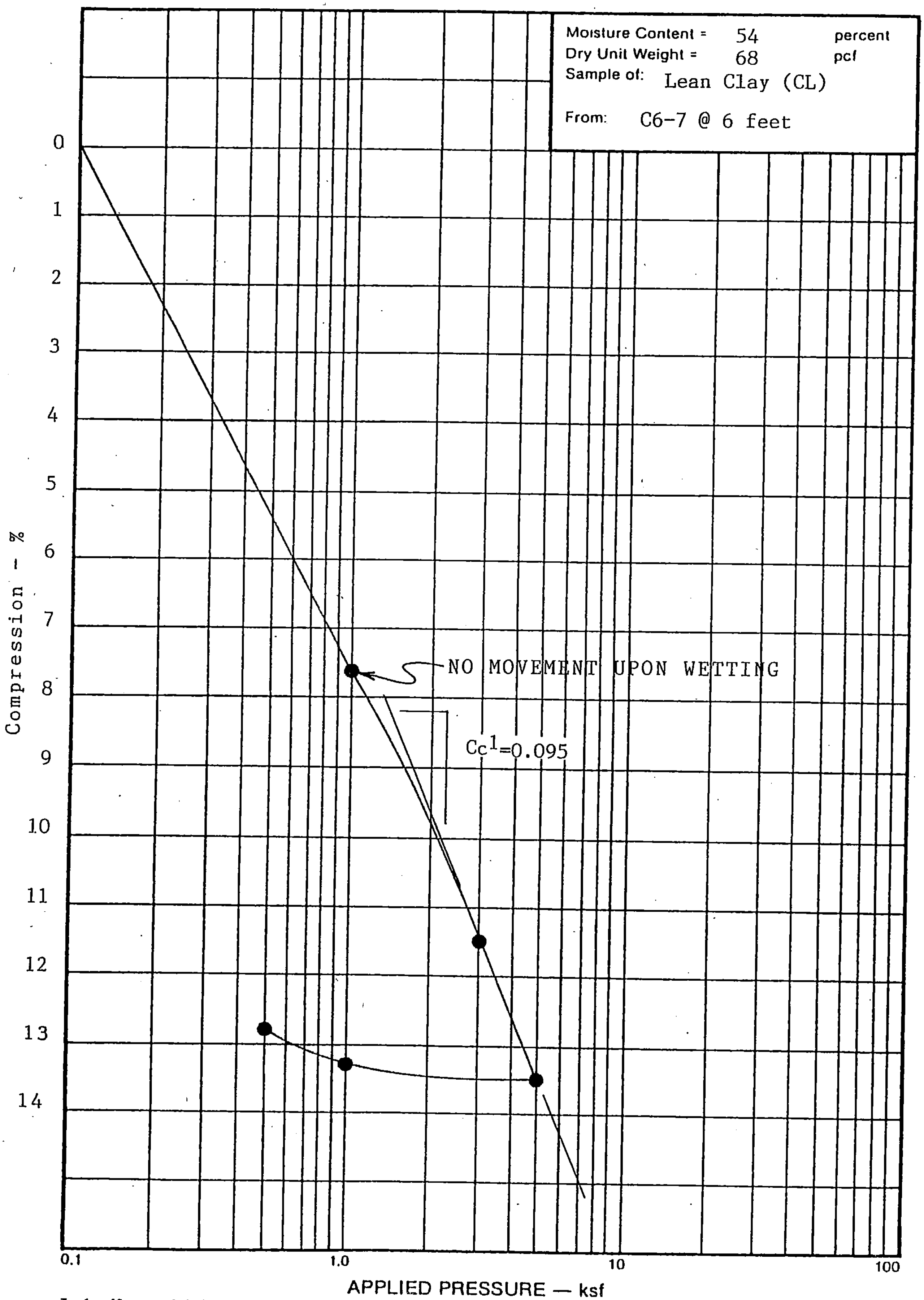


Job No. 11791

SWELL-CONSOLIDATION TEST RESULTS

Fig. A-3

Applied Geotechnical Engineering Consultants



Job No. 11791

SWELL-CONSOLIDATION TEST RESULTS

Fig. A-4

Project Number 11791

TABLE I
SUMMARY OF LABORATORY TEST RESULTS

Boring	Depth (ft)	Water Content (%)	Dry Density (pcf)	Grain Size Gravel (%)	Grain Size Sand (%)	Grain Size Clay/Silt (%)	Atterberg Limits LL%	Atterberg Limits PI%	Unconfined Compressive Strength (psf)	Description
C6-5	6	49	73			97			525	Lean Clay
	10	48	74			97			655	Lean Clay
	35	27	97			59	38	21		Sandy Ln Clay
C6-6	0	12	117			91	28	13		Lean Clay
	2	17	104			95				Lean Clay
	8	47	74			98	42	17	730	Lean Clay
	12	49	74			96			775	Lean Clay
	30	60	65			98			690	Lean Clay
C6-7	0	14	117			86				Lean Clay
	4	37	82			83			735	Lean Clay w/ Sand
	6	54	68			96				Lean Clay
	10	52	71			98			635	Lean Clay

APPENDIX B

PROPOSED LANDFILL

CELL PROFILES

Configuration

Size: each cell is approx. 800' x 800'

Slopes: interior 3H : 1V
exterior 2½H : 1V

Crest width: approx. 20'

Liner systems (top down)

Cell Floor
2' soil cover
double-sided geocomposite
80 mil textured HDPE
GCL
80 mil textured HDPE
double-sided geocomposite
60 mil textured HDPE
3' Compacted Clay Liner

Cell Floor to 10' up Slope
2' soil cover
80 mil textured HDPE
GCL
80 mil textured HDPE
double-sided geocomposite
60 mil textured HDPE
3' Compacted Clay Liner

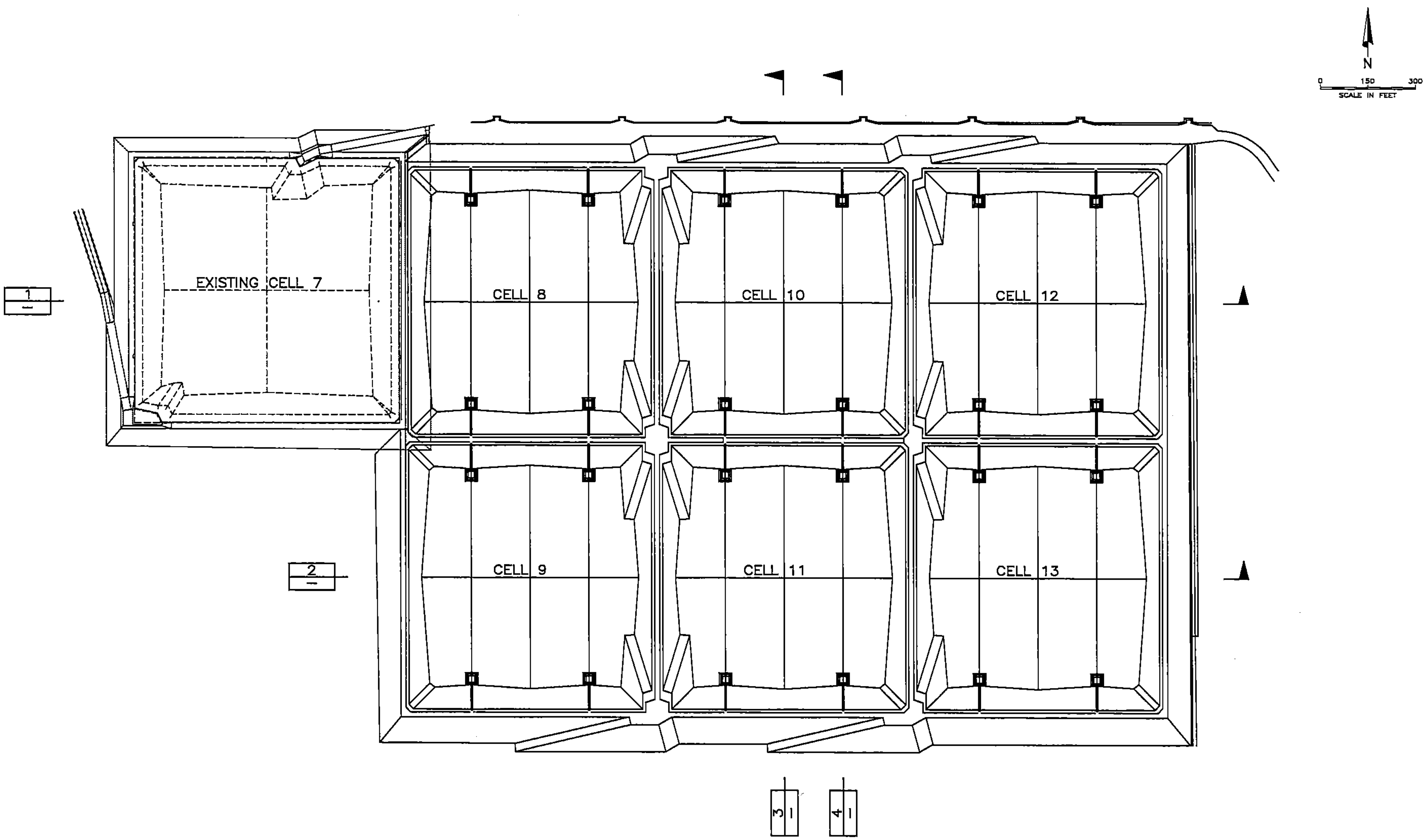
Upper Slope
2' soil cover
80 mil textured HDPE
GCL
double-sided geocomp.
60 mil textured HDPE
3' Compacted Clay Liner

Cover Liner (top)
4" Stone mulch
2' Soil cover
double-sided drainage composit
60 mil HDPE textured liner
GCL
6" soil cushion

Cover Liner (perimeter)
(3H:1V. Slope)
4" Stone mulch
2' compacted Clay soil
60 mil HDPE textured liner
compacted clay cap

Elevations:

Existing Grade ~ 4239' to 4240'
Top of Embankment 4267'
Sump (top Clay Liner) ~4242'
Closure (peak) 4306'
(top 3:1 slope) ~4293'



PLAN VIEW

PROGRESS PRINT
7.10.2017
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PROJECTS\064 – CLEAN HARBORS\65.100 – CELL 8 AND 9 DESIGN\CAD\LAYOUT\PLAN VIEW.DWG
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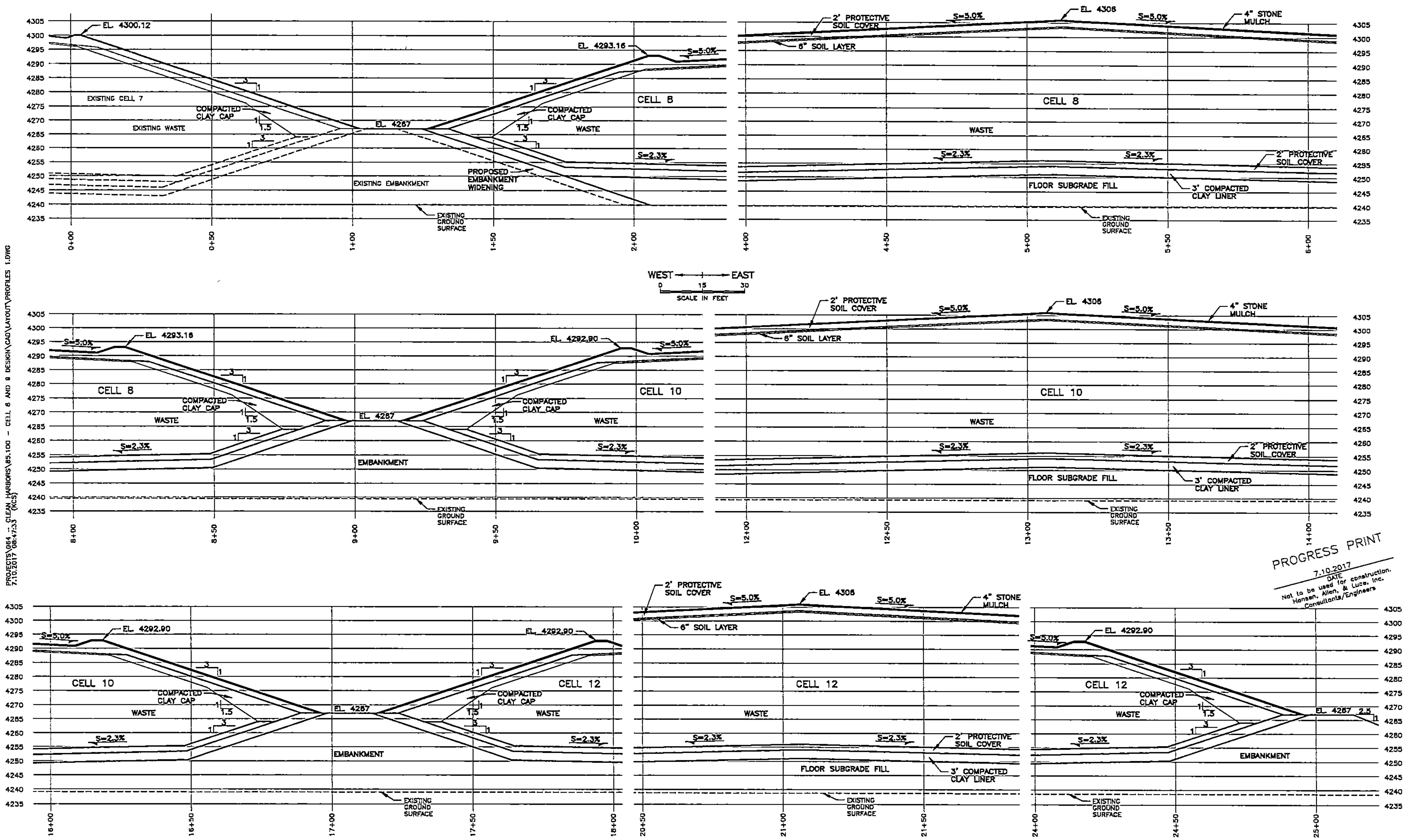

EL. 4300.12
EL. 4293.16
S=5.0%
EXISTING CELL 7
EXISTING WASTE
COMPACTED CLAY CAP
1.5
EL. 4267
CELL 8
WASTE
S=2.3%
PROPOSED EMBANKMENT WIDENING
EXISTING EMBANKMENT
EXISTING GROUND SURFACE
2' PROTECTIVE SOIL COVER
EL. 4306
4" STONE MULCH
6" SOIL LAYER
FLOOR SUBGRADE FILL
3' COMPACTED CLAY LINER
EL. 4292.90
CELL 10
EMBANKMENT
CELL 12
WEST
EAST
SCALE IN FEET
0
15
30
0+00
0+50
1+00
1+50
2+00
4+00
4+50
5+00
5+50
6+00
8+00
8+50
9+00
9+50
10+00
12+00
12+50
13+00
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25+00
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7.10.2017
DATE
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Consultants/Engineers
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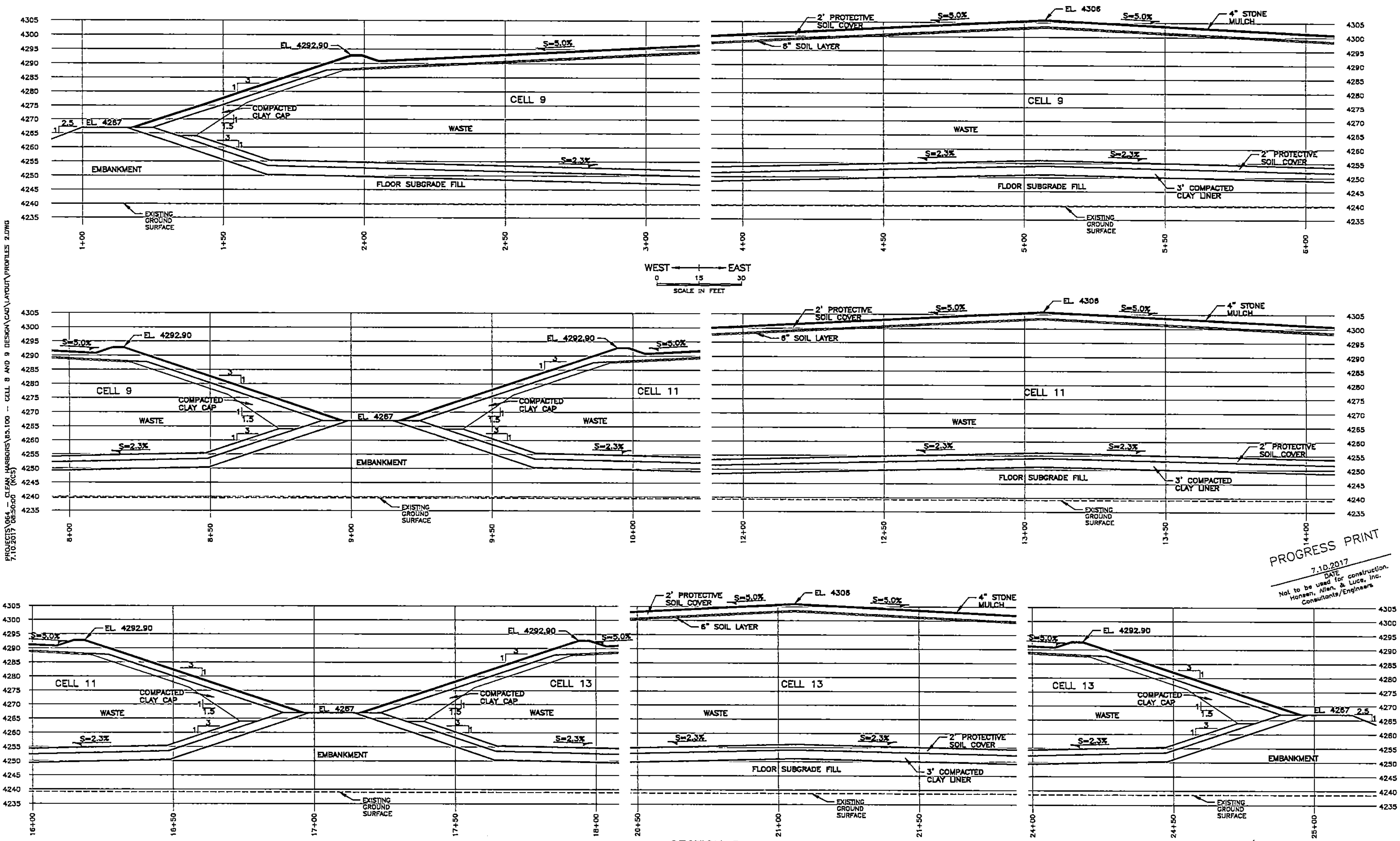
SECTION 1



SECTION 2

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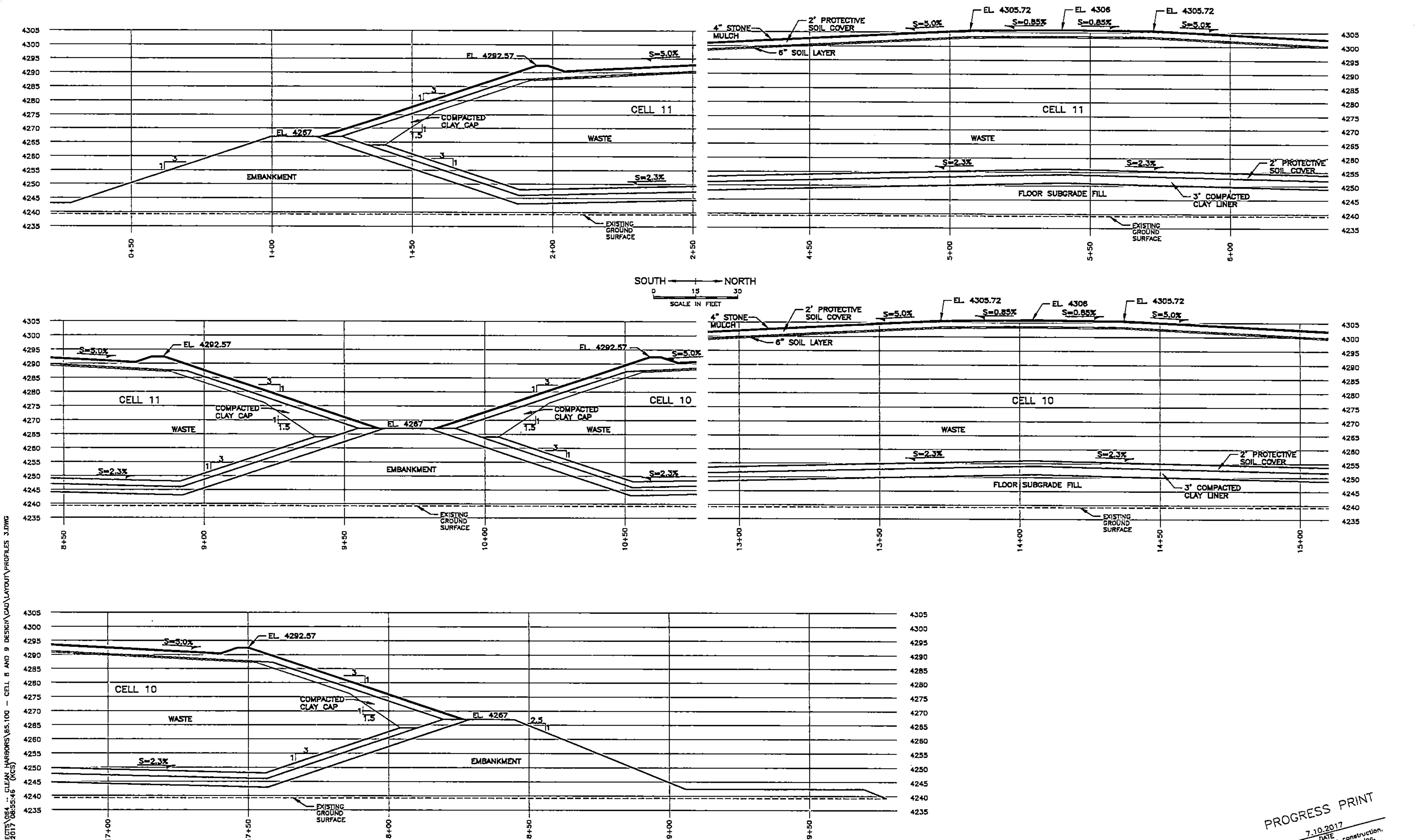

SECTION 3

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Consultants/Engineers

11/5

SECTION 4

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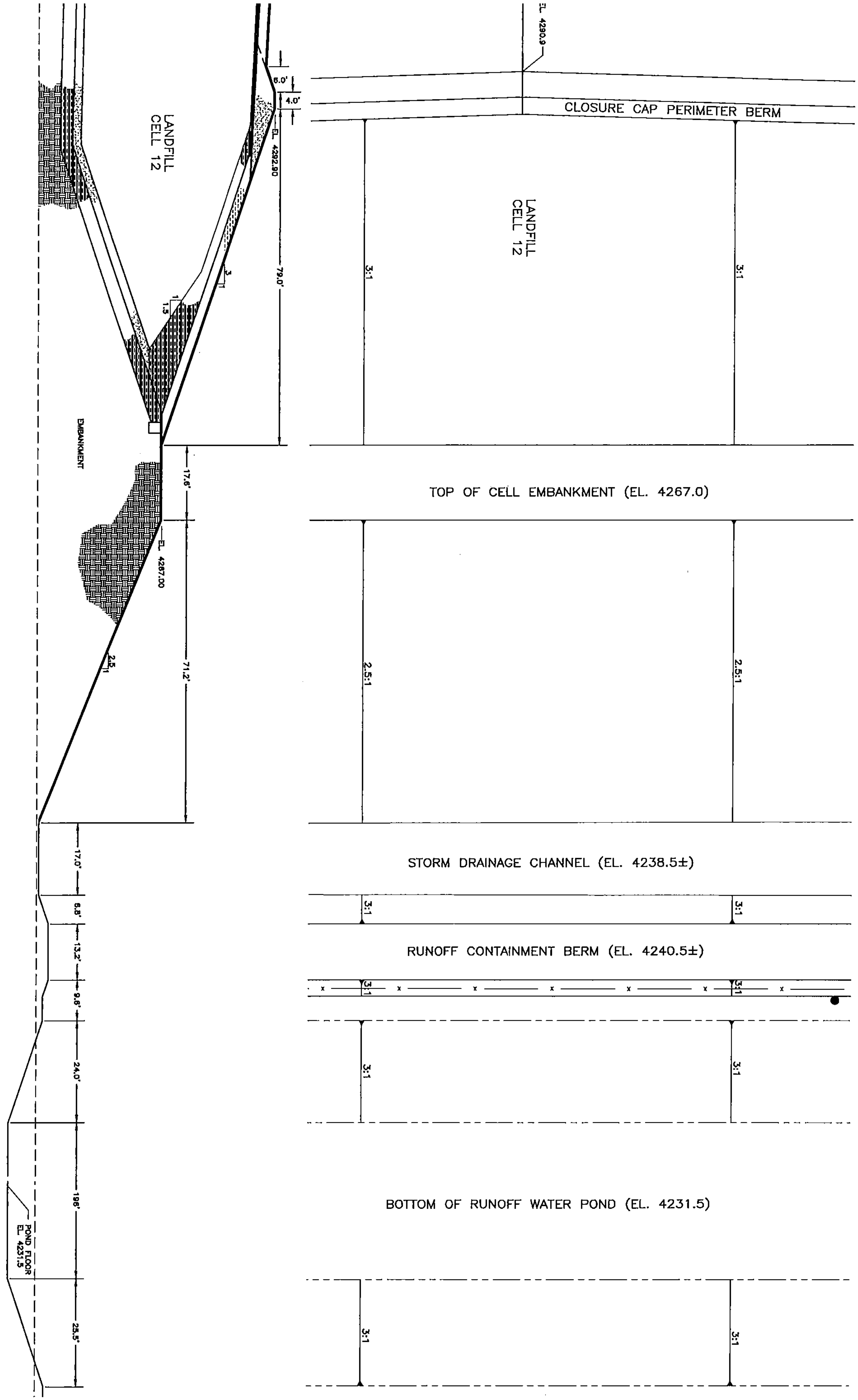
Hansen, Allen, & Luce, Inc.
Consultants/Engineers


EL 4290.9
CLOSURE CAP PERIMETER BERM
LANDFILL CELL 12
3:1
3:1
TOP OF CELL EMBANKMENT (EL. 4267.0)
2.5:1
2.5:1
STORM DRAINAGE CHANNEL (EL. 4238.5±)
RUNOFF CONTAINMENT BERM (EL. 4240.5±)
BOTTOM OF RUNOFF WATER POND (EL. 4231.5)
LANDFILL CELL 12
EMBANKMENT
6.0'
4.0'
EL 4292.90
79.0'
17.6'
EL 4267.00
71.2'
17.0'
8.8'
13.2'
9.6'
24.0'
198'
25.5'
POND FLOOR EL 4231.5

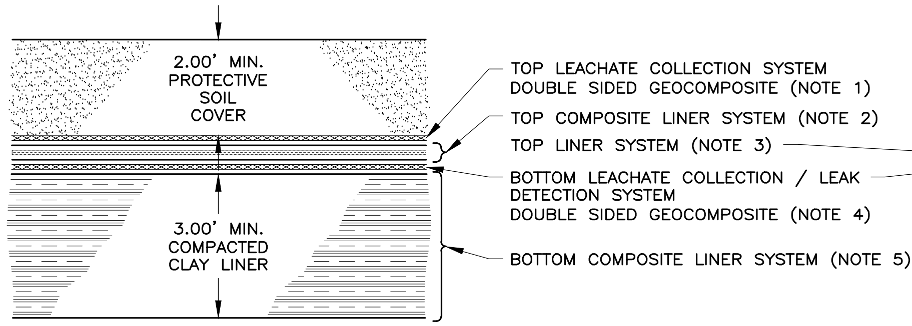
11/2

NOTES:

1. TOP LEACHATE COLLECTION SYSTEM CONSISTS OF DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   - 8 OZ. NON-WOVEN GEOTEXTILE
   - GEONET
   - 8 OZ. NON-WOVEN GEOTEXTILE

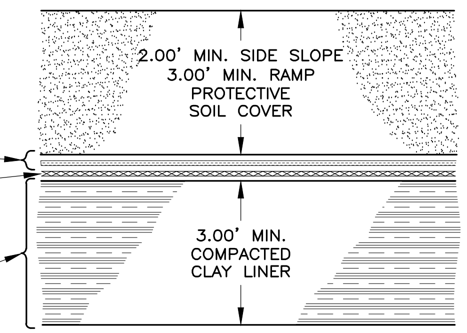
   } MIN. GEOCOMPOSITE TRANSMISSIVITY OF 6.0×10^{-4} M^2/SEC, TYP.)
2. TOP COMPOSITE LINER SYSTEM ON THE FLOOR AND TO A DISTANCE OF 10 FEET UP THE INTERIOR SLOPES CONSISTS OF:
   - 80-MIL HDPE GEOMEMBRANE (TEXTURED)
   - GEOSYNTHETIC CLAY LINER (GCL)
   - 80-MIL HDPE GEOMEMBRANE (TEXTURED)
3. TOP LINER SYSTEM ON THE INTERIOR SIDESLOPES FROM A DISTANCE OF 10 FEET UP THE SLOPES TO THE ANCHOR TRENCH AT THE TOP OF THE SLOPES CONSISTS OF:
   - 80-MIL HDPE GEOMEMBRANE (TEXTURED)
   - GEOSYNTHETIC CLAY LINER (GCL)
4. BOTTOM LEACHATE COLLECTION / LEAK DETECTION SYSTEM CONSISTS OF DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   - 8 OZ. NON-WOVEN GEOTEXTILE
   - GEONET
   - 8 OZ. NON-WOVEN GEOTEXTILE

   } MIN. GEOCOMPOSITE TRANSMISSIVITY OF 2.7×10^{-4} M^2/SEC, TYP.)
5. BOTTOM COMPOSITE LINER SYSTEM CONSISTS OF:
   - 60-MIL HDPE GEOMEMBRANE (TEXTURED)
   - COMPACTED CLAY LINER (CCL)
6. PROTECTIVE SOIL COVER PLACED ON THE INTERIOR SLOPES SHALL ONLY BE PLACED TO A VERTICAL HEIGHT OF 10-FEET ABOVE THE LEVEL OF THE COVER ON WASTE MATERIALS IN THE LANDFILL CELLS.
7. PROTECTIVE SOIL COVER ON RAMP TO CONSIST OF 18 INCHES OF COMPACTED SOIL (95% ASTM D-698) AND 18 INCHES OF ROAD BASE AGGREGATE AS SHOWN ON SHEET LF-8.
8. PROTECTIVE SOIL COVER ON FLOOR EXTENDING A DISTANCE OF 20 FEET FROM THE BASE OF THE RAMP TO CONSIST OF 12 INCHES OF COMPACTED SOIL (95% ASTM D-698) AND 12 INCHES OF ROAD BASE AGGREGATE AS SHOWN ON SHEET LF-8.



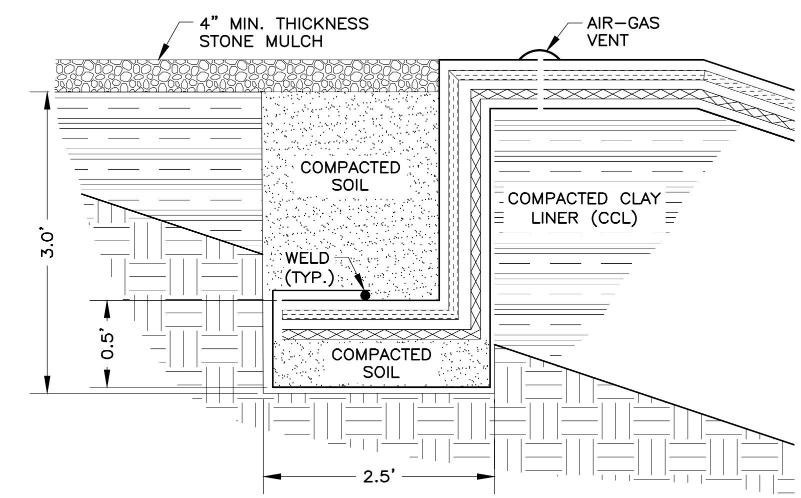
FLOOR LINER SYSTEM DETAIL A/– A/LF-8

N.T.S.



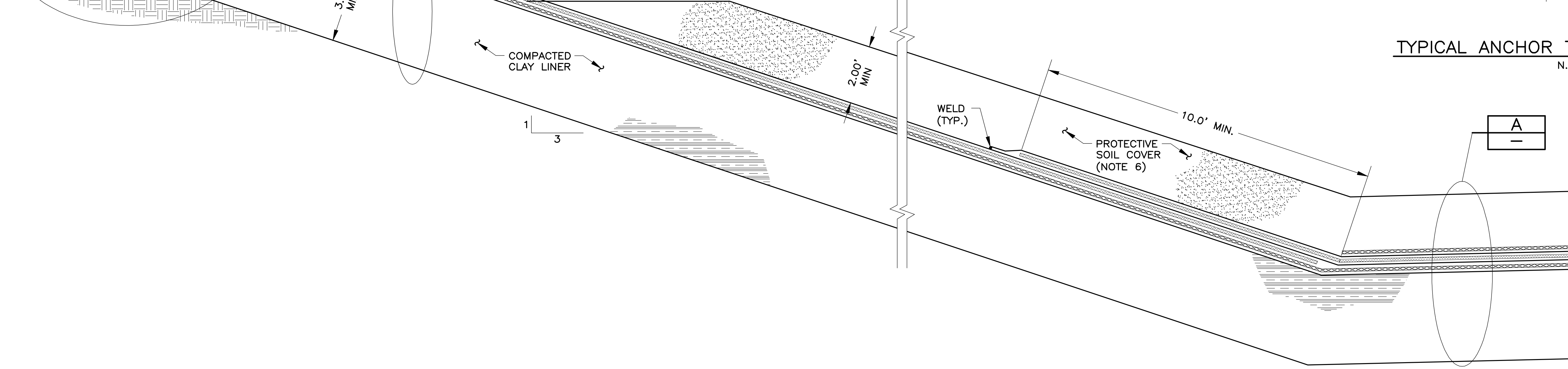
SIDESLOPE LINER SYSTEM DETAIL B/– B/LF-8

N.T.S.



TYPICAL ANCHOR TRENCH DETAIL C/–

N.T.S.



TYPICAL SIDESLOPE LINER SYSTEM DETAILS 1/LF-2

N.T.S.

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FILE DATE: 11.10.2017 11:32:25 (CAH)

10/07

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER — GORDON L. JONES — No. 5048470-2202 — STATE OF UTAH

PROJECT ENGINEER

DESIGNED	KCS	3			
DRAFTED	CAH	2			
CHECKED	GLJ	1			
DATE	NOVEMBER 2017	NO.	DATE	REVISIONS	BY / APVD.

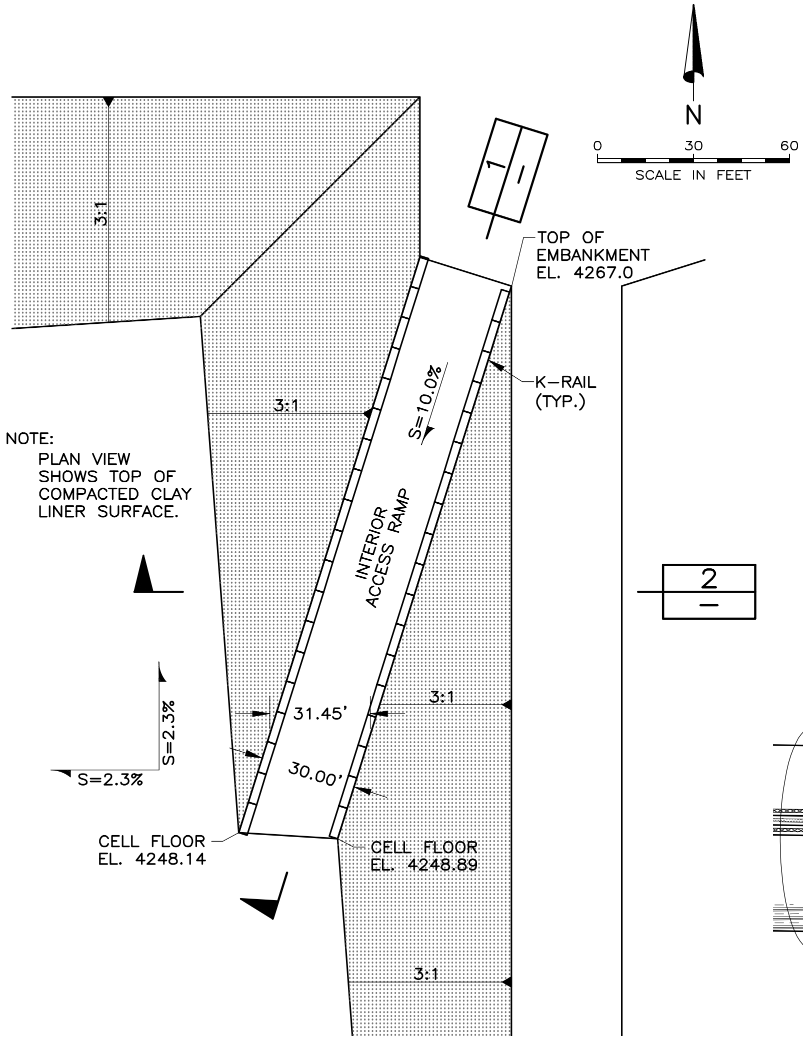
SCALE: AS SHOWN

CleanHarbors® ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8-13
LANDFILL
DETAILS

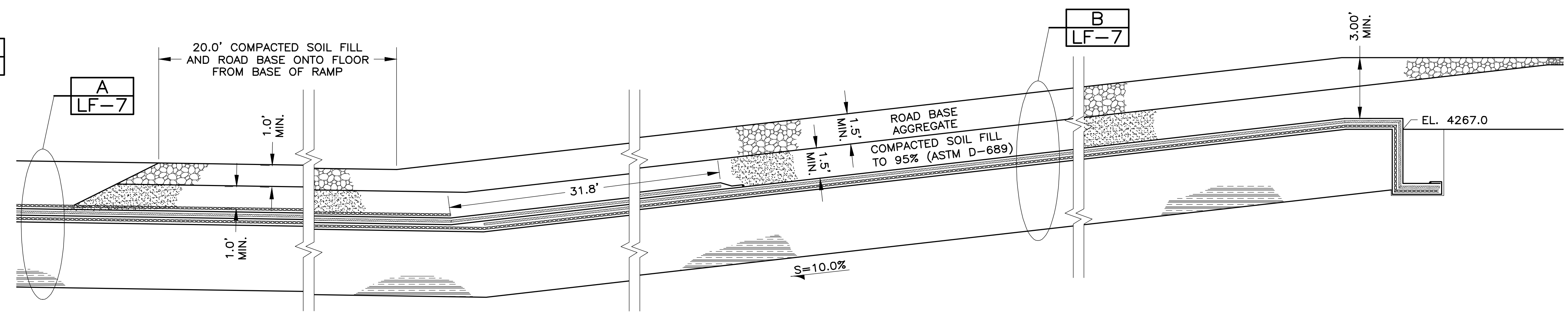
SHEET LF-7

064.85.100



TYPICAL INTERIOR ACCESS RAMP

N.T.S.



TYPICAL RAMP SECTION 1

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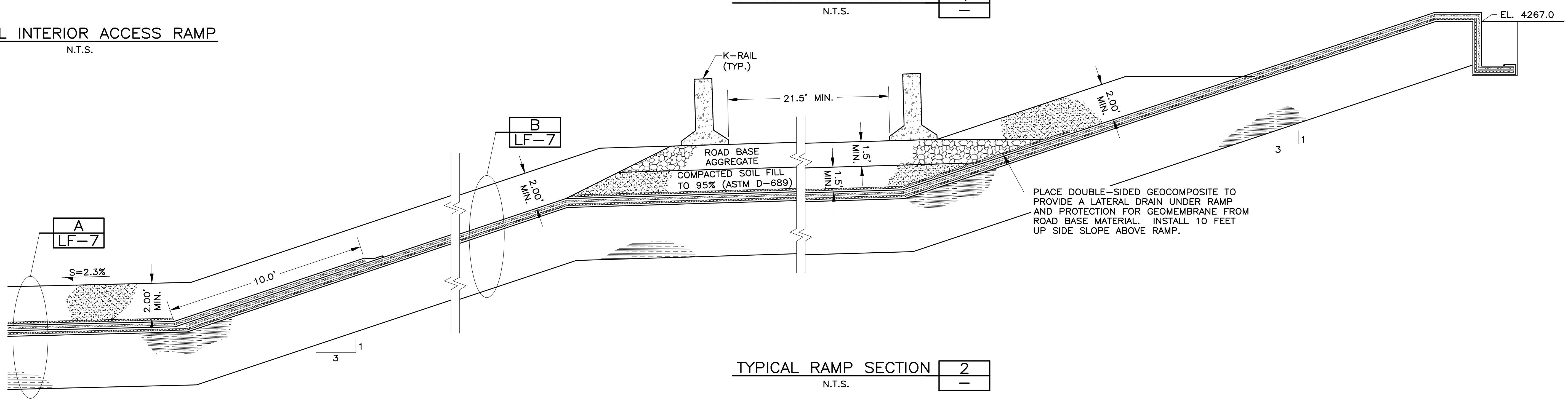


TYPICAL RAMP SECTION 2

N.T.S.

FILE NAME: PROJECTS\064 - CLEAN HARBORS\85.100 - CELL 8 AND 9 DESIGN\CAD\WORKING\LF-8 RAMP SECTIONS.DWG
FILE DATE: 11.10.2017 11:33:33 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER GORDON L. JONES No. 5048470-2202 11/10/2017 STATE OF UTAH

PROJECT ENGINEER

DESIGNED KCS	3				
DRAFTED CAH	2				
CHECKED GLJ	1				
DATE NOVEMBER 2017	NO.	DATE	REVISIONS	BY	APVD.

SCALE: AS SHOWN

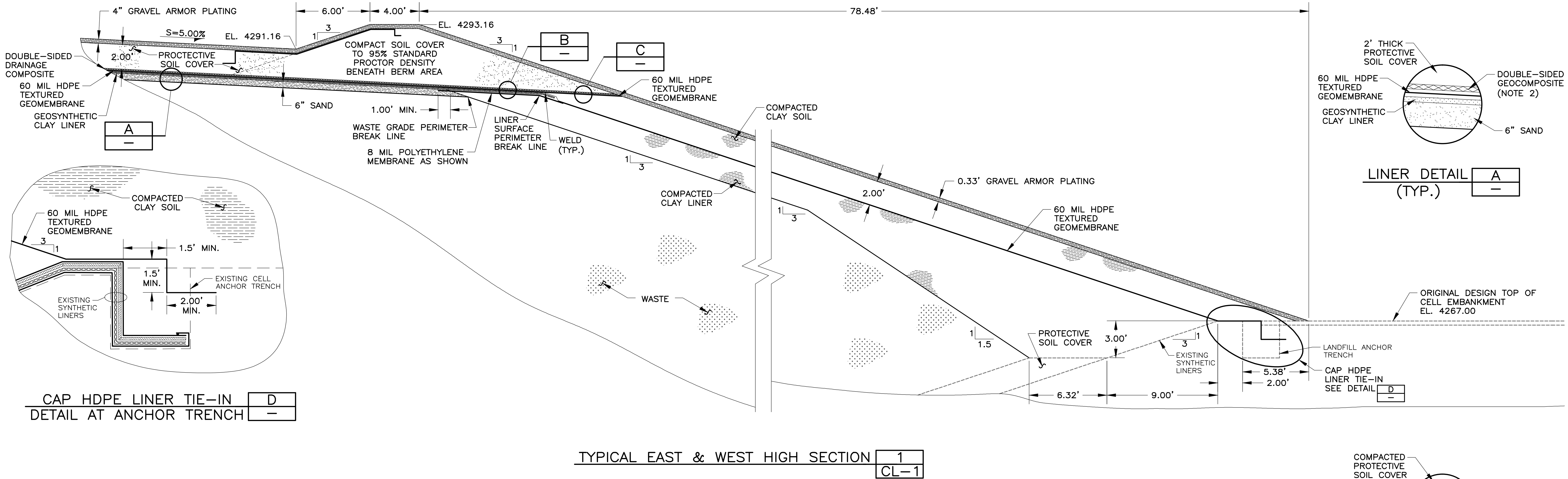
CleanHarbors® ENVIRONMENTAL SERVICES, INC.

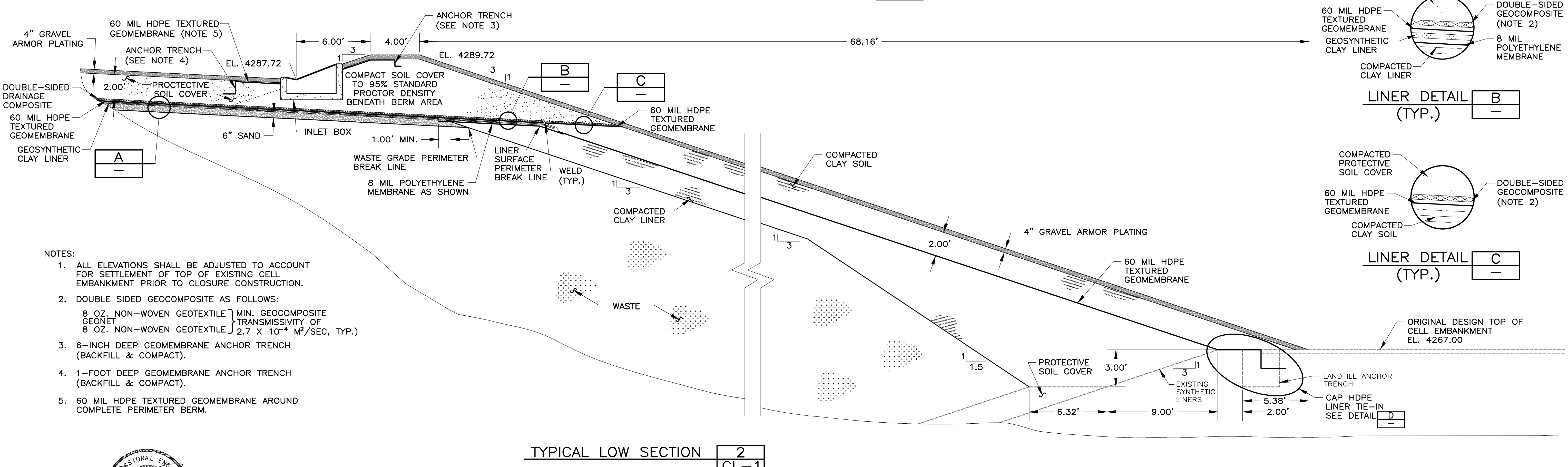
GRASSY MOUNTAIN FACILITY CELLS 8-13
LANDFILL
TYPICAL ACCESS RAMPS

SHEET LF-8

064.85.100

10/07





NOTES:

1. ALL ELEVATIONS SHALL BE ADJUSTED TO ACCOUNT FOR SETTLEMENT OF TOP OF EXISTING CELL EMBANKMENT PRIOR TO CLOSURE CONSTRUCTION.
2. DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   8 OZ. NON–WOVEN GEOTEXTILE, GEONET, 8 OZ. NON–WOVEN GEOTEXTILE } MIN. GEOCOMPOSITE TRANSMISSIVITY OF 2.7×10^{-4} M²/SEC, TYP.)
3. 6–INCH DEEP GEOMEMBRANE ANCHOR TRENCH (BACKFILL & COMPACT).
4. 1–FOOT DEEP GEOMEMBRANE ANCHOR TRENCH (BACKFILL & COMPACT).
5. 60 MIL HDPE TEXTURED GEOMEMBRANE AROUND COMPLETE PERIMETER BERM.

FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\CL–7 HIGH LOW SECTIONS 8.DWG
FILE DATE: 11.10.2017 11:48:49 (CAH)

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER No. 5048470-2202 GORDON L. JONES STATE OF UTAH — PROJECT ENGINEER

DESIGNED	KCS	3			
DRAFTED	CAH	2			
CHECKED	GLJ	1			
DATE	NOVEMBER 2017	NO.	DATE	REVISIONS	BY / APVD.

SCALE: NOT TO SCALE

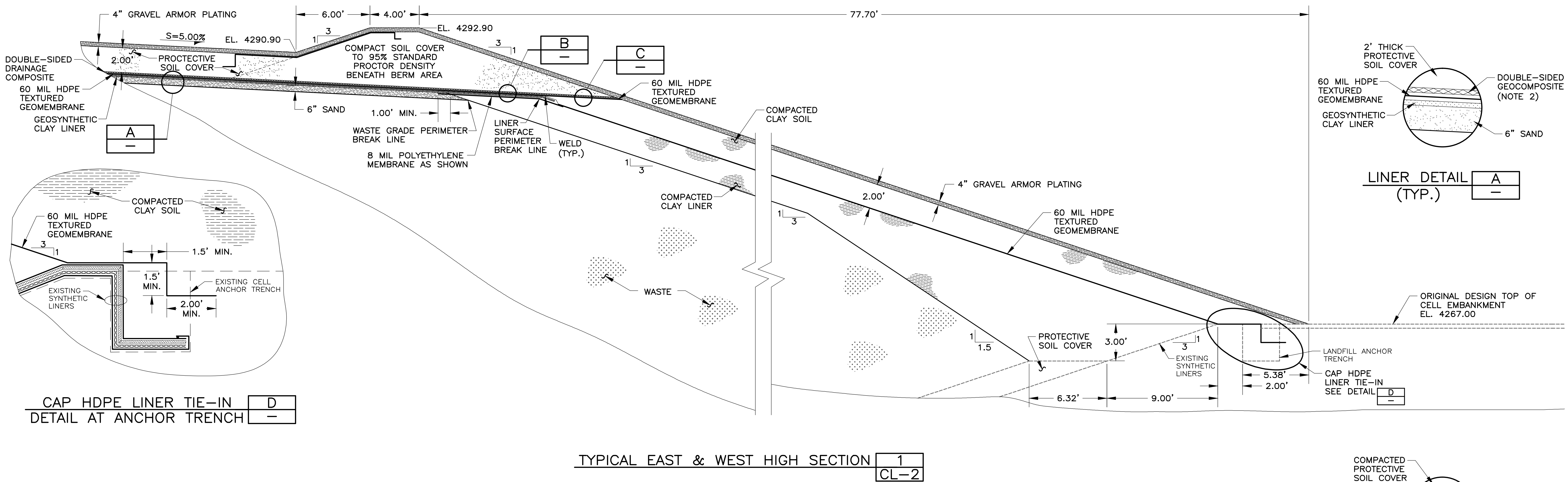
CleanHarbors ENVIRONMENTAL SERVICES, INC.

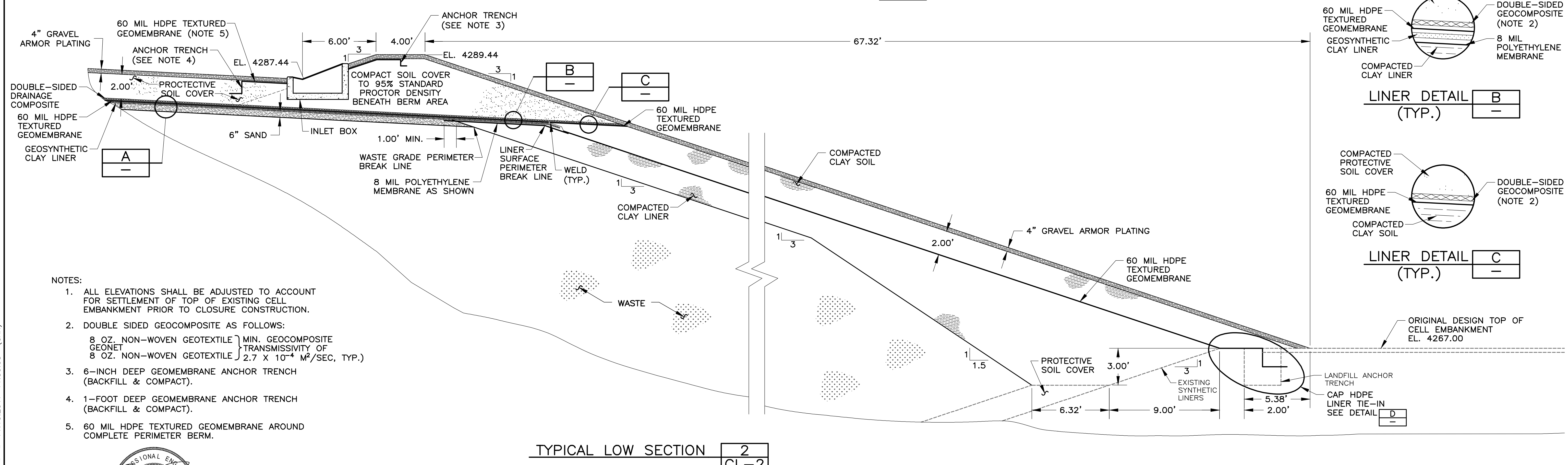
GRASSY MOUNTAIN FACILITY CELLS 8–13 CLOSURE
HIGH–LOW SECTIONS CELL 8

SHEET CL–7

064.85.100

10/07





NOTES:

1. ALL ELEVATIONS SHALL BE ADJUSTED TO ACCOUNT FOR SETTLEMENT OF TOP OF EXISTING CELL EMBANKMENT PRIOR TO CLOSURE CONSTRUCTION.
2. DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   8 OZ. NON–WOVEN GEOTEXTILE / GEONET / 8 OZ. NON–WOVEN GEOTEXTILE } MIN. GEOCOMPOSITE TRANSMISSIVITY OF 2.7×10^{-4} M^2/SEC, TYP.)
3. 6–INCH DEEP GEOMEMBRANE ANCHOR TRENCH (BACKFILL & COMPACT).
4. 1–FOOT DEEP GEOMEMBRANE ANCHOR TRENCH (BACKFILL & COMPACT).
5. 60 MIL HDPE TEXTURED GEOMEMBRANE AROUND COMPLETE PERIMETER BERM.

FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\CL–8 HIGH LOW SECTIONS 9–13.DWG
FILE DATE: 11.10.2017 11:50:08 (CAH)

10/07

HANSEN ALLEN & LUCE INC ENGINEERS

PROFESSIONAL ENGINEER — GORDON L. JONES — No. 5048470-2202 — 11/10/2017 — STATE OF UTAH

PROJECT ENGINEER

DESIGNED	KCS	3			
DRAFTED	CAH	2			
CHECKED	GLJ	1			
DATE	NOVEMBER 2017	NO.	DATE	REVISIONS	BY / APVD.

SCALE: NOT TO SCALE

CleanHarbors ENVIRONMENTAL SERVICES, INC.

GRASSY MOUNTAIN FACILITY CELLS 8–13 CLOSURE
HIGH–LOW SECTIONS CELLS 9–13

SHEET CL–8

064.85.100

APPENDIX C

SOIL STRENGTH PARAMETERS

Clean Harbors Landfill Cells 8 to 13
Project No. 1160276
Field & Lab Data
Water 4232 assumed

Soil	1	2	3	4	5	6
Soil	CL	CL.ML	CL/S	ML	SM/ML	SM

Boring	Depth (ft)	Elev (ft)	Eff. Stress (ksf)	N	Torvane (ksf)	Ct (ksf)	Pocket Pen (tsf)	Cp (ksf)	Cuc (ksf)	Material
L-1	2	4249.2	0.240	40						5
4251.2	5	4246.2	0.600	18						5
	10	4241.2	1.200	13			4.5	4.5		2
	15	4236.2	1.800				1.3	1.3		2
	20	4231.2	2.350	3	0.19	0.15	0.2	0.2		1
	25	4226.2	2.638		0.23	0.2	0.9	0.9		1
	30	4221.2	2.926	5	0.24	0.21	1.7	1.7		1
	35	4216.2	3.214		0.27	0.24	0.7	0.7		3
	40	4211.2	3.502	4	0.19	0.15	0.4	0.4		3
	45	4206.2	3.790		0.15	0.11	0.8	0.8		3
	50	4201.2	4.078	23						6
	55	4196.2	4.366		0.55	0.69	2	2		1
	60	4191.2	4.654	21	0.27	0.24	0.5	0.5		2
	65	4186.2	4.942		0.23	0.2	0.5	0.5		2
	70	4181.2	5.230	10	0.18	0.15	0.4	0.4		1
	75	4176.2	5.518		0.31	0.3	0.8	0.8		1
	80.5	4170.7	5.835	8	0.27	0.24				1
	85.5	4165.7	6.123		0.36	0.37				3
	90.5	4160.7	6.411	31	0.14	0.11				2
	95.5	4155.7	6.699		0.14	0.11				6
	100.5	4150.7	6.987	152						6
L-2	2	4240.1	0.240	25	0.3	0.28				2
4242.1	5	4237.1	0.600	40	0.34	0.34				1
	10	4232.1	1.200		0.27	0.24	0.8	0.8		1
	20.5	4221.6	1.811	42						6
	30.5	4211.6	2.387				0.5	0.5		2
	40.5	4201.6	2.963	20	0.45	0.52	4.5	4.5		2
	50.5	4191.6	3.539		0.34	0.34	1.9	1.9		1
	60.5	4181.6	4.115	6	0.13	0.1	0.1	0.1		3
L-3	2	4237.1	0.240	66	0.35	0.35	4.5	4.5		1
4239.1	5	4234.1	0.600	7	0.36	0.37	1.7	1.7		1
	10	4229.1	1.019		0.27	0.24	0.7	0.7		1
	15	4224.1	1.307	4						3
	20	4219.1	1.595		0.18	0.15	0.3	0.3		3
	25	4214.1	1.883	2			0.3	0.3	0.188	3
	30	4209.1	2.171		0.33	0.33	1.6	1.6		1
	35	4204.1	2.459	11	0.3	0.28	0.9	0.9		1
	40	4199.1	2.747							4
	45	4194.1	3.035	12						2
	50	4189.1	3.323		0.47	0.55	1.7	1.7		1
	55	4184.1	3.611	11	0.43	0.48	2.2	2.2		3
	60	4179.1	3.899		0.46	0.53	1	1		1

Clean Harbors Landfill Cells 8 to 13
Project No. 1160276
Field & Lab Data
Water 4232 assumed

Soil	1	2	3	4	5	6
Soil	CL	CL.ML	CL/S	ML	SM/ML	SM

Boring	Depth (ft)	Elev (ft)	Eff. Stress (ksf)	N	Torvane (ksf)	Ct (ksf)	Pocket Pen (tsf)	Cp (ksf)	Cuc (ksf)	Material
	65	4174.1	4.187	11	0.42	0.46	1	1		3
	70	4169.1	4.475							3
	75	4164.1	4.763	38						3
	80.5	4158.6	5.080		0.41	0.44	2	2		3
	85.5	4153.6	5.368	12			1	1	0.445	1
	90.5	4148.6	5.656				1	1		1
	95.5	4143.6	5.944	9	0.2	0.16	1.7	1.7		2
	100.5	4138.6	6.232		0.45	0.52	2.3	2.3		1
L-4	2	4244.4	0.240	10	0.6	0.78				2
4246.4	5	4241.4	0.600	11						2
	10	4236.4	1.200	8						2
	15.5	4230.9	1.791							2
	20.5	4225.9	2.079	2	0.19	0.15	0.5	0.5		1
	23	4223.4	2.223		0.21	0.17	0.8	0.8		1
	30.5	4215.9	2.655	5	0.08	0.05	0.1	0.1		2
	40.5	4205.9	3.231				0.1	0.1		6
	50.5	4195.9	3.807	13			0.7	0.7	0.575	1
	60.5	4185.9	4.383		0.13	0.1				2
L-6	2	4234.2	0.240	9	0.2	0.16	1	1		1
4236.2	5	4231.2	0.550		0.1	0.07	0.3	0.3		1
	10	4226.2	0.838	2	0.13	0.1	0.2	0.2		3
	20.5	4215.7	1.443		0.22	0.18	0.5	0.5		3
	30.5	4205.7	2.019	12						2
	40.5	4195.7	2.595		0.19	0.15	0.3	0.3		1
	50.5	4185.7	3.171	7			1	1		1
	60.5	4175.7	3.747		0.26	0.23	0.7	0.7		3
L-8	2	4237.9	0.240	58						1
4239.9	5	4234.9	0.600	11	0.16	0.12				1
	10	4229.9	1.069		0.23	0.2				1
	15	4224.9	1.357	3	0.26	0.23				1
	25	4214.9	1.933		0.14	0.1				3
	35	4204.9	2.509	16			4.5	4.5		3
	45	4194.9	3.085							5
	55	4184.9	3.661	5	0.21	0.17	1.2	1.2		1
	60	4179.9	3.949		0.31	0.3	1.1	1.1		1
L-10	2	4248.3	0.240	12			4.5	4.5		5
4250.3	5	4245.3	0.600	12						1
	10	4240.3	1.200	12	0.24	0.21				1
	15.5	4234.8	1.860	8	0.2	0.16				1
	20.5	4229.8	2.323		0.16	0.12	0.1	0.1		1

Clean Harbors Landfill Cells 8 to 13	Soil	1	2	3	4	5	6
Project No. 1160276	Soil	CL	CL.ML	CL/S	ML	SM/ML	SM

Field & Lab Data
Water 4232 assumed

Boring	Depth (ft)	Elev (ft)	Eff. Stress (ksf)	N	Torvane (ksf)	Ct (ksf)	Pocket Pen (tsf)	Cp (ksf)	Cuc (ksf)	Material
	25.5	4224.8	2.611		0.16	0.12	0.4	0.4		1
	30.5	4219.8	2.899	2	0.24	0.21				3
	35.5	4214.8	3.187		0.22	0.18	0.3	0.3		3
	40.5	4209.8	3.475	5			0.5	0.5	0.410	3
	45.5	4204.8	3.763				0.2	0.2		3
	50.5	4199.8	4.051	90						6
	55.5	4194.8	4.339		0.33	0.33	1	1		1
	60.5	4189.8	4.627	2			0.6	0.6	0.450	1
L-12	2	4239.8	0.240	52	0.5	0.6	4.5	4.5		1
4241.8	5	4236.8	0.600	23			2.2	2.2		1
	10	4231.8	1.188		0.35	0.35	1.8	1.8		1
	20.5	4221.3	1.792	3	0.1	0.07	0.1	0.1		3
	30.5	4211.3	2.368		0.11	0.08	0.1	0.1		2
	40.5	4201.3	2.944	9	0.25	0.22	1.8	1.8		2
	50.5	4191.3	3.520							2
	60.5	4181.3	4.096	3			0.3	0.3	0.475	1
L-14	2	4238.6	0.240	50	0.55	0.69				1
4240.6	5	4235.6	0.600	19	0.38	0.4				1
	10	4230.6	1.113		0.22	0.18	1	1		1
	15	4225.6	1.401	2	0.28	0.26	0.8	0.8		1
	20	4220.6	1.689	34						6
	25	4215.6	1.977		0.076	0.05	0.1	0.1		3
	30	4210.6	2.265	4	0.14	0.11	0.5	0.5		3
	35	4205.6	2.553		0.036	0.02	0.1	0.1		3
	40	4200.6	2.841	6	0.11	0.08	1.7	1.7		3
	45	4195.6	3.129				0.8	0.8		4
	50	4190.6	3.417	8	0.52	0.63	0.9	0.9		1
	55	4185.6	3.705				0.9	0.9		1
	60	4180.6	3.993	7			0.8	0.8	0.510	1
	65	4175.6	4.281		0.45	0.52	1.3	1.3		1
	70	4170.6	4.569	8	0.32	0.31	1	1		3
	75	4165.6	4.857				1	1		6
	80.5	4160.1	5.173	45						6
	85.5	4155.1	5.461	10	0.43	0.48	1.5	1.5		1
	90.5	4150.1	5.749		0.45	0.52	1.5	1.5		3
	95.5	4145.1	6.037	15	0.56	0.7	1.8	1.8		1
	100.5	4140.1	6.325		0.14	0.11	2	2		1
L-15	2	4237.8	0.240	48	0.74	1.03	4.5	4.5		1
4239.8	5	4234.8	0.600	12	0.36	0.37	4.5	4.5		1
	10	4229.8	1.063		0.23	0.2	0.8	0.8		1
	20	4219.8	1.639	85						6

4/26

Clean Harbors Landfill Cells 8 to 13
Project No. 1160276
Field & Lab Data
Water 4232 assumed

Soil	1	2	3	4	5	6
Soil	CL	CL.ML	CL/S	ML	SM/ML	SM

Boring	Depth (ft)	Elev (ft)	Eff. Stress (ksf)	N	Torvane (ksf)	Ct (ksf)	Pocket Pen (tsf)	Cp (ksf)	Cuc (ksf)	Material
	30	4209.8	2.215							1
	32	4207.8	2.330	6	0.24	0.21	0.6	0.6		3
	40	4199.8	2.791		0.28	0.26	1.1	1.1		2
	50	4189.8	3.367	9	0.44	0.5	1.2	1.2		1
	60	4179.8	3.943		0.26	0.23	0.6	0.6		3
L-17	2	4238.1	0.240	44	0.42	0.46	4.5	4.5		1
4240.1	5	4235.1	0.600	13	0.27	0.24	4.5	4.5		1
	8	4232.1	0.960		0.35	0.35	1.1	1.1		1
	15.5	4224.6	1.398	12	0.15	0.11	0.8	0.8		2
	25.5	4214.6	1.974		0.22	0.18	0.5	0.5		1
	35.5	4204.6	2.550	14			2.8	2.8	1.185	2
	45.5	4194.6	3.126		0.4	0.43	1.2	1.2		2
	55.5	4184.6	3.702	7			0.4	0.4	0.373	3
	60.5	4179.6	3.990		0.2	0.16	0.3	0.3		3
L-19	4	4236.4	0.480	55	0.56	0.7	4.5	4.5		1
4240.4	7	4233.4	0.840	3	0.32	0.31	0.8	0.8		1
	10	4230.4	1.100		0.17	0.13	0.5	0.5		1
	20	4220.4	1.676	101						6
	30	4210.4	2.252		0.07	0.04	0.1	0.1		3
	40	4200.4	2.828	4			0.1	0.1	0.238	2
	45	4195.4	3.116	3			0.5	0.5	0.210	2
	50	4190.4	3.404		0.3	0.28				1
	60	4180.4	3.980		0.41	0.44	1.2	1.2		1
L-21	2	4243.1	0.240	7			4	4		2
4245.1	5	4240.1	0.600	6			2.2	2.2		3
	10	4235.1	1.200	6	0.16	0.12	1.9	1.9		2
	12	4233.1	1.440		0.1	0.07				1
	14	4231.1	1.624							1
	20	4225.1	1.969	1			0.3	0.3	0.345	1
	30	4215.1	2.545		0.11	0.08	0.1	0.1		1
	40	4205.1	3.121	9	0.21	0.17	0.5	0.5		3
	50	4195.1	3.697							2
	60	4185.1	4.273	18						2
L-23	2	4234.8	0.240	9	0.38	0.4	1.7	1.7		1
4236.8	5	4231.8	0.588		0.42	0.47	1.3	1.3		1
	10	4226.8	0.876	1	0.28	0.26	0.6	0.6		1
	20	4216.8	1.452		0.03	0.02	0.1	0.1		3
	30	4206.8	2.028	10						3
	40	4196.8	2.604							4
	50	4186.8	3.180	7			0.6	0.6	0.628	1

Clean Harbors Landfill Cells 8 to 13
Project No. 1160276
Field & Lab Data
Water 4232 assumed

Soil	1	2	3	4	5	6
Soil	CL	CL.ML	CL/S	ML	SM/ML	SM

Boring	Depth (ft)	Elev (ft)	Eff. Stress (ksf)	N	Torvane (ksf)	Ct (ksf)	Pocket Pen (tsf)	Cp (ksf)	Cuc (ksf)	Material
	60	4176.8	3.756		0.27	0.25	0.6	0.6		3
L-24	2	4242.2	0.240	20	0.41	0.44	4.5	4.5		1
4244.2	5	4239.2	0.600	12	0.37	0.38	4.5	4.5		1
	10	4234.2	1.200	8			4.5	4.5		1
	15	4229.2	1.625		0.28	0.26	0.6	0.6		1
	20	4224.2	1.913	1			0.6	0.6	0.388	1
	25	4219.2	2.201		0.15	0.11	0.1	0.1		1
	30	4214.2	2.489	2	0.2	0.16	0.4	0.4		1
	35	4209.2	2.777				0.6	0.6		1
	40	4204.2	3.065	11						3
	45	4199.2	3.353				0.8	0.8		3
	50	4194.2	3.641	8	0.5	0.6	0.7	0.7		2
	55	4189.2	3.929		0.52	0.63	1.5	1.5		3
	60	4184.2	4.217	12	0.39	0.42	0.3	0.3		2
	65	4179.2	4.505		0.36	0.37	0.8	0.8		1
	70	4174.2	4.793	10	0.4	0.43	0.5	0.5		1
	75	4169.2	5.081							6
	80.5	4163.7	5.398	12						3
	85.5	4158.7	5.686		0.24	0.21	4.5	4.5		3
	90.5	4153.7	5.974	44						3
	95.5	4148.7	6.262	14	0.47	0.55	1	1		1
	100.5	4143.7	6.550	43	0.68	0.92	4.5	4.5		2
L-26	2	4237.8	0.240	33	0.55	0.69	4.5	4.5		1
4239.8	5	4234.8	0.600	8	0.26	0.23	2.5	2.5		1
	10	4229.8	1.063		0.275	0.19	1	1		1
	15.5	4224.3	1.380	1			0.1	0.1	0.183	1
	20.5	4219.3	1.668							3
	25.5	4214.3	1.956	3			0.5	0.5		3
	30.5	4209.3	2.244							3
	35.5	4204.3	2.532		0.6	0.77				3
	40.5	4199.3	2.820	16						3
	45.5	4194.3	3.108		0.15	0.11	0.3	0.3		3
	50.5	4189.3	3.396	3						3
	55.5	4184.3	3.684				1	1		1
	60.5	4179.3	3.972	4			0.4	0.4	0.288	1
L-27	2	4235.5	0.240	8	0.5	0.6	3.3	3.3		1
4237.5	5	4232.5	0.600		0.42	0.46	2.2	2.2		1
	10	4227.5	0.919	1	0.18	0.15	0.2	0.2		1
	15	4222.5	1.207		0.5	0.6				3
	20	4217.5	1.495	1			0.6	0.6	0.460	3
	25	4212.5	1.783		0.31	0.3	0.6	0.6		3

Clean Harbors Landfill Cells 8 to 13
Project No. 1160276
Field & Lab Data
Water 4232 assumed

Soil	1	2	3	4	5	6
Soil	CL	CL.ML	CL/S	ML	SM/ML	SM

Boring	Depth (ft)	Elev (ft)	Eff. Stress (ksf)	N	Torvane (ksf)	Ct (ksf)	Pocket Pen (tsf)	Cp (ksf)	Cuc (ksf)	Material
	30	4207.5	2.071	8						3
	35	4202.5	2.359		0.29	0.27	1.5	1.5		1
	40	4197.5	2.647	5					0.693	2
	45	4192.5	2.935		0.37	0.38	0.9	0.9		1
	50	4187.5	3.223	15	0.5	0.6	1.3	1.3		1
	55	4182.5	3.511				0.6	0.6		1
	60	4177.5	3.799	3	0.24	0.21	0.8	0.8		1
L-28	2	4237.7	0.240	16	0.37	0.38	4.5	4.5		1
4239.7	5	4234.7	0.600		0.3	0.28	4	4		1
	10	4229.7	1.056	1	0.17	0.13	0.5	0.5		1
	15	4224.7	1.344		0.3	0.28	1	1		1
	20	4219.7	1.632	6	0.2	0.16	0.3	0.3		3
	25	4214.7	1.920		0.05	0.03	0.1	0.1		3
	30	4209.7	2.208	4			0.1	0.1		2
	35	4204.7	2.496		0.39	0.42	0.6	0.6		3
	40	4199.7	2.784	4			0.6	0.6		2
	45	4194.7	3.072				0.8	0.8		2
	50	4189.7	3.360	9						2
	55	4184.7	3.648		0.39	0.42	0.8	0.8		1
	60	4179.7	3.936	7	0.22	0.18	0.6	0.6		1
L-29	2	4234.8	0.240	7	0.37	0.38	4.5	4.5		1
4236.8	5	4231.8	0.588		0.32	0.31	0.8	0.8		1
	10	4226.8	0.876	2	0.17	0.13	0.3	0.3		1
	15.5	4221.3	1.192		0.3	0.28	0.7	0.7		3
	20.5	4216.3	1.480	2			0.5	0.5	0.248	3
	25.5	4211.3	1.768		0.11	0.08	0.2	0.2		2
	30.5	4206.3	2.056	12						6
	35.5	4201.3	2.344				0.2	0.2		2
	40.5	4196.3	2.632	6	0.2	0.16	0.7	0.7		2
	45.5	4191.3	2.920		0.37	0.39	0.8	0.8		1
	50.5	4186.3	3.208	7	0.32	0.31	0.8	0.8		1
	55.5	4181.3	3.496		0.58	0.73	1.2	1.2		1
	60.5	4176.3	3.784	4	0.21	0.17	1.2	1.2		3
L-30	2	4235.6	0.240	24	0.4	0.43	4.5	4.5		1
4237.6	5	4232.6	0.600	5	0.27	0.24	4.5	4.5		1
	10	4227.6	0.925		0.24	0.21	0.4	0.4		1
	15	4222.6	1.213	5	0.14	0.11	0.1	0.1		3
	20	4217.6	1.501		0.17	0.13	0.1	0.1		1
	25	4212.6	1.789	2	0.14	0.11	0.5	0.5		1
	30	4207.6	2.077		0.13	0.09	0.1	0.1		3
	35	4202.6	2.365	5			0.7	0.7	0.315	3

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Clean Harbors Landfill Cells 8 to 13
Project No. 1160276
Field & Lab Data
Water 4232 assumed

Soil	1	2	3	4	5	6
Soil	CL	CL.ML	CL/S	ML	SM/ML	SM

Boring	Depth (ft)	Elev (ft)	Eff. Stress (ksf)	N	Torvane (ksf)	Ct (ksf)	Pocket Pen (tsf)	Cp (ksf)	Cuc (ksf)	Material
	40	4197.6	2.653							2
	45	4192.6	2.941	14	0.74	1.03	2.6	2.6		2
	50	4187.6	3.229		0.3	0.28	3.5	3.5		1
	55	4182.6	3.517	8						3
	60	4177.6	3.805		0.33	0.33	0.7	0.7		1
	65	4172.6	4.093	7	0.2	0.16	0.8	0.8		1
	70	4167.6	4.381		0.24	0.21	0.7	0.7		3
	75	4162.6	4.669	49						6
	80.5	4157.1	4.986		0.32	0.31	1.2	1.2		3
	85.5	4152.1	5.274	20	0.66	0.88	1	1		3
	90.5	4147.1	5.562		0.34	0.34	1.5	1.5		1
	95.5	4142.1	5.850	8	0.42	0.46	1	1		1
	100.5	4137.1	6.138				4.5	4.5		2
B-1A	0	4244.8	0.000	13			4.5	4.5		1
4244.8	2	4242.8	0.240	7			3.7	3.7		1
	4	4240.8	0.480	4			2.4	2.4		1
	9	4235.8	1.080	1			1.5	1.5	0.158	1
	14	4230.8	1.605	0			0.5	0.5	0.168	1
	19	4225.8	1.893	0			0.6	0.6		1
	24	4220.8	2.181	1			0.6	0.6		1
	29	4215.8	2.469	1			0.7	0.7		1
	34	4210.8	2.757	1			0.6	0.6		1
	39	4205.8	3.045	1			0.3	0.3		1
B-2A	0	4242.5	0.000	9			4.5	4.5		1
4242.5	2	4240.5	0.240	5			2.1	2.1		1
	4	4238.5	0.480	5						1
	9	4233.5	1.080	2			1.1	1.1		1
	14	4228.5	1.462	1			0.3	0.3		1
	19	4223.5	1.750	1			0.2	0.2		1
	24	4218.5	2.038	0			0.7	0.7		1
	29	4213.5	2.326	1			0.3	0.3		1
	34	4208.5	2.614	1			0.3	0.3		3
	39	4203.5	2.902	25						6
B-3A	0	4243.2	0.000	11			4.5	4.5		1
4243.2	2	4241.2	0.240	13			4.5	4.5		1
	4	4239.2	0.480	5						1
	9	4234.2	1.080	1			0.6	0.6		1
	14	4229.2	1.505	1			0.6	0.6		1
	19	4224.2	1.793	1			0.8	0.8		1
	24	4219.2	2.081							3
	29	4214.2	2.369	0			0.3	0.3		1

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Clean Harbors Landfill Cells 8 to 13
Project No. 1160276
Field & Lab Data
Water 4232 assumed

Soil	1	2	3	4	5	6
Soil	CL	CL.ML	CL/S	ML	SM/ML	SM

Boring	Depth (ft)	Elev (ft)	Eff. Stress (ksf)	N	Torvane (ksf)	Ct (ksf)	Pocket Pen (tsf)	Cp (ksf)	Cuc (ksf)	Material
	34	4209.2	2.657	0			0.2	0.2		3
	39	4204.2	2.945	0			0.6	0.6		3
	44	4199.2	3.233	0						1
	49	4194.2	3.521	1			0.9	0.9		1
	54	4189.2	3.809	2			1.2	1.2		1
	59	4184.2	4.097	0			0.7	0.7		1
	64	4179.2	4.385	0			0.7	0.7		1
	69	4174.2	4.673	7			0.9	0.9		3
	74	4169.2	4.961	26						6
	79	4164.2	5.249	8			1.3	1.3		3
	84	4159.2	5.537	32			3	3		6
	89	4154.2	5.825	22			3.6	3.6		1
	94	4149.2	6.113	1			1.1	1.1		1
	99	4144.2	6.401	12			4.5	4.5		1
B-1B	0	4238.2	0.000	28			4.5	4.5		1
4238.2	2	4236.2	0.240	17			3	3		1
	4	4234.2	0.480	6			3.3	3.3		1
	9	4229.2	0.905	0			0.9	0.9		1
	14	4224.2	1.193	0			0.3	0.3		1
	19	4219.2	1.481				0.5	0.5		1
	24	4214.2	1.769	1			0.5	0.5		1
	29	4209.2	2.057	0			0.6	0.6		1
	34	4204.2	2.345	5			1.4	1.4		3
	39	4199.2	2.633	0			0.7	0.7		1
	44	4194.2	2.921	0			0.8	0.8		1
	49	4189.2	3.209	0			1.2	1.2		1
	54	4184.2	3.497	0			0.9	0.9		1
	59	4179.2	3.785	1			0.7	0.7		1
	64	4174.2	4.073	5			0.7	0.7		1
	69	4169.2	4.361	2			0.8	0.8		1
	74	4164.2	4.649	14			2.7	2.7		1
	79	4159.2	4.937	25						6
	84	4154.2	5.225	0			1.7	1.7		1
	89	4149.2	5.513	5			2.2	2.2		1
	94	4144.2	5.801	3			1.2	1.2		1
	99	4139.2	6.089	2			0.9	0.9		1
B-2B	0	4237.5	0.000	22			4.5	4.5		1
4237.5	2	4235.5	0.240	7			4.5	4.5		1
	4	4233.5	0.480	1			0.8	0.8		1
	9	4228.5	0.862	0			0.7	0.7		1
	14	4223.5	1.150				0.7	0.7		1
	19	4218.5	1.438	5			0.4	0.4		1

Clean Harbors Landfill Cells 8 to 13
Project No. 1160276
Field & Lab Data
Water 4232 assumed

Soil	1	2	3	4	5	6
Soil	CL	CL.ML	CL/S	ML	SM/ML	SM

Boring	Depth (ft)	Elev (ft)	Eff. Stress (ksf)	N	Torvane (ksf)	Ct (ksf)	Pocket Pen (tsf)	Cp (ksf)	Cuc (ksf)	Material
	24	4213.5	1.726	0			0.2	0.2		2
	29	4208.5	2.014	1			0.4	0.4		2
	34	4203.5	2.302	1			1.8	1.8		2
	39	4198.5	2.590	0			0.8	0.8		2
	44	4193.5	2.878	2			1.6	1.6		1
	49	4188.5	3.166	0			1.3	1.3		1
	54	4183.5	3.454	5			3.5	3.5		3
	59	4178.5	3.742	7			0.6	0.6		3
	64	4173.5	4.030	4			0.8	0.8		3
	69	4168.5	4.318	2						3
	74	4163.5	4.606	10						6
	79	4158.5	4.894	16			1.6	1.6		1
	84	4153.5	5.182	0			1.7	1.7		1
	89	4148.5	5.470	0			2.3	2.3		1
	94	4143.5	5.758	1			1.1	1.1		1
	99	4138.5	6.046	5			2.8	2.8		1
B-3B	0	4239.9	0.000	13			4.5	4.5		1
4239.9	2	4237.9	0.240	13			4.5	4.5		1
	4	4235.9	0.480	6			1.5	1.5		1
	9	4230.9	1.011				0.8	0.8		1
	11	4228.9	1.127				0.7	0.7		1
	19	4220.9	1.587	1						3
	24	4215.9	1.875	1			0.4	0.4		3
	29	4210.9	2.163	0			0.3	0.3		3
	34	4205.9	2.451	1			0.3	0.3		1
	39	4200.9	2.739	10			1.8	1.8		2
	44	4195.9	3.027	4			2.8	2.8		2
	49	4190.9	3.315	4			2	2		2
	54	4185.9	3.603	1			1.1	1.1		1
	59	4180.9	3.891	2			0.7	0.7		1
	64	4175.9	4.179	1			0.8	0.8		1
	69	4170.9	4.467	15			0.8	0.8		1
	74	4165.9	4.755	6			0.7	0.7		1
	79	4160.9	5.043	25			2.5	2.5		1
	84	4155.9	5.331	28						6
	89	4150.9	5.619	31						6
	94	4145.9	5.907	7			0.9	0.9		1
	99	4140.9	6.195	7			1.7	1.7		1
B-4B	0	4237.3	0.000	20			4.5	4.5		1
4237.3	2	4235.3	0.240	5			1.8	1.8		1
	4	4233.3	0.480				1.1	1.1		1
	9	4228.3	0.849	0			0.6	0.6		1

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Clean Harbors Landfill Cells 8 to 13
Project No. 1160276
Field & Lab Data
Water 4232 assumed

Soil	1	2	3	4	5	6
Soil	CL	CL.ML	CL/S	ML	SM/ML	SM

Boring	Depth (ft)	Elev (ft)	Eff. Stress (ksf)	N	Torvane (ksf)	Ct (ksf)	Pocket Pen (tsf)	Cp (ksf)	Cuc (ksf)	Material
	14	4223.3	1.137	1			0.2	0.2		1
	19	4218.3	1.425	3			0.3	0.3		1
	24	4213.3	1.713	0			0.3	0.3		1
	29	4208.3	2.001	0			0.3	0.3		1
	34	4203.3	2.289	0			0.8	0.8		3
	39	4198.3	2.577	7						3
	44	4193.3	2.865	5			2.2	2.2		1
	49	4188.3	3.153	0			0.8	0.8		1
	54	4183.3	3.441	11				0		6
	59	4178.3	3.729	10			0.4	0.4		6
	64	4173.3	4.017	4						6
	69	4168.3	4.305	4			1.1	1.1		3
	74	4163.3	4.593	9			1.2	1.2		3
	79	4158.3	4.881	12			1.7	1.7		3
	84	4153.3	5.169	14						6
	89	4148.3	5.457	4			2.6	2.6		1
	94	4143.3	5.745	3			1.3	1.3		1
	99	4138.3	6.033	4			2.8	2.8		1

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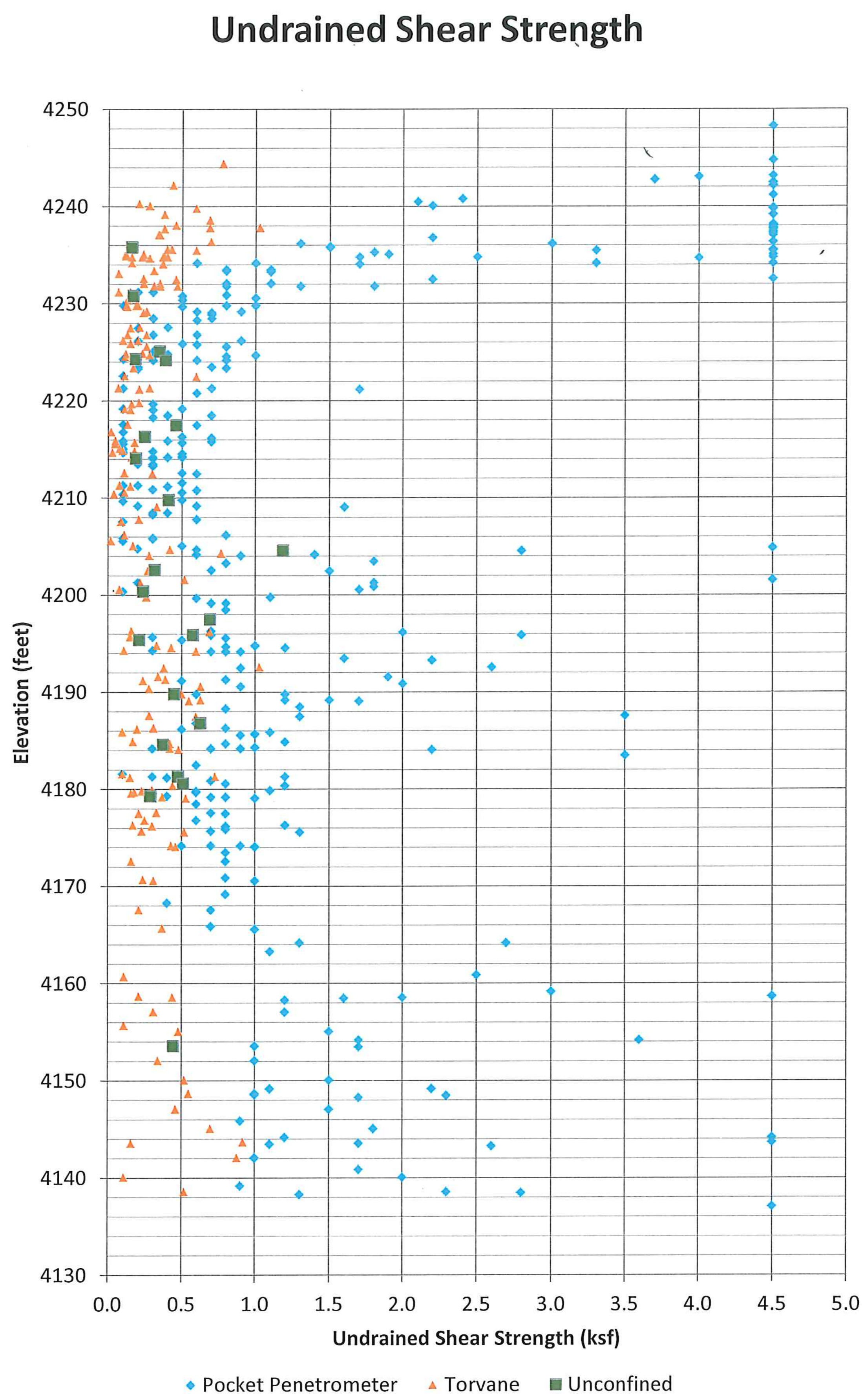
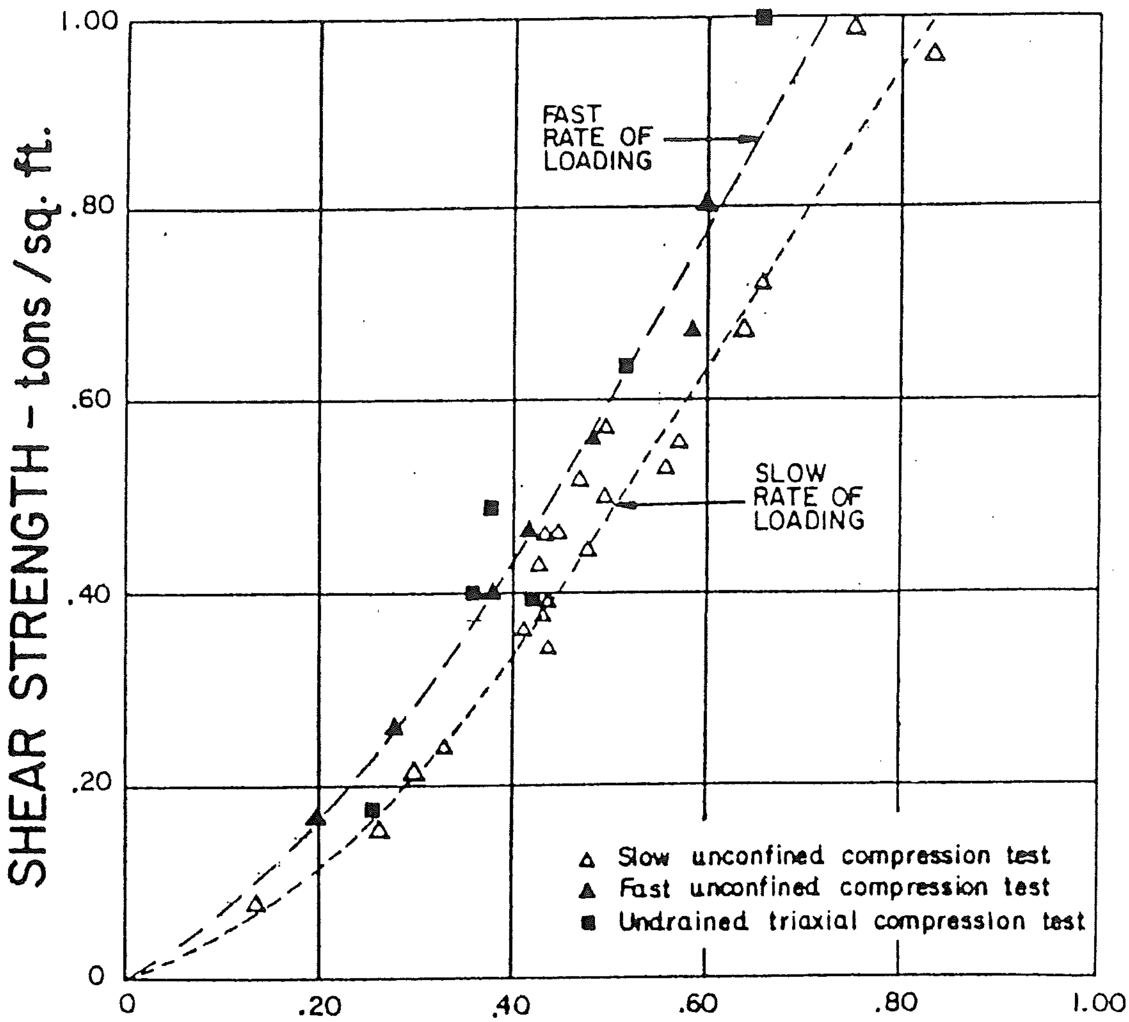


Undrained Shear Strength
4250
4240
4230
4220
4210
4200
4190
4180
4170
4160
4150
4140
4130
Elevation (feet)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
Undrained Shear Strength (ksf)
Pocket Penetrometer
Torvane
Unconfined

STRENGTH CORRELATION



TORVANE SHEAR STRENGTH - tons / sq. ft.
(RATE OF STRESS INCREASE = 0.1 Tsf/sec)

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JRM
SUBJECT Correlation of strength of clay with CPT data SHEET 13 OF 26

$q_c = C_u N_K + \sigma_0$ Robertson & Campanella

q_c = Tip resistance

C_u = undrained shear strength

N_K = cone factor 11-19 with 15 ave
for $P_I = 18 \rightarrow N_K = 18$

σ_0 = in-situ total stress

check correlation of N_K with UC test results

CL3 was CPT near NEC of site
water assumed at 4232 feet (~7' depth)

at 63 ft. $q_c = 11$ TSF or 22 ksf

$\sigma_0 = (130)(7) + (56)(120) = 7630$ psf

$C_u = \frac{q_c - \sigma_0}{N_K} = \frac{22 - 7.63}{18} = \underline{0.798 \text{ ksf}}$

at 25 ft $q_c = 5.4$ Tsf or 10.8 ksf

$\sigma_0 = (130)(7) + (18)(120) = 3070$ psf

$C_u = \frac{10.8 - 3.07}{18} = \underline{0.429 \text{ ksf}}$

at 84 ft $q_c = 13.4$ Tsf or 26.8 ksf

$\sigma_0 = (130)(7) + (77)(120) = 10.15$ ksf

$C_u = \frac{27.0 - 10.15}{18} = \underline{0.936 \text{ ksf}}$

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JRH
SUBJECT Correlation of Strength of clay with CPT data SHEET 14 OF 26

Check correlation of N_K with UC test results

Boring	Depth, ft	Correlated CPT #	Resulting N_K
L-3	25	CL-3	22 *
L-3	85.5	CL-3	25 *
L-4	50.5	CL-1	20.5
L-10	40.5	CL-7	16
L-10	60.5	CL-7	14
L-12	60	CL-13	16
L-14	60	CL-14	16
L-17	35.5	CL-9	16
L-17	55.5	CL-9	34 *
L-19	40	CL-14	34 *
L-19	45	CL-14	35 *
L-21	20	CL-24	20
L-23	50	CL-30	19
L-24	20	CL-24	18
L-26	15.5	CL-25	26 *
L-26	60.5	CL-26	18
L-27	20	CL-26	15.5
L-27	40	CL-26	11 *
L-29	20.5	CL-30	42 *
L-30	35	CL-30	25.5 *

average 22
non * test average 17

CPT data correlates well with lab UC results

Lowest q_c for upper sand is CL-26

$q_c = 32.4$ TSF at 6.55 m (21.5 ft)

$\sigma_0' = (130)(8) + (120-62.4)(13.5) = 1818$ psf

1 bar = 2088.6 psf

$\sigma_0' = \frac{1818}{2088.6} = 0.87$ bars $\qquad q_c = 31$ bars

from Fig 5.5 $\quad \phi = 36°$

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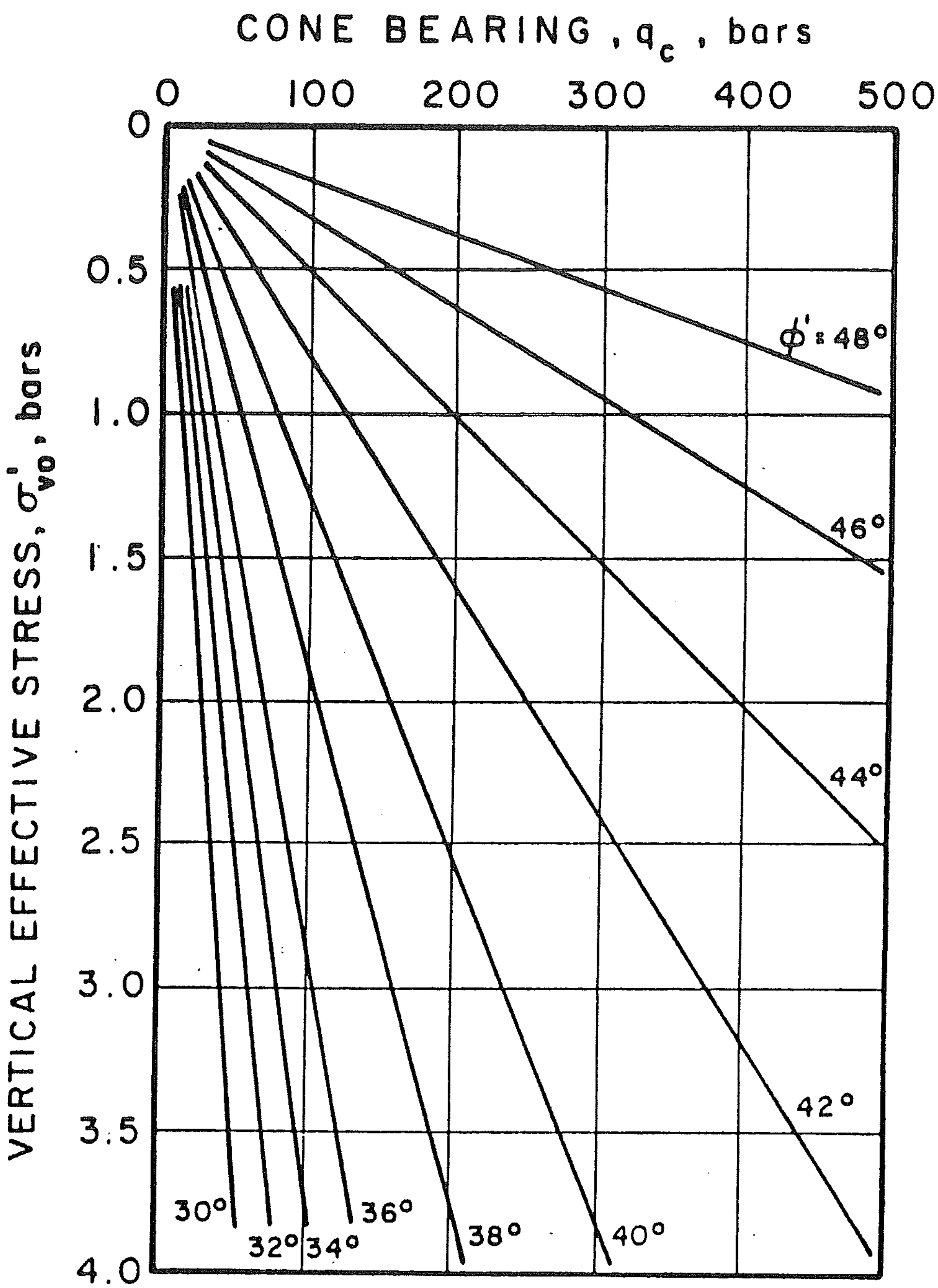

Fig. 5.5. Proposed Correlation between Cone Bearing and Peak Friction Angle for Uncemented, Quartz Sands (After Robertson and Campanella, 1983)

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JRM

SUBJECT Soil Strength Testing and Summary SHEET 17 OF 26

Additional testing

Triaxial shear - multistage

TH-21 @ 4' $\overline{CU}$ $\bar{\phi} = 34.9°$ $\bar{c} = 0.16$ Ksf
$\phi = 32.1°$ $c = 0.10$ Ksf
-200 = 77% wc = 17.6% LL = 28% PI = 13% N = 13/12

TH-15 @ 11' $\overline{CU}$ $\bar{\phi} = 33.5°$ $\bar{c} = 0.2$ Ksf
$\phi = 20.5°$ $c = 0.2$ Ksf
-200 = 99% wc = 55.7% LL = 47% PI = 23% N = 4/12

C6-7 @ 0' $\bar{\phi} = 42°$ $\bar{c} = 20$ psf
$\phi = 38°$ $c = 0$
-200 ≈ 86% wc = 14% N = 42/12

L-2 @ 30½' $\bar{\phi} = 26°$ $\bar{c} = 100$ psf
$\phi = 13°$ $c = 240$ psf
-200 = 100% wc = 65% LL = 66% PI = 40%

L-4 @ 28' $\bar{\phi} = 25°$ $\bar{c} = 460$ psf
$\phi = 12°$ $c = 610$ psf
-200 = 99% wc = 48% LL = 46% PI = 25%

L-6 @ 20½' $\bar{\phi} = 32°$ $\bar{c} = 230$ psf
$\phi = 17°$ $c = 150$ psf
-200 = 100% wc = 58% LL = 46% PI = 19%

L-8 @ 60' $\bar{\phi} = 22°$ $\bar{c} = 750$ psf
$\phi = 12°$ $c = 870$ psf
-200 = 100% wc = 59% LL = 63% PI = 36%

L-14 @ 45' $\bar{\phi} = 35°$ $\bar{c} = 110$ psf
$\phi = 20°$ $c = 120$ psf
-200 = 81% wc = 33% LL = 29% PI = 11%

L-17 @ 8' $\bar{\phi} = 43°$ $\bar{c} = 150$ psf
$\phi = 10°$ $c = 840$ psf
wc = 59%

L-17 @ 25' $\bar{\phi} = 41°$ $\bar{c} = 340$ psf
$\phi = 19°$ $c = 270$ psf
-200 = 89% wc = 52% LL = 49% PI = 25%

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JRM

SUBJECT Soil Strength Testing and Summary SHEET 18 OF 26

Additional testing (cont)

Triaxial shear

L-19 @ 50½' $\bar{\phi} = 33^\circ$ $\bar{c} = 410$ psf

$\phi = 22^\circ$ $c = 420$ psf

-200 = 100% wc = 31% LL = 45% PI = 25%

L-24 @ 35' $\bar{\phi} = 24^\circ$ $\bar{c} = 100$ psf

$\phi = 12^\circ$ $c = 270$ psf

-200 = 100% wc = 67% LL = 68% PI = 42%

Direct Shear

L-1 @ 50' $\phi_p = 34.3^\circ$ $c = 0$

L-10 @ 50½' $\phi_p = 31.3^\circ$ $c = 0$

L-14 @ 20' $\phi_p = 37.6^\circ$ $c = 0$

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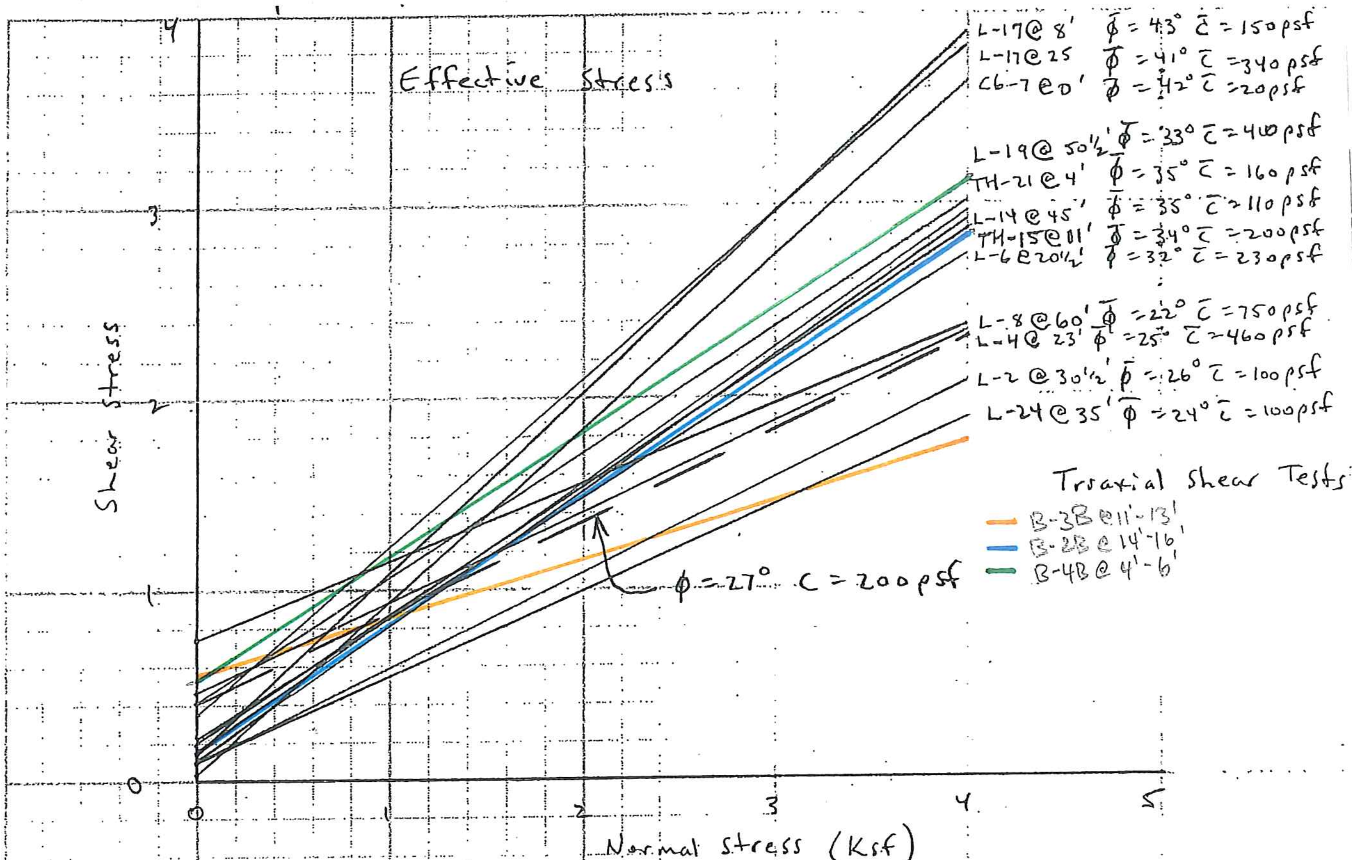
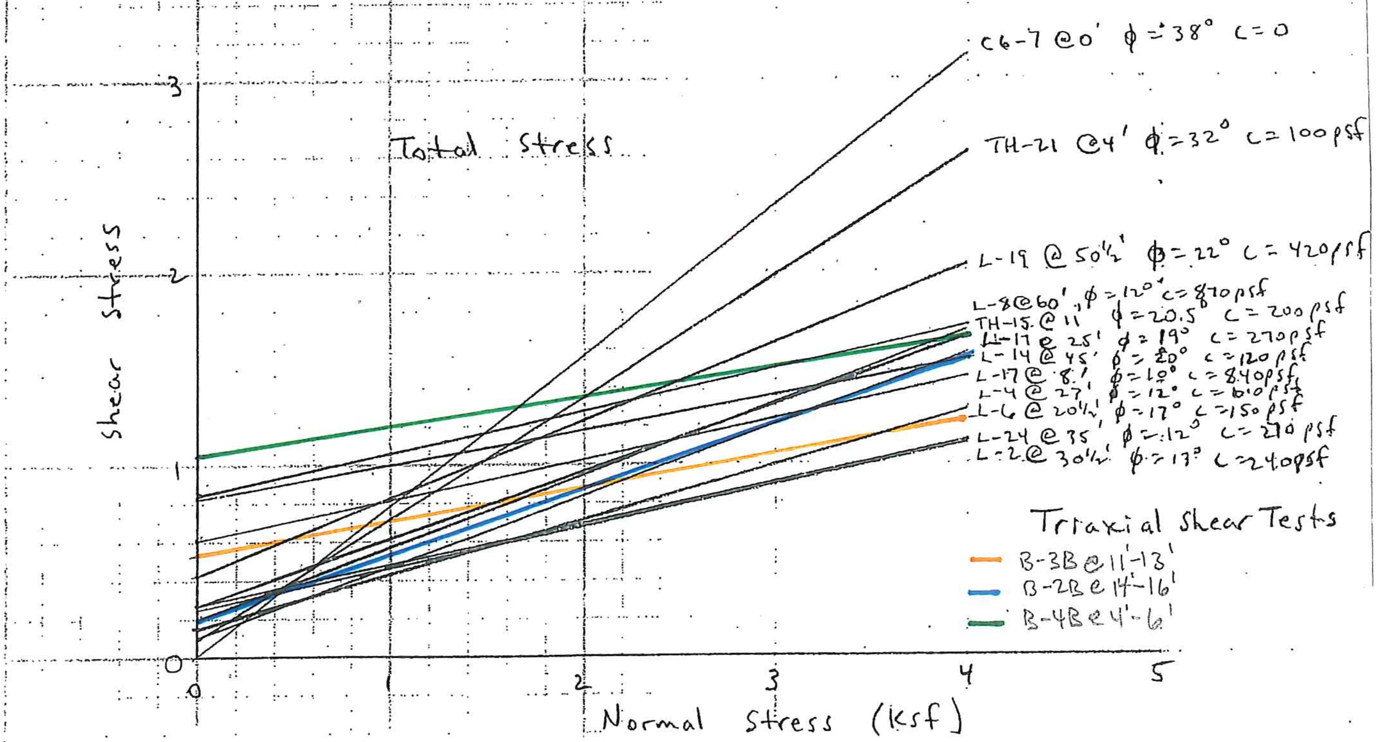
PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JRM

SUBJECT Soil Strength Testing Summary SHEET 19 OF 26





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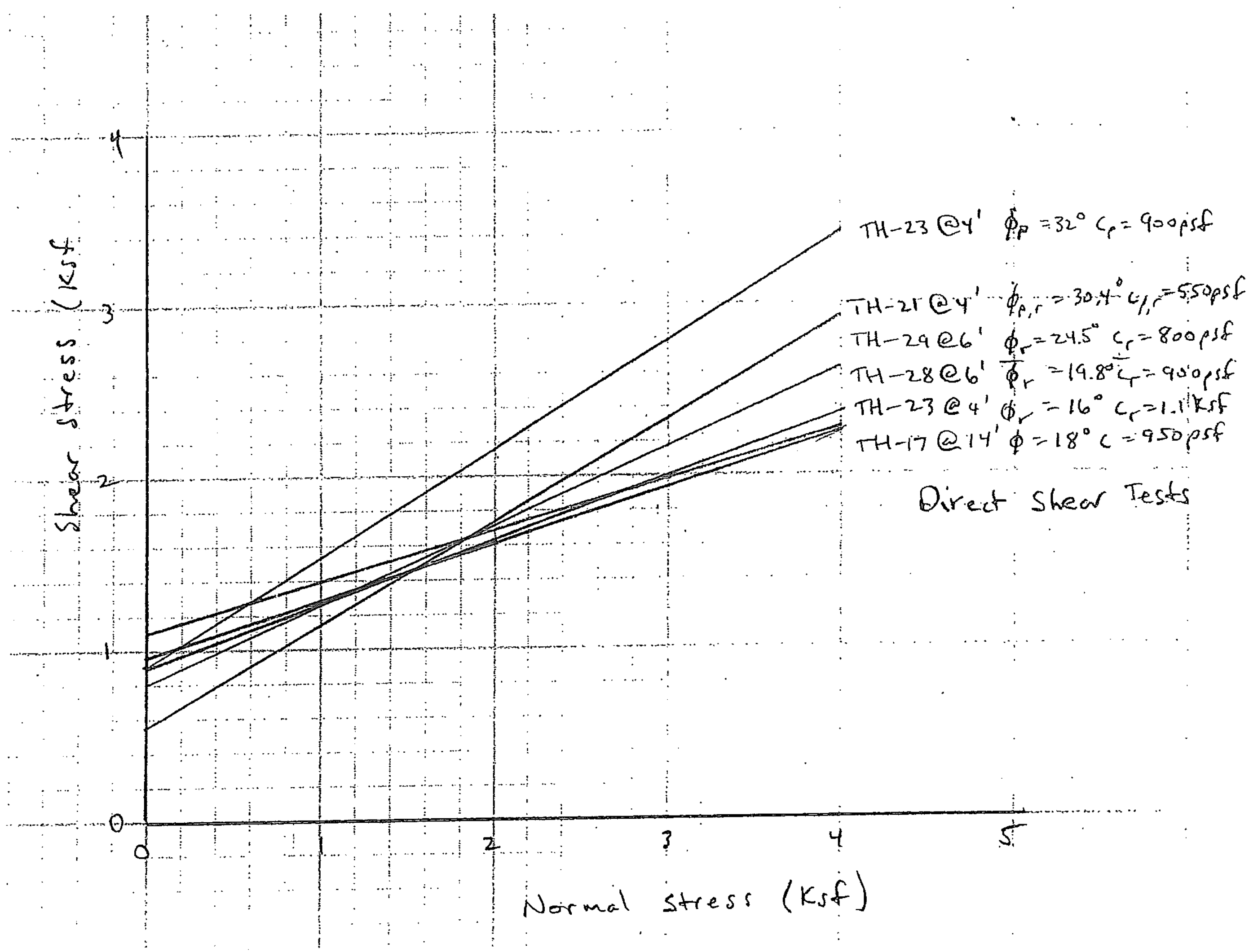
PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JTR

SUBJECT Soil Strength Testing and Summary SHEET 20 OF 26



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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JRM

SUBJECT Soil Strength Testing and Summary SHEET 21 OF 26

Undrained Conditions

A. Embankment Fill

Unconfined Compression
c = 435 to 7750 psf
ave = 2656 psf
Direct Shear - remolded
$\phi = 32°$ c = 1600 psf
Direct Shear undisturbed
$\sigma_N = 1.0$ Ksf $\tau = 1.1$ Ksf
$\sigma_N = 2.0$ Ksf $\tau = 1.9$ Ksf
} Cell 1

B. Upper Stiff Clay

Unconfined Compression

c = 4 to 7.75 Ksf ave = 5.6 Ksf	Cell 1
c = 1.195 to 2.37 Ksf ave = 1.78 Ksf	Cell 2
c = 0.585 to 4.475 Ksf ave = 2.73 Ksf	Cell 3
c = 0.84 to 8.425 Ksf ave = 3.967 Ksf	Cell X
c = 0.785 to 11.7 Ksf ave = 5.68 Ksf	Cell Y
c = 0.840 to 5.30 Ksf ave = 3.54 Ksf	Cell Z
c = 0.945 to 4.995 Ksf ave = 2.29 Ksf	Cell 4
c = 0.13 to 11.6 Ksf ave = 4.88 Ksf	Cell 5
c = 0.368 to 0.865 Ksf ave = 0.58 Ksf	Cell 6

Pocket Penetrometer
1.1 to > 4.5 Ksf — all cells
ave > 4.5 Ksf

Direct Shear - cu
$\phi = 32°$ c = 0.94 Ksf — Cell 3

Triaxial Shear - Multistage - $\overline{CU}$

$\phi = 32.1°$ c = 0.10 Ksf	Cell 3
$\phi = 38°$ c = 0	Cell 6
$\phi = 22°$ c = 0.75 Ksf	LTU

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JRM

SUBJECT Soil Strength Testing and Summary SHEET 22 OF 26

C. Soft Clay

Unconfined Compression

c = 145 psf	Cell 1
c = 220 to 850 psf	Cell 2
ave = 550 psf	
c = 225 to 2215 psf	Cell 3
ave = 1040 psf	
c = 235 to 1040 psf	Cell X
ave = 535 psf	
c = 235 psf	Cell Y
c = 235 psf to 488 psf	Cell Z
ave = 370 psf	
c = 195 psf	Cell 4
c = 325 to 333 psf	Cell 5
ave = 329 psf	
c = 263 to 525 psf	Cell 6
ave = 724 psf	
c = 183 to 460 psf	LTU
ave = 354 psf	

Pocket Penetrometer

< 100 to 2500 psf	Cell 1
< 100 to 700 psf	2
< 100 to 4300 psf	3
100 to 900 psf	X
< 100 to 1200 psf	Y
< 100 to 1500 psf	4
200 to 700 psf	Z
< 100 to 700 psf	5
250 to 550 psf	6

Direct Shear

Test Type	σ_N	τ	ϕ	c	Cell
CU	2.0 ksf	1.5 ksf			1
UU			38.7°	170 psf	2
UU			31.7°	260 psf	2
CU			30.4°	550 psf	3
CD			22.7°	940 psf	3
CU			45°	600 psf	3
UU			18°	950 psf	X

Triaxial Shear - multistage - $\overline{CIU}$

$\phi = 20.5°$	$c = 0.2$ ksf	Cell 2
$\phi = 33.5°$	$\bar{c} = 0.2$ ksf	Cell 2
$\bar{\phi} = 26°$	$\bar{c} = 0.1$ ksf	LTU
$\bar{\phi} = 25°$	$\bar{c} = 0.46$ ksf	LTU
$\bar{\phi} = 32°$	$c = 0.23$ ksf	LTU
$\bar{\phi} = 41°$	$\bar{c} = 0.34$ ksf	LTU
$\phi = 33°$	$c = 0.41$ ksf	LTU

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JRM
SUBJECT Soil Strength Testing and Summary SHEET 23 OF 26

D. Clay and Silty Sand
Unconfined Compression
C = 200 to 460 psf — Cell 1
ave = 300 psf
C = 150 to 710 psf — Cell X
ave = 430 psf
C = 1040 psf — Cell Y
C = 150 to 1650 psf — Cell Z
ave = 720 psf
C = 320 to 1075 psf — Cell 5
ave = 541 psf
C = 300 to 1650 psf — Cell 6
ave = 765 psf
C = 188 to 1185 psf — LTU
ave = 471 psf

Triaxial Shear

$\bar{\phi} = 22°$	$\bar{c}$ = 0.75 ksf	LTU
$\bar{\phi} = 35°$	$\bar{c}$ = 0.11 ksf	LTU
$\bar{\phi} = 24°$	$\bar{c}$ = 0.10 ksf	LTU

Direct Shear on Sand

ϕ_p = 34.3°	c = 0	LTU	L-1 @ 50'
ϕ_p = 31.3°	c = 0	LTU	L-10 @ 50½'
ϕ_p = 37.6°	c = 0	LTU	L-14 @ 20'
ϕ_p = 30.4°	c = 0	LTU	L-14 @ 20'

Strength Parameter for Stability Analysis
A. End of Construction - during placement of embankment and clay liner - prior to synthetic liner placement
1. Embankment material
- with controlled placement of fill, use a drained strength for construction and long term conditions
- based on cell 1 embankment material tests **$\bar{\phi}$ = 34° $\bar{c}$ = 400 psf**
- ϕ is increased 2° above direct shear results
- c is less than test results (drilling for monitor wells through the embankment indicates very dense and hard materials)
- assuming a 35' high embankment, the shear strength calculates as: 35 ft (130 pcf) tan 34° + 400 psf = 3469 psf. The calculated value is greater than the average (2656) undrained strength obtained from UC tests and direct shear tests. The average shear strength used in the analysis $\frac{35}{2}$(130) tan 34° + 400 = 1935 psf is less than the average test values.

2. Clay liner material
- Classifies as CL, CL-ML and ML materials with LL = 22 to 49 PI = 5 to 25 -200 = 85 to 100

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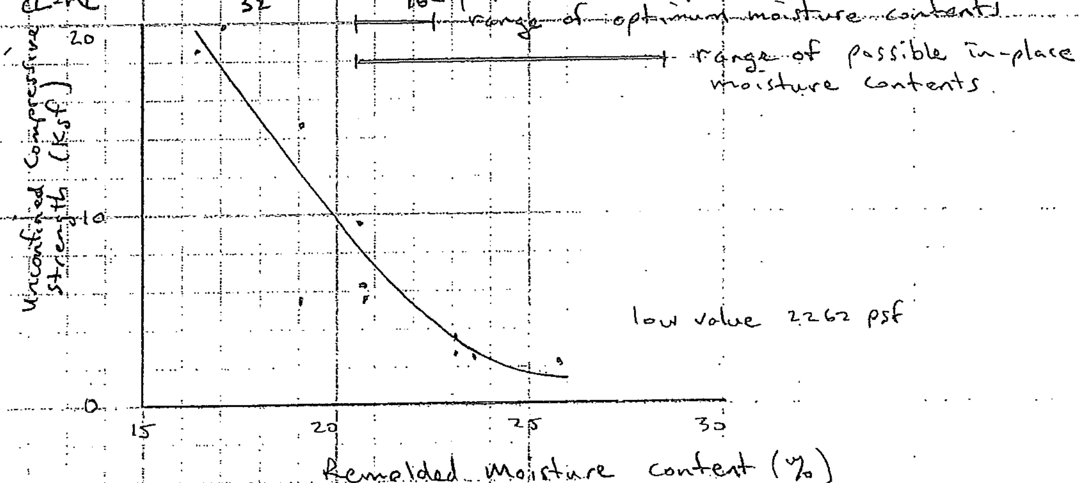
SUBJECT Soil Strength Testing and Summary SHEET 24 OF 26

- NAVFAC DM-7 (1986) pg 7.2-39, Table I gives typical properties

Soil Type	$\bar{\phi}$ (sat)	$\bar{c}$ (sat)	c (as compacted)
CL	28°	270 psf	1800 psf
ML	32°	190 psf	1400 psf
CL-ML	32°	460 psf	1350 psf



- Based on tests and typical properties

Undrained strength - to allow for moisture contents up to 27%. c = 750 psf

Drained strength - following typical properties
$\bar{\phi} = 28°$ $\bar{c} = 270$ psf

The drained parameters will be used in the stability analysis for the landfill. The undrained strength will be used for traffic loading on the clay.

3. Sand cover and synthetic liner
For overall stability assume no strength in the synthetic materials and $\phi = 28°$ $c = 100$ psf for silt/clay/sand cover materials.

4. Stiff clay, transitioning to soft clay - based on lab & field tests

Elev.	cohesion
38 - 36	3700 psf
36 - 34	1900 psf
34 - 32	500 psf
32 - 30	200 psf

Field and lab tests indicate c will vary in the upper stiff clay from 585 psf to 11700 psf.

5. Clay and Silty Sand
- The sand occurs as thin to medium thick layers
- UC results range from 150 to 1650 psf
- Direct Shear tests indicate $\sigma_N = 2.0$ ksf $\tau = 1.0$ ksf
  - ∴ if $\phi = 0 \Rightarrow c = 1000$ psf
  - $\phi = 18° \Rightarrow c = 950$ psf
  - $\phi = 26° \Rightarrow c = 0$
  - Tests on sand $\phi_p = 34.3°, 31.3°, 37.6°$
- Penetration resistance indicates $\phi = 28$-$32°$ ave. 30°
- Cone penetration Test correlation give $\phi' = 36°$ min.
- Use a combination of ϕ and c

$\phi = 30°$ $c = 200$ psf

B. Long Term Conditions
- Pore Pressure monitoring in the upper soils of Cell 2 indicate a fairly rapid decrease in pore pressure during construction
- NAVFAC DM-7 (1971) Fig 3.7 indicates that for PI ranging from 8 to 20 the ϕ may range from 22° to 27°
- Patton & Hendron indicate a residual shear strength of 12°-14°

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/30/17 BY JRM

SUBJECT Subsurface Profile & Strength Parameters SHEET 26 OF 26

Elev. Top (ft)	Soil	End of Construction		Long Term		γ (pcf)
		φ (deg)	c (psf)	φ (deg)	c (psf)	
varies	Landfill	–	–	25	100	120
varies	Soil Cover	–	–	28	100	120
varies	clay	28	270	28	270	110
varies	Embankment	34	400	34	400	130
4239-4240	clay	0	3700	30	200	130
4236	clay	0	1900	30	200	120
4234	clay	0	500	30	200	110
4232	clay	0	200	30	200	110
4230	clay	0	200	27	200	110
4220	SM/CL	26	200	30	200	110
4218	clay	0	200	27	200	110
4208	SM/ML/CL	26	200	30	200	110
4197	clay	0	200	27	200	110
4191	SM/CL	26	200	30	200	110
4185	clay	0	200	27	200	110
4175	SM/CL	26	200	30	200	110
4169	clay	0	200	27	200	110
4165	SM/CL	26	200	30	200	110
4153	clay	0	200	27	200	110
4149	SM/CL	26	200	30	200	110
4140	clay	0	200	27	200	110
4119	SM/CL	26	200	30	200	110
4104	clay	0	200	27	200	110
4093	SM/CL	26	200	30	200	110

APPENDIX D

POTENTIAL FOR

TENSION CRACKS

Determine critical height of embankment for tension cracking

H_T = height of embankment when tension cracking begins

$$H_T = \frac{S_{us}}{\gamma_E} N_T$$

S_{us} = undrained shear strength of foundation at surface

highest case of S_{us} = 3700 psf

ave. for upper 20' $= \frac{3(3700) + 2(1900) + 2(500) + 12(200)}{19}$

= 963 psf

γ_E = 130. pcf (embankment)

N_T is function of $\frac{\text{Embank. modulus}}{\text{Found. modulus}} = \frac{K_E}{K_F}$

and $\frac{\text{Embank. width}}{\text{depth of influence}} = \frac{W}{D}$

K_E could range from 30 - 750

K_F could range from 390 - 970

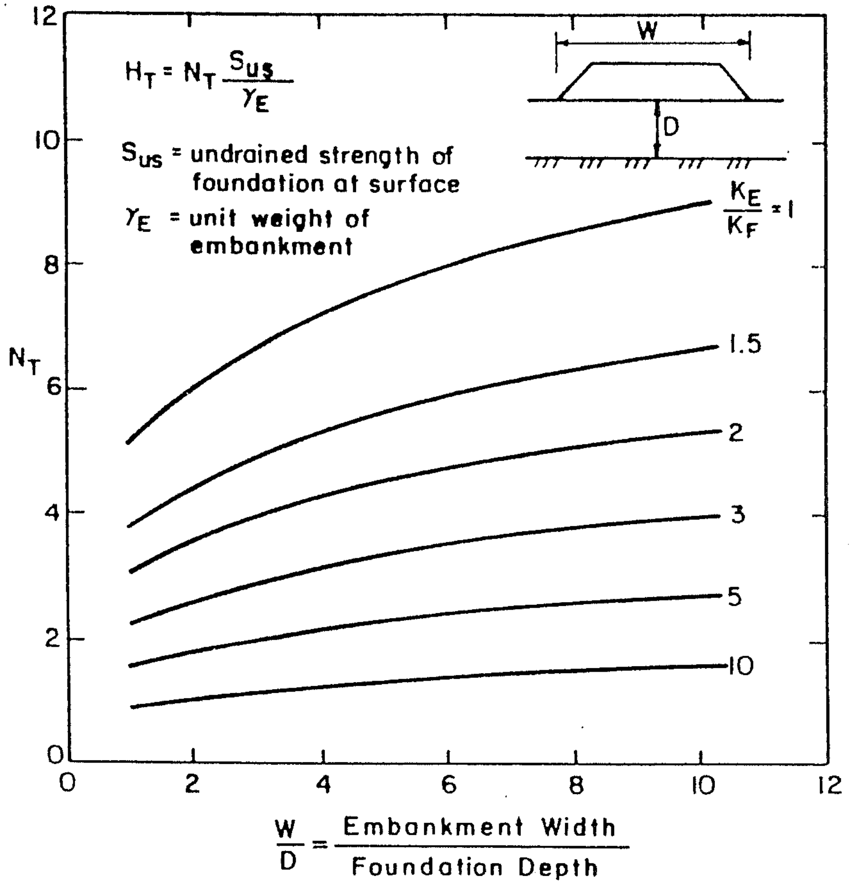
$\frac{W}{D} = \frac{174}{19} = 9$ max

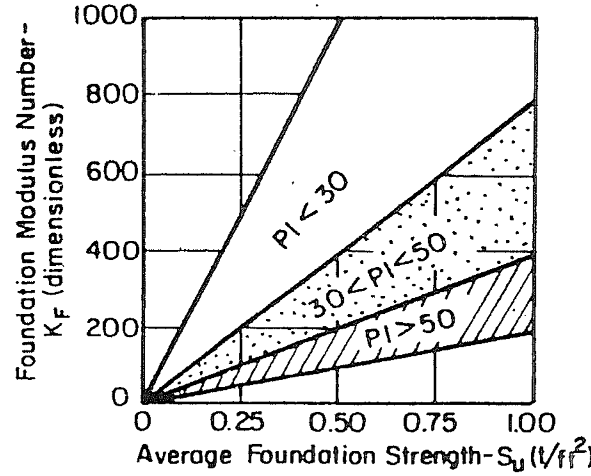
Assume D is limited to dominant sand @ 31'

$\frac{W}{D} = \frac{174}{31} = 5.6$ $\frac{K_E}{K_F} = \frac{750}{390} = 1.92$

$N_T = 4.85$ $H_T = \frac{963}{130}(4.85) = 36'$

with max embank. height 28', cracking due to tension is not expected





Typical values of K_E for compacted fills

Unified Class.	Compaction Water Content		
	Optimum - 3%	Optimum	Optimum + 3%
GC	300 - 1200	200-500	75 - 300
SP	400 - 1000	400-1000	400-1000
SM	300 - 750	300 - 750	300 - 750
SC	250 - 1000	150 - 600	50 - 250
ML	250 - 1000	150 - 600	50 - 250
CL	250 - 1000	100 - 400	30 - 200
CH	100 - 400	50 - 200	20 - 100

Values shown apply to fill materials compacted to dry densities from 90% to 95% of the Std. AASHO maximum. In general, the value of K_E increases with increasing dry density at a given water content.

Fig. 4 CHART FOR ESTIMATING H_T = HEIGHT OF EMBANKMENT WHEN CRACKING WILL BEGIN. (after Chirapuntu and Duncan, 1975.) An Engineering manual for Slope Stability Studies by Duncan and Buchignani, 1975; Univ. of CA. Berkeley

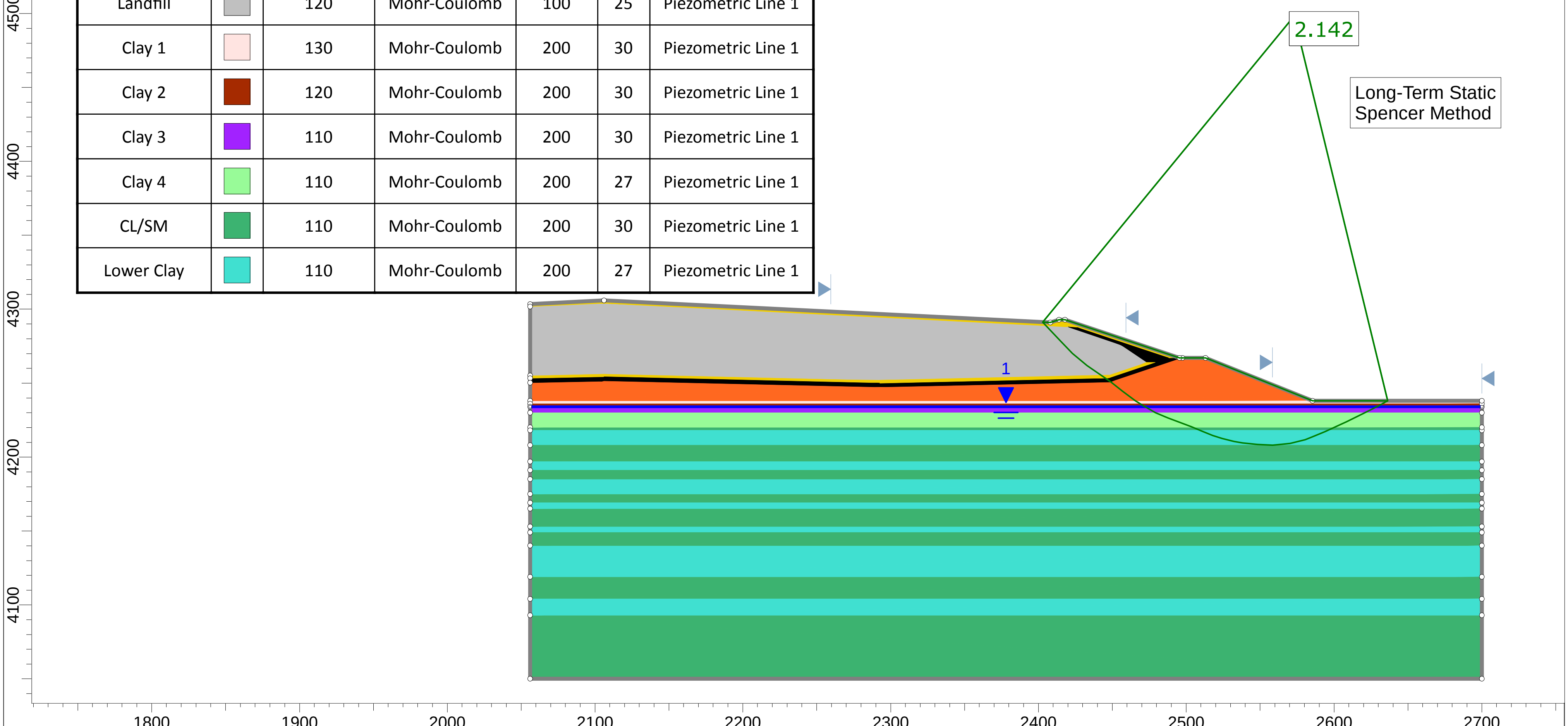
2/2

APPENDIX E-1

SLOPE STABILITY

LONG TERM STATIC

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Soil Cover		120	Mohr-Coulomb	100	28	Piezometric Line 1
Clay Liner		110	Mohr-Coulomb	270	28	Piezometric Line 1
Embankment		130	Mohr-Coulomb	400	34	Piezometric Line 1
Landfill		120	Mohr-Coulomb	100	25	Piezometric Line 1
Clay 1		130	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 2		120	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 3		110	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 4		110	Mohr-Coulomb	200	27	Piezometric Line 1
CL/SM		110	Mohr-Coulomb	200	30	Piezometric Line 1
Lower Clay		110	Mohr-Coulomb	200	27	Piezometric Line 1



Project	SLIDE - An Interactive Slope Stability Program
Analysis Description	Cells 8 to 13 - Long Term Static
Drawn By	JRM
Scale	1:1208
Company	AGEC
Date	9/8/2017
File Name	1160276 Cell 8 to 13 long term static.slim

SLIDEINTERPRET 7.013

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	1160276 Cell 8 to 13 long term static
Last saved with Slide version:	7.013
Project Title:	SLIDE - An Interactive Slope Stability Program
Analysis:	Cells 8 to 13 - Long Term Static
Author:	JRM
Company:	AGEC
Date Created:	9/8/2017

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
	Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Search Method:	Auto Refine Search
Divisions along slope:	10
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Material Properties

Property	Soil Cover	Clay Liner	Embankment	Landfill	Clay 1	Clay 2	Clay 3	Clay 4
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	110	130	120	130	120	110	110
Cohesion [psf]	100	270	400	100	200	200	200	200
Friction Angle [deg]	28	28	34	25	30	30	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1	1	1	1	1	1	1

Property	CL/SM	Lower Clay
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	110	110
Cohesion [psf]	200	200
Friction Angle [deg]	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1

List Of Coordinates

Piezoline

X	Y
2056	4234
2700	4234

External Boundary

X	Y
2056	4303.5
2056	4301.77
2056	4255.2
2056	4253.2
2056	4250.2
2056	4238
2056	4236
2056	4234
2056	4230
2056	4220
2056	4218
2056	4208
2056	4197
2056	4191
2056	4185
2056	4175
2056	4169
2056	4165
2056	4153
2056	4149
2056	4140
2056	4119
2056	4104
2056	4093
2056	4050
2700	4050
2700	4093
2700	4104
2700	4119
2700	4140
2700	4149
2700	4153
2700	4165
2700	4169
2700	4175
2700	4185
2700	4191
2700	4197
2700	4208
2700	4218
2700	4220
2700	4230
2700	4234
2700	4236
2700	4238
2585.5	4238
2513	4267
2497.5	4267
2495.5	4267
2418	4292.9
2414	4292.9
2408	4291
2106	4306

Material Boundary

X	Y
2056	4301.77
2106	4304
2420	4288
2426.5	4287.5
2488	4267
2495.5	4267

Material Boundary

X	Y
2420	4288
2455	4276
2473	4264
2479	4264
2488	4267

Material Boundary

X	Y
2056	4255.2
2106	4256.3
2292.5	4252
2447.5	4255.5
2473	4264

Material Boundary

X	Y
2056	4253.2
2106	4254.3
2292.5	4250
2447.5	4253.5
2479	4264

Material Boundary

X	Y
2056	4250.2
2106	4251.3
2292.5	4247
2448	4250.5
2497.5	4267

Material Boundary

X	Y
2056	4238
2585.5	4238

Material Boundary

X	Y
2056	4236
2700	4236

Material Boundary

X	Y
2056	4234
2700	4234

Material Boundary

X	Y
2056	4230
2700	4230

Material Boundary

X	Y
2056	4220
2700	4220

Material Boundary

X	Y
2056	4218
2700	4218

Material Boundary

X	Y
2056	4208
2700	4208

Material Boundary

X	Y
2056	4197
2700	4197

Material Boundary

X	Y
2056	4191
2700	4191

Material Boundary

X	Y
2056	4185
2700	4185

Material Boundary

X	Y
2056	4175
2700	4175

Material Boundary

X	Y
2056	4169
2700	4169

Material Boundary

X	Y
2056	4165
2700	4165

Material Boundary

X	Y
2056	4153
2700	4153

Material Boundary

X	Y
2056	4149
2700	4149

Material Boundary

X	Y
2056	4140
2700	4140

Material Boundary

X	Y
2056	4119
2700	4119

Material Boundary

X	Y
2056	4104
2700	4104

Material Boundary

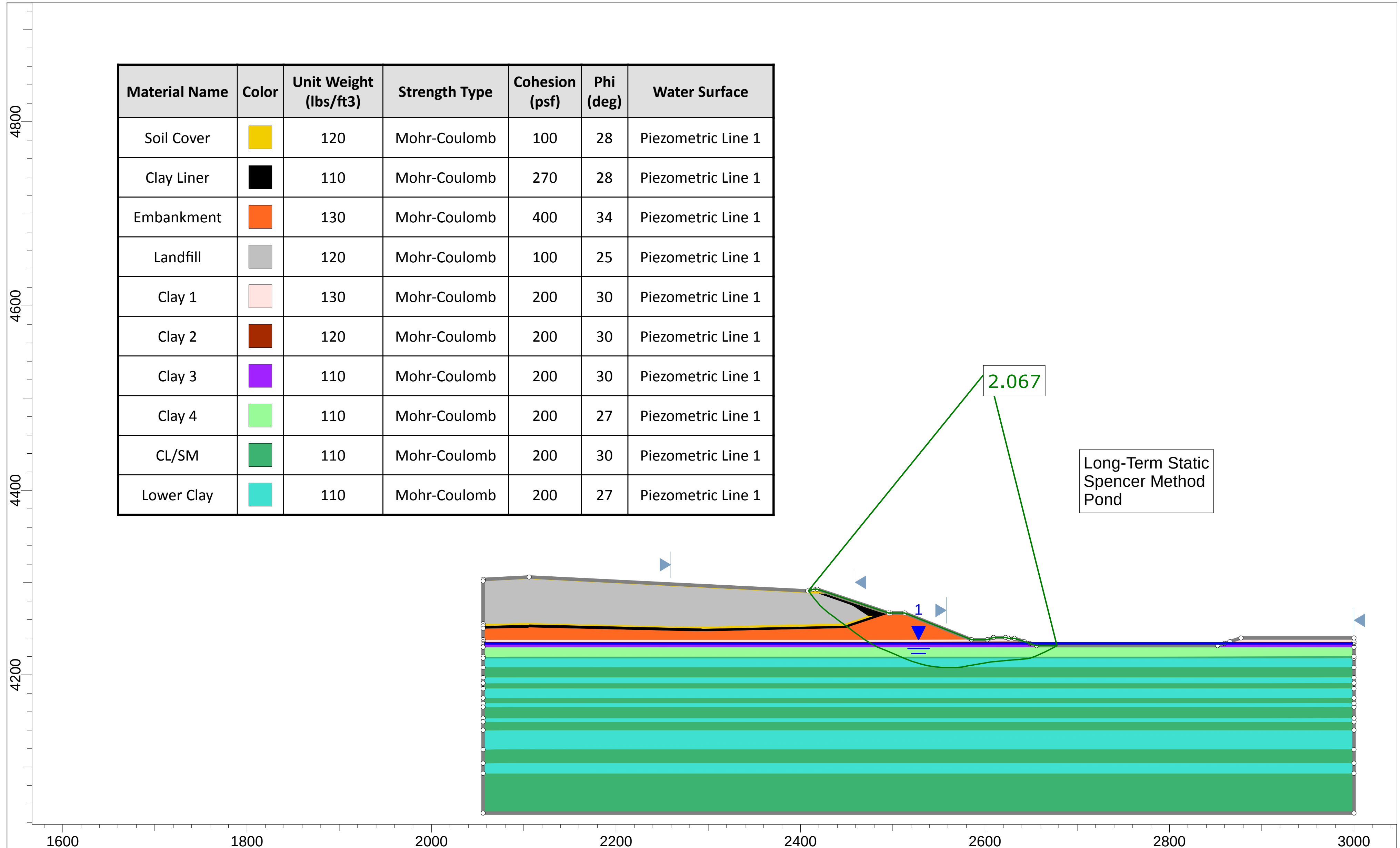
X	Y
2056	4093
2700	4093

APPENDIX E-2

SLOPE STABILITY - NEAR POND

LONG TERM STATIC

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Soil Cover		120	Mohr-Coulomb	100	28	Piezometric Line 1
Clay Liner		110	Mohr-Coulomb	270	28	Piezometric Line 1
Embankment		130	Mohr-Coulomb	400	34	Piezometric Line 1
Landfill		120	Mohr-Coulomb	100	25	Piezometric Line 1
Clay 1		130	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 2		120	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 3		110	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 4		110	Mohr-Coulomb	200	27	Piezometric Line 1
CL/SM		110	Mohr-Coulomb	200	30	Piezometric Line 1
Lower Clay		110	Mohr-Coulomb	200	27	Piezometric Line 1



Project	SLIDE - An Interactive Slope Stability Program		
Analysis Description	Cells 8 to 13 - Long Term Static - Pond		
Drawn By JRM	*Scale* 1:1723	*Company* AGEC	
Date 9/8/2017	*File Name* 1160276 Cell 8 to 13 long term static pond.slim		

SLIDEINTERPRET 7.013

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	1160276 Cell 8 to 13 long term static pond
Last saved with Slide version:	7.013
Project Title:	SLIDE - An Interactive Slope Stability Program
Analysis:	Cells 8 to 13 - Long Term Static - Pond
Author:	JRM
Company:	AGEC
Date Created:	9/8/2017

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
	Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Search Method:	Auto Refine Search
Divisions along slope:	10
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Material Properties

Property	Soil Cover	Clay Liner	Embankment	Landfill	Clay 1	Clay 2	Clay 3	Clay 4
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	110	130	120	130	120	110	110
Cohesion [psf]	100	270	400	100	200	200	200	200
Friction Angle [deg]	28	28	34	25	30	30	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1	1	1	1	1	1	1

Property	CL/SM	Lower Clay
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	110	110
Cohesion [psf]	200	200
Friction Angle [deg]	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1

List Of Coordinates

Piezoline

X	Y
2056	4234
3000	4234

External Boundary

X	Y
2056	4303.5
2056	4301.77
2056	4255.2
2056	4253.2
2056	4250.2
2056	4238
2056	4236
2056	4234
2056	4230

2056	4220
2056	4218
2056	4208
2056	4197
2056	4191
2056	4185
2056	4175
2056	4169
2056	4165
2056	4153
2056	4149
2056	4140
2056	4119
2056	4104
2056	4093
2056	4050
3000	4050
3000	4093
3000	4104
3000	4119
3000	4140
3000	4149
3000	4153
3000	4165
3000	4169
3000	4175
3000	4185
3000	4191
3000	4197
3000	4208
3000	4218
3000	4220
3000	4230
3000	4234
3000	4236
3000	4240
2877.6	4240
2865.6	4236
2859.6	4234
2852.1	4231.5
2656.1	4231.5
2648.6	4234
2642.6	4236
2632.1	4239.5
2625.5	4239.5
2622.5	4240.5
2609.3	4240.5
2602.5	4238
2585.5	4238
2513	4267
2497.5	4267
2495.5	4267
2418	4292.9
2414	4292.9
2408	4291
2106	4306

Material Boundary

X	Y
2056	4301.77
2106	4304
2420	4288
2426.5	4287.5
2488	4267
2495.5	4267

Material Boundary

X	Y
2420	4288
2455	4276
2473	4264
2479	4264
2488	4267

Material Boundary

X	Y
2056	4255.2
2106	4256.3
2292.5	4252
2447.5	4255.5
2473	4264

Material Boundary

X	Y
2056	4253.2
2106	4254.3
2292.5	4250
2447.5	4253.5
2479	4264

Material Boundary

X	Y
2056	4250.2
2106	4251.3
2292.5	4247
2448	4250.5
2497.5	4267

Material Boundary

X	Y
2056	4238
2585.5	4238

Material Boundary

X	Y
2056	4236
2642.6	4236

Material Boundary

X	Y
2056	4234
2648.6	4234

Material Boundary

X	Y
2056	4230
3000	4230

Material Boundary

X	Y
2056	4220
3000	4220

Material Boundary

X	Y
2056	4218
3000	4218

Material Boundary

X	Y
2056	4208
3000	4208

Material Boundary

X	Y
2056	4197
3000	4197

Material Boundary

X	Y
2056	4191
3000	4191

Material Boundary

X	Y
2056	4185
3000	4185

Material Boundary

X	Y
2056	4175
3000	4175

Material Boundary

X	Y
2056	4169
3000	4169

Material Boundary

X	Y
2056	4165
3000	4165

Material Boundary

X	Y
2056	4153
3000	4153

Material Boundary

X	Y
2056	4149
3000	4149

Material Boundary

X	Y
2056	4140
3000	4140

Material Boundary

X	Y
2056	4119
3000	4119

Material Boundary

X	Y
2056	4104
3000	4104

Material Boundary

X	Y
2056	4093
3000	4093

Material Boundary

X	Y
2859.6	4234
3000	4234

Material Boundary

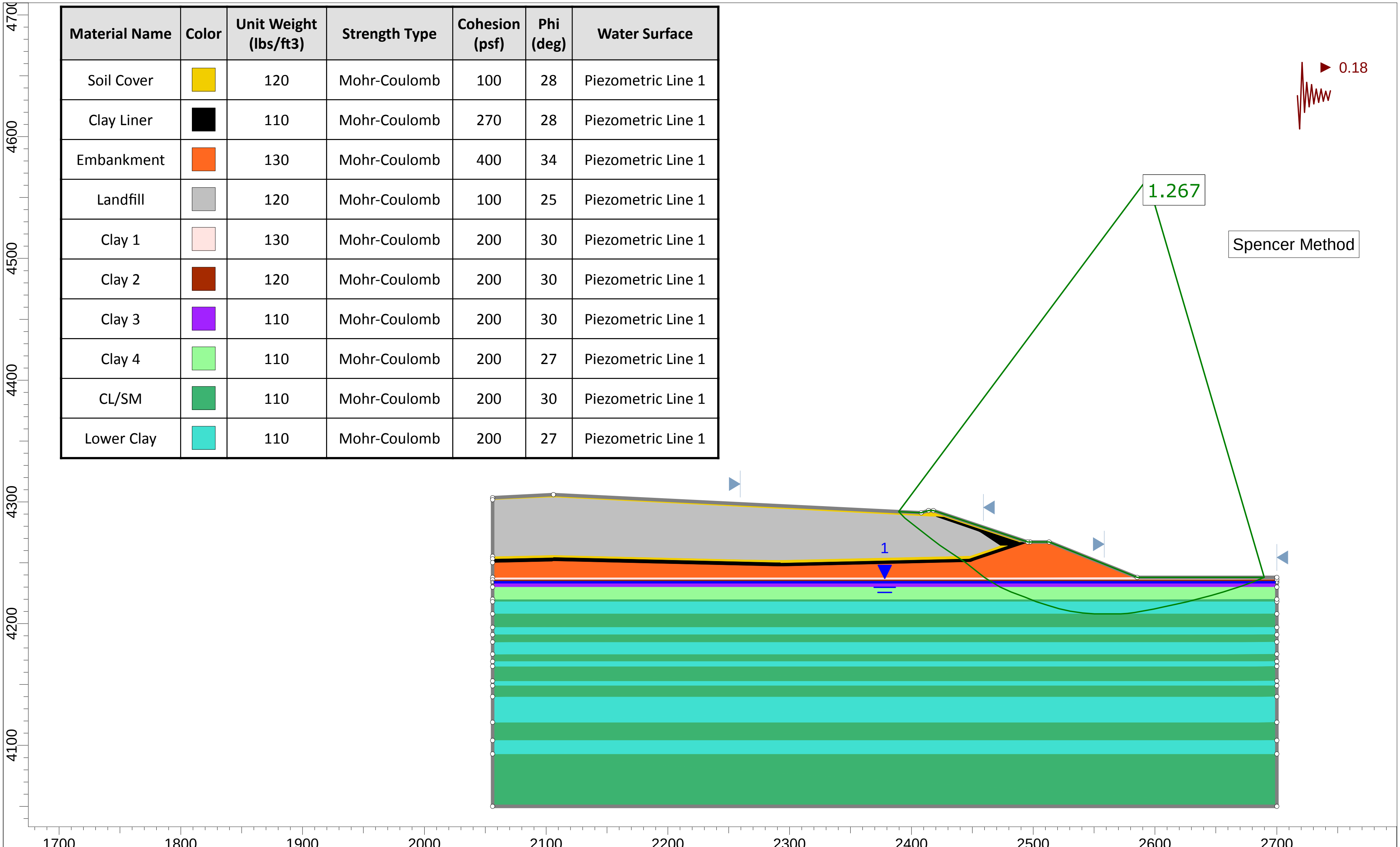
X	Y
2865.6	4236
3000	4236

APPENDIX E-3

SLOPE STABILITY

LONG TERM SEISMIC

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Soil Cover		120	Mohr-Coulomb	100	28	Piezometric Line 1
Clay Liner		110	Mohr-Coulomb	270	28	Piezometric Line 1
Embankment		130	Mohr-Coulomb	400	34	Piezometric Line 1
Landfill		120	Mohr-Coulomb	100	25	Piezometric Line 1
Clay 1		130	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 2		120	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 3		110	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 4		110	Mohr-Coulomb	200	27	Piezometric Line 1
CL/SM		110	Mohr-Coulomb	200	30	Piezometric Line 1
Lower Clay		110	Mohr-Coulomb	200	27	Piezometric Line 1



Project	SLIDE - An Interactive Slope Stability Program
Analysis Description	Cells 8 to 13 - Long Term Seismic
Drawn By	JRM
Scale	1:1308
Company	AGEC
Date	9/8/2017
File Name	1160276 Cell 8 to 13 long term seismic.slim

SLIDEINTERPRET 7.013

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	1160276 Cell 8 to 13 long term seismic
Last saved with Slide version:	7.013
Project Title:	SLIDE - An Interactive Slope Stability Program
Analysis:	Cells 8 to 13 - Long Term Seismic
Author:	JRM
Company:	AGEC
Date Created:	9/8/2017

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
	Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Search Method:	Auto Refine Search
Divisions along slope:	10
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Loading

Seismic Load Coefficient (Horizontal): 0.18

Material Properties

Property	Soil Cover	Clay Liner	Embankment	Landfill	Clay 1	Clay 2	Clay 3	Clay 4
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	110	130	120	130	120	110	110
Cohesion [psf]	100	270	400	100	200	200	200	200
Friction Angle [deg]	28	28	34	25	30	30	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1	1	1	1	1	1	1

Property	CL/SM	Lower Clay
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	110	110
Cohesion [psf]	200	200
Friction Angle [deg]	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1

List Of Coordinates

Piezoline

X	Y
2056	4234
2700	4234

External Boundary

X	Y
2056	4303.5
2056	4301.77
2056	4255.2
2056	4253.2
2056	4250.2
2056	4238
2056	4236
2056	4234
2056	4230
2056	4220
2056	4218
2056	4208
2056	4197
2056	4191
2056	4185
2056	4175
2056	4169
2056	4165
2056	4153
2056	4149
2056	4140
2056	4119
2056	4104
2056	4093
2056	4050
2700	4050
2700	4093
2700	4104
2700	4119
2700	4140
2700	4149
2700	4153
2700	4165
2700	4169
2700	4175
2700	4185
2700	4191
2700	4197
2700	4208
2700	4218
2700	4220
2700	4230
2700	4234
2700	4236
2700	4238
2585.5	4238
2513	4267
2497.5	4267
2495.5	4267
2418	4292.9
2414	4292.9
2408	4291
2106	4306

Material Boundary

X	Y
2056	4301.77
2106	4304
2420	4288
2426.5	4287.5
2488	4267
2495.5	4267

Material Boundary

X	Y
2420	4288
2455	4276
2473	4264
2479	4264
2488	4267

Material Boundary

X	Y
2056	4255.2
2106	4256.3
2292.5	4252
2447.5	4255.5
2473	4264

Material Boundary

X	Y
2056	4253.2
2106	4254.3
2292.5	4250
2447.5	4253.5
2479	4264

Material Boundary

X	Y
2056	4250.2
2106	4251.3
2292.5	4247
2448	4250.5
2497.5	4267

Material Boundary

X	Y
2056	4238
2585.5	4238

Material Boundary

X	Y
2056	4236
2700	4236

Material Boundary

X	Y
2056	4234
2700	4234

Material Boundary

X	Y
2056	4230
2700	4230

Material Boundary

X	Y
2056	4220
2700	4220

Material Boundary

X	Y
2056	4218
2700	4218

Material Boundary

X	Y
2056	4208
2700	4208

Material Boundary

X	Y
2056	4197
2700	4197

Material Boundary

X	Y
2056	4191
2700	4191

Material Boundary

X	Y
2056	4185
2700	4185

Material Boundary

X	Y
2056	4175
2700	4175

Material Boundary

X	Y
2056	4169
2700	4169

Material Boundary

X	Y
2056	4165
2700	4165

Material Boundary

X	Y
2056	4153
2700	4153

Material Boundary

X	Y
2056	4149
2700	4149

Material Boundary

X	Y
2056	4140
2700	4140

Material Boundary

X	Y
2056	4119
2700	4119

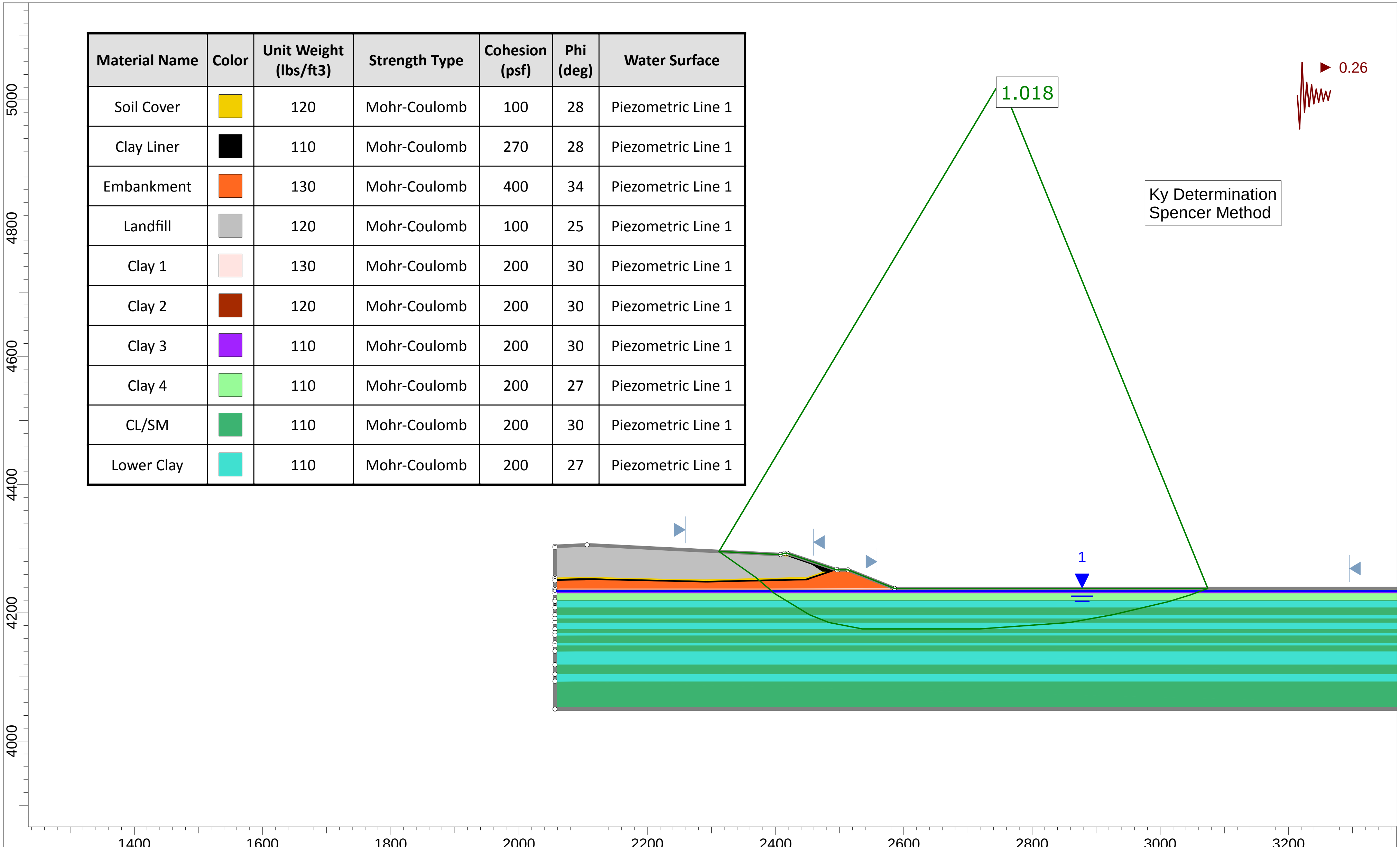
Material Boundary

X	Y
2056	4104
2700	4104

Material Boundary

X	Y
2056	4093
2700	4093

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Soil Cover		120	Mohr-Coulomb	100	28	Piezometric Line 1
Clay Liner		110	Mohr-Coulomb	270	28	Piezometric Line 1
Embankment		130	Mohr-Coulomb	400	34	Piezometric Line 1
Landfill		120	Mohr-Coulomb	100	25	Piezometric Line 1
Clay 1		130	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 2		120	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 3		110	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 4		110	Mohr-Coulomb	200	27	Piezometric Line 1
CL/SM		110	Mohr-Coulomb	200	30	Piezometric Line 1
Lower Clay		110	Mohr-Coulomb	200	27	Piezometric Line 1



Project	SLIDE - An Interactive Slope Stability Program
Analysis Description	Cells 8 to 13 - Long Term Seismic
Drawn By	JRM
Scale	1:2485
Company	AGEC
Date	9/8/2017
File Name	1160276 Cell 8 to 13 long term - determine Ky enlarged.slim

SLIDEINTERPRET 7.013

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	1160276 Cell 8 to 13 long term - determine Ky enlarged
Last saved with Slide version:	7.013
Project Title:	SLIDE - An Interactive Slope Stability Program
Analysis:	Cells 8 to 13 - Long Term Seismic
Author:	JRM
Company:	AGEC
Date Created:	9/8/2017

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
	Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Search Method:	Auto Refine Search
Divisions along slope:	10
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Loading

Seismic Load Coefficient (Horizontal): 0.26

Material Properties

Property	Soil Cover	Clay Liner	Embankment	Landfill	Clay 1	Clay 2	Clay 3	Clay 4
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	110	130	120	130	120	110	110
Cohesion [psf]	100	270	400	100	200	200	200	200
Friction Angle [deg]	28	28	34	25	30	30	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1	1	1	1	1	1	1

Property	CL/SM	Lower Clay
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	110	110
Cohesion [psf]	200	200
Friction Angle [deg]	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1

List Of Coordinates

Piezoline

X	Y
2056	4234
3700	4234

External Boundary

X	Y
2056	4303.5
2056	4301.77
2056	4255.2
2056	4253.2
2056	4250.2
2056	4238
2056	4236
2056	4234
2056	4230
2056	4220
2056	4218
2056	4208
2056	4197
2056	4191
2056	4185
2056	4175
2056	4169
2056	4165
2056	4153
2056	4149
2056	4140
2056	4119
2056	4104
2056	4093
2056	4050
3700	4050
3700	4093
3700	4104
3700	4119
3700	4140
3700	4149
3700	4153
3700	4165
3700	4169
3700	4175
3700	4185
3700	4191
3700	4197
3700	4208
3700	4218
3700	4220
3700	4230
3700	4234
3700	4236
3700	4238
2585.5	4238
2513	4267
2497.5	4267
2495.5	4267
2418	4292.9
2414	4292.9
2408	4291
2106	4306

Material Boundary

X	Y
2056	4301.77
2106	4304
2420	4288
2426.5	4287.5
2488	4267
2495.5	4267

Material Boundary

X	Y
2420	4288
2455	4276
2473	4264
2479	4264
2488	4267

Material Boundary

X	Y
2056	4255.2
2106	4256.3
2292.5	4252
2447.5	4255.5
2473	4264

Material Boundary

X	Y
2056	4253.2
2106	4254.3
2292.5	4250
2447.5	4253.5
2479	4264

Material Boundary

X	Y
2056	4250.2
2106	4251.3
2292.5	4247
2448	4250.5
2497.5	4267

Material Boundary

X	Y
2056	4238
2585.5	4238

Material Boundary

X	Y
2056	4236
3700	4236

Material Boundary

X	Y
2056	4234
3700	4234

Material Boundary

X	Y
2056	4230
3700	4230

Material Boundary

X	Y
2056	4220
3700	4220

Material Boundary

X	Y
2056	4218
3700	4218

Material Boundary

X	Y
2056	4208
3700	4208

Material Boundary

X	Y
2056	4197
3700	4197

Material Boundary

X	Y
2056	4191
3700	4191

Material Boundary

X	Y
2056	4185
3700	4185

Material Boundary

X	Y
2056	4175
3700	4175

Material Boundary

X	Y
2056	4169
3700	4169

Material Boundary

X	Y
2056	4165
3700	4165

Material Boundary

X	Y
2056	4153
3700	4153

Material Boundary

X	Y
2056	4149
3700	4149

Material Boundary

X	Y
2056	4140
3700	4140

Material Boundary

X	Y
2056	4119
3700	4119

Material Boundary

X	Y
2056	4104
3700	4104

Material Boundary

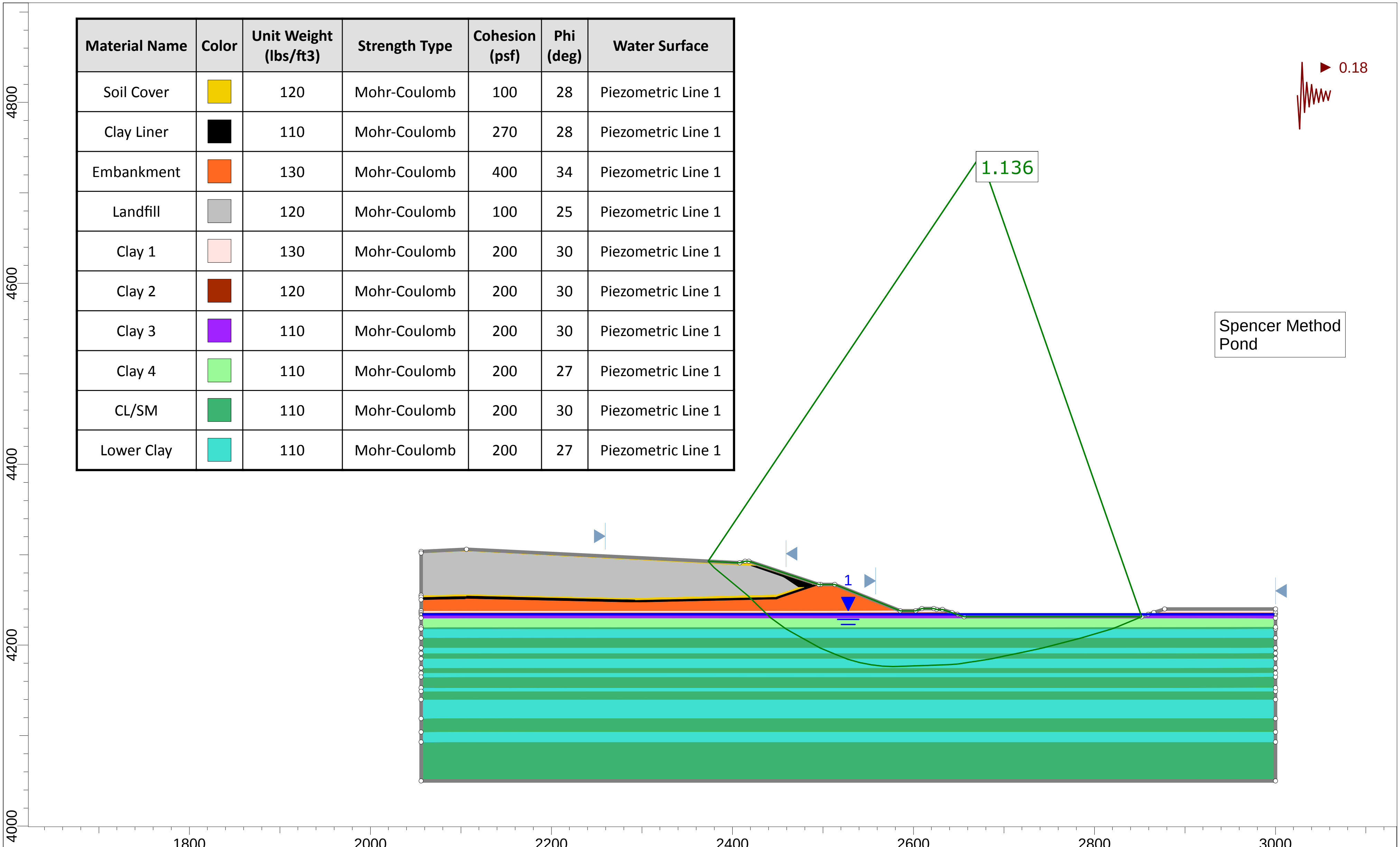
X	Y
2056	4093
3700	4093

APPENDIX E-4

SLOPE STABILITY - NEAR POND

LONG TERM SEISMIC

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Soil Cover		120	Mohr-Coulomb	100	28	Piezometric Line 1
Clay Liner		110	Mohr-Coulomb	270	28	Piezometric Line 1
Embankment		130	Mohr-Coulomb	400	34	Piezometric Line 1
Landfill		120	Mohr-Coulomb	100	25	Piezometric Line 1
Clay 1		130	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 2		120	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 3		110	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 4		110	Mohr-Coulomb	200	27	Piezometric Line 1
CL/SM		110	Mohr-Coulomb	200	30	Piezometric Line 1
Lower Clay		110	Mohr-Coulomb	200	27	Piezometric Line 1



Project	SLIDE - An Interactive Slope Stability Program		
Analysis Description	Cells 8 to 13 - Long Term Seismic - Pond		
Drawn By JRM	*Scale* 1:1761	*Company* AGEC	
Date 9/8/2017		*File Name* 1160276 Cell 8 to 13 long term seismic pond.slim	

SLIDEINTERPRET 7.013

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	1160276 Cell 8 to 13 long term seismic pond
Slide Modeler Version:	7.013
Project Title:	SLIDE - An Interactive Slope Stability Program
Analysis:	Cells 8 to 13 - Long Term Seismic - Pond
Author:	JRM
Company:	AGEC
Date Created:	9/8/2017

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
	Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Search Method:	Auto Refine Search
Divisions along slope:	10
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Loading

Seismic Load Coefficient (Horizontal): 0.18

Material Properties

Property	Soil Cover	Clay Liner	Embankment	Landfill	Clay 1	Clay 2	Clay 3	Clay 4
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	110	130	120	130	120	110	110
Cohesion [psf]	100	270	400	100	200	200	200	200
Friction Angle [deg]	28	28	34	25	30	30	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1	1	1	1	1	1	1

Property	CL/SM	Lower Clay
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	110	110
Cohesion [psf]	200	200
Friction Angle [deg]	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1

Global Minimums

Method: spencer

FS	1.135850
Axis Location:	2673.843, 4741.095
Left Slip Surface Endpoint:	2373.121, 4292.732
Right Slip Surface Endpoint:	2852.100, 4231.500
Resisting Moment:	4.942e+008 lb-ft
Driving Moment:	4.35091e+008 lb-ft
Resisting Horizontal Force:	819105 lb
Driving Horizontal Force:	721135 lb
Total Slice Area:	21947.4 ft2
Surface Horizontal Width:	478.979 ft
Surface Average Height:	45.8212 ft

Global Minimum Coordinates

Method: spencer

X	Y
2373.12	4292.73
2379.68	4285.77
2393.88	4273.88
2405.48	4264.3
2417.08	4254.72
2429.59	4242.39
2442.31	4230.07
2459.31	4218.06
2468.28	4212.76
2496.88	4197.04
2512.81	4190.4
2527.36	4184.34
2540.56	4180.76
2553.39	4178.27
2565.66	4176.83
2577.45	4176.34
2616	4177.69
2641.48	4178.59
2650.16	4179.39
2662.31	4181.17
2667.73	4182.03
2686.33	4185.02
2701.16	4188.13
2715.58	4191.16
2729.39	4194.06
2742.79	4196.98
2781.44	4206.91
2785.27	4207.97
2819.14	4218.03
2825.12	4220.03
2852.1	4231.5

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 1476
Number of Invalid Surfaces: 3025

Error Codes:

Error Code -105 reported for 291 surfaces
Error Code -112 reported for 368 surfaces
Error Code -113 reported for 2348 surfaces
Error Code -116 reported for 17 surfaces
Error Code -1000 reported for 1 surface

Error Codes

The following errors were encountered during the computation:

-105 = More than two surface / slope intersections with no valid slip surface.
-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.
-113 = Surface intersects outside slope limits.
-116 = Not enough slices to analyze the surface Increase the number of slices in the job control in the modeler.

-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.13585

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	2.31924	326.547	-46.7084	Soil Cover	100	28	105.939	120.331	38.2368	-3588.09	38.2368
2	4.24172	2286.75	-46.7084	Landfill	100	25	202.053	229.502	277.717	-3370.8	277.717
3	14.2015	20839.3	-39.9259	Landfill	100	25	470.589	534.518	931.829	-2859.51	931.829
4	11.596	31061.2	-39.5701	Landfill	100	25	802.153	911.126	1739.47	-2189.7	1739.47
5	11.483	44708.2	-39.5701	Landfill	100	25	1132.61	1286.47	2544.39	-1594.64	2544.39
6	0.112974	517.007	-39.5701	Soil Cover	100	28	1459.22	1657.46	2929.15	-1295.66	2929.15
7	1.88956	8850.23	-44.5701	Soil Cover	100	28	1387.37	1575.84	2775.65	-1234.67	2775.65
8	2.98644	14533.5	-44.5701	Clay Liner	270	28	1555.94	1767.32	2816.04	-1084.8	2816.04
9	7.63529	40411.3	-44.5701	Embankment	400	34	2046.16	2324.13	2852.64	-758.342	2852.64
10	4.53417	26390.6	-44.0883	Embankment	400	34	2241.77	2546.32	3182.05	-386.635	3182.05
11	2.06468	12602.8	-44.0883	Clay 1	200	30	1981.61	2250.81	3552.1	-187.2	3552.1
12	2.06468	12948.5	-44.0883	Clay 2	200	30	2032.25	2308.33	3651.73	-62.4	3651.73
13	4.0595	26327.1	-44.0883	Clay 3	200	30	2048.79	2327.12	3806.97	122.689	3684.28
14	14.2511	98276.9	-35.2393	Clay 4	200	27	2077.18	2359.37	4797.48	559.489	4238
15	2.751	19889.6	-35.2393	CL/SM	200	30	2244.54	2549.46	5003.64	934.235	4069.41
16	8.96459	66275.6	-30.5583	Lower Clay	200	27	2134.23	2424.16	5525.16	1160.01	4365.15
17	8.66491	65841.4	-28.8008	Lower Clay	200	27	2127.97	2417.06	5824.99	1473.77	4351.22
18	19.9357	159461	-28.8008	CL/SM	200	30	2287.86	2598.67	6118.99	1964.35	4154.64
19	0.095796	798.362	-22.616	CL/SM	200	30	2479.35	2816.17	6838.88	2307.55	4531.33
20	14.4027	124871	-22.616	Lower Clay	200	27	2269.26	2577.54	7162.18	2496	4666.18
21	1.43289	12943	-22.616	CL/SM	200	30	2578.9	2929.24	7429.01	2701.82	4727.19
22	12.9698	117189	-22.616	CL/SM	200	30	2491.72	2830.22	7444.7	2889.02	4555.68
23	1.58581	14257.4	-22.616	Lower Clay	200	27	2141.51	2432.43	7459.61	3078.21	4381.4
24	13.1914	116609	-15.1944	Lower Clay	200	27	2263.22	2570.68	7863.34	3210.6	4652.74
25	12.8371	109074	-10.9589	Lower Clay	200	27	2176.4	2472.06	7859.09	3399.93	4459.16
26	12.2713	98906.5	-6.70049	Lower Clay	200	27	2070.23	2351.47	7744.97	3522.47	4222.5
27	11.7817	88846.4	-2.39821	Lower Clay	200	27	1945.36	2209.64	7526.99	3582.84	3944.15
28	19.2782	132888	2.01703	Lower Clay	200	27	1779.43	2021.16	7151.27	3577.06	3574.21
29	19.2782	133045	2.01703	Lower Clay	200	27	1805.25	2050.49	7166.46	3534.69	3631.77
30	25.4793	173394	2.01711	Lower Clay	200	27	1782.93	2025.14	7067.56	3485.51	3582.05
31	8.67627	53469.5	5.28622	Lower Clay	200	27	1587.21	1802.83	6578.19	3432.46	3145.73
32	12.1484	69092.3	8.30829	Lower Clay	200	27	1470.56	1670.34	6237.77	3352.07	2885.7
33	5.42382	29773.3	8.98565	Lower Clay	200	27	1428.02	1622.02	6060.84	3269.96	2790.88
34	18.5022	97665.3	9.13252	Lower Clay	200	27	1382.5	1570.31	5839.79	3150.4	2689.39
35	0.0957966	489.918	9.13252	CL/SM	200	30	1541.72	1751.16	5743.81	3057.12	2686.69
36	14.8313	73294.7	11.8682	CL/SM	200	30	1594.52	1811.14	5749.97	2959.39	2790.58
37	13.6459	62945	11.8682	CL/SM	200	30	1496.86	1700.21	5371.12	2772.67	2598.45
38	0.778011	3459.04	11.8682	Lower Clay	200	27	1256.8	1427.54	5087.28	2678.1	2409.18
39	13.8049	59049.8	11.8682	Lower Clay	200	27	1214.29	1379.25	4896.89	2582.48	2314.41
40	13.3988	53029.9	12.2563	Lower Clay	200	27	1143.37	1298.7	4557.46	2401.15	2156.31
41	0.0957999	363.69	14.421	Lower Clay	200	27	1157.33	1314.55	4497	2309.57	2187.43
42	38.5538	125289	14.421	CL/SM	200	30	1163.84	1321.95	3942.74	1999.48	1943.26
43	3.83544	10149.7	15.4149	CL/SM	200	30	997.56	1133.08	3273.32	1657.17	1616.15
44	0.0958202	247.845	16.5378	CL/SM	200	30	1007.45	1144.31	3258.87	1623.29	1635.58
45	33.6777	68534.2	16.5378	Lower Clay	200	27	719.012	816.69	2520.72	1310.4	1210.32
46	0.0957965	142.108	16.5378	CL/SM	200	30	636.627	723.113	1903.57	997.513	906.061
47	5.88541	8083.23	18.5204	CL/SM	200	30	631.936	717.784	1831.94	935.113	896.829
48	0.0958562	121.089	18.5204	Clay 4	200	27	524.268	595.49	1648.79	872.598	776.193
49	23.4486	16724.3	23.0301	Clay 4	200	27	401.525	456.072	1063.17	560.598	502.57
50	3.52862	291.111	23.0301	Clay 3	200	30	190.523	216.406	231.216	202.8	28.4163

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.13585

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	2373.12	4292.73	0	0	0
2	2375.44	4290.27	-92.7861	-22.9376	13.8857
3	2379.68	4285.77	712.209	176.065	13.8857
4	2393.88	4273.88	8855.21	2189.09	13.8857
5	2405.48	4264.3	21813.6	5392.52	13.8856
6	2416.96	4254.81	41000.4	10135.7	13.8857
7	2417.08	4254.72	41202	10185.5	13.8856
8	2418.97	4252.86	45340.2	11208.5	13.8856
9	2421.95	4249.91	51594.3	12754.6	13.8857
10	2429.59	4242.39	64701.7	15994.9	13.8857
11	2434.12	4238	73263.4	18111.4	13.8857
12	2436.19	4236	78544.8	19417	13.8857
13	2438.25	4234	83983	20761.4	13.8857
14	2442.31	4230.07	95375.1	23577.6	13.8856
15	2456.56	4220	131763	32573	13.8856
16	2459.31	4218.06	138892	34335.5	13.8857
17	2468.28	4212.76	160933	39784.2	13.8857
18	2476.94	4208	182095	45015.6	13.8857
19	2496.88	4197.04	232252	57415	13.8857
20	2496.97	4197	232431	57459.3	13.8857
21	2511.38	4191	265198	65559.4	13.8857
22	2512.81	4190.4	268267	66318.1	13.8857
23	2525.78	4185	297268	73487.5	13.8857
24	2527.36	4184.34	301366	74500.7	13.8857
25	2540.56	4180.76	320673	79273.3	13.8856
26	2553.39	4178.27	331903	82049.6	13.8857
27	2565.66	4176.83	335467	82930.8	13.8857
28	2577.45	4176.34	332254	82136.4	13.8857
29	2596.72	4177.01	317015	78369.1	13.8857
30	2616	4177.69	301296	74483.1	13.8856
31	2641.48	4178.59	280737	69400.8	13.8857
32	2650.16	4179.39	271309	67070.3	13.8857
33	2662.31	4181.17	254815	62992.7	13.8857
34	2667.73	4182.03	247231	61117.8	13.8857
35	2686.23	4185	221862	54846.4	13.8857
36	2686.33	4185.02	221714	54809.8	13.8857
37	2701.16	4188.13	193336	47794.6	13.8857
38	2714.81	4191	168837	41738.2	13.8857
39	2715.58	4191.16	167650	41444.8	13.8857
40	2729.39	4194.06	147310	36416.4	13.8857
41	2742.79	4196.98	128270	31709.5	13.8856
42	2742.88	4197	128114	31670.9	13.8856
43	2781.44	4206.91	66707	16490.6	13.8857
44	2785.27	4207.97	61246.3	15140.7	13.8857
45	2785.37	4208	61101.6	15104.9	13.8857
46	2819.05	4218	24016	5936.98	13.8857
47	2819.14	4218.03	23926.4	5914.84	13.8857
48	2825.03	4220	18050.4	4462.24	13.8857
49	2825.12	4220.03	17969	4442.12	13.8857
50	2848.57	4230	966.707	238.979	13.8857
51	2852.1	4231.5	0	0	0

List Of Coordinates

Piezoline

X	Y
2056	4234
3000	4234

External Boundary

X	Y
2056	4303.5
2056	4301.77
2056	4255.2
2056	4253.2
2056	4250.2
2056	4238
2056	4236
2056	4234
2056	4230
2056	4220
2056	4218
2056	4208
2056	4197
2056	4191
2056	4185
2056	4175
2056	4169
2056	4165
2056	4153
2056	4149
2056	4140
2056	4119
2056	4104
2056	4093
2056	4050
3000	4050
3000	4093
3000	4104
3000	4119
3000	4140
3000	4149
3000	4153
3000	4165
3000	4169
3000	4175
3000	4185
3000	4191
3000	4197
3000	4208
3000	4218
3000	4220
3000	4230
3000	4234
3000	4236
3000	4240
2877.6	4240
2865.6	4236
2859.6	4234
2852.1	4231.5
2656.1	4231.5
2648.6	4234
2642.6	4236
2632.1	4239.5
2625.5	4239.5
2622.5	4240.5
2609.3	4240.5
2602.5	4238
2585.5	4238
2513	4267
2497.5	4267

2495.5	4267
2418	4292.9
2414	4292.9
2408	4291
2106	4306

Material Boundary

X	Y
2056	4301.77
2106	4304
2420	4288
2426.5	4287.5
2488	4267
2495.5	4267

Material Boundary

X	Y
2420	4288
2455	4276
2473	4264
2479	4264
2488	4267

Material Boundary

X	Y
2056	4255.2
2106	4256.3
2292.5	4252
2447.5	4255.5
2473	4264

Material Boundary

X	Y
2056	4253.2
2106	4254.3
2292.5	4250
2447.5	4253.5
2479	4264

Material Boundary

X	Y
2056	4250.2
2106	4251.3
2292.5	4247
2448	4250.5
2497.5	4267

Material Boundary

X	Y
2056	4238
2585.5	4238

Material Boundary

X	Y
2056	4236
2642.6	4236

Material Boundary

X	Y
2056	4234
2648.6	4234

Material Boundary

X	Y
2056	4230
3000	4230

Material Boundary

X	Y
2056	4220
3000	4220

Material Boundary

X	Y
2056	4218
3000	4218

Material Boundary

X	Y
2056	4208
3000	4208

Material Boundary

X	Y
2056	4197
3000	4197

Material Boundary

X	Y
2056	4191
3000	4191

Material Boundary

X	Y
2056	4185
3000	4185

Material Boundary

X	Y
2056	4175
3000	4175

Material Boundary

X	Y
2056	4169
3000	4169

Material Boundary

X	Y
2056	4165
3000	4165

Material Boundary

X	Y
2056	4153
3000	4153

Material Boundary

X	Y
2056	4149
3000	4149

Material Boundary

X	Y
2056	4140
3000	4140

Material Boundary

X	Y
2056	4119
3000	4119

Material Boundary

X	Y
2056	4104
3000	4104

Material Boundary

X	Y
2056	4093
3000	4093

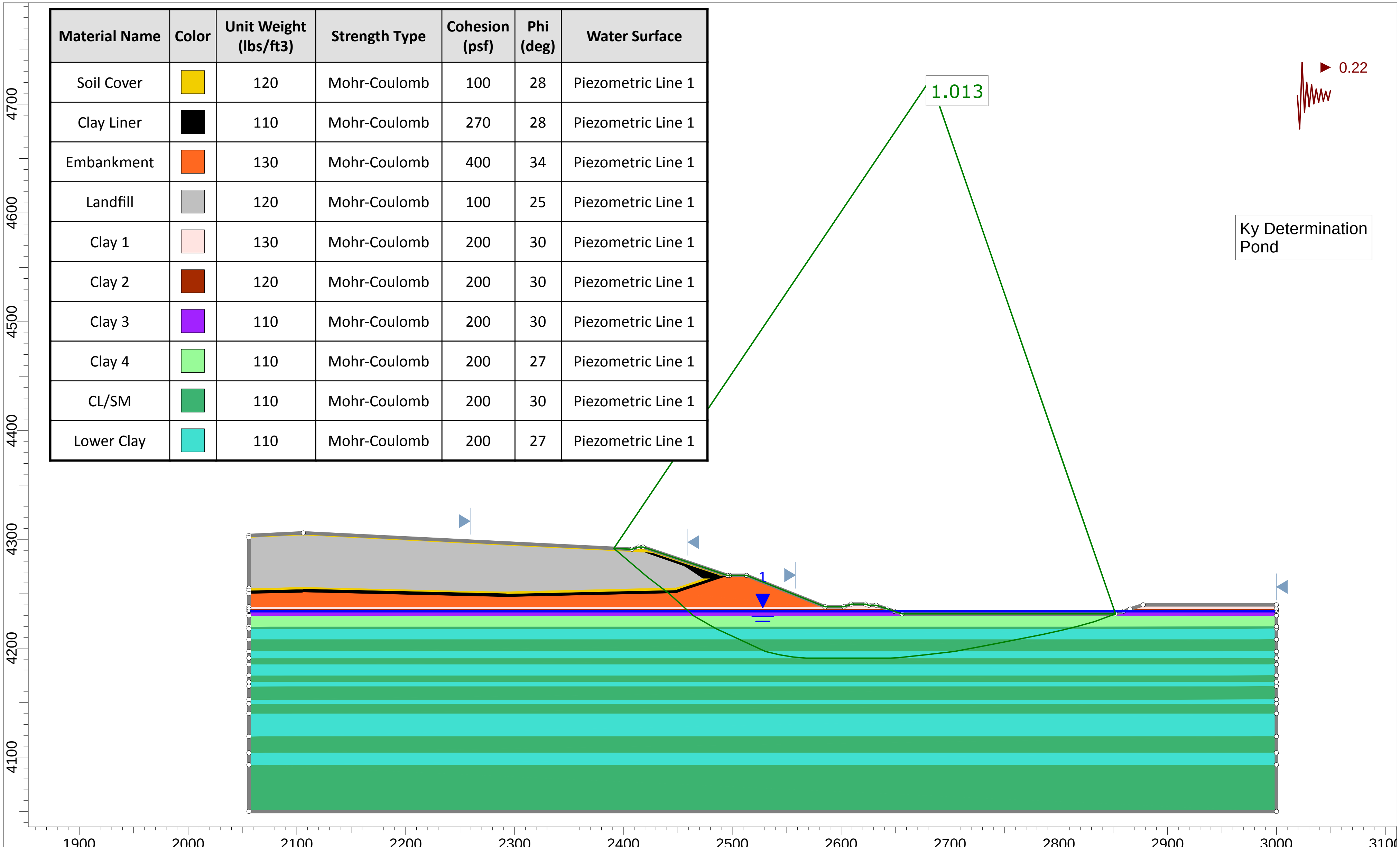
Material Boundary

X	Y
2859.6	4234
3000	4234

Material Boundary

X	Y
2865.6	4236
3000	4236

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Soil Cover		120	Mohr-Coulomb	100	28	Piezometric Line 1
Clay Liner		110	Mohr-Coulomb	270	28	Piezometric Line 1
Embankment		130	Mohr-Coulomb	400	34	Piezometric Line 1
Landfill		120	Mohr-Coulomb	100	25	Piezometric Line 1
Clay 1		130	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 2		120	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 3		110	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 4		110	Mohr-Coulomb	200	27	Piezometric Line 1
CL/SM		110	Mohr-Coulomb	200	30	Piezometric Line 1
Lower Clay		110	Mohr-Coulomb	200	27	Piezometric Line 1



Project	SLIDE - An Interactive Slope Stability Program		
Analysis Description	Cells 8 to 13 - Determine Ky - Pond		
Drawn By JRM	*Scale* 1:1464	*Company*	AGEC
Date 9/8/2017		*File Name*	1160276 Cell 8 to 13 Determine Ky pond.slim

SLIDEINTERPRET 7.013

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	1160276 Cell 8 to 13 Determine Ky pond
Slide Modeler Version:	7.013
Project Title:	SLIDE - An Interactive Slope Stability Program
Analysis:	Cells 8 to 13 - Determine Ky - Pond
Author:	JRM
Company:	AGEC
Date Created:	9/8/2017

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
	Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Search Method:	Auto Refine Search
Divisions along slope:	10
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Loading

Seismic Load Coefficient (Horizontal): 0.22

Material Properties

Property	Soil Cover	Clay Liner	Embankment	Landfill	Clay 1	Clay 2	Clay 3	Clay 4
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	110	130	120	130	120	110	110
Cohesion [psf]	100	270	400	100	200	200	200	200
Friction Angle [deg]	28	28	34	25	30	30	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1	1	1	1	1	1	1

Property	CL/SM	Lower Clay
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	110	110
Cohesion [psf]	200	200
Friction Angle [deg]	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1

Global Minimums

Method: spencer

FS	1.013340
Axis Location:	2681.986, 4722.564
Left Slip Surface Endpoint:	2391.203, 4291.834
Right Slip Surface Endpoint:	2852.100, 4231.500
Resisting Moment:	3.67337e+008 lb-ft
Driving Moment:	3.62503e+008 lb-ft
Resisting Horizontal Force:	644465 lb
Driving Horizontal Force:	635983 lb
Total Slice Area:	16691.5 ft2
Surface Horizontal Width:	460.897 ft
Surface Average Height:	36.2153 ft

Global Minimum Coordinates

Method: spencer

X	Y
2391.2	4291.83
2421.96	4265.55
2441.93	4250.29
2464.23	4230.05
2485.1	4218.04
2507.83	4207.54
2530.45	4197.02
2543.47	4193.92
2555.99	4191.94
2567.99	4191
2620.11	4191
2645.43	4191
2652.77	4191.38
2677.43	4193.93
2703.84	4197.01
2727.94	4201.4
2743.83	4204.45
2785.27	4212.68
2803.51	4216.71
2816.85	4220.02
2832.75	4224.52
2852.1	4231.5

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 1431
Number of Invalid Surfaces: 3070

Error Codes:

Error Code -105 reported for 292 surfaces
Error Code -112 reported for 371 surfaces
Error Code -113 reported for 2388 surfaces
Error Code -116 reported for 16 surfaces
Error Code -1000 reported for 3 surfaces

Error Codes

The following errors were encountered during the computation:

-105 = More than two surface / slope intersections with no valid slip surface.
-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.
-113 = Surface intersects outside slope limits.
-116 = Not enough slices to analyze the surface Increase the number of slices in the job control in the modeler.
-1000 = No valid slip surfaces are generated at a grid center. Unable to draw a surface.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.01334

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	2.94518	418.93	-40.5178	Soil Cover	100	28	124.799	126.464	49.7717	-3530.33	49.7717
2	9.26896	6786.25	-40.5178	Landfill	100	25	291.701	295.592	419.449	-3204.65	419.449
3	9.26896	15567.7	-40.5178	Landfill	100	25	563.996	571.52	1011.18	-2710.35	1011.18
4	9.26896	25660.4	-40.5178	Landfill	100	25	876.954	888.653	1691.27	-2216.06	1691.27
5	13.5098	46690.8	-37.3888	Landfill	100	25	1122.8	1137.78	2225.52	-1646.78	2225.52
6	2.54185	9830.7	-37.3888	Soil Cover	100	28	1379.58	1397.98	2441.14	-1264.03	2441.14
7	3.91873	15747.6	-37.3888	Clay Liner	270	28	1568.87	1589.8	2482.18	-1109.98	2482.18
8	13.5442	62833.8	-42.2223	Embankment	400	34	2030.32	2057.4	2457.19	-633.071	2457.19
9	2.20397	11610.1	-42.2223	Clay 1	200	30	1902.41	1927.79	2992.62	-187.2	2992.62
10	2.20397	11966.3	-42.2223	Clay 2	200	30	1956.07	1982.16	3086.79	-62.4	3086.79
11	4.34948	24509.8	-42.2223	Clay 3	200	30	1969.8	1996.08	3234.05	123.145	3110.91
12	8.73593	51247.3	-29.9155	Clay 4	200	27	2109.86	2138.01	4206.69	403.118	3803.57
13	8.73593	53281.4	-29.9155	Clay 4	200	27	2054.08	2081.48	4409.39	716.773	3692.62
14	3.40195	21410.4	-29.9155	CL/SM	200	30	2239.66	2269.54	4519.23	934.672	3584.56
15	10.8731	70166.2	-24.788	Lower Clay	200	27	2142	2170.57	5019.88	1152.41	3867.47
16	10.8731	74514.3	-24.788	Lower Clay	200	27	2150.99	2179.68	5351.08	1465.74	3885.34
17	0.986582	7059.05	-24.788	CL/SM	200	30	2430.86	2463.29	5556.74	1636.62	3920.12
18	11.3065	83473.4	-24.9538	CL/SM	200	30	2430.09	2462.51	5733.76	1814.98	3918.78
19	11.3065	84063.3	-24.9538	CL/SM	200	30	2281.75	2312.19	5801.69	2143.28	3658.41
20	13.0262	94601.7	-13.4063	Lower Clay	200	27	2245.61	2275.57	6477.82	2404.3	4073.52
21	12.5167	86084.9	-8.95791	Lower Clay	200	27	2143.39	2171.98	6432.96	2562.73	3870.23
22	12.0036	76829.6	-4.49747	Lower Clay	200	27	2017.76	2044.68	6274.14	2653.74	3620.4
23	10.4237	61180	2.08968e-009	Lower Clay	200	27	1882.09	1907.2	6033.78	2683.2	3350.58
24	10.4237	55820.2	2.02969e-009	Lower Clay	200	27	1599.89	1621.23	5472.53	2683.2	2789.33
25	10.4237	54515.7	2.08968e-009	Lower Clay	200	27	1531.2	1551.63	5335.92	2683.2	2652.72
26	10.4237	55746.7	2.08968e-009	Lower Clay	200	27	1596.02	1617.31	5464.82	2683.2	2781.62
27	10.4237	57903.4	2.08968e-009	Lower Clay	200	27	1709.57	1732.38	5690.66	2683.2	3007.46
28	12.6588	69170	-1.71082e-008	Lower Clay	200	27	1659.72	1681.86	5591.52	2683.2	2908.32
29	12.6588	64847.9	-1.71123e-008	Lower Clay	200	27	1472.34	1491.98	5218.85	2683.2	2535.65
30	7.3433	34461.4	2.97996	Lower Clay	200	27	1325.36	1343.04	4914.61	2671.27	2243.34
31	12.3292	53748.8	5.88865	Lower Clay	200	27	1244.52	1261.12	4702.24	2619.67	2082.57
32	12.3292	51821.2	5.88865	Lower Clay	200	27	1199.56	1215.56	4533.47	2540.32	1993.15
33	8.80323	35887.5	6.66322	Lower Clay	200	27	1189.32	1205.19	4441.35	2468.56	1972.79
34	8.80323	34891.6	6.66322	Lower Clay	200	27	1160.47	1175.95	4319.8	2404.39	1915.41
35	8.80323	33895.7	6.66322	Lower Clay	200	27	1131.62	1146.72	4198.25	2340.21	1858.04
36	12.0507	44263.8	10.3205	CL/SM	200	30	1369.15	1387.41	4296.31	2239.66	2056.65
37	12.0507	41354.9	10.3205	CL/SM	200	30	1289.01	1306.21	4018.74	2102.73	1916.01
38	15.8847	49926.5	10.8832	CL/SM	200	30	1212.14	1228.31	3720.06	1938.97	1781.09
39	8.92923	25694.4	11.2314	CL/SM	200	30	1133.61	1148.73	3431.61	1788.36	1643.25
40	8.92923	23952.8	11.2314	CL/SM	200	30	1067.09	1081.33	3204.23	1677.72	1526.51
41	11.7934	28966.9	11.2314	Lower Clay	200	27	865.135	876.676	2877.39	1549.33	1328.06
42	11.7934	25928.9	11.2314	Lower Clay	200	27	791.116	801.669	2584.04	1403.2	1180.84
43	9.12076	17867.8	12.4507	Lower Clay	200	27	744.464	754.395	2355.36	1267.3	1088.06
44	9.12076	15847.4	12.4507	Lower Clay	200	27	678.639	687.692	2098.79	1141.64	957.149
45	5.19154	8077.4	13.9404	Lower Clay	200	27	648.48	657.131	1935.77	1038.61	897.159
46	8.05728	11078.8	13.9404	CL/SM	200	30	670	678.938	1765.55	936	829.547
47	0.0925293	116.933	13.9404	Clay 4	200	27	557.922	565.365	1589.95	872.883	717.072
48	15.891	16131.9	15.8	Clay 4	200	27	503.873	510.595	1341.45	731.87	609.577
49	15.1953	7087.38	19.8323	Clay 4	200	27	358.726	363.511	741.492	420.586	320.906
50	4.15905	343.122	19.8323	Clay 3	200	30	219.826	222.759	242.219	202.8	39.4194

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.01334

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	2391.2	4291.83	0	0	0
2	2394.15	4289.32	-150.117	-41.7766	15.5515
3	2403.42	4281.4	1961.71	545.931	15.5515
4	2412.69	4273.47	8168.88	2273.34	15.5515
5	2421.96	4265.55	19082.9	5310.65	15.5515
6	2435.46	4255.23	37164.2	10342.5	15.5515
7	2438.01	4253.29	40562.4	11288.3	15.5516
8	2441.93	4250.29	45312.8	12610.2	15.5515
9	2455.47	4238	61837.9	17209.1	15.5516
10	2457.67	4236	66184.5	18418.7	15.5515
11	2459.88	4234	70679.5	19669.6	15.5515
12	2464.23	4230.05	80268.7	22338.2	15.5515
13	2472.96	4225.03	94256.4	26230.9	15.5515
14	2481.7	4220	110198	30667.3	15.5515
15	2485.1	4218.04	116135	32319.6	15.5515
16	2495.97	4213.02	133488	37148.7	15.5515
17	2506.85	4208	153362	42679.6	15.5515
18	2507.83	4207.54	155049	43149	15.5515
19	2519.14	4202.28	176103	49008.4	15.5516
20	2530.45	4197.02	199323	55470.1	15.5515
21	2543.47	4193.92	210995	58718.6	15.5516
22	2555.99	4191.94	215798	60055.2	15.5515
23	2567.99	4191	214404	59667.2	15.5515
24	2578.42	4191	208245	57953.2	15.5515
25	2588.84	4191	203849	56729.8	15.5515
26	2599.26	4191	199882	55625.7	15.5515
27	2609.69	4191	195510	54409	15.5515
28	2620.11	4191	190428	52994.9	15.5515
29	2632.77	4191	184635	51382.8	15.5516
30	2645.43	4191	180264	50166.2	15.5515
31	2652.77	4191.38	176234	49044.8	15.5515
32	2665.1	4192.65	166735	46401.3	15.5515
33	2677.43	4193.93	157581	43853.9	15.5516
34	2686.23	4194.95	150439	41866.2	15.5515
35	2695.04	4195.98	143457	39923.1	15.5515
36	2703.84	4197.01	136635	38024.5	15.5515
37	2715.89	4199.21	120445	33519.1	15.5516
38	2727.94	4201.4	105191	29273.9	15.5515
39	2743.83	4204.45	85558.7	23810.4	15.5515
40	2752.76	4206.23	75004.6	20873.3	15.5515
41	2761.68	4208	65064.4	18107	15.5515
42	2773.48	4210.34	54495.7	15165.8	15.5515
43	2785.27	4212.68	44818.6	12472.7	15.5515
44	2794.39	4214.7	37216.2	10357	15.5515
45	2803.51	4216.71	30286.4	8428.5	15.5515
46	2808.7	4218	26202.2	7291.91	15.5516
47	2816.76	4220	19710.1	5485.18	15.5515
48	2816.85	4220.02	19647.7	5467.81	15.5515
49	2832.75	4224.52	9157.49	2548.47	15.5515
50	2847.94	4230	1202.11	334.54	15.5516
51	2852.1	4231.5	0	0	0

List Of Coordinates

Piezoline

X	Y
2056	4234
3000	4234

External Boundary

X	Y
2056	4303.5
2056	4301.77
2056	4255.2
2056	4253.2
2056	4250.2
2056	4238
2056	4236
2056	4234
2056	4230
2056	4220
2056	4218
2056	4208
2056	4197
2056	4191
2056	4185
2056	4175
2056	4169
2056	4165
2056	4153
2056	4149
2056	4140
2056	4119
2056	4104
2056	4093
2056	4050
3000	4050
3000	4093
3000	4104
3000	4119
3000	4140
3000	4149
3000	4153
3000	4165
3000	4169
3000	4175
3000	4185
3000	4191
3000	4197
3000	4208
3000	4218
3000	4220
3000	4230
3000	4234
3000	4236
3000	4240
2877.6	4240
2865.6	4236
2859.6	4234
2852.1	4231.5
2656.1	4231.5
2648.6	4234
2642.6	4236
2632.1	4239.5
2625.5	4239.5
2622.5	4240.5
2609.3	4240.5
2602.5	4238
2585.5	4238
2513	4267
2497.5	4267
2495.5	4267

2418	4292.9
2414	4292.9
2408	4291
2106	4306

Material Boundary

X	Y
2056	4301.77
2106	4304
2420	4288
2426.5	4287.5
2488	4267
2495.5	4267

Material Boundary

X	Y
2420	4288
2455	4276
2473	4264
2479	4264
2488	4267

Material Boundary

X	Y
2056	4255.2
2106	4256.3
2292.5	4252
2447.5	4255.5
2473	4264

Material Boundary

X	Y
2056	4253.2
2106	4254.3
2292.5	4250
2447.5	4253.5
2479	4264

Material Boundary

X	Y
2056	4250.2
2106	4251.3
2292.5	4247
2448	4250.5
2497.5	4267

Material Boundary

X	Y
2056	4238
2585.5	4238

Material Boundary

X	Y
2056	4236
2642.6	4236

Material Boundary

X	Y
2056	4234
2648.6	4234

Material Boundary

X	Y
2056	4230
3000	4230

Material Boundary

X	Y
2056	4220
3000	4220

Material Boundary

X	Y
2056	4218
3000	4218

Material Boundary

X	Y
2056	4208
3000	4208

Material Boundary

X	Y
2056	4197
3000	4197

Material Boundary

X	Y
2056	4191
3000	4191

Material Boundary

X	Y
2056	4185
3000	4185

Material Boundary

X	Y
2056	4175
3000	4175

Material Boundary

X	Y
2056	4169
3000	4169

Material Boundary

X	Y
2056	4165
3000	4165

Material Boundary

X	Y
2056	4153
3000	4153

Material Boundary

X	Y
2056	4149
3000	4149

Material Boundary

X	Y
2056	4140
3000	4140

Material Boundary

X	Y
2056	4119
3000	4119

Material Boundary

X	Y
2056	4104
3000	4104

Material Boundary

X	Y
2056	4093
3000	4093

Material Boundary

X	Y
2859.6	4234
3000	4234

Material Boundary

X	Y
2865.6	4236
3000	4236

APPENDIX E-5

SIMPLIFIED DEFORMATION ANALYSIS

AGEC
Applied GeoTech

PROJECT NO. 1160276 TITLE Cells 8-13 DATE 9/6/17 BY JRM

SUBJECT Simplified Deformation SHEET 1 OF 2

Based on Bray and Travasarou, 2007

Consider a range of periods for the landfill

T_s = 0.05 sec	$1.5\,T_s$ = 0.075 sec
0.5	0.75
1.0	1.5
1.5	2.25

From pseudostatic stability analysis $K_y = 0.26$ g

From Site Response Analysis

T	S
0.075 s	0.2 g
0.75	0.55
1.5	0.38
2.25 s	0.2

Based on:

$$\ln(D) = -1.10 - 2.83\ln(k_y) - 0.333(\ln(k_y))^2 + 0.566\ln(k_y)\ln(S_a(1.5T_s)) + 3.04\ln(S_a(1.5T_s)) - 0.244(\ln(S_a(1.5T_s)))^2 + 1.50T_s + 0.278(M-7) \pm \varepsilon$$

M	6.2
Ky	0.26 g
Eps	0.66

Ts (sec)	1.5Ts (sec)	Sa(1.5Ts) (g)	D (cm)	D -eps (cm)	D + eps (cm)
0.1	0.08	0.20	0.1	0.0	0.2
0.5	0.75	0.55	3.3	1.7	6.3
1.0	1.50	0.38	2.6	1.3	5.0
1.5	2.25	0.20	0.9	0.4	1.6

Estimated deformation max. 6 cm = 2½ inches

Cell 12 - next to pond

Ky = 0.22g

M	6.2
Ky	0.22 g
Eps	0.66

Ts (sec)	1.5Ts (sec)	Sa(1.5Ts) (g)	D (cm)	D -eps (cm)	D + eps (cm)
0.1	0.08	0.20	0.2	0.1	0.3
0.5	0.75	0.55	4.7	2.5	9.2
1.0	1.50	0.38	3.9	2.0	7.5
1.5	2.25	0.20	1.4	0.7	2.6

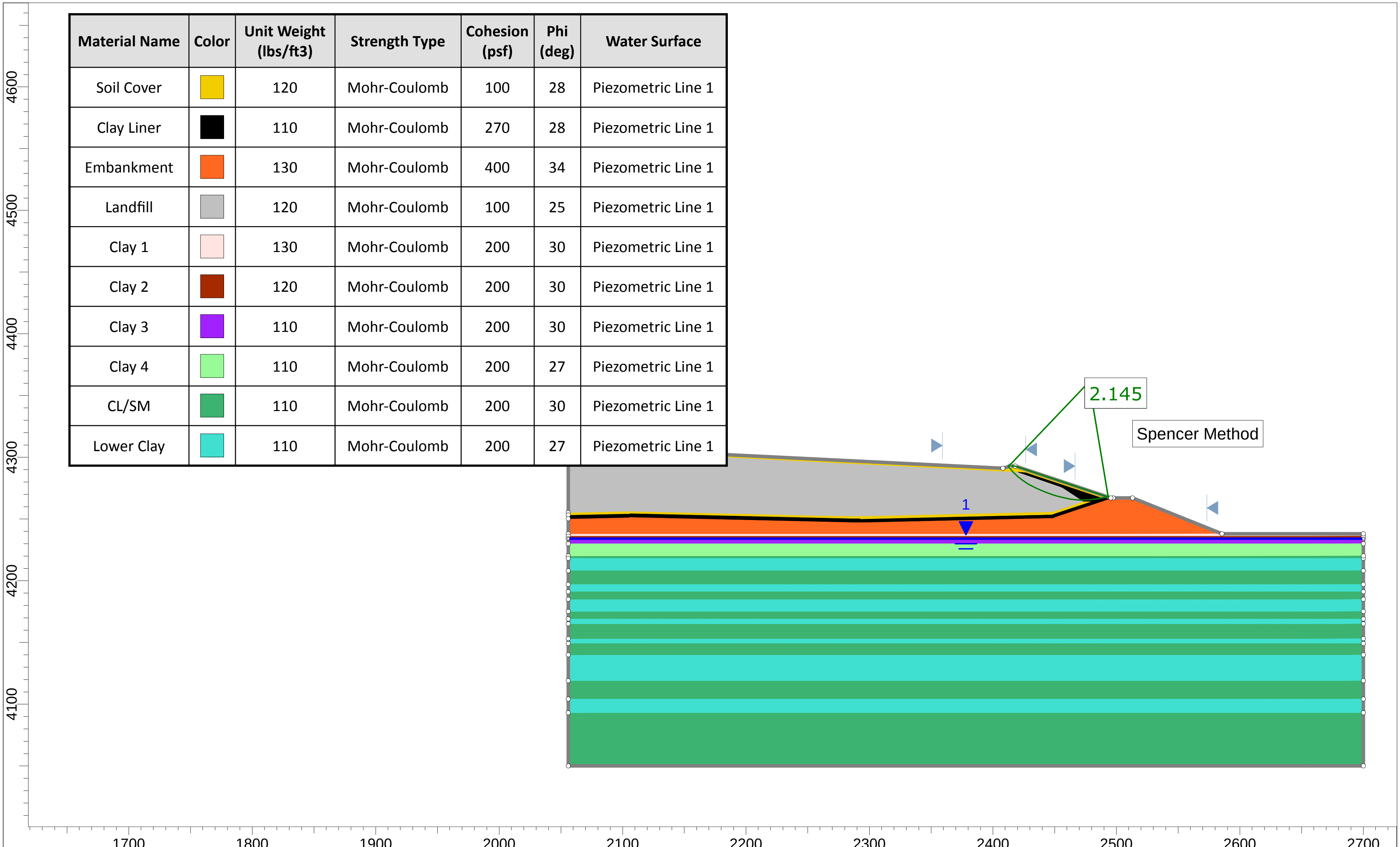
Estimated deformation max 9 cm = 3½ inches

APPENDIX E-6

SLOPE STABILITY - CLOSURE CAP

LONG TERM STATIC

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Soil Cover		120	Mohr-Coulomb	100	28	Piezometric Line 1
Clay Liner		110	Mohr-Coulomb	270	28	Piezometric Line 1
Embankment		130	Mohr-Coulomb	400	34	Piezometric Line 1
Landfill		120	Mohr-Coulomb	100	25	Piezometric Line 1
Clay 1		130	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 2		120	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 3		110	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 4		110	Mohr-Coulomb	200	27	Piezometric Line 1
CL/SM		110	Mohr-Coulomb	200	30	Piezometric Line 1
Lower Clay		110	Mohr-Coulomb	200	27	Piezometric Line 1



Project	SLIDE - An Interactive Slope Stability Program		
Analysis Description	Cells 8 to 13 - Long Term Static (Cap)		
Drawn By JRM	*Scale* 1:1291	*Company* AGEC	
Date 9/8/2017		*File Name* 1160276 Cell 8 to 13 cap - long term static.slim	

SLIDEINTERPRET 7.013

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	1160276 Cell 8 to 13 cap - long term static
Last saved with Slide version:	7.013
Project Title:	SLIDE - An Interactive Slope Stability Program
Analysis:	Cells 8 to 13 - Long Term Static (Cap)
Author:	JRM
Company:	AGEC
Date Created:	9/8/2017

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
	Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Search Method:	Auto Refine Search
Divisions along slope:	10
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Material Properties

Property	Soil Cover	Clay Liner	Embankment	Landfill	Clay 1	Clay 2	Clay 3	Clay 4
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	110	130	120	130	120	110	110
Cohesion [psf]	100	270	400	100	200	200	200	200
Friction Angle [deg]	28	28	34	25	30	30	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1	1	1	1	1	1	1

Property	CL/SM	Lower Clay
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	110	110
Cohesion [psf]	200	200
Friction Angle [deg]	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1

List Of Coordinates

Piezoline

X	Y
2056	4234
2700	4234

External Boundary

X	Y
2056	4303.5
2056	4301.77
2056	4255.2
2056	4253.2
2056	4250.2
2056	4238
2056	4236
2056	4234
2056	4230
2056	4220
2056	4218
2056	4208
2056	4197
2056	4191
2056	4185
2056	4175
2056	4169
2056	4165
2056	4153
2056	4149
2056	4140
2056	4119
2056	4104
2056	4093
2056	4050
2700	4050
2700	4093
2700	4104
2700	4119
2700	4140
2700	4149
2700	4153
2700	4165
2700	4169
2700	4175
2700	4185
2700	4191
2700	4197
2700	4208
2700	4218
2700	4220
2700	4230
2700	4234
2700	4236
2700	4238
2585.5	4238
2513	4267
2497.5	4267
2495.5	4267
2418	4292.9
2414	4292.9
2408	4291
2106	4306

Material Boundary

X	Y
2056	4301.77
2106	4304
2420	4288
2426.5	4287.5
2488	4267
2495.5	4267

Material Boundary

X	Y
2420	4288
2455	4276
2473	4264
2479	4264
2488	4267

Material Boundary

X	Y
2056	4255.2
2106	4256.3
2292.5	4252
2447.5	4255.5
2473	4264

Material Boundary

X	Y
2056	4253.2
2106	4254.3
2292.5	4250
2447.5	4253.5
2479	4264

Material Boundary

X	Y
2056	4250.2
2106	4251.3
2292.5	4247
2448	4250.5
2497.5	4267

Material Boundary

X	Y
2056	4238
2585.5	4238

Material Boundary

X	Y
2056	4236
2700	4236

Material Boundary

X	Y
2056	4234
2700	4234

Material Boundary

X	Y
2056	4230
2700	4230

Material Boundary

X	Y
2056	4220
2700	4220

Material Boundary

X	Y
2056	4218
2700	4218

Material Boundary

X	Y
2056	4208
2700	4208

Material Boundary

X	Y
2056	4197
2700	4197

Material Boundary

X	Y
2056	4191
2700	4191

Material Boundary

X	Y
2056	4185
2700	4185

Material Boundary

X	Y
2056	4175
2700	4175

Material Boundary

X	Y
2056	4169
2700	4169

Material Boundary

X	Y
2056	4165
2700	4165

Material Boundary

X	Y
2056	4153
2700	4153

Material Boundary

X	Y
2056	4149
2700	4149

Material Boundary

X	Y
2056	4140
2700	4140

Material Boundary

X	Y
2056	4119
2700	4119

Material Boundary

X	Y
2056	4104
2700	4104

Material Boundary

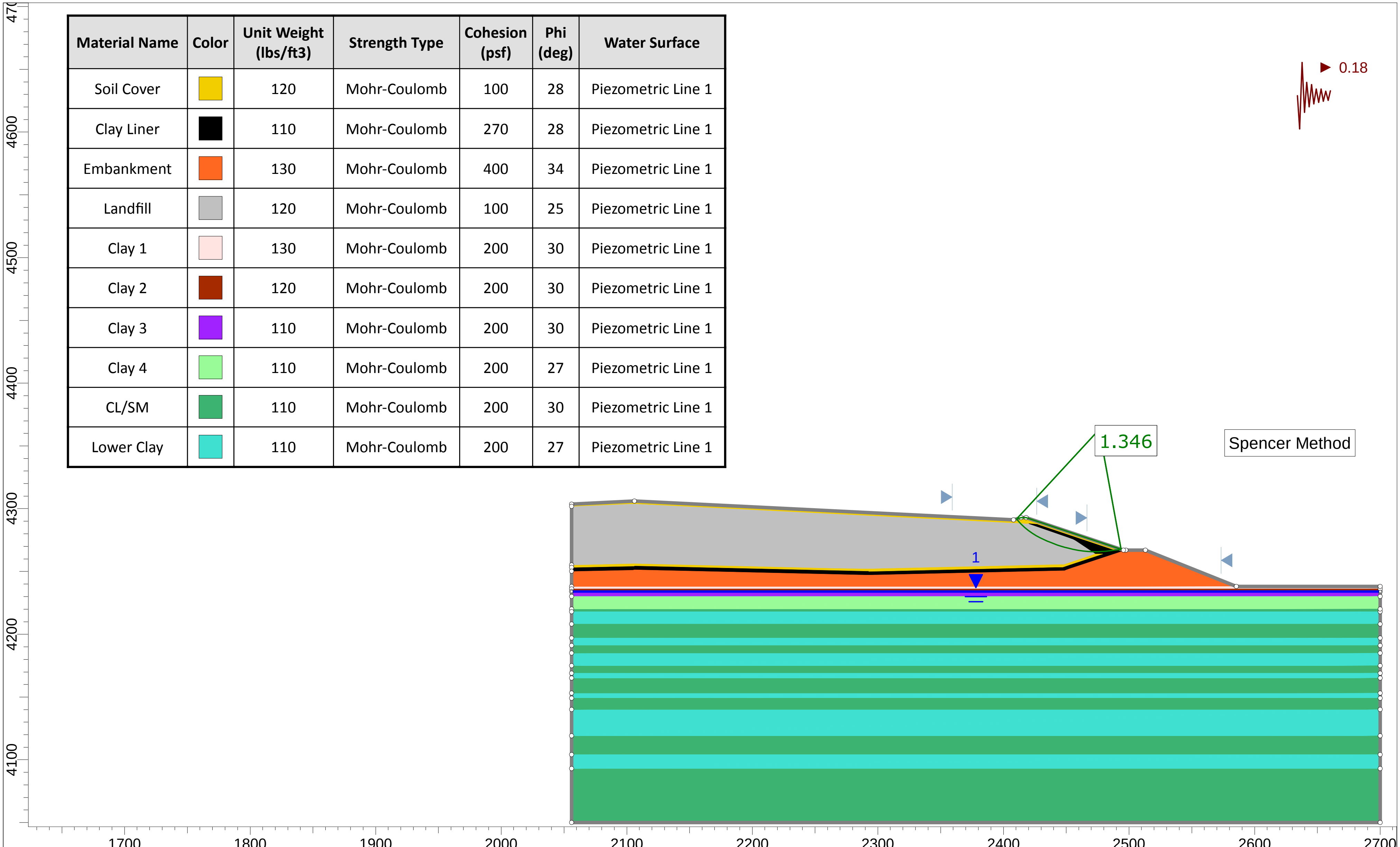
X	Y
2056	4093
2700	4093

APPENDIX E-7

SLOPE STABILITY - CLOSURE CAP

LONG TERM SEISMIC

Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface
Soil Cover		120	Mohr-Coulomb	100	28	Piezometric Line 1
Clay Liner		110	Mohr-Coulomb	270	28	Piezometric Line 1
Embankment		130	Mohr-Coulomb	400	34	Piezometric Line 1
Landfill		120	Mohr-Coulomb	100	25	Piezometric Line 1
Clay 1		130	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 2		120	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 3		110	Mohr-Coulomb	200	30	Piezometric Line 1
Clay 4		110	Mohr-Coulomb	200	27	Piezometric Line 1
CL/SM		110	Mohr-Coulomb	200	30	Piezometric Line 1
Lower Clay		110	Mohr-Coulomb	200	27	Piezometric Line 1



Project	SLIDE - An Interactive Slope Stability Program
Analysis Description	Cells 8 to 13 - Long Term Seismic (Cap)
Drawn By	JRM
Scale	1:1269
Company	AGEC
Date	9/8/2017
File Name	1160276 Cell 8 to 13 cap - long term seismic.slim

SLIDEINTERPRET 7.013

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	1160276 Cell 8 to 13 cap - long term seismic
Slide Modeler Version:	7.013
Project Title:	SLIDE - An Interactive Slope Stability Program
Analysis:	Cells 8 to 13 - Long Term Seismic (Cap)
Author:	JRM
Company:	AGEC
Date Created:	9/8/2017

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
	Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Search Method:	Auto Refine Search
Divisions along slope:	10
Circles per division:	10
Number of iterations:	10
Divisions to use in next iteration:	50%
Number of vertices per surface:	12
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Loading

Seismic Load Coefficient (Horizontal): 0.18

Material Properties

Property	Soil Cover	Clay Liner	Embankment	Landfill	Clay 1	Clay 2	Clay 3	Clay 4
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	120	110	130	120	130	120	110	110
Cohesion [psf]	100	270	400	100	200	200	200	200
Friction Angle [deg]	28	28	34	25	30	30	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1	1	1	1	1	1	1

Property	CL/SM	Lower Clay
Color		
Strength Type	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	110	110
Cohesion [psf]	200	200
Friction Angle [deg]	30	27
Water Surface	Piezometric Line 1	Piezometric Line 1
Hu Value	1	1

Global Minimums

Method: spencer

FS	1.346120
Axis Location:	2476.245, 4362.938
Left Slip Surface Endpoint:	2410.448, 4291.775
Right Slip Surface Endpoint:	2493.697, 4267.603
Resisting Moment:	5.37697e+006 lb-ft
Driving Moment:	3.99444e+006 lb-ft
Resisting Horizontal Force:	51994.3 lb
Driving Horizontal Force:	38625.5 lb
Total Slice Area:	797.967 ft2
Surface Horizontal Width:	83.249 ft
Surface Average Height:	9.58531 ft

Global Minimum Coordinates

Method: spencer

X	Y
2410.45	4291.78
2411.86	4290.01
2414.14	4287.55
2416.95	4284.93
2419.77	4282.6
2422.83	4280.43
2426.17	4278.39
2429.07	4276.82
2432.04	4275.36
2434.79	4274.13
2437.52	4273.01
2440.17	4272
2442.93	4271.04
2445.75	4270.14
2448.71	4269.27
2451.7	4268.49
2455.17	4267.68
2459.58	4266.83
2463.47	4266.25
2467.23	4265.85
2470.55	4265.64
2475.27	4265.71
2478.48	4265.86
2481.42	4266.09
2484.09	4266.38
2487.98	4267
2491.63	4267.27
2493.7	4267.6

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 2039
Number of Invalid Surfaces: 2462

Error Codes:

Error Code -105 reported for 86 surfaces
Error Code -111 reported for 4 surfaces
Error Code -113 reported for 2372 surfaces

Error Codes

The following errors were encountered during the computation:

-105 = More than two surface / slope intersections with no valid slip surface.
-111 = safety factor equation did not converge
-113 = Surface intersects outside slope limits.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.34612

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	1.40708	186.317	-51.3793	Soil Cover	100	28	87.1095	117.26	32.461	-3550.22	32.461
2	1.55332	613.598	-47.2101	Soil Cover	100	28	147.646	198.75	185.721	-3442.91	185.721
3	0.726812	425.664	-47.2101	Landfill	100	25	176.609	237.737	295.379	-3366.06	295.379
4	1.40907	1015.34	-42.9349	Landfill	100	25	214.309	288.485	404.207	-3300.66	404.207
5	1.40907	1237.01	-42.9349	Landfill	100	25	246.788	332.206	497.968	-3218.86	497.968
6	1.40645	1441.1	-39.6483	Landfill	100	25	289.268	389.389	620.597	-3141.59	620.597
7	1.40645	1580.44	-39.6483	Landfill	100	25	310.772	418.337	682.679	-3068.86	682.679
8	1.52968	1833.03	-35.3061	Landfill	100	25	345.566	465.173	783.115	-2998.7	783.115
9	1.52968	1931.9	-35.3061	Landfill	100	25	360.504	485.282	826.242	-2931.1	826.242
10	1.67266	2209.25	-31.4291	Landfill	100	25	392.278	528.053	917.961	-2865.41	917.961
11	1.67266	2294.77	-31.4291	Landfill	100	25	404.746	544.837	953.956	-2801.62	953.956
12	1.4516	2053.54	-28.4044	Landfill	100	25	430.762	579.857	1029.06	-2745.24	1029.06
13	1.4516	2105.45	-28.4044	Landfill	100	25	439.843	592.081	1055.27	-2696.25	1055.27
14	1.48155	2195.91	-26.1195	Landfill	100	25	460.449	619.819	1114.76	-2649.1	1114.76
15	1.48155	2236.82	-26.1195	Landfill	100	25	467.678	629.551	1135.62	-2603.77	1135.62
16	1.37396	2106.11	-24.1202	Landfill	100	25	485.276	653.24	1186.43	-2561.91	1186.43
17	1.37396	2131.65	-24.1202	Landfill	100	25	490.273	659.966	1200.85	-2523.52	1200.85
18	1.36587	2140.38	-22.3725	Landfill	100	25	504.969	679.749	1243.28	-2486.79	1243.28
19	1.36587	2157.54	-22.3725	Landfill	100	25	508.422	684.397	1253.24	-2451.71	1253.24
20	1.32517	2106.24	-20.7685	Landfill	100	25	521.083	701.44	1289.79	-2418.48	1289.79
21	1.32517	2115.56	-20.7685	Landfill	100	25	523.059	704.1	1295.49	-2387.13	1295.49
22	1.37922	2208.35	-19.2591	Landfill	100	25	534.016	718.849	1327.12	-2356.41	1327.12
23	1.37922	2211.63	-19.2591	Landfill	100	25	534.698	719.768	1329.1	-2326.34	1329.1
24	1.41141	2263.17	-17.7595	Landfill	100	25	544.469	732.921	1357.3	-2297.2	1357.3
25	1.41141	2259.65	-17.7595	Landfill	100	25	543.742	731.942	1355.21	-2268.99	1355.21
26	1.48106	2363.59	-16.2513	Landfill	100	25	552.273	743.426	1379.83	-2241.42	1379.83
27	1.48106	2352.15	-16.2513	Landfill	100	25	549.971	740.327	1373.18	-2214.48	1373.18
28	1.49269	2355.25	-14.74	Landfill	100	25	557.084	749.902	1393.72	-2188.76	1393.72
29	1.49269	2336.02	-14.74	Landfill	100	25	553.171	744.634	1382.43	-2164.25	1382.43
30	1.73762	2689.63	-13.107	Landfill	100	25	559.084	752.594	1399.49	-2139.38	1399.49
31	1.73762	2652.57	-13.107	Landfill	100	25	552.462	743.68	1380.38	-2114.13	1380.38
32	2.20339	3289.81	-10.9353	Landfill	100	25	556.863	749.605	1393.08	-2088.23	1393.08
33	2.20339	3191.49	-10.9353	Landfill	100	25	542.6	730.405	1351.91	-2061.66	1351.91
34	1.94494	2725.31	-8.45092	Landfill	100	25	544.251	732.627	1356.67	-2039.36	1356.67
35	1.94494	2628.44	-8.45092	Landfill	100	25	527.785	710.462	1309.14	-2021.33	1309.14
36	1.88174	2441.69	-6.02462	Landfill	100	25	526.075	708.16	1304.21	-2006.12	1304.21
37	1.88174	2332.72	-6.02462	Landfill	100	25	506.275	681.507	1247.04	-1993.73	1247.04
38	1.65914	1959.31	-3.58507	Landfill	100	25	501.952	675.688	1234.57	-1984.29	1234.57
39	1.65914	1860.44	-3.58507	Landfill	100	25	480.855	647.289	1173.67	-1977.8	1173.67
40	2.36112	2470.5	0.8345	Clay Liner	270	28	702.322	945.41	1270.26	-1975.63	1270.26
41	2.36112	2256.58	0.8345	Clay Liner	270	28	662.315	891.555	1168.97	-1977.78	1168.97
42	1.60564	1407.71	2.70565	Clay Liner	270	28	644.479	867.546	1123.82	-1981.22	1123.82
43	1.60564	1299.52	2.70565	Clay Liner	270	28	613.759	826.193	1046.05	-1985.95	1046.05
44	1.47049	1091.64	4.41987	Clay Liner	270	28	598.011	804.994	1006.18	-1991.87	1006.18
45	1.47049	993.747	4.41987	Clay Liner	270	28	566.73	762.887	926.989	-1998.96	926.989
46	1.33459	813.986	6.26311	Clay Liner	270	28	550.675	741.274	886.341	-2007.07	886.341
47	1.33459	726.992	6.26311	Clay Liner	270	28	518.997	698.632	806.138	-2016.21	806.138
48	3.88992	1582.54	8.97584	Clay Liner	270	28	470.801	633.754	684.121	-2039.95	684.121
49	3.64808	774.318	4.22918	Soil Cover	100	28	191.499	257.781	296.744	-2067.54	296.744
50	2.06567	126.954	9.18431	Soil Cover	100	28	129.068	173.741	138.686	-2086.38	138.686

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.34612

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	2410.45	4291.78	0	0	0
2	2411.86	4290.01	-31.8594	-12.7863	21.8673
3	2413.41	4288.34	160.891	64.5709	21.8672
4	2414.14	4287.55	341.069	136.882	21.8672
5	2415.54	4286.24	751.765	301.709	21.8673
6	2416.95	4284.93	1279.52	513.513	21.8672
7	2418.36	4283.76	1855.39	744.629	21.8672
8	2419.77	4282.6	2498.45	1002.71	21.8672
9	2421.3	4281.51	3148.15	1263.46	21.8673
10	2422.83	4280.43	3839.52	1540.93	21.8673
11	2424.5	4279.41	4519.34	1813.76	21.8672
12	2426.17	4278.39	5230.49	2099.17	21.8672
13	2427.62	4277.6	5782.67	2320.78	21.8673
14	2429.07	4276.82	6351.58	2549.11	21.8673
15	2430.56	4276.09	6874.46	2758.95	21.8672
16	2432.04	4275.36	7409.15	2973.54	21.8672
17	2433.41	4274.75	7851.36	3151.02	21.8673
18	2434.79	4274.13	8300.19	3331.15	21.8673
19	2436.15	4273.57	8694.71	3489.48	21.8673
20	2437.52	4273.01	9093.2	3649.41	21.8673
21	2438.84	4272.51	9429.99	3784.57	21.8672
22	2440.17	4272	9768.7	3920.51	21.8673
23	2441.55	4271.52	10069.2	4041.11	21.8673
24	2442.93	4271.04	10370.3	4161.96	21.8673
25	2444.34	4270.59	10622.8	4263.28	21.8672
26	2445.75	4270.14	10874.7	4364.38	21.8672
27	2447.23	4269.7	11077.9	4445.94	21.8673
28	2448.71	4269.27	11279.6	4526.88	21.8672
29	2450.2	4268.88	11419.3	4582.95	21.8673
30	2451.7	4268.49	11557	4638.2	21.8672
31	2453.43	4268.08	11635.8	4669.86	21.8673
32	2455.17	4267.68	11711.8	4700.34	21.8673
33	2457.37	4267.25	11670	4683.58	21.8673
34	2459.58	4266.83	11624.5	4665.29	21.8672
35	2461.52	4266.54	11448.5	4594.68	21.8673
36	2463.47	4266.25	11273.4	4524.41	21.8673
37	2465.35	4266.05	10982	4407.45	21.8673
38	2467.23	4265.85	10696.9	4293.02	21.8672
39	2468.89	4265.75	10345.1	4151.83	21.8672
40	2470.55	4265.64	10004.1	4015	21.8673
41	2472.91	4265.68	8746.87	3510.41	21.8672
42	2475.27	4265.71	7549.04	3029.69	21.8673
43	2476.88	4265.79	6682.35	2681.85	21.8672
44	2478.48	4265.86	5851.41	2348.37	21.8673
45	2479.95	4265.98	5054.18	2028.41	21.8672
46	2481.42	4266.09	4294.32	1723.46	21.8673
47	2482.76	4266.24	3576.09	1435.21	21.8673
48	2484.09	4266.38	2896.23	1162.35	21.8672
49	2487.98	4267	929.361	372.984	21.8673
50	2491.63	4267.27	290.079	116.419	21.8673
51	2493.7	4267.6	0	0	0

List Of Coordinates

Piezoline

X	Y
2056	4234
2700	4234

External Boundary

X	Y
2056	4303.5
2056	4301.77
2056	4255.2
2056	4253.2
2056	4250.2
2056	4238
2056	4236
2056	4234
2056	4230
2056	4220
2056	4218
2056	4208
2056	4197
2056	4191
2056	4185
2056	4175
2056	4169
2056	4165
2056	4153
2056	4149
2056	4140
2056	4119
2056	4104
2056	4093
2056	4050
2700	4050
2700	4093
2700	4104
2700	4119
2700	4140
2700	4149
2700	4153
2700	4165
2700	4169
2700	4175
2700	4185
2700	4191
2700	4197
2700	4208
2700	4218
2700	4220
2700	4230
2700	4234
2700	4236
2700	4238
2585.5	4238
2513	4267
2497.5	4267
2495.5	4267
2418	4292.9
2414	4292.9
2408	4291
2106	4306

Material Boundary

X	Y
2056	4301.77
2106	4304
2420	4288
2426.5	4287.5
2488	4267
2495.5	4267

Material Boundary

X	Y
2420	4288
2455	4276
2473	4264
2479	4264
2488	4267

Material Boundary

X	Y
2056	4255.2
2106	4256.3
2292.5	4252
2447.5	4255.5
2473	4264

Material Boundary

X	Y
2056	4253.2
2106	4254.3
2292.5	4250
2447.5	4253.5
2479	4264

Material Boundary

X	Y
2056	4250.2
2106	4251.3
2292.5	4247
2448	4250.5
2497.5	4267

Material Boundary

X	Y
2056	4238
2585.5	4238

Material Boundary

X	Y
2056	4236
2700	4236

Material Boundary

X	Y
2056	4234
2700	4234

Material Boundary

X	Y
2056	4230
2700	4230

Material Boundary

X	Y
2056	4220
2700	4220

Material Boundary

X	Y
2056	4218
2700	4218

Material Boundary

X	Y
2056	4208
2700	4208

Material Boundary

X	Y
2056	4197
2700	4197

Material Boundary

X	Y
2056	4191
2700	4191

Material Boundary

X	Y
2056	4185
2700	4185

Material Boundary

X	Y
2056	4175
2700	4175

Material Boundary

X	Y
2056	4169
2700	4169

Material Boundary

X	Y
2056	4165
2700	4165

Material Boundary

X	Y
2056	4153
2700	4153

Material Boundary

X	Y
2056	4149
2700	4149

Material Boundary

X	Y
2056	4140
2700	4140

Material Boundary

X	Y
2056	4119
2700	4119

Material Boundary

X	Y
2056	4104
2700	4104

Material Boundary

X	Y
2056	4093
2700	4093

APPENDIX E-8

INTERFACE STABILITY

SOIL PROTECTIVE COVER

PROJECT NO. 1160276 TITLE Cells 8 - 13 DATE 9/1/17 BY JRm

SUBJECT Protective Soil Cover Stability SHEET 1 OF 2

Interface Surfaces: (lower 10 ft)
- soil cover / Textured 80 mil HDPE
- Textured 80 mil HDPE / GCL
- GCL / Textured 80 mil HDPE
- Textured 80 mil HDPE / welded geocomposite (Non-woven geotextile)
- welded geocomposite / textured 60 mil HDPE
- textured 60 mil HDPE / clay liner

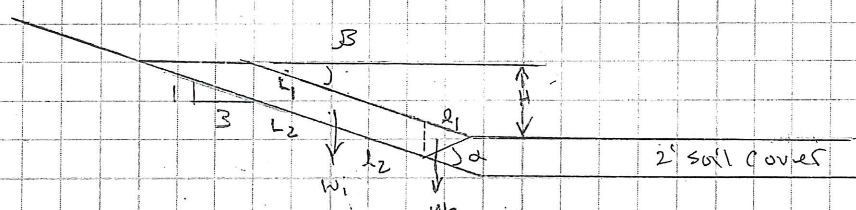
* critical surface is soil cover / textured HDPE

$\phi_{soil} = 28°$ use 85% 23.8° for contact

Interface Surfaces: (above 10' up slope)
- soil cover / textured 80 mil HDPE
- Textured 80 mil HDPE / GCL
- GCL / double-sided geocomposite
- double-sided geocomposit / 60 mil textured HDPE
- 60 mil textured HDPE / clay liner

* critical surface assumed between GCL and double-sided geocomposite
assumed $\phi = 22.5°$

Configuration:



$\alpha = 45° - \frac{28}{2} = 31°$ (where 28° is assumed ϕ for soil cover)

$\beta = \tan^{-1} 1/3 = 18.43°$

Failure slope $= \alpha - \beta = 12.57° = \theta$

$w_1 = \left(\frac{L_1 + L_2}{2}\right)(d)(\gamma)$ $d = 2'$, $\gamma = 110$ pcf

$l_1 = \frac{2}{\tan\alpha} + 2\tan\beta = 3.995$

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 9/1/17 BY JRM

SUBJECT Protective Soil Cover Stability SHEET 2 OF 2

$$l_2 = \frac{2}{\tan\beta} - \frac{2}{\tan\alpha} = 2.671$$

$$L_1 = \frac{H}{\sin\beta} - l_1 \qquad L_2 = \frac{H}{\sin\beta} + l_2$$

$$w_1 = \left[\frac{\frac{H}{\sin\beta} - 3.995 + \frac{H}{\sin\beta} + 2.671}{2}\right](2)(110)$$

$$= \left[\frac{2H}{\sin\beta} - 1.324\right](110) = 695.70H - 145.64$$

$$w_2 = \tfrac{1}{2} l_1 d \gamma = \tfrac{1}{2}(3.995)(2)(110) = 439.45 \text{ lb}$$

$$SF = \frac{\text{Resisting Forces}}{\text{Driving Forces}}$$

$$= \frac{w_1 \cos\beta \tan\phi_\ell + w_2 \cos\theta \tan\phi_{soil} + w_2 \sin\theta}{w_1 \sin\beta}$$

$$= \frac{(695.70H - 145.64)(\cos 18.43^\circ)(\tan 22.5^\circ) + (439.45)(\cos 12.57^\circ)(\tan 28^\circ) + (439.45)(\sin 12.57^\circ)}{(695.70H - 145.64)(\sin 18.43)}$$

$$= \frac{273.4H + 262.76}{219.94H - 46.04}$$

H	SF
2	2.1
4	1.6
6	1.5
8	1.4
10	1.4

Including small amount of tension in the 80 mil HDPE

$$SF = \frac{273.4H + 262.76 + T}{219.94H - 46.04}$$

for H = 10 ft
T = 200 lb/ft

SF = 1.5 OK

APPENDIX E-9

INTERFACE STABILITY

ENTRY RAMP

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PROJECT NO. 1160276 TITLE Cell 8-13 DATE 9/7/16 BY JRM

SUBJECT Entry Ramp Stability SHEET 1 OF 1

Slope : 10% = 5.71°

Interface Surfaces

Lower Ramp: soil cover (3') / textured 80 mil HDPE
textured 80 mil HDPE / GCL
GCL / textured 80 mil HDPE
textured 80 mil HDPE / double sided geocomposite
double sided geocomposite / textured 60 mil HDPE
textured 60 mil HDPE / clay liner

Upper Ramp: soil cover / textured 80 mil HDPE
textured 80 mil HDPE / GCL
GCL / double sided geocomposit
double sided geocomposit / textured 60 mil HDPE
textured 60 mil HDPE / clay liner

critical interface is GCL / double-sided geocomposit

$\phi = 22.5°$

Stability:

$$\text{static } SF = \frac{\tan 22.5°}{\tan 5.71°} = 4.1 > 1.5 \quad \text{ok}$$

$$\text{Seismic } SF = \left[\frac{\cos i}{\sin i + k \cos i}\right] \tan\phi$$

$$= \left[\frac{\cos 5.71°}{\sin 5.71° + 0.18 \cos 5.71°}\right] \tan 22.5°$$

$$= 1.5 > 1.3 \quad \text{ok}$$

APPENDIX E-10

INTERFACE STABILITY

CLOSURE CAP

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 9/19/17 BY JRM

SUBJECT Interface Stability - Closure Cap SHEET 1 OF 2

① 3H:1V slope around perimeter of closure cap

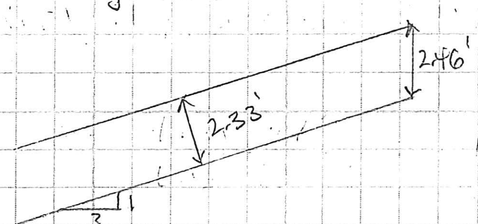
- 60 mil textured HDPE / compacted clay

For clay in contact with textured HDPE, the strength of the clay is expected to control.
(Jones & Dixon, 1998)

For compacted clay: $c = 270$ psf
$\phi = 28°$ use $28(.95) = 23.8°$
$\gamma = 120$ pcf

Slope = 3H:1V = 18.43°

Slope Length (l) = 65 ft



$W = (120)(2.33)(65) = 18,174$ lb/ft

$W \cos 18.43° = 17,242$ lb/ft

$W \cos 18.43° \tan 23.8° = 7,605$ lb/ft

$cl = (270)(65) = 17,550$ lb/ft

Seismic $= (0.18)(W) = 3,271$ lb/ft

$W \sin 18.43° = 5,746$ lb/ft

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 9/19/17 BY JRM

SUBJECT Interface Stability - Closure Cap SHEET 2 OF 2

Static:

Driving = 5,746 lb/ft

Resist = 7,605 + 17,550 = 25,155 lb/ft

$FS = \frac{25,155}{5,746} = 4.4$ OK

Seismic:

Driving = 5,746 + 3,271 = 9,017 lb/ft

Resist = 25,155 lb/ft

$FS = \frac{25,155}{9,017} = 2.8$ OK

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 9/19/17 BY JRM

SUBJECT Interface Stability - Closure Cap SHEET 1 OF

(2) 5% Slope at top of closure cap

$5\% = 2.86°$

critical surface is textured HDPE vs. geocomposite based on previous testing by AGEC $\phi = 26.9°$ (wet)

Static Stability:

$$FS = \frac{\tan 26.9°}{\tan 2.86°} = 10 \quad ok$$

Seismic Stability:

$$FS = \left[\frac{\cos 2.86}{\sin 2.86 + 0.18 \cos 2.86}\right] \tan 26.9° = 2.2 \quad ok$$

APPENDIX F

BEARING CAPACITY

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JRM

SUBJECT Bearing Capacity SHEET 1 OF 2

Typical cell dimensions 780' x 780' (inside crest to inside crest)
1050' x 174' (embankment)

Load ave 58' high x 120 = 6960 psf single cell

28' high x 130 = 3640 psf embankment

Bearing - undrained $\phi = 0$ for clay

Meyerhoff

$$q_{ult} = cN_c s_c d_c + \bar{q} N_q s_q d_q + \tfrac{1}{2} \gamma B N_\gamma s_\gamma d_\gamma$$

$$N_q = e^{\pi \tan\phi} \tan^2(45 + \tfrac{\phi}{2}) = 1 \quad \text{for } \phi = 0$$

$$N_c = (N_q - 1)\cot\phi = 5.7 \quad \text{for } \phi = 0$$

$$N_\gamma = (N_q - 1)\tan(1.4\phi) = 0 \quad \text{for } \phi = 0$$

$$s_q = s_\gamma = d_q = d_\gamma = 1 \quad \text{for } \phi = 0$$

$$s_c = 1 + 0.2 K_p \frac{B}{L} \quad K_p = \tan^2(45 + \tfrac{\phi}{2}) = 1 \text{ for } \phi = 0$$

$$q_{ult} = c(5.14)\left(1 + 0.2\left(\tfrac{780}{780}\right)\right) = 6.17c \quad \text{single cell}$$

$$= c(5.14)\left(1 + 0.2\left(\tfrac{174}{1050}\right)\right) = 5.31c \quad \text{embank. only}$$

		Entire cell		Embmk. only	
	c, psf	qult, ksf	SF	qult, ksf	SF
upper clay	3700	22.8	4.5	19.6	5.8
2nd clay	1900	11.7	2.3	10.1	3.0
Ave upper 19'	963	5.9	1.2	5.1	1.5

Bearing - drained $\phi = 27°$ $c = 200$ psf $K_p = 2.663$ $N_q = 13.2$

$N_c = 23.94$ $s_c(\text{cell}) = 1.533$ $s_c(\text{embmk}) = 1.088$

$N_\gamma = 9.463$ $s_\gamma = 1 + 0.1 K_p \frac{B}{L}$ $s_\gamma(\text{cell}) = 1.266$ $s_\gamma(\text{embank}) = 1.044$

$$q_{ult} = 200(23.94)(1.533)(1) + \tfrac{1}{2}(110)(780)(9.463)(1.266)(1) = 521 \text{ ksf (cell)}$$

$$= 200(23.94)(1.088)(1) + \tfrac{1}{2}(110)(174)(9.463)(1.044)(1) = 100 \text{ ksf (emb.)}$$

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PROJECT NO. 1160276 TITLE Cells 8-13 DATE 8/31/17 BY JRM

SUBJECT Bearing Capacity SHEET 2 OF 2

under drained condition

$$FS_{coll} = \frac{521}{6.96} = 75$$

$$FS_{emb} = \frac{100}{3.64} = 27$$

- The embankment and fill will be placed slow enough that undrained conditions are not reached.
- The rate of loading will result in a condition closer to the drained case.
- Slope stability analysis will govern design.

For the bearing capacity of the soil cover use

$$q_{all} = 250\ B + 600\ D$$ (from previous work)

For the bearing capacity of the clay liner

q_{all} = 1,500 psf static
2,000 psf impact load

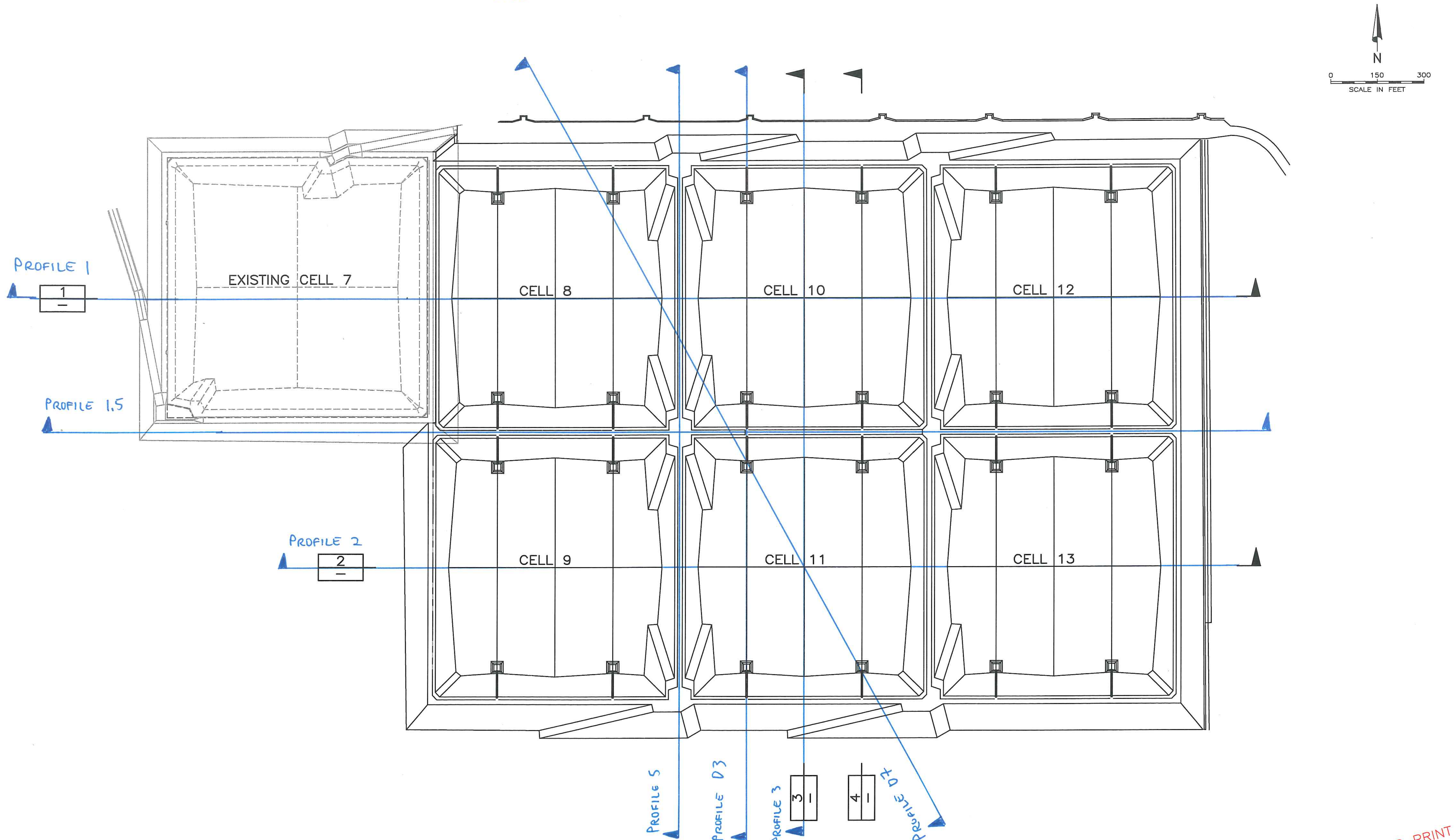
(From previous work)

APPENDIX G

SETTLEMENT ANALYSIS

CLEAN HARBORS 116026 TJN 6/29/17

PREDICTED SETTLEMENT PROFILES



PLAN VIEW

PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\LAYOUT\PLAN VIEW.DWG
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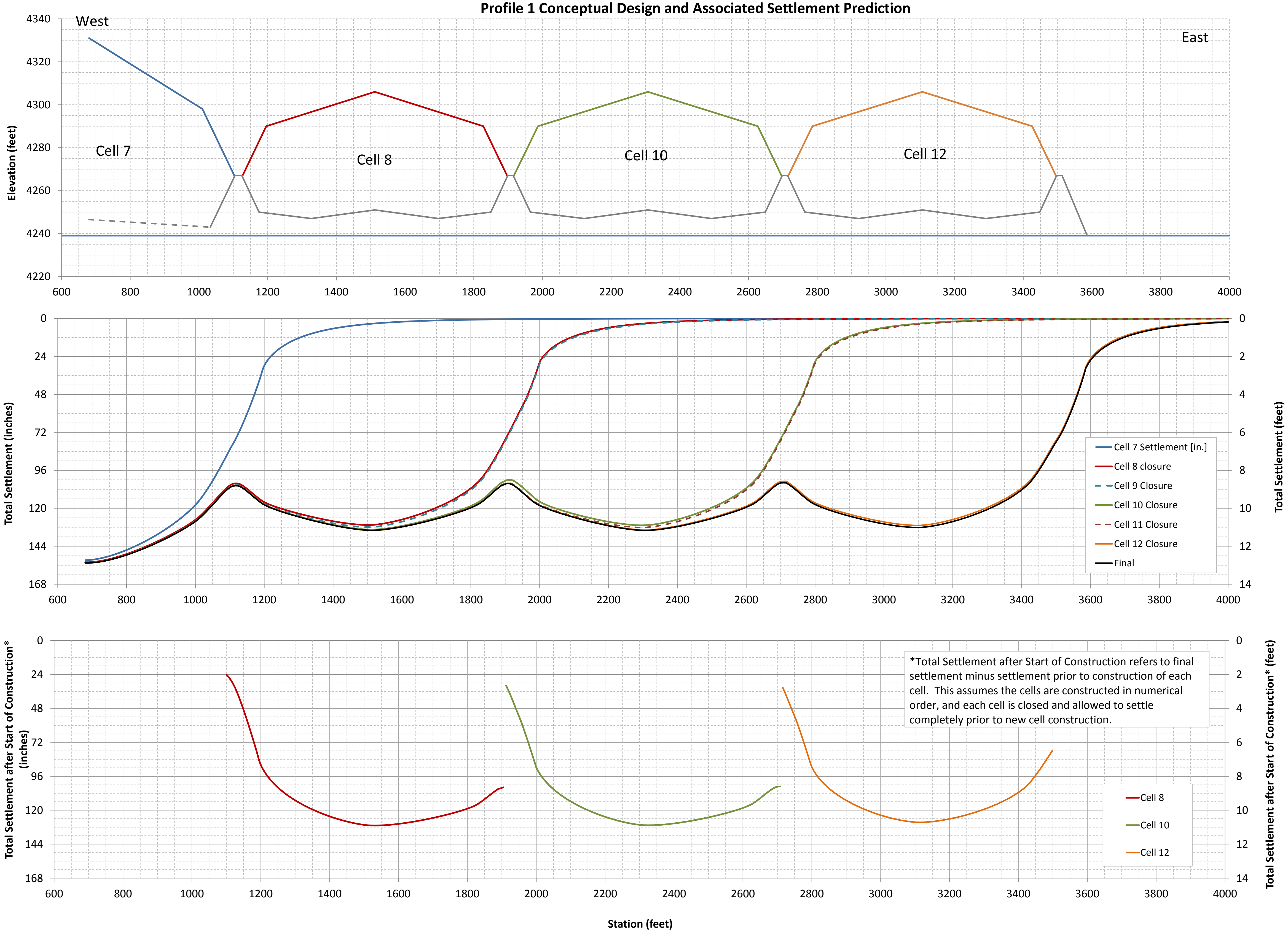
Consultants/Engineers

Profile 1 Conceptual Design and Associated Settlement Prediction



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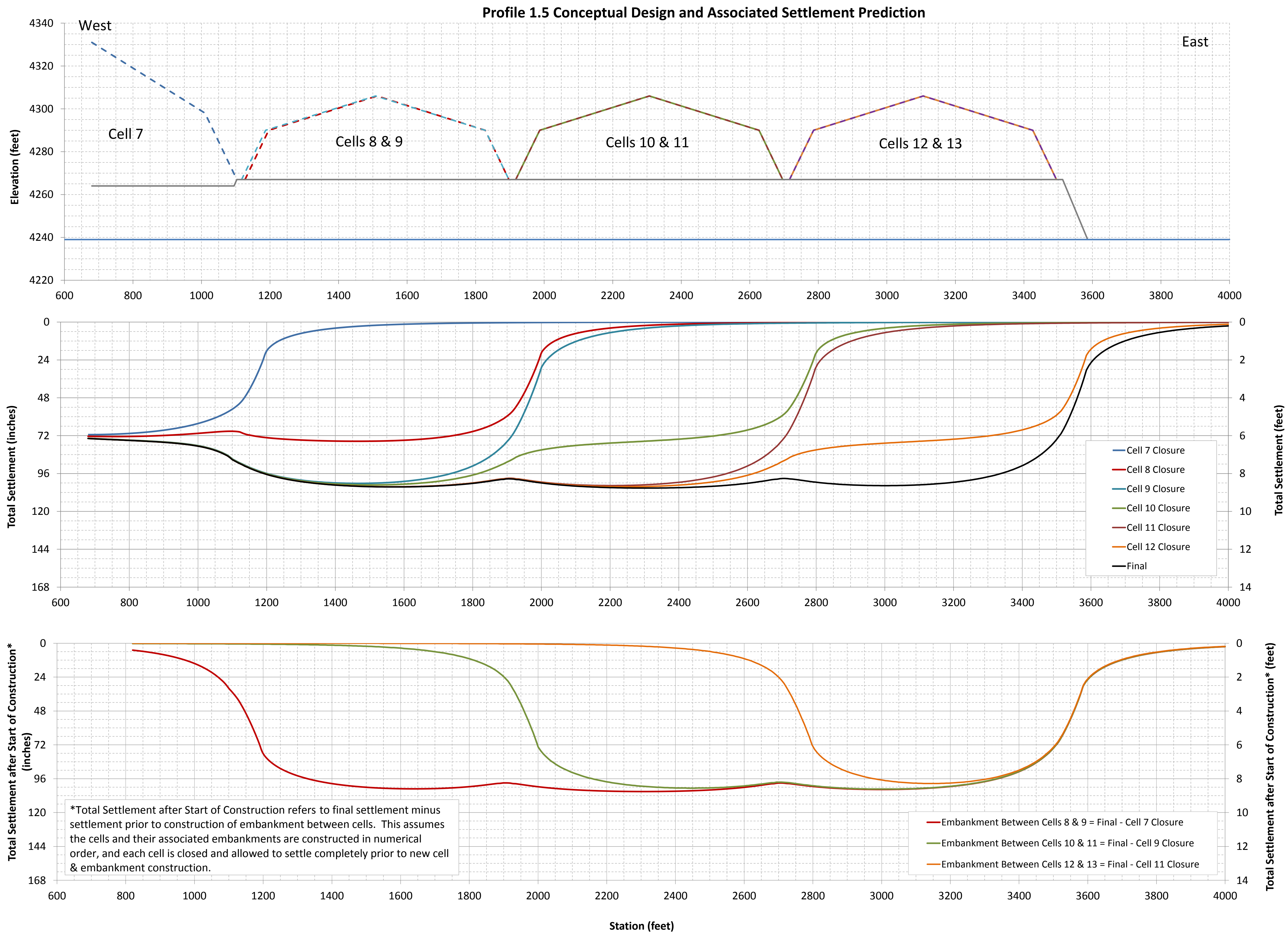
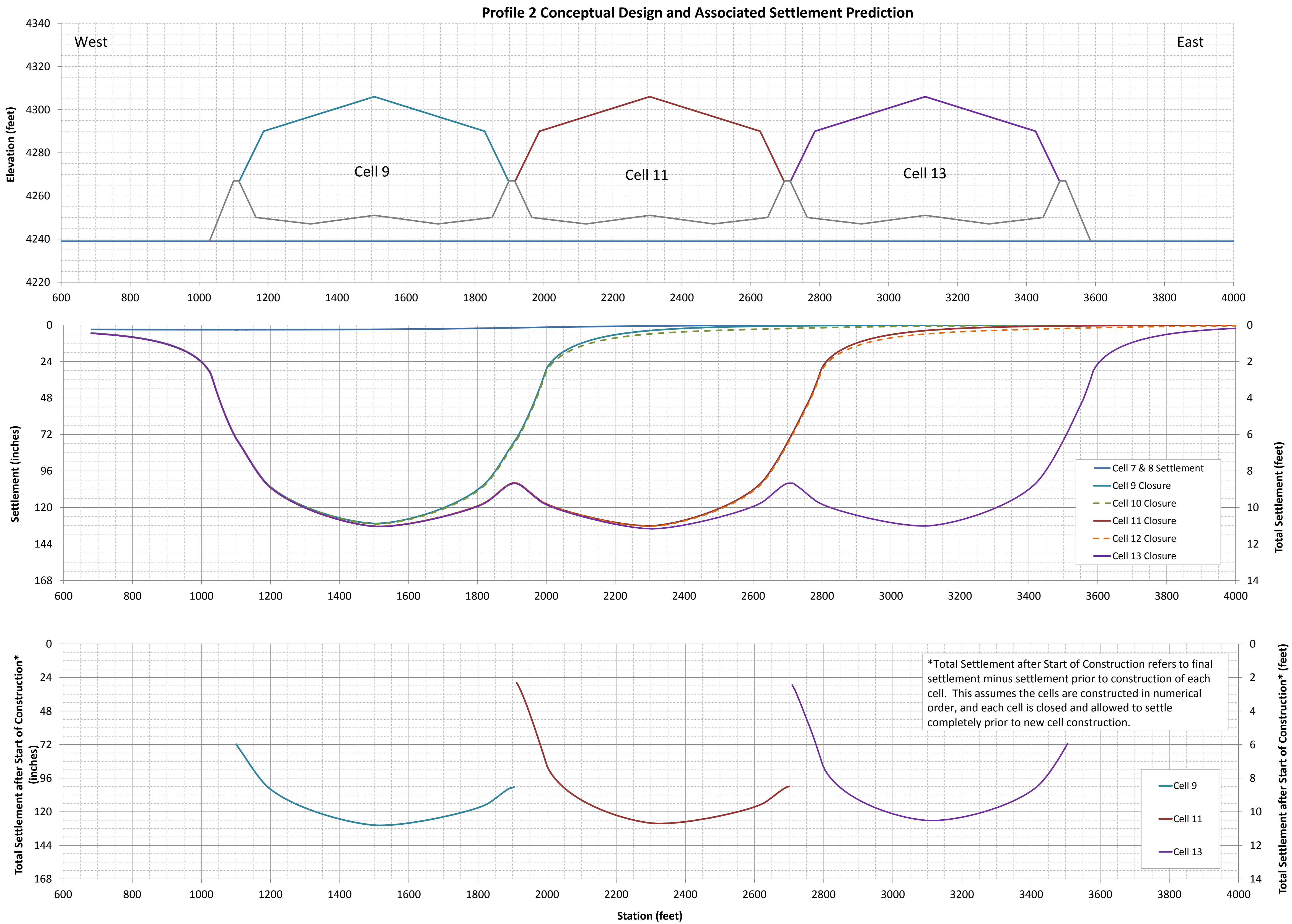
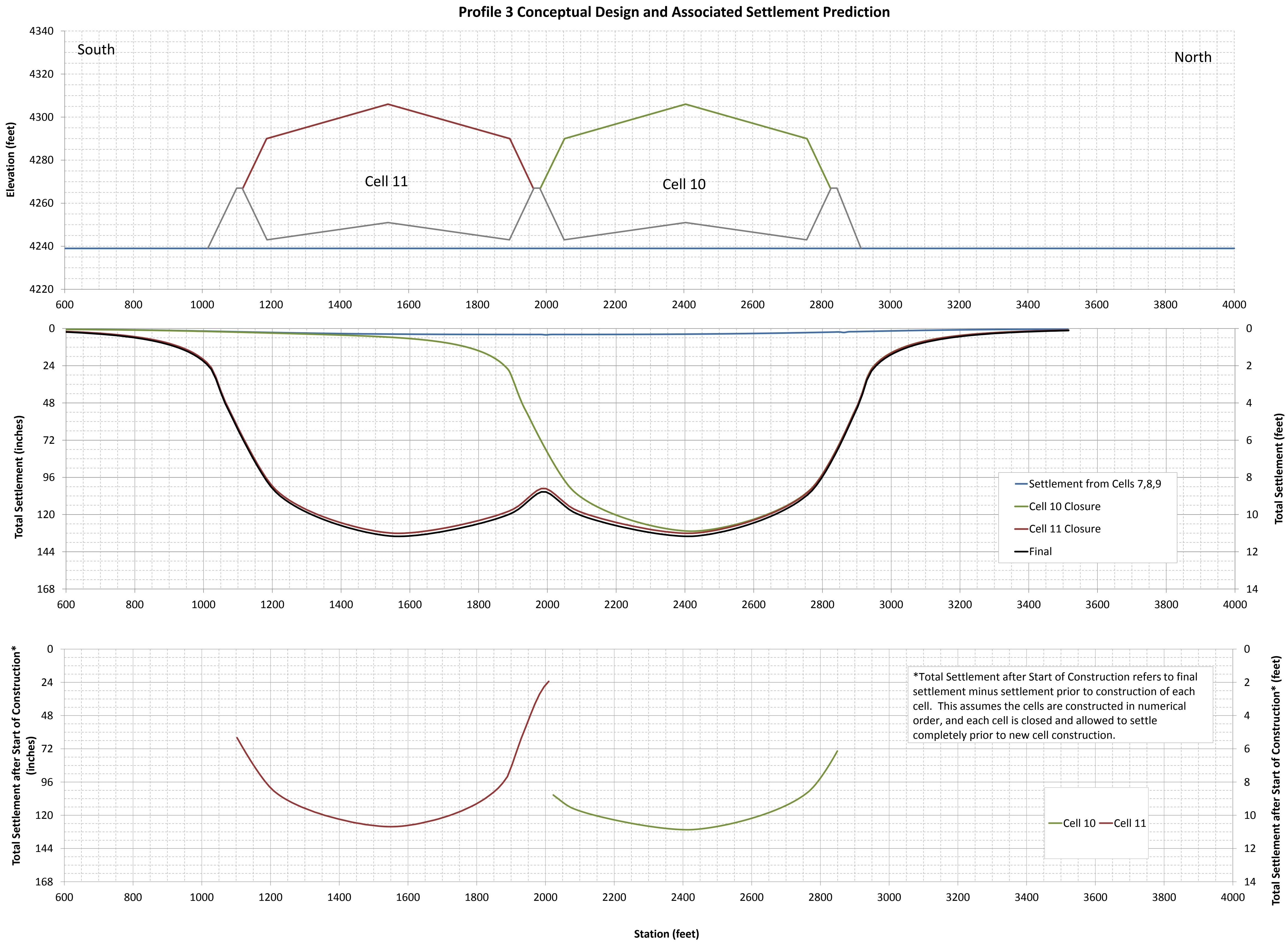

Profile 1.5 Conceptual Design and Associated Settlement Prediction
West
East
Cell 7
Cells 8 & 9
Cells 10 & 11
Cells 12 & 13
Elevation (feet)
Total Settlement (inches)
Total Settlement (feet)
Cell 7 Closure
Cell 8 Closure
Cell 9 Closure
Cell 10 Closure
Cell 11 Closure
Cell 12 Closure
Final
Total Settlement after Start of Construction* (inches)
Total Settlement after Start of Construction* (feet)
*Total Settlement after Start of Construction refers to final settlement minus settlement prior to construction of embankment between cells. This assumes the cells and their associated embankments are constructed in numerical order, and each cell is closed and allowed to settle completely prior to new cell & embankment construction.
Embankment Between Cells 8 & 9 = Final - Cell 7 Closure
Embankment Between Cells 10 & 11 = Final - Cell 9 Closure
Embankment Between Cells 12 & 13 = Final - Cell 11 Closure
Station (feet)


Profile 2 Conceptual Design and Associated Settlement Prediction
West
East
Cell 9
Cell 11
Cell 13
Elevation (feet)
Settlement (inches)
Total Settlement (feet)
Cell 7 & 8 Settlement
Cell 9 Closure
Cell 10 Closure
Cell 11 Closure
Cell 12 Closure
Cell 13 Closure
Total Settlement after Start of Construction* (inches)
Total Settlement after Start of Construction* (feet)
*Total Settlement after Start of Construction refers to final settlement minus settlement prior to construction of each cell. This assumes the cells are constructed in numerical order, and each cell is closed and allowed to settle completely prior to new cell construction.
Cell 9
Cell 11
Cell 13
Station (feet)



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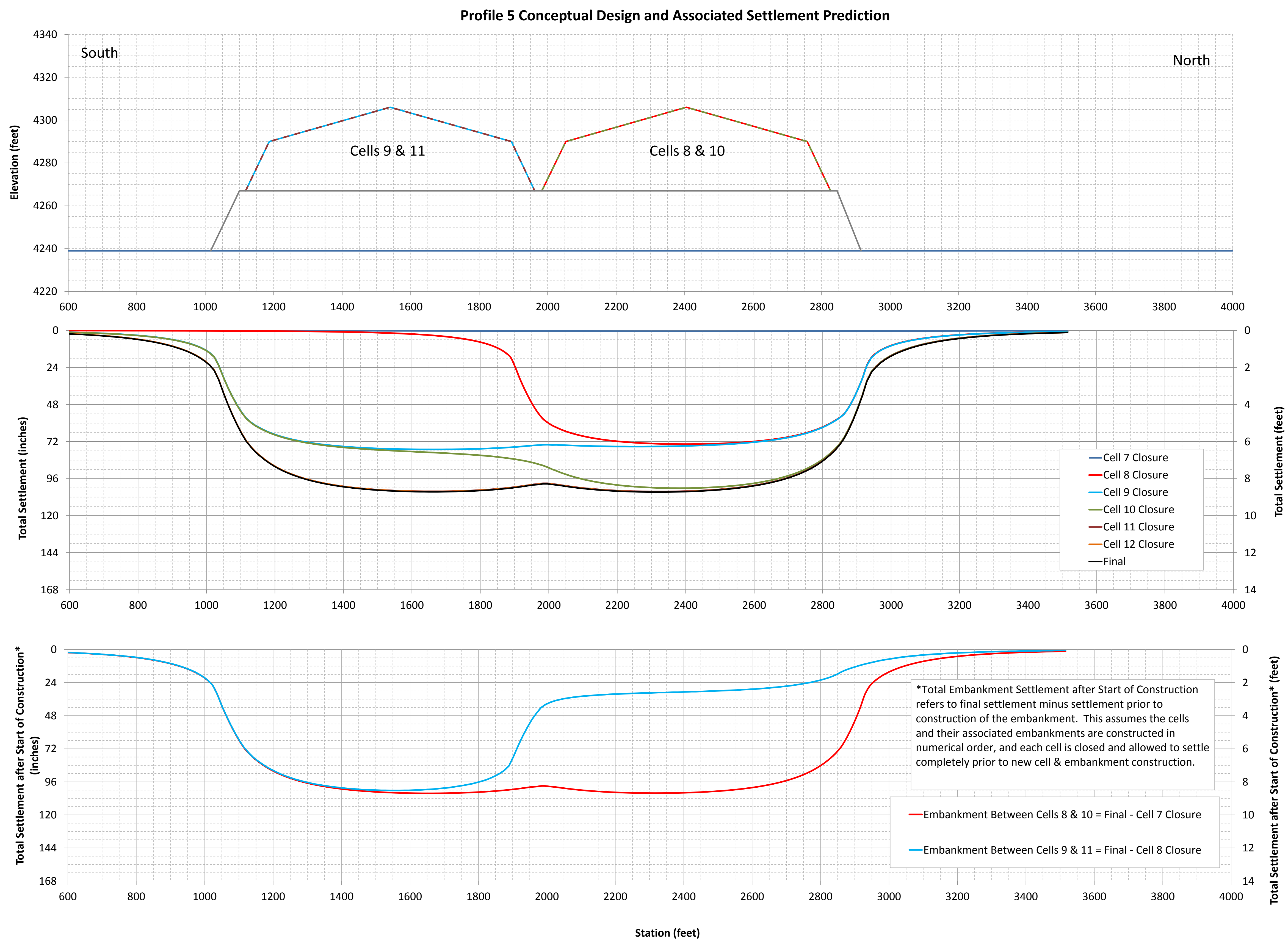

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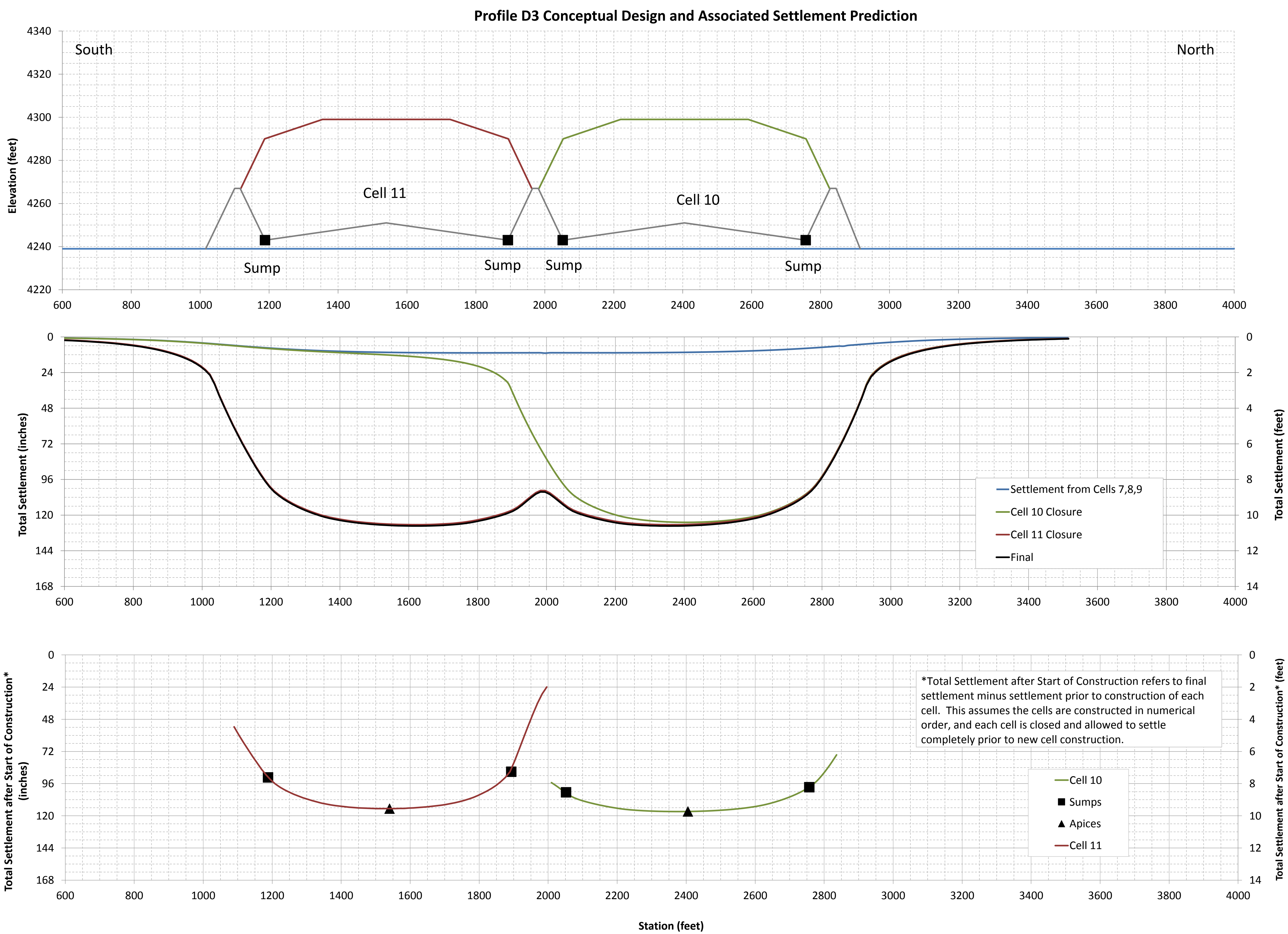

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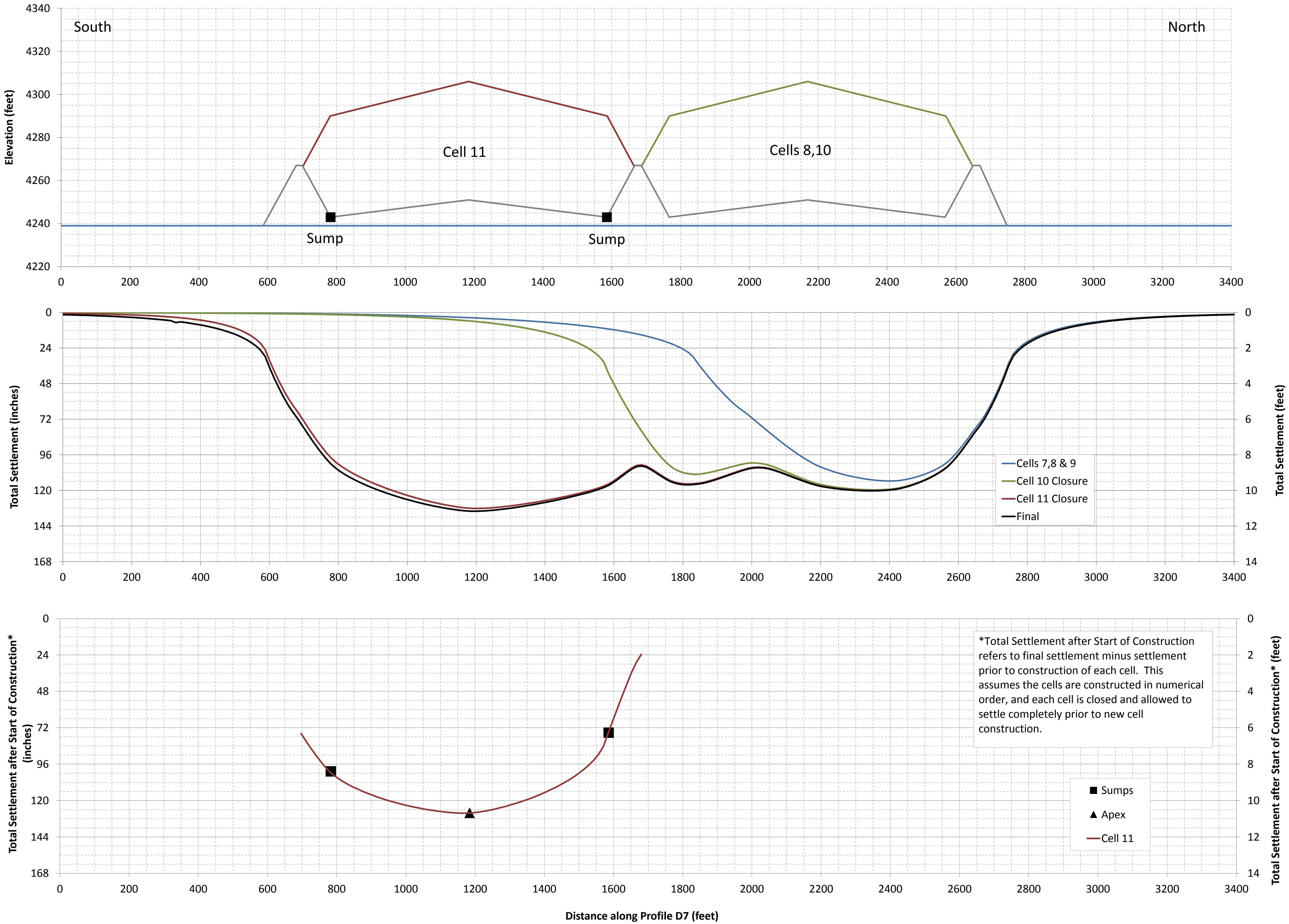
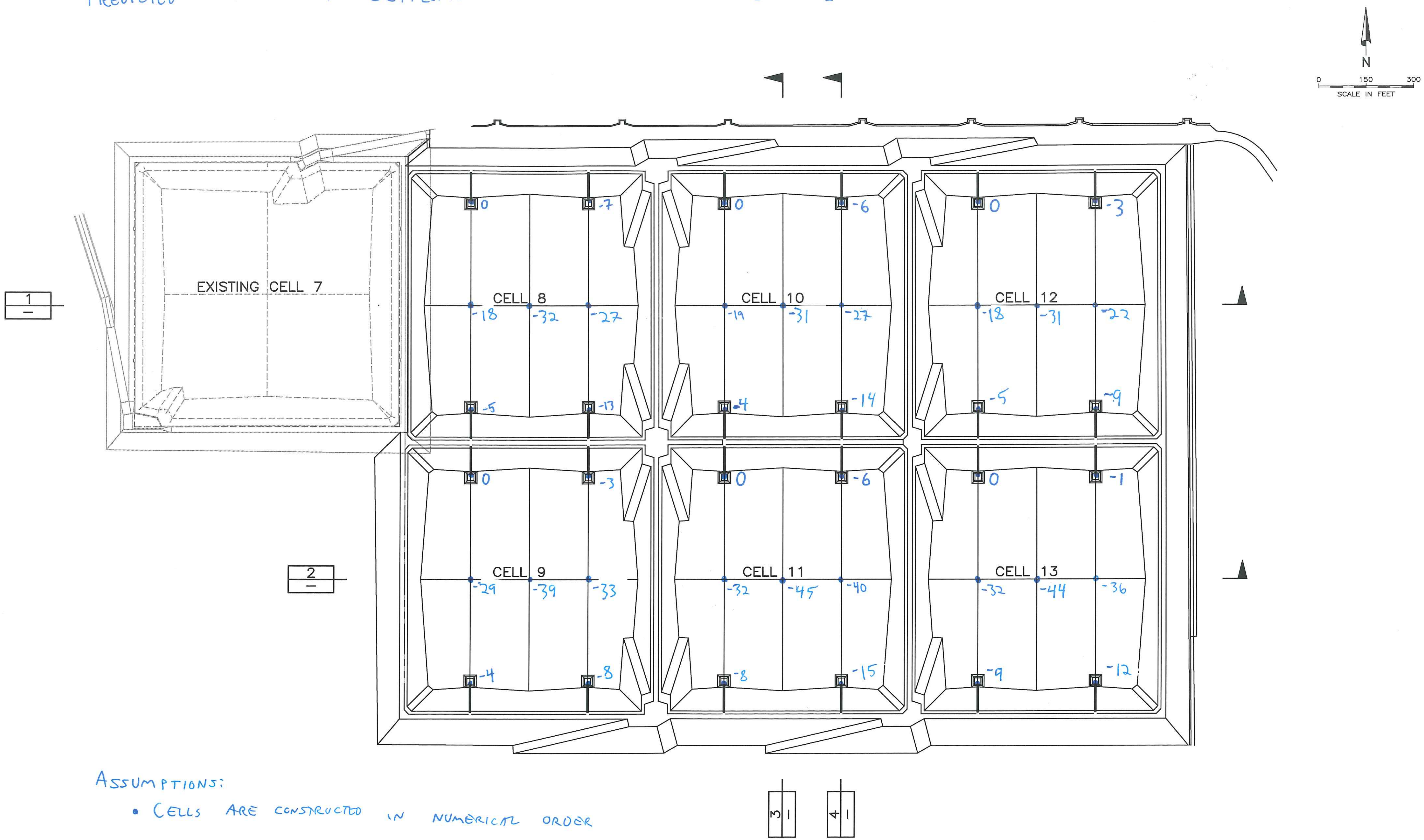
Profile D7 Conceptual Design and Associated Settlement Prediction



CLEAN HARBORS 116026 IJN 6/29/17
UPDATED 10/2/17

PREDICTED DIFFERENTIAL SETTLEMENT WITHIN EACH CELL [INCHES]



ASSUMPTIONS:

- CELLS ARE CONSTRUCTED IN NUMERICAL ORDER
- EACH CELL IS CLOSED AND ALLOWED TO SETTLE COMPLETELY PRIOR TO NEW CELL CONSTRUCTION

INDIVIDUAL DATUMS (0) SET FOR EACH CELL, AS THE HIGHEST OF THE 7 POINTS LABELLED FOR ANY GIVEN CELL.

PLAN VIEW

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APPENDIX H

SEISMIC ANALYSIS

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PROJECT NO. 1160276 TITLE CLEAN HARBORS, CELLS 8-13 DATE 8/31/17 BY WR/TJN
SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 1 OF 19

SITE SPECIFIC GROUND RESPONSE ANALYSIS

DETERMINE: PEAK HORIZONTAL GROUND ACCELERATION

ANALYSIS STEPS:

I. ESTIMATE DEPTH TO BEDROCK

II. DEFINE SOIL PROFILE ABOVE BEDROCK

III. ESTIMATE SOIL PARAMETERS

IV. ESTIMATE ROCK ACCELERATION

V. SELECT STRONG MOTION RECORDS

VI. USE COMPUTER PROGRAM "SHAKE2000" TO PERFORM GROUND RESPONSE ANALYSIS

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SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 2 OF 19

I. ESTIMATE DEPTH TO BEDROCK

(SEE ANALYSIS OF QUATERNARY AND TERTIARY SEDIMENTS)

DEPTH USED = 480 FEET

II. DEFINE SOIL PROFILE ABOVE BEDROCK

- IN A REPORT PERFORMED BY CHEN & ASSOC. IN FEB. 1986 A 300 FOOT DEEP EXPLORATORING BORING WAS DRILLED. (PROJECT # 520885)

THE LOGS FOR THE 300' BORING ARE SHOWN ON SHEETS 3 AND 4

THE COMPUTER PROGRAM "SHAKE" WILL ALLOW 20 LAYERS OF DIFFERENT SOIL TYPES INCLUDING THE BEDROCK

SOIL PROFILE

DEPTH INTERVAL (ft)	SOIL TYPE	# OF SUBLAYERS
0 - 15'	CLAY	2
15 - 45'	SAND	2
45 - 56'	CLAY	1
56 - 83'	SAND	1
83 - 115'	CLAY	2
115 - 160'	SAND	2
160 - 190'	SAND	1
190 - 235'	CLAY	2
235 - 305	SAND	2
* 305 - 380	CLAY	2
380 - 480	GRAVEL	2
** 480 -	BEDROCK	1
		TOTAL 20

* SOIL TYPES BELOW 305' WERE ESTIMATED BASED ON ANALYSIS OF QUATERNARY AND TERTIARY SEDIMENTS

NOTE: THE LAYER DIVISIONS WERE COMPARED WITH THE SOIL LAYER TYPES FROM THE SONIC LOG, WHICH WAS REPORTED IN THE SAME ABOVE REFERENCED REPORT.

** SEE SHEET 17

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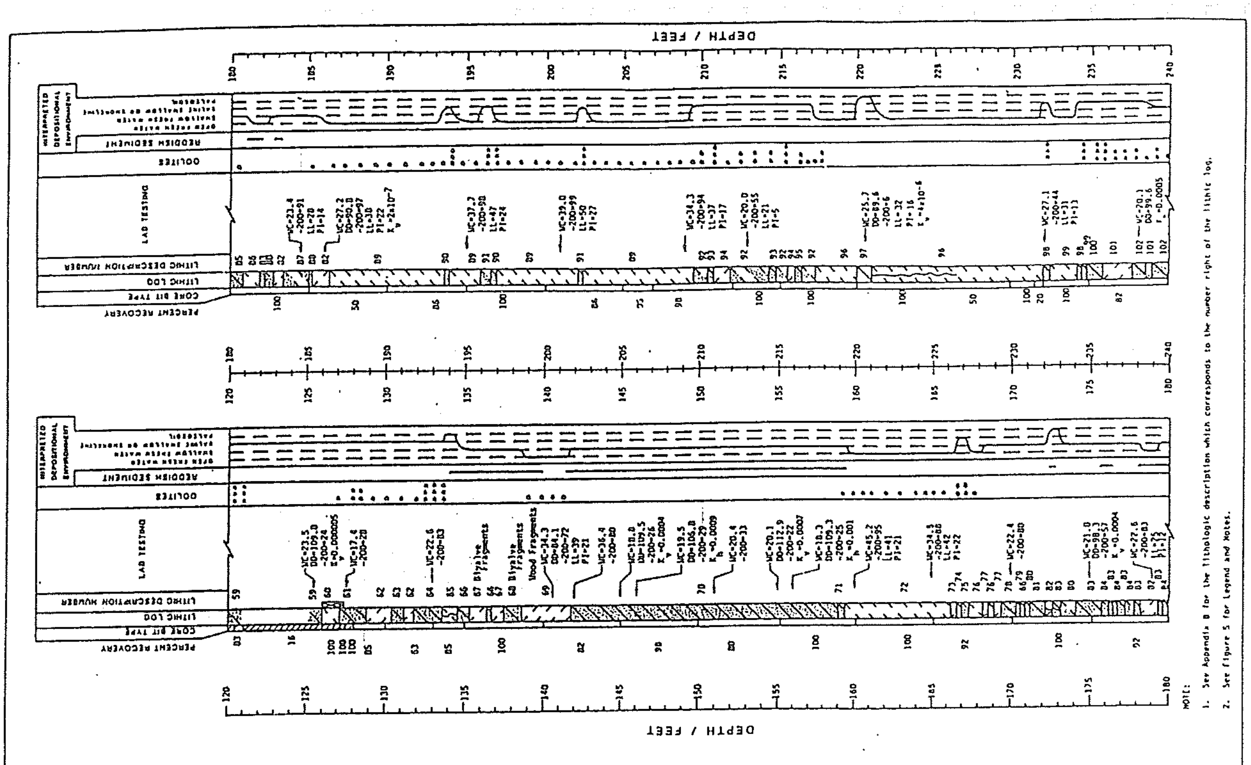
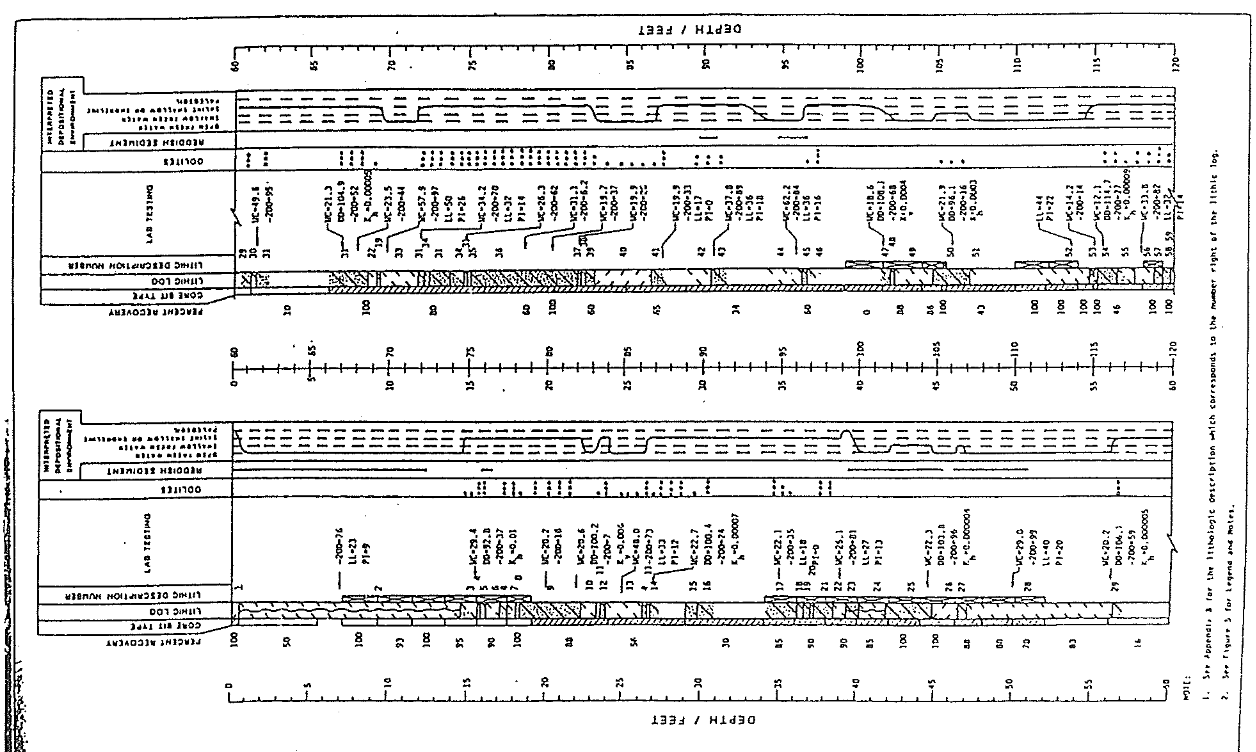
PROJECT NO. 1160276 TITLE Clean Harbors, Cells 8-13 DATE 8/31/17 BY WR/TJN

SUBJECT Seismic Response Analysis SHEET 3 OF 19



#520885 Chen & Associates LOG AND INTERPRETATION OF CORE Figure 3



#520885 Chen & Associates LOG AND INTERPRETATION OF CORE Figure 2

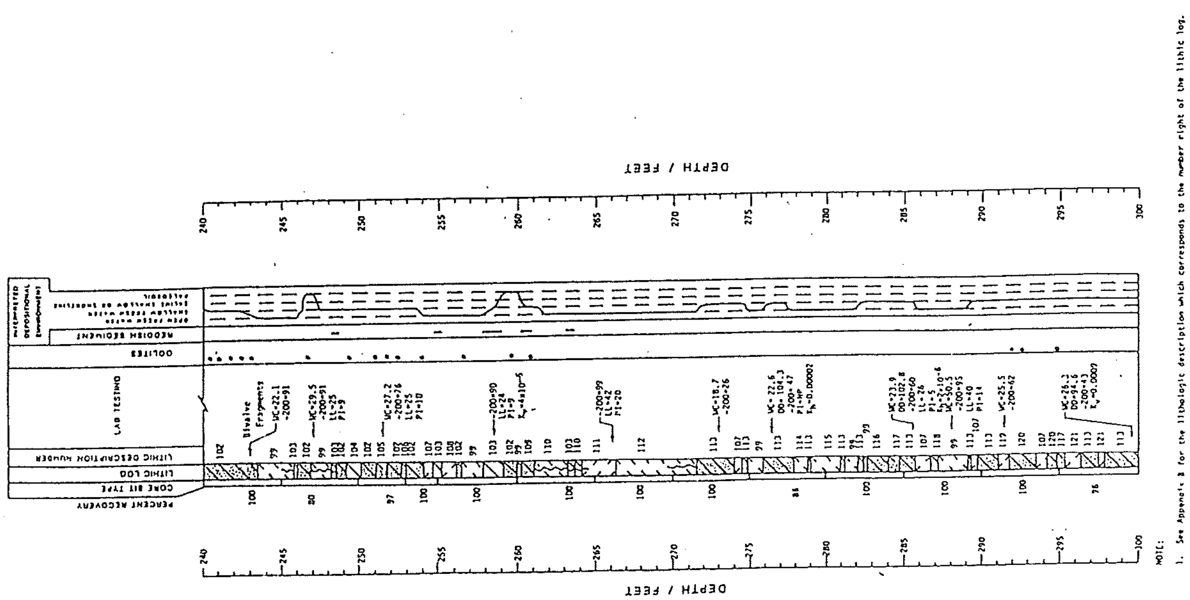
NOTES

1. The boring was drilled during the period of August 20, 1985 to August 30, 1985 with a 5-inch core bit.
2. The location of the boring is shown on Figure 1.
3. The elevation of the boring is approximately 4240 feet above sea level. The elevation is taken from a contour map of the site.
4. A water level is not indicated on the log since a drilling fluid was used during the drilling operation.
5. WC = Water Content (%);
   DD = Dry Density (pcf);
   -200 = Percent Passing No. 200 Sieve;
   LL = Liquid Limit (%);
   PI = Plasticity Index (%);
   K_v = Vertical Permeability (cm/sec);
   K_h = Horizontal Permeability (cm/sec).

LEGEND

- Clay
- Silty Clay
- Silt
- Silty Sand and Clay
- Clayey Sand
- Silty Sand
- Clayey Gravel
- Indicates no recovery of core in this zone.
- Indicates boring advanced using carbide, face-discharge core bit. The number left of symbol indicates percent of sample recovered.
- Indicates boring advanced using punch core system. The number left of symbol indicates the percent of sample recovered.
- Indicates Shelby tube sample obtained.
- 50 / 51 The numbers right of the log correspond to the soil description listed in Appendix B.
- Indicates portion of core which is porous.

#520885	Chen & Associates	LEGEND AND NOTES OF EXPLORATORY BORING	Figure 5



#520885	Chen & Associates	LOG AND INTERPRETATION OF CORE	Figure 4

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PROJECT NO. 1160276 TITLE CLEAN HARBORS, CELLS 8-13 DATE 8/31/17 BY WR / TJN

SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 5 OF 19

III. ESTIMATE SOIL PARAMETERS

DETERMINE: γ_{TOT} (TOTAL UNIT WEIGHT)

THE FOLLOWING VALUES OF γ_{TOT} WERE OBTAINED FROM LABORATORY TESTS PERFORMED ON SAMPLES FROM THE 300' BORING

DEPTH (ft)	γ_{TOT} (PCF)	DEPTH (CONT.)	γ_{TOT} (CONT.)
16	120	145	130
23	120	146	128
30	123	155	128
45	127	175	119
57	128	186	116
68	127	220	113
102	128	238	120
115	129	277	128
126	136	286	127
141	113	300	120

THE FOLLOWING γ_{TOT} VALUES WERE USED:

DEPTH INTERVAL (FT)	γ_{TOT} (PCF)
0-30'	120
30-40'	123
40-95'	127
95-125'	128
125-135'	135
135-145'	120
145-150'	130
150-160'	128
160-275'	120
275-300'	128
300-355'	120
355-370	125
370-480	130

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PROJECT NO. 1160276 TITLE CLEAN HARBORS, CELLS 8-13 DATE 8/31/17 BY WR/TJN

SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 6 OF 19

- CALCULATE EFFECTIVE STRESS TO DETERMINE SHEAR WAVE VELOCITIES AND MODULUS REDUCTION RELATIONSHIPS FOR SANDS

THE SPREADSHEET ON SHEET 9 HAS CALCULATED THE EFFECTIVE STRESSES AT 5' INTERVALS WITH THE ESTIMATED TOTAL UNIT WEIGHT VALUES AND THE GROUNDWATER LEVEL AT A DEPTH OF 10 FEET BELOW THE SURFACE.

SAMPLE CALCULATION:

$$\sigma_o' = \gamma' H$$

CALCULATED AT 15' $\sigma_o' = (120) \times (10) + (120 - 62.4)5 = 1488 \text{ psf}$ ✓

- ESTIMATE S_u (UNDRAINED SHEAR STRENGTH) FOR CLAY LAYERS

THERE IS SOME DATA AVAILABLE ON S_u FOR SOILS FROM 0 TO 60' AND NO DATA ON SOIL BELOW 60', THUS S_u VALUES WERE ESTIMATED AS FOLLOWS:

CLAY LAYER DEPTH INTERVAL	S_u (psf)
0 - 15'	300
45 - 56'	450
83 - 115'	600
190 - 235'	800
305 - 380'	1250

- CALCULATE SHEAR MODULUS (G) FOR SAND AND GRAVEL:

$$G = 1000 K_2 (\sigma_o')^{1/2}$$ (eq. 8.48 DAS, FUNDAMENTALS OF SOIL DYNAMICS)

K_2 = COEFFICENT BASED ON SHEAR STRAIN AND RELATIVE DENSITY

σ_o' = EFFECTIVE STRESS

K_2 VALUES OBTAINED FROM FIGURES 8.15 & 8.16 ON SHEET 7

![AGEC Applied GeoTech]

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PROJECT NO. 1160276 TITLE CLEAN HARBORS, CELLS 8-13 DATE 8/31/17 BY WR/TJN

SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 7 OF 19

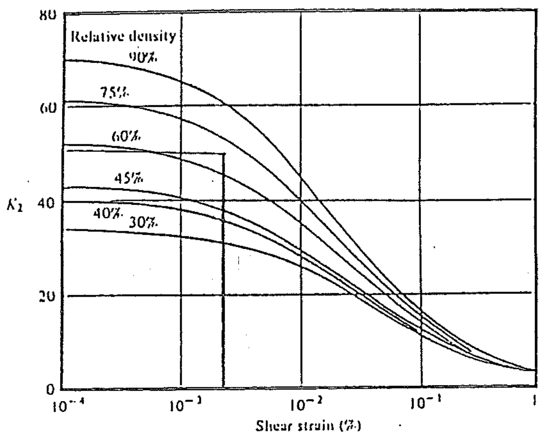
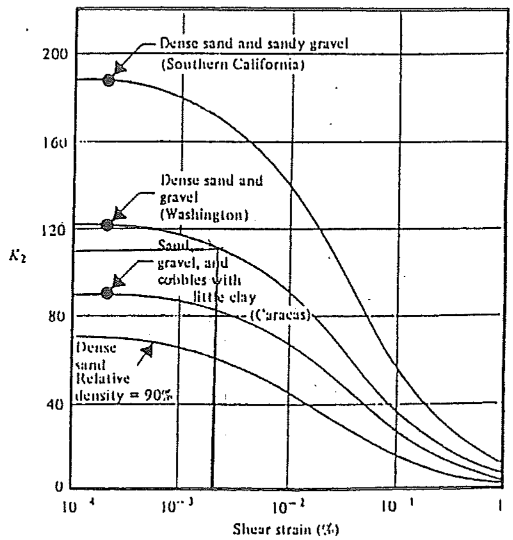


FIGURE 8.15 Values of K_2 [Eq. (8.48)] for sand at different relative densities. [Seed, H. B., and Idriss, I. M. (1970, Fig. 5).]

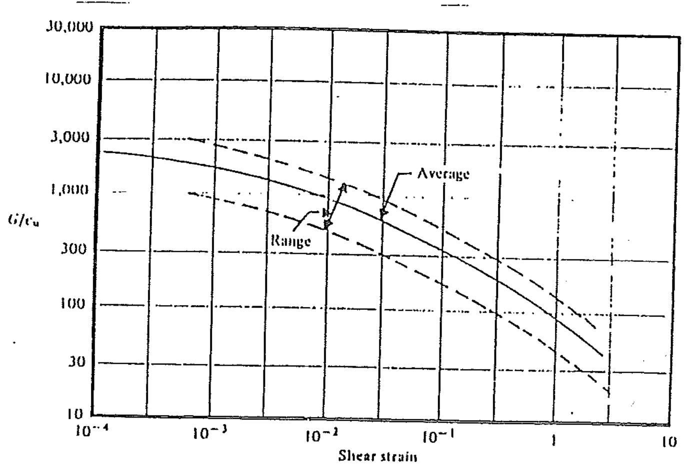
RELATIVE DENSITY FOR SAND ≈ 70% WITH SHEAR STRAIN ≈ 0.03%

USE $K_2 \approx 50$ SANDS

FIGURE 8.16 Values of K_2 for gravelly soil. [Seed, H. B., and Idriss, I. M. (1970, Fig. 16).]



USE $K_2 \approx 110$ FOR GRAVELS



USE $G = 2000\,C_u$

NOTE C_u = UNDRAINED SHEAR STRENGTH

FIGURE 8.17 *In situ* shear modulus for saturated clays. [Seed, H. B., and Idriss, I. M. (1970, Fig. 13).]

FIGURES 8.15 - 8.17 DAS FUNDAMENTALS OF SOIL DYNAMICS

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PROJECT NO. 1160276 TITLE CLEAN HARBORS, CELLS 8-13 DATE 8/31/17 BY WR/TJN

SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 8 OF 19

THE SPREADSHEET ON SHEET 9 ALSO HAS CALCULATED THE SHEAR MODULUS VALUES BASED ON THE ESTIMATED K_2 VALUE AND THE CALCULATED σ_0' VALUES.

SAMPLE CALCULATION: $G = K_2 1000 (\sigma_0')^{\frac{1}{2}}$

FOR SAND AT 20' $G = 50(1000)(1776)^{\frac{1}{2}} = 2.11 \times 10^6$ psf

- CALCULATE SHEAR MODULUS FOR CLAY BASED ON FIG. 8.17 (SHEET 7)

$G = 2000 C_u$ WHERE $C_u = S_u$ (UNDRAINED SHEAR STRENGTH)

THE SPREADSHEET ON SHEET 9 ALSO HAS CALCULATED THE SHEAR MODULUS FOR CLAY:

SAMPLE CALCULATION:

FOR CLAY 15' $G = 2000(300) = 600,000$ psf

- CONVERT G TO V_s (SHEAR WAVE VELOCITY)

$$V_s = \left(\frac{G}{\rho}\right)^{1/2}$$ (eq. 20-15 BOWLES, FOUNDATION ANALYSIS AND DESIGN, 1988)

WHERE

G = SHEAR MODULUS

$\rho = \frac{\gamma}{g}$

g = gravity (FT/SEC²)

γ = UNIT WEIGHT (lb/FT³)

THE SPREADSHEET ON SHEET 9 ALSO HAS CONVERTED THE SHEAR MODULUS, G TO V_s, SHEAR WAVE VELOCITY (FT/SEC). THESE VALUES ARE LISTED IN THE COLUMN TITLED V_s (CALCULATED)

SAMPLE CALCULATION: FOR CLAY AT 5' $V_s = \left(\frac{600,000}{\left(\frac{120}{32.2}\right)}\right)^{1/2} = 401$ FT/SEC

THE SPREADSHEET ALSO CALCULATES THE AVERAGE V_s FOR EACH SOIL LAYER.

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SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 9 OF 19

Shear Wave Velocity Estimates based on calcultations and Sonic log:

GROUNDWATER DEPTH = 10 feet

DEPTH feet	UNIT WT. pcf	EFF. STRESS psf	SOIL TYPE	Su (estimated)	G (modulus)	Vs (calculated)	Vs (ave.calc)	Vs (sonic log)	Vs (average)	Vs (value used)	Vs 80%	Vs 120%
0	120	0	CLAY	300	600000	401						
5	120	600	CLAY	300	600000	401						
10	120	1200	CLAY	300	600000	401						
15	120	1488	CLAY	300	600000	401	401	579	490	525	420	630
20	120	1776	SAND		2107130.8	752						
25	120	2084	SAND		2271663.3	781						
30	123	2387	SAND		2432591.2	798						
35	123	2670	SAND		2583602.1	822						
40	127	2993	SAND		2735416.9	833						
45	127	3318	SAND		2879238	854	807	806	806	800	640	960
50	127	3639	CLAY	450	900000	478						
55	127	3962	CLAY	450	900000	478	478	660	569	625	500	750
60	127	4285	SAND		3272995.6	911						
65	127	4608	SAND		3394112.6	928						
70	127	4931	SAND		3511054	944						
75	127	5254	SAND		3624224.1	959						
80	127	5577	SAND		3733965.7	973	943	948	945	940	752	1128
85	127	5900	CLAY	600	1200000	552						
90	127	6223	CLAY	600	1200000	552						
95	128	6551	CLAY	600	1200000	549						
100	128	6879	CLAY	600	1200000	549						
105	128	7207	CLAY	600	1200000	549						
110	128	7535	CLAY	600	1200000	549						
115	128	7863	CLAY	600	1200000	549	550	757	654	750	600	900
120	128	8191	SAND		4525207.2	1067						
125	135	8554	SAND		4624391.9	1050						
130	135	8917	SAND		4721493.4	1061						
135	120	9205	SAND		4797134.6	1135						
140	120	9493	SAND		4871601.4	1143						
145	130	9831	SAND		4957570	1108						
150	128	10159	SAND		5039593.2	1128						
155	128	10487	SAND		5120302.7	1135	1103	1065	1084	1100	880	1320
160	120	10775	SAND		5190134.9	1160						
165	120	11063	SAND		5259039.8	1168						
170	120	11351	SAND		5327053.6	1196						
175	120	11639	SAND		5394209.9	1203						
180	120	11927	SAND		5460540.3	1210						
185	120	12215	SAND		5526074.6	1218	1199	1247	1223	1200	960	1440
190	120	12503	CLAY	800	1600000	655						
195	120	12791	CLAY	800	1600000	655						
200	120	13079	CLAY	800	1600000	655						
205	120	13367	CLAY	800	1600000	655						
210	120	13655	CLAY	800	1600000	655						
215	120	13943	CLAY	800	1600000	655						
220	120	14231	CLAY	800	1600000	655						
225	120	14519	CLAY	800	1600000	655						
230	120	14807	CLAY	800	1600000	655	655	1084	870	1000	800	1200
235	120	15095	SAND		6143085.5	1284						
240	120	15383	SAND		6201411.1	1290						
245	120	15671	SAND		6259193.2	1296						
250	120	15959	SAND		6316446.8	1302						
255	120	16247	SAND		6373186	1308						
260	120	16535	SAND		6429424.5	1313						
265	120	16823	SAND		6485175.4	1319	1302	1189	1245	1300	1040	1560
270	120	17111	SAND		6540451.1	1325						
275	128	17439	SAND		6602840.3	1289						
280	128	17767	SAND		6664645.5	1295						
285	128	18095	SAND		6725882.8	1301						
290	128	18423	SAND		6786567.6	1307						
295	128	18751	SAND		6846714.5	1312						
300	120	19039	SAND		6899094.1	1361	1313	1418	1364	1350	1080	1620
305	120	19327	CLAY	1250	2500000	819						
310	120	19615	CLAY	1250	2500000	819						
315	120	19903	CLAY	1250	2500000	819						
320	120	20191	CLAY	1250	2500000	819						
325	120	20479	CLAY	1250	2500000	819						
330	120	20767	CLAY	1250	2500000	819						
335	120	21055	CLAY	1250	2500000	819	819			1100	880	1320
340	120	21343	CLAY	1250	2500000	819						
345	120	21631	CLAY	1250	2500000	819						
350	120	21919	CLAY	1250	2500000	819						
355	125	22232	CLAY	1250	2500000	802						
360	125	22545	CLAY	1250	2500000	802						
365	125	22858	CLAY	1250	2500000	802						
370	130	23196	CLAY	1250	2500000	787	807			1100	880	1320
375	130	23534	GRAVEL		16874875	2044						
380	130	23872	GRAVEL		16995623	2052						
385	130	24210	GRAVEL		17115519	2059						
390	130	24548	GRAVEL		17234582	2066						
395	130	24886	GRAVEL		17352827	2073						
400	130	25224	GRAVEL		17470272	2080						
405	130	25562	GRAVEL		17586933	2087						
410	130	25900	GRAVEL		17702825	2094						
415	130	26238	GRAVEL		17817963	2101						
420	130	26576	GRAVEL		17932362	2108	2076			2100	1680	2520
425	130	26914	GRAVEL		18046036	2114						
430	130	27252	GRAVEL		18158998	2121						
435	130	27590	GRAVEL		18271262	2127						
440	130	27928	GRAVEL		18382840	2134						
445	130	28266	GRAVEL		18493745	2140						
450	130	28604	GRAVEL		18603989	2147						
455	130	28942	GRAVEL		18713583	2153						
460	130	29280	GRAVEL		18822540	2159						
465	130	29618	GRAVEL		18930869	2165						
470	130	29956	GRAVEL		19038582	2172	2143			2100	1680	2520

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SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 10 OF 19

- COMPARE V_S VALUES (CALCULATED) WITH V_S VALUES DETERMINED FROM SONIC LOG. THE SONIC LOG WAS OBTAINED FROM THE REPORT PREPARED BY CHEN & ASSOC. (PROJECT # 520885) REPORTED IN FEBRUARY, 1986. THE SONIC LOG IS A RECORDING OF THE TIME REQUIRED FOR A COMPRESSIONAL SOUND WAVE TO TRAVERSE ONE FOOT OF FORMATION. THIS VALUE IS KNOWN AS THE INTERVAL TRANSIT TIME AND IS THE RECIPROCAL OF THE COMPRESSIONAL SOUND WAVE IN THE MATERIAL

THE FOLLOWING AVERAGE INTERVAL TRANSIT TIMES HAVE BEEN DETERMINED FROM THE SONIC LOG SHOWN ON SHEET 12.

DEPTH INTERVAL (FT.)	SONIC LOG VALUE (SEC/FT.)
0 - 15	0.000188
15 - 45	0.000190
45 - 56	0.000190
56 - 83	0.000180
83 - 115	0.000185
115 - 160	0.000175
160 - 190	0.000175
190 - 235	0.000172
235 - 270	0.000165
270 - 290	0.000168

CONVERT SONIC LOG VALUES TO V_P:

$$V_P \text{ (ft/sec)} = 1/\text{SONIC LOG VALUE (SEC/FT)}$$

SAMPLE CALCULATION: $V_P = \frac{1}{0.000188} = 5319$ FT/SEC

DEPTH INTERVAL	V_P	DEPTH INTERVAL	V_P
0-15	5319	115-160	5714
15-45	5263	160-190	5714
45-56	5263	190-235	5814
56-83	5556	235-270	6061
83-115	5405	270-290	5952

THE U.S.G.S HAS RECENTLY PERFORMED DOWN HOLE SHEAR WAVE VELOCITY TESTS IN SALT LAKE VALLEY, UTAH

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SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 11 OF 19

THE RESULTS OF THESE TESTS ARE PUBLISHED BY TINSLEY AND OTHERS, 1991 "GEOLOGIC ASPECTS OF OF SHEAR-WAVE VELOCITY AND RELATIVE GROUND RESPONSE IN SALT LAKE VALLEY, UTAH"

THE PAPER DOES NOT REPORT SOIL PROFILES FOR THE 20-SITES AT WHICH THE WORK WAS PERFORMED. AFTER CONVERSING ABOUT THE PROFILES WITH MR. TINSLEY (U.S.G.S.) THREE SITES WERE CHOSEN FOR COMPARISON:

SITE	SITE LOCATION	LATITUDE	LONGITUDE	ELEVATION (FT)
SLCAIR	SALTAIR, MORTON SALT CO.	40.78170	111.97670	4208
SLCKSL	KSL RADIO TRANSMITTER	40.7780	112.10030	4215
SLCDUC	DUCK CLUB	40.79800	112.10080	4215

THESE SITE ARE NEAR THE SAME ELEVATION AS THE U.S.P.C.I. CELL 6 SITE, THE PROFILES GENERALLY CONSIST OF LAKE BONNEVILLE SEDIMENTS WHICH ARE INTERLAYERED SANDS, SILTS AND CLAYS.

DURING THE STUDY BOTH V_p & V_s VALUES WERE MEASURED, THUS BY USING THE FOLLOWING RELATIONSHIP, POISSON'S RATIO (μ) WERE CALCULATED:

$$\mu = \frac{\left(\frac{V_p^2}{2V_s^2} - 1\right)}{\left(\frac{V_p^2}{V_s^2} - 1\right)}$$

ESTIMATE μ, BASED ON COMPARISON WITH THE THREE U.S.G.S. SITES.

IT WAS REPORTED THAT THE SLCAIR SITE WAS PREDOMINANTLY FINE-GRAINED SAND, THE SLCKSL SITE WAS INTERLAYERED AND THE SLCDUC SITE CONTAINED MORE CLAY THAN THE OTHER SITES.

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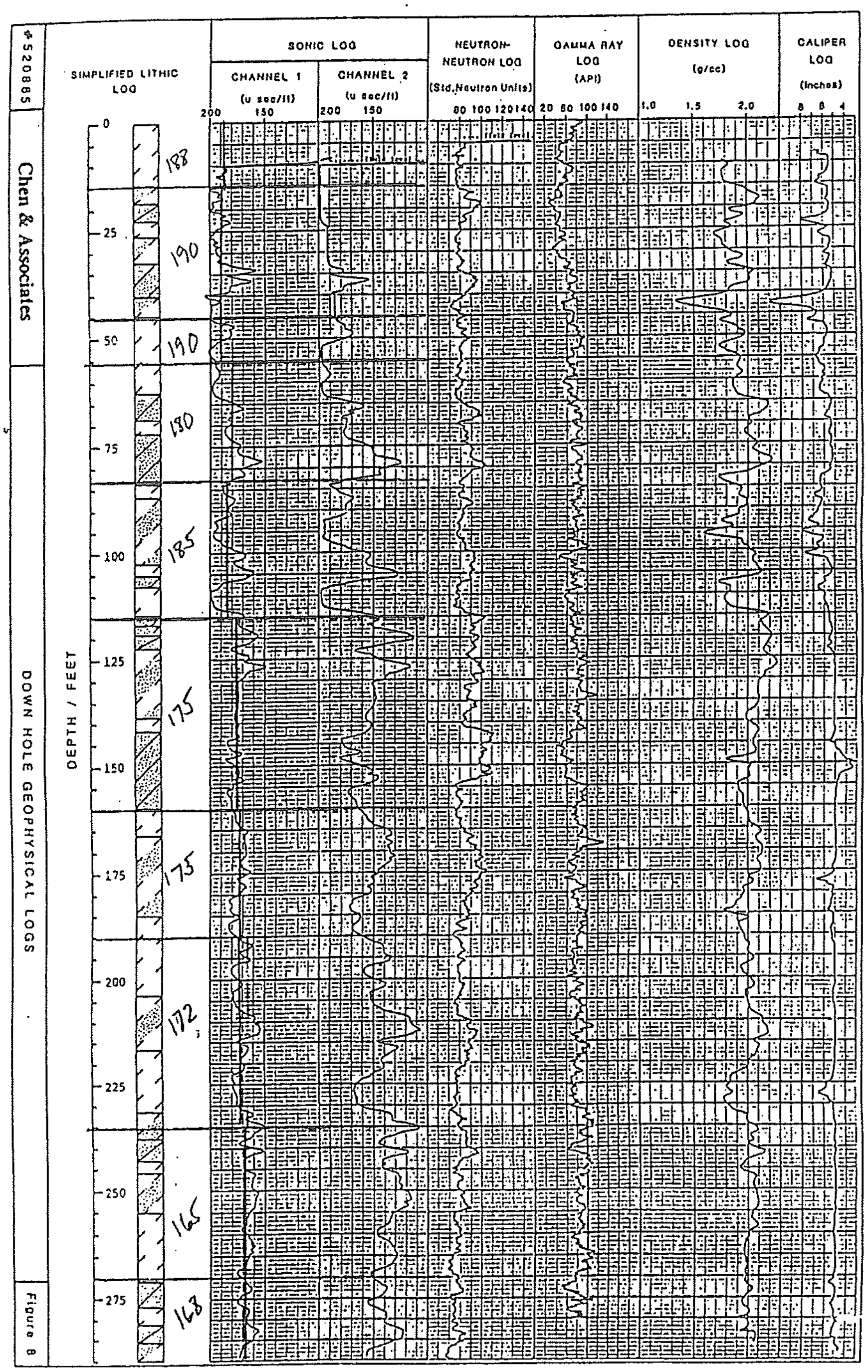
SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 12 OF 19

SONIC LOG OBTAINED FROM CHEN & ASSOC. REPORT #520885



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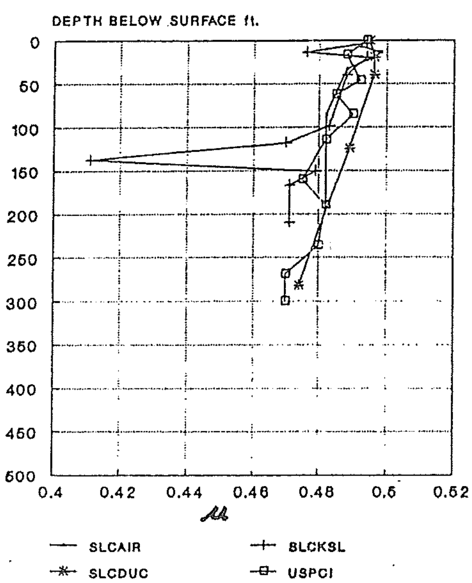
SUBJECT Seismic Response Analysis SHEET 13 OF 19

DEPTH INTERVAL (ft)	POISSON'S RATIO μ
0-15'	0.494
15-45'	0.488
45-56'	0.492
56-83'	0.485
83-115'	0.490
115-160'	0.482
160-190'	0.475
190-235'	0.482
235-270'	0.480
270-290'	0.470

PLOT VALUES OF μ WITH THREE U.S.G.S COMPARISON SITES:

POISSON'S RATIO COMPARISON



THE PLOT SHOWS GOOD COMPARISON WITH THE U.S.G.S DATA.

USING V_p VALUES FROM SONIC LOG AND ESTIMATE μ VALUES, CALCULATE V_s:

$$V_s = V_p \left(\frac{1-2\mu}{2-2\mu} \right)^{1/2}$$

SAMPLE CALCULATION:

$$V_s = 5319 \left(\frac{1-2(0.494)}{2-2(0.494)} \right)^{1/2} = 579 \text{ FT/SEC}$$

DEPTH INTERVAL	V_s (FT/SEC)
0-15'	579
15-45'	806
45-56'	660
56-83'	948
83-115'	757
115-160'	1065
160-190'	1247
190-235'	1084
235-270'	1189
270-290'	1416

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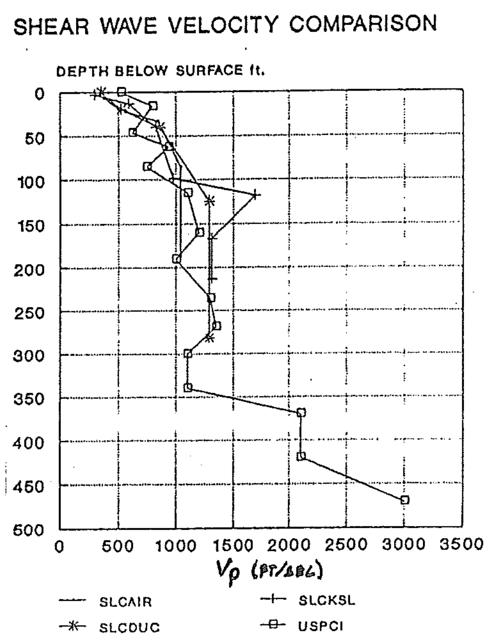
SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 14 OF 19

THE SPREADSHEET ON SHEET 9 HAS AVERAGED THE VALUES OF V_S (CALCULATED) AND V_S (SONIC LOG). AFTER REVIEWING THE VALUES OF V_S THE FOLLOWING V_S VALUES WERE USED IN THE ANALYSIS:

DEPTH INTERVAL	V_S (FT/SEC)
0-15'	525
15-45'	800
45-56'	625
56-83'	940
83-115'	750
115-160'	1100
160-190'	1200
190-235'	1000
235-270'	1300
270'-305'	1350
305-380'	1100
380-480'	2100
480-	3000

THE VALUES OF V_S USED AT THE USPCI SITE COMPARED WITH THE THREE U.S.G.S. SITES ARE SHOWN BELOW:



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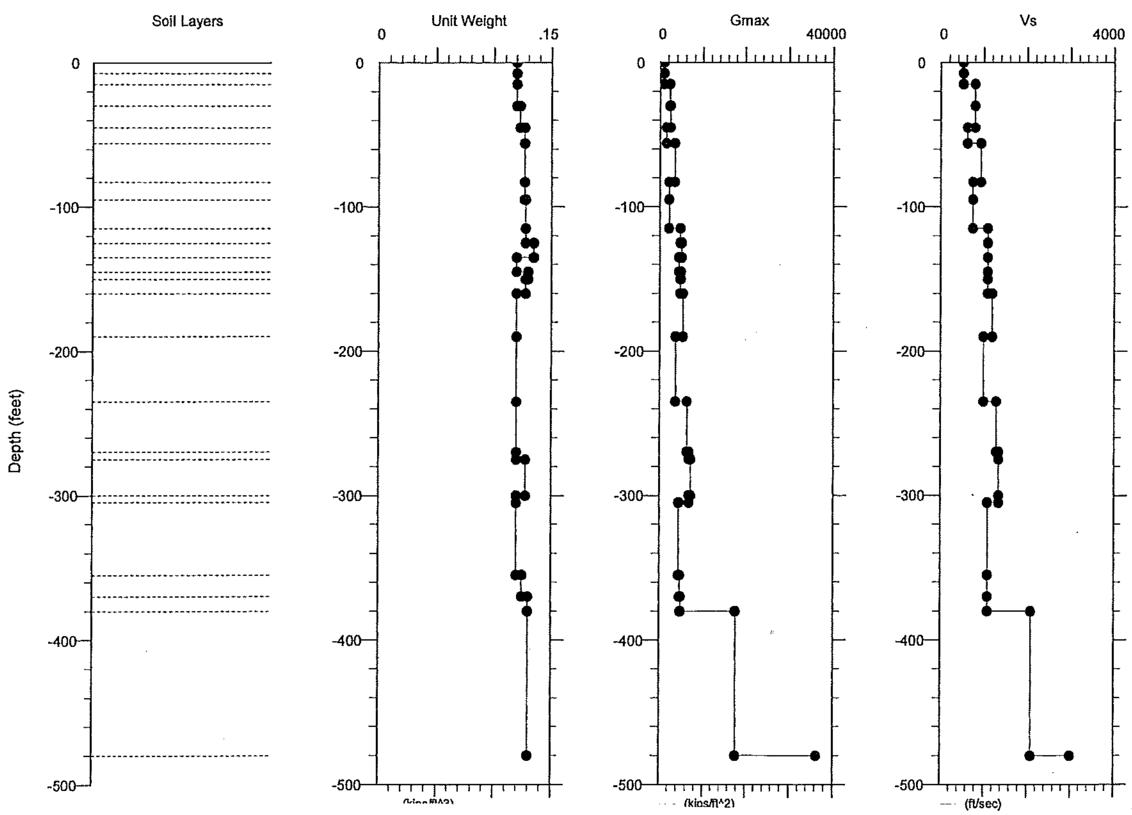
PROJECT NO. 1160276 TITLE Clean Harbors, Cells 8-13 DATE 8/31/17 BY TJN

SUBJECT Seismic Response Analysis SHEET 15 OF 19

Values Used for Analysis

Layer Number	Soil Type	Top Depth [ft]	Bottom Depth [ft]	Layer Thickness [ft]	Unit Weight [pcf]	Vs [ft/s]
1	2	0	7.5	7.5	120	525
2	2	7.5	15	7.5	120	525
3	1	15	30	15	120	800
4	1	30	45	15	123	800
5	2	45	56	11	127	625
6	1	56	83	27	127	940
7	2	83	95	12	127	750
8	2	95	115	20	128	750
9	1	115	125	10	128	1100
10	1	125	135	10	135	1100
11	1	135	145	10	120	1100
12	1	145	150	5	130	1100
13	1	150	160	10	128	1100
14	1	160	190	30	120	1200
15	2	190	235	45	120	1000
16	1	235	270	35	120	1300
17	1	270	275	5	120	1350
18	1	275	300	25	128	1350
19	1	300	305	5	120	1350
20	2	305	355	50	120	1100
21	2	355	370	15	125	1100
22	2	370	380	10	130	1100
23	3	380	480	100	130	2100
24	4	480			130	3000



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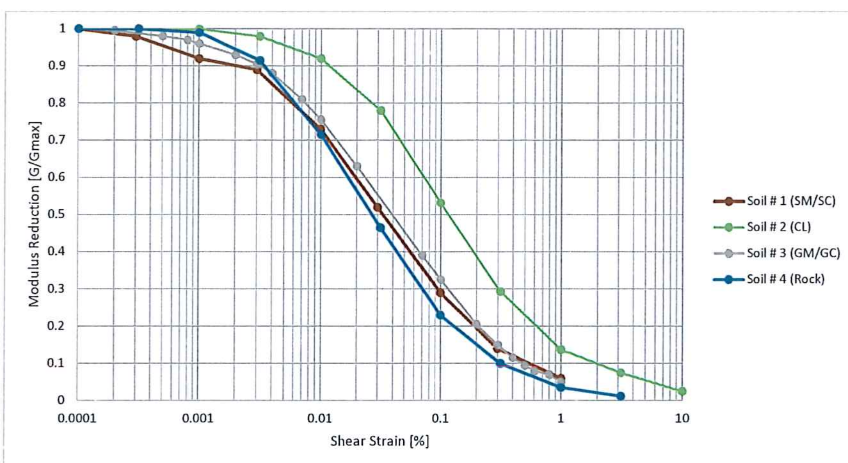
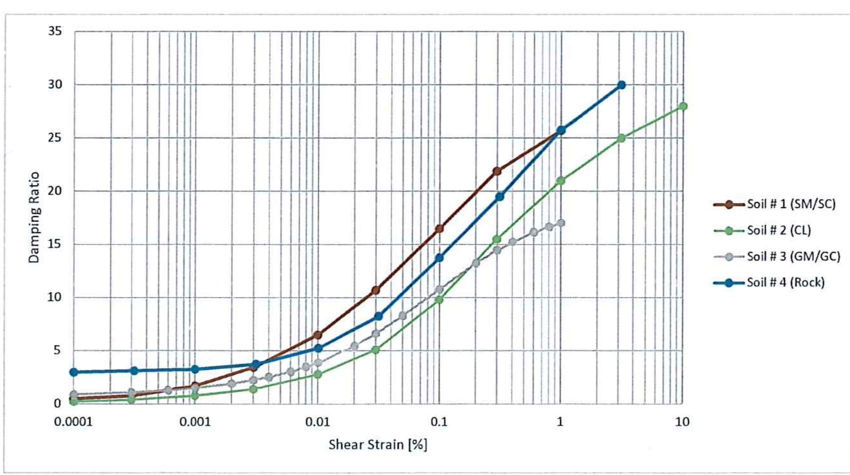
SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 16 OF 19

Dynamic Soil Properties

Soil Type #	Soil Type	Modulus Reduction Model	Damping Ratio Model
1	SM/SC	Sand, Avg. (Seed & Idriss, 1970)	Sand, Avg. (Seed & Idriss, 1970)
2	CL	Clay, PI = 20-40 (Sun et al, 1988)	Clay (Idriss, 1990)
3	GM/GC	Gravel, mean (Rollins et al, 1998)	Gravel, mean (Rollins et al, 1998)
4	bedrock	rock 501 to 1000 ft. (EPRI, 1993)	rock 501 to 1000 ft. (EPRI, 1993)

Soil # 1 (SM/SC)				Soil # 2 (CL)				Soil # 3 (GM/GC)				Soil # 4 (Rock)			
Strain [%]	Modulus Reduction [G/Gmax]	Strain [%]	Damping Ratio	Strain [%]	Modulus Reduction [G/Gmax]	Strain [%]	Damping Ratio	Strain [%]	Modulus Reduction [G/Gmax]	Strain [%]	Damping Ratio	Strain [%]	Modulus Reduction [G/Gmax]	Strain [%]	Damping Ratio
0.0001	1	0.0001	0.5	0.0001	1	0.0001	0.24	0.0001	1	0.0001	0.9	0.0001	1	0.0001	3
0.0003	0.98	0.0003	0.8	0.001	0.999	0.0003	0.42	0.0002	0.995	0.0003	1.11	0.000316	1	0.000316	3.13
0.001	0.92	0.001	1.7	0.00316	0.98	0.001	0.8	0.0005	0.98	0.0006	1.3	0.001	0.99	0.001	3.27
0.003	0.89	0.003	3.45	0.01	0.92	0.003	1.4	0.0008	0.97	0.001	1.5	0.00316	0.915	0.00316	3.75
0.01	0.73	0.01	6.5	0.0316	0.78	0.01	2.8	0.001	0.96	0.002	1.91	0.0101	0.715	0.0101	5.25
0.03	0.52	0.03	10.7	0.1	0.532	0.03	5.1	0.002	0.93	0.003	2.24	0.0316	0.465	0.0316	8.25
0.1	0.29	0.1	16.5	0.316	0.293	0.1	9.8	0.003	0.905	0.004	2.54	0.1	0.23	0.1	13.75
0.3	0.14	0.3	21.9	1	0.137	0.3	15.5	0.004	0.88	0.006	3.05	0.316	0.1	0.316	19.5
1	0.06	1	25.7	3.16	0.075	1	21	0.007	0.81	0.008	3.5	1	0.035	1	25.75
				10	0.025	3.16	25	0.01	0.755	0.01	3.89	3.16	0.012	3.16	30
						10	28	0.02	0.63	0.02	5.45				
								0.07	0.39	0.03	6.61				
								0.1	0.325	0.05	8.28				
								0.2	0.205	0.1	10.79				
								0.3	0.15	0.2	13.23				
								0.4	0.115	0.3	14.47				
								0.5	0.095	0.4	15.24				
								0.6	0.08	0.6	16.14				
								0.8	0.07	0.8	16.66				
								1	0.05	1	17.01				





IV. ESTIMATE ROCK ACCELERATION AT CLEAN HARBORS SITE

N 40.817° W 113.206°

→ THE ROCK PGA FOR 2% PROBABILITY OF EXCEEDANCE IN 50 YEARS IS 0.147, TAKEN FROM FIG. 22-7 OF ASCE 7-10 (USING USGS U.S. SEISMIC DESIGN MAPS TOOL AT EARTHQUAKE.USGS.GOV). PRINT-OUT PROVIDED IN BACK.

V. SELECT STRONG GROUND MOTION RECORDS:

→ SELECT GROUND MOTION RECORDS TO MATCH THE MEAN MAGNITUDE, DISTANCE, & PGA FROM THE USGS DEAGGREGATION TOOL. PRINTOUT PROVIDED IN BACK.

MEAN DISTANCE, r = 26 km
MEAN MAGNITUDE, m = 6.2
PGA = 0.147
ROCK MOTIONS, $V_s \gtrsim$ 760 m/s (2,500 ft/s) (NO LESS THAN 400)

Location	Year	RSN	Filename	Fault Type	M	distance [km]	Vs30 [m/s]	PGA [g]	Target PGA [g]	acceleration scaling factor
Norcia, Italy	1979	156	CSC-EW	Normal	5.9	5	585	0.208	0.147	0.7
Norcia, Italy	1979	156	CSC-NS	Normal	5.9	5	585	0.154	0.147	1.0
Irpinia, Italy	1980	291	VLT000	Normal	6.9	30	575	0.096	0.147	1.5
Irpinia, Italy	1980	291	VLT270	Normal	6.9	30	575	0.099	0.147	1.5
Edgecumbe, New Zealand	1987	587	MAT083	Normal	6.6	16	551	0.283	0.147	0.5
Edgecumbe, New Zealand	1987	587	MAT353	Normal	6.6	16	551	0.24	0.147	0.6
Northridge, CA	1992	957	HOW060	Reverse	6.69	17	582	0.111	0.147	1.3
Northridge, CA	1992	957	HOW330	Reverse	6.69	17	582	0.159	0.147	0.9
Little Skull Mtn., NV	1992	1741	LSM2000	Normal	5.65	25	593	0.118	0.147	1.2
Little Skull Mtn., NV	1992	1741	LSM2270	Normal	5.65	25	593	0.09	0.147	1.6
Lazio-Abruzzo, Italy	1984	3605	CSS000	Normal	5.8	24	437	0.145	0.147	1.0
Lazio-Abruzzo, Italy	1984	3605	CSS090	Normal	5.8	24	437	0.113	0.147	1.3
Umbria, Italy	1984	4316	PTL000	Normal	5.6	25	497	0.194	0.147	0.8
Umbria, Italy	1984	4316	PTL090	Normal	5.6	25	497	0.19	0.147	0.8
Umbria Marche, Italy	1997	4351	MTL000	Normal	6	25	437	0.116	0.147	1.3
Umbria Marche, Italy	1997	4351	MTL270	Normal	6	25	437	0.109	0.147	1.3

RUN SHAKE 2000

OPTION 1 DYNAMIC SOIL PROPERTIES

		MODULUS REDUCTION	DAMPING
(1)	SAND:	SAND, AVE. (SEED & IDRISS, 1970)	SAND, AVE (SEED & IDRISS, 1
(2)	CLAY:	CLAY, PI = 20-40 (SUN ET AL, 1988)	CLAY (IDRISS, 1990)
(3)	GRAVEL:	GRAVEL, MEAN (ROLLINS ET AL, 1998)	GRAVEL, MEAN (ROLLINS ET AL, 1
(4)	BEDROCK:	ROCK 501 TO 1000 FT (EPRI, 1993)	ROCK 501 TO 1000 FT (EPRI, 1

OPTION 2: SOIL PROFILE

* VALUES USED FROM ABOVE

OPTION 3: INPUT MOTIONS

* MOTIONS USED FROM ABOVE

OPTION 4: INPUT MOTION

* INPUT MOTION SET TO BE BEDROCK MOTION AT TOP OF LAYER 24 (480 FT DEPTH)

OPTION 5: NO. OF ITERATIONS

- SET # OF ITERATIONS TO 10
- SET STRAIN RATIO TO $\frac{M-1}{10} = \frac{6.2-1}{10} = 0.52$

OPTION 6: ACCELERATION AT SUBLAYER

- SET ACCELERATION & TIME HISTORY TO BE RECORDED WITHIN TOP SUBLAYER, MAX. ACCELERATION ONLY IN SUBSEQUENT SUBLAYERS. ODD SUBLAYERS ONLY

OPTION 7: STRESS & STRAIN TIME HISTORIES TO BE COMPUTED AT TOP OF LAYER 1

AGEC
Applied GeoTech

PROJECT NO. 1160276 TITLE CLEAN HARBORS, CELLS 8-13 DATE 8/31/17 BY TJN

SUBJECT SEISMIC RESPONSE ANALYSIS SHEET 19 OF 19

OPTION 9: RESPONSE SPECTRUM AT SURFACE

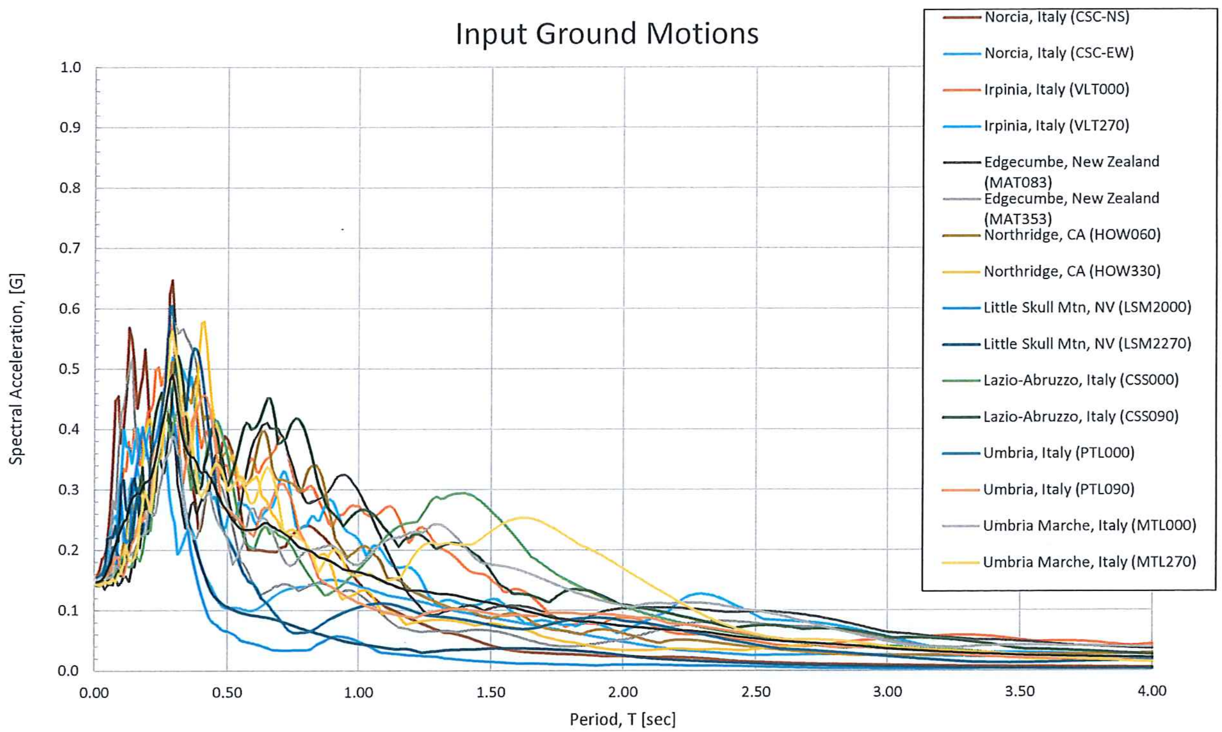
- CALCULATE RESPONSE SPECTRUM AT TOP OF ISOLATOR 1, OUTCROP MOTION

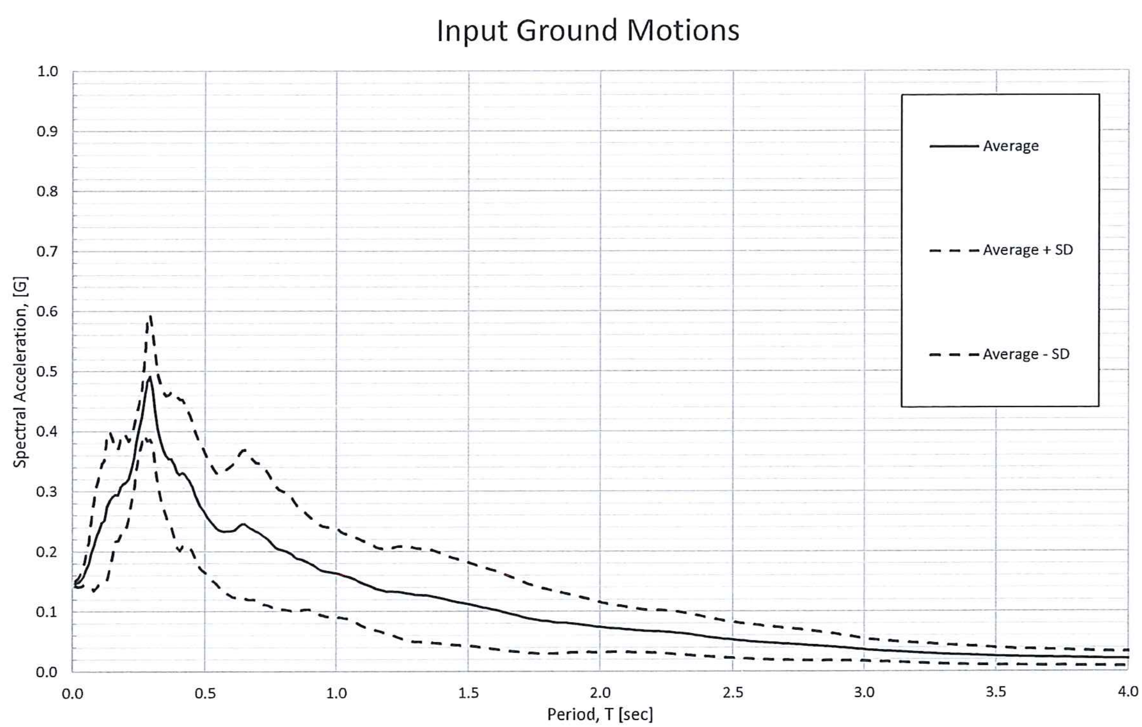
RESULTS

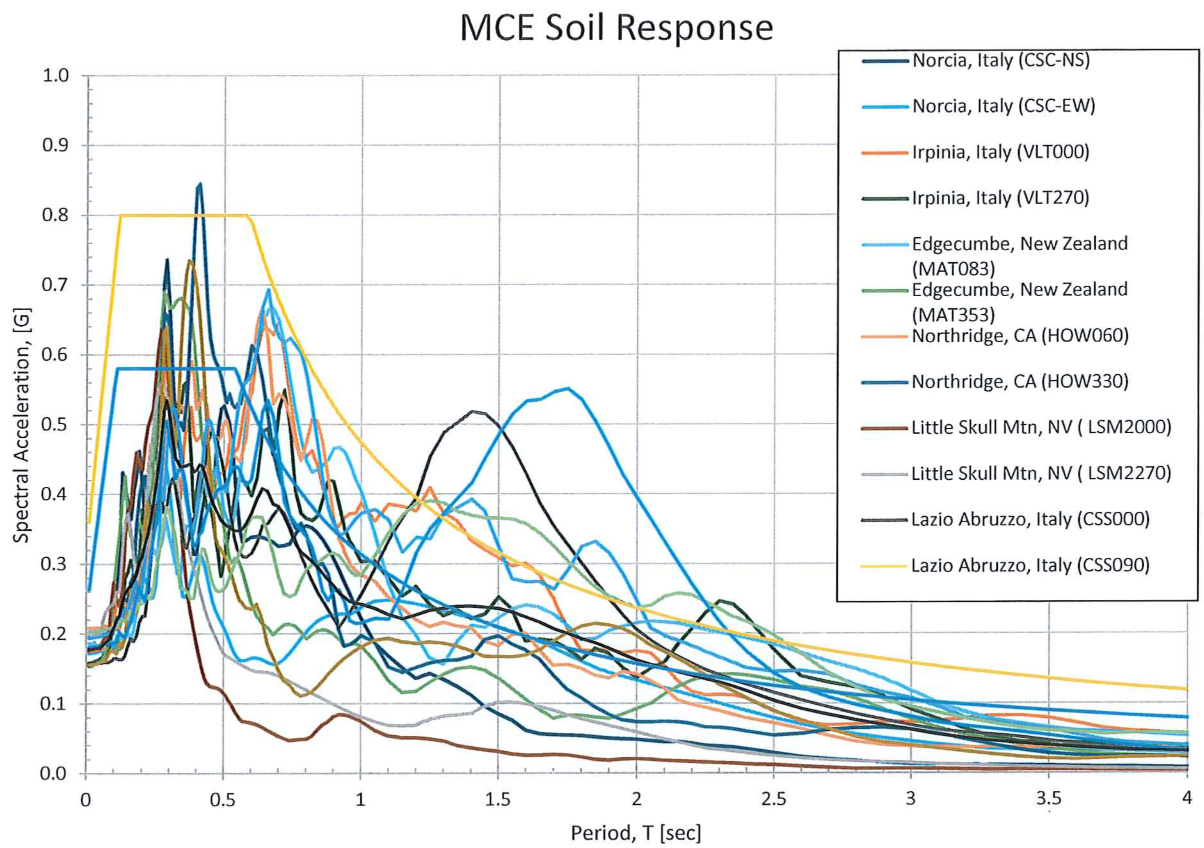
AVERAGE PGA FOR MAXIMUM CONSIDERED EARTHQUAKE (MCE)

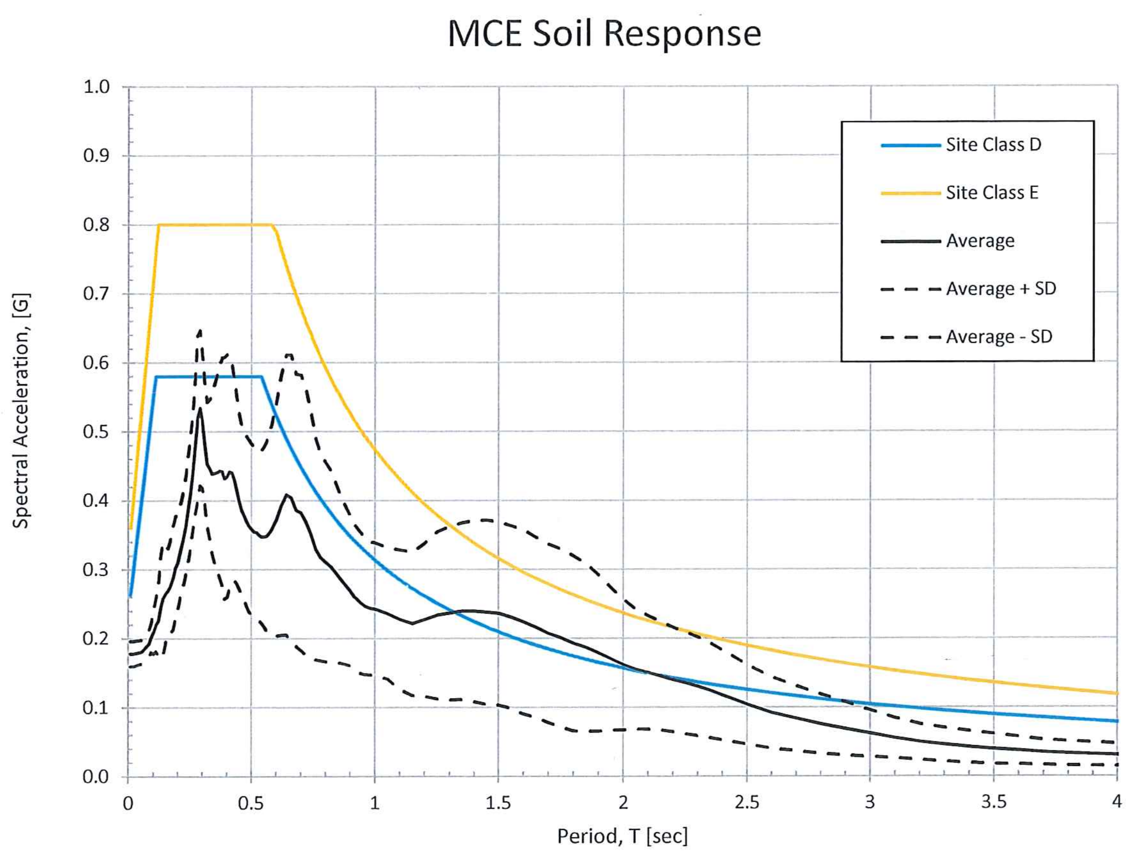
= 0.18 g

* RESULTS ARE SHOWN IN FOLLOWING PAGES


Input Ground Motions
Spectral Acceleration, [G]
Period, T [sec]
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
4.00
Norcia, Italy (CSC-NS)
Norcia, Italy (CSC-EW)
Irpinia, Italy (VLT000)
Irpinia, Italy (VLT270)
Edgecumbe, New Zealand (MAT083)
Edgecumbe, New Zealand (MAT353)
Northridge, CA (HOW060)
Northridge, CA (HOW330)
Little Skull Mtn, NV (LSM2000)
Little Skull Mtn, NV (LSM2270)
Lazio-Abruzzo, Italy (CSS000)
Lazio-Abruzzo, Italy (CSS090)
Umbria, Italy (PTL000)
Umbria, Italy (PTL090)
Umbria Marche, Italy (MTL000)
Umbria Marche, Italy (MTL270)


Input Ground Motions
Spectral Acceleration, [G]
Period, T [sec]
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
Average
Average + SD
Average - SD


MCE Soil Response
Spectral Acceleration, [G]
Period, T [sec]
Norcia, Italy (CSC-NS)
Norcia, Italy (CSC-EW)
Irpinia, Italy (VLT000)
Irpinia, Italy (VLT270)
Edgecumbe, New Zealand (MAT083)
Edgecumbe, New Zealand (MAT353)
Northridge, CA (HOW060)
Northridge, CA (HOW330)
Little Skull Mtn, NV (LSM2000)
Little Skull Mtn, NV (LSM2270)
Lazio Abruzzo, Italy (CSS000)
Lazio Abruzzo, Italy (CSS090)


MCE Soil Response
Spectral Acceleration, [G]
Period, T [sec]
Site Class D
Site Class E
Average
Average + SD
Average - SD

Period	Norcia, Italy		Irpinia, Italy		Edgecumbe, New Zealand		Northridge, CA		Little Skull Mountain, NV		Lazio-Abruzzo, Italy		Umbria, Italy		Umbria Marche, Italy				
	Norcia, Italy (CSC-NS)	Norcia, Italy (CSC-EW)	Irpinia, Italy (VLT000)	Irpinia, Italy (VLT270)	Edgecumbe, New Zealand (MAT083)	Edgecumbe, New Zealand (MAT353)	Northridge, CA (HOW060)	Northridge, CA (HOW330)	Little Skull Mtn, NV (LSM2000)	Little Skull Mtn, NV (LSM2270)	Lazio Abruzzo, Italy (CSS000)	Lazio Abruzzo, Italy (CSS090)	Umbria, Italy (PTL000)	Umbria, Italy (PTL090)	Umbria Marche, Italy (MTL000)	Umbria Marche, Italy (MTL270)	Average	Average + SD	Average - SD
	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%	Sa 5%			
(sec)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)	(g)			
0.01	0.15	0.17	0.17	0.16	0.19	0.16	0.21	0.20	0.18	0.20	0.16	0.19	0.16	0.17	0.20	0.18	0.18	0.20	0.16
0.02	0.16	0.17	0.18	0.16	0.19	0.15	0.21	0.20	0.18	0.20	0.16	0.19	0.16	0.17	0.20	0.18	0.18	0.20	0.16
0.03	0.16	0.17	0.18	0.16	0.19	0.16	0.21	0.20	0.18	0.20	0.16	0.19	0.16	0.17	0.20	0.18	0.18	0.20	0.16
0.04	0.16	0.17	0.18	0.16	0.18	0.16	0.21	0.20	0.18	0.20	0.15	0.20	0.16	0.18	0.20	0.18	0.18	0.20	0.16
0.05	0.16	0.18	0.18	0.16	0.18	0.16	0.21	0.20	0.18	0.20	0.16	0.20	0.16	0.18	0.20	0.18	0.18	0.20	0.16
0.06	0.16	0.18	0.18	0.17	0.19	0.16	0.21	0.20	0.19	0.22	0.16	0.20	0.16	0.18	0.21	0.18	0.18	0.20	0.17
0.07	0.18	0.18	0.18	0.17	0.19	0.18	0.21	0.20	0.20	0.23	0.16	0.20	0.16	0.18	0.21	0.19	0.19	0.21	0.17
0.08	0.19	0.19	0.19	0.17	0.19	0.19	0.21	0.20	0.18	0.24	0.16	0.20	0.17	0.18	0.21	0.19	0.19	0.21	0.17
0.09	0.22	0.19	0.20	0.20	0.19	0.21	0.21	0.20	0.24	0.24	0.16	0.20	0.18	0.18	0.21	0.19	0.20	0.22	0.18
0.1	0.23	0.18	0.22	0.21	0.19	0.27	0.21	0.21	0.27	0.24	0.16	0.20	0.18	0.18	0.21	0.19	0.21	0.24	0.18
0.11	0.27	0.20	0.24	0.21	0.19	0.31	0.22	0.22	0.25	0.26	0.16	0.21	0.17	0.19	0.21	0.19	0.22	0.26	0.18
0.12	0.32	0.18	0.25	0.21	0.19	0.34	0.21	0.23	0.24	0.26	0.16	0.22	0.19	0.20	0.21	0.20	0.23	0.27	0.18
0.13	0.43	0.19	0.23	0.23	0.19	0.39	0.22	0.26	0.26	0.32	0.16	0.22	0.18	0.21	0.22	0.20	0.25	0.32	0.17
0.14	0.41	0.19	0.22	0.23	0.20	0.43	0.22	0.25	0.34	0.36	0.17	0.24	0.19	0.22	0.22	0.20	0.26	0.34	0.18
0.15	0.39	0.21	0.25	0.29	0.20	0.37	0.23	0.25	0.38	0.37	0.18	0.24	0.23	0.22	0.22	0.21	0.26	0.34	0.19
0.16	0.36	0.23	0.24	0.31	0.19	0.34	0.25	0.27	0.38	0.35	0.19	0.25	0.26	0.22	0.23	0.22	0.27	0.33	0.21
0.17	0.41	0.28	0.26	0.29	0.21	0.33	0.23	0.28	0.43	0.31	0.19	0.26	0.25	0.22	0.23	0.24	0.28	0.34	0.21
0.18	0.43	0.31	0.26	0.28	0.23	0.35	0.23	0.36	0.46	0.27	0.20	0.28	0.23	0.23	0.23	0.25	0.29	0.36	0.21
0.19	0.46	0.29	0.29	0.32	0.26	0.36	0.25	0.40	0.44	0.29	0.22	0.25	0.26	0.25	0.24	0.27	0.30	0.38	0.23
0.2	0.42	0.28	0.31	0.38	0.27	0.35	0.30	0.42	0.43	0.30	0.22	0.27	0.29	0.25	0.24	0.26	0.31	0.38	0.24
0.21	0.37	0.28	0.38	0.36	0.29	0.34	0.30	0.43	0.47	0.36	0.23	0.32	0.35	0.28	0.25	0.25	0.33	0.39	0.26
0.22	0.32	0.27	0.42	0.37	0.31	0.33	0.30	0.40	0.50	0.41	0.26	0.34	0.39	0.34	0.25	0.27	0.34	0.41	0.28
0.23	0.34	0.26	0.47	0.36	0.32	0.40	0.35	0.38	0.51	0.46	0.30	0.36	0.36	0.36	0.25	0.31	0.36	0.43	0.29
0.24	0.44	0.25	0.48	0.35	0.32	0.44	0.40	0.37	0.52	0.50	0.35	0.39	0.39	0.40	0.26	0.34	0.39	0.46	0.31
0.25	0.46	0.27	0.47	0.42	0.31	0.43	0.41	0.40	0.56	0.53	0.38	0.39	0.43	0.42	0.29	0.36	0.41	0.49	0.33
0.26	0.47	0.32	0.49	0.46	0.32	0.54	0.42	0.48	0.61	0.55	0.41	0.41	0.45	0.45	0.31	0.38	0.44	0.53	0.36
0.27	0.57	0.39	0.49	0.47	0.33	0.65	0.41	0.57	0.64	0.56	0.41	0.41	0.54	0.49	0.33	0.44	0.48	0.58	0.38
0.28	0.70	0.43	0.56	0.52	0.35	0.69	0.44	0.66	0.63	0.56	0.37	0.39	0.63	0.52	0.36	0.50	0.52	0.64	0.40
0.29	0.74	0.44	0.60	0.54	0.37	0.68	0.49	0.66	0.59	0.54	0.38	0.46	0.64	0.53	0.38	0.51	0.53	0.65	0.42
0.3	0.67	0.41	0.54	0.52	0.34	0.67	0.51	0.64	0.55	0.52	0.41	0.50	0.57	0.52	0.38	0.48	0.52	0.61	0.42
0.31	0.58	0.37	0.43	0.53	0.33	0.67	0.46	0.57	0.51	0.49	0.42	0.53	0.50	0.47	0.36	0.46	0.48	0.57	0.40
0.32	0.52	0.33	0.44	0.53	0.30	0.68	0.49	0.46	0.47	0.46	0.41	0.52	0.47	0.41	0.34	0.42	0.45	0.54	0.36
0.33	0.49	0.29	0.43	0.52	0.29	0.68	0.52	0.50	0.42	0.42	0.39	0.50	0.52	0.44	0.31	0.43	0.45	0.55	0.35
0.34	0.46	0.28	0.39	0.52	0.29	0.68	0.53	0.50	0.37	0.39	0.37	0.47	0.61	0.48	0.27	0.44	0.44	0.55	0.32
0.35	0.42	0.25	0.46	0.56	0.32	0.68	0.52	0.43	0.33	0.36	0.34	0.42	0.68	0.52	0.26	0.43	0.44	0.57	0.31
0.36	0.40	0.25	0.50	0.56	0.35	0.67	0.51	0.53	0.28	0.34	0.32	0.39	0.72	0.55	0.26	0.41	0.44	0.58	0.30
0.37	0.38	0.27	0.51	0.51	0.35	0.67	0.57	0.60	0.25	0.32	0.33	0.37	0.73	0.58	0.26	0.38	0.44	0.60	0.29
0.38	0.36	0.28	0.52	0.45	0.35	0.65	0.59	0.68	0.23	0.31	0.36	0.35	0.73	0.61	0.25	0.35	0.44	0.61	0.28
0.39	0.31	0.29	0.43	0.38	0.36	0.62	0.57	0.78	0.21	0.29	0.37	0.34	0.72	0.62	0.25	0.33	0.43	0.61	0.26
0.4	0.31	0.31	0.48	0.41	0.37	0.57	0.52	0.84	0.19	0.28	0.38	0.38	0.70	0.64	0.27	0.33	0.44	0.61	0.26
0.41	0.35	0.31	0.43	0.43	0.39	0.52	0.53	0.84	0.17	0.27	0.40	0.42	0.66	0.64	0.30	0.34	0.44	0.61	0.27
0.42	0.38	0.31	0.49	0.43	0.41	0.48	0.55	0.81	0.15	0.25	0.43	0.44	0.61	0.64	0.32	0.35	0.44	0.60	0.28
0.43	0.40	0.30	0.47	0.40	0.42	0.46	0.53	0.74	0.14	0.24	0.45	0.49	0.55	0.62	0.32	0.37	0.43	0.58	0.28
0.44	0.41	0.28	0.44	0.38	0.40	0.45	0.52	0.67	0.13	0.23	0.47	0.51	0.49	0.59	0.31	0.38	0.42	0.55	0.28
0.45	0.40	0.26	0.41	0.38	0.40	0.44	0.49	0.62	0.13	0.21	0.49	0.50	0.44	0.55	0.29	0.39	0.40	0.53	0.27
0.46	0.39	0.25	0.39	0.37	0.42	0.42	0.48	0.60	0.12	0.20	0.49	0.49	0.39	0.50	0.27	0.39	0.39	0.51	0.26
0.47	0.45	0.23	0.42	0.34	0.44	0.40	0.48	0.59	0.12	0.20	0.48	0.47	0.34	0.44	0.26	0.40	0.38	0.50	0.26
0.48	0.50	0.23	0.43	0.32	0.42	0.39	0.48	0.58	0.12	0.19	0.47	0.43	0.33	0.38	0.26	0.41	0.37	0.49	0.25
0.49	0.52	0.22	0.43	0.28	0.40	0.38	0.48	0.57	0.12	0.18	0.45	0.41	0.32	0.37	0.26	0.41	0.36	0.49	0.24
0.5	0.53	0.21	0.43	0.30	0.38	0.36	0.50	0.55	0.12	0.17	0.43	0.41	0.31	0.37	0.26	0.41	0.36	0.48	0.23
0.51	0.52	0.20	0.44	0.33	0.37	0.34	0.51	0.53	0.11	0.17	0.41	0.40	0.31	0.36	0.27	0.42	0.35	0.48	0.23
0.52	0.50	0.19	0.47	0.35	0.36	0.31	0.49	0.54	0.10	0.17	0.38	0.43	0.30	0.36	0.28	0.43	0.35	0.48	0.23
0.53	0.47	0.18	0.47	0.38	0.35	0.30	0.46	0.53	0.10	0.16	0.36	0.46	0.28	0.35	0.29	0.44	0.35	0.47	0.23
0.54	0.43	0.17	0.46	0.40	0.37	0.31	0.46	0.52	0.08	0.16	0.34	0.49	0.27	0.35	0.30	0.44	0.35	0.47	0.22
0.55	0.39	0.17	0.47	0.42	0.40	0.31	0.45	0.53	0.08	0.16	0.32	0.52	0.26	0.34	0.31	0.44	0.35	0.48	0.22
0.56	0.35	0.16	0.49	0.43	0.44	0.30	0.45	0.53	0.08	0.16	0.31	0.54	0.25	0.34	0.32	0.43	0.35	0.48	0.21
0.57	0.33	0.16	0.51	0.42	0.47	0.29	0.46	0.56	0.07	0.15	0.31	0.56	0.24	0.33	0.33	0.42	0.35	0.50	0.21
0.58	0.33	0.16	0.54	0.42	0.51	0.27	0.48	0.56	0.07	0.15	0.31	0.56	0.24	0.34	0.35	0.41	0.36	0.51	0.21
0.6	0.34	0.17	0.54	0.40	0.57	0.25	0.56	0.61	0.07	0.15	0.31	0.57	0.24	0.39	0.37	0.42	0.37	0.54	0.20
0.62	0.34	0.17	0.61	0.42	0.62	0.23	0.64	0.60	0.07	0.15	0.33	0.61	0.24	0.43	0.37	0.47	0.39	0.58	0.20
0.64	0.34	0.16	0.64	0.49	0.64	0.22	0.67	0.56	0.07	0.15	0.35	0.67	0.22	0.46	0.37	0.52	0.41	0.61	0.21
0.66	0.34	0.16	0.64	0.50	0.67	0.21	0.62	0.51	0.06	0.14	0.36	0.69	0.19	0.50	0.35	0.53	0.40	0.61	0.20
0.68	0.33	0.16	0.63	0.46	0.67	0.20	0.53	0.46	0.06	0.14	0.37	0.65	0.17	0.54	0.31	0.51	0.39	0.58	0.19
0.7	0.33	0.16	0.65	0.52	0.65	0.21	0.54	0.43	0.05	0.14	0.38	0.62	0.15	0.55	0.28	0.46	0.38	0.58	0.18
0.72	0.33	0.16	0.60	0.55	0.61	0.21	0.54	0.40	0.05	0.14	0.37	0.62	0.13	0.54	0.26	0.39	0.37	0.56	0.18
0.74	0.33	0.17	0.54	0.50	0.56	0.21	0.51	0.37	0.05	0.13	0.36	0.62	0.13	0.50	0.25	0.37	0.35	0.53	0.17
0.76	0.34	0.18	0.48	0.41	0.52	0.21	0.47	0.35	0.05	0.13	0.34	0.61	0.12	0.45	0.26	0.36	0.33	0.49	0.17
0.78	0.35	0.19	0.45	0.37	0.48	0.20	0.45	0.36	0.05	0.12	0.31	0.60	0.11	0.33	0.28	0.35	0.32	0.47	0.17
0.8	0.36	0.20	0.46	0.37	0.45	0.19	0.48	0.34	0.05	0.12	0.29	0.57	0.11	0.36	0.29	0.34	0.31	0.46	0.17
0.82	0.35	0.21	0.46	0.36	0.43	0.20	0.51	0.31	0.05	0.12	0.28	0.53	0.12	0.32	0.30	0.32	0.30	0.44	0.17
0.84	0.35	0.22	0.44	0.37	0.44	0.20	0.50	0.30	0.06	0.11	0.26	0.47	0.12	0.29	0.30	0.30	0.30	0.43	0.17
0.86	0.34	0.22	0.41	0.39	0.44	0.21	0.47	0.30	0.07	0.11	0.25	0.42	0.13	0.25	0.31	0.26	0.29	0.41	0.16
0.88	0.32	0.23	0.38	0.42	0.45	0.20	0.42	0.29	0.07	0.10	0.24	0.38	0.14	0.23	0.31	0.25	0.28	0.39	0.16
0.9	0.31	0.23	0.36	0.42	0.47	0.20	0.37	0.25	0.08	0.10	0.22	0.36	0.15	0.22	0.32	0.26	0.27	0.38	0.16
0.92	0.29	0.23	0.35	0.39	0.47	0.19	0.34	0.21	0.08	0.10	0.21	0.34	0.16	0.22	0.31	0.26	0.26	0.36	0.15
0.94	0.27	0.23	0.37	0.35	0.46	0.18	0.32	0.18	0.08	0.09	0.22	0.34	0.17	0.21	0.30	0.25	0.25	0.35	0.15
0.96	0.26	0.23	0.37	0.33	0.44	0.19	0.30	0.19	0.08	0.09	0.23	0.35	0.17	0.20	0.29	0.22	0.25	0.35	0.15
0.98	0.24	0.23	0.37	0.32	0.42	0.19	0.23	0.19	0.08	0.08	0.24	0.37	0.18	0.20	0.23	0.22	0.24	0.34	0.15
1	0.22	0.24	0.39	0.30	0.40	0.18	0.29	0.20	0.07	0.08	0.26	0.37	0.18	0.19	0.23	0.22	0.24	0.34	0.15
1.05	0.19	0.25	0.36	0.30	0.34	0.16	0.28	0.19	0.06	0.07	0.29	0.38	0.19	0.18	0.31	0.22	0.24	0.33	0.14
1.1	0.17	0.25	0.39	0.28	0.27	0.13	0.25	0.15	0.05	0.07	0.33	0.36	0.19	0.16	0.35	0.22	0.23	0.33	0.13
1.15	0.15	0.25	0.38	0.25	0.22	0.12	0.24	0.15	0.05	0.07	0.37	0.32	0.19	0.16	0.37	0.26	0.22	0.33	0.12
1.2	0.14	0.24	0.38	0.27	0.20	0.12	0.22	0.15	0.05	0.07	0.39	0.34	0.19	0.18	0.39	0.32	0.23	0.34	0.12
1.25	0.14	0.24	0.41	0.24	0.17	0.13	0.21	0.16	0.05	0.08	0.45	0.34	0.19	0.19	0.39	0.35	0.23	0.35	0.11
1.3	0.13	0.23	0.37	0.23	0.16	0.14	0.22	0.16	0.05	0.08	0.49	0.37	0.19	0.20	0.39	0.37	0.24	0.36	0.11
1.35	0.12	0.23	0.36	0.23	0.19	0.15	0.21	0.16	0.04	0.08	0.50	0.38	0.18	0.21	0.38	0.39	0.24	0.37	0.11
1.4	0.11	0.22	0.33	0.22	0.21	0.15	0.21	0.17	0.04	0.09	0.52	0.39	0.18	0.21	0.37	0.42	0.24	0.37	0.11
1.45	0.10	0.22	0.32	0.23	0.21	0.15	0.19	0.19	0.03	0.10	0.52	0.38	0.17	0.20	0.37	0.45	0.24	0.37	0.10
1.5	0.09	0.21	0.31	0.25	0.22	0.14	0.18	0.20	0.03	0.10	0.50	0.33	0.17	0.21	0.37	0.49	0.24	0.37	0.10
1.55	0.08	0.20	0.30	0.24	0.24	0.12	0.20	0.19	0.03	0.10	0.47	0.28	0.17	0.22	0.36	0.52	0.23	0.36	0.10
1.6	0.06	0.20	0.30	0.19	0.24	0.11	0.20	0.18	0.03	0.10	0.43	0.27	0.17	0.22	0.36	0.53	0.22	0.36	0.09
1.65	0.06	0.19	0.28	0.19	0.24	0.09	0.18	0.16	0.03	0.10	0.39	0.27	0.18	0.23	0.34	0.54	0.22	0.35	0.09
1.7	0.06	0.18	0.25	0.19	0.23	0.08	0.15	0.14	0.03	0.09	0.35	0.26	0.19	0.24	0.33	0.55	0.21	0.34	0.08
1.75	0.05	0.17	0.21	0.18	0.21	0.08	0.16	0.12	0.03	0.08	0.33	0.29	0.20	0.24	0.30	0.55	0.20	0.33	0.07
1.8	0.05	0.16	0.18	0.16	0.19	0.08	0.15	0.11	0.02	0.08	0.30	0.32	0.21	0.24	0.28	0.54	0.19	0.32	0.07
1.85	0.05	0.15	0.18	0.18	0.19	0.08	0.14	0.10	0.02	0.07	0.27	0.33	0.21	0.23	0.27	0.50	0.19	0.31	0.07
1.9	0.05	0.14	0.18	0.17	0.20	0.08	0.14	0.08	0.02	0.07	0.25	0.32	0.21	0.23	0.25	0.47	0.18	0.29	0.07
1.95	0.05	0.14	0.17	0.15	0.21	0.09	0.15	0.08	0.02	0.06	0.23	0.29	0.21	0.22	0.24	0.43	0.17	0.27	0.07
2	0.05	0.13	0.18	0.14	0.22	0.09	0.14	0.07	0.02	0.06	0.21	0.25	0.20	0.21	0.24	0.40	0.16	0.26	0.07
2.05	0.05	0.13	0.17	0.15	0.22	0.10	0.13	0.07	0.02	0.05	0.19	0.21	0.18	0.20	0.24	0.36	0.16	0.24	0.07
2.1	0.05	0.12	0.15	0.16	0.22	0.11	0.12	0.07	0.02	0.05	0.18	0.20	0.17	0.20	0.25	0.33	0.15	0.23	0.07
2.15	0.04	0.12	0.13	0.19	0.21	0.12	0.11	0.07	0.02	0.04	0.17	0.19	0.16	0.19	0.26	0.30	0.15	0.22	0.07
2.2	0.04	0.11	0.12	0.21	0.21	0.13	0.10	0.07	0.02	0.04	0.16	0.18	0.15	0.17	0.26	0.27	0.14	0.22	0.06
2.25	0.04	0.11	0.11	0.23	0.21	0.14	0.09	0.07	0.02	0.04	0.15	0.17	0.14	0.16	0.25	0.24	0.14	0.21	0.06
2.3	0.04	0.10	0.11	0.25	0.20	0.14	0.09	0.07	0.02	0.03	0.14	0.17	0.13	0.15	0.23	0.22	0.13	0.20	0.06
2.35	0.04	0.09	0.11	0.24	0.20	0.14	0.08	0.06	0.01	0.03	0.13	0.16	0.12	0.14	0.22	0.19	0.12	0.19	0.06
2.4	0.03	0.09	0.11	0.22	0.13	0.14	0.08	0.06	0.01	0.03	0.13	0.15	0.11	0.13	0.22	0.17	0.12	0.18	0.05
2.5	0.03	0.08	0.09	0.18	0.18	0.13	0.07	0.05	0.01	0.03	0.12	0.15	0.09	0.11	0.20	0.14	0.10	0.16	0.05
2.6	0.02	0.07	0.07	0.14	0.17	0.12	0.06	0.06	0.01	0.02	0.10	0.15	0.08	0.10	0.17	0.12	0.09	0.14	0.04
2.7	0.02	0.06	0.07	0.13	0.16	0.12	0.05	0.06	0.01	0.02	0.09	0.14	0.06	0.09	0.14	0.11	0.08	0.13	0.04
2.8	0.02	0.06	0.07	0.12	0.15	0.11	0.05	0.06	0.01	0.02	0.09	0.13	0.05	0.07	0.12	0.10	0.08	0.12	0.03
2.9	0.01	0.05	0.07	0.11	0.14	0.09	0.04	0.07	0.01	0.02	0.08	0.12	0.04	0.07	0.11	0.09	0.07	0.11	0.03
3	0.01	0.05	0.07	0.09	0.12	0.08	0.04	0.06	0.01	0.01	0.07	0.11	0.04	0.06	0.10	0.08	0.06	0.10	0.03
3.1	0.01	0.04	0.08	0.08	0.10	0.06	0.04	0.06	0.01	0.01	0.06	0.10	0.04	0.05	0.09	0.07	0.06	0.08	0.03
3.2	0.01	0.04	0.08	0.06	0.09	0.06	0.04	0.05	0.01	0.01	0.06	0.08	0.03	0.05	0.08	0.07	0.05	0.08	0.02
3.3	0.01	0.03	0.08	0.05	0.08	0.05	0.04	0.04	0.00	0.01	0.06	0.07	0.03	0.05	0.07	0.06	0.05	0.07	0.02
3.4	0.01	0.03	0.08	0.04	0.07	0.04	0.04	0.03	0.01	0.01	0.05	0.07	0.02	0.04	0.06	0.06	0.04	0.07	0.02
3.5	0.01	0.03	0.08	0.04	0.07	0.04	0.04	0.03	0.01	0.01	0.05	0.06	0.02	0.04	0.06	0.05	0.04	0.06	0.02
3.6	0.01	0.03	0.07	0.04	0.06	0.03	0.04	0.03	0.01	0.01	0.04	0.06	0.02	0.04	0.06	0.05	0.04	0.06	0.02
3.7	0.01	0.03	0.06	0.04	0.06	0.03	0.04	0.02	0.00	0.01	0.04	0.05	0.02	0.04	0.06	0.04	0.03	0.05	0.02
3.8	0.01	0.03	0.06	0.04	0.06	0.03	0.04	0.02	0.00	0.01	0.04	0.04	0.02	0.03	0.06	0.04	0.03	0.05	0.02
3.9	0.01	0.03	0.06	0.04	0.06	0.02	0.04	0.02	0.00	0.01	0.04	0.04	0.02	0.03	0.06	0.04	0.03	0.05	0.01
4	0.01	0.03	0.05	0.04	0.05	0.02	0.04	0.02	0.00	0.01	0.03	0.04	0.02	0.03	0.06	0.03	0.03	0.05	0.01
4.1	0.01	0.03	0.06	0.04	0.05	0.02	0.04	0.02	0.00	0.01	0.03	0.04	0.02	0.03	0.05	0.03	0.03	0.05	0.01
4.2	0.01	0.03	0.06	0.04	0.05	0.02	0.04	0.02	0.00	0.00	0.03	0.04	0.02	0.03	0.05	0.03	0.03	0.04	0.01
4.3	0.01	0.03	0.05	0.04	0.05	0.02	0.04	0.02	0.00	0.00	0.03	0.03	0.02	0.02	0.05	0.03	0.03	0.04	0.01
4.4	0.01	0.02	0.05	0.04	0.05	0.02	0.04	0.02	0.00	0.00	0.03	0.03	0.02	0.02	0.05	0.03	0.03	0.04	0.01
4.5	0.01	0.02	0.05	0.04	0.04	0.02	0.04	0.02	0.00	0.00	0.03	0.03	0.02	0.02	0.05	0.02	0.03	0.04	0.01
4.6	0.01	0.02	0.04	0.04	0.04	0.02	0.04	0.02	0.00	0.00	0.03	0.03	0.02	0.02	0.05	0.02	0.03	0.04	0.01
4.7	0.01	0.02	0.04	0.04	0.04	0.02	0.04	0.02	0.00	0.00	0.03	0.03	0.02	0.02	0.05	0.02	0.02	0.04	0.01
4.8	0.01	0.02	0.03	0.04	0.04	0.02	0.03	0.01	0.00	0.00	0.02	0.02	0.02	0.02	0.05	0.02	0.02	0.04	0.01
4.9	0.01	0.02	0.03	0.04	0.04	0.01	0.03	0.01	0.00	0.00	0.02	0.02	0.02	0.02	0.05	0.02	0.02	0.04	0.01
5	0.00	0.02	0.03	0.04	0.04	0.01	0.03	0.01	0.00	0.00	0.02	0.02	0.01	0.02	0.05	0.02	0.02	0.03	0.01
5.1	0.00	0.02	0.03	0.04	0.04	0.01	0.03	0.01	0.00	0.00	0.02	0.02	0.01	0.02	0.05	0.02	0.02	0.03	0.01
5.2	0.00	0.02	0.03	0.03	0.04	0.01	0.03	0.01	0.00	0.00	0.02	0.02	0.01	0.02	0.05	0.02	0.02	0.03	0.01
5.4	0.00	0.02	0.03	0.03	0.04	0.01	0.02	0.01	0.00	0.00	0.02	0.02	0.01	0.02	0.04	0.02	0.02	0.03	0.01
5.6	0.00	0.01	0.02	0.03	0.03	0.01	0.02	0.01	0.00	0.00	0.02	0.02	0.01	0.02	0.04	0.02	0.02	0.03	0.01
5.8	0.00	0.01	0.02	0.02	0.03	0.01	0.02	0.01	0.00	0.00	0.02	0.01	0.01	0.02	0.04	0.02	0.01	0.02	0.01
6	0.00	0.01	0.02	0.02	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.02	0.01	0.02	0.00
6.2	0.00	0.01	0.02	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.00
6.4	0.00	0.01	0.02	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.01	0.01	0.02	0.00
6.6	0.00	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.00
6.8	0.00	0.01	0.01	0.01	0.03	0.01	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.00
7	0.00	0.01	0.01	0.01	0.03	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.00
7.3	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.03	0.01	0.01	0.02	0.00
7.6	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00
8	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00
8.5	0.00	0.01	0.01	0.01	0.02	0.00	0.01	0.01	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00
9	0.00	0.01	0.00	0.01	0.02	0.00	0.00	0.01	0.00	0.00	0.01	0.01	0.00	0.01	0.02	0.01	0.01	0.01	0.00
9.5	0.00	0.01	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.00
10	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00
10.5	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.01	0.00

Unified Hazard Tool

Please do not use this tool to obtain ground motion parameter values for the design code reference documents covered by the U.S. Seismic Design Maps web tools (e.g., the International Building Code and the ASCE 7 or 41 Standard). The values returned by the two applications are not identical.

^ Input

Edition

Dynamic: Conterminous U.S. 2008

Spectral Period

Peak ground acceleration

Latitude

Decimal degrees

40.817

Time Horizon

Return period in years

2475

Longitude

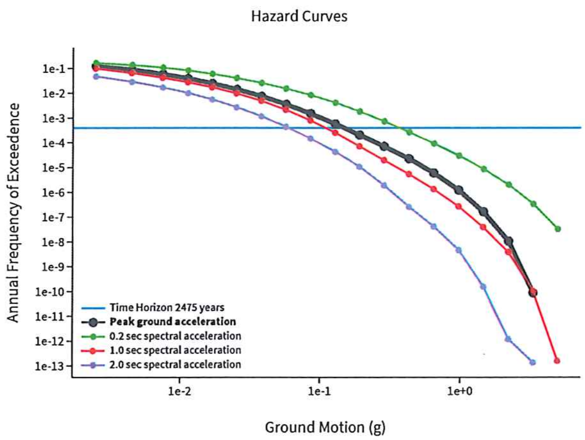
Decimal degrees, negative values for western long...

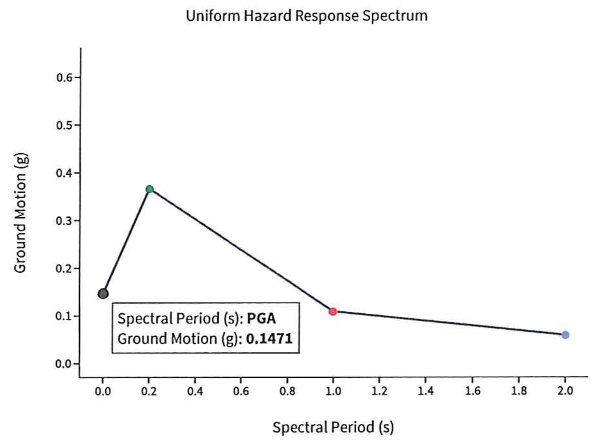
-113.206

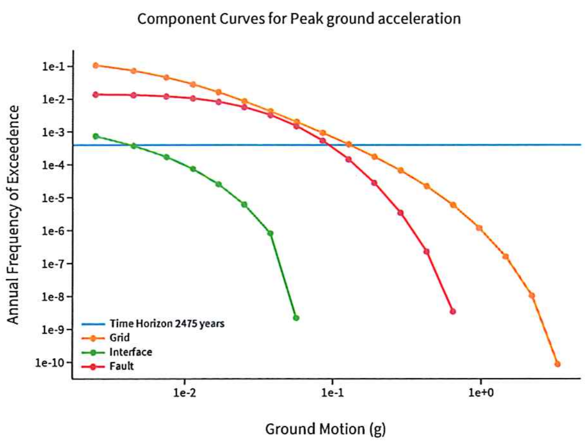
Site Class

760 m/s (B/C boundary)

Hazard Curve





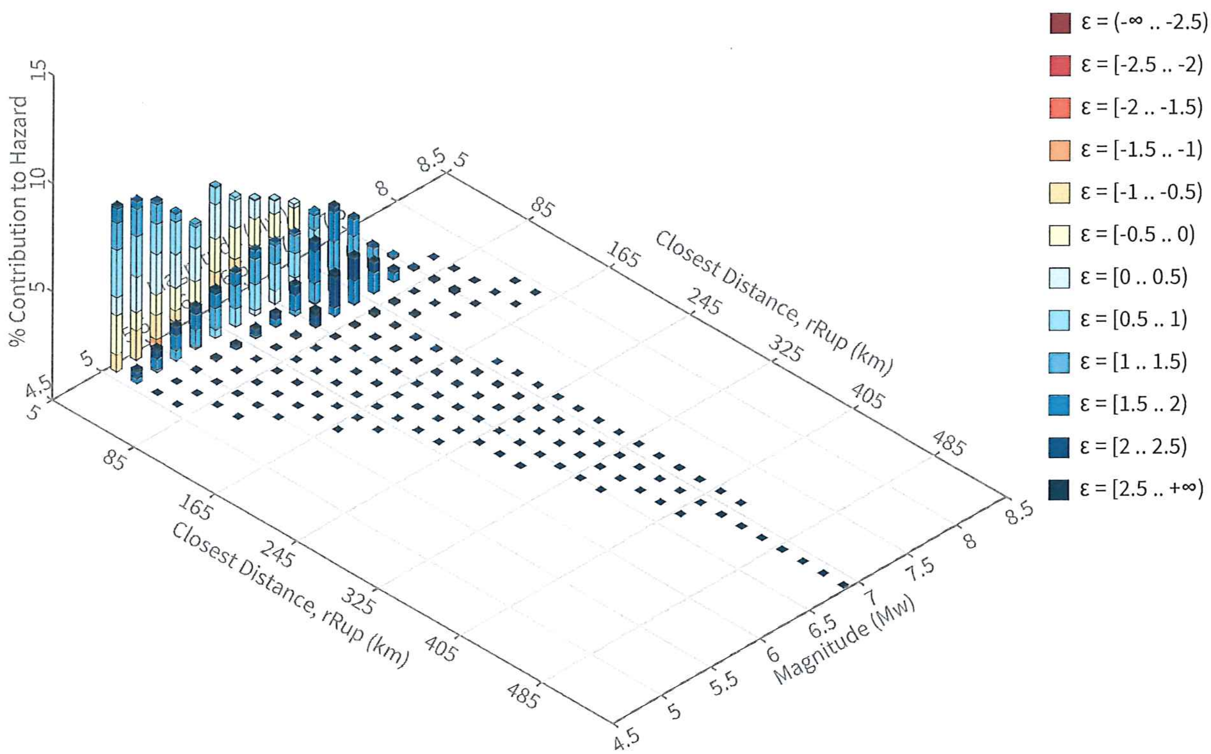


View Raw Data

Deaggregation

Component

Total



Summary statistics for, Deaggregation: Total

Deaggregation targets

Return period: 2475 yrs
Exceedance rate: 0.0004040404 yr^{-1}
PGA ground motion: 0.14706357 g

Recovered targets

Return period: 2635.1078 yrs
Exceedance rate: 0.00037949112 yr^{-1}

Totals

Binned: 100 %
Residual: 0 %
Trace: 0.68 %

Mean (for all sources)

r: 25.99 km
m: 6.17
ε_0: 0.65 σ

Mode (largest r-m bin)

r: 9.87 km
m: 5.1
ε_0: 0.51 σ
Contribution: 7.61 %

Mode (largest ε_0 bin)

r: 11.21 km

Deaggregation Contributors

Source Set ↳ Source	Type	r	m	ε_0	lon	lat	az	%
EXTmap.ch.in (opt)	Grid							53.11
PointSourceFinite: -113.206, 40.902		10.17	5.73	-0.02	113.206°W	40.902°N	0.00	7.20
PointSourceFinite: -113.206, 40.830		5.22	5.56	-0.83	113.206°W	40.830°N	0.00	7.05
PointSourceFinite: -113.206, 40.929		12.43	5.82	0.21	113.206°W	40.929°N	0.00	5.38
PointSourceFinite: -113.206, 40.893		9.44	5.71	-0.11	113.206°W	40.893°N	0.00	3.63
PointSourceFinite: -113.206, 40.956		14.72	5.92	0.40	113.206°W	40.956°N	0.00	2.89
PointSourceFinite: -113.206, 41.001		18.58	6.07	0.66	113.206°W	41.001°N	0.00	1.97
PointSourceFinite: -113.206, 40.938		13.19	5.85	0.28	113.206°W	40.938°N	0.00	1.84
PointSourceFinite: -113.206, 41.010		19.36	6.10	0.70	113.206°W	41.010°N	0.00	1.80
PointSourceFinite: -113.206, 41.055		23.35	6.23	0.91	113.206°W	41.055°N	0.00	1.67
PointSourceFinite: -113.206, 40.965		15.49	5.95	0.46	113.206°W	40.965°N	0.00	1.39
PointSourceFinite: -113.206, 41.046		22.54	6.20	0.87	113.206°W	41.046°N	0.00	1.35
PointSourceFinite: -113.206, 40.974		16.26	5.98	0.51	113.206°W	40.974°N	0.00	1.33
PointSourceFinite: -113.206, 41.109		28.29	6.35	1.11	113.206°W	41.109°N	0.00	1.32
PointSourceFinite: -113.206, 40.983		17.03	6.01	0.56	113.206°W	40.983°N	0.00	1.26
PointSourceFinite: -113.206, 40.992		17.80	6.04	0.61	113.206°W	40.992°N	0.00	1.18
PointSourceFinite: -113.206, 41.136		30.82	6.40	1.20	113.206°W	41.136°N	0.00	1.15
EXTmap.gr.in (opt)	Grid							26.34
PointSourceFinite: -113.206, 40.902		10.17	5.73	-0.02	113.206°W	40.902°N	0.00	3.59
PointSourceFinite: -113.206, 40.830		5.22	5.56	-0.83	113.206°W	40.830°N	0.00	3.52
PointSourceFinite: -113.206, 40.929		12.43	5.82	0.21	113.206°W	40.929°N	0.00	2.69
PointSourceFinite: -113.206, 40.893		9.44	5.71	-0.11	113.206°W	40.893°N	0.00	1.81
PointSourceFinite: -113.206, 40.956		14.72	5.92	0.40	113.206°W	40.956°N	0.00	1.44
ut.3dip.ch	Fault							12.22
Stansbury 50		40.72	7.07	1.18	112.659°W	40.690°N	106.94	3.70
Stansbury 40		37.15	7.07	1.03	112.659°W	40.690°N	106.94	2.30
ut.3dip.gr	Fault							6.94
Stansbury 50		44.57	6.81	1.52	112.659°W	40.690°N	106.94	2.22
Stansbury 40		41.54	6.81	1.40	112.659°W	40.690°N	106.94	1.33

APPENDIX I

LIQUEFACTION ANALYSIS

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PROJECT NO. 1160276 TITLE CLEAN HARBORS DATE 10/2/2017 BY TJN

SUBJECT LIQ. INDUCED SETTLEMENT - CPT SHEET 1 OF 1

LIQUEFACTION - INDUCED SETTLEMENT ESTIMATES WERE CALCULATED FROM 15 CPT SOUNDINGS PREVIOUSLY PERFORMED ON THE SITE. THE NCEER 1998 METHOD WAS USED, WITHIN THE CLIQ V2.0 SOFTWARE DEVELOPED BY PETER ROBERTSON & GREGG DRILLING. AN EARTHQUAKE MAGNITUDE OF 6.2 WAS USED, WITH A PGA OF 0.18 G.

A LAYER TRANSITION CORRECTION WAS USED, SUCH THAT SETTLEMENT WAS NOT CALCULATED FOR LAYERS IN WHICH I_c WAS RAPIDLY CHANGING, WITHIN $1.70 \leq I_c \leq 3.00$. THIS ATTEMPTS TO CORRECT FOR ADDITIONAL SETTLEMENT ESTIMATED DUE TO READINGS AFFECTED BY TRANSITIONING FROM CLAY-LIKE TO SAND-LIKE MATERIAL AND VICE VERSA.

THE FOLLOWING LIQUEFACTION - INDUCED SETTLEMENTS WERE CALCULATED:

CPT	ESTIMATED SETTLEMENT (IN)
L-1	3.5
L-3	1.7
L-5	0.8
L-7	1.4
L-9	1.5
L-11	4.5
L-13	1.5
L-14	1.4
L-16	2.9
L-18	2.0
L-20	3.5
L-31	0.6
L-32	0.7
L-33	0.4
L-34	0.3

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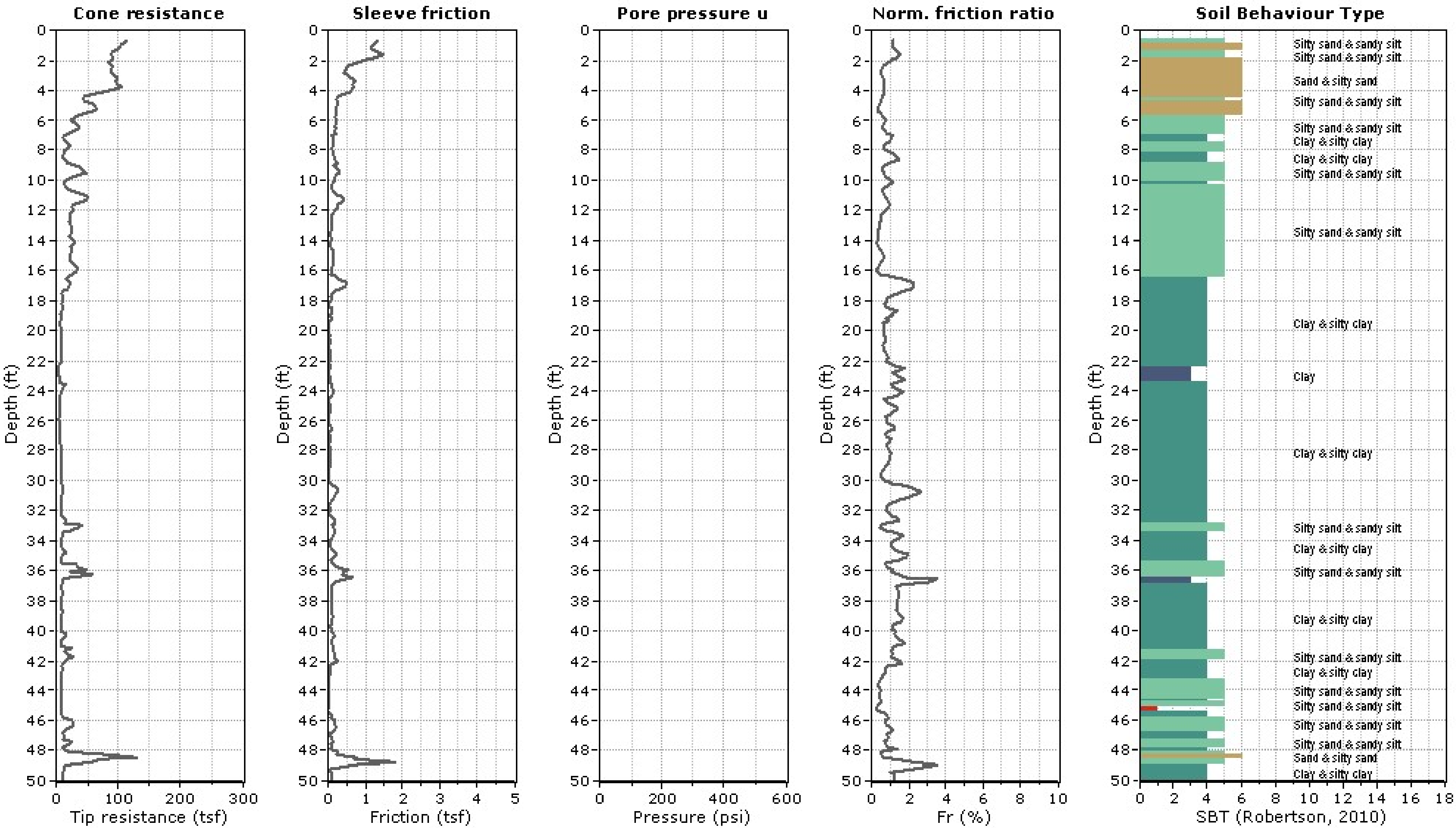
Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-1
Total depth: 91.37 ft, Date: 2/1/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling



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600 W. Sandy Parkway
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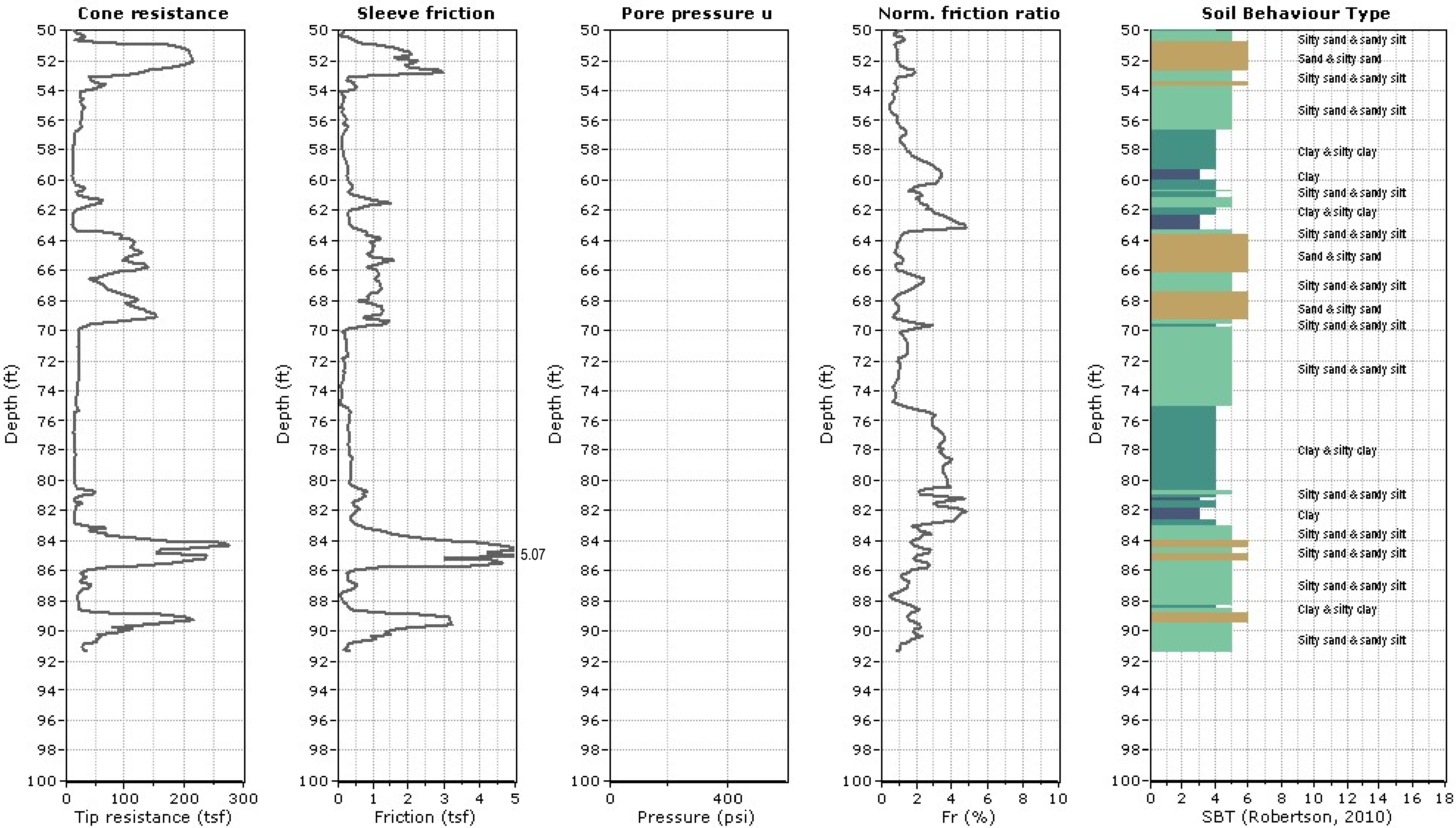
CPT: L-1
Total depth: 91.37 ft, Date: 2/1/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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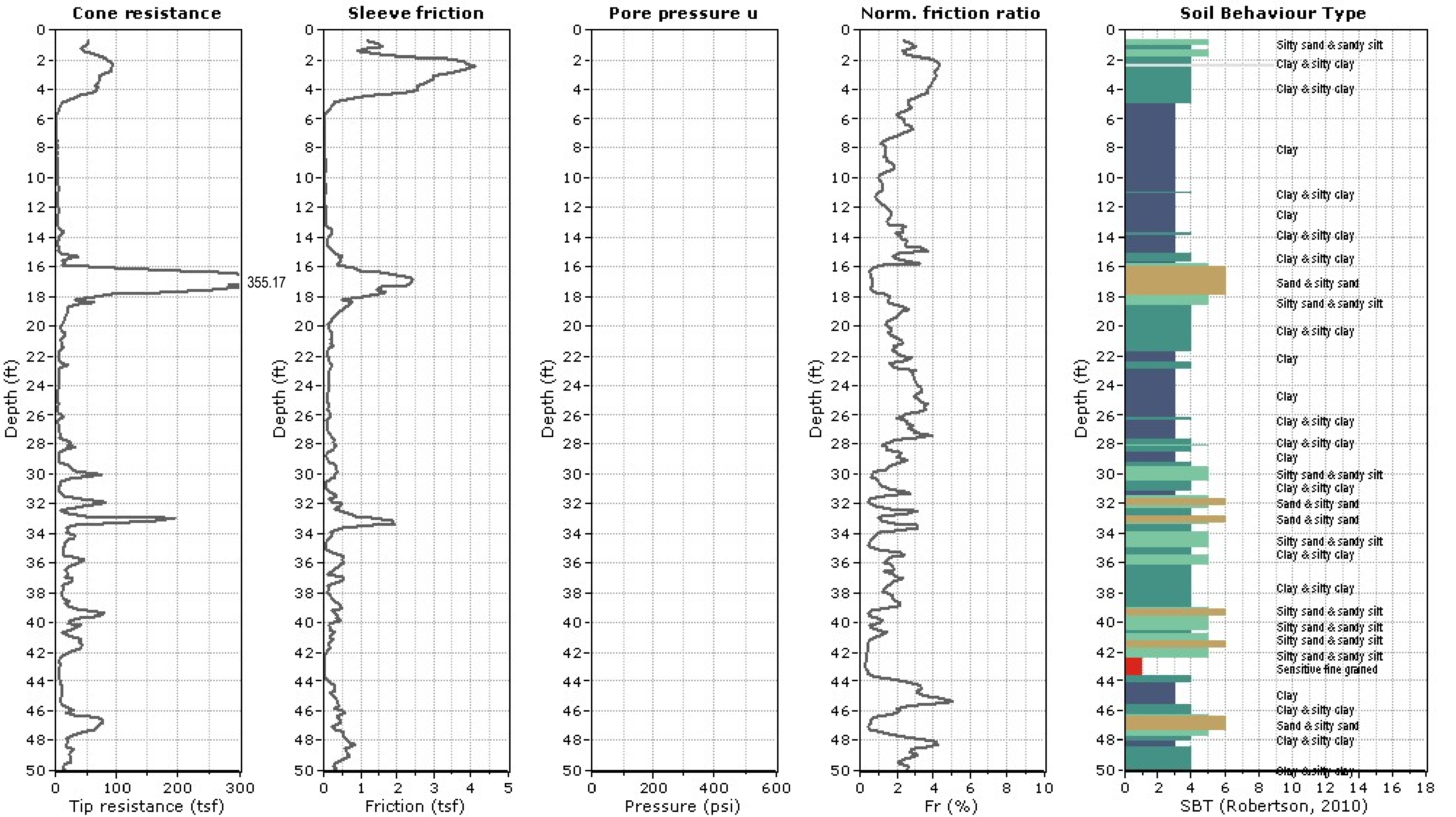
CPT: L-3
Total depth: 91.54 ft, Date: 4/7/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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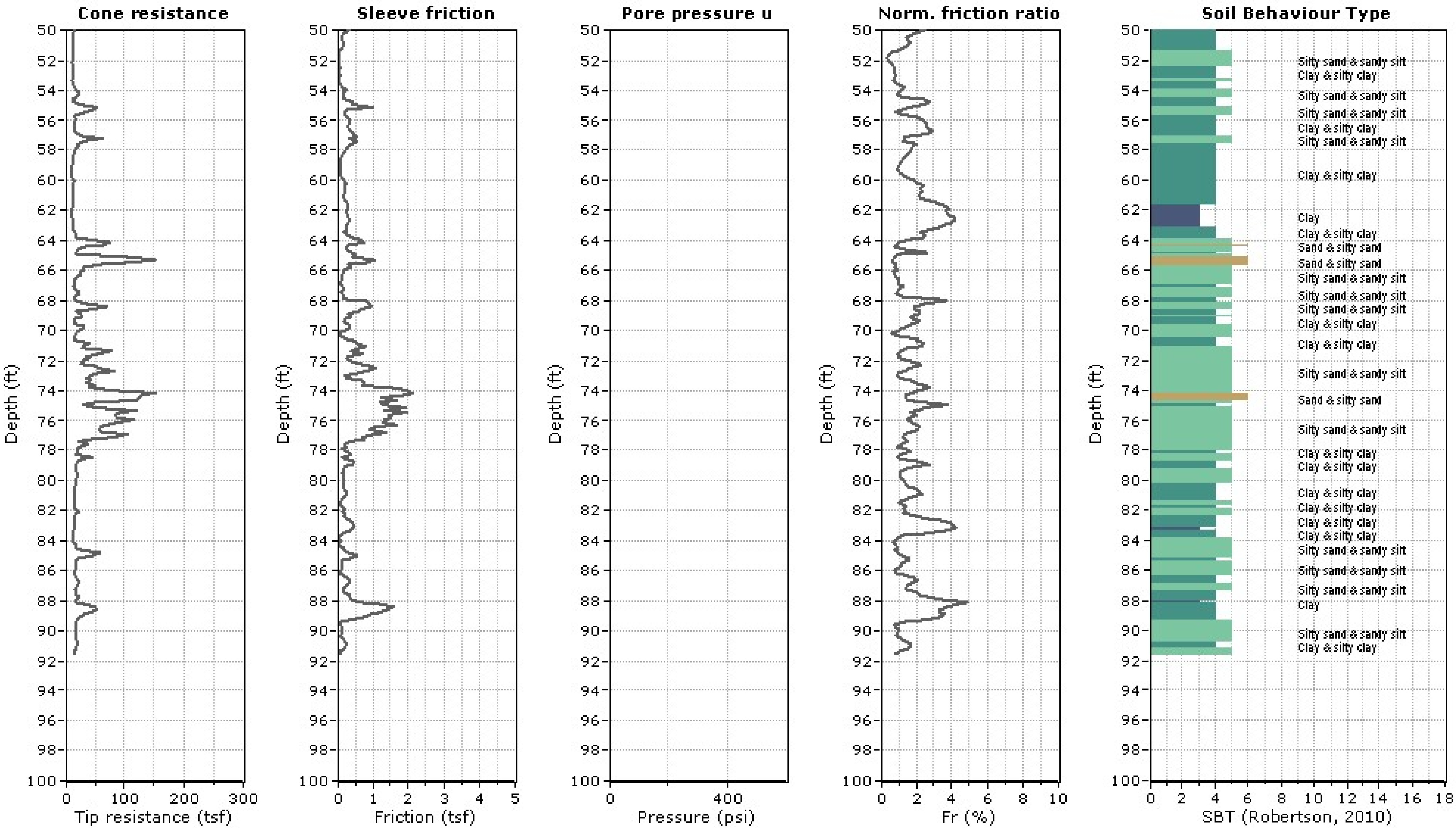
CPT: L-3

Total depth: 91.54 ft, Date: 4/7/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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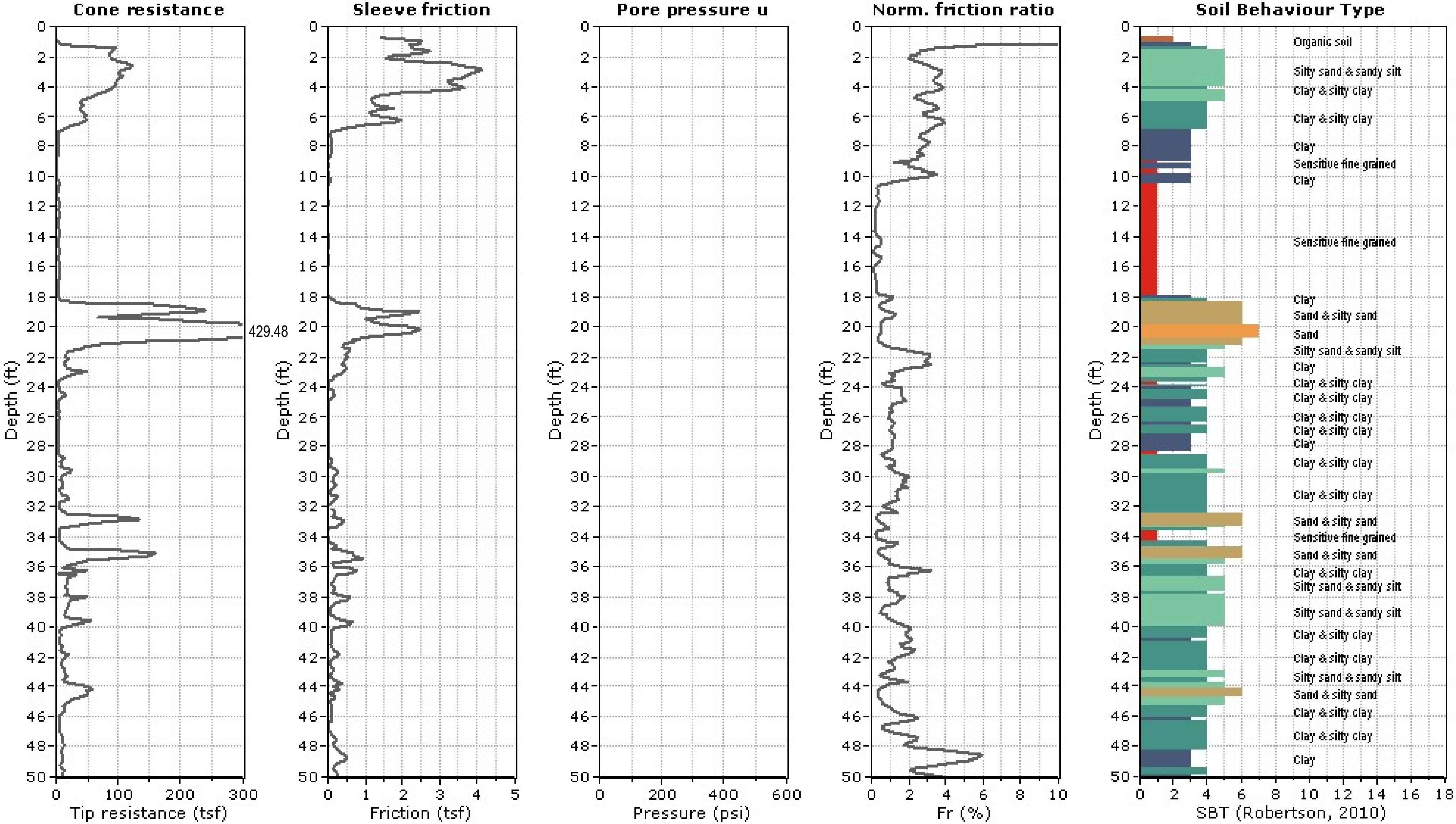
Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-5
Total depth: 91.04 ft, Date: 4/29/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling



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600 W. Sandy Parkway
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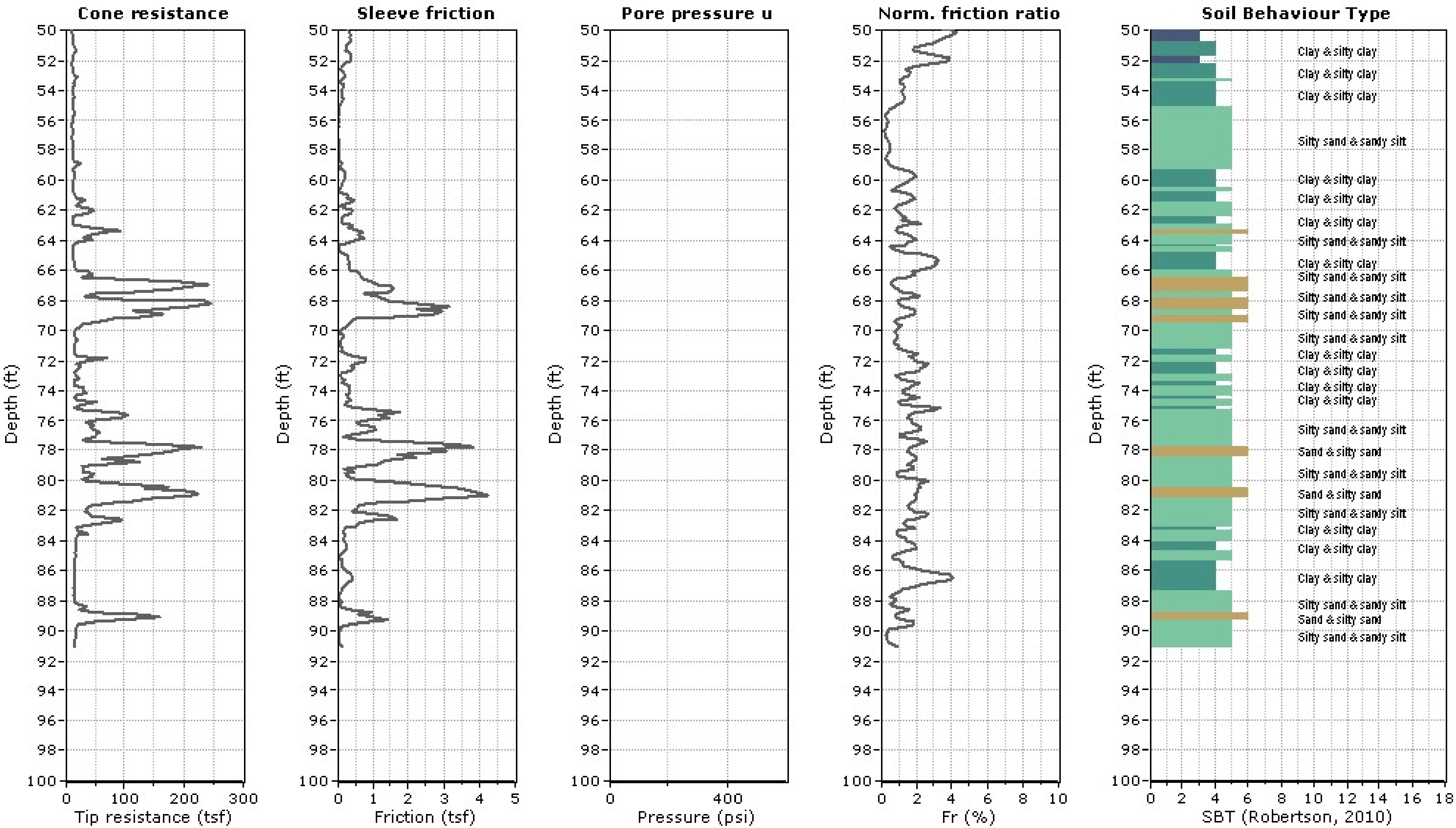
801.566.6399

CPT: L-5

Total depth: 91.04 ft, Date: 4/29/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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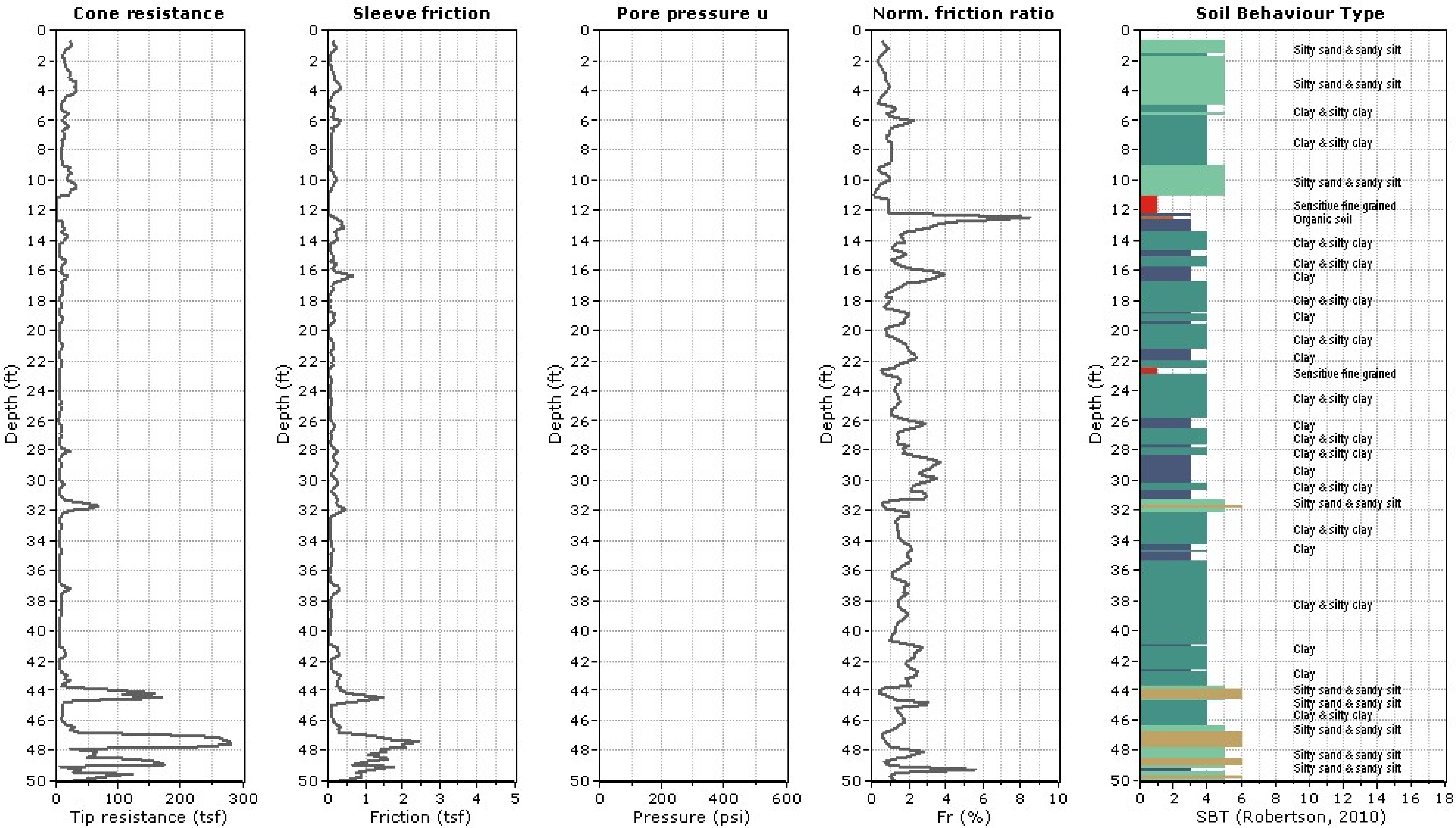
CPT: L-7
Total depth: 91.37 ft, Date: 4/27/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



600 W. Sandy Parkway
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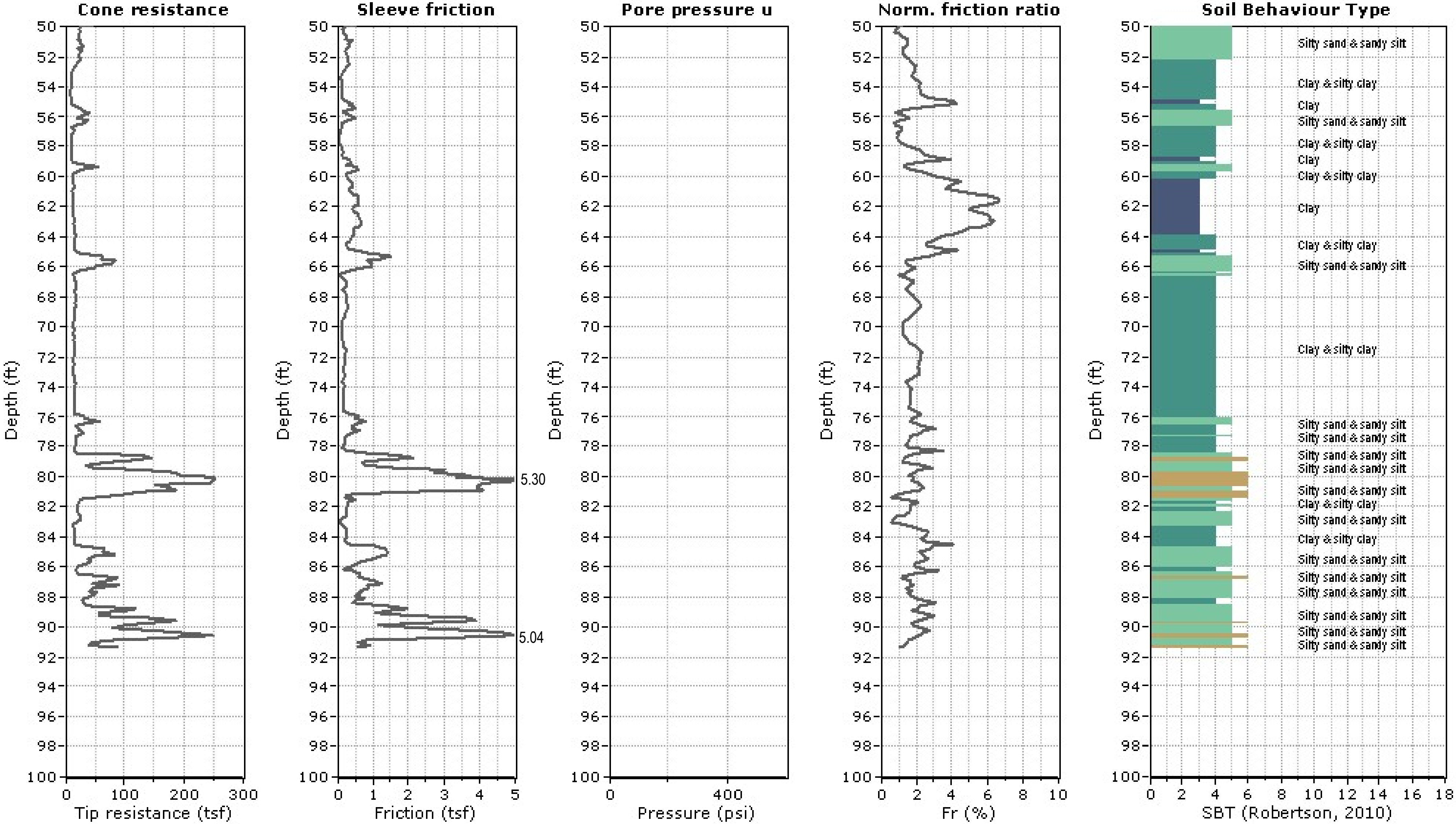
CPT: L-7
Total depth: 91.37 ft, Date: 4/27/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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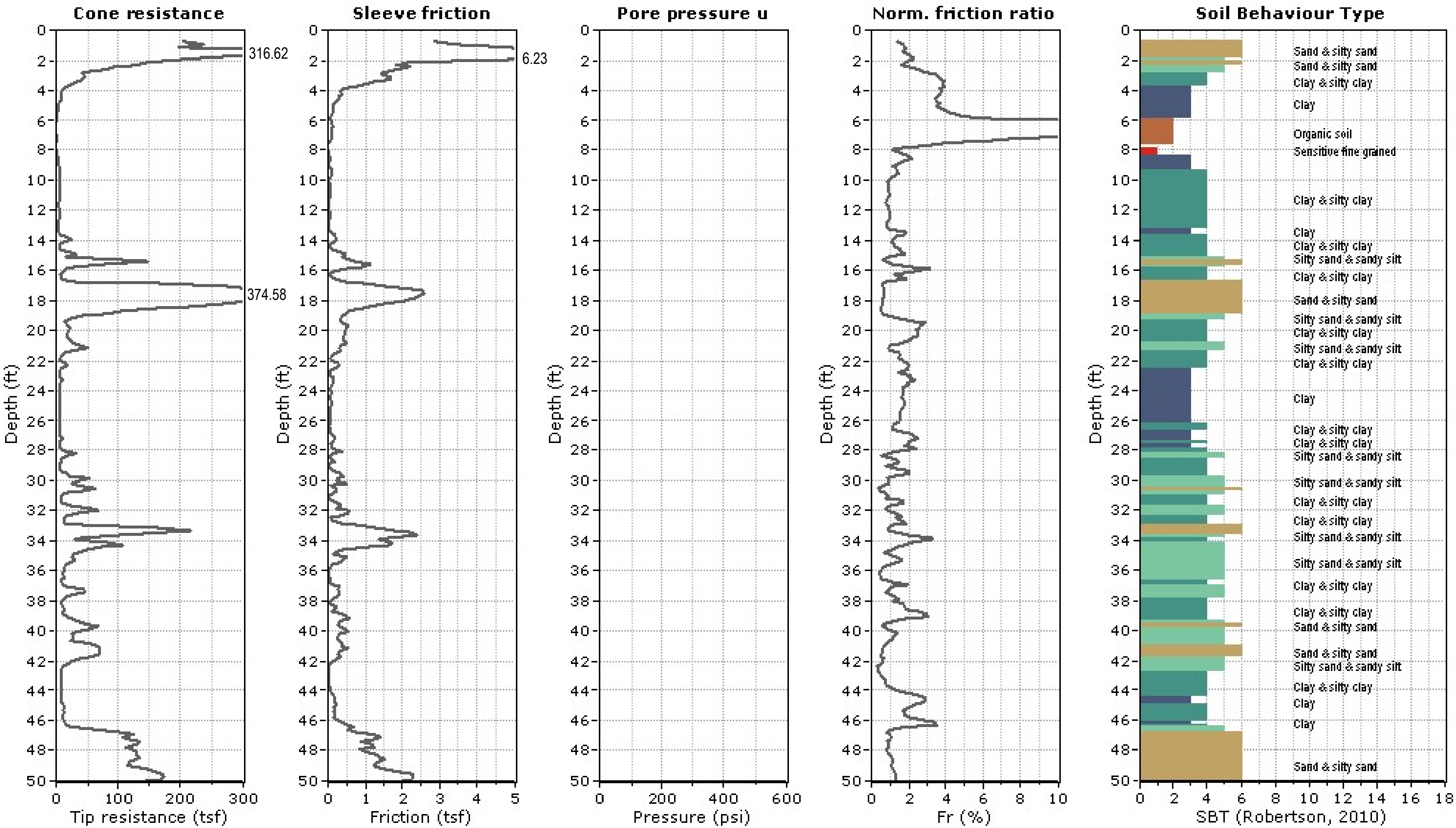
CPT: L-9
Total depth: 78.90 ft, Date: 4/30/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: 1160276 - Clean Harbors
Location: see Figure 1



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600 W. Sandy Parkway
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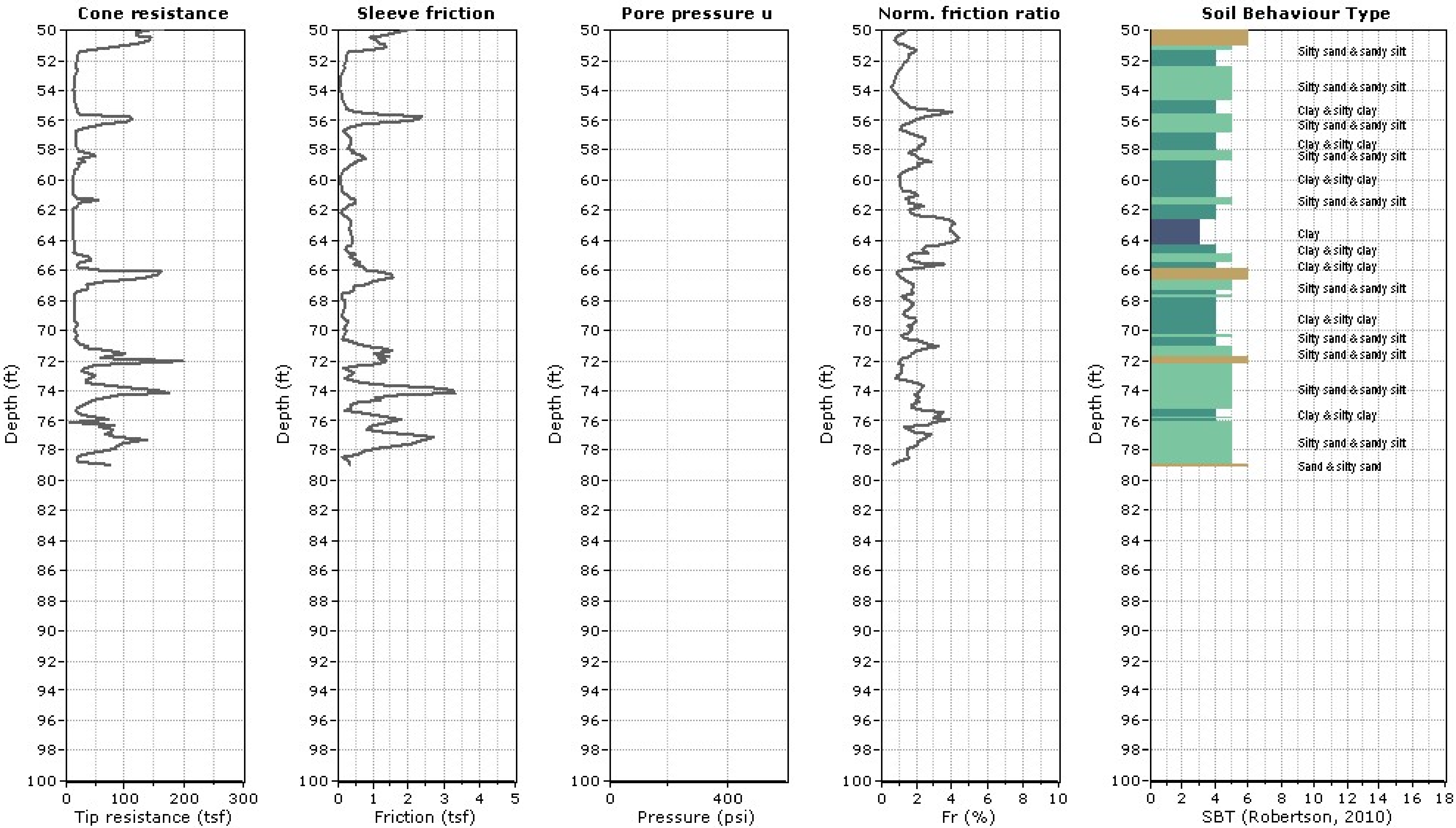
CPT: L-9
Total depth: 78.90 ft, Date: 4/30/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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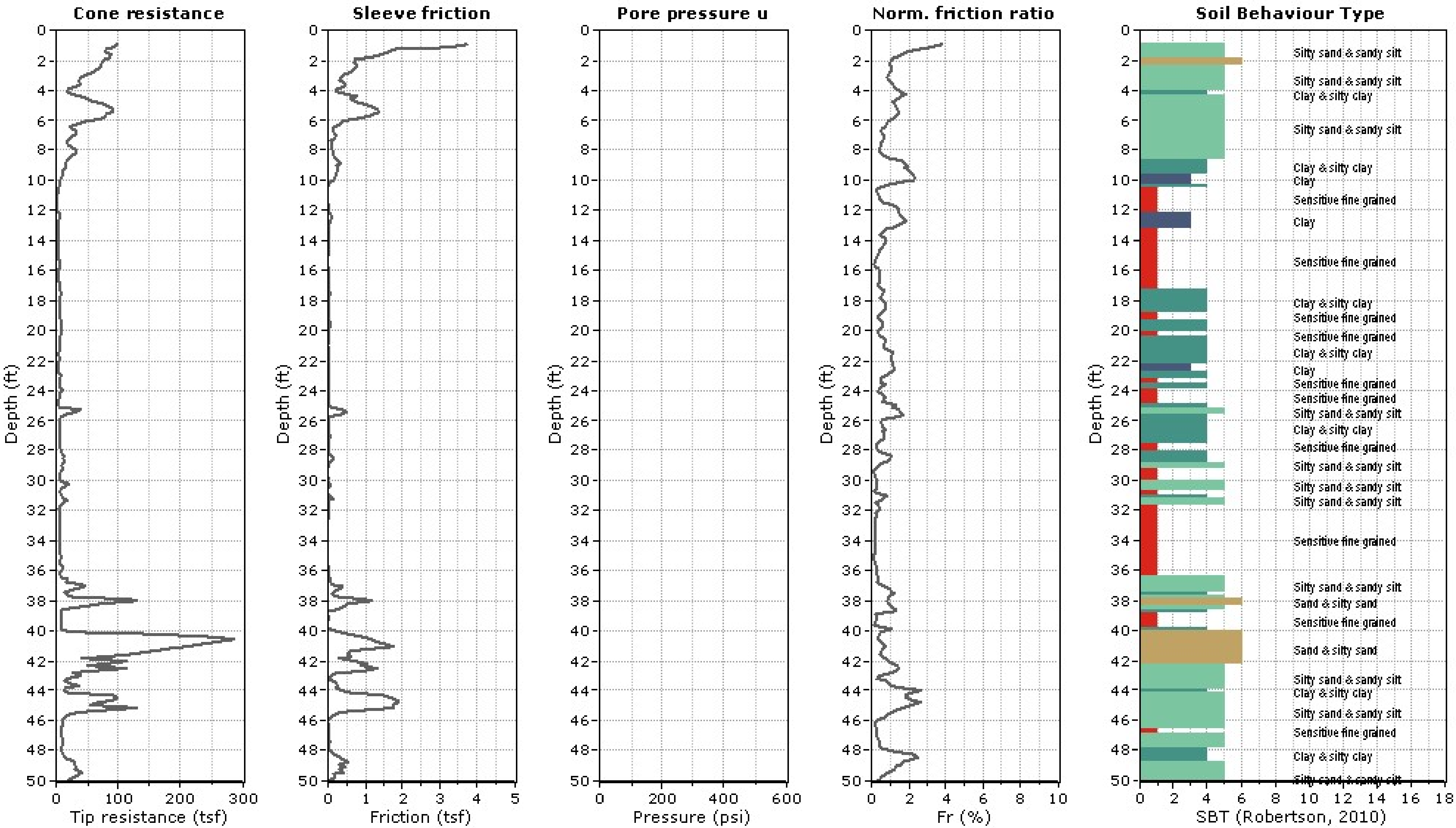
CPT: L-11
Total depth: 84.15 ft, Date: 4/27/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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600 W. Sandy Parkway
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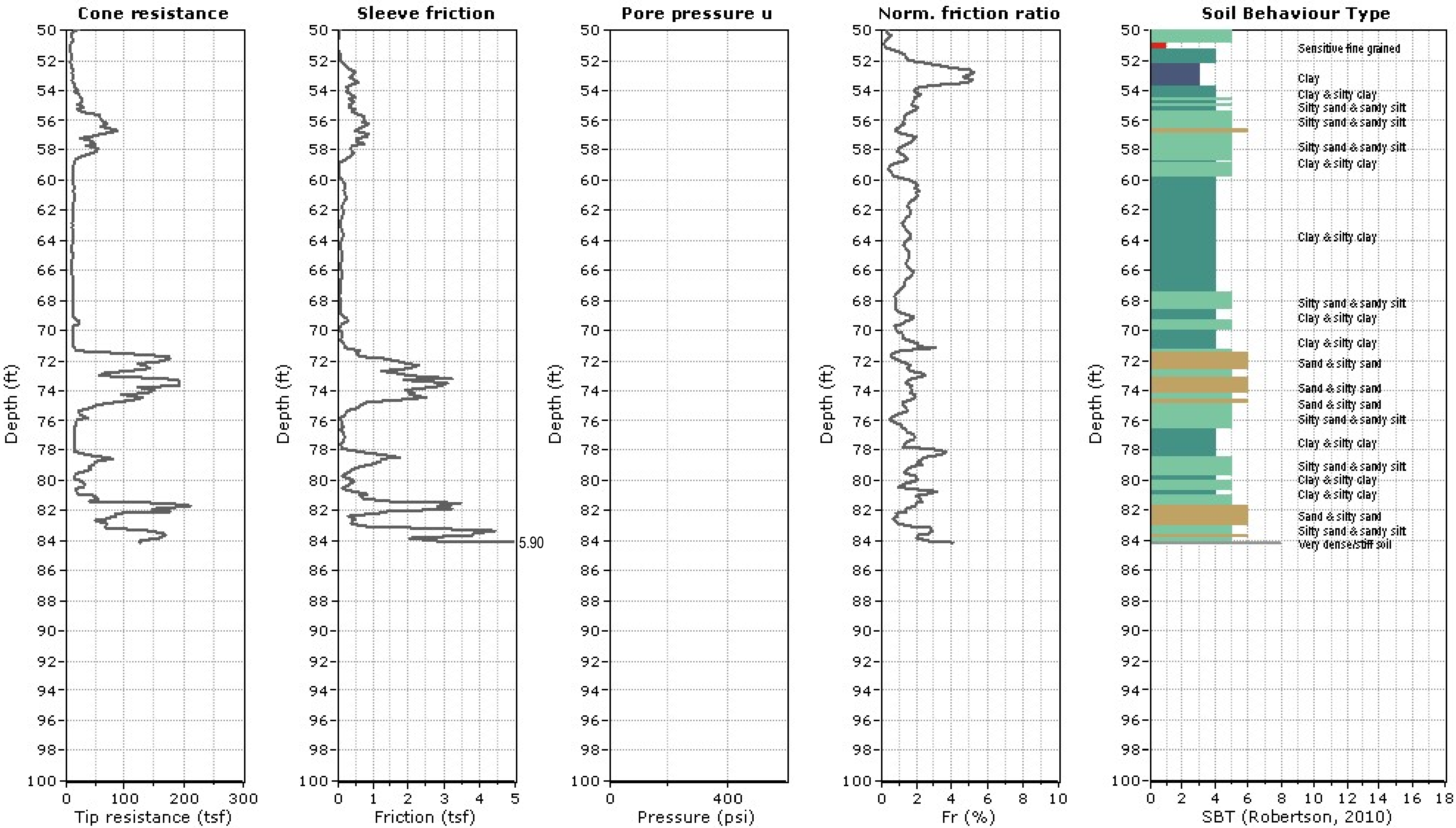
CPT: L-11
Total depth: 84.15 ft, Date: 4/27/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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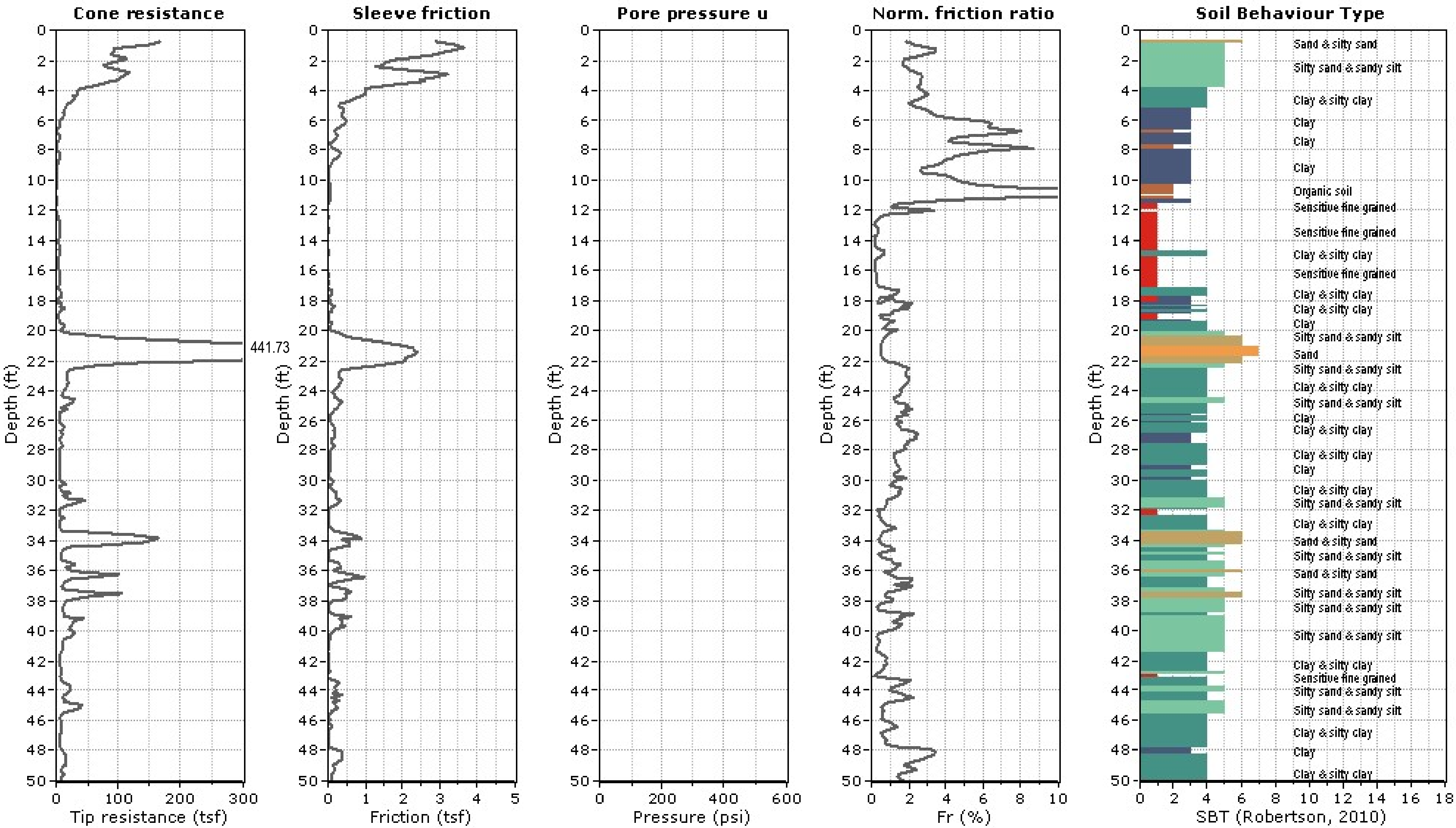
CPT: L-13
Total depth: 77.59 ft, Date: 4/27/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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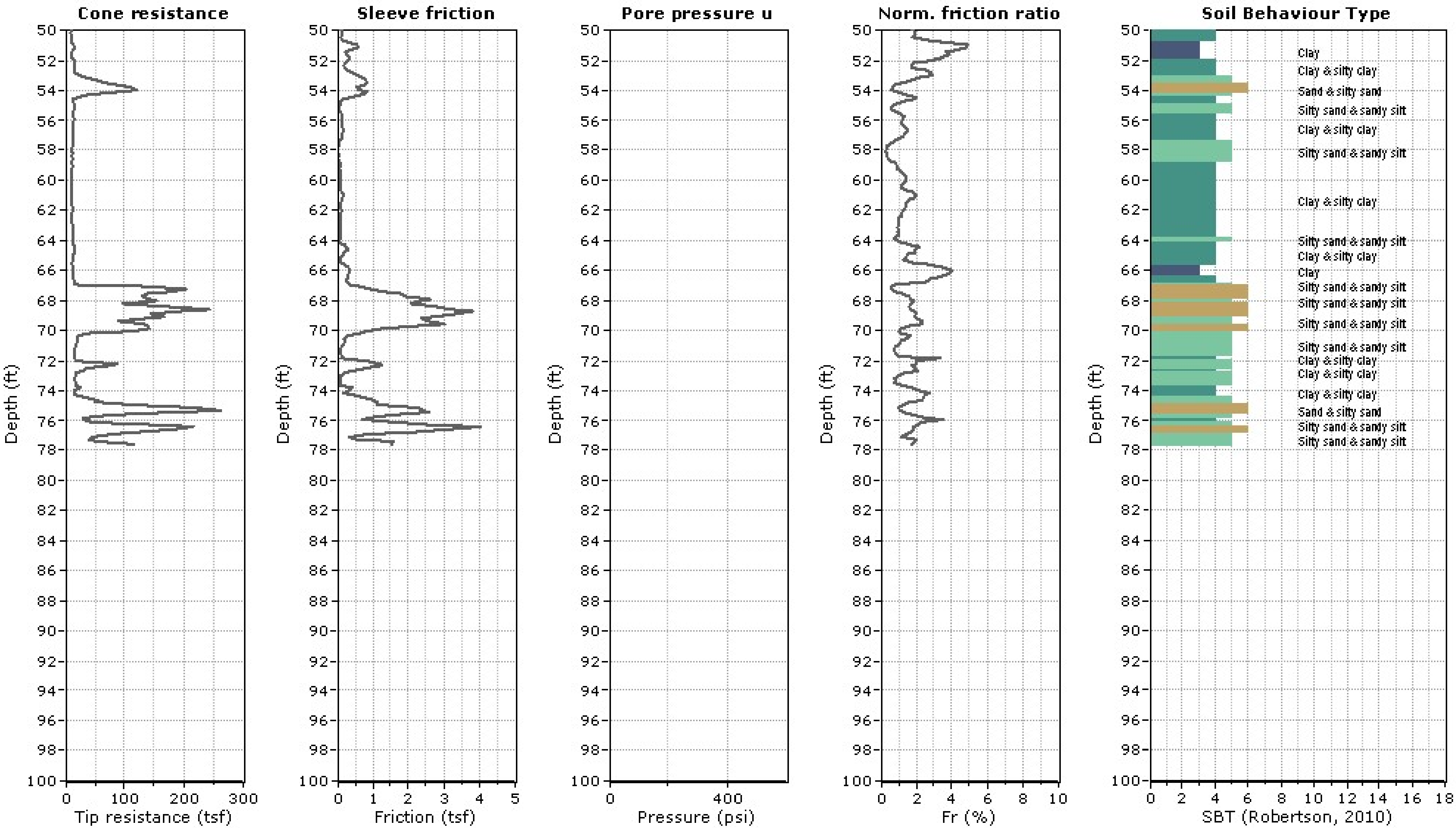
CPT: L-13
Total depth: 77.59 ft, Date: 4/27/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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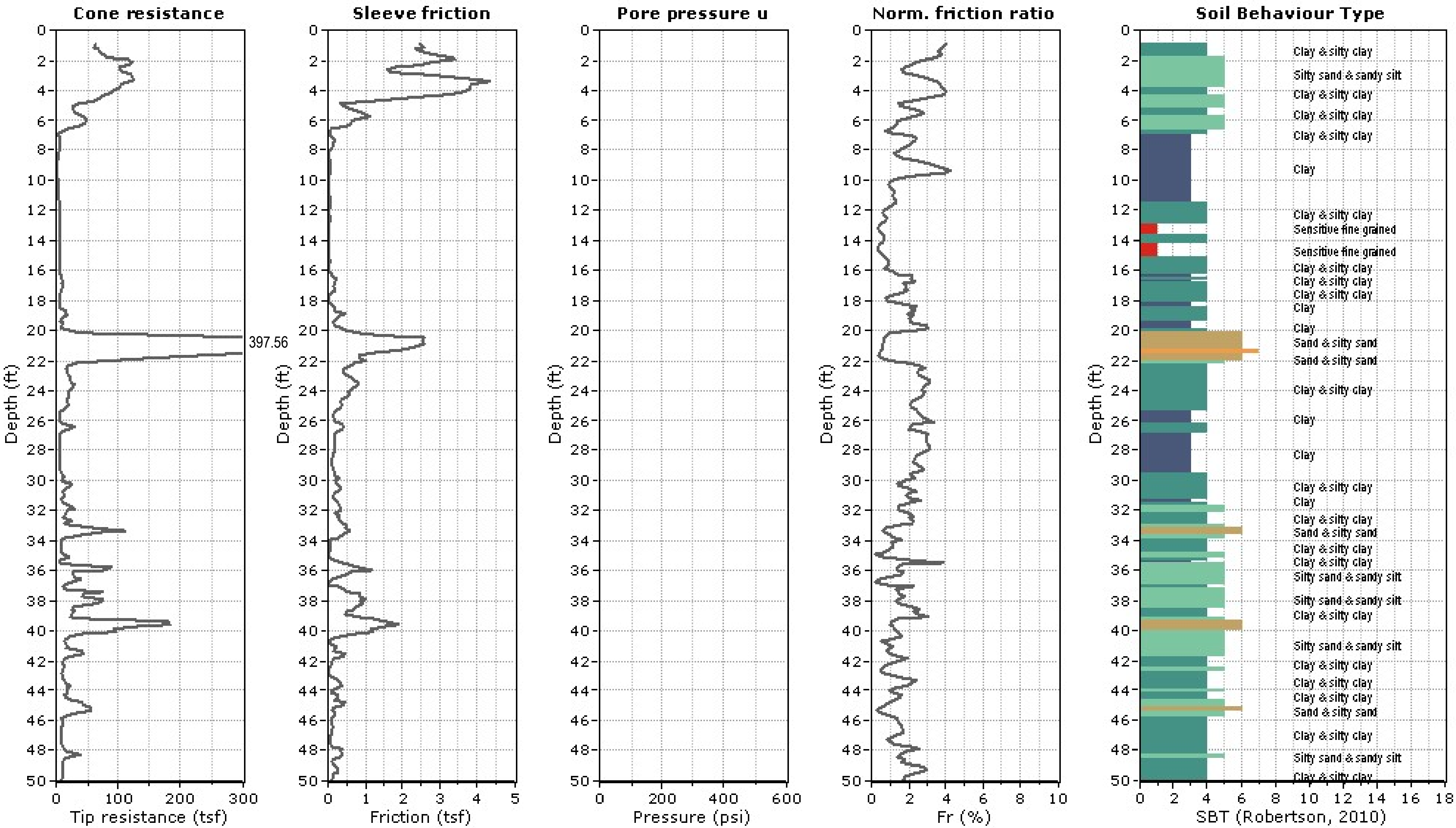
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-14
Total depth: 77.43 ft, Date: 4/10/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling



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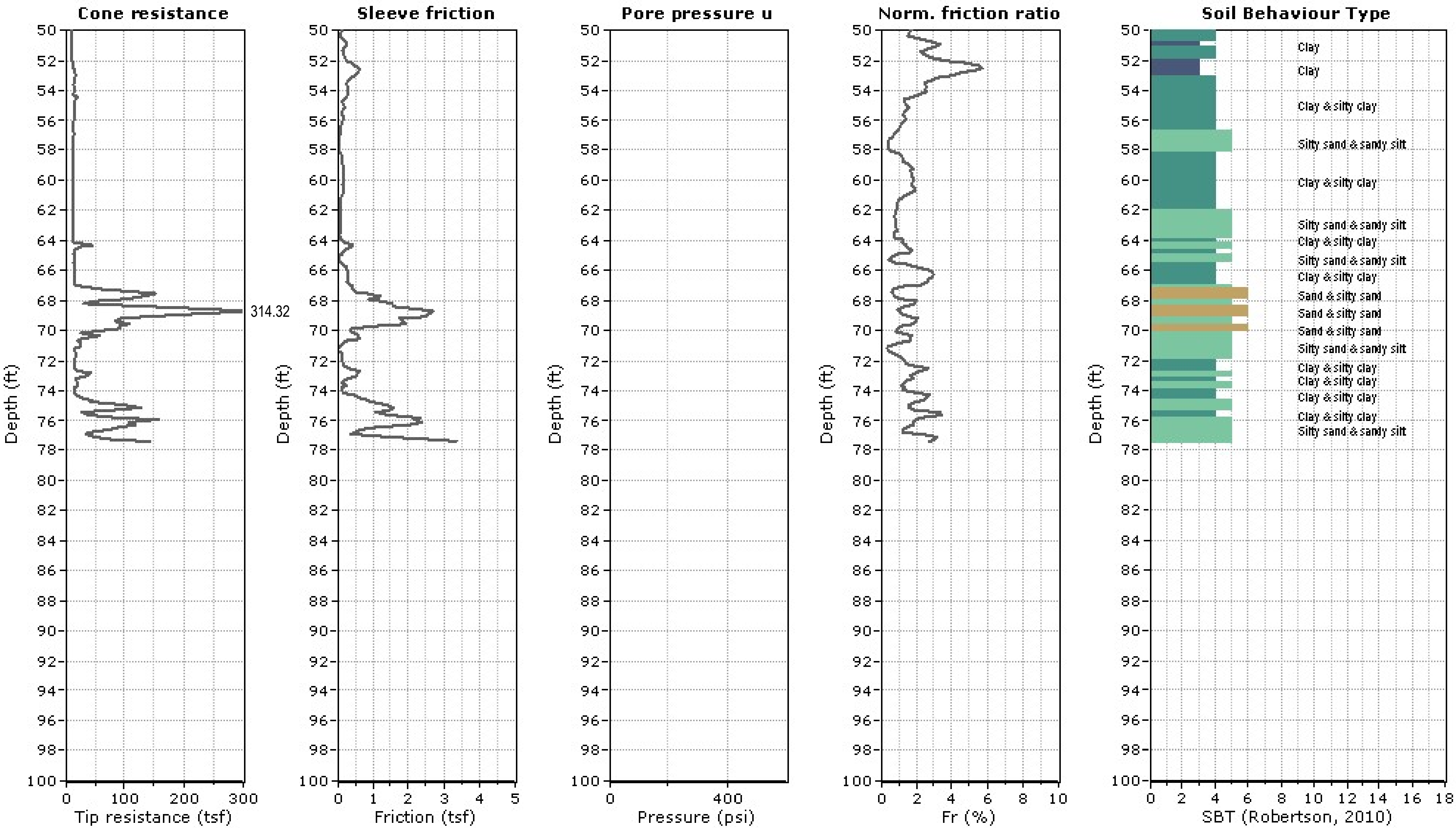
CPT: L-14
Total depth: 77.43 ft, Date: 4/10/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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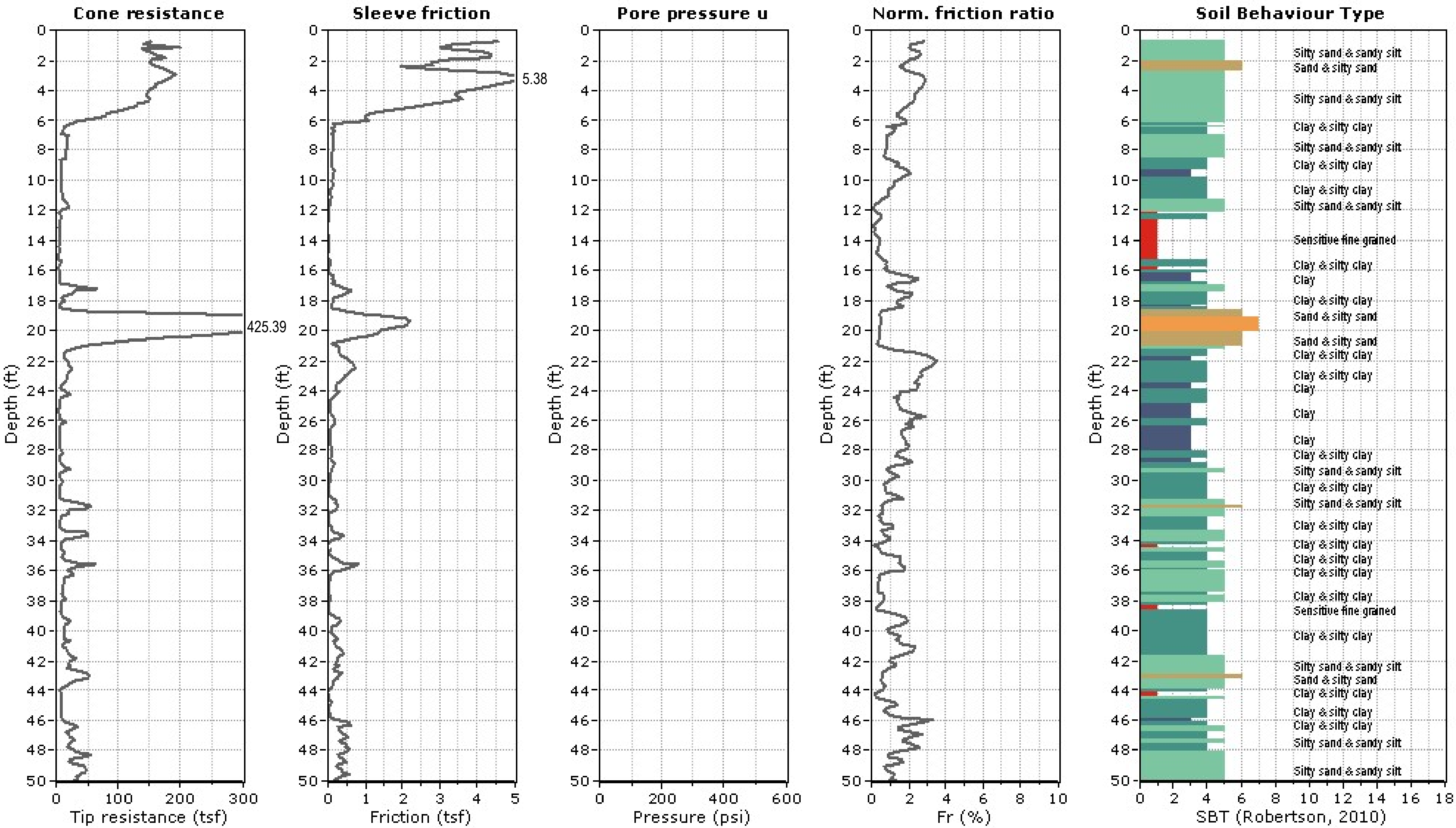
CPT: L-16
Total depth: 81.36 ft, Date: 4/27/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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600 W. Sandy Parkway
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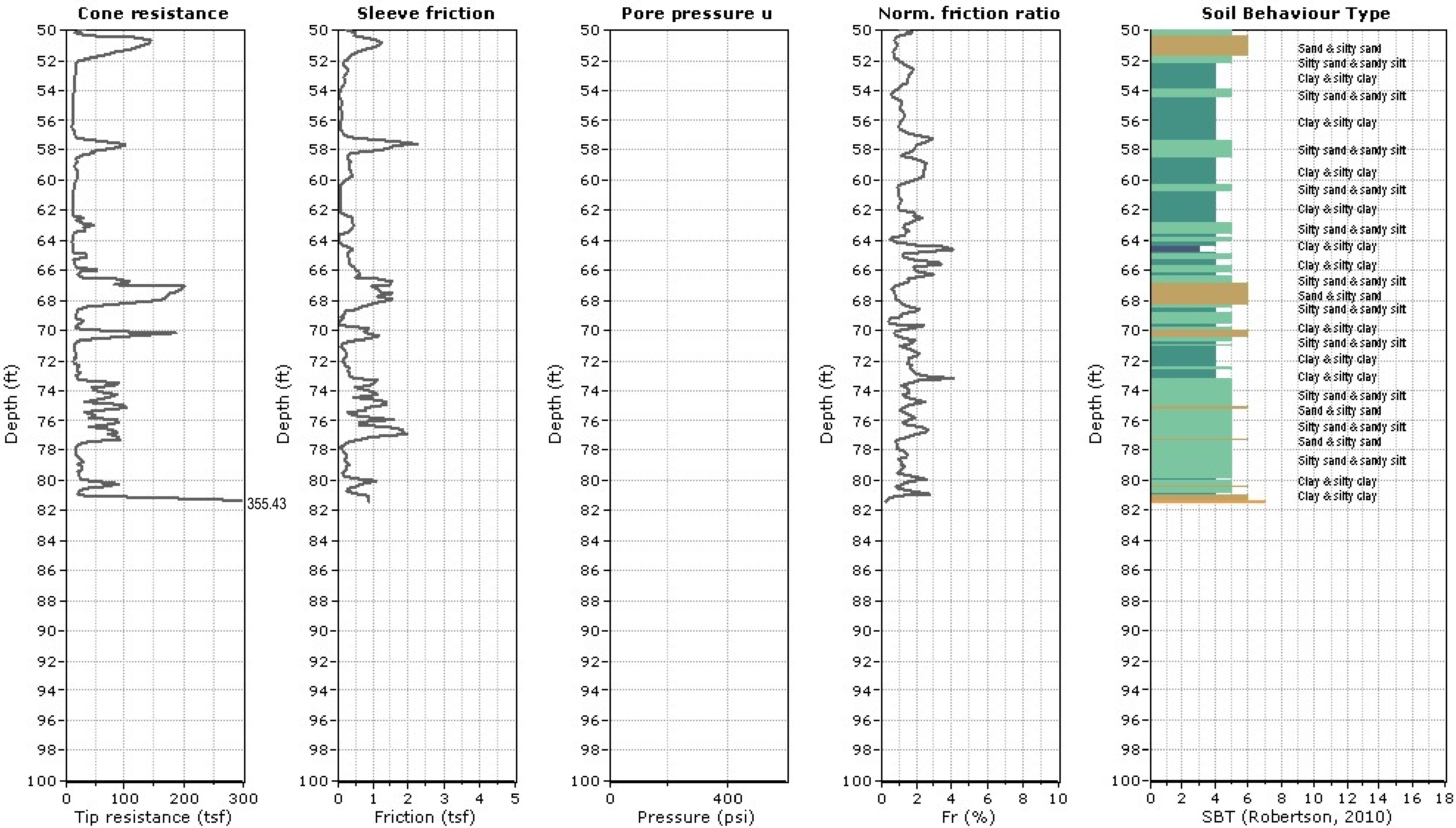
CPT: L-16
Total depth: 81.36 ft, Date: 4/27/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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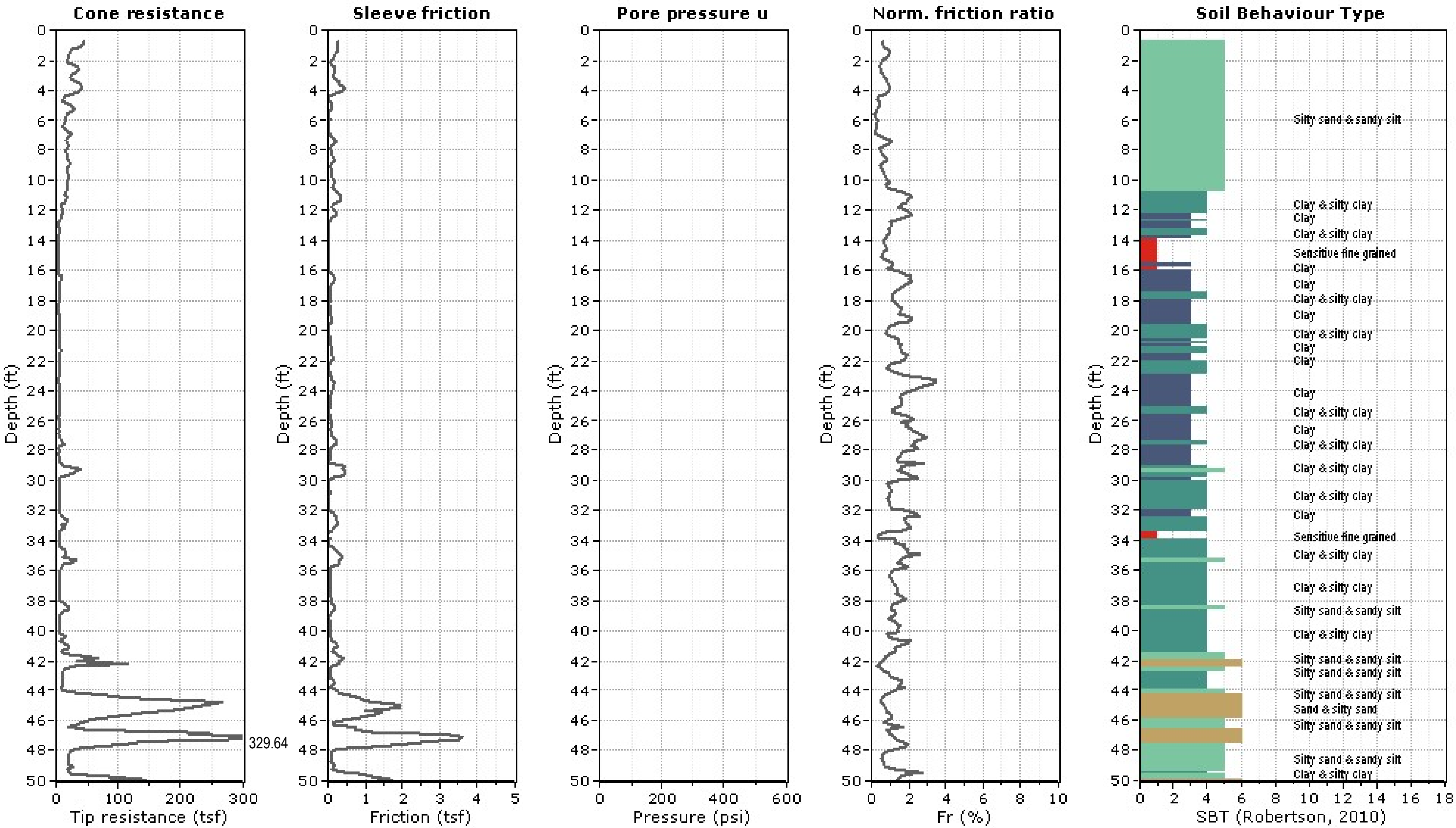
Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-18
Total depth: 79.07 ft, Date: 7/23/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling



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600 W. Sandy Parkway
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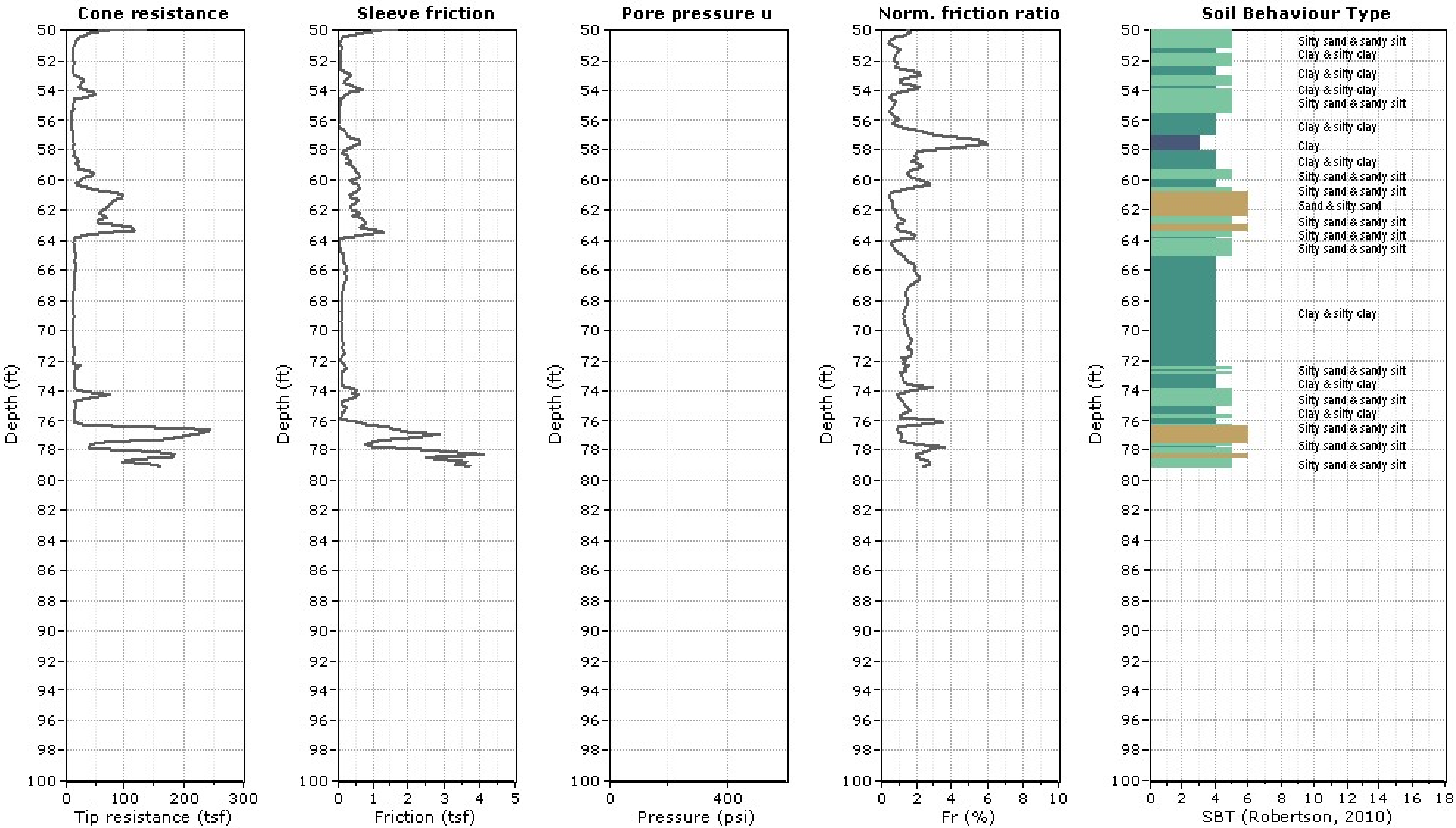
CPT: L-18
Total depth: 79.07 ft, Date: 7/23/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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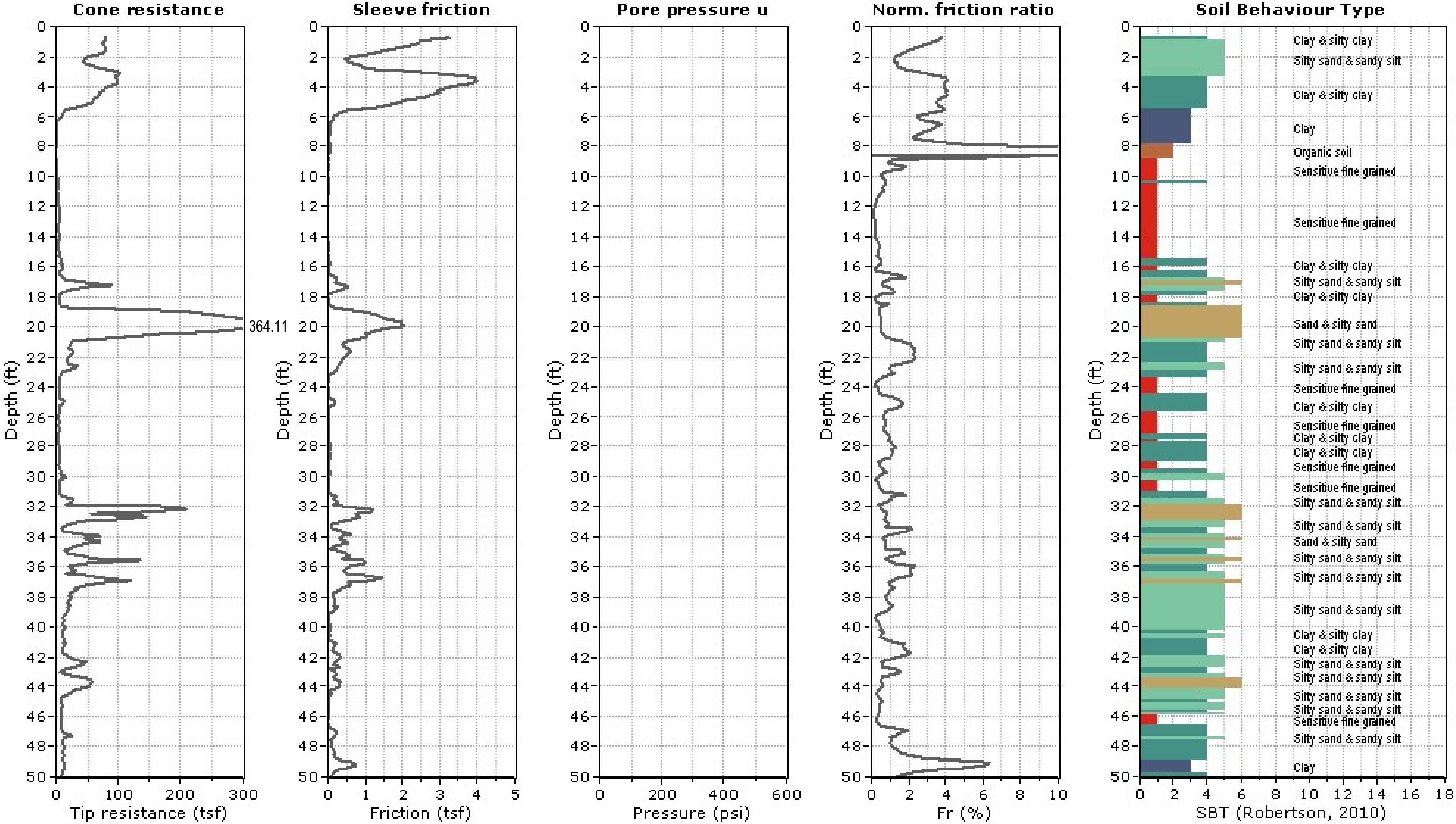
CPT: L-20
Total depth: 53.81 ft, Date: 4/28/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: 1160276 - Clean Harbors
Location: see Figure 1



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600 W. Sandy Parkway
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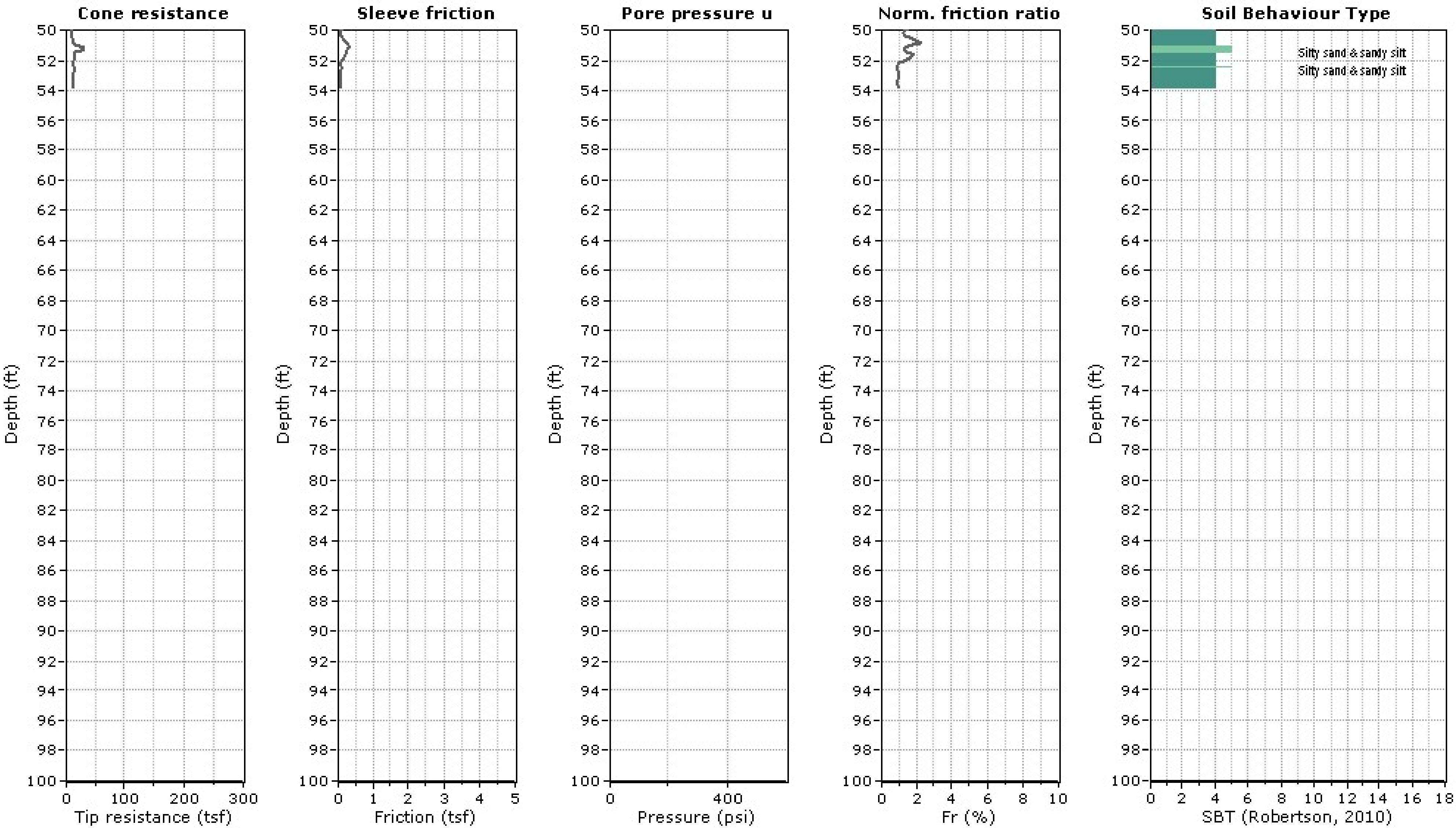
801.566.6399

CPT: L-20
Total depth: 53.81 ft, Date: 4/28/1992
Surface Elevation: 0.00 ft
Cone Type: H215
Cone Operator: Earthtec Drilling

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



600 W. Sandy Parkway
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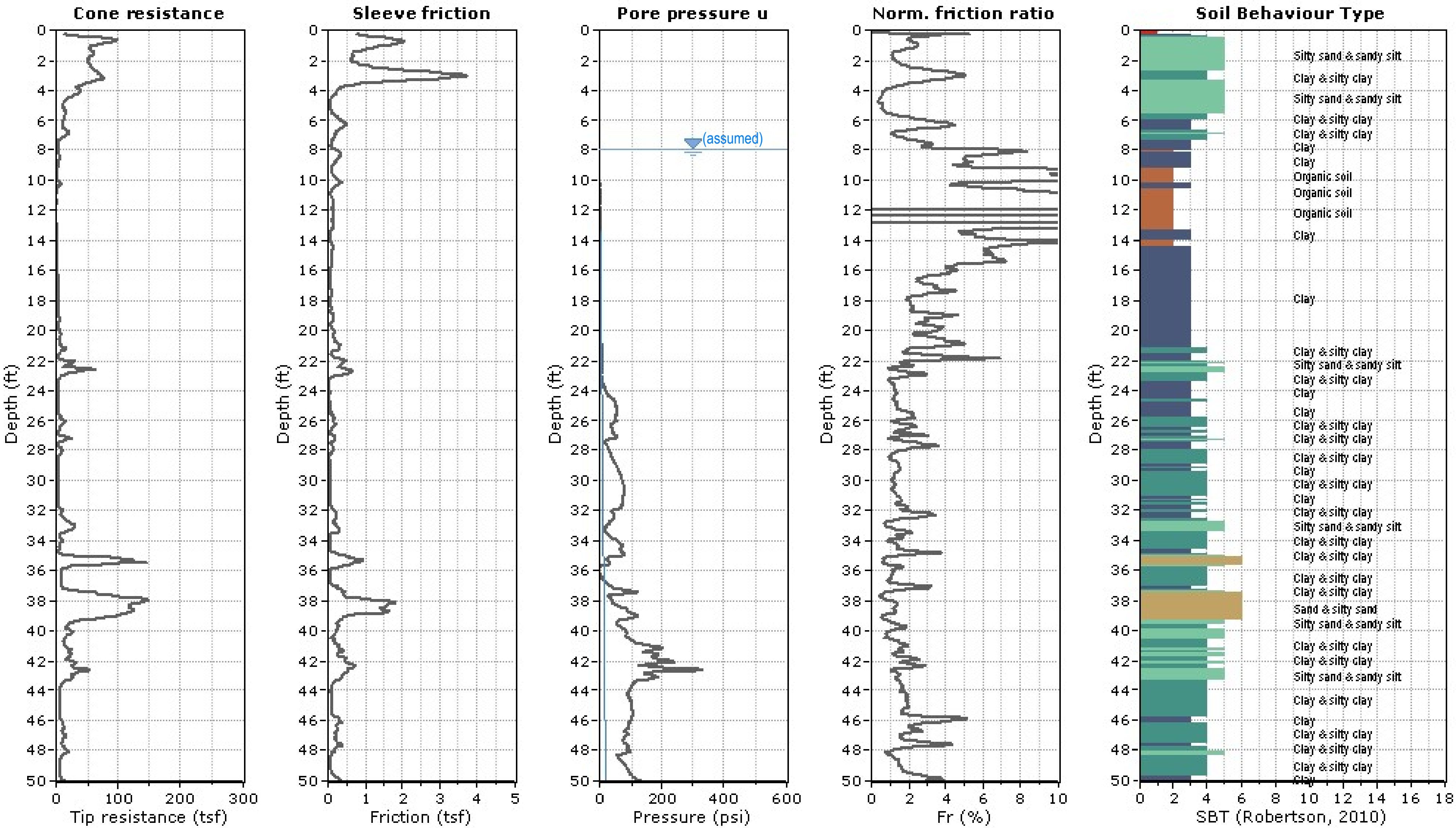
CPT: L-31

Total depth: 124.54 ft, Date: 8/17/1995
Surface Elevation: 4240.80 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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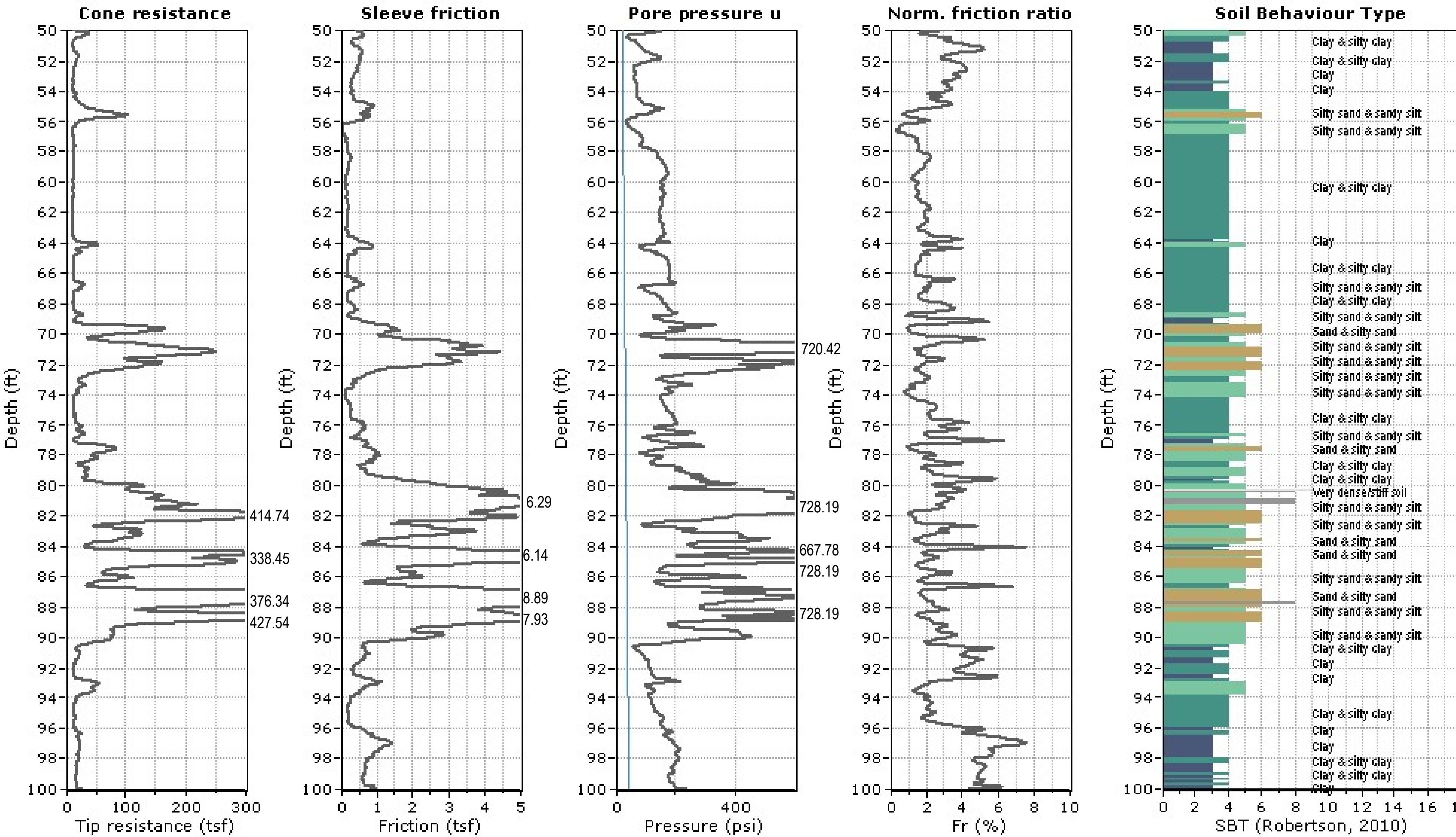
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-31
Total depth: 124.54 ft, Date: 8/17/1995
Surface Elevation: 4240.80 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.



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600 W. Sandy Parkway
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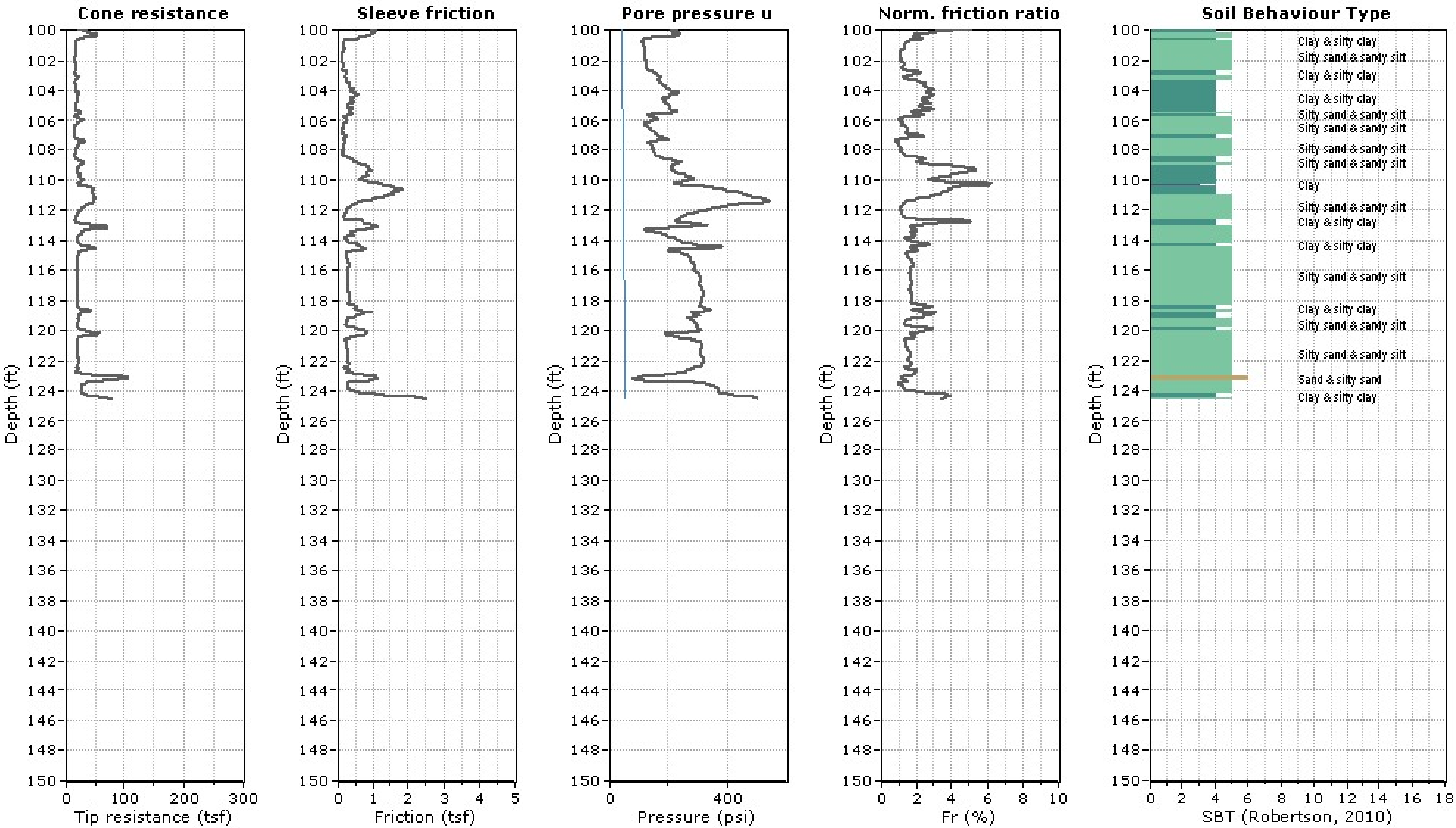
801.566.6399

Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-31
Total depth: 124.54 ft, Date: 8/17/1995
Surface Elevation: 4240.80 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.



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600 W. Sandy Parkway
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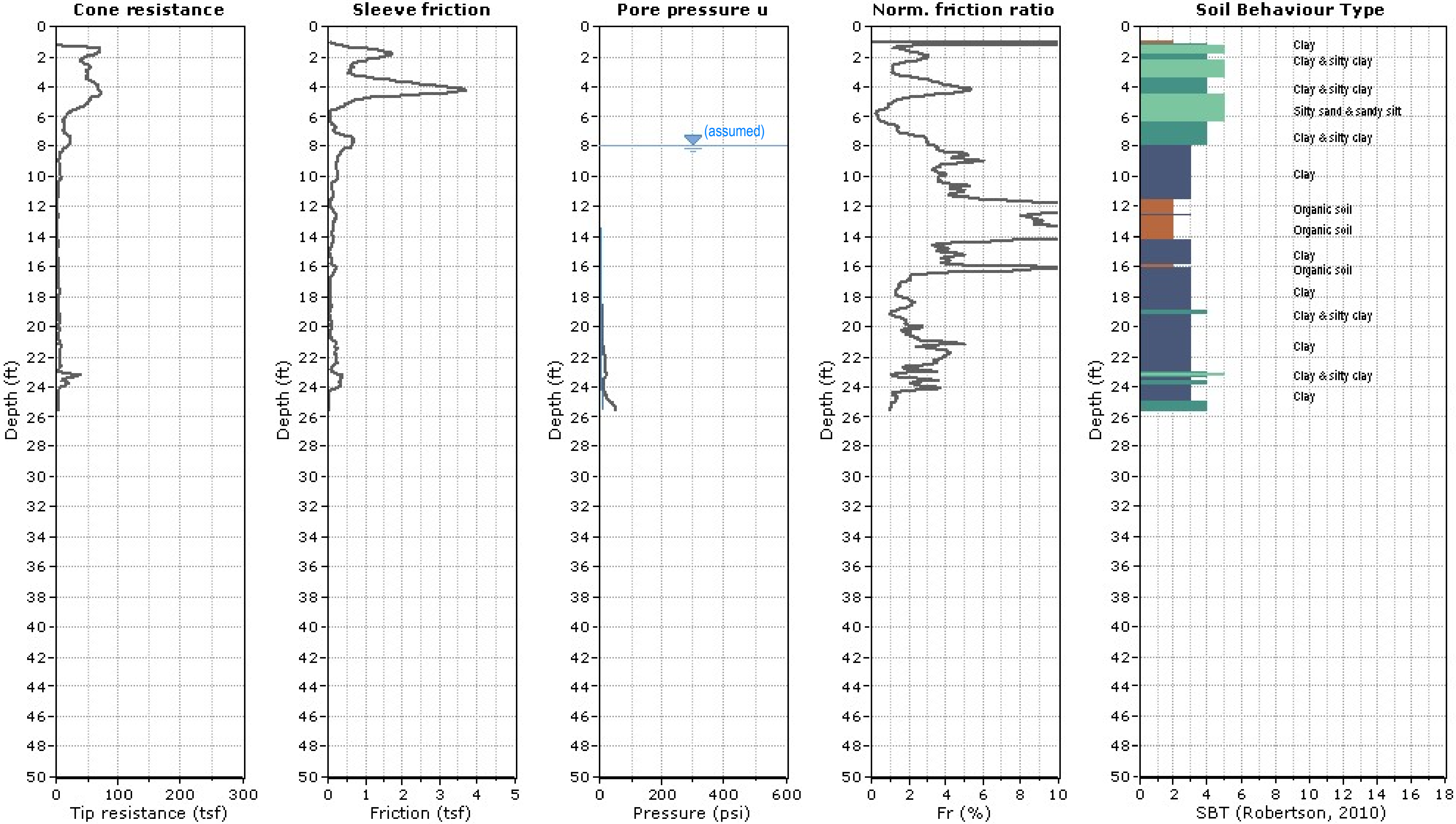
801.566.6399

Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-31B
Total depth: 25.52 ft, Date: 8/18/1995
Surface Elevation: 4240.80 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.



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600 W. Sandy Parkway
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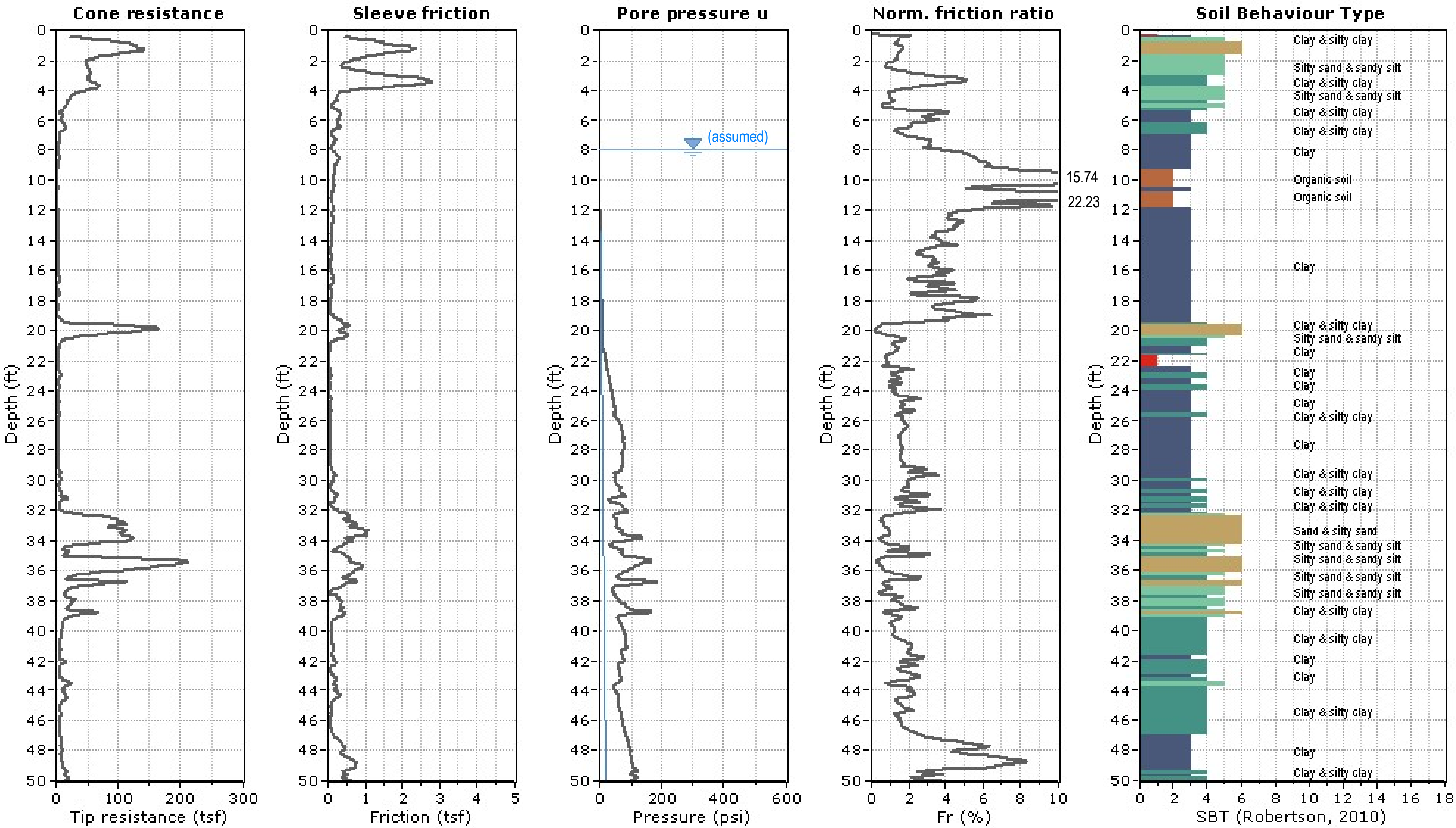
801.566.6399

CPT: L-32
Total depth: 249.08 ft, Date: 8/17/1995
Surface Elevation: 4239.00 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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600 W. Sandy Parkway
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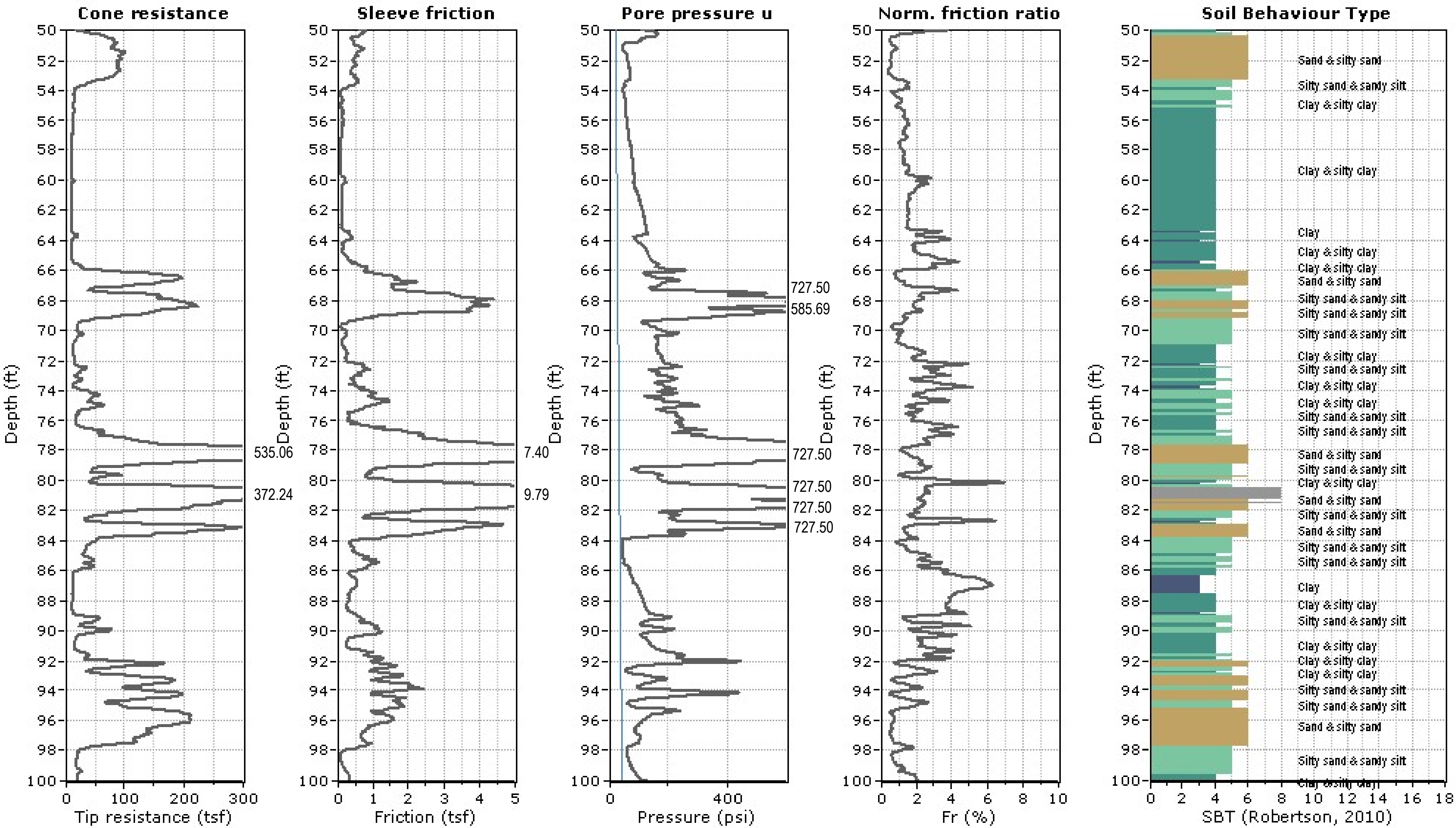
801.566.6399

CPT: L-32
Total depth: 249.08 ft, Date: 8/17/1995
Surface Elevation: 4239.00 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

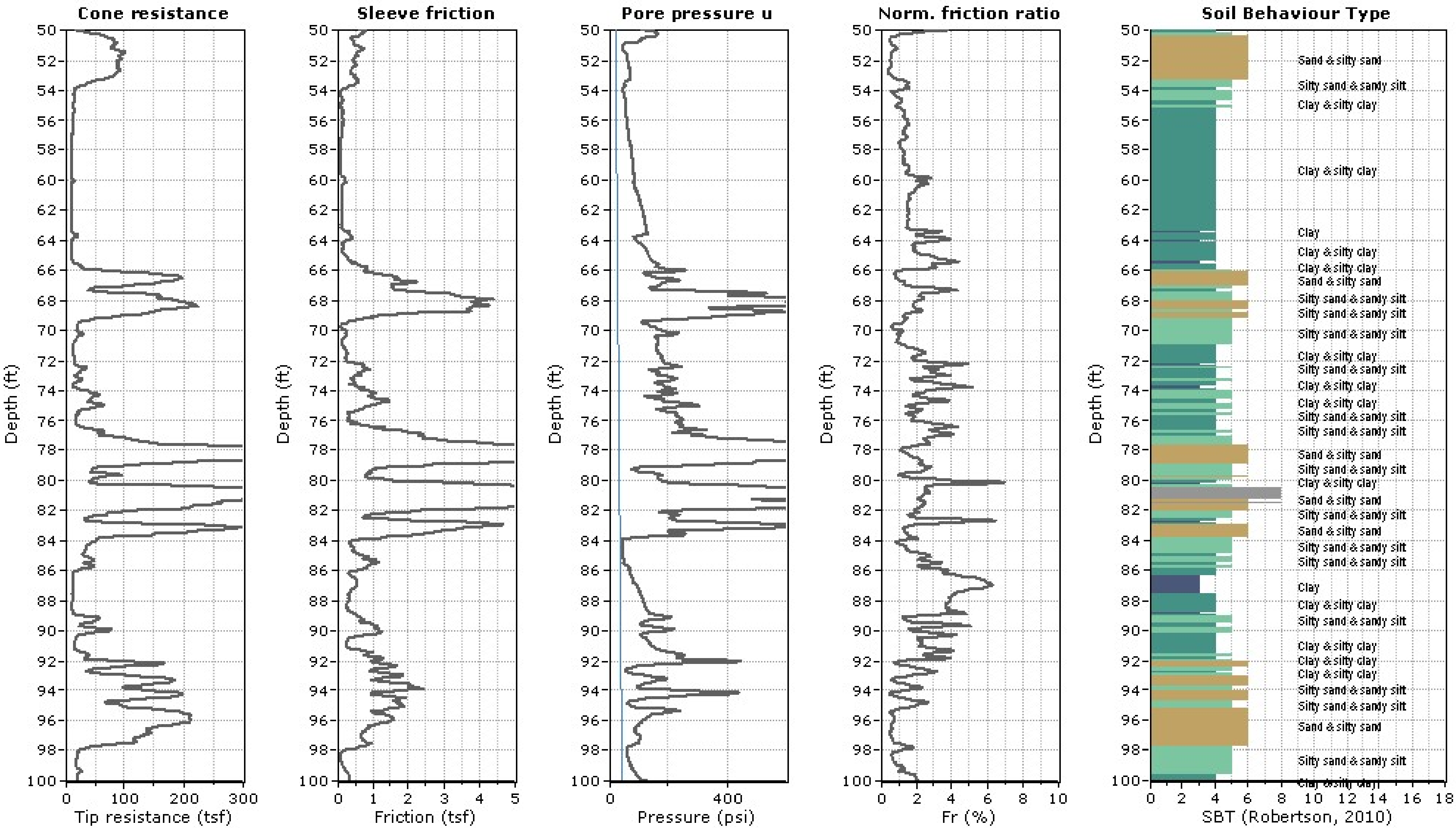


600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

CPT: L-32

Total depth: 249.08 ft, Date: 8/17/1995
Surface Elevation: 4239.00 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.

Project: 1160276 - Clean Harbors
Location: see Figure 1



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600 W. Sandy Parkway
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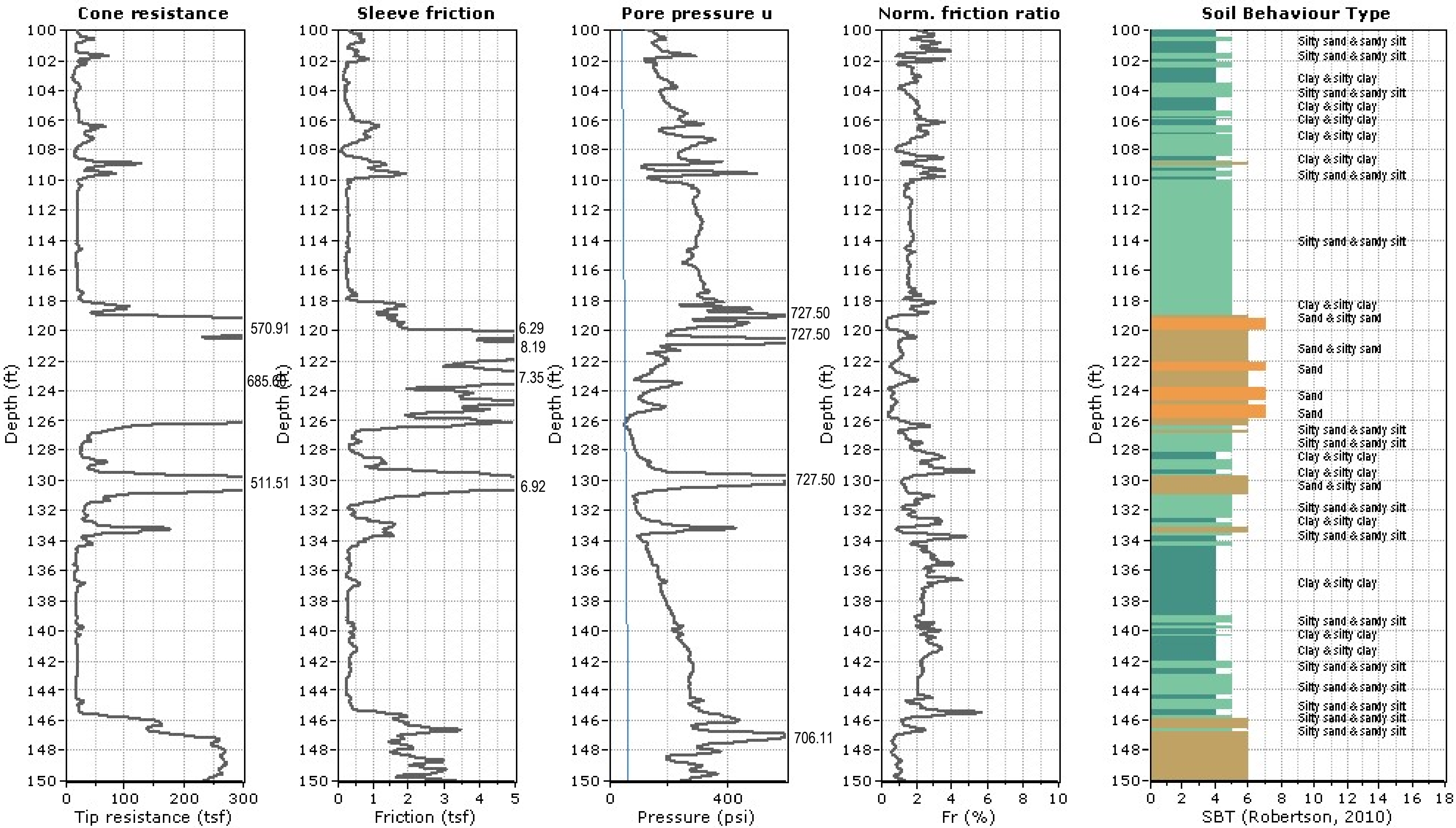
CPT: L-32
Total depth: 249.08 ft, Date: 8/17/1995
Surface Elevation: 4239.00 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.

Project: 1160276 - Clean Harbors
Location: see Figure 1



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600 W. Sandy Parkway
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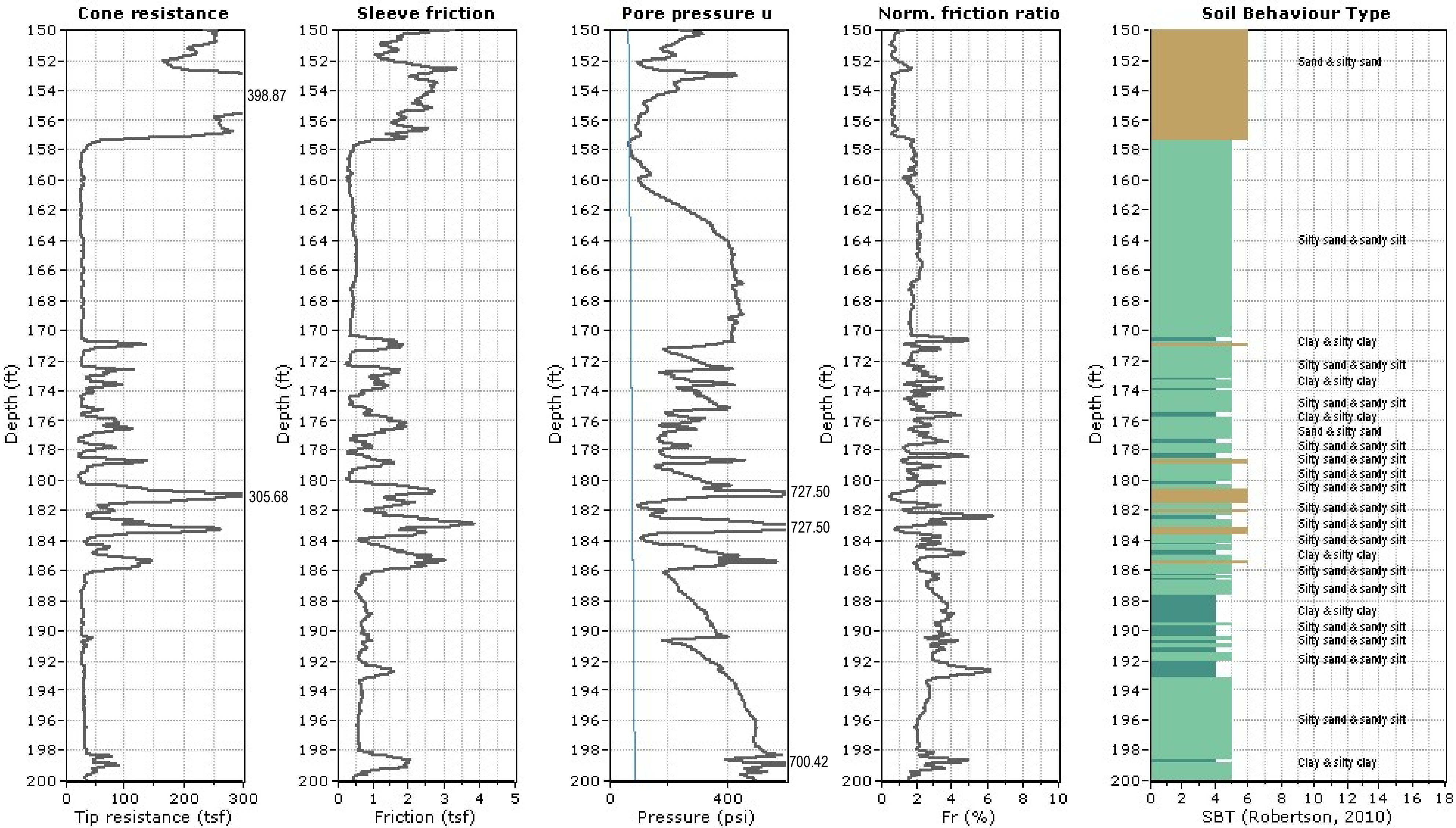
CPT: L-32
Total depth: 249.08 ft, Date: 8/17/1995
Surface Elevation: 4239.00 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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600 W. Sandy Parkway
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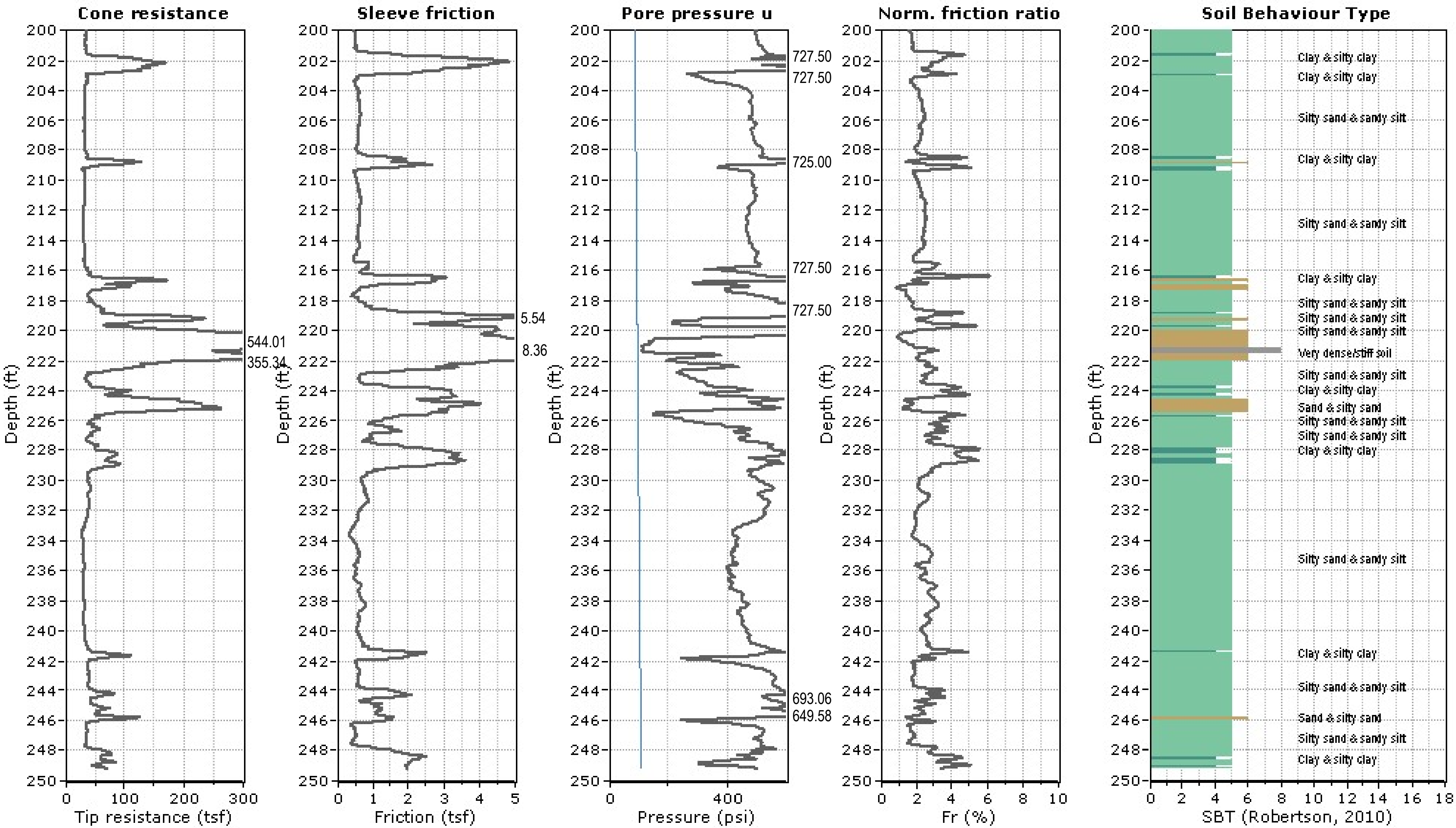
801.566.6399

CPT: L-32

Total depth: 249.08 ft, Date: 8/17/1995
Surface Elevation: 4239.00 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

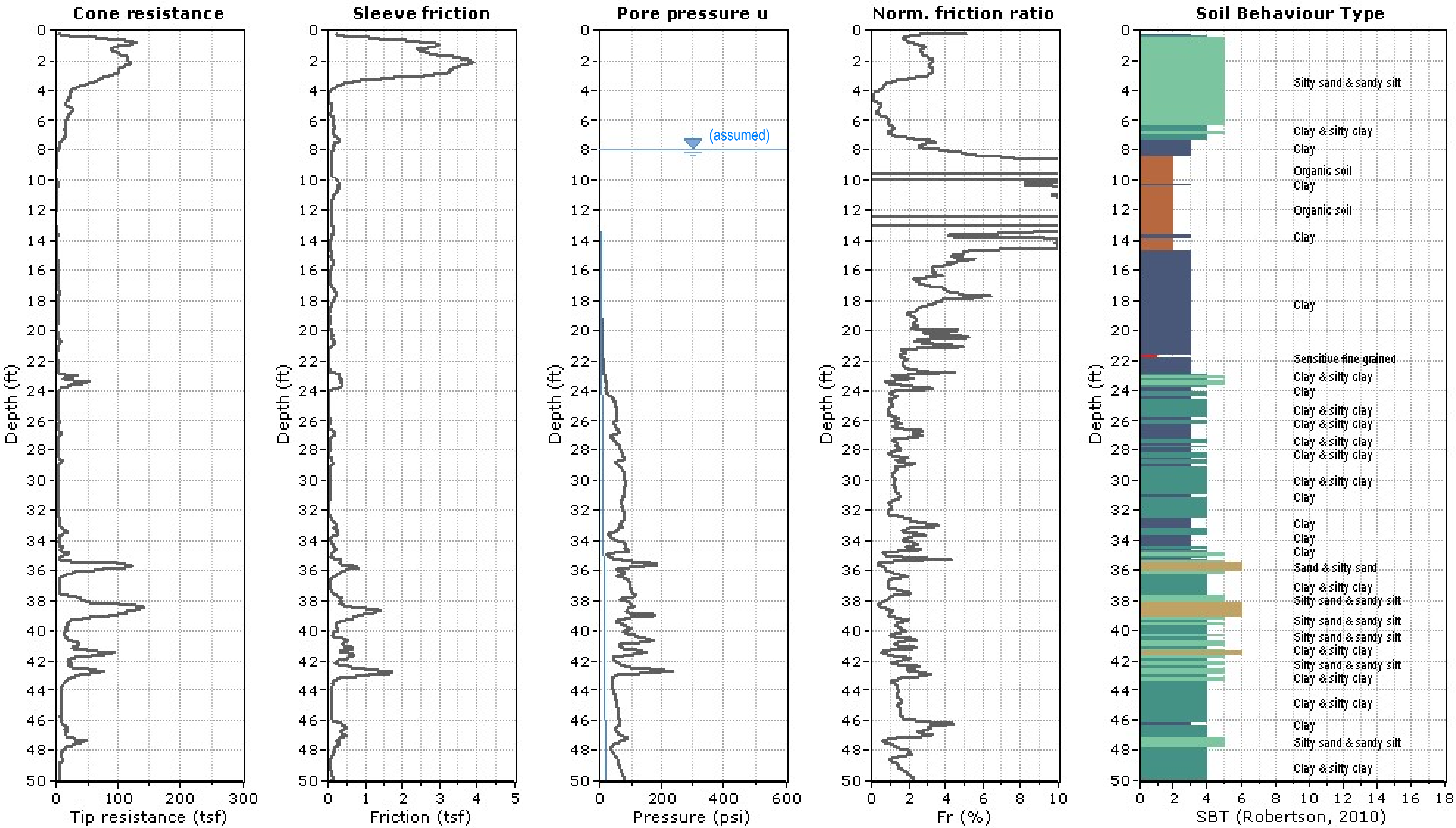


AGEC
Applied GeoTech

600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-33
Total depth: 122.11 ft, Date: 8/17/1995
Surface Elevation: 4241.30 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.



AGEC Applied GeoTech

600 W. Sandy Parkway
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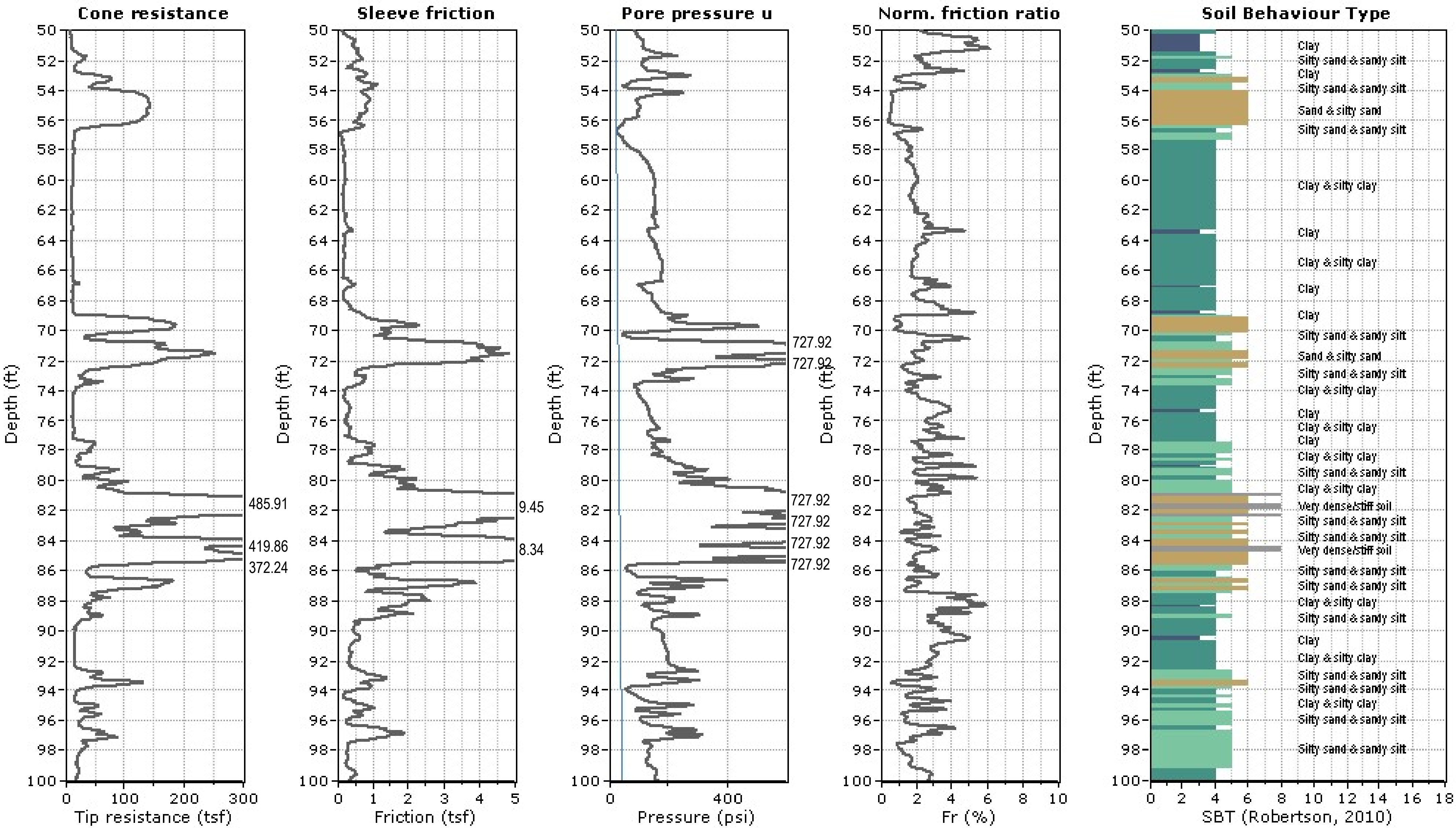
801.566.6399

CPT: L-33
Total depth: 122.11 ft, Date: 8/17/1995
Surface Elevation: 4241.30 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

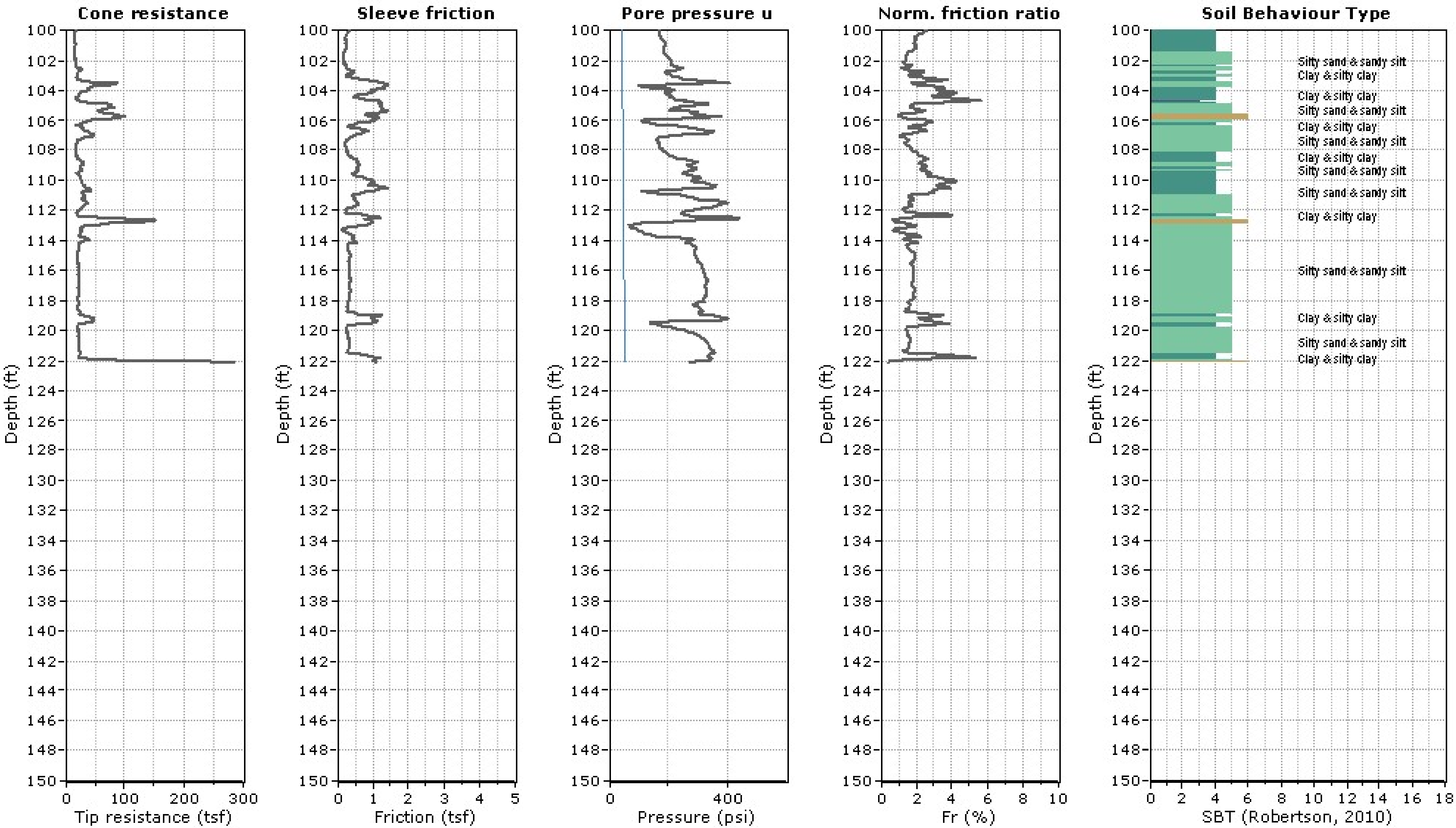


Applied GeoTech

600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-33
Total depth: 122.11 ft, Date: 8/17/1995
Surface Elevation: 4241.30 ft
Cone Type: # F7.5CKEW852
Cone Operator: Fugro Geosciences, Inc.



Project file: H:\AGEC Project Files\2016 Projects\1160276 GT - C Landfill (JEN)\CPT Data\Fugro CPT Data.cpt

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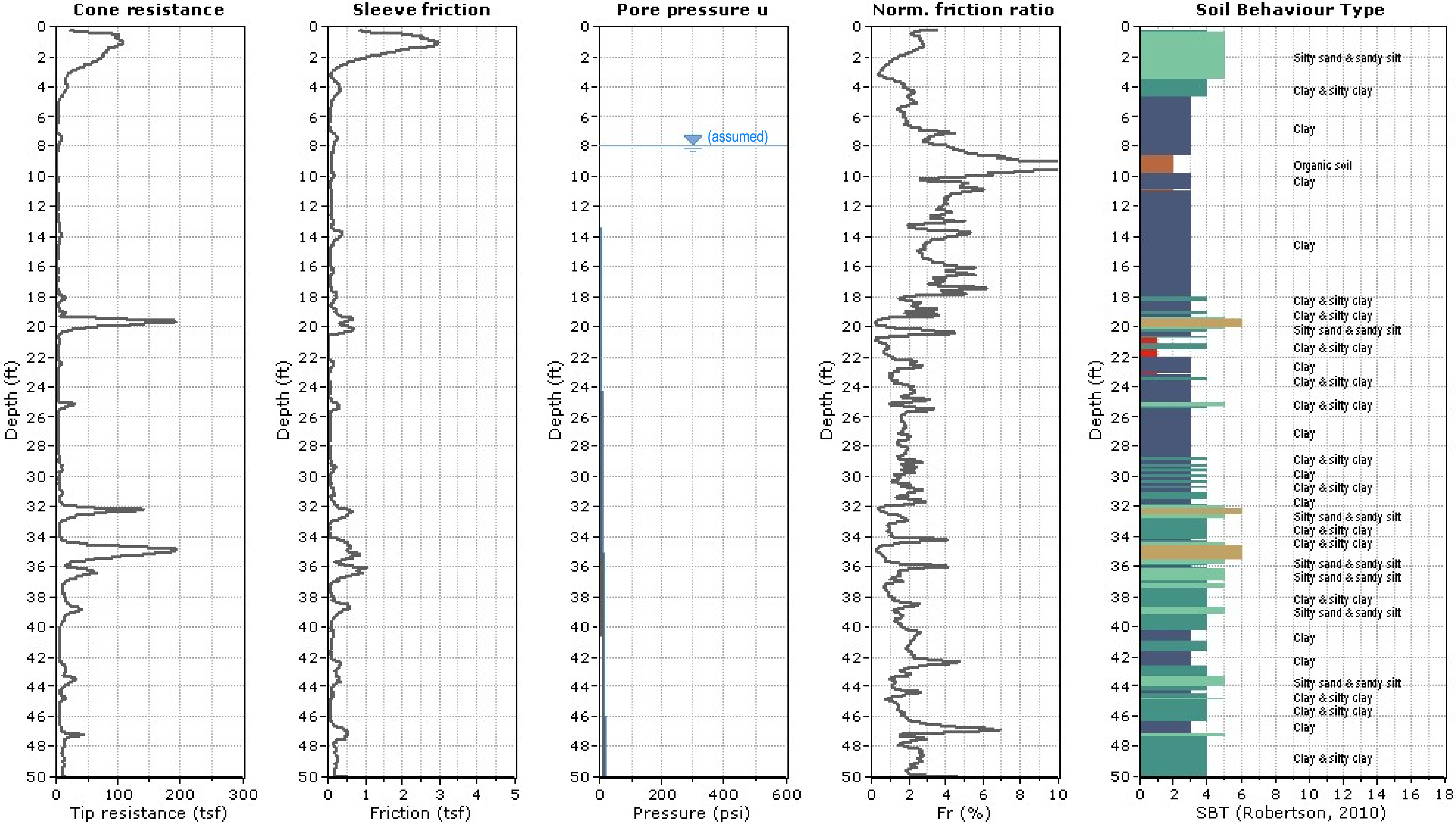
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

CPT: L-34
Total depth: 118.05 ft, Date: 8/18/1995
Surface Elevation: 4238.80 ft
Cone Type: # F7.5CEW852
Cone Operator: Fugro Geosciences, Inc.

Project: 1160276 - Clean Harbors
Location: see Figure 1



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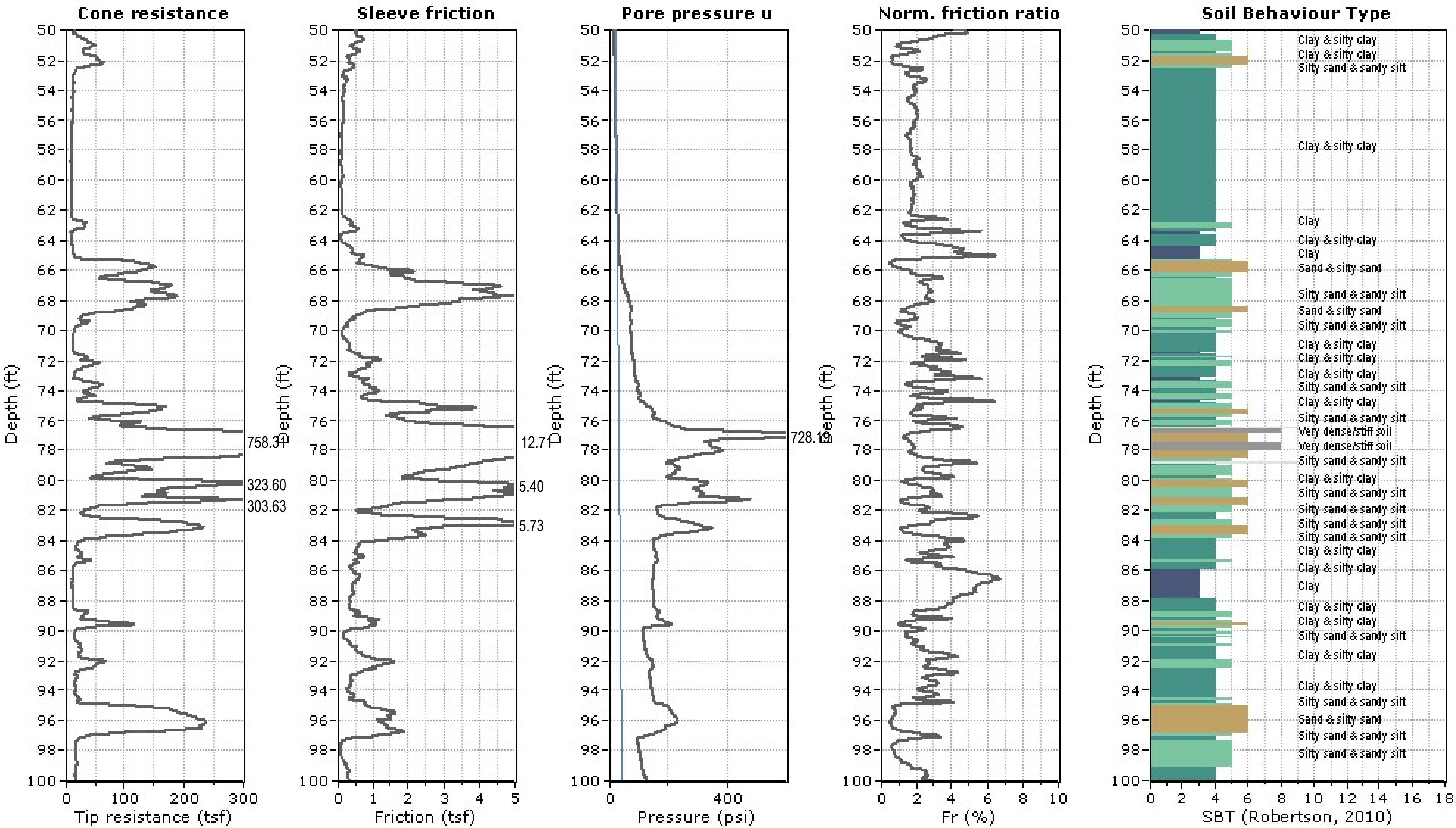
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

CPT: L-34

Total depth: 118.05 ft, Date: 8/18/1995
Surface Elevation: 4238.80 ft
Cone Type: # F7.5CEW852
Cone Operator: Fugro Geosciences, Inc.

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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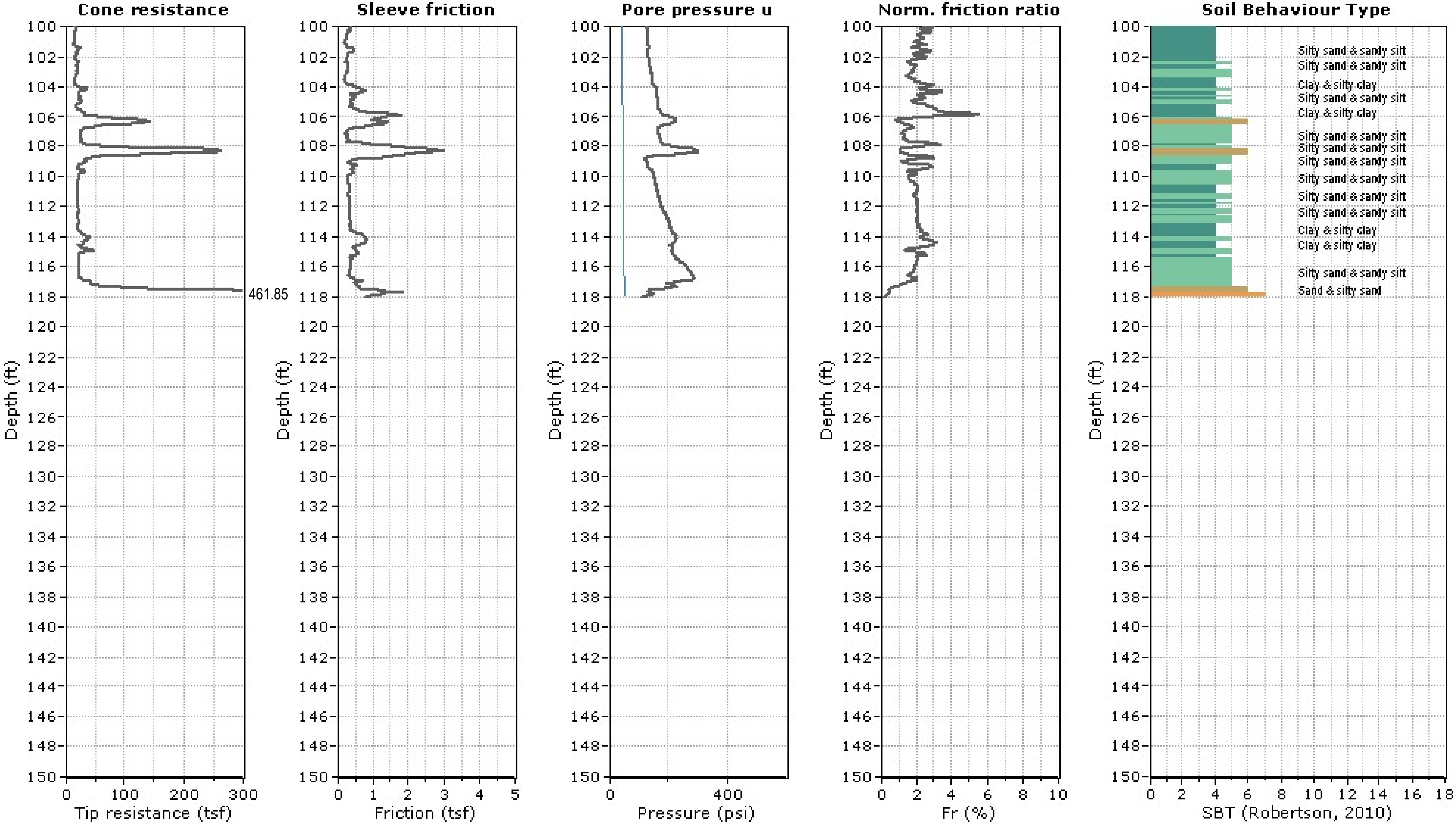
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

CPT: L-34
Total depth: 118.05 ft, Date: 8/18/1995
Surface Elevation: 4238.80 ft
Cone Type: # F7.5CEW852
Cone Operator: Fugro Geosciences, Inc.

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**



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600 W. Sandy Parkway
Sandy, UT 84070
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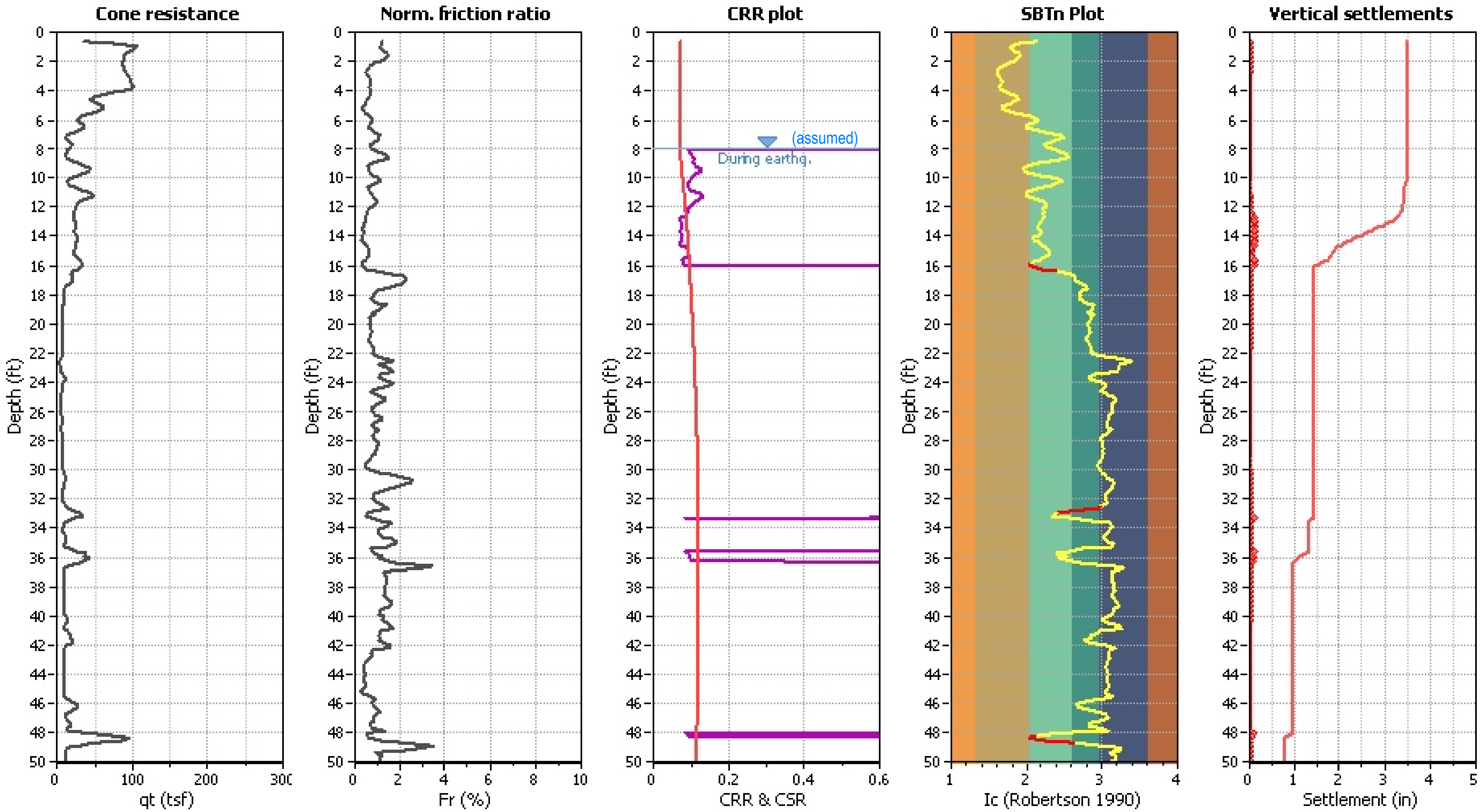
Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-1
Total depth: 91.37 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	9999.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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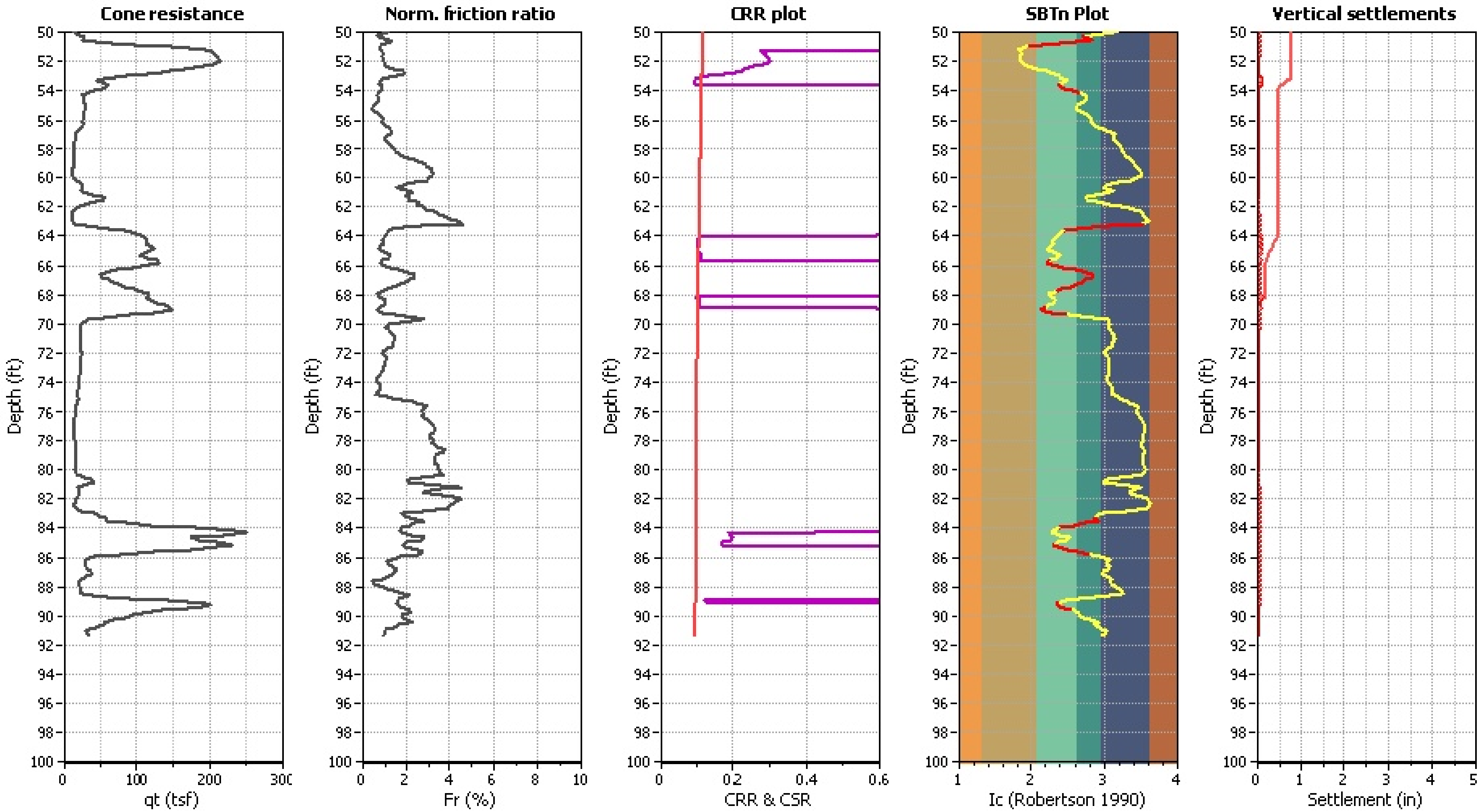
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-1
Total depth: 91.37 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	9999.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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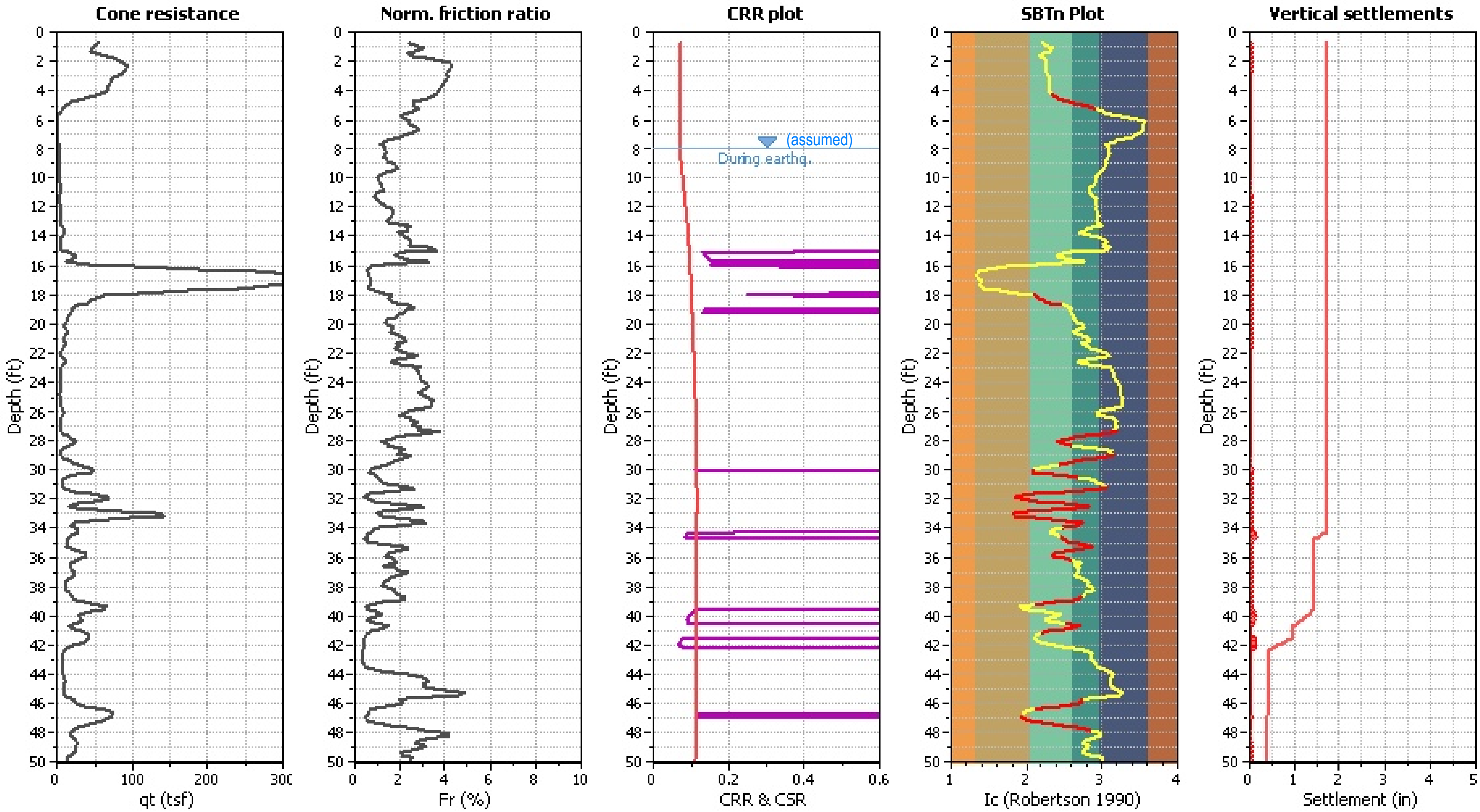
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-3
Total depth: 91.54 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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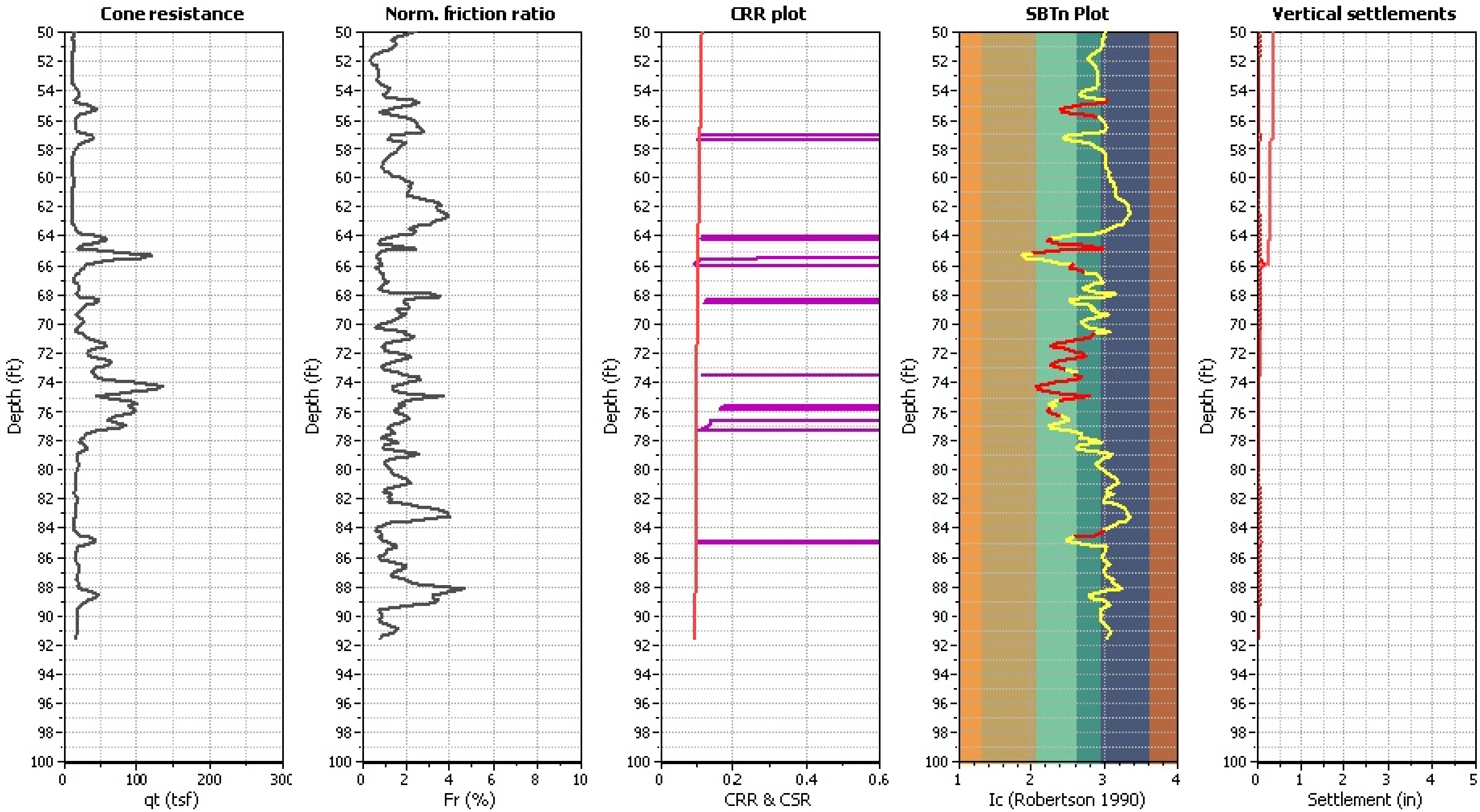
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-3
Total depth: 91.54 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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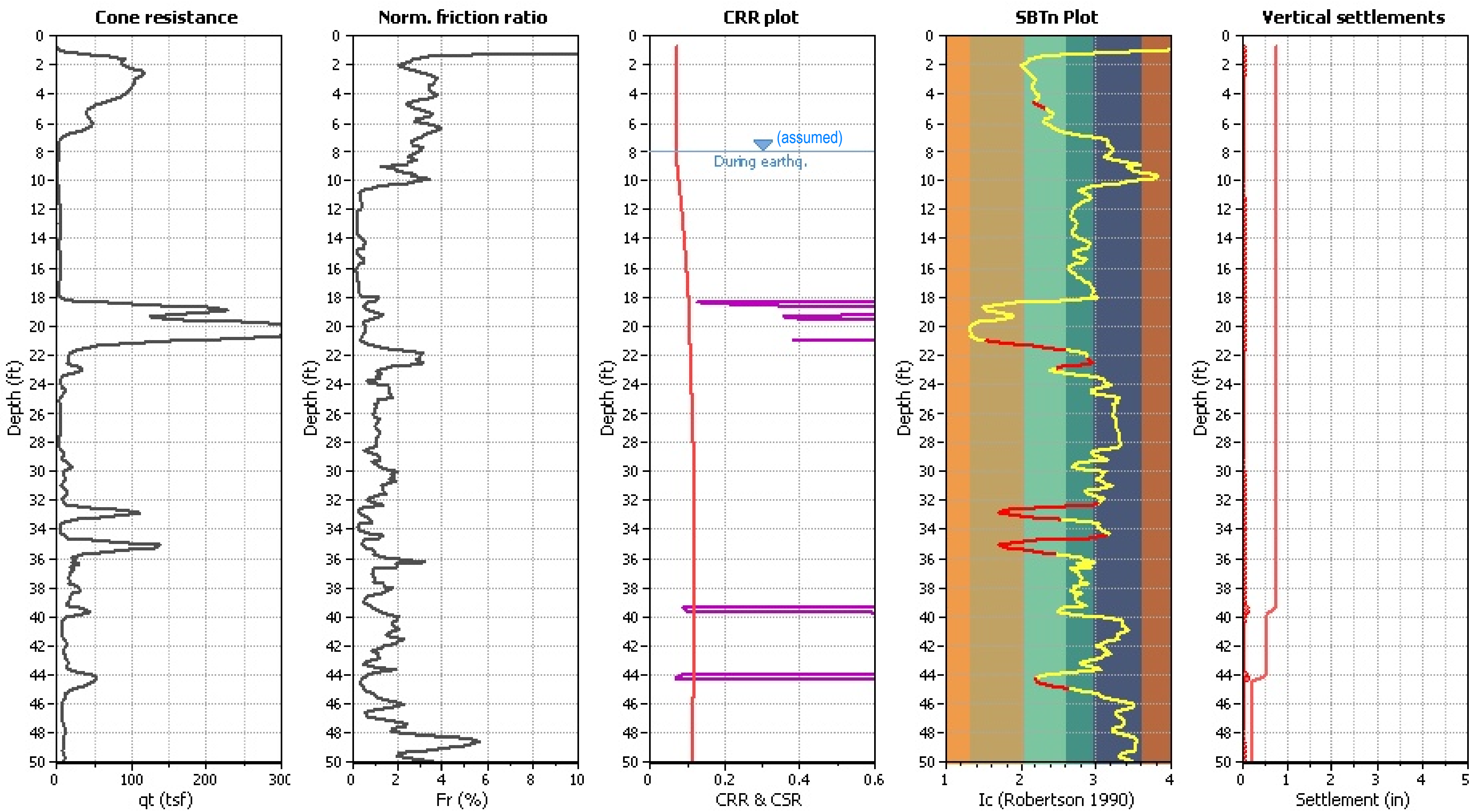
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-5
Total depth: 91.04 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	9999.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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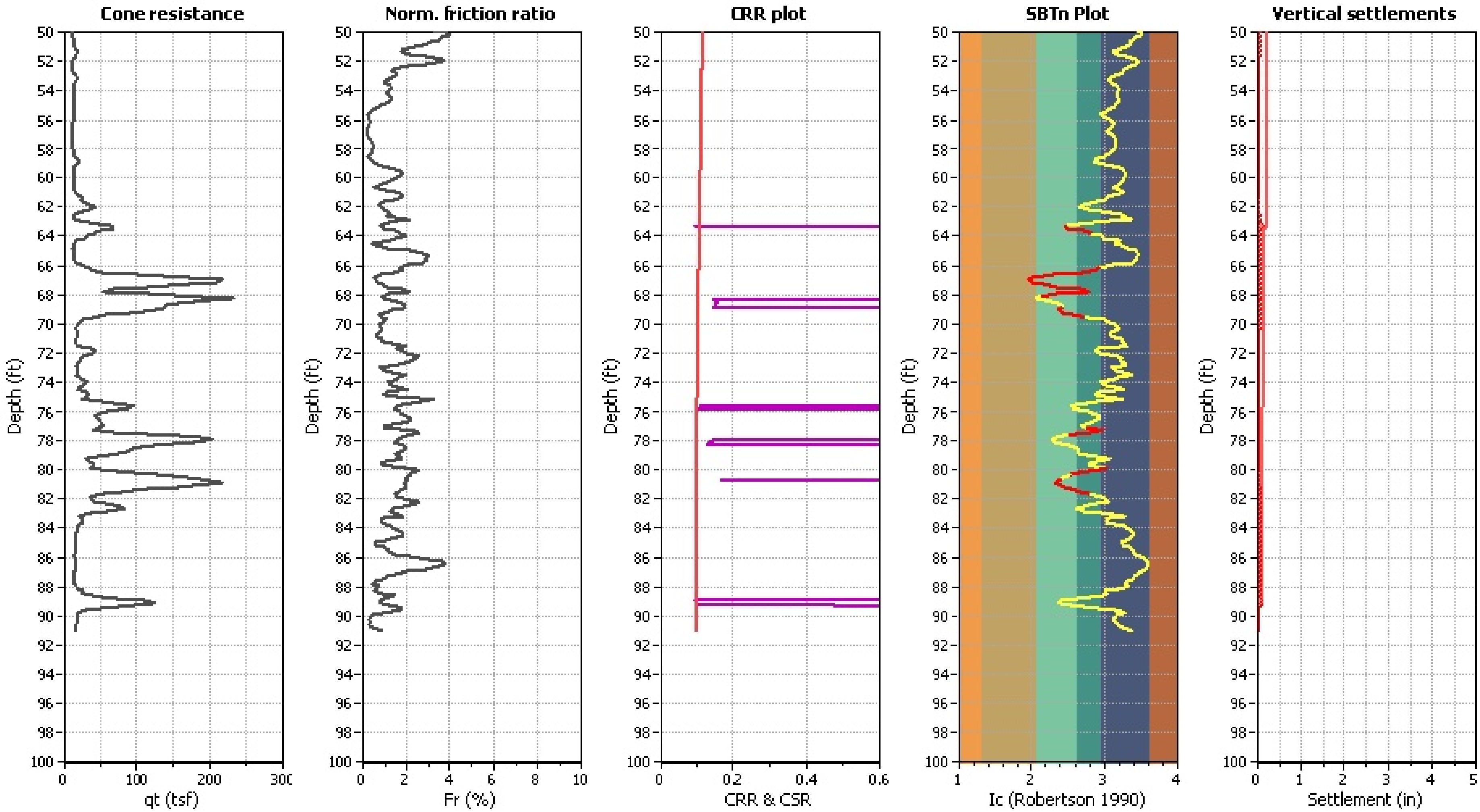
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-5
Total depth: 91.04 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	9999.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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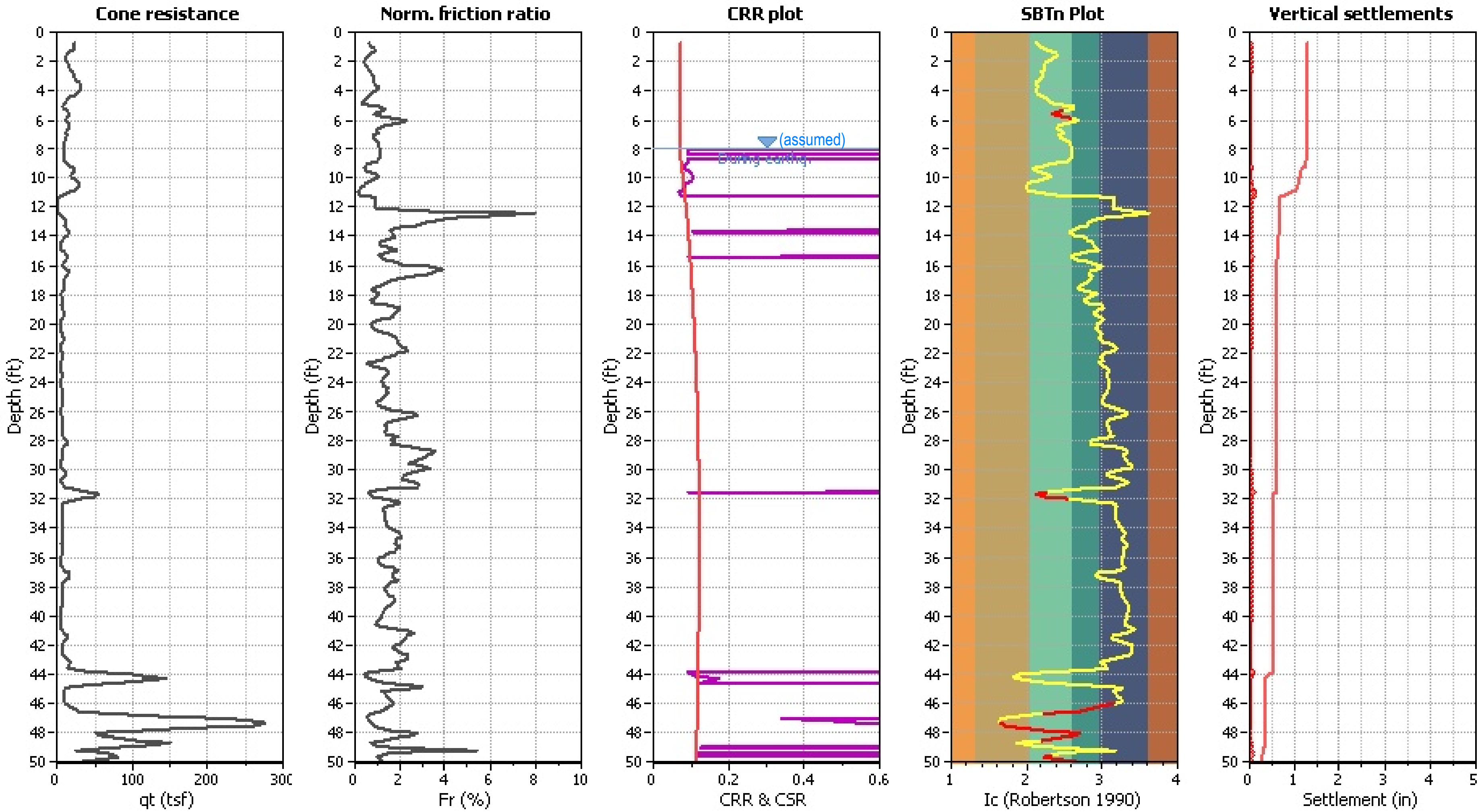
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-7
Total depth: 91.37 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	9999.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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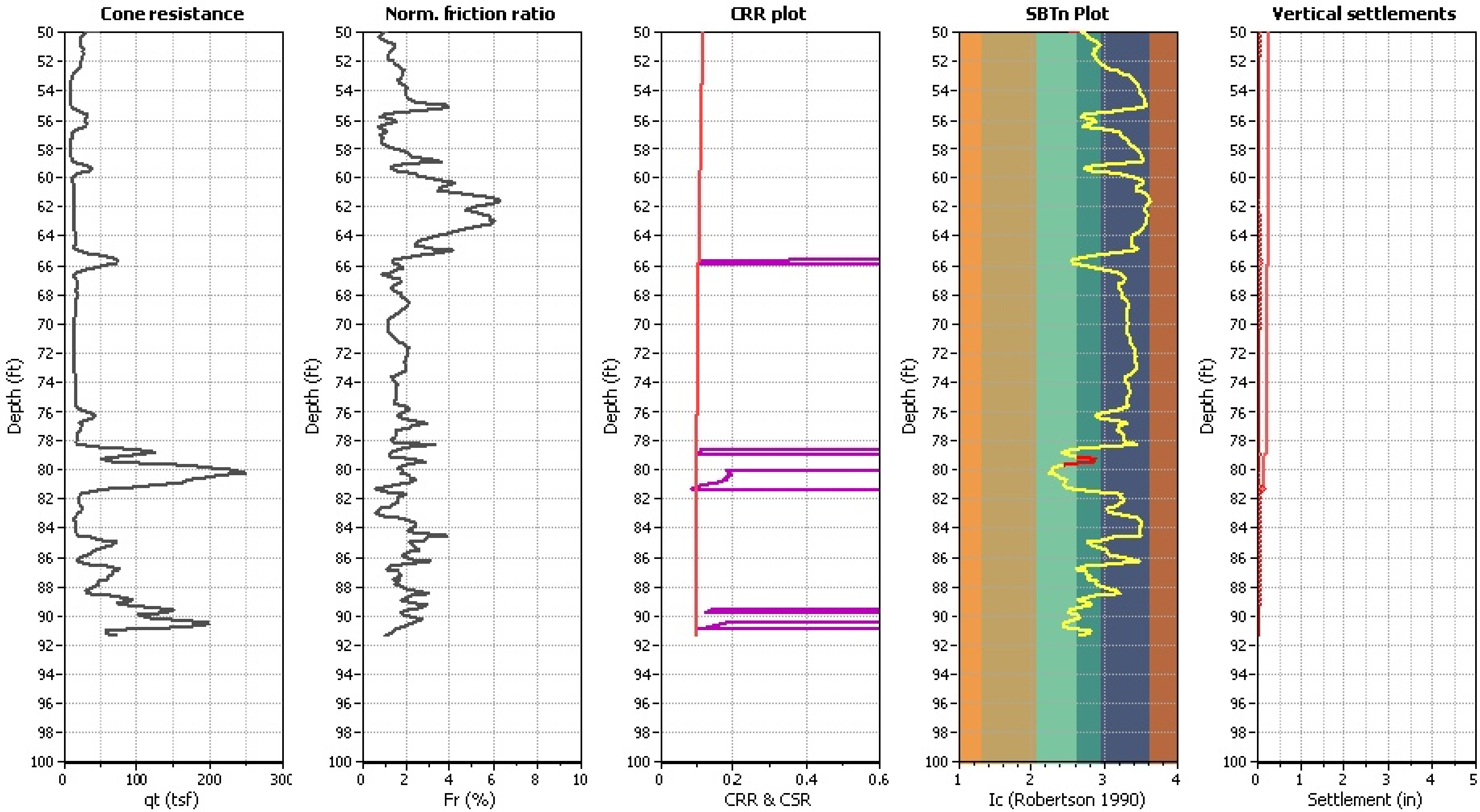
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-7
Total depth: 91.37 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	9999.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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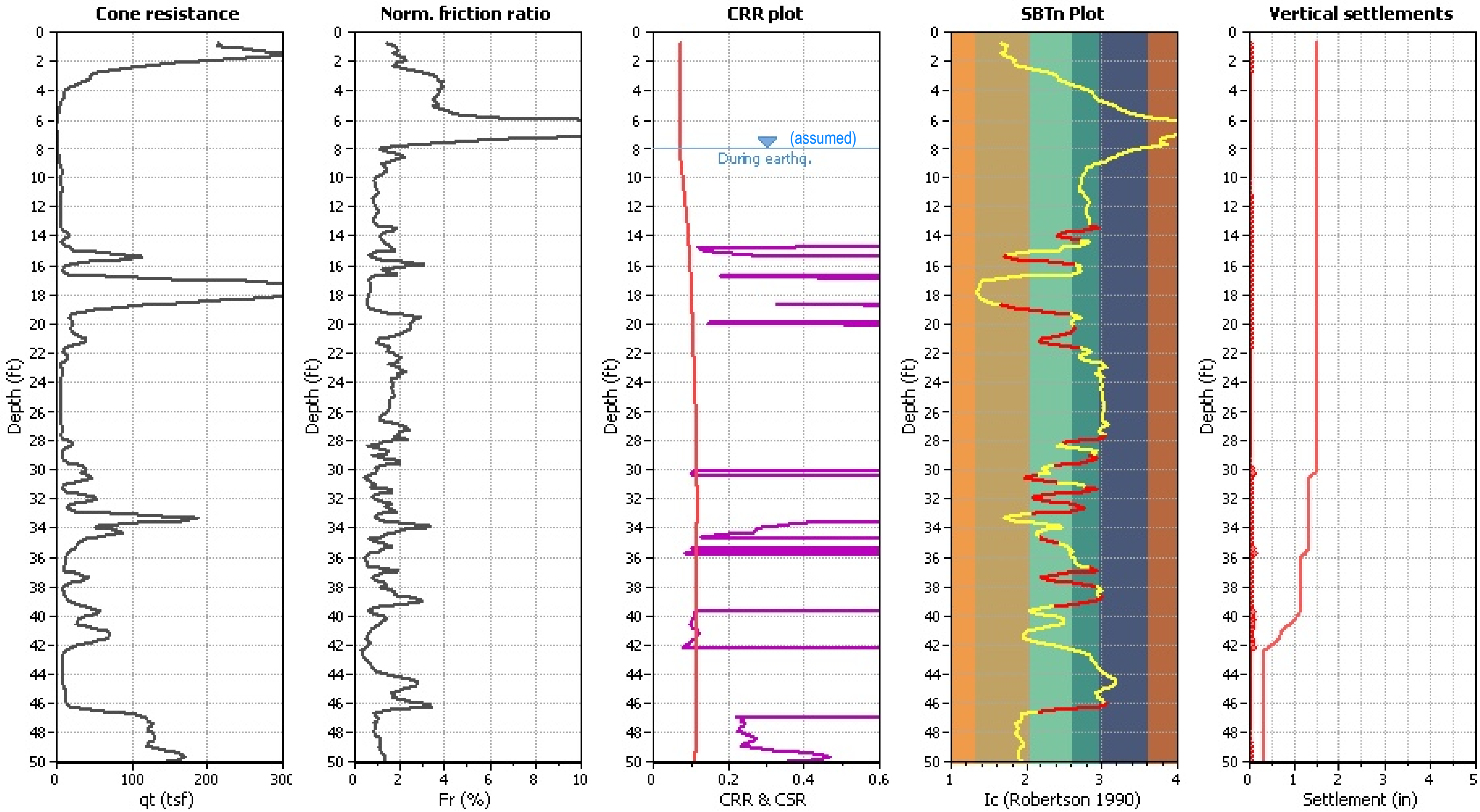
801.566.6399

Project: **1160276 - Clean Harbors**

Location: **see Figure 1**

CPT: L-9

Total depth: 78.90 ft



Analysis method: NCEER (1998)
Fines correction method: NCEER (1998)
Points to test: Based on Ic value
Earthquake magnitude M_w: 6.20
Peak ground acceleration: 0.18

G.W.T. (in-situ): 8.00 ft
G.W.T. (earthq.): 8.00 ft
Average results interval: 3
Ic cut-off value: 2.60
Unit weight calculation: Based on SBT

Use fill: No
Fill height: N/A
Fill weight: N/A
Trans. detect. applied: Yes
K_σ applied: Yes

Clay like behavior applied: Sands only
Limit depth applied: No
Limit depth: N/A
MSF method: Method based

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600 W. Sandy Parkway
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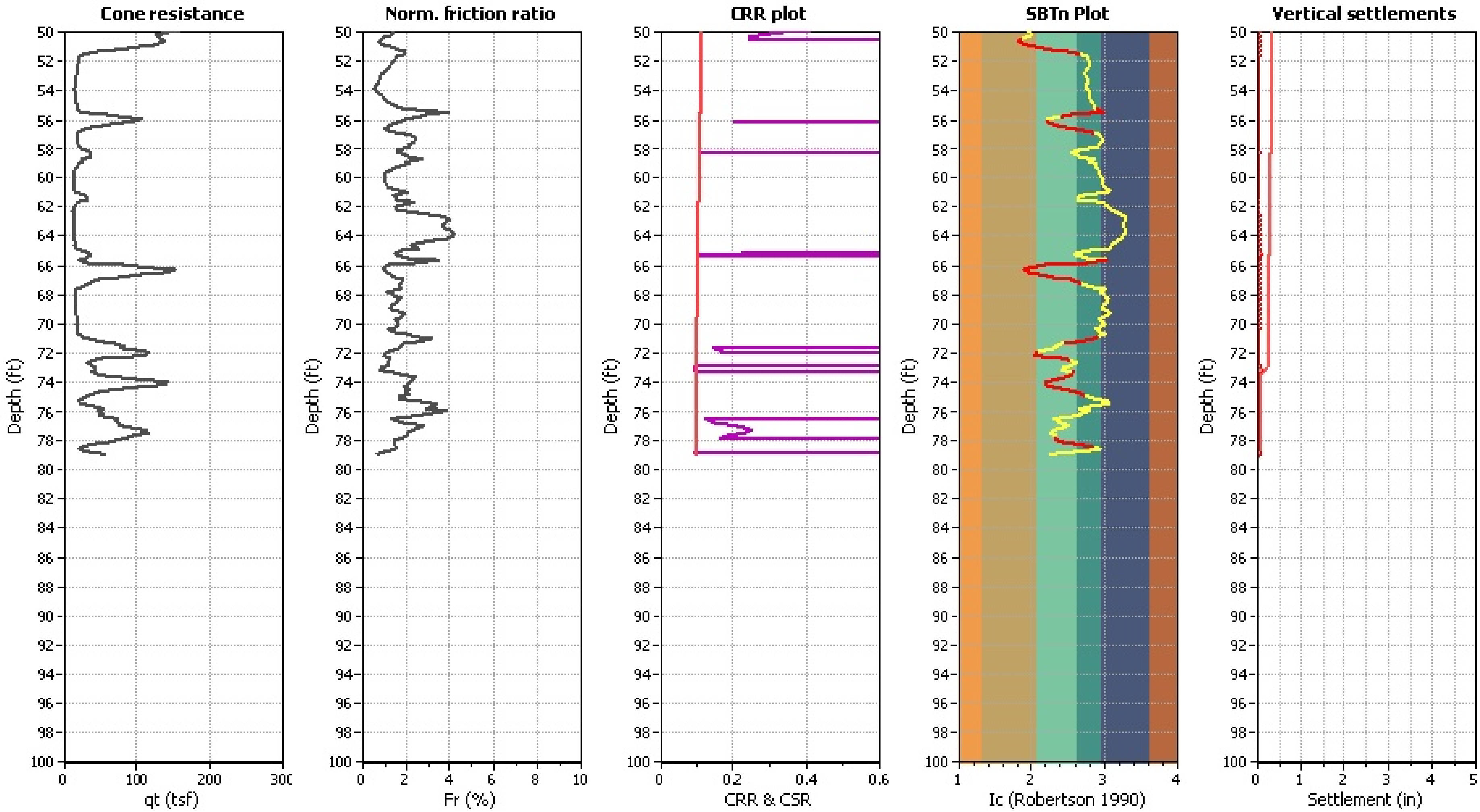
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-9
Total depth: 78.90 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

600 W. Sandy Parkway
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801.566.6399

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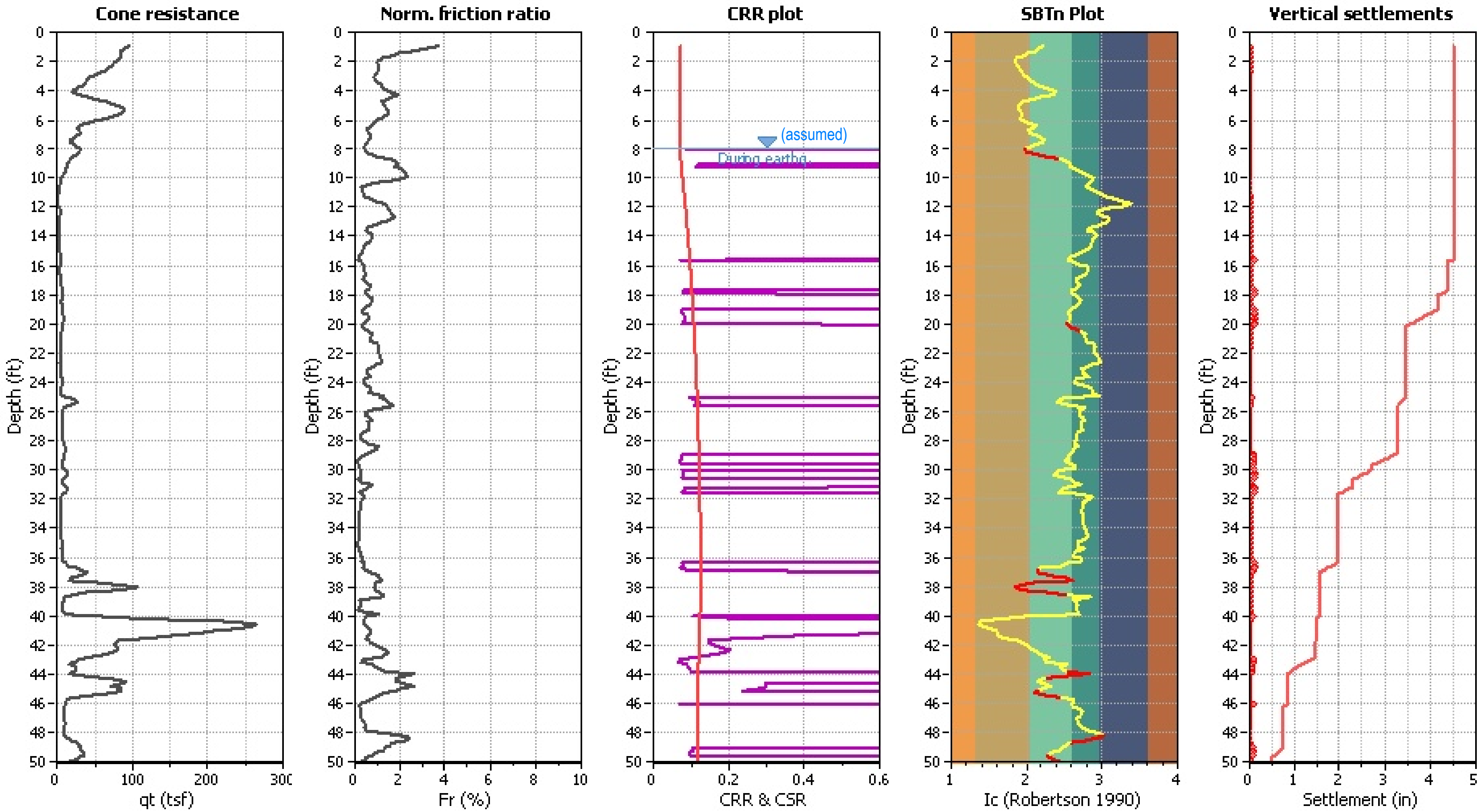
Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-11
Total depth: 84.15 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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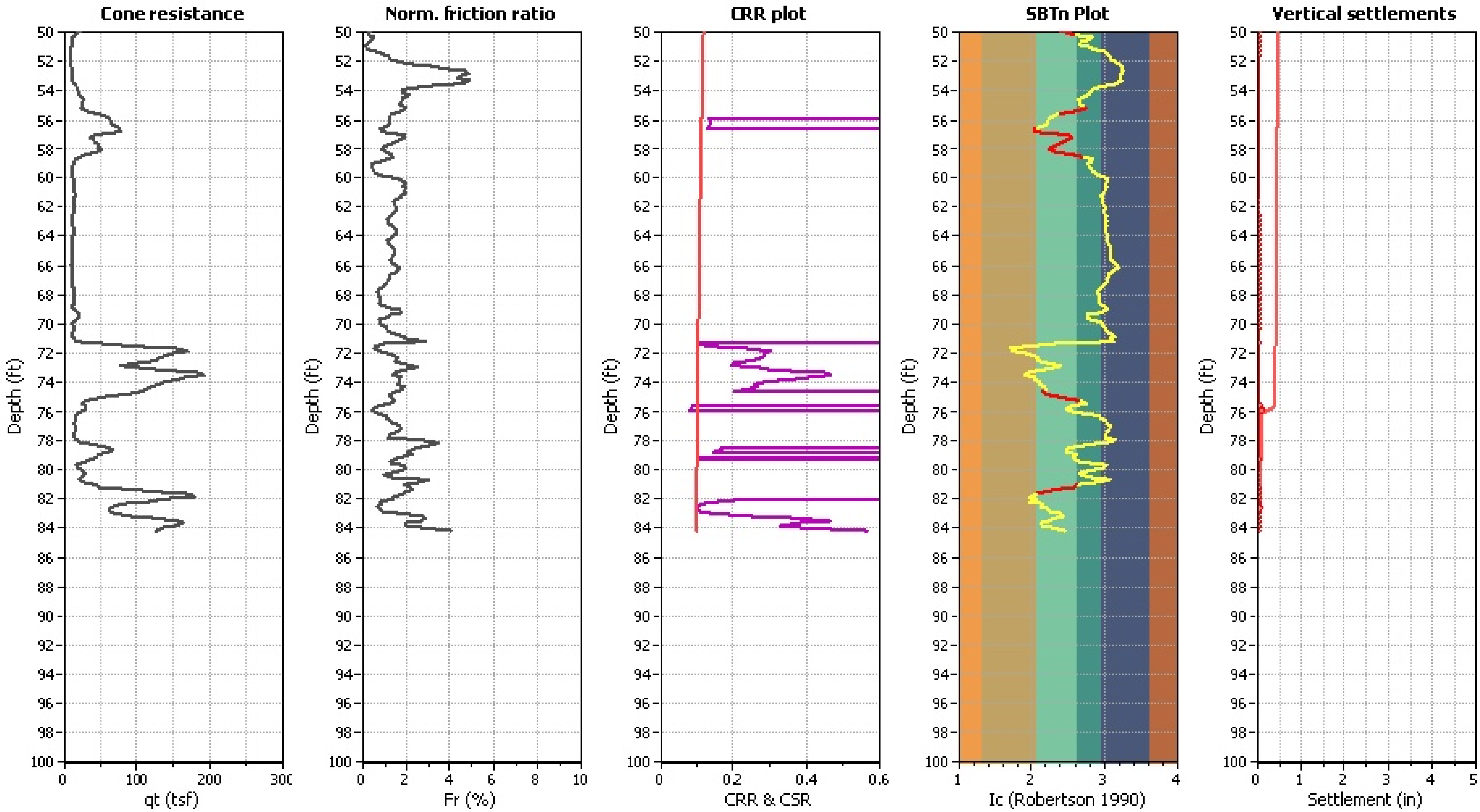
801.566.6399

Project: **1160276 - Clean Harbors**

Location: **see Figure 1**

CPT: L-11

Total depth: 84.15 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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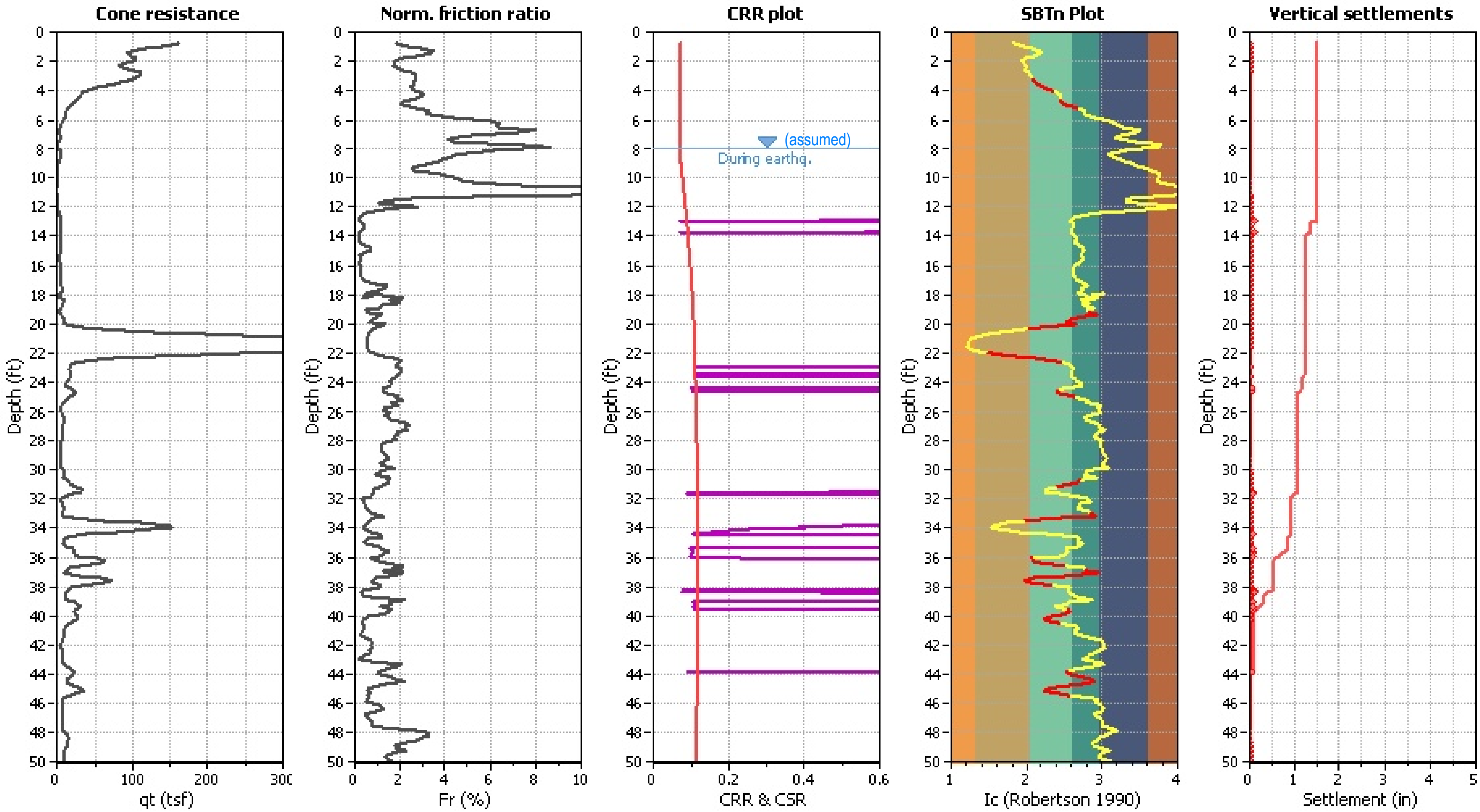
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-13
Total depth: 77.59 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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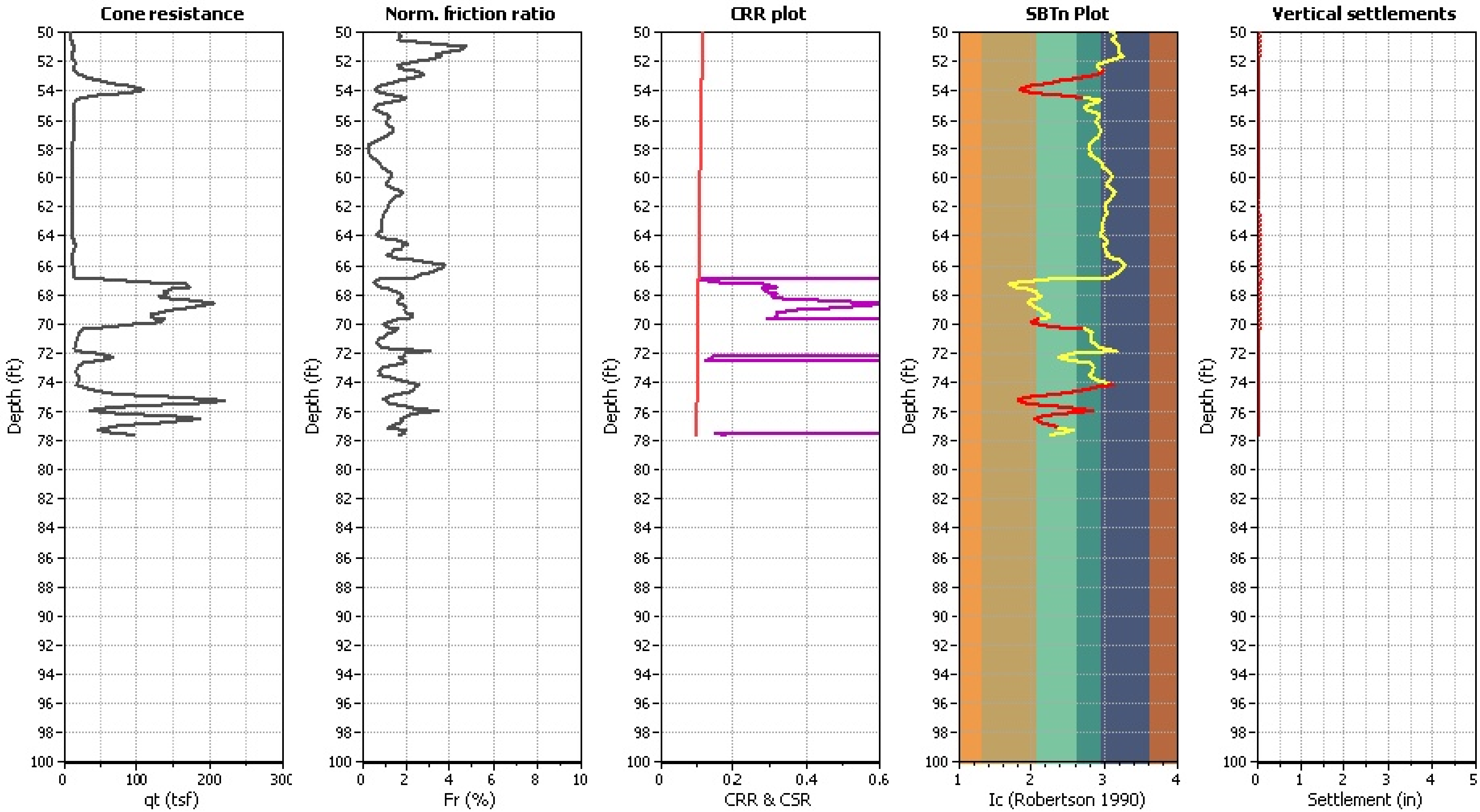
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-13
Total depth: 77.59 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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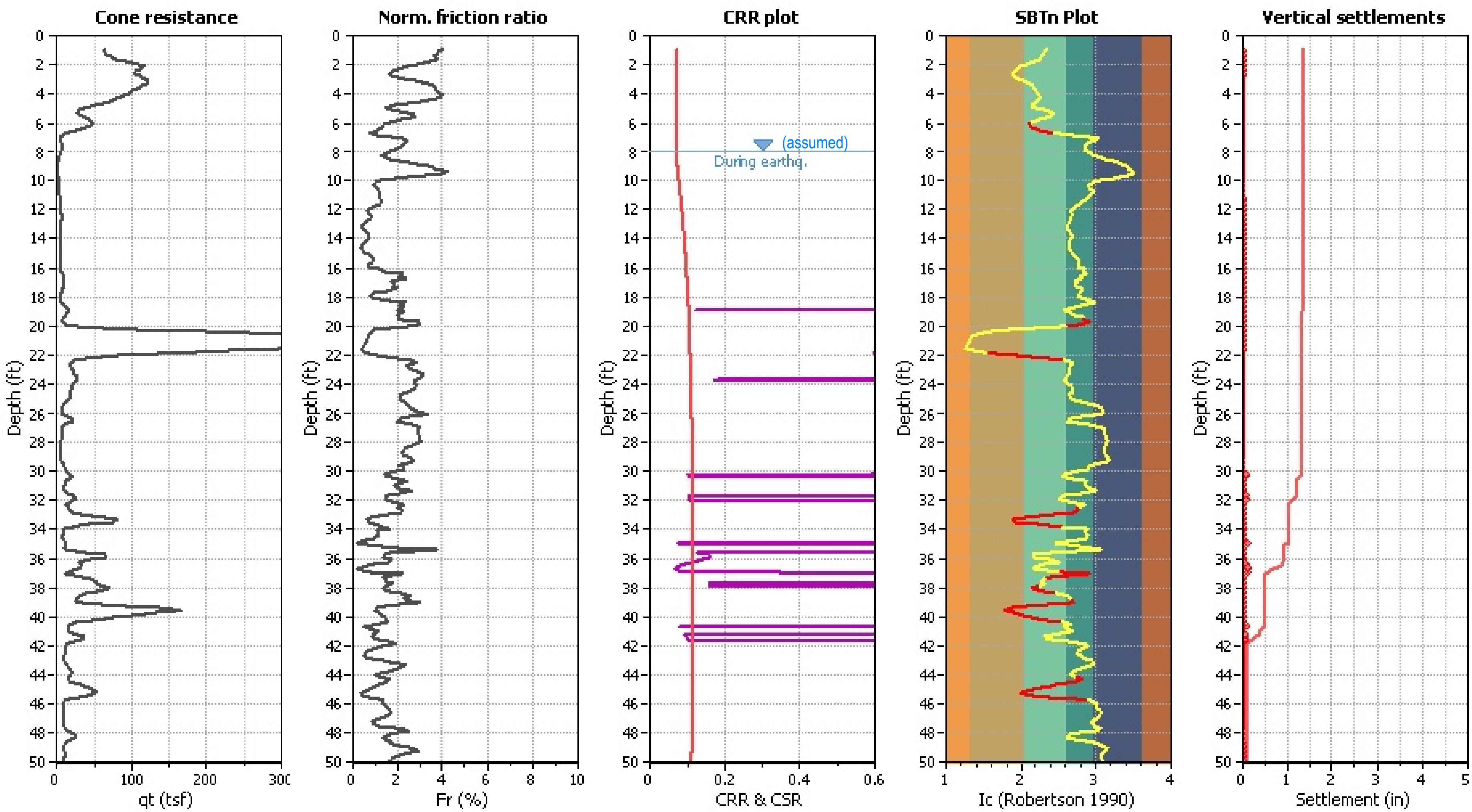
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-14
Total depth: 77.43 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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801.566.6399

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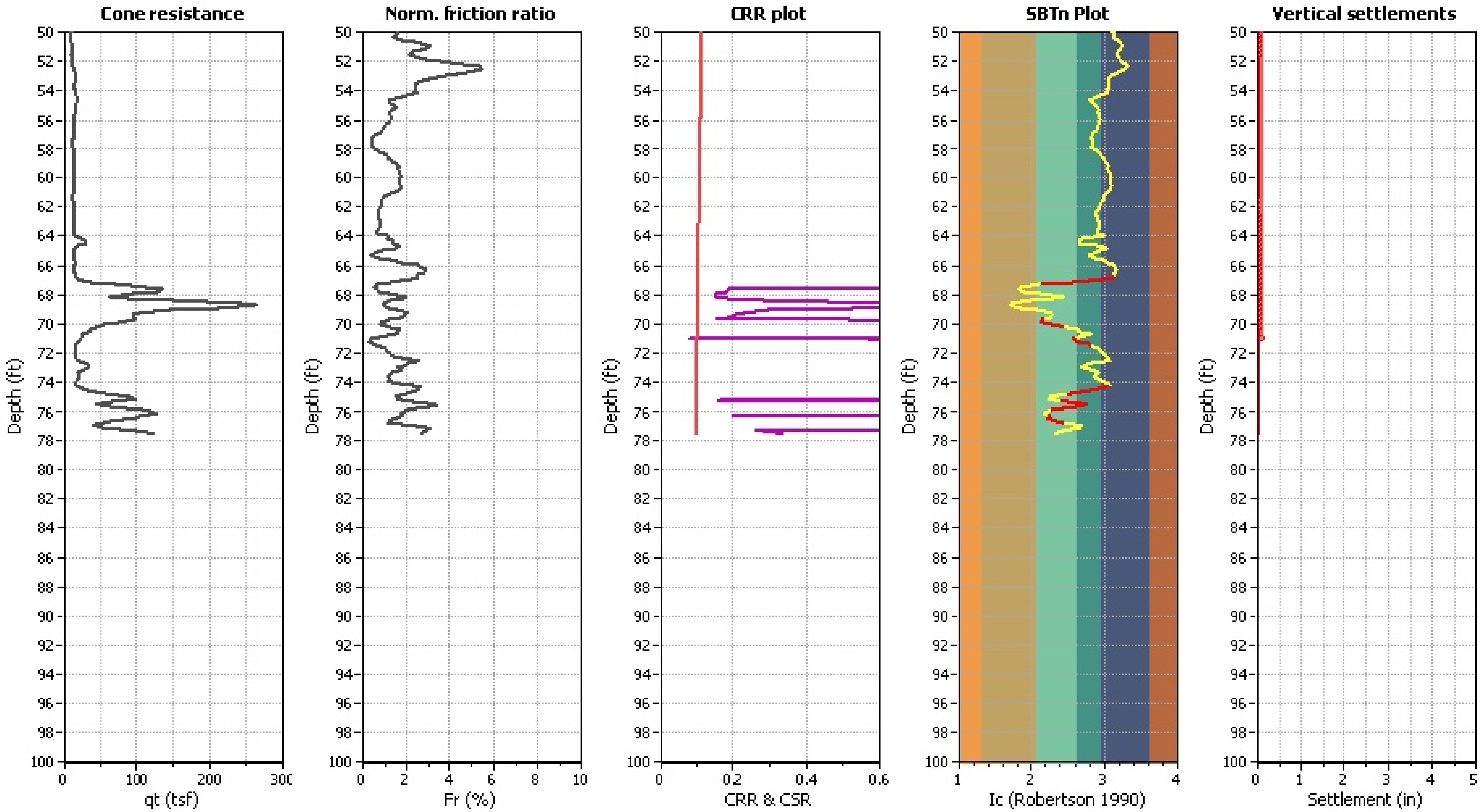
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-14
Total depth: 77.43 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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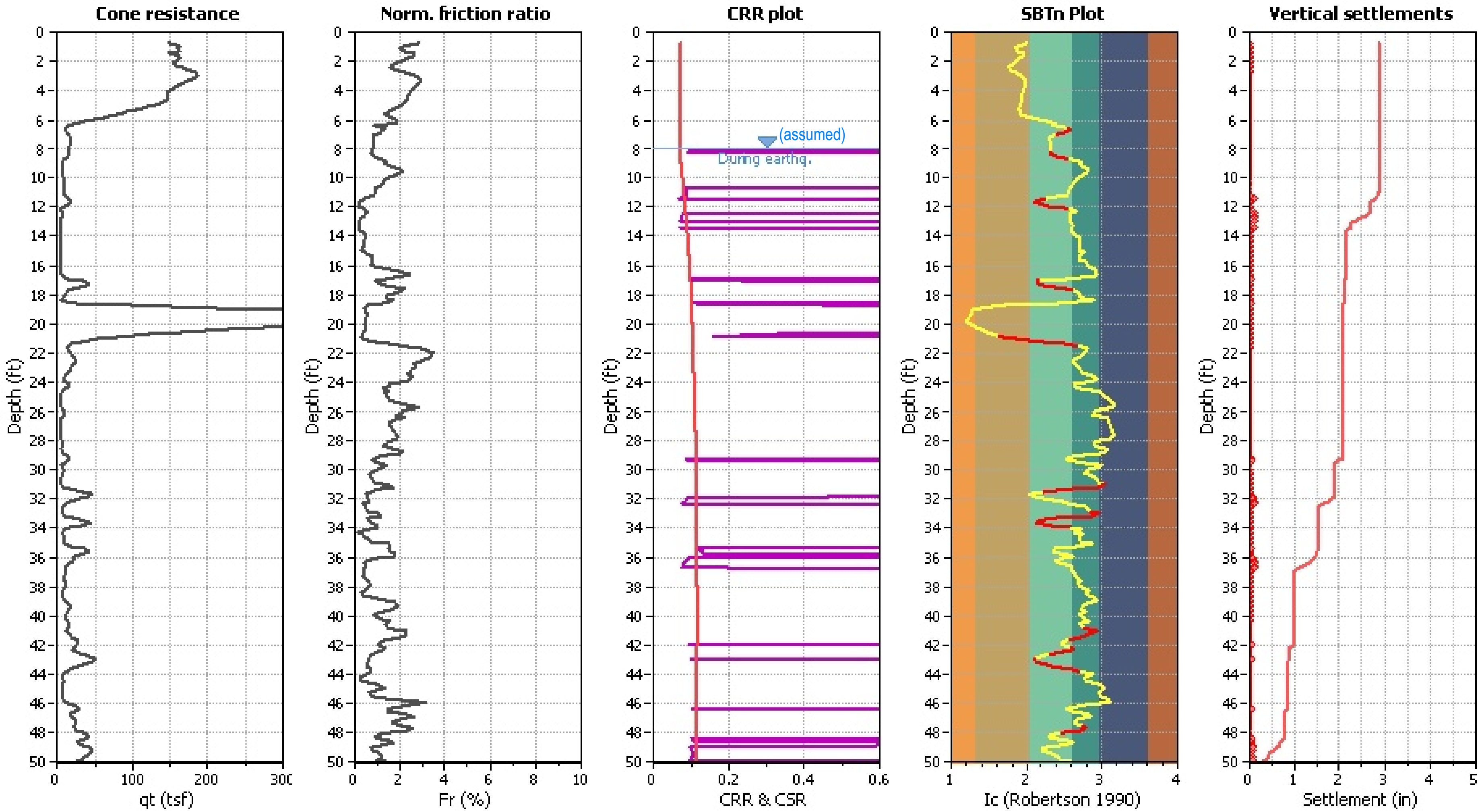
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-16
Total depth: 81.36 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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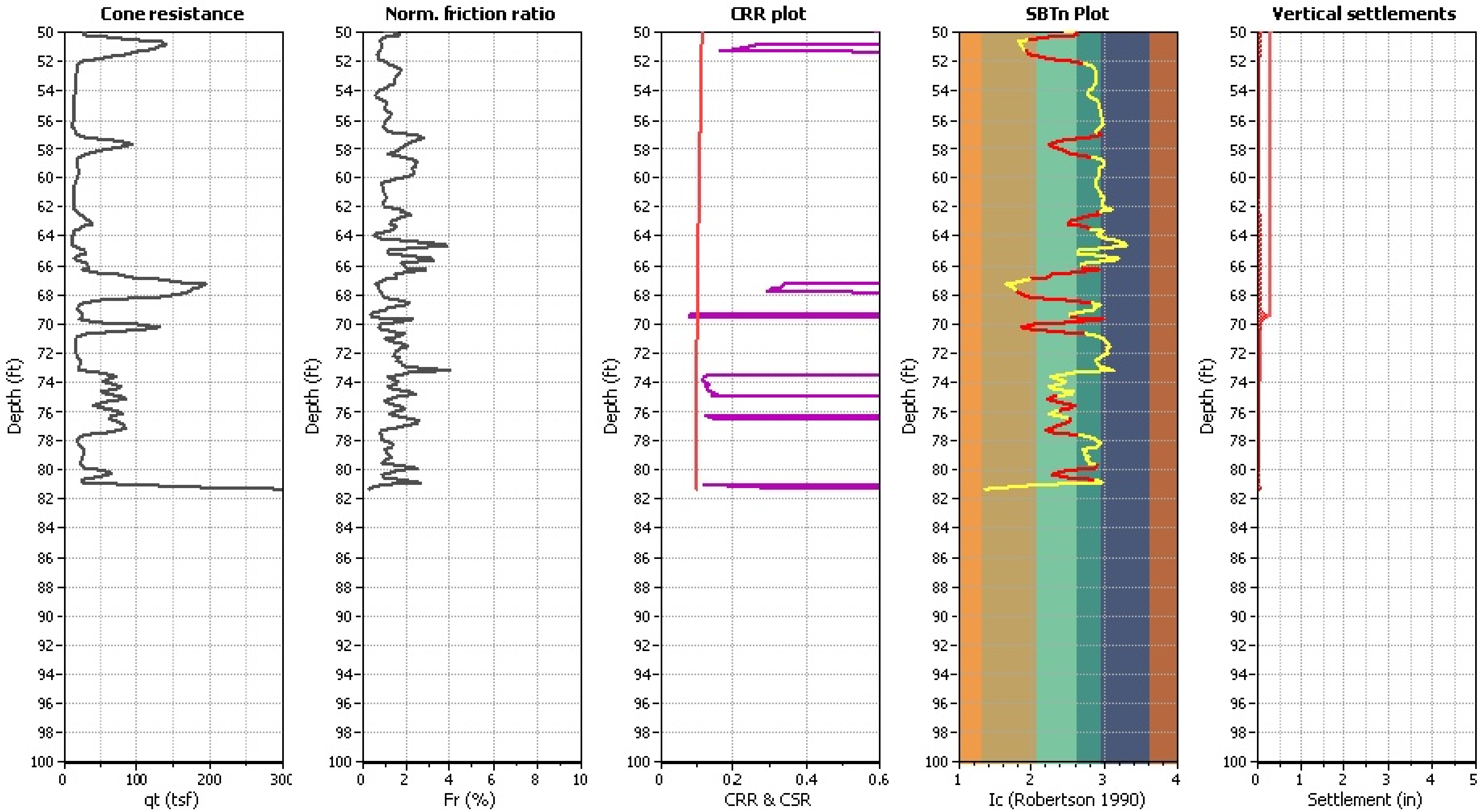
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-16
Total depth: 81.36 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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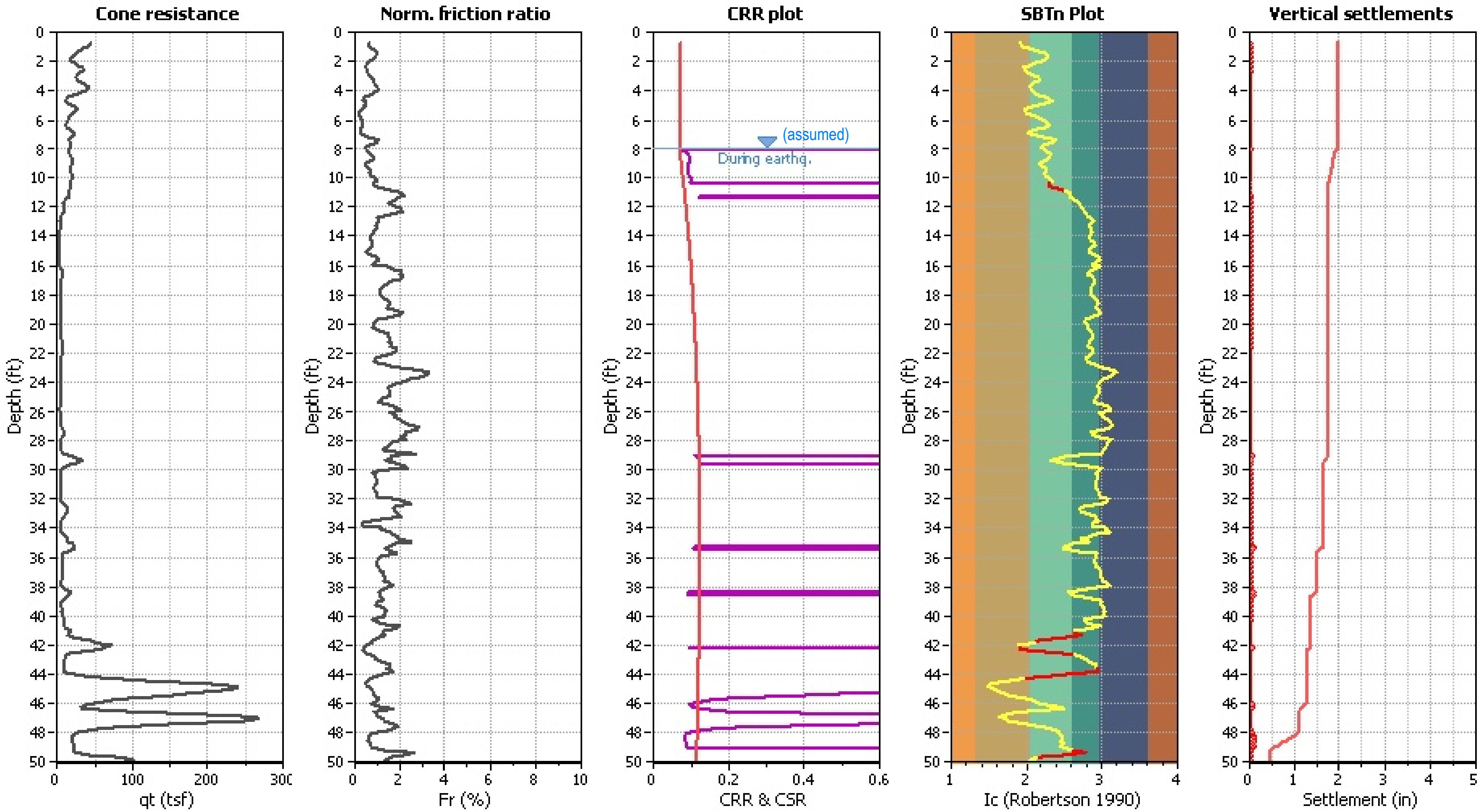
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-18
Total depth: 79.07 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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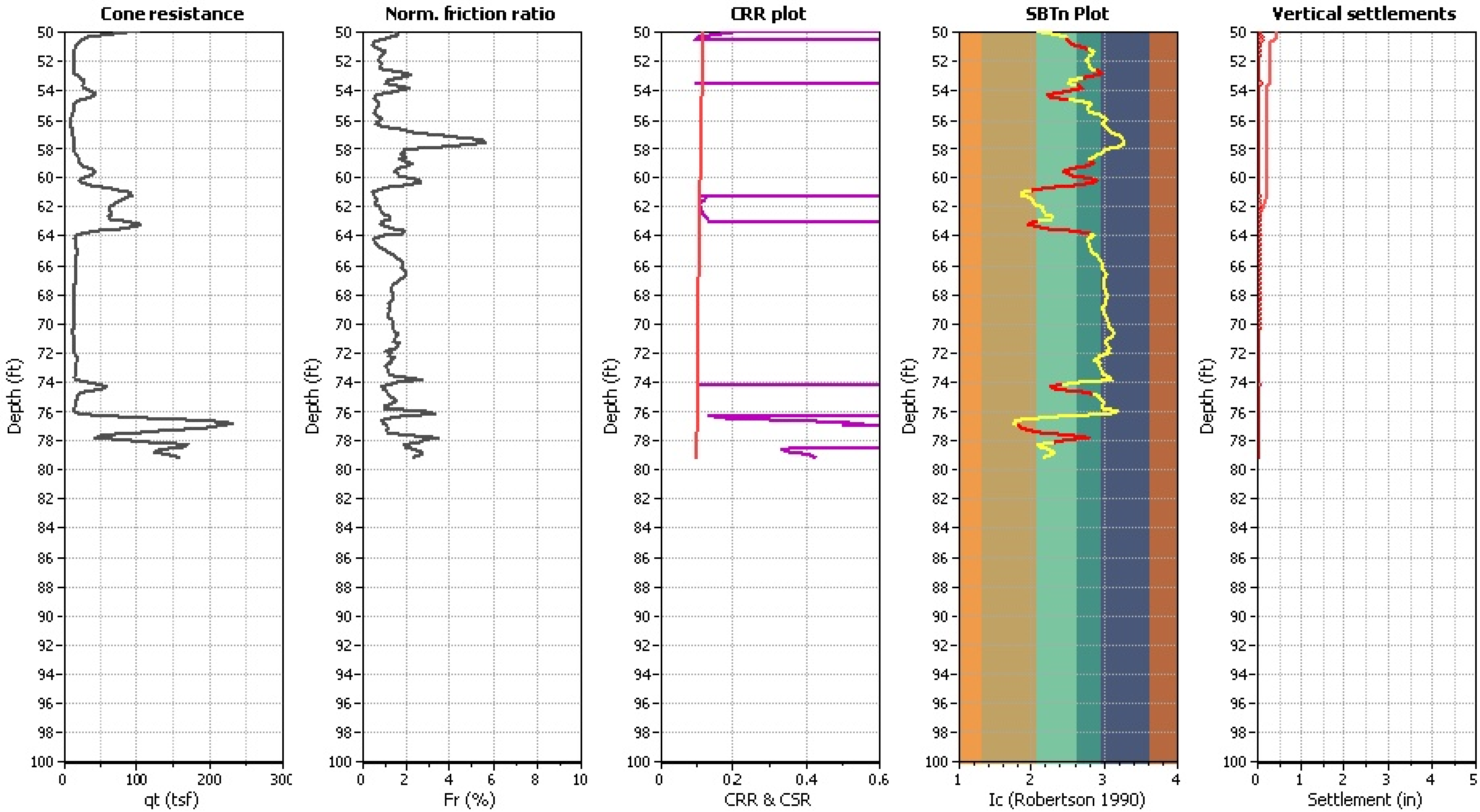
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-18
Total depth: 79.07 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
Sandy, UT 84070
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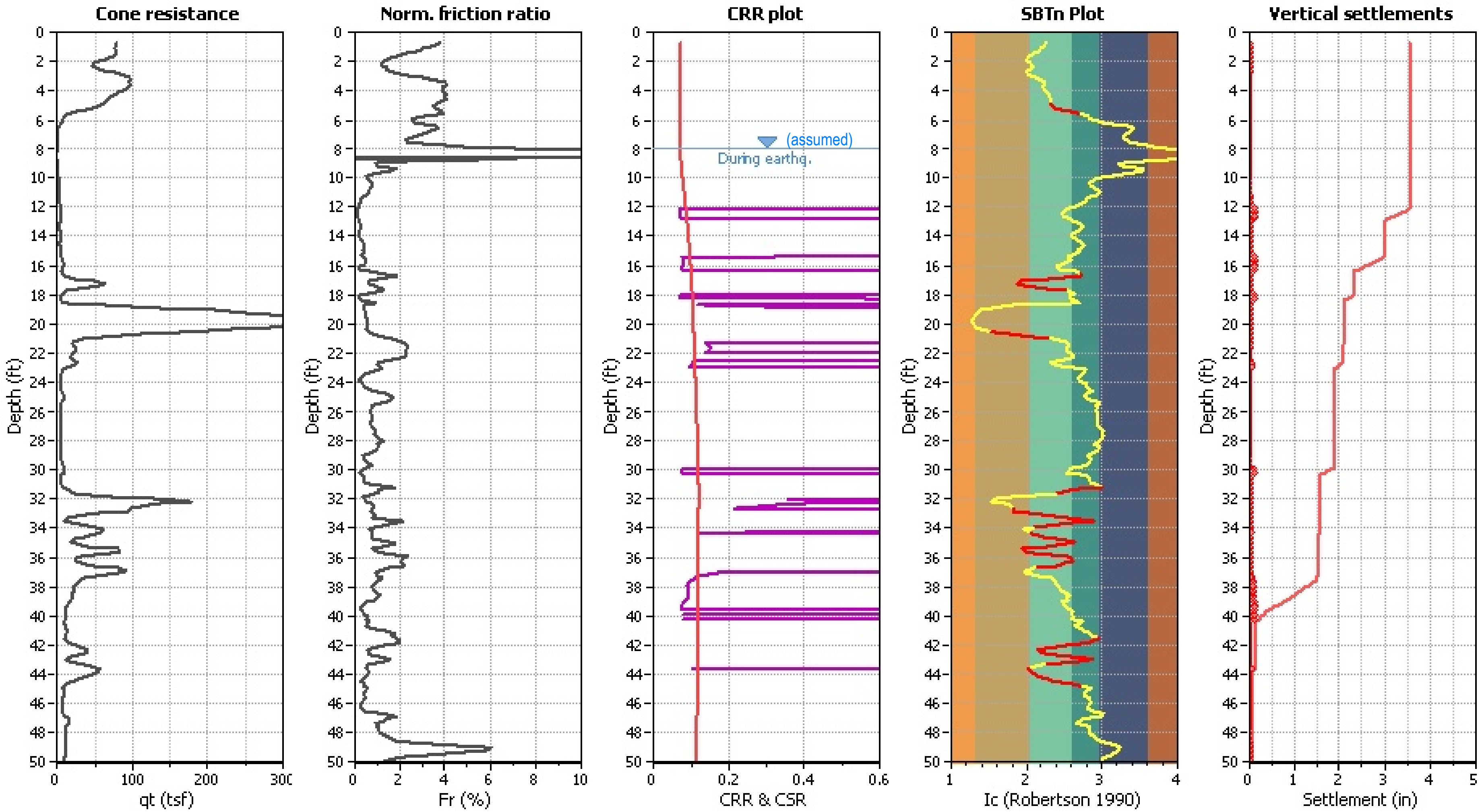
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-20
Total depth: 53.81 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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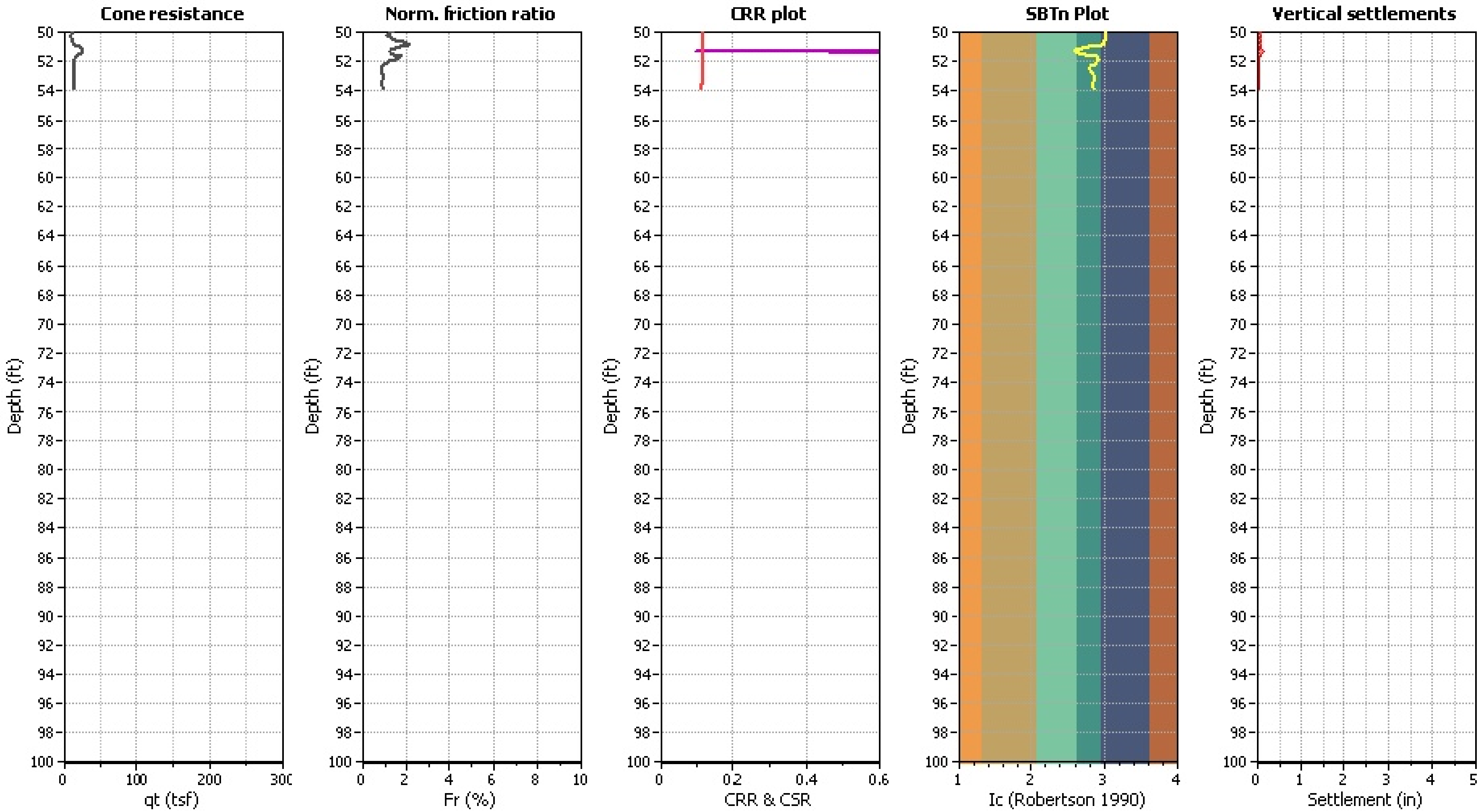
Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-20
Total depth: 53.81 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

600 W. Sandy Parkway
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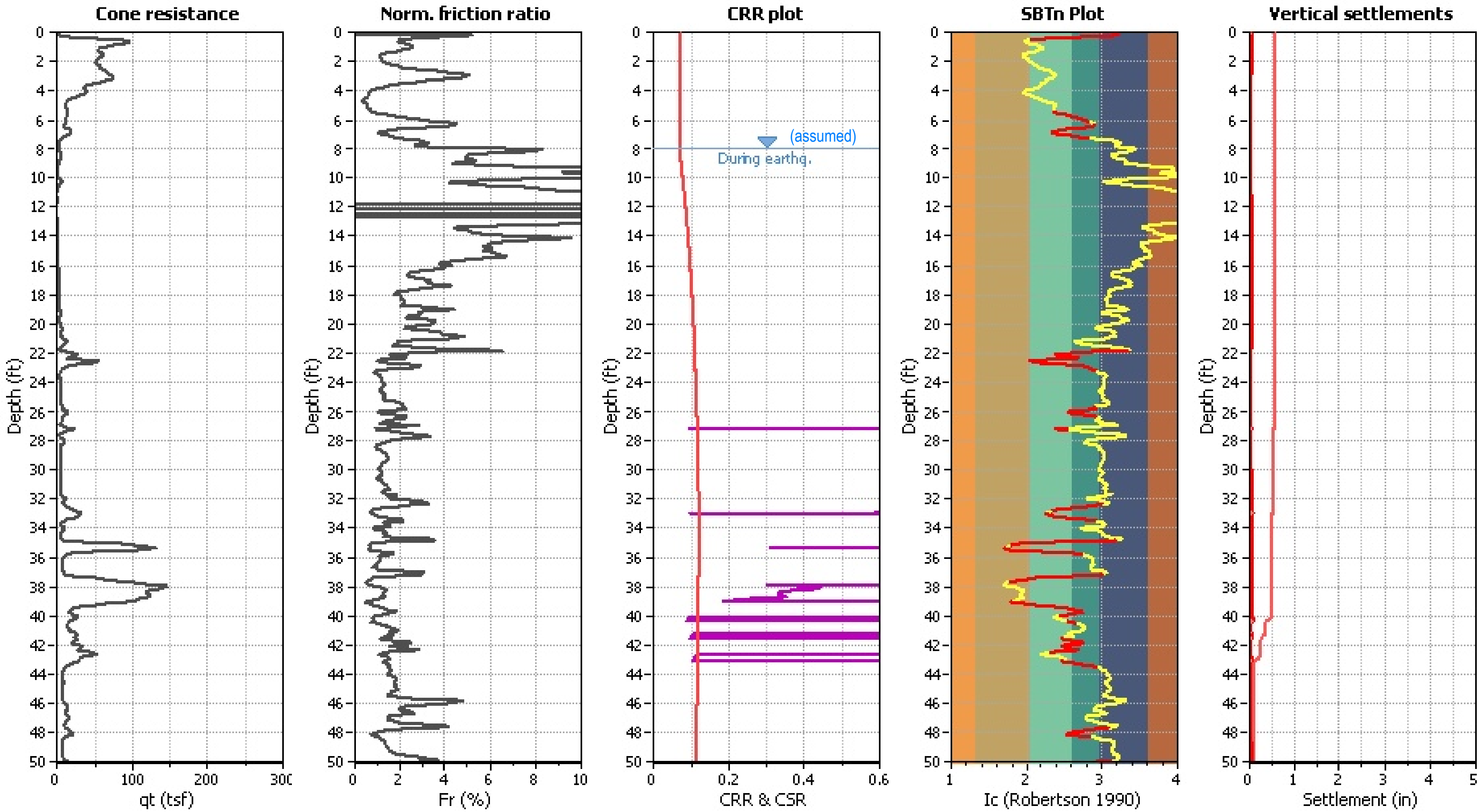
Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-31
Total depth: 124.54 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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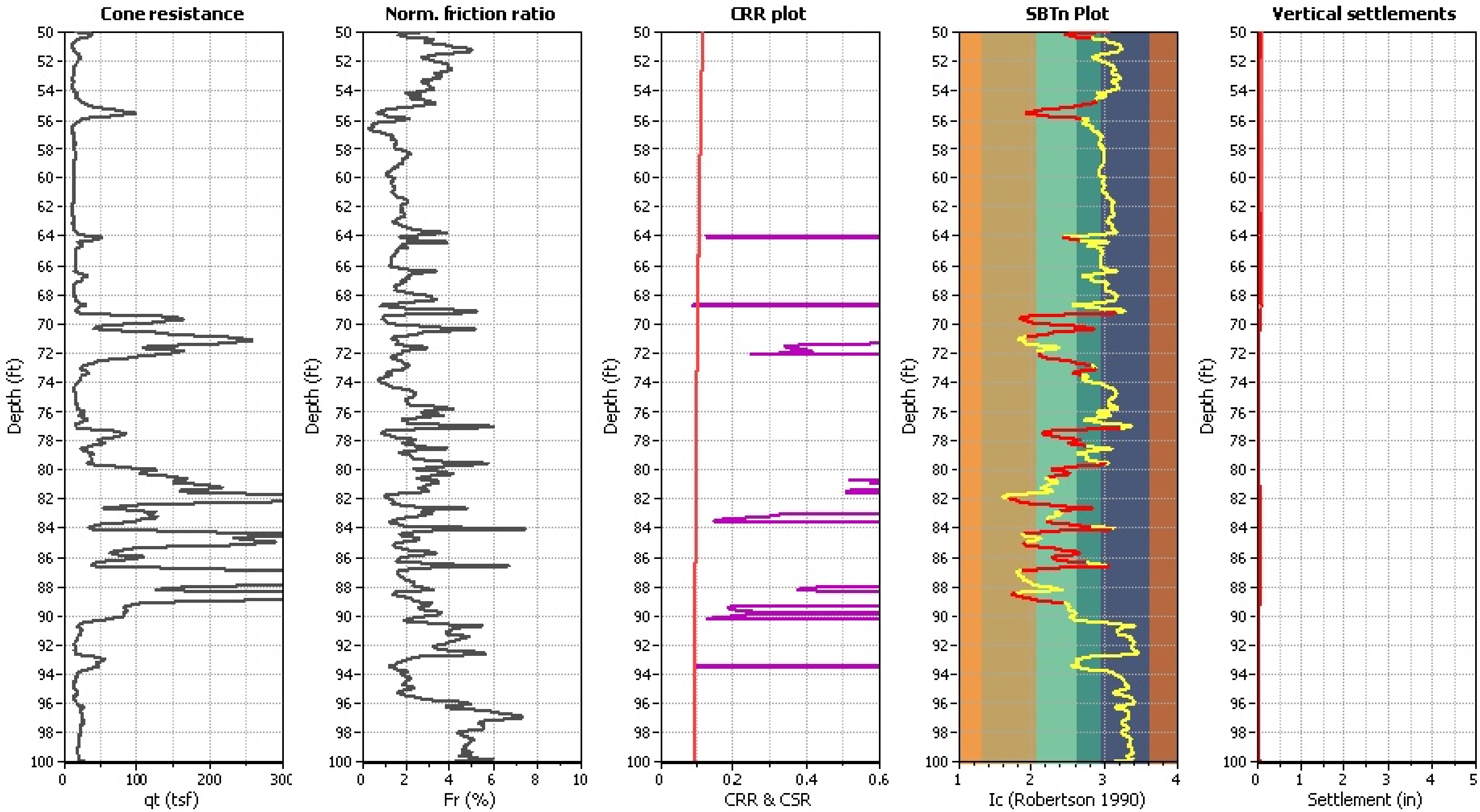
801.566.6399

Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-31
Total depth: 124.54 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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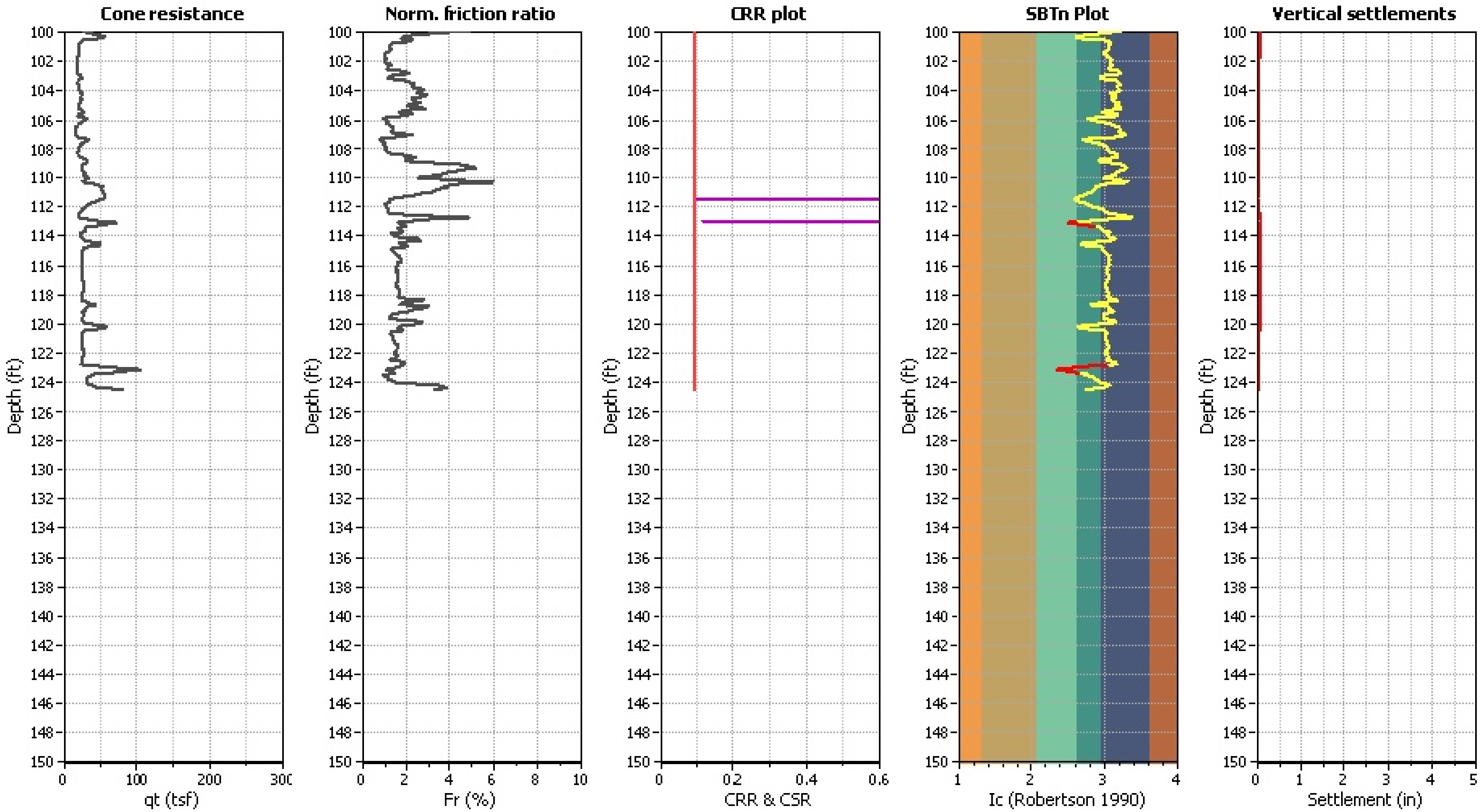
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-31
Total depth: 124.54 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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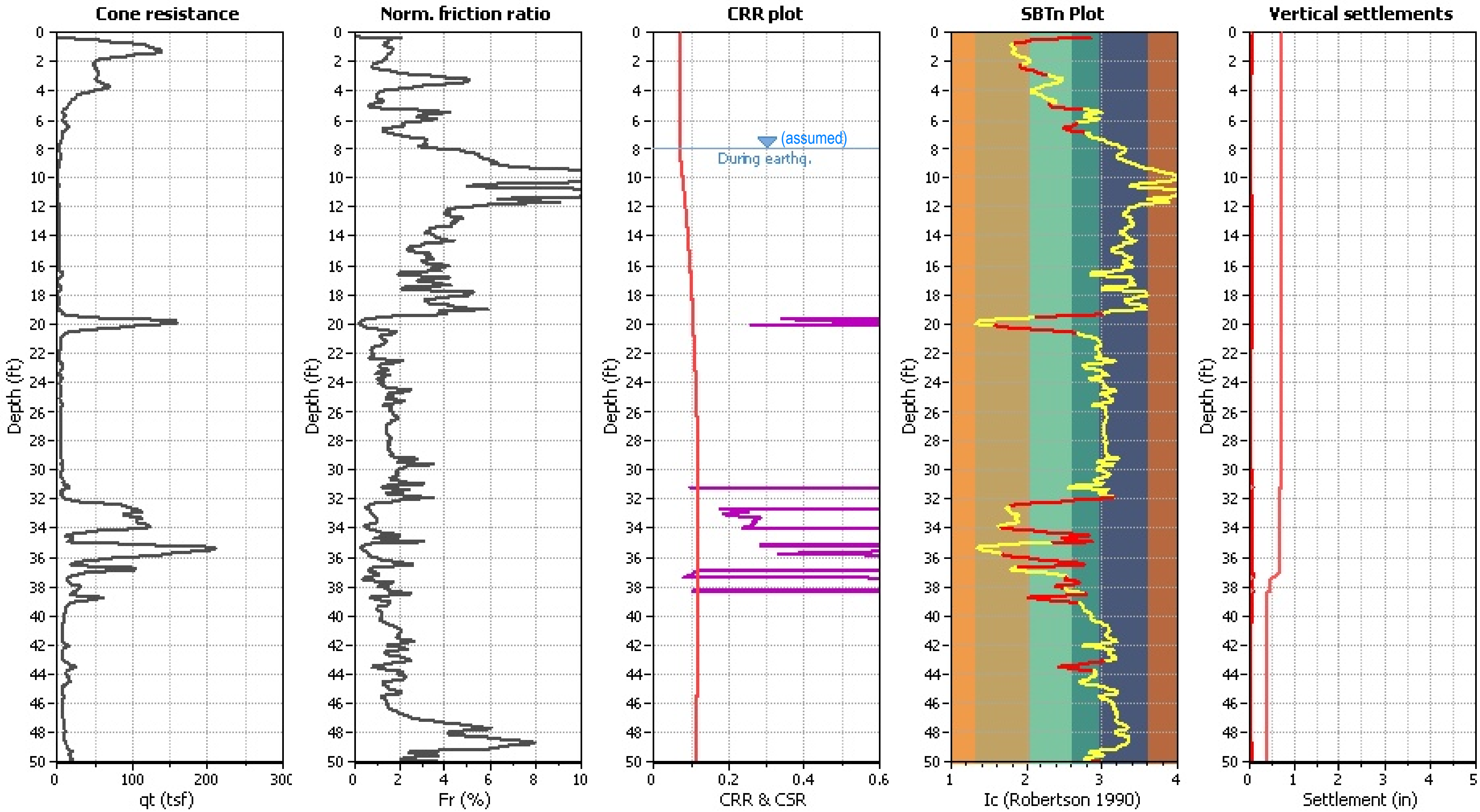
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-32
Total depth: 249.08 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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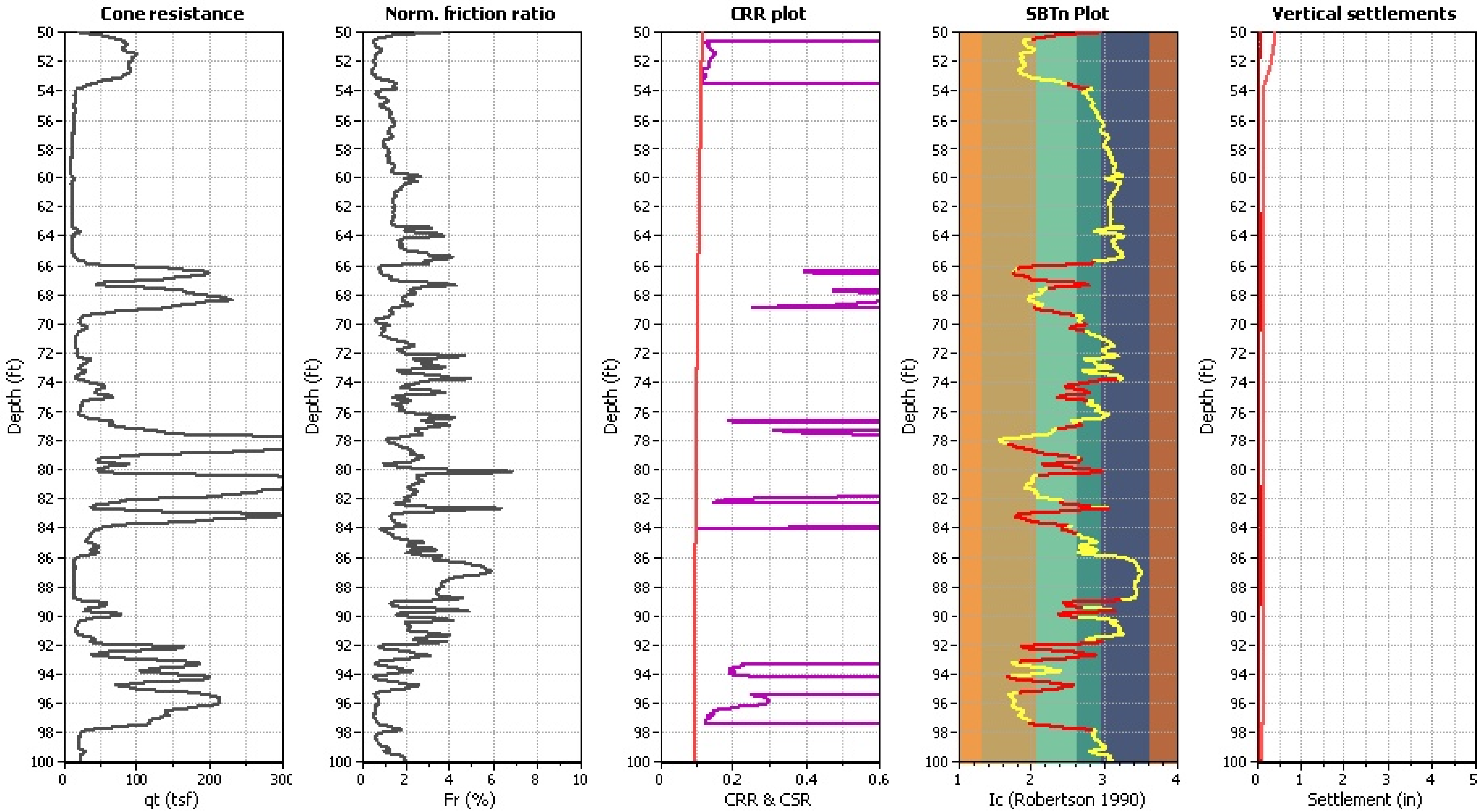
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-32
Total depth: 249.08 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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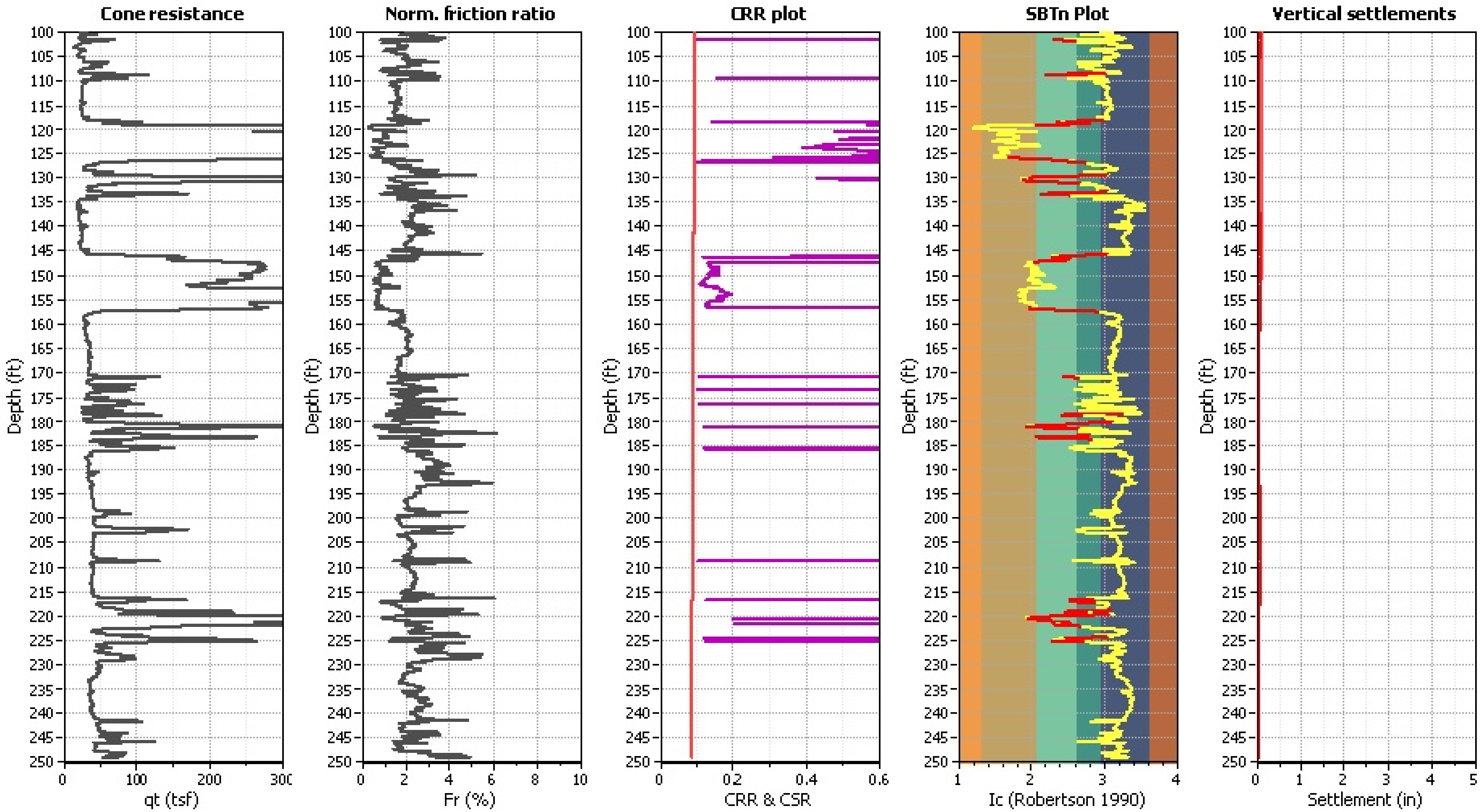
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-32
Total depth: 249.08 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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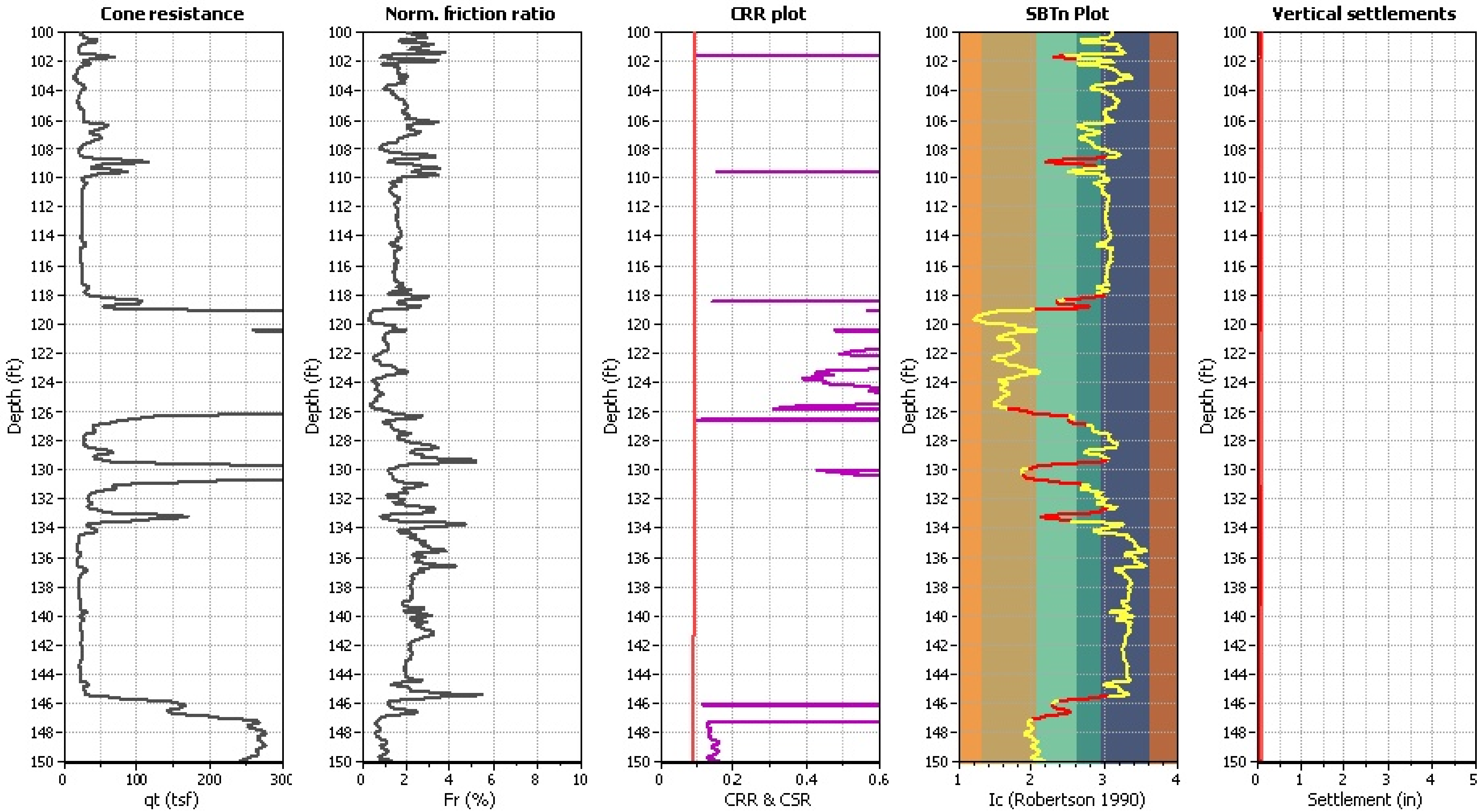
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: 1160276 - Clean Harbors
Location: see Figure 1

CPT: L-32
Total depth: 249.08 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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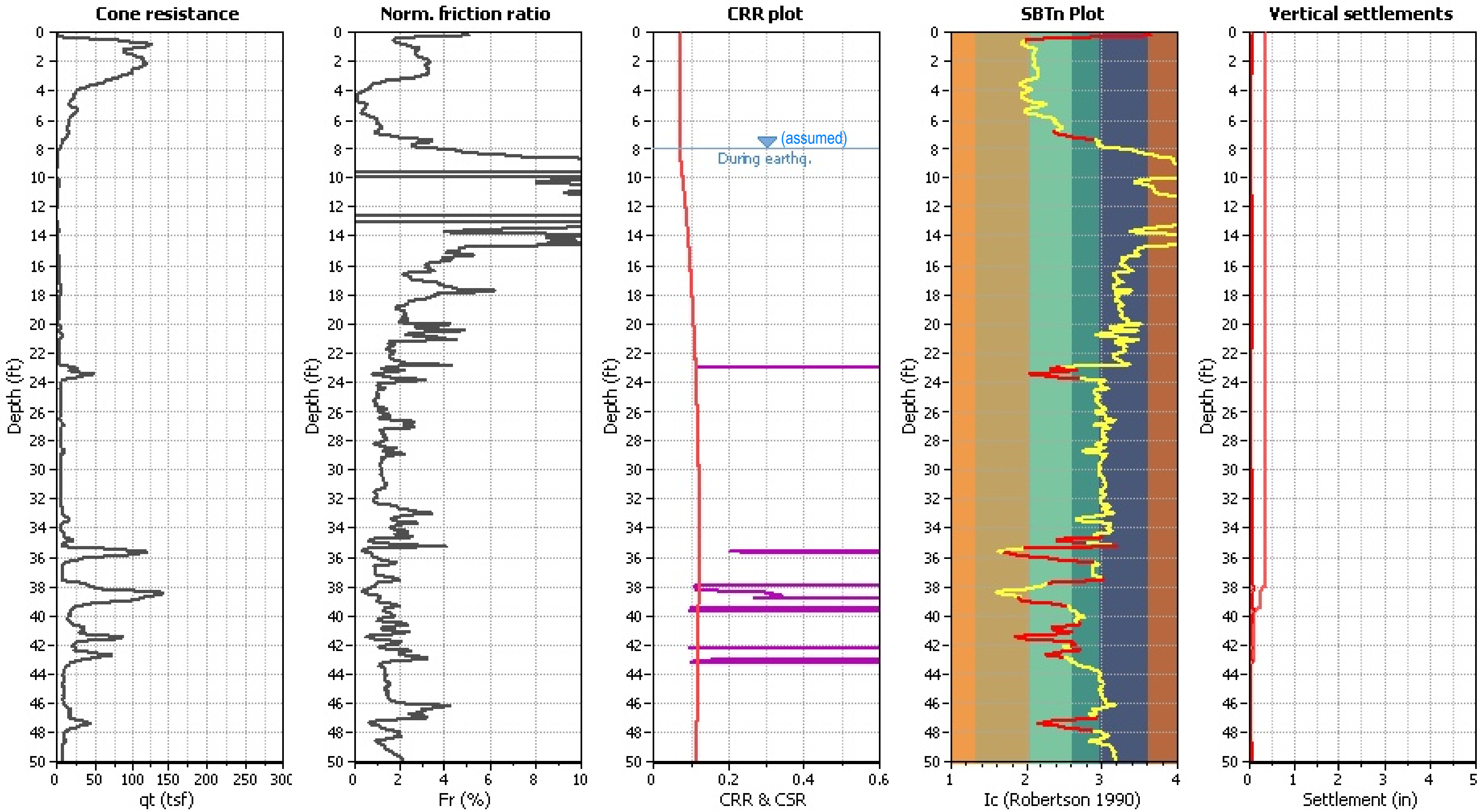
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-33
Total depth: 122.11 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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600 W. Sandy Parkway
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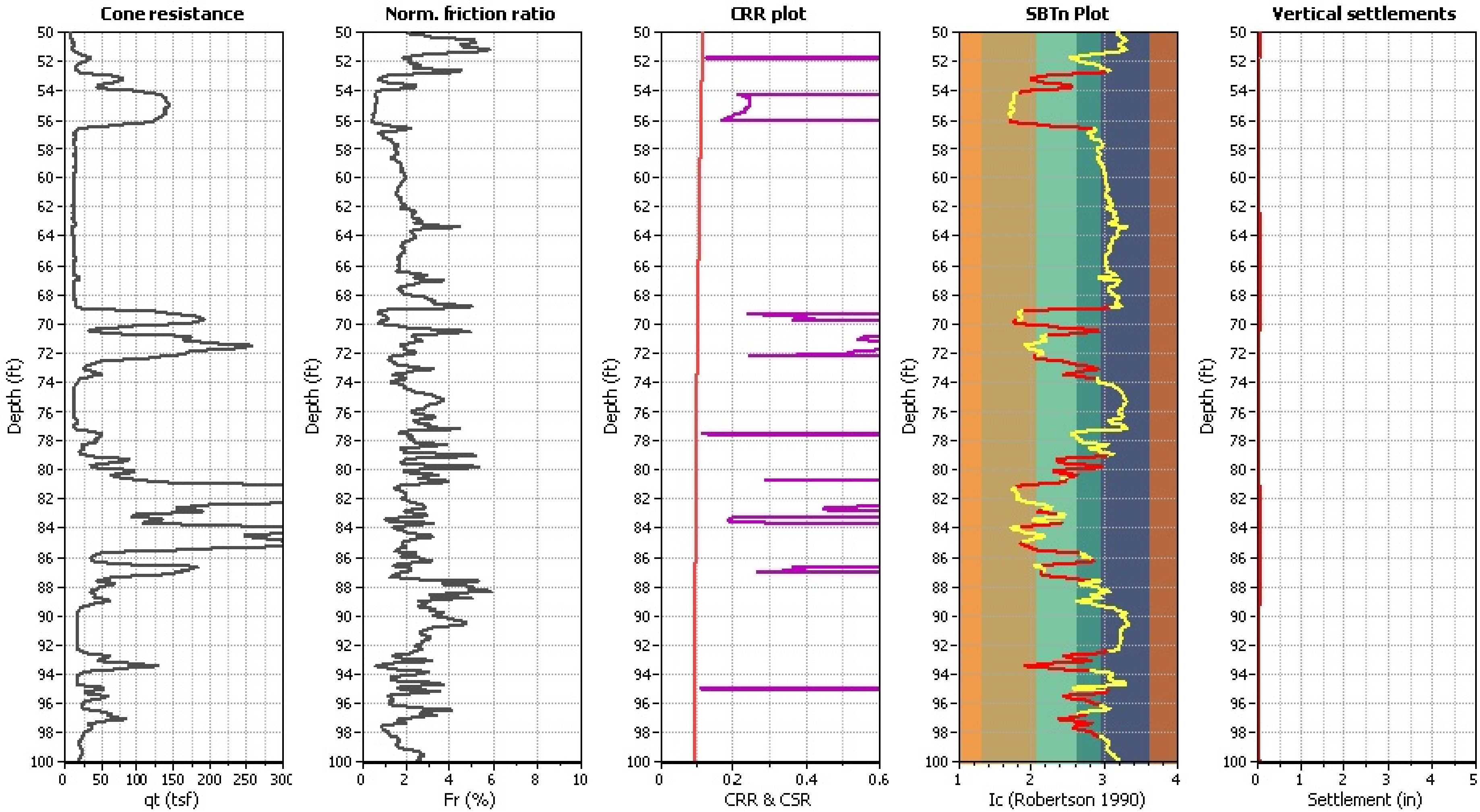
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-33
Total depth: 122.11 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

AGEC Applied GeoTech

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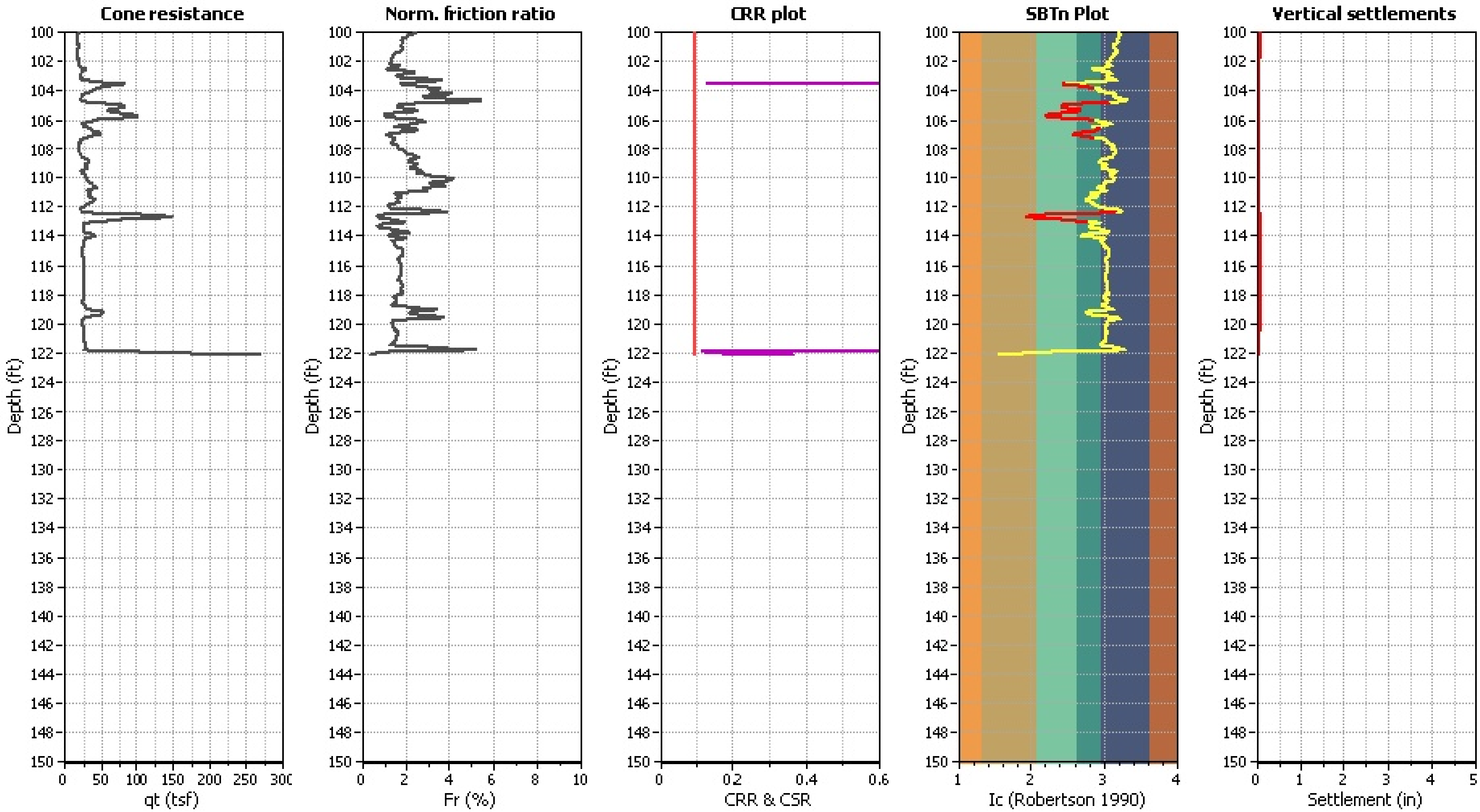
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-33
Total depth: 122.11 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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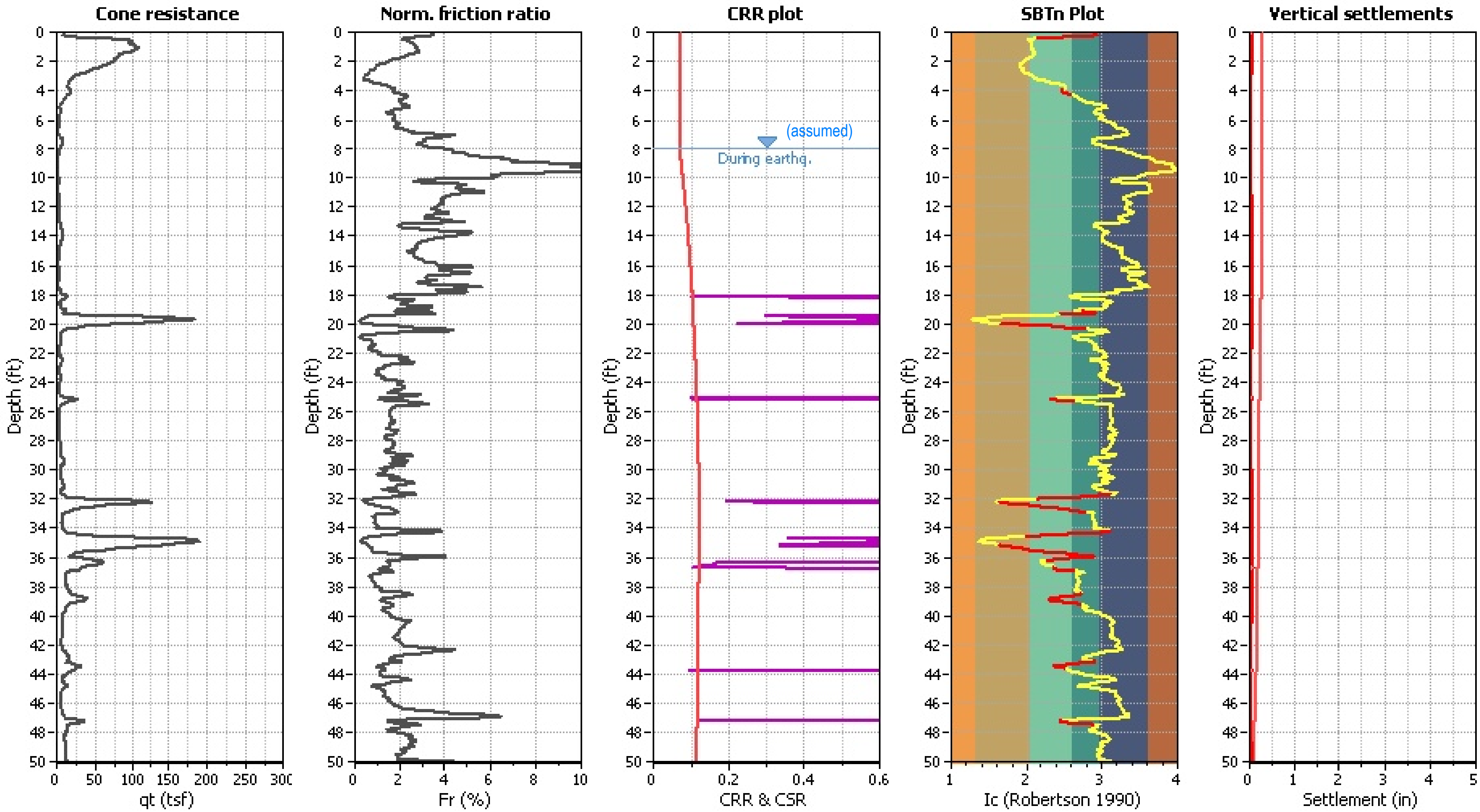
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-34
Total depth: 118.05 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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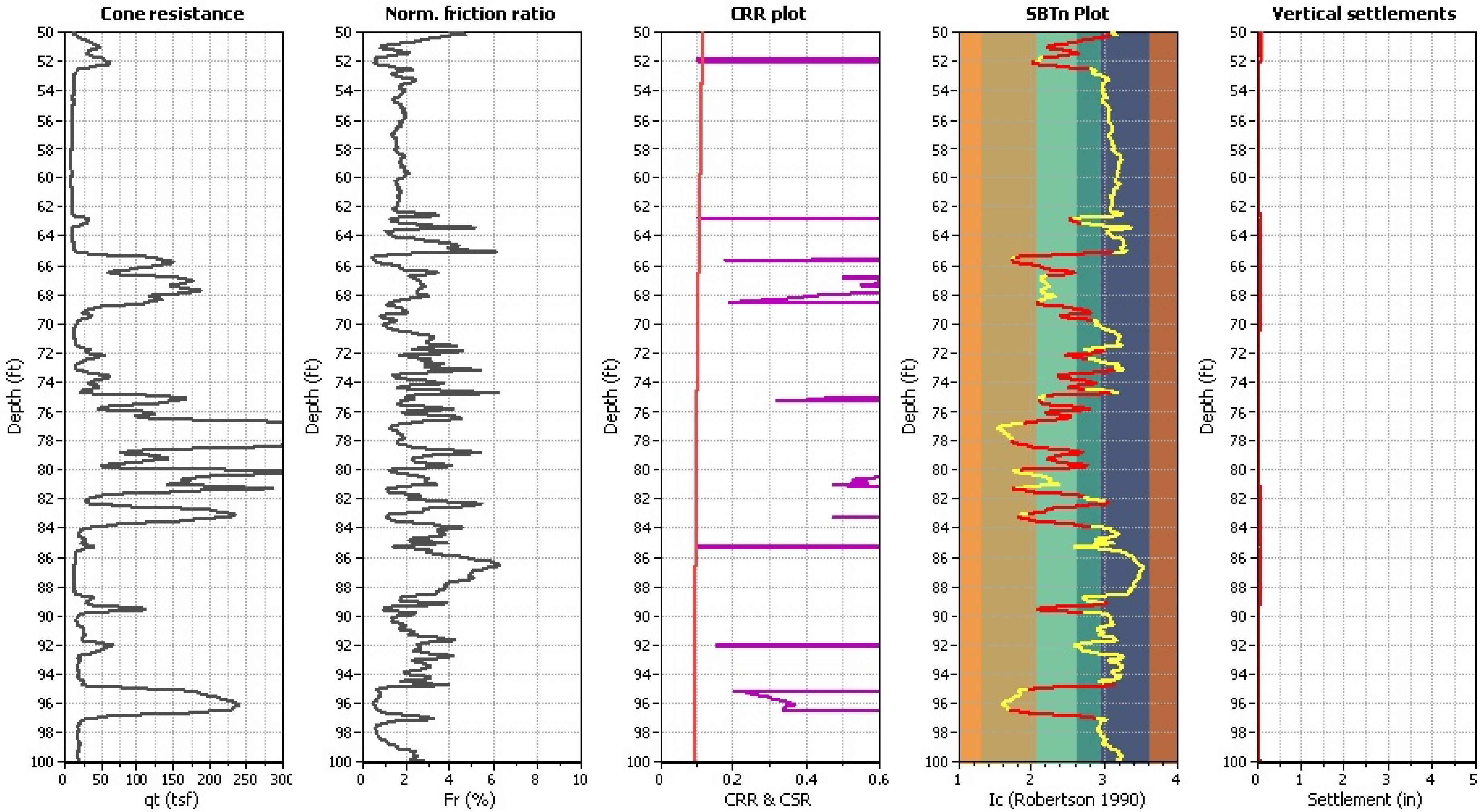
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-34
Total depth: 118.05 ft



Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

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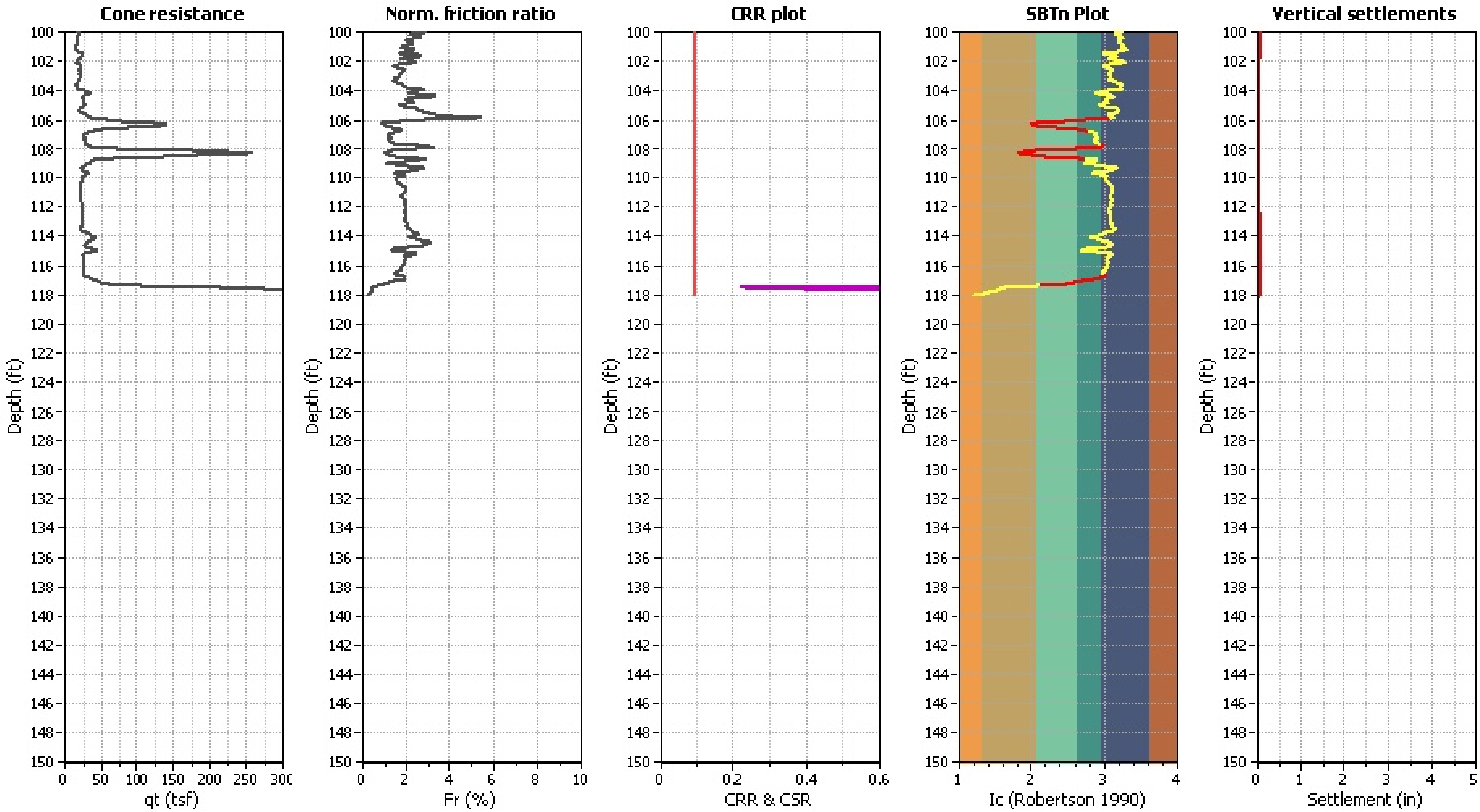
600 W. Sandy Parkway
Sandy, UT 84070
801.566.6399

Project: **1160276 - Clean Harbors**
Location: **see Figure 1**

CPT: L-34
Total depth: 118.05 ft



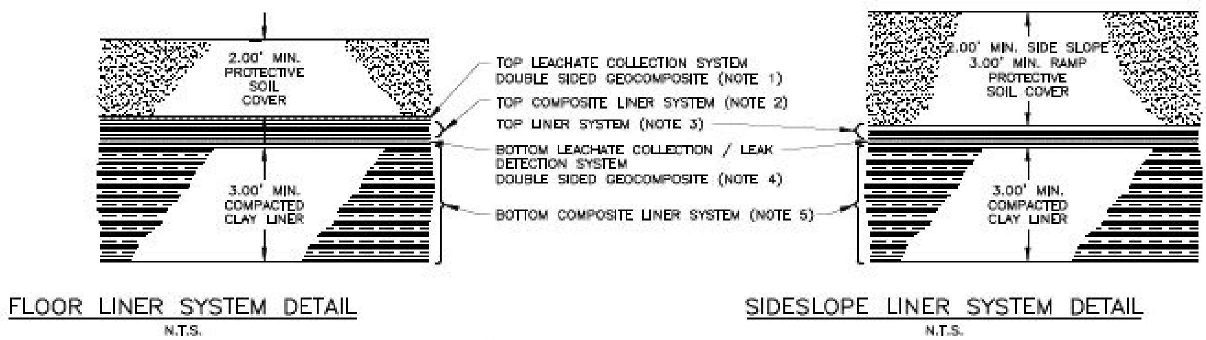
Analysis method:	NCEER (1998)	G.W.T. (in-situ):	8.00 ft	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	NCEER (1998)	G.W.T. (earthq.):	8.00 ft	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	6.20	Ic cut-off value:	2.60	Trans. detect. applied:	Yes	MSF method:	Method based
Peak ground acceleration:	0.18	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

APPENDIX C

Liner System Calculations

I. Lining System Configurations and Geomembrane Properties

A. The figures below provide details of the lining systems, the leachate collection system, and the leak detection/leachate collection system for the landfill cells. The figure on the left provides details for the floor area and lower 10 feet of the side slopes. The figure on the right provides details for the rest of sideslope areas.



NOTES:

1. TOP LEACHATE COLLECTION SYSTEM CONSISTS OF DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   8 OZ. NON-WOVEN GEOTEXTILE / GEONET / 8 OZ. NON-WOVEN GEOTEXTILE } MIN. GEOCOMPOSITE TRANSMISSIVITY OF 6.0 X 10^{-4} M²/SEC, TYP.)
2. TOP COMPOSITE LINER SYSTEM ON THE FLOOR AND TO A DISTANCE OF 10 FEET UP THE INTERIOR SLOPES CONSISTS OF:
   80-MIL HDPE GEOMEMBRANE (TEXTURED)
   GEOSYNTHETIC CLAY LINER (GCL)
   80-MIL HDPE GEOMEMBRANE (TEXTURED)
3. TOP LINER SYSTEM ON THE INTERIOR SIDESLOPES FROM A DISTANCE OF 10 FEET UP THE SLOPES TO THE ANCHOR TRENCH AT THE TOP OF THE SLOPES CONSISTS OF:
   80-MIL HDPE GEOMEMBRANE (TEXTURED)
   GEOSYNTHETIC CLAY LINER (GCL)
4. BOTTOM LEACHATE COLLECTION / LEAK DETECTION SYSTEM CONSISTS OF DOUBLE SIDED GEOCOMPOSITE AS FOLLOWS:
   8 OZ. NON-WOVEN GEOTEXTILE / GEONET / 8 OZ. NON-WOVEN GEOTEXTILE } MIN. GEOCOMPOSITE TRANSMISSIVITY OF 2.7 X 10^{-4} M²/SEC, TYP.)
5. BOTTOM COMPOSITE LINER SYSTEM CONSISTS OF:
   60-MIL HDPE GEOMEMBRANE (TEXTURED)
   COMPACTED CLAY LINER (CCL)

B. Typical properties of 60 mil and 80 mil HDPE geomembranes from three representative suppliers are tabulated below. The most conservative values are in bold and will be used for calculation purposes.

Property	Test Method	60 Mil		80 Mil	
		Smooth	Texture	Smooth	Texture
Poly-Flex					
Minimum Thickness (mils)	ASTM D 5199	**54**	**51**	**72**	**68**
Tensile Strength at Break (lbs/inch of width)	ASTM D 6693	***228***	***90***	***304***	***120***
Yield Strength (lbs/inch of width)	ASTM D 6693	***126***	***126***	***168***	***168***
Elongation at Break (percent)	ASTM D 6693	**700**	**100**	**100**	**700**
Elongation at yield (percent)	ASTM D 6693	***12***	***12***	***12***	***12***
GSE					
Minimum Thickness (mils)	ASTM D 5199	54	54	72	72
Tensile Strength at Break (lbs/inch of width)	ASTM D 6693	243	115	327	155
Yield Strength at Break (lbs/inch of width)	ASTM D 6693	132	132	177	177
Elongation at Break (percent)	ASTM D 6693	800	200	800	200

Property	Test Method	60 Mil		80 Mil	
		Smooth	Texture	Smooth	Texture
Elongation at yield (percent)	ASTM D 6693	13	13	13	13
AGRU (Texture is assumed as MicroSpike)					
Minimum Thickness (mils)	ASTM D 5199	54	51	72	68
Tensile Strength at Break (lbs/inch of width)	ASTM D 6693	240	132	320	176
Yield Strength at Break (lbs/inch of width)	ASTM D 6693	132	132	176	176
Elongation at Break (percent)	ASTM D 6693	700	350	700	350
Elongation at yield (percent)	ASTM D 6693	13	13	13	13

C. Overburden Loading On the Lining Materials from a Completed and Closed Cell

Upon closure of the landfills the top of the closure caps are designed to be at elevation 4306. The floor directly below the high point on the closure cap is at elevation 4254.07 for a total height of cover above the lining materials of about 52 feet (use 53 feet for calculations purposes). The following provides the materials, their densities, and their thicknesses used to estimate the overburden loading on the lining materials.

Description	Density (lbs/ft^3)	Height (ft)	Loading (lbs/ft^2)
Protective Soil Cover	125	2.0	250
Waste	120	48.17	5,780
Soil Layer	125	0.5	63
Protective Cover	125	2.0	250
Stone Mulch	110	0.33	37
Total Overburden Loading			**6,380**

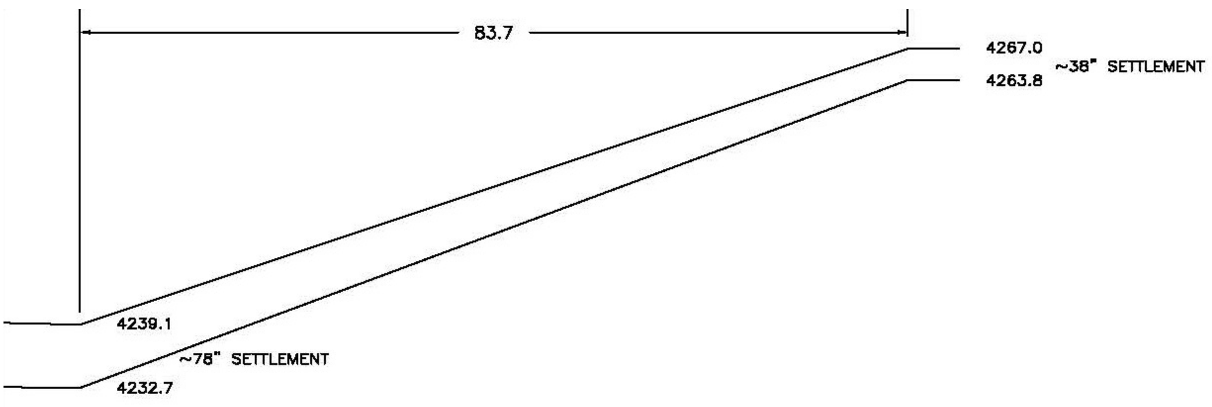
II. Gap Analysis

The small gap (~0.5-inch) formed between the ribs in the geonet has formed the basis for completing a gap analysis on previous landfill projects at the Grassy Mountain Facility. Previous project designs placed bottom lining system directly over compacted clay liner which provided a continuous support system to the bottom geomembrane. However, the other lining systems were placed directly over leachate systems comprised of geonet materials and were exposed to the gaps between the geonet ribs. The methodology used to evaluate the ability of the geomembrane materials to bridge the gap in the geonet was presented in a paper entitled "Design of Geotextiles Associated with Geomembranes" by J. P. Giroud, which is presented in a publication entitled, "Geotextiles and Geomembranes Definitions, Properties and Design Selected Papers, Revisions and Comments, Third Edition, Industrial Fabrics Association International, 1985, St. Paul, Minnesota. On all previous projects, each gap analysis completed showed the geomembrane materials to have sufficient strength properties to bridge the gap in the underlying geonet under the loading conditions anticipated within the landfill cells.

Design conditions within Landfill Cells 8 through 13 provide a continuous support system to the geomembrane materials at all levels rather than directly bridging the gap in the geonet materials. The bottom lining system is provided with continuous support from the underlying compacted clay liner. The bottom geomembrane in the top lining system is provided with continuous support from the non-woven geotextile that provides the upper and lower boundaries to the double sided geocomposite, and the upper geomembrane in the top lining system is provided continuous support from the GCL. Therefore, no significant gaps are expected to be bridged by the geomembrane materials.

III. Settlement Analysis

As the cell is filled, and settlement occurs, the geomembrane will be forced to elongate. The figure below represents the approximate differential settlement the liner systems may experience based on settlement projection profiles included in the geotechnical investigation report from Applied Geotechnical Engineering Consultants. The settlement profiles indicate the settlement at the top of the east embankment of Cell 10 embankments to be on the order of 38 inches and approximately 78 inches at the toe of the embankment slope between construction and final closure.



$$Slope\ Length\ Before\ Settlement = \sqrt{83.7^2 + (67 - 39.1)^2} = 88.2\ ft$$

$$Slope\ Length\ After\ Settlement = \sqrt{83.7^2 + (63.8 - 32.7)^2} = 89.3\ ft$$

$$Percent\ Elongation = \frac{(89.3 - 88.2)}{88.2} = 1.24\ percent$$

$$SF_{settlement} = \frac{Elongation\ at\ Yield}{Calculated\ Elongation}$$

Gundle Lining Systems (currently GSE) conducted laboratory tests (Laboratory Report #443) that show elongation at yield decreases with decreasing temperature. The lab report indicate this decrease for the HDPE geomembrane tested to be from 15% at 20°C (68°F) to 6.7% at -50°C (-58°F), a 55% decrease. Assuming a temperature extreme of -50oC during the settlement process would result in a safety factor of 5.4 against exceeding the elongation at yield for the HDPE geomembrane materials.

$$At\ -50^oC\ \ SF_{settlement} = \frac{6.7}{1.24} = 5.4\ \boldsymbol{OK}$$

IV. Loading during installation of 2-foot Soil Protective Cover and during cell operation.

In order to protect the synthetic geomembrane and leachate collection systems from stress due to uneven loadings from installation and operational machinery, the bearing capacity of the underlying clay or soil must not be exceeded. As long as the foundation for the synthetic geomembrane remains firm and does not fail, then differential stresses on the geomembrane, other than settlement already discussed, should not occur that could damage the geomembrane.

Assumed possible loading to be checked are:

A. HS-20 Truck Loading
B. Standard Caterpillar Track-Type Loader with 3.25 cy bucket
C. Caterpillar 977L Track-Type Loader with 5.0 cy bucket
D. Standard Caterpillar D6D Track-Type Dozer
E. Caterpillar 824C Wheel-Type Dozer Tractor (40 psi)
F. Caterpillar 966C Wheel Loader with 3.25 cy bucket (40 psi)
G. Caterpillar 14G Motor Grader
H. Caterpillar 235 Excavator/Backhoe

Bearing capacity values for the clay liner material under the primary and secondary HDPE geomembranes, as provided by Applied Geotechnical Engineering Consultants, are:

Ultimate Clay Bearing Capacity	4,500 lbs/ft^2
Allowable Clay Bearing Capacity (with safety factor of 3.0)	1,500 lbs/ft^2
Allowable Clay Bearing Capacity with Impact Loading	2,000 lbs/ft^2
Load Distribution through Soil Protective Cover	0.5 H : 1.0 V
Soil Protective Cover Density	125 lbs/ft^3

The bearing capacity of the soil protective cover can be determined from the following equation which assumes a Safety Factor of 3.

$$Allowable\ Bearing\ Capacity = (250\ x\ width\ of\ load) + (600\ x\ depth\ of\ soil)$$

The above equation is valid for a single track, or dual tire.

The Allowable Bearing Capacity due Impact Loading, is obtained by multiplying the above value by 1.5. The Factor of Safety against failure is reduced to 2.0.

A. HS-20 TRUCK LOADING

HS-20 Truck Loading gives:

$$Single\ Axle\ trucks:\ 32{,}000\ \frac{lbs}{axle}\ or\ 16{,}000\ \frac{lbs}{dual}$$
$$Alternate\ Loading\ for\ Double\ Axle\ trucks:\ 24{,}000\ \frac{lbs}{axle}\ or\ 12{,}000\ \frac{lbs}{dual}$$

1. Evaluate Single Axle Truck Loading above Clay = 32,000 lbs/axle or 16,000 lbs/dual

Assume 30" of soil cover required above the geomembrane so that the bearing capacity of the clay is not exceeded. Assuming a tire pressure of 90 psi, which is believed to be conservative for truck tires, the area over which the load is spread at the surface of the soil cover equals:

$$\frac{16{,}000\ lbs}{90\ psi} = 178\ in^2$$

The contact area for the truck tires approximates a rectangular area with the length approximately 40 percent greater than the width. Therefore the width equals:

$$\sqrt{\frac{178}{1.4}} = 11.28\ in$$

And the resulting length of the load equals:

$$1.4(11.28) = 15.79\ in$$

The area over which the load is distributed on the clay assuming a load distribution 0.5H to 1.0 V, and a soil protective cover thickness of 30 inches is:

$$Length = (30\ in)(0.5)(2\ directions) + 15.79\ in = 45.79\ in$$

$$Width = (30\ in)(0.5)(2\ directions) + 11.28\ in = 41.28\ in$$

$$Area\ of\ load\ applied = (45.79\ in)(41.28\ in) = 1{,}890\ in^2 = 13.13\ ft^2$$

$$Bearing\ Pressure\ on\ Clay\ from\ Applied\ Loading = \frac{applied\ truck\ load + soil\ load}{Area}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Applied\ Loading = \frac{16{,}000\ lbs + \left(\frac{30}{12}\right)(125)(13.13)}{13.13}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Applied\ Loading = 1{,}531\frac{lbs}{ft^2} \approx 1{,}500\frac{lbs}{ft^2}\ \ \boldsymbol{OK}$$

$$Actual\ Safety\ Factor\ from\ Applied\ Loading = \frac{4{,}500}{1{,}531} = 2.94\ \boldsymbol{OK}$$

The impact loading factor to be applied is 1.2, supplied by the American Association of State Highway and Transportation Officials in "Standard Specifications for Highway Bridges," Edition 12. Therefore, Bearing Pressure on the clay due to impact loading:

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = \frac{1.2(16{,}000\ lbs) + \left(\frac{30}{12}\right)(125)(13.13)}{13.13}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = 1{,}775\ \frac{lbs}{ft^2}$$

Since 1,775 lbs/ft^2 < 2,000 lbs/ft^2, the 30 inch soil protective layer is adequate for the clay under the primary geomembrane.

2. Evaluate Double Axle Truck Loading above Clay = 24,000 lbs/axle or 12,000 lbs/dual

Assume 24" of soil cover required above the geomembrane so that the bearing capacity of the clay is not exceeded. Assuming a tire pressure of 90 psi, which is believed to be conservative for truck tires, the area over which the load is spread at the surface of the soil cover equals:

$$\frac{12{,}000\ lbs}{90\ psi} = 133\ in^2$$

The contact area for the truck tires approximates a rectangular area with the length approximately 40 percent greater than the width. Therefore the width equals:

$$\sqrt{\frac{133}{1.4}} = 9.75\ in$$

And the resulting length of the load equals:

$$1.4(9.75) = 13.65\ in$$

The area over which the load is distributed on the clay assuming a load distribution 0.5H to 1.0 V, and a soil protective cover thickness of 30 inches is:

$$Length = (24\ in)(0.5)(2\ directions) + 13.65\ in = 37.65\ in$$

$$Width = (24\ in)(0.5)(2\ directions) + 9.75\ in = 33.75\ in$$

$$Area\ of\ load\ applied = (37.65\ in)(33.75\ in) = 1{,}271\ in^2 = 8.82\ ft^2$$

$$Bearing\ Pressure\ on\ Clay\ from\ Applied\ Loading = \frac{applied\ truck\ load + soil\ load}{Area}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Applied\ Loading = \frac{12{,}000\ lbs + \left(\frac{24}{12}\right)(125)(8.82)}{8.82}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Applied\ Loading = 1{,}610\frac{lbs}{ft^2} \approx 1{,}500\frac{lbs}{ft^2}\ \boldsymbol{OK}$$

$$Actual\ Safety\ Factor\ from\ Applied\ Loading = \frac{4{,}500}{1{,}610} = 2.80\ \boldsymbol{OK}$$

The impact loading factor to be applied is 1.2, supplied by the American Association of State Highway and Transportation Officials in "Standard Specifications for Highway Bridges," Edition 12. Therefore Bearing Pressure on the clay due to impact loading:

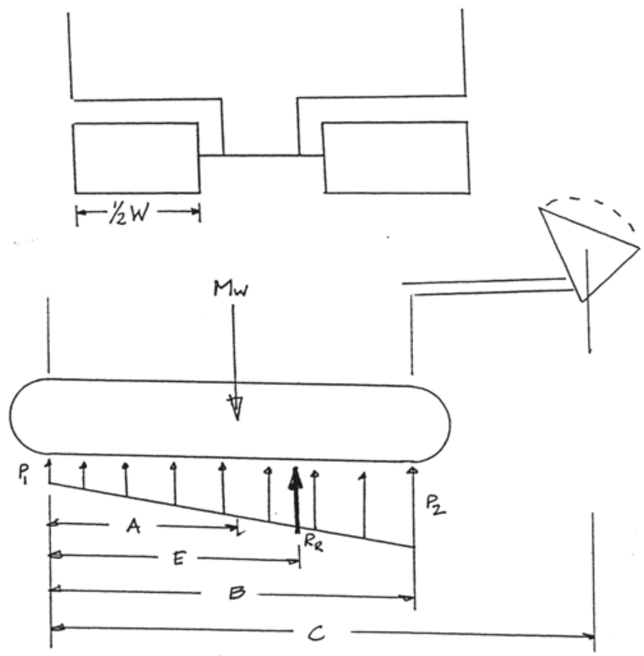
$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = \frac{1.2(12{,}000\ lbs) + \left(\frac{24}{12}\right)(125)(8.82)}{8.82}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = 1{,}883\ \frac{lbs}{ft^2}$$

Since 1,883 lbs/ft^2 < 2,000 lbs/ft^2, the 24 inch soil protective layer is adequate for the clay under the primary geomembrane.

B. Caterpillar 977L with 3.25 cy bucket

All of the following calculations are based on information obtained from Caterpillar Machinery. The older machinery is assumed to be worse case due to the motor being located at the front section rather than the rear, as in the case of the newer equipment.



A = Distance from back drive to empty machine center of gravity with the bucket extended to its furthest horizontal distance
B = Distance between sprockets - Wheel base
C = Distance from back drive to load center of gravity
D = Track Width
R_r = Resultant reaction from the pressure distribution
P_1 = Pressure on minimum side of pressure distribution
P_2 = Pressure on maximum side of pressure distribution
M_w = Machine operating weight with an empty bucket
L_w = Load weight in bucket
E = Distance of R_r from rear drive

The standard dimension to be used for the Caterpillar 977L with the 3.25 cy bucket are:

$A = 57.48\ in$ $\qquad M_w = 49{,}380\ lbs$

$B = 111.1\ in$ $\qquad \frac{1}{2}W = 18\ in$

$C = 185.02\ in$ $\qquad \Upsilon = 125\ \frac{lbs}{ft^3} = 3{,}375\ \frac{lbs}{yd^3}$

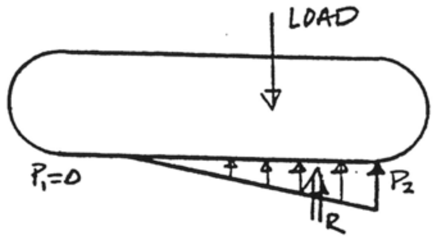
$$L_w = 3.25(3{,}375) = 10{,}969\ lbs$$
$$R_r = 49{,}380 + 10{,}969 = 60{,}349\ lbs$$

$$\sum M_n = 0 = 60{,}349(E) - 10{,}969(185.02) - 49{,}380(57.48)$$

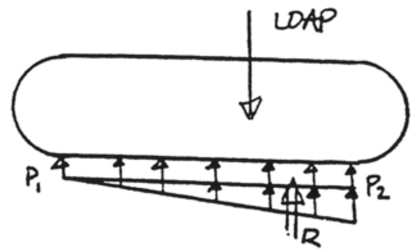
$$Solving\ for\ E\ gives: E = 80.66\ in = 6.72\ ft$$

$If\ (B-E)(3) \leq B$, then the loading placed on the soil under the track is triangular as shown below (left) with $P_1 = 0$.

$If\ (B-E)(3) > B$, then the loading is a triangular distribution superimposed on a rectangular distribution as shown below at the right.



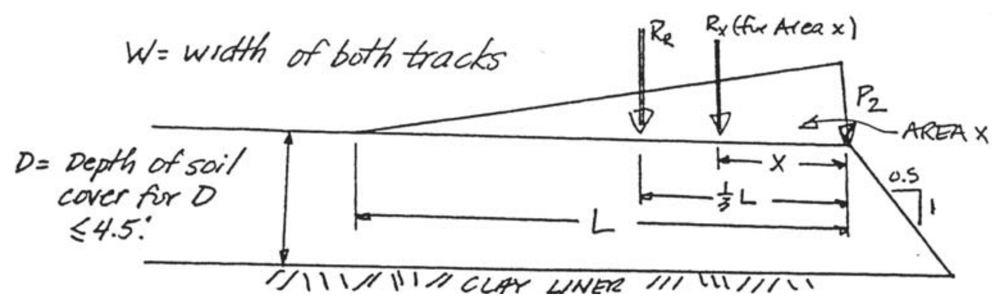
$(B-E)(3) \leq B$



$(B-E)(3) > B$

$(B-E)(3) = (111.1 - 80.66)(3) = 91.32 \leq 111.11$ therefore the loading distribution is triangular as shown above (left).

The worst case load distributed through the soil layer to the clay is not obtained by assuming the entire triangular distribution acting over the applicable area of the track is transferred to the clay surface. Obviously, from the triangular distribution, the larger loading occurs as P_2 is approached. For example, if only loading on the clay created by the pressure distribution right of R_r is compared with the loading on the clay from the pressure distribution left of R_r it can be shown that the loading created right of Rr is much greater than that created left of R_r. This is obvious due to the fact that the total load right of R_r is greater, but the area over which the maximum loading will occur can be derived mathematically as follows:



Note: R_x is assumed to distribute in 3 directions (the front and two sides) but not to the back since the back part of the pressure triangle would tend to counter R_x in the backward direction.

$$R_r = 0.5P_2LW \qquad \frac{P_x}{(L-X)} = \frac{P_2}{L}$$

$$P_2 = \frac{2R_r}{(LW)} \qquad P_x = \frac{P_S(L-X)}{L}$$

$$R_x = \frac{(P_2 + P_x)(W)(X)}{2}$$

$$R_x = 0.5\left(P_2 + \left(\frac{P_2(L-X)}{L}\right)\right)(W)(X) = 0.5P_2WX\left(1 + \frac{(L-X)}{L}\right)$$

$$R_x = 0.5P_2WX\left(2 - \frac{X}{L}\right)$$

Given that the bearing area from one track does not overlap the other track, the Bearing Area is as follows:

$$Area = 2\ tracks\left[(0.5D + X)\left(2D(0.5) + \left(\frac{W}{2}\right)\right)\right] = \left(\frac{D}{2} + X\right)(2D + W)$$

$$Area = D^2 + D\left(\frac{W}{2}\right) + X(2D + W)$$

$$Bearing\ on\ Clay = \frac{(R_x + Weight\ of\ Soil)}{Bearing\ Area} = \frac{\left(R_x + \Upsilon_s(Bearing\ Area)(Soil\ Depth)\right)}{Bearing\ Area}$$

$$Bearing\ on\ Clay = \frac{\left(0.5P_2WX\left(2 - \frac{X}{L}\right) + \Upsilon_s(D)\left(D^2 + D\left(\frac{W}{2}\right)\right) + X(2D + W)\right)}{\left(D^2 + D\left(\frac{W}{2}\right) + X(2D + W)\right)}$$

$$Bearing\ on\ Clay = \frac{\left(0.5P_2WX\left(2 - \frac{X}{L}\right)\right)}{\left((2D + W)\left(\frac{D}{2} + X\right)\right)} + \Upsilon_sD$$

To derive the maximum, take the derivative of the bearing with respect to x, and set the equation equal to zero and solve.

$$\frac{d}{dx}\left(\frac{u}{v}\right) = \frac{\left(V\left(\frac{du}{dx}\right) - U\left(\frac{dv}{dx}\right)\right)}{V^2}$$

$$\frac{du}{dx} = \frac{P_2WX}{2}\left(-\frac{1}{L}\right) + \left(2 - \frac{X}{L}\right)\left(\frac{P_2W}{2}\right) = \frac{P_2WX}{2L} + \left(\frac{P_2WX}{2L}\right) = (P_2W) - \frac{P_2WX}{L} = (P_2W)\left(1 - \frac{X}{L}\right)$$

$$\frac{du}{dx} = (2D) + W$$

$$\frac{\Upsilon bearing}{\Upsilon x} = \frac{(2D + W)\left(\frac{D}{2} + X\right)\left[P_2W\left(1 + \frac{X}{L}\right)\right] - \left(\frac{P_2WX}{2}\right)\left(2 - \frac{X}{L}\right)(2D + W)}{\left[(2D + W)\left(\frac{D}{2} + X\right)\right]^2}$$

Reducing the equation leads to:

$$0 = x^2 + DX - DL$$

From the quadratic equation $ax^2 + bx + c = 0$, where

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

By substituting the correct values into the equation gives the formula for maximum loading:

$$x = \frac{-D \pm \sqrt{D^2 - 4(1)(-DL)}}{2(1)} = \frac{-D \pm \sqrt{D^2 + 4DL}}{2}$$

1. Check maximum loading for Caterpillar 977L with standard bucket on clay base under primary geomembrane.

   Assume the depth of soil cover (D) equals 2 feet.

   $$L = (B - E)(3) = (111.1 - 80.66)(3) = 91.32\ in = 7.61\ ft$$
   $$W = (2)(18\ in) = 36\ in = 3\ ft$$

   $$x = \frac{-2 \pm \sqrt{2^2 + 4(2)(7.61)}}{2} = 3.03\ ft$$

   $$P_2 = \frac{2R_r}{LW} = \frac{2(60{,}349\ lbs)}{(7.61\ ft)(3\ ft)} = 5{,}287\ \frac{lbs}{ft^2}$$

   $$R_x = \frac{P_2WX}{2}\left(2 - \frac{X}{L}\right) = \frac{5{,}287(3)(3.03)}{2}\left(2 - \frac{3.03}{7.61}\right) = 38{,}491\ lbs$$

$$Bearing\ Area = D^2 + D\frac{W}{2} + X(2D + W) = 2^2 + 2\frac{3}{2} + 3.03[2(2) + 3] = 28.21\ ft^2$$

$$Bearing\ Pressure\ on\ Clay = \frac{R_x + \Upsilon_2(Bearing\ Area)(Soil\ Depth)}{Area}$$

$$Bearing\ Pressure\ on\ Clay = \frac{38{,}491 + 125(28.21)\left(\frac{12}{24}\right)}{28.21} = 1{,}614\ \frac{lbs}{ft^2} \approx 1{,}500\ \frac{lbs}{ft^2}\ \boldsymbol{OK}$$

$$Actual\ Safety\ Factor\ from\ Applied\ Loading = \frac{4{,}500}{1{,}614} = 2.79\ \boldsymbol{OK}$$

The impact loading factor to be applied is 1.2 (for 2 foot of cover), supplied by the American Association of State Highway and Transportation Officials in "Standard Specifications for Highway Bridges," Edition 12. Therefore Bearing Pressure on the clay due to impact loading:

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = \frac{1.2(38{,}491) + \left(\frac{24}{12}\right)(125)(28.21)}{28.21}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = 1{,}887\frac{lbs}{ft^2} < 2{,}000\ \frac{lbs}{ft^2}\ \boldsymbol{OK}$$

The 24 inch soil protective layer is adequate for the clay under the primary geomembrane for the 977L with the 3.25 cy bucket.

C. Caterpillar 977L with 5 cy bucket

Check Caterpillar 977L owned by Clean Harbors and used during operation of the cell with a non-standard 5 cy bucket. All dimensions are the same as the previous calculation, except that the bucket capacity is significantly larger than with the 3.25 cy bucket.

The standard dimension to be used for the Caterpillar 977L with the 5.0 cy bucket are:

$A = 57.48\ in$	$M_w = 49{,}380\ lbs$
$B = 111.1\ in$	$\frac{1}{2}W = 18\ in$
$C = 197.02\ in$	$\Upsilon = 125\ \frac{lbs}{ft^3} = 3375\ \frac{lbs}{yd^3}$

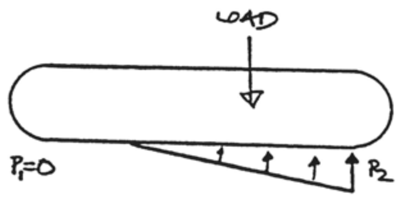
$L_w = 5(3{,}375) = 16{,}875\ lbs$
$R_r = 49{,}380 + 16{,}875 = 66{,}255\ lbs$

$$\sum M_n = 0 = 66{,}255(E) - 16{,}875(197.02) - 49{,}380(57.48)$$

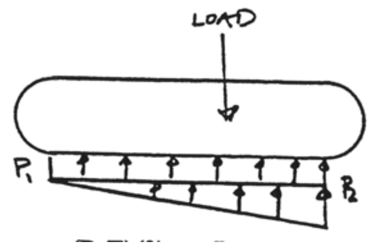
$Solving\ for\ E\ gives: E = 93.02\ in = 7.75\ ft$

$If\ (B - E)(3) \leq B$, then the loading placed on the soil under the track is triangular as shown below (left) with $P_1 = 0$.

$If\ (B - E)(3) > B$, then the loading is a triangular distribution superimposed on a rectangular distribution as shown below at the right..



$(B-E)(3) \leq B$



$(B-E)(3) > B$

$(B-E)(3) = (111.1 - 93.02)(3) = 54 < 111.11$, therefore the loading distribution is triangular as shown above (left).

Following the same worst case loading scheme as derived previously,

$$x = \frac{-D \pm \sqrt{D^2 + 4DL}}{2}$$

1. Assume the depth of soil cover (D) equals 3.5 feet.

$$L = (B-E)(3) = 54\ in = 4.5\ ft$$
$$W = (2)(18\ in) = 36\ in = 3\ ft$$

$$x = \frac{-3.5 \pm \sqrt{3.5^2 + 4(3.5)(4.5)}}{2} = 2.59\ ft$$

$$P_2 = \frac{2R_r}{LW} = \frac{2(66{,}255\ lbs)}{(4.5\ ft)(3\ ft)} = 9{,}816\ \frac{lbs}{ft^2}$$

$$R_x = \frac{P_2 W X}{2}\left(2 - \frac{X}{L}\right) = \frac{9{,}816(3)(2.59)}{2}\left(2 - \frac{2.59}{4.5}\right) = 54{,}321\ lbs$$

$$Bearing\ Area = D^2 + D\frac{W}{2} + X(2D + W) = 3.5^2 + 3.5\frac{3}{2} + 2.59[2(3.5) + 3] = 43.4\ ft^2$$

$$Bearing\ Pressure\ on\ Clay = \frac{R_x + \Upsilon_2(Bearing\ Area)(Soil\ Depth)}{Area}$$

$$Bearing\ Pressure\ on\ Clay = \frac{54{,}321 + 125(43.4)(3.5)}{43.4} = 1{,}689\ \frac{lbs}{ft^2} > 1{,}500\ \frac{lbs}{ft^2}$$

$$Actual\ Safety\ Factor = \frac{3(1{,}575)}{1{,}689} = 2.8\ which\ is\ adequate\ \boldsymbol{OK}$$

The impact loading factor to be applied is 1.0 (for greater than 3 feet of soil cover), therefore, 3.5 feet is an acceptable cover above the clay for the Clean Harbors 977L 5 cy loader.

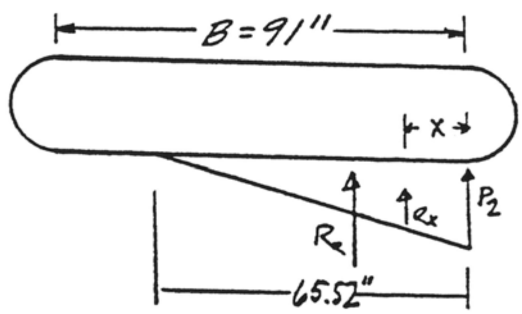
D. Track Type Dozer - Caterpillar D6D

The standard track type loader analyzed (977L) had an effective track length carry weight of the equipment with a full bucket of approximately 72 percent. During a discussion with Don Miller (an engineer for the Caterpillar Tractor Company) Mr. Miller said that for flat dozing, as would be the case while spreading the soil protective cover, the assumption of 72% effective track area would be conservative. The 72% effective track length will therefore be used in the following calculations.

$$Weight = 35{,}500\ lbs\ (highest\ weight\ assuming\ ripper\ attachment)$$
$$Track\ Width\ \left(\frac{W}{2}\right) = 18\ in$$
$$Track\ Length\ on\ ground(B) = 91\ in$$
$$Effective\ Track\ Length\ (L) = 0.72(91) = 65.52\ in = 5.46\ ft$$

Assume that triangular loading applies.

The worst case condition utilized the same equations that were developed for the worst case conditions in the front end loader section (977L).



R_r = 35,500 lbs

1. Check Clay sub-base for primary geomembrane.

   Assume a height of cover = 2.0 feet

$$x = \frac{-2.0 \pm \sqrt{2.0^2 + 4(2.0)(5.46)}}{2} = 2.45\ ft$$

$$P_2 = \frac{2R_r}{LW} = \frac{2(35{,}500\ lbs)}{(5.46\ ft)(3\ ft)} = 4{,}335\ \frac{lbs}{ft^2}$$

$$R_x = \frac{P_2 WX}{2}\left(2 - \frac{X}{L}\right) = \frac{4{,}335(3)(2.45)}{2}\left(2 - \frac{2.45}{5.46}\right) = 24{,}714\ lbs$$

$$Bearing\ Area = D^2 + D\frac{W}{2} + X(2D + W) = 2.0^2 + 2.0\frac{3}{2} + 2.45[2(2.0) + 3] = 24.15\ ft^2$$

$$Bearing\ Pressure\ on\ Soil\ Cover = \frac{R_x + \Upsilon_2(Bearing\ Area)(Soil\ Depth)}{Area}$$

$$Bearing\ Pressure\ on\ Soil\ Cover = \frac{24{,}714 + 125(24.15)(2.0)}{24.15} = 1{,}273\ \frac{lbs}{ft^2} < 1{,}500\ \frac{lbs}{ft^2}$$

The impact loading factor to be applied is 1.2 (for 2 foot of cover), supplied by the American Association of State Highway and Transportation Officials in "Standard Specifications for Highway Bridges," Edition 12. Therefore Bearing Pressure on the clay due to impact loading:

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = \frac{1.2(24{,}714) + \left(\frac{24}{12}\right)(125)(24.15)}{28.21}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = 1{,}478\frac{lbs}{ft^2} < 2{,}000\frac{lbs}{ft^2}\ \boldsymbol{OK}$$

E. Caterpillar 824C and 824B Wheel Type Dozer

1. Machine Specifications - reference "Caterpillar Performance Handbook" edition 16.

Model	Weight	Wheel Base
824C	66,975 lbs	11'-7" (11.58 ft)
824B	73,480 lbs	11'-8" (11.67 ft)

The 824B is an older model. Because the 824B is heavier, loading for the 824B will be analyzed. If the 824B proves to be acceptable, extrapolate to the lighter 824C.

Caterpillar representatives in Peoria, Illinois indicated that the weight distribution is 55% to the rear and 45% to the front. Based upon this load distribution, the maximum load for a single tire would be:

$$Maximum\ Single\ Tire\ Loading = \frac{(0.55)(73{,}480)}{2} = 20{,}207\ lbs$$

Assuming a maximum tire pressure of 40 psi, the area over which the load is spread at the surface of the soil cover is:

$$Tire\ Contact\ Area\ on\ soil = \frac{20{,}207\ lbs}{40\ \frac{lbs}{in^2}} = 505\ in^2$$

Given that the standard tire width is 29.5 inches, the dimensions over which the load is spread is calculated as follows:

$$Width\ of\ tire\ contact\ on\ soil = 29.5\ in$$

$$Length\ of\ tire\ contact\ on\ soil = \frac{505\ in^2}{29.5\ in} = 17.1\ in$$

The area over which the load is distributed on the clay assuming a load distribution 0.5H to 1.0 V, and a soil protective cover thickness of 24 inches is:

$$Width\ of\ load\ distribution\ on\ clay = (24\ in)(0.5)(2\ directions) + 29.5\ in = 53.5\ in$$

$$Length\ of\ load\ distribution\ on\ clay = (24\ in)(0.5)(2\ directions) + 17.1\ in = 41.1\ in$$

$$Area\ of\ load\ distribution\ on\ clay = (53.5\ in)(41.1\ in) = 2{,}199\ in^2 = 15.27 ft^2$$

$$Bearing\ Pressure\ on\ Clay = \frac{applied\ wheel\ loading + soil\ load}{Area}$$

$$Bearing\ Pressure\ on\ Clay = \frac{20{,}207\ lbs + \left(\frac{24}{12}\right)(125)(15.27)}{15.27} = 1{,}573\frac{lbs}{ft^2} \approx 1{,}500\frac{lbs}{ft^2}\ \ \boldsymbol{OK}$$

The impact loading factor to be applied is 1.2 (for 2 foot of cover), supplied by the American Association of State Highway and Transportation Officials in "Standard Specifications for Highway Bridges," Edition 12.

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = \frac{1.2(20{,}207) + \left(\frac{24}{12}\right)(125)(15.27)}{15.27}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = 1{,}840\frac{lbs}{ft^2} < 2{,}000\frac{lbs}{ft^2}\ \ \boldsymbol{OK}$$

Two feet of protective soil cover is adequate.

F. Caterpillar 966C Wheel Loader with 3.25 cy bucket

According to the Caterpillar Tractor Company in Peoria, Illinois, with the bucket empty and under static conditions, it can be assumed that 50 to 55% of the loader weight is on the front axle. With the bucket fully loaded and under static conditions, it can be assumed that 70 to 80% of the total weight of the machine and the load is on the front axle of the rubber tired loader. To be conservative, this analysis assumes that 80% of the load is on the front end of the loader.

1. Machine Specifications

$$Shipping\ Weight = 37{,}100\ lbs$$
$$Rated\ Capacity = 3.43yd^3$$
$$Load\ Weight = 3.43yd^3\left(125\frac{lbs}{ft^3}\right)\left(27\frac{ft^3}{yd^3}\right) = 11{,}576\ lbs$$

$$Total\ Weight = 37{,}100 + 11{,}576 = 48{,}676\ lbs$$

$$Load\ on\ a\ single\ front\ tire = (0.5)(48{,}676)(80\%) = 19{,}470\ lbs$$

Assuming a maximum tire pressure of 40 psi, the area over which the load is spread at the surface of the soil cover is:

$$Tire\ Contact\ Area\ on\ soil = \frac{19{,}470\ lbs}{40\ \frac{lbs}{in^2}} = 486.8\ in^2$$

Given that the standard tire width is 20.5 inches, the dimensions over which the load is spread is calculated as follows:

$$Width\ of\ tire\ contact\ on\ soil = 20.5\ in$$

$$Length\ of\ tire\ contact\ on\ soil = \frac{486.8\ in^2}{20.5\ in} = 23.74\ in$$

The area over which the load is distributed on the clay assuming a load distribution 0.5H to 1.0 V, and a soil protective cover thickness of 24 inches is:

$$Width\ of\ load\ distribution\ on\ clay = (24\ in)(0.5)(2\ directions) + 20.5\ in = 44.5\ in$$

$$Length\ of\ load\ distribution\ on\ clay = (24\ in)(0.5)(2\ directions) + 23.74\ in = 47.7\ in$$

$$Area\ of\ load\ distribution\ on\ clay = (44.5\ in)(47.7\ in) = 2{,}124\ in^2 = 14.75 ft^2$$

$$Bearing\ Pressure\ on\ Clay = \frac{applied\ wheel\ loading + soil\ load}{Area}$$

$$Bearing\ Pressure\ on\ Clay = \frac{49{,}470\ lbs + \left(\frac{24}{12}\right)(125)(14.75)}{14.75} = 1{,}570\frac{lbs}{ft^2} \approx 1{,}500\frac{lbs}{ft^2}\ \ \boldsymbol{OK}$$

The impact loading factor to be applied is 1.2 (for 2 foot of cover), supplied by the American Association of State Highway and Transportation Officials in "Standard Specifications for Highway Bridges," Edition 12.

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = \frac{1.2(19{,}470) + \left(\frac{24}{12}\right)(125)(14.75)}{14.75}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = 1{,}834\frac{lbs}{ft^2} < 2{,}000\frac{lbs}{ft^2}\ \ \boldsymbol{OK}$$

Two feet of protective soil cover is adequate.

G. Caterpillar 14G Motor Grader

The Caterpillar Tractor Company in Peoria, Illinois provided the following information regarding a 14G Motor Grader:

Wheel Loading Distribution	Without Ripper	With Ripper
Front Axles	10,700 lbs	11,010 lbs
Rear Axles	29,950 lbs	34,310 lbs
Total	40,650 lbs	45,320 lbs

$Wheel\ Base - from\ front\ axle\ to\ center\ of\ tandem\ axles\ in\ rear = 21' - 2"\ (21.17 ft)$
$Distance\ from\ the\ center\ of\ the\ tandum\ axle\ to\ either\ rear\ wheel = 32.5"\ (2.71 ft)$

1. Assuming the load to be distributed equally on the rear tandem axle and assuming the weight distribution to be equal on all four tires of the rear axle, then the load per tire on the rear axle is:

$$Load\ on\ one\ rear\ tire = \frac{34{,}310}{4} = 8{,}576\ lbs\ (use\ 9{,}000\ lbs)$$

Assuming a maximum tire pressure of 45 psi, the area over which the load is spread at the surface of the soil cover is:

$$Tire\ Contact\ Area\ on\ soil = \frac{9000\ lbs}{45\ \frac{lbs}{in^2}} = 200\ in^2$$

Given that the standard tire width is 20.5 inches, the dimensions over which the load is spread is calculated as follows:

$$Width\ of\ tire\ contact\ on\ soil = 20.5\ in$$

$$Length\ of\ tire\ contact\ on\ soil = \frac{200\ in^2}{20.5\ in} = 9.8\ in$$

The area over which the load is distributed on the clay assuming a load distribution 0.5H to 1.0 V, and a soil protective cover thickness of 24 inches is:

$$Width\ of\ load\ distribution\ on\ clay = (24\ in)(0.5)(2\ directions) + 20.5\ in = 44.5\ in$$

$$Length\ of\ load\ distribution\ on\ clay = (24\ in)(0.5)(2\ directions) + 9.8\ in = 33.8\ in$$

$$Area\ of\ load\ distribution\ on\ clay = (44.5\ in)(33.8\ in) = 1{,}504\ in^2 = 10.4\ ft^2$$

$$Bearing\ Pressure\ on\ Clay = \frac{applied\ wheel\ loading + soil\ load}{Area}$$

$$Bearing\ Pressure\ on\ Clay = \frac{9000\ lbs + \left(\frac{24}{12}\right)(125)(10.4)}{10.4} = 1{,}115\frac{lbs}{ft^2} \approx 1{,}500\frac{lbs}{ft^2}\ \ \boldsymbol{OK}$$

The impact loading factor to be applied is 1.2 (for 2 foot of cover), supplied by the American Association of State Highway and Transportation Officials in "Standard Specifications for Highway Bridges," Edition 12. Therefore Bearing Pressure on the clay due to impact loading:

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = \frac{1.2(9{,}000) + \left(\frac{24}{12}\right)(125)(10.4)}{10.4}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = 1{,}288\frac{lbs}{ft^2} < 2{,}000\frac{lbs}{ft^2}\ \ \boldsymbol{OK}$$

The 24 inch soil protective layer is adequate.

Check the bearing pressure if for some reason two of the back tires were to carry the complete load distributed to the rear of the 14G.

$$Load\ on\ one\ rear\ tire = \frac{34{,}310}{2} = 17{,}155\ lbs\ (use\ 17{,}200\ lbs)$$

Assuming a maximum tire pressure of 45 psi, the area over which the load is spread at the surface of the soil cover is:

$$Tire\ Contact\ Area\ on\ soil = \frac{17{,}200\ lbs}{45\ \frac{lbs}{in^2}} = 382\ in^2$$

Given that the standard tire width is 20.5 inches, the dimensions over which the load is spread is calculated as follows:

$$Width\ of\ tire\ contact\ on\ soil = 20.5\ in$$

$$Length\ of\ tire\ contact\ on\ soil = \frac{382\ in^2}{20.5\ in} = 18.6\ in$$

The area over which the load is distributed on the clay assuming a load distribution 0.5H to 1.0 V, and a soil protective cover thickness of 24 inches is:

$$Width\ of\ load\ distribution\ on\ clay = (24\ in)(0.5)(2\ directions) + 20.5\ in = 44.5\ in$$

$$Length\ of\ load\ distribution\ on\ clay = (24\ in)(0.5)(2\ directions) + 18.6\ in = 42.6\ in$$

$$Area\ of\ load\ distribution\ on\ clay = (44.5\ in)(42.6\ in) = 1{,}896\ in^2 = 13.2\ ft^2$$

$$Bearing\ Pressure\ on\ Clay = \frac{applied\ wheel\ loading + soil\ load}{Area}$$

$$Bearing\ Pressure\ on\ Clay = \frac{17{,}200\ lbs + \left(\frac{24}{12}\right)(125)(13.2)}{13.2} = 1{,}553\frac{lbs}{ft^2} \approx 1{,}500\frac{lbs}{ft^2}\ \ \boldsymbol{OK}$$

The impact loading factor to be applied is 1.2 (for 2 foot of cover), supplied by the American Association of State Highway and Transportation Officials in "Standard Specifications for Highway Bridges," Edition 12. Therefore Bearing Pressure on the clay due to impact loading:

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = \frac{1.2(17{,}200) + \left(\frac{24}{12}\right)(125)(13.2)}{13.2}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = 1{,}814\frac{lbs}{ft^2} < 2{,}000\frac{lbs}{ft^2}\ \ \boldsymbol{OK}$$

The 24 inch soil protective layer is adequate

H. Caterpillar 235 Excavator - Backhoe

Based upon information provided by Caterpillar Machinery, the following characteristics belong to the 235 Excavator - Backhoe:

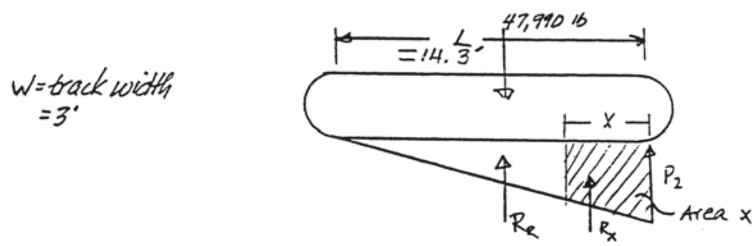
Machine Specifications

$$Operating\ Weight = 86{,}700\ lbs$$
$$Rated\ Capacity = 2.75yd^3$$
$$Load\ Weight = 2.75yd^3\left(125\frac{lbs}{ft^3}\right)\left(27\frac{ft^3}{yd^3}\right) = 9{,}280\ lbs$$
$$Total\ Weight\ Loaded = 95{,}980\ lbs$$

$$Load\ on\ a\ single\ track = (0.5)(95{,}980) = 47{,}990\ lbs$$

Loading Distribution:

Assume that triangular loading applies. The worst case condition utilized the same equations that were developed for the worst case conditions in the front end loader section (977L).



1. Check Clay sub-base for primary geomembrane.

   Assume a height of cover = 2.0 feet

$$x = \frac{-2.0 \pm \sqrt{2.0^2 + 4(2.0)(14.3)}}{2} = 4.4\,ft$$

$$P_2 = \frac{2R_r}{LW} = \frac{2(47{,}990\ lbs)}{(14.3\,ft)(3\,ft)} = 2{,}237\ \frac{lbs}{ft^2}$$

$$P_x = \frac{P_2(L - X)}{L} = \frac{2{,}237(14.3 - 4.4)}{14.3} = 1{,}549\ \frac{lbs}{ft^2}$$

$$R_x = \frac{(P_2 + P_x)(W)(X)}{2} = \frac{(2{,}237 + 1{,}549)}{2}(3)(4.4) = 24{,}988\ lbs$$

The area over which the load is distributed on the clay assuming a load distribution 0.5H to 1.0 V, and a soil protective cover thickness of 24 inches is:

$$Width\ of\ load\ distribution\ on\ clay = (2\,ft)(0.5)(2\ directions) + 1.5\,ft = 3.5\,ft$$

$$Length\ of\ load\ distribution\ on\ clay = (2\,ft)(0.5)(1\ direction) + 4.4\,ft = 5.4\,ft$$

$$Area\ of\ load\ distribution\ on\ clay = (3.5\,ft)(5.4\,ft) = 18.9\,ft^2$$

$$Bearing\ Pressure\ on\ Clay = \frac{R_x + \Upsilon_s(Bearing\ Area)(Soil\ Depth)}{Area}$$

$$Bearing\ Pressure\ on\ Clay = \frac{24{,}988 + (2.0)(125)(18.9)}{18.9} = 1{,}572\ \frac{lbs}{ft^2} \approx 1{,}500\ \frac{lbs}{ft^2}\ \boldsymbol{OK}$$

The impact loading factor to be applied is 1.2 (for 2 foot of cover), supplied by the American Association of State Highway and Transportation Officials in "Standard Specifications for Highway Bridges," Edition 12. Therefore Bearing Pressure on the clay due to impact loading:

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = \frac{1.2(24{,}988) + (2)(125)(18.9)}{18.9}$$

$$Bearing\ Pressure\ on\ Clay\ from\ Impact\ Loading = 1{,}837\frac{lbs}{ft^2} < 2{,}000\frac{lbs}{ft^2}\ \boldsymbol{OK}$$

The 24 inch soil protective layer is adequate.

CLEAN HARBORS
GRASSY MOUNTAIN FACILITY

PARTIAL LIST OF EQUIPMENT EVALUATED FOR PLACEMENT OF SOIL PROTECTIVE COVER DURING CONSTRUCTION AND FOR PLACEMENT OF WASTE DURING OPERATIONS

Prepared by
Hansen, Allen & Luce, Inc.

November 2017

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GENERAL OPERATING CONDITIONS

The subgrade to the soil protective cover consists of a geocomposite on top of a geomembrane with additional underlying geosynthetic materials. Care should always be taken to avoid tearing, puncturing, folding or damaging in any way the geomembrane liner and drainage systems during placement of the soil protective cover material.

No machinery (except for hand operated compactors) should be allowed on the inside slopes of the cell during placement of the soil protective cover.

Soil protective cover should be placed out in front of the equipment used to place the soil cover such that the minimum separation requirements are maintained at all times between the HDPE geomembrane liners and/or the geotextile filter fabric and the wheels or tracks of the equipment used to place the soil protective cover material.

Track Type Equipment

Care should be exercised when using any track type equipment to avoid sharp pivoting turns and/or operating the equipment in any manner that may displace the soil under the equipment and, thus, cause stresses to the underlying HDPE liner and/or drainage systems. Care should also be exercised not to allow the tracks, grousers, blades, buckets or any other part of the equipment to come into contact with the underlying HDPE liner and drainage systems.

Wheel Type Equipment

Care should be exercised when using any wheel type equipment to avoid spinning of tires and/or operating the equipment in any manner that may displace the soil under the tires and, thus, cause stresses to the underlying HDPE liner and/or drainage systems. Care should also be exercised not to allow the tires, blades, buckets or any other part of the equipment to come into contact with the underlying HDPE liner and drainage systems. Maximum tire pressures listed herein must be maintained for the separation indicated.

SPECIFIC OPERATING CONDITIONS

Separation distances listed herein are the minimum required so as not to exceed the allowable bearing capacities of the subgrade soils forming the subgrade to the underlying HDPE geomembrane liner and synthetic drainage systems. The Owner may stipulate additional requirements or separation distances for equipment (considering grouser length on tracks, potential operator mistakes, precision of grade control and soil cover thickness measurements, etc.) in order to provide additional protection to the underlying liner and drainage systems. The values below do not replace the permit drawing soil cover thickness requirements and are operational guidelines only.

Manufacturer and Model No.	**Operating Conditions/Restrictions**	
	Clay Liner Subgrade to HDPE Liner System	**Soil Cover Subgrade to HDPE Liner System**
EXCAVATORS (TRACK TYPE)		
Caterpillar 225B LC	• Maintain 1.5 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 22 inches. Max. bucket size of 2.1 cy.	• Maintain 1.3 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 22 inches. Max. bucket size of 2.1 cy.
Caterpillar 231D	• Maintain 1.0 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 36 inches. Max. bucket size of 2.6 cy.	• Maintain 1.0 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 36 inches. Max. bucket size of 2.6 cy.
Caterpillar 235	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 24 inches. Max. bucket size of 3.0 cy.	• Maintain 1.5 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 24 inches.
Caterpillar 245	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 30 inches for the standard machine and 36 inches for the heavy lift trencher.	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 30 inches for the standard machine and 36 inches for the heavy lift trencher.
Caterpillar EL200B	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system.	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system.
Caterpillar EL240C	• Maintain 0.5 ft. min. separation between the tracks and the underlying liner system.	• Maintain 0.75 ft. min. separation between the tracks and the underlying liner system.
Caterpillar 330	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 24 inches. Max. bucket size is 2.75 cy.	• Maintain 1.5 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 24 inches. Max. bucket size is 2.75 cy.
Caterpillar 350L	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 24 inches. Max. bucket size of 2.9 cy.	• Maintain 1.5 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 24 inches. Max. bucket size of 2.9 cy.

Manufacturer and Model No.	Operating Conditions/Restrictions	
	Clay Liner Subgrade to HDPE Liner System	**Soil Cover Subgrade to HDPE Liner System**
Hitachi EX120	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system.	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system.
Hitachi EX200	• Maintain 0.75 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 24 inches. Max. bucket size is 1.6 cy.	• Maintain 1.0 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 24 inches. Max. bucket size is 1.6 cy.
Hitachi EX200LC-2	• Maintain 0.7 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 24 inches.	• Maintain 1.0 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 24 inches.
Kobelco K907LC	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system.	• Maintain 2.0 ft. min. separation between the tracks and the underlying liner system.
John Deere 350G LC	• Maintain 0.90 ft. min. separation between the tracks and the underlying liner system.	• Maintain 1.2 ft. min. separation between the tracks and the underlying liner system.
BACKHOE/LOADERS (WHEEL TYPE)		
Case 580K & 580 Super K	• Maintain 2.0 ft. or more of separation between the tires and the underlying liner system with a max. front tire pressure of 55 psi and a max. rear tire pressure of 45 psi.	• Maintain 2.0 ft. or more of separation between the tires and the underlying liner system with a max. front tire pressure of 55 psi and a max. rear tire pressure of 45 psi.
Caterpillar 426B	• Maintain 1.0 ft. or more of separation between the tires and the underlying liner system with a max. front tire pressure of 65 psi and a max. rear tire pressure of 30 psi.	• Maintain 1.2 ft. or more of separation between the tires and the underlying liner system with a max. front tire pressure of 70 psi and a max. rear tire pressure of 32 psi.
Caterpillar 436	• Maintain 1.0 ft. or more of separation between the tires and the underlying liner system with a max. front tire pressure of 40 psi and a max. rear tire pressure of 28 psi. Max. loader bucket size of 1.4 cy. • Maintain 1.25 ft. or more of separation between the tires and the underlying liner system with a max. front tire pressure of 60 psi and a max. rear tire pressure of 28 psi. Max. loader bucket size of 1.4 cy.	• Not Evaluated

Manufacturer and Model No.	Operating Conditions/Restrictions	
	Clay Liner Subgrade to HDPE Liner System	Soil Cover Subgrade to HDPE Liner System
COMPACTORS (DOUBLE DRUM)		
Bomag BW35	• Maintain 0.5 ft. min. separation between the drums and the underlying liner system.	• Maintain 0.5 ft. min. separation between the drums and the underlying liner system.
Bomag BW60S Walk Behind	• Maintain 0.33 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism at half amplitude or less. • Maintain 0.6 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism at full amplitude.	• Maintain 1.0 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism at full amplitude.
Bomag BW120	• Maintain 1.0 ft. min. separation between the drums and the underlying liner system.	• Maintain 1.0 ft. min. separation between the drums and the underlying liner system.
Bomag BW213D	• Maintain 1.25 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism turned off.	• Maintain 1.25 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism turned off.
Caterpillar CB-224B	• Maintain 0.5 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism at full amplitude.	• Maintain 1.0 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism at full amplitude.
Dynapac CC50A	• Maintain 1.5 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism turned off.	• Not Evaluated
Dynapac CC50S	• Maintain 1.0 ft. min. separation between the drums and the underlying liner system.	• Maintain 1.0 ft. min. separation between the drums and the underlying liner system.
Ingersoll-Rand DD-24	• Maintain 0.5 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism turned off. • Maintain 0.6 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism turned on.	• Maintain 0.9 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism turned off. • Maintain 1.0 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism turned on.

Manufacturer and Model No.	Operating Conditions/Restrictions	
	Clay Liner Subgrade to HDPE Liner System	Soil Cover Subgrade to HDPE Liner System
Mikasa MRV-24G	• Maintain 0.75 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism at full amplitude.	• Not Evaluated
Wacker 1650 lbs. Walk Behind	• Maintain 0.65 ft. min. separation between the drums and the underlying liner system.	• Maintain 0.65 ft. min. separation between the drums and the underlying liner system.
COMPACTORS (SINGLE DRUM)		
Caterpillar CS-553	• Maintain 2.0 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism turned off or set at low amplitude.	• Maintain 2.0 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism turned off or set at low amplitude.
Caterpillar CS-563	• Maintain 1.0 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism turned off. Max. tire pressure of 60 psi. • Maintain 2.0 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism set no higher than low amplitude. Max. tire pressure of 60 psi. • Maintain 2.8 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism set at or below high amplitude. Max. tire pressure of 60 psi.	• Not Evaluated

Manufacturer and Model No.	Operating Conditions/Restrictions	
	Clay Liner Subgrade to HDPE Liner System	Soil Cover Subgrade to HDPE Liner System
Dynapac CA151	• Maintain 0.5 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism off. Max. tire pressure of 20 psi. • Maintain 0.75 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism off. Max. tire pressure of 35 psi. • Maintain 1.0 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism off. Max. tire pressure of 60 psi. • Maintain 1.5 ft. min. separation between the drum and tires and the underlying liner system with the vibratory mechanism set at low amplitude. Max. tire pressure of 60 psi.	• Not Evaluated
Ingersoll-Rand SD-115D	• Maintain 1.0 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism turned off. • Maintain 1.5 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism turned on low amplitude • May not be operated at high amplitude.	• Maintain 1.2 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism turned off. • Maintain 1.5 ft. min. separation between the drums and the underlying liner system with the vibratory mechanism turned on low amplitude • May not be operated at high amplitude.
CRANES		
Grove RT500C	• Maintain 2.5 ft. min. separation between the tires and support plates on the outriggers and the underlying liner system. Max. boom extension is 46 feet from the crane pivot point. Max. material handling bucket size is 1.5 cy. or max. crane load is 6,000 lbs.	• Not Evaluated
DOZERS (TRACK TYPE)		
Caterpillar D6D	• Maintain 1.0 ft. min. separation between the tracks and the underlying liner system.	• Maintain 1.2 ft. min. separation below the tracks and the underlying liner system.

Manufacturer and Model No.	Operating Conditions/Restrictions	
	Clay Liner Subgrade to HDPE Liner System	Soil Cover Subgrade to HDPE Liner System
Caterpillar D6D LGP	• Based on loading only 0.1 ft. min. separation is needed, however, maintain 1.0 ft. min. separation between the tracks and the underlying liner system to reduce the risk of damage to the liner system.	• Maintain 1.0 ft. min. separation below the tracks and the underlying liner system.
Caterpillar D6H	• Maintain 1.0 ft. min. separation between the tracks and the underlying liner system.	• Maintain 1.1 ft. min. separation below the tracks and the underlying liner system.
Caterpillar D6H LGP	• Maintain 2.0 ft. min. separation below the tracks and the underlying liner system.	• Maintain 1.0 ft. min. separation below the tracks and the underlying liner system.
Caterpillar D6H LGP Series II	• Based on loading only 0.1 ft. min. separation is needed, however, maintain 1.0 ft. min. separation between the tracks and the underlying liner system to reduce the risk of damage to the liner system.	• Based on loading only 0.5 ft. min. separation is required. However, maintain 1.0 ft. min. separation between the tracks and the underlying liner system to reduce the risk of damage to the liner system.
Caterpillar D7H	• Maintain 1.4 ft. min. separation below the tracks and the underlying liner system. Minimum track width is 22 inches.	• Maintain 1.3 ft. min. separation below the tracks and the underlying liner system. Minimum track width is 22 inches.
Caterpillar D8K	• Maintain 2.0 ft. min. separation below the tracks and the underlying liner system. Minimum track width is 27 inches.	• Maintain 1.5 ft. min. separation below the tracks and the underlying liner system. Minimum track width is 27 inches.
John Deere 550B	• Maintain 2.0 ft. min. separation below the tracks and the underlying liner system.	• Maintain 2.0 ft. min. separation below the tracks and the underlying liner system.
John Deere 550G	• Maintain 0.9 ft. min. separation below the tracks and the underlying liner system. Minimum track width is 18 inches.	• Maintain 1.1 ft. min. separation below the tracks and the underlying liner system. Minimum track width is 18 inches.
John Deere 650G	• Maintain 0.9 ft. min. separation below the tracks and the underlying liner system. Minimum track width is 18 inches.	• Maintain 1.2 ft. min. separation below the tracks and the underlying liner system. Minimum track width is 18 inches.

Manufacturer and Model No.	Operating Conditions/Restrictions	
	Clay Liner Subgrade to HDPE Liner System	**Soil Cover Subgrade to HDPE Liner System**
DOZERS (WHEEL TYPE)		
Caterpillar 824B	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi.
Caterpillar 824C	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi.
FORK LIFTS		
Gradall 20,500 lbs.	• Maintain 1.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 28 psi. • Maintain 1.25 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi.	• Not Evaluated
LOADERS (SKID STEER)		
Bobcat 743	• Maintain 0.5 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 24 psi. • Maintain 0.75 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 38 psi. • Maintain 1.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 50 psi.	• Maintain 0.5 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 16 psi. • Maintain 0.75 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 36 psi. • Maintain 1.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi.
Bobcat 753	• Maintain 0.5 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 22 psi. • Maintain 0.75 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 34 psi. • Maintain 1.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 60 psi.	• Maintain 0.5 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 15 psi. • Maintain 0.75 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 36 psi.

Manufacturer and Model No.	Operating Conditions/Restrictions	
	Clay Liner Subgrade to HDPE Liner System	Soil Cover Subgrade to HDPE Liner System
Bobcat 763	• Maintain 0.7 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 28 psi.	• Maintain 0.5 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 14 psi. • Maintain 0.75 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 32 psi.
Case 1840	• Maintain 0.5 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 20 psi. • Maintain 1.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 50 psi.	• Not Evaluated
Gehl 4615	• Maintain 1.0 ft. min. separation between the tires and the underlying liner system.	• Not Evaluated
LOADERS (TRACK TYPE)		
Caterpillar 963	• Maintain 2.1 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 21.7 inches.	• Maintain 1.6 ft. min. separation between the tracks and the underlying liner system. Minimum track width is 21.7 inches.
LOADERS (WHEEL TYPE)		
Caterpillar 950	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 65 psi.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 65 psi.
Caterpillar 966B	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 45 psi. Max. bucket size is 3.0 cy.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 45 psi. Max. bucket size is 3.0 cy.
Caterpillar 966C	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi. Max. bucket size is 3.25 cy.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi. Max. bucket size is 3.25 cy.
Caterpillar 966D	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 35 psi. Max. bucket size is 4.25 cy.	• Not Evaluated

Manufacturer and Model No.	Operating Conditions/Restrictions	
	Clay Liner Subgrade to HDPE Liner System	Soil Cover Subgrade to HDPE Liner System
Caterpillar 970	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 35 psi. Max. bucket size is 5 cy. • Maintain 2.25 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi. Max. bucket size is 5 cy.	• Not Evaluated
Caterpillar 970F	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 35 psi. Max. bucket size is 5 cy. • Maintain 2.25 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi. Max. bucket size is 5 cy.	• Not Evaluated
Caterpillar 977L	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi. Max. bucket size is 3.25 cy.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi. Max. bucket size is 3.25 cy.
John Deere 544E	• Maintain 1.75 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi. Max. bucket size is 2.25 cy. • Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 55 psi. Max. bucket size is 2.25 cy.	• Not Evaluated
John Deere 544G	• Maintain 1.75 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 50 psi. Max. bucket size is 2.25 cy. • Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 55 psi. Max. bucket size is 2.25 cy.	• Not Evaluated
John Deere 644G	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 35 psi. Max. bucket size is 4.5 cy.	• Not Evaluated

Manufacturer and Model No.	Operating Conditions/Restrictions Clay Liner Subgrade to HDPE Liner System	 Soil Cover Subgrade to HDPE Liner System
Volvy BM L70C	• Maintain 1.5 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 30 psi. Max. bucket size is 2.4 cy. • Maintain 1.75 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi. Max. bucket size is 2.4 cy. • Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 55 psi. Max. bucket size is 2.4 cy.	• Maintain 1.5 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 25 psi. Max. bucket size is 2.4 cy. • Maintain 1.75 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 35 psi. Max. bucket size is 2.4 cy. • Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 60 psi. Max. bucket size is 2.4 cy.
	MAINTAINERS	
Huber M-850A	• Maintain 0.5 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 25 psi. • Maintain 1.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 50 psi.	• Not Evaluated
	MOTOR GRADERS	
Caterpillar 14G	• Maintain 1.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 35 psi. • Maintain 1.25 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi.	• Maintain 1.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 20 psi. • Maintain 1.25 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi.
Caterpillar 140G	• Maintain 1.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 35 psi.	• Maintain 1.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 20 psi. • Maintain 1.25 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 40 psi.
John Deere 570B	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 55 psi.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 55 psi.

Manufacturer and Model No.	Operating Conditions/Restrictions	
	Clay Liner Subgrade to HDPE Liner System	Soil Cover Subgrade to HDPE Liner System
SCRAPERS		
Caterpillar 613C	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 50 psi.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 50 psi.
TRACTORS (WHEEL TYPE)		
Steiger CA260, CA325, CA360, CU280, CU325, CU360, (42,000 lbs.)	• Maintain 1.1 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 20 psi. • Maintain 1.25 ft. min. separation between the tires and the underlying liner system with a max. tire pressure of 23 psi.	• Not Evaluated
TRUCKS (HIGHWAY)		
AASHTO HS-20	• Maintain 2.5 ft. min. separation between the tires and the underlying liner system.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system.
AASHTO HS-20 Alternate Loading	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system.
Pick-up type	• Maintain 0.75 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 50 psi.	• Maintain 0.75 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 50 psi.
HAUL TRUCKS (OFF-HIGHWAY)		
Terex 2766 B	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 44 psi. • Maintain 2.1 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 48 psi. • Maintain 2.2 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 56 psi. • Maintain 2.3 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 60 psi.	• Maintain 2.0 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 60 psi.

Manufacturer and Model No.	Operating Conditions/Restrictions	
	Clay Liner Subgrade to HDPE Liner System	Soil Cover Subgrade to HDPE Liner System
Volvo Haul Truck (A35D or Equivalent)	• Empty, maintain 2.0 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 60 psi. • Fully loaded, maintain 3.0 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 60 psi.	• Fully loaded, maintain 2.0 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 60 psi. • Fully loaded, maintain 3.0 ft. min. separation between the tires and the underlying liner system. Max. tire pressure is 60 psi.

APPENDIX D

Leachate Collection and Removal System,
Leak Detection System,
And Action Leakage Rate (ALR)
Calculations

The HELP Model was used to determine leachate quantities for the leachate collection system as well as other useful information. The required input to the model was determined as listed below:

- The evaporation and solar radiation values that were used in the model were generated from default data corresponding to the Salt Lake area as designated in the HELP Model program.
- Precipitation and average temperature data input for Dugway, Utah were found at the US Climate Data website, www.usclimatedata.com.
- The evaporative zone depth was assumed to be 4 inches for the waste layer and the sandy soils used as protective cover over the geosynthetic materials. These numbers were derived based on specific soils information and suggested values from the HELP Model Users Guide.
- The maximum leaf area index was assumed to be zero based on the arid desert conditions that exist in the area.
- The curve number for the protective cover soils was generated by the HELP Model based on soils data. Soils information was found at the NRCS Web Soil Survey (https://websoilsurvey.nrcs.usda.gov). The soils in the area where the landfill cells are located are classified as silts and the area where borrow is typically extracted for the landfill is classified as sands. In order to be conservative, fine sand was used in the model for the protective cover. The soils associated with the waste material are unknown and could be a variety of soils due to the nature of the landfill. A conservative approach was again applied with the assumption that the waste material would be made up of sandy soils.
- The drainage net was applied as the default in the HELP model and then specific parameters altered to match typical geocomposite values
    - Thickness 0.225 inches
    - Hydraulic Conductivity 4.72 cm/sec
- The geomembrane is assumed to have a pinhole density of 1 hole per acre, an installation defect of 1 per acre, and an installation quality of 3 or good.

The model was set up according to the designs for the layer system. From the HELP Model manual, Table 4 entitled "Default Soil, Waste, and Geosynthetic Characteristics" was used to determine which layer classification to use. The model used 5-7 layers that are summarized below:

Layer	Thickness (in.)	Porosity (Vol/Vol)	Hydraulic Conductivity (cm/sec)
Waste Material (assumed sandy soils)	0-576	0.437	0.0058
Protective Soil Cover	24	0.457	0.0031
Drainage Net – Geocomposite	0.25	0.85	4.72
HDPE Liner	0.08	0	2.0E-13
Drainage Net – Geocomposite	0.25	0.85	4.72
HDPE Liner	0.06	0	2.0E-13
Barrier Soil Liner (Clay)	36	0.464	6.4E-5

The Help Model was run for different waste heights in order to determine the prevailing condition to apply to the leachate collection system. This was determined to be at the "no waste" level where the protective soil is covering the drainage net but no waste has been added. The results are summarized in the following table:

Model Run – Waste Height	**Peak Daily Collected at Geonet (in.)**	**Annual Average Collected at Geonet (in.)**
No waste	0.13165	1.330
10 ft Waste	0.01934	1.431
30 ft Waste	0.01646	1.043
48 ft Waste	0.01546	0.698

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\HELP3\CHHELP\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\CHHELP\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\CHHELP\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\CHHELP\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\CHHELP\NOWASTE6.D10
OUTPUT DATA FILE:           C:\HELP3\CHHELP\NOWASTE6.OUT


TIME:  10:56     DATE:   9/26/2017


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

     TITLE:  2017 Cells 8 to 13

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
```

MATERIAL TEXTURE NUMBER 3

```
THICKNESS                    =     24.00   INCHES
POROSITY                     =      0.4570 VOL/VOL
FIELD CAPACITY               =      0.0830 VOL/VOL
WILTING POINT                =      0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1241 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.310000009000E-02 CM/SEC
```

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 0

```
THICKNESS                    =      0.22   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0102 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   4.71999979000     CM/SEC
SLOPE                        =      2.30   PERCENT
DRAINAGE LENGTH              =    262.0    FEET
```

LAYER 3

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 35

```
THICKNESS                    =      0.08   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD
```

LAYER 4

```
              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                  =      0.22   INCHES
POROSITY                   =      0.8500 VOL/VOL
FIELD CAPACITY             =      0.0100 VOL/VOL
WILTING POINT              =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0104 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =   4.71999979000     CM/SEC
SLOPE                      =      2.30   PERCENT
DRAINAGE LENGTH            =    262.0    FEET


                        LAYER  5
                        --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                  =      0.06   INCHES
POROSITY                   =      0.0000 VOL/VOL
FIELD CAPACITY             =      0.0000 VOL/VOL
WILTING POINT              =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY      =  3 - GOOD


                        LAYER  6
                        --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  11
THICKNESS                  =     36.00   INCHES
POROSITY                   =      0.4640 VOL/VOL
FIELD CAPACITY             =      0.3100 VOL/VOL
WILTING POINT              =      0.1870 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.4640 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.639999998000E-04 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 3 WITH BARE
GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND
A SLOPE LENGTH OF 415. FEET.

SCS RUNOFF CURVE NUMBER	=	80.20	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	3.250	ACRES
EVAPORATIVE ZONE DEPTH	=	4.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.530	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	1.828	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.132	INCHES
INITIAL SNOW WATER	=	0.039	INCHES
INITIAL WATER IN LAYER MATERIALS	=	19.688	INCHES
TOTAL INITIAL WATER	=	19.727	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
SALT LAKE CITY UTAH

STATION LATITUDE	=	40.76	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	117	
END OF GROWING SEASON (JULIAN DATE)	=	289	
EVAPORATIVE ZONE DEPTH	=	4.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	6.70	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	48.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	39.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	65.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.59	0.67	0.94	0.83	1.18	0.51
0.55	0.63	0.71	0.91	0.63	0.47

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
27.00	33.00	43.00	50.50	60.00	70.00
78.00	76.00	65.00	51.00	37.00	27.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH
AND STATION LATITUDE = 40.76 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.51	0.60	1.06	0.77	0.99	0.55
	0.52	0.58	0.67	0.84	0.68	0.50
STD. DEVIATIONS	0.26	0.27	0.42	0.33	0.52	0.40
	0.36	0.54	0.47	0.65	0.37	0.20
RUNOFF						
TOTALS	0.027	0.051	0.063	0.000	0.000	0.000
	0.000	0.000	0.000	0.001	0.000	0.005

STD. DEVIATIONS	0.076	0.065	0.090	0.000	0.000	0.000
	0.000	0.000	0.000	0.003	0.000	0.014

EVAPOTRANSPIRATION

TOTALS	0.359	0.375	0.868	0.655	0.811	0.517
	0.384	0.498	0.486	0.529	0.442	0.415
STD. DEVIATIONS	0.149	0.179	0.348	0.292	0.458	0.358
	0.248	0.392	0.424	0.428	0.230	0.153

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS	0.0872	0.0600	0.1187	0.1397	0.1175	0.1049
	0.1033	0.0989	0.0826	0.1205	0.1730	0.1252
STD. DEVIATIONS	0.0399	0.0367	0.1189	0.0737	0.0926	0.0768
	0.0926	0.0964	0.0806	0.1072	0.1661	0.1023

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.0368	0.0283	0.0342	0.0444	0.0392	0.0371
	0.0372	0.0354	0.0309	0.0359	0.0461	0.0405
STD. DEVIATIONS	0.0088	0.0086	0.0187	0.0125	0.0146	0.0145
	0.0145	0.0141	0.0159	0.0140	0.0220	0.0177

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.0369	0.0284	0.0340	0.0444	0.0392	0.0372
	0.0371	0.0354	0.0310	0.0356	0.0462	0.0406
STD. DEVIATIONS	0.0089	0.0085	0.0185	0.0125	0.0146	0.0146
	0.0143	0.0141	0.0160	0.0139	0.0222	0.0177

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0012	0.0009	0.0016	0.0020	0.0016	0.0015
	0.0014	0.0014	0.0012	0.0017	0.0025	0.0017
STD. DEVIATIONS	0.0005	0.0006	0.0016	0.0010	0.0013	0.0011
	0.0013	0.0013	0.0011	0.0015	0.0024	0.0014

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0005	0.0004	0.0005	0.0006	0.0005	0.0005
	0.0005	0.0005	0.0004	0.0005	0.0007	0.0006
STD. DEVIATIONS	0.0001	0.0001	0.0003	0.0002	0.0002	0.0002
	0.0002	0.0002	0.0002	0.0002	0.0003	0.0002

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	8.27	(1.428)	97537.8	100.00
RUNOFF	0.146	(0.1356)	1722.78	1.766
EVAPOTRANSPIRATION	6.339	(1.1544)	74783.41	76.671
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1.33143	(0.53077)	15707.597	16.10411
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.44605	(0.08218)	5262.294	5.39513
AVERAGE HEAD ON TOP OF LAYER 3	0.002	(0.001)		
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.44601	(0.08213)	5261.786	5.39461
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00005	(0.00001)	0.545	0.00056

```
 AVERAGE HEAD ON TOP             0.001 (    0.000)
   OF LAYER  5

 CHANGE IN WATER STORAGE         0.005   (  0.3240)         61.69      0.063

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


↑
*****************************************************************************

                PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------    -------------
      PRECIPITATION                              1.07         12623.325

      RUNOFF                                     0.281         3318.5300

      DRAINAGE COLLECTED FROM LAYER  2           0.13165       1553.18005

      PERCOLATION/LEAKAGE THROUGH LAYER  3       0.008553       100.90652

      AVERAGE HEAD ON TOP OF LAYER  3            0.056

      MAXIMUM HEAD ON TOP OF LAYER  3            0.111

      LOCATION OF MAXIMUM HEAD IN LAYER  2
            (DISTANCE FROM DRAIN)                2.7 FEET

      DRAINAGE COLLECTED FROM LAYER  4           0.00818         96.54688

      PERCOLATION/LEAKAGE THROUGH LAYER  6       0.000001         0.00805

      AVERAGE HEAD ON TOP OF LAYER  5            0.003

      MAXIMUM HEAD ON TOP OF LAYER  5            0.004

      LOCATION OF MAXIMUM HEAD IN LAYER  4
            (DISTANCE FROM DRAIN)               94.6 FEET

      SNOW WATER                                 0.78          9180.0303


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.3372

      MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.0330
```

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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****

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	3.1757	0.1323
2	0.0023	0.0100
3	0.0000	0.0000
4	0.0022	0.0100
5	0.0000	0.0000
6	16.7040	0.4640
SNOW WATER	0.000	

****
****

```
↑
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\CHHELP\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\CHHELP\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\CHHELP\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\CHHELP\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\CHHELP\10WASTE6.D10
OUTPUT DATA FILE:           C:\HELP3\CHHELP\10WASTE6.OUT


TIME:  11:21     DATE:   9/26/2017


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

     TITLE:  2017 Cells 8 to 13

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                  LAYER  1
                                  --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
```

MATERIAL TEXTURE NUMBER 2

```
THICKNESS                   =    120.00   INCHES
POROSITY                    =      0.4370 VOL/VOL
FIELD CAPACITY              =      0.0620 VOL/VOL
WILTING POINT               =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0717 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER

MATERIAL TEXTURE NUMBER 3

```
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4570 VOL/VOL
FIELD CAPACITY              =      0.0830 VOL/VOL
WILTING POINT               =      0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0830 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.310000009000E-02 CM/SEC
```

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER

MATERIAL TEXTURE NUMBER 0

```
THICKNESS                   =      0.22   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   4.71999979000     CM/SEC
SLOPE                       =      2.30   PERCENT
DRAINAGE LENGTH             =    262.0    FEET
```

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER

MATERIAL TEXTURE NUMBER 35

```
THICKNESS                    =      0.08   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                        LAYER  5
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.22   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   4.71999979000     CM/SEC
SLOPE                        =      2.30   PERCENT
DRAINAGE LENGTH              =    262.0    FEET


                        LAYER  6
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD
```

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 11

```
THICKNESS                   =     36.00   INCHES
POROSITY                    =      0.4640 VOL/VOL
FIELD CAPACITY              =      0.3100 VOL/VOL
WILTING POINT               =      0.1870 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4640 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.639999998000E-04 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 415. FEET.

```
SCS RUNOFF CURVE NUMBER            =     79.60
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      3.250  ACRES
EVAPORATIVE ZONE DEPTH             =      4.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      0.481  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      1.748  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      0.096  INCHES
INITIAL SNOW WATER                 =      0.039  INCHES
INITIAL WATER IN LAYER MATERIALS   =     27.302  INCHES
TOTAL INITIAL WATER                =     27.341  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
SALT LAKE CITY   UTAH

```
STATION LATITUDE                        =  40.76 DEGREES
MAXIMUM LEAF AREA INDEX                 =   0.00
START OF GROWING SEASON (JULIAN DATE)   =    117
```

END OF GROWING SEASON (JULIAN DATE) = 289
EVAPORATIVE ZONE DEPTH = 4.0 INCHES
AVERAGE ANNUAL WIND SPEED = 6.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 67.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 48.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 39.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 65.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.59	0.67	0.94	0.83	1.18	0.51
0.55	0.63	0.71	0.91	0.63	0.47

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
27.00	33.00	43.00	50.50	60.00	70.00
78.00	76.00	65.00	51.00	37.00	27.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH
AND STATION LATITUDE = 40.76 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
	-------	-------	-------	-------	-------	-------
PRECIPITATION						
TOTALS	0.51	0.60	1.06	0.77	0.99	0.55
	0.52	0.58	0.67	0.84	0.68	0.50
STD. DEVIATIONS	0.26	0.27	0.42	0.33	0.52	0.40
	0.36	0.54	0.47	0.65	0.37	0.20
RUNOFF						
TOTALS	0.009	0.009	0.027	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.035	0.022	0.049	0.000	0.000	0.000
	0.000	0.000	0.000	0.002	0.000	0.001
EVAPOTRANSPIRATION						
TOTALS	0.357	0.378	0.792	0.635	0.776	0.515
	0.364	0.473	0.461	0.505	0.426	0.403
STD. DEVIATIONS	0.147	0.168	0.356	0.277	0.437	0.355
	0.236	0.377	0.381	0.396	0.214	0.154
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.1004	0.1031	0.1281	0.1436	0.1030	0.1031
	0.1119	0.1238	0.1261	0.1338	0.1340	0.1202
STD. DEVIATIONS	0.0735	0.0764	0.1043	0.0814	0.0714	0.0685
	0.0729	0.0729	0.0937	0.0863	0.0777	0.0649
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0355	0.0350	0.0399	0.0432	0.0359	0.0353
	0.0379	0.0409	0.0397	0.0423	0.0424	0.0410
STD. DEVIATIONS	0.0195	0.0182	0.0224	0.0202	0.0183	0.0180
	0.0192	0.0189	0.0201	0.0193	0.0175	0.0166
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.0355	0.0349	0.0399	0.0432	0.0360	0.0352
	0.0379	0.0409	0.0397	0.0423	0.0424	0.0410
STD. DEVIATIONS	0.0194	0.0181	0.0223	0.0203	0.0183	0.0180

	0.0191	0.0189	0.0201	0.0193	0.0175	0.0165

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0014	0.0016	0.0018	0.0020	0.0014	0.0015
	0.0015	0.0017	0.0018	0.0018	0.0019	0.0017
STD. DEVIATIONS	0.0010	0.0012	0.0014	0.0012	0.0010	0.0010
	0.0010	0.0010	0.0013	0.0012	0.0011	0.0009

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0005	0.0005	0.0005	0.0006	0.0005	0.0005
	0.0005	0.0006	0.0006	0.0006	0.0006	0.0006
STD. DEVIATIONS	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	8.27 (1.428)	97537.8	100.00
RUNOFF	0.045 (0.0751)	529.85	0.543
EVAPOTRANSPIRATION	6.084 (1.1579)	71779.60	73.592

```
 LATERAL DRAINAGE COLLECTED      1.43115 (  0.69088)     16884.033   17.31024
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH     0.46906 (  0.18618)      5533.722     5.67341
   LAYER  4

 AVERAGE HEAD ON TOP             0.002 (    0.001)
   OF LAYER  4

 LATERAL DRAINAGE COLLECTED      0.46899 (  0.18619)      5532.934    5.67260
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH     0.00005 (  0.00002)         0.566     0.00058
   LAYER  7

 AVERAGE HEAD ON TOP             0.001 (    0.000)
   OF LAYER  6

 CHANGE IN WATER STORAGE         0.238   (  0.9490)       2810.82      2.882

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


↑
******************************************************************************

              PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
   ------------------------------------------------------------------------
                                              (INCHES)      (CU. FT.)
                                             ----------   -------------
     PRECIPITATION                              1.07        12623.325

     RUNOFF                                     0.164        1939.5251

     DRAINAGE COLLECTED FROM LAYER  3           0.01934       228.18678

     PERCOLATION/LEAKAGE THROUGH LAYER  4       0.003231       38.11965

     AVERAGE HEAD ON TOP OF LAYER  4            0.008

     MAXIMUM HEAD ON TOP OF LAYER  4            0.015

     LOCATION OF MAXIMUM HEAD IN LAYER  3
           (DISTANCE FROM DRAIN)               24.3 FEET

     DRAINAGE COLLECTED FROM LAYER  5           0.00309        36.50105
```

```
PERCOLATION/LEAKAGE THROUGH LAYER  7       0.000000         0.00340

AVERAGE HEAD ON TOP OF LAYER  6            0.001

MAXIMUM HEAD ON TOP OF LAYER  6            0.001

LOCATION OF MAXIMUM HEAD IN LAYER  5
      (DISTANCE FROM DRAIN)              163.1 FEET

SNOW WATER                                 0.78          9180.0303


MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.3727

MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.0240


 ***  Maximum heads are computed using McEnroe's equations.  ***

      Reference:  Maximum Saturated Depth over Landfill Liner
                  by Bruce M. McEnroe, University of Kansas
                  ASCE Journal of Environmental Engineering
                  Vol. 119, No. 2, March 1993, pp. 262-270.

*******************************************************************************
```

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

                 FINAL WATER STORAGE AT END OF YEAR   30
    ----------------------------------------------------------------------
                  LAYER        (INCHES)       (VOL/VOL)
                  -----        --------       ---------
                    1           14.2074         0.1184

                    2            3.5705         0.1488

                    3            0.0039         0.0172

                    4            0.0000         0.0000

                    5            0.0028         0.0125

                    6            0.0000         0.0000
```

```
            7           16.7040         0.4640

        SNOW WATER       0.000

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                DEVELOPED BY ENVIRONMENTAL LABORATORY                     **
**                  USAE WATERWAYS EXPERIMENT STATION                       **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:     C:\HELP3\CHHELP\DATA4.D4
TEMPERATURE DATA FILE:       C:\HELP3\CHHELP\DATA7.D7
SOLAR RADIATION DATA FILE:   C:\HELP3\CHHELP\DATA13.D13
EVAPOTRANSPIRATION DATA:     C:\HELP3\CHHELP\DATA11.D11
SOIL AND DESIGN DATA FILE:   C:\HELP3\CHHELP\30WASTE6.D10
OUTPUT DATA FILE:            C:\HELP3\CHHELP\30WASTE6.OUT


TIME:  11:58     DATE:   9/26/2017


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

     TITLE:  2017 Cells 8 to 13

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
```

```
            MATERIAL TEXTURE NUMBER   2
THICKNESS                 =    360.00   INCHES
POROSITY                  =      0.4370 VOL/VOL
FIELD CAPACITY            =      0.0620 VOL/VOL
WILTING POINT             =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0652 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                    LAYER  2
                    --------

        TYPE 1 - VERTICAL PERCOLATION LAYER
            MATERIAL TEXTURE NUMBER   3
THICKNESS                 =     24.00   INCHES
POROSITY                  =      0.4570 VOL/VOL
FIELD CAPACITY            =      0.0830 VOL/VOL
WILTING POINT             =      0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0830 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.310000009000E-02 CM/SEC


                    LAYER  3
                    --------

          TYPE 2 - LATERAL DRAINAGE LAYER
            MATERIAL TEXTURE NUMBER   0
THICKNESS                 =      0.22   INCHES
POROSITY                  =      0.8500 VOL/VOL
FIELD CAPACITY            =      0.0100 VOL/VOL
WILTING POINT             =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   4.71999979000     CM/SEC
SLOPE                     =      2.30   PERCENT
DRAINAGE LENGTH           =    262.0    FEET


                    LAYER  4
                    --------

          TYPE 4 - FLEXIBLE MEMBRANE LINER
            MATERIAL TEXTURE NUMBER  35
```

```
THICKNESS                   =      0.08   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  5
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.22   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   4.71999979000     CM/SEC
SLOPE                       =      2.30   PERCENT
DRAINAGE LENGTH             =    262.0    FEET


                        LAYER  6
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD
```

```
                     LAYER  7
                     --------

          TYPE 3 - BARRIER SOIL LINER
          MATERIAL TEXTURE NUMBER  11
THICKNESS                   =     36.00   INCHES
POROSITY                    =      0.4640 VOL/VOL
FIELD CAPACITY              =      0.3100 VOL/VOL
WILTING POINT               =      0.1870 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4640 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.639999998000E-04 CM/SEC




          GENERAL DESIGN AND EVAPORATIVE ZONE DATA
          ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
          A SLOPE LENGTH OF  415. FEET.

SCS RUNOFF CURVE NUMBER              =     79.60
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      3.250  ACRES
EVAPORATIVE ZONE DEPTH               =      4.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      0.481  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =      1.748  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      0.096  INCHES
INITIAL SNOW WATER                   =      0.039  INCHES
INITIAL WATER IN LAYER MATERIALS     =     42.182  INCHES
TOTAL INITIAL WATER                  =     42.221  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR




          EVAPOTRANSPIRATION AND WEATHER DATA
          -----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          SALT LAKE CITY        UTAH

    STATION LATITUDE                        =  40.76 DEGREES
    MAXIMUM LEAF AREA INDEX                 =   0.00
    START OF GROWING SEASON (JULIAN DATE)   =    117
```

```
END OF GROWING SEASON (JULIAN DATE)    =    289
EVAPORATIVE ZONE DEPTH                 =   4.0  INCHES
AVERAGE ANNUAL WIND SPEED              =   6.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY  =  67.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY  =  48.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY  =  39.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY  =  65.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    SALT LAKE CITY      UTAH

         NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
-------     -------     -------     -------     -------     -------
  0.59        0.67        0.94        0.83        1.18        0.51
  0.55        0.63        0.71        0.91        0.63        0.47


NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    SALT LAKE CITY      UTAH

    NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
-------     -------     -------     -------     -------     -------
 27.00       33.00       43.00       50.50       60.00       70.00
 78.00       76.00       65.00       51.00       37.00       27.50


NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    SALT LAKE CITY      UTAH
           AND STATION LATITUDE  =  40.76 DEGREES


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

         AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    1 THROUGH   30
-------------------------------------------------------------------------------
```

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.51	0.60	1.06	0.77	0.99	0.55
	0.52	0.58	0.67	0.84	0.68	0.50
STD. DEVIATIONS	0.26	0.27	0.42	0.33	0.52	0.40
	0.36	0.54	0.47	0.65	0.37	0.20
RUNOFF						
TOTALS	0.009	0.009	0.027	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.035	0.022	0.049	0.000	0.000	0.000
	0.000	0.000	0.000	0.002	0.000	0.001
EVAPOTRANSPIRATION						
TOTALS	0.357	0.378	0.792	0.635	0.776	0.515
	0.364	0.473	0.461	0.505	0.426	0.403
STD. DEVIATIONS	0.147	0.168	0.356	0.277	0.437	0.355
	0.236	0.377	0.381	0.396	0.214	0.154
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.0893	0.0547	0.0738	0.1098	0.0883	0.0749
	0.0816	0.0842	0.0847	0.1008	0.1058	0.0954
STD. DEVIATIONS	0.0769	0.0644	0.0894	0.0930	0.0716	0.0703
	0.0773	0.0800	0.0814	0.0885	0.0864	0.0826
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0306	0.0214	0.0250	0.0334	0.0303	0.0268
	0.0288	0.0290	0.0285	0.0319	0.0333	0.0318
STD. DEVIATIONS	0.0233	0.0188	0.0231	0.0252	0.0223	0.0213
	0.0227	0.0234	0.0231	0.0249	0.0239	0.0234
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.0307	0.0215	0.0250	0.0333	0.0304	0.0268
	0.0288	0.0290	0.0284	0.0319	0.0333	0.0318
STD. DEVIATIONS	0.0233	0.0189	0.0230	0.0252	0.0223	0.0213

```
                        0.0227   0.0234   0.0230   0.0248   0.0239   0.0234

  PERCOLATION/LEAKAGE THROUGH LAYER  7
  ------------------------------------
    TOTALS              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS     0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
    AVERAGES            0.0012   0.0008   0.0010   0.0016   0.0012   0.0011
                        0.0011   0.0012   0.0012   0.0014   0.0015   0.0013

    STD. DEVIATIONS     0.0011   0.0010   0.0012   0.0013   0.0010   0.0010
                        0.0011   0.0011   0.0012   0.0012   0.0012   0.0011

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES            0.0004   0.0003   0.0003   0.0005   0.0004   0.0004
                        0.0004   0.0004   0.0004   0.0004   0.0005   0.0004

    STD. DEVIATIONS     0.0003   0.0003   0.0003   0.0004   0.0003   0.0003
                        0.0003   0.0003   0.0003   0.0003   0.0003   0.0003

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


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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   30
-------------------------------------------------------------------------------
                                    INCHES            CU. FEET       PERCENT
                                -------------------   -------------  ---------
 PRECIPITATION                    8.27    (   1.428)     97537.8     100.00

 RUNOFF                           0.045   (  0.0751)       529.85      0.543

 EVAPOTRANSPIRATION               6.084   (  1.1579)     71779.60     73.592
```

```
 LATERAL DRAINAGE COLLECTED      1.04327 (  0.82436)     12307.932   12.61863
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH     0.35090 (  0.25430)      4139.800    4.24430
   LAYER  4

 AVERAGE HEAD ON TOP             0.001 (    0.001)
   OF LAYER  4

 LATERAL DRAINAGE COLLECTED      0.35085 (  0.25428)      4139.113    4.24360
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH     0.00004 (  0.00002)         0.430    0.00044
   LAYER  7

 AVERAGE HEAD ON TOP             0.000 (    0.000)
   OF LAYER  6

 CHANGE IN WATER STORAGE         0.744   (  1.1708)       8780.88     9.003

*******************************************************************************
```

↑

```
******************************************************************************

             PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
   ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------   -------------
      PRECIPITATION                              1.07         12623.325

      RUNOFF                                     0.164         1939.5251

      DRAINAGE COLLECTED FROM LAYER  3           0.01646        194.24217

      PERCOLATION/LEAKAGE THROUGH LAYER  4       0.002996        35.34221

      AVERAGE HEAD ON TOP OF LAYER  4            0.007

      MAXIMUM HEAD ON TOP OF LAYER  4            0.011

      LOCATION OF MAXIMUM HEAD IN LAYER  3
            (DISTANCE FROM DRAIN)               56.7 FEET

      DRAINAGE COLLECTED FROM LAYER  5           0.00274         32.27100
```

```
    PERCOLATION/LEAKAGE THROUGH LAYER  7       0.000000         0.00305

    AVERAGE HEAD ON TOP OF LAYER  6            0.001

    MAXIMUM HEAD ON TOP OF LAYER  6            0.002

    LOCATION OF MAXIMUM HEAD IN LAYER  5
          (DISTANCE FROM DRAIN)                0.0 FEET

    SNOW WATER                                 0.78          9180.0303


    MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.3727

    MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.0240


     ***  Maximum heads are computed using McEnroe's equations.  ***

          Reference:  Maximum Saturated Depth over Landfill Liner
                      by Bruce M. McEnroe, University of Kansas
                      ASCE Journal of Environmental Engineering
                      Vol. 119, No. 2, March 1993, pp. 262-270.

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```

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

                 FINAL WATER STORAGE AT END OF YEAR   30
    ----------------------------------------------------------------------
                  LAYER        (INCHES)       (VOL/VOL)
                  -----        --------       ---------
                    1           44.1328         0.1226

                    2            3.7058         0.1544

                    3            0.0044         0.0196

                    4            0.0000         0.0000

                    5            0.0029         0.0129

                    6            0.0000         0.0000
```

```
            7            16.7040          0.4640

        SNOW WATER       0.000

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******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:    C:\HELP3\CHHELP\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\CHHELP\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\CHHELP\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\CHHELP\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\CHHELP\48WASTE6.D10
OUTPUT DATA FILE:           C:\HELP3\CHHELP\48WASTE6.OUT


TIME:  12: 8     DATE:   9/26/2017


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

     TITLE:  2017 Cells 8 to 13

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
              COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.


                                   LAYER  1
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
```

```
              MATERIAL TEXTURE NUMBER   2
THICKNESS                   =    576.00   INCHES
POROSITY                    =      0.4370 VOL/VOL
FIELD CAPACITY              =      0.0620 VOL/VOL
WILTING POINT               =      0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0640 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.579999993000E-02 CM/SEC


                       LAYER  2
                       --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   3
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4570 VOL/VOL
FIELD CAPACITY              =      0.0830 VOL/VOL
WILTING POINT               =      0.0330 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0830 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.310000009000E-02 CM/SEC


                       LAYER  3
                       --------

             TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.22   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =   4.71999979000     CM/SEC
SLOPE                       =      2.30   PERCENT
DRAINAGE LENGTH             =    262.0    FEET


                       LAYER  4
                       --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
```

```
THICKNESS                    =      0.08   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD
```

```
                        LAYER  5
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.22   INCHES
POROSITY                     =      0.8500 VOL/VOL
FIELD CAPACITY               =      0.0100 VOL/VOL
WILTING POINT                =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =   4.71999979000     CM/SEC
SLOPE                        =      2.30   PERCENT
DRAINAGE LENGTH              =    262.0    FEET
```

```
                        LAYER  6
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                    =      0.06   INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD
```

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 11

THICKNESS	=	36.00	INCHES
POROSITY	=	0.4640	VOL/VOL
FIELD CAPACITY	=	0.3100	VOL/VOL
WILTING POINT	=	0.1870	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4640	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.639999998000E-04	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 2 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 415. FEET.

SCS RUNOFF CURVE NUMBER	=	79.60	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	3.250	ACRES
EVAPORATIVE ZONE DEPTH	=	4.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.481	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	1.748	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.096	INCHES
INITIAL SNOW WATER	=	0.039	INCHES
INITIAL WATER IN LAYER MATERIALS	=	55.574	INCHES
TOTAL INITIAL WATER	=	55.613	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
SALT LAKE CITY UTAH

STATION LATITUDE	=	40.76	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	117	

END OF GROWING SEASON (JULIAN DATE) = 289
EVAPORATIVE ZONE DEPTH = 4.0 INCHES
AVERAGE ANNUAL WIND SPEED = 6.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 67.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 48.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 39.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 65.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.59	0.67	0.94	0.83	1.18	0.51
0.55	0.63	0.71	0.91	0.63	0.47

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
27.00	33.00	43.00	50.50	60.00	70.00
78.00	76.00	65.00	51.00	37.00	27.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR SALT LAKE CITY UTAH
AND STATION LATITUDE = 40.76 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.51	0.60	1.06	0.77	0.99	0.55
	0.52	0.58	0.67	0.84	0.68	0.50
STD. DEVIATIONS	0.26	0.27	0.42	0.33	0.52	0.40
	0.36	0.54	0.47	0.65	0.37	0.20
RUNOFF						
TOTALS	0.009	0.009	0.027	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.035	0.022	0.049	0.000	0.000	0.000
	0.000	0.000	0.000	0.002	0.000	0.001
EVAPOTRANSPIRATION						
TOTALS	0.357	0.378	0.792	0.635	0.776	0.515
	0.364	0.473	0.461	0.505	0.426	0.403
STD. DEVIATIONS	0.147	0.168	0.356	0.277	0.437	0.355
	0.236	0.377	0.381	0.396	0.214	0.154
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.0611	0.0414	0.0506	0.0698	0.0568	0.0473
	0.0552	0.0632	0.0612	0.0670	0.0656	0.0585
STD. DEVIATIONS	0.0750	0.0555	0.0735	0.0913	0.0649	0.0650
	0.0704	0.0750	0.0788	0.0891	0.0822	0.0681
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0217	0.0164	0.0181	0.0217	0.0207	0.0178
	0.0208	0.0225	0.0209	0.0214	0.0215	0.0213
STD. DEVIATIONS	0.0235	0.0189	0.0213	0.0255	0.0215	0.0204
	0.0220	0.0233	0.0234	0.0250	0.0241	0.0219
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.0216	0.0165	0.0180	0.0216	0.0208	0.0178
	0.0207	0.0225	0.0209	0.0215	0.0215	0.0213
STD. DEVIATIONS	0.0235	0.0189	0.0212	0.0255	0.0215	0.0204

```
                    0.0220   0.0233   0.0233   0.0250   0.0241   0.0220

  PERCOLATION/LEAKAGE THROUGH LAYER  7
  ------------------------------------
    TOTALS              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS     0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
    AVERAGES            0.0008   0.0006   0.0007   0.0010   0.0008   0.0007
                        0.0008   0.0009   0.0009   0.0009   0.0009   0.0008

    STD. DEVIATIONS     0.0010   0.0008   0.0010   0.0013   0.0009   0.0009
                        0.0010   0.0010   0.0011   0.0012   0.0012   0.0009

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES            0.0003   0.0002   0.0002   0.0003   0.0003   0.0003
                        0.0003   0.0003   0.0003   0.0003   0.0003   0.0003

    STD. DEVIATIONS     0.0003   0.0003   0.0003   0.0004   0.0003   0.0003
                        0.0003   0.0003   0.0003   0.0003   0.0003   0.0003

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



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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH   30
-------------------------------------------------------------------------------
                                      INCHES            CU. FEET      PERCENT
                                 -------------------  -------------  ---------
 PRECIPITATION                     8.27    (   1.428)      97537.8     100.00

 RUNOFF                            0.045   (  0.0751)        529.85      0.543

 EVAPOTRANSPIRATION                6.084   (  1.1579)      71779.60     73.592
```

LATERAL DRAINAGE COLLECTED FROM LAYER 3	0.69773 (0.80299)	8231.459	8.43925
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.24481 (0.25545)	2888.203	2.96111
AVERAGE HEAD ON TOP OF LAYER 4	0.001 (0.001)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.24477 (0.25543)	2887.636	2.96053
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00003 (0.00003)	0.308	0.00032
AVERAGE HEAD ON TOP OF LAYER 6	0.000 (0.000)		
CHANGE IN WATER STORAGE	1.196 (1.1147)	14108.95	14.465

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	1.07	12623.325
RUNOFF	0.164	1939.5251
DRAINAGE COLLECTED FROM LAYER 3	0.01546	182.37108
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.002902	34.24012
AVERAGE HEAD ON TOP OF LAYER 4	0.007	
MAXIMUM HEAD ON TOP OF LAYER 4	0.015	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 5	0.00268	31.60188

```
PERCOLATION/LEAKAGE THROUGH LAYER  7       0.000000         0.00300

AVERAGE HEAD ON TOP OF LAYER  6            0.001

MAXIMUM HEAD ON TOP OF LAYER  6            0.005

LOCATION OF MAXIMUM HEAD IN LAYER  5
      (DISTANCE FROM DRAIN)                0.0 FEET

SNOW WATER                                 0.78         9180.0303


MAXIMUM VEG. SOIL WATER (VOL/VOL)                  0.3727

MINIMUM VEG. SOIL WATER (VOL/VOL)                  0.0240


 ***  Maximum heads are computed using McEnroe's equations.  ***

      Reference:  Maximum Saturated Depth over Landfill Liner
                  by Bruce M. McEnroe, University of Kansas
                  ASCE Journal of Environmental Engineering
                  Vol. 119, No. 2, March 1993, pp. 262-270.

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

                   FINAL WATER STORAGE AT END OF YEAR   30
    ----------------------------------------------------------------------
                    LAYER        (INCHES)       (VOL/VOL)
                    -----        --------       ---------
                      1           71.0553         0.1234

                      2            3.7241         0.1552

                      3            0.0044         0.0197

                      4            0.0000         0.0000

                      5            0.0029         0.0129

                      6            0.0000         0.0000
```

7 16.7040 0.4640

SNOW WATER 0.000

****
****

1. Determine the required geocomposite transmissivity to provide sufficient capacity to convey the leachate to the leachate collection pipes.

   a. Bearing pressure over the geocomposite.

   The Normal Bearing Pressure (P):

   <u>53' Depth above Liner</u>

Gravel Armor Plating (6 in @ 110 pcf)	=	55 psf	
Closure Material (Soil) (2.5 ft @ 125 pcf)	=	313 psf	
Waste (48 ft @ 120 pcf)	=	5,760 psf	
Soil Cover (2 ft @ 125 pcf)	=	250 psf	
	=	6,378 psf	(use 6,400 psf)
TOTAL	=	44.4 psi	

   b. Required geocomposite capacity

   The geocomposite will be required to conduct the greatest amount of water at the low side of the planar slopes just prior to discharging leachate into the leachate collection pipes. The boundary conditions for the composite (from top to bottom) are:

   - Closure and Waste Loading (as calculated above)
   - 2' protective soil cover comprised of a silty sand soil
   - Geocomposite
   - 80-mil HDPE geomembrane liner

   The geocomposite capacity is dependent on the length of the flow path of the leachate before it enters into the pipe drainage system. The length of the flow path from the furthest point of the cell to where the flow will reach the leachate pipe is 262 ft.

   The HELP Model was used to predict leachate rates from the geocomposite. Several runs were computed at varying waste heights above the geomembrane to determine a governing peak rate. The following tables summarize results from the HELP model for the varying waste height conditions.

   Average Annual and Average Daily Leachate Rates

   <u>Leachate Collection System (above top liner system)</u>

   Average Annual Leachate Rates and corresponding Average Day Leachate Rates based on the Average Annual Leachate Rates are provided in the following tables.

LANDFILL CELL 8

Waste height	Average Annual Leachate Rates			Average Day Leachate Rates	
(ft)	(in)	(cf/sump)	(gal/sump)	(cf/sump)	(gal/sump)
0	1.33143	17,179.8	128,505	47.1	352
10	1.43115	18,466.5	138,129	50.6	378
30	1.04327	13,461.6	100,693	36.9	276
48	0.69773	9,003.0	67,342	24.7	184

LANDFILL CELLS 9-13

Waste height	Average Annual Leachate Rates			Average Day Leachate Rates	
(ft)	(in)	(cf/sump)	(gal/sump)	(cf/sump)	(gal/sump)
0	1.33143	17,595.5	131,614	48.2	361
10	1.43115	18,913.4	141,472	51.8	388
30	1.04327	13,787.3	103,129	37.8	283
48	0.69773	9,220.9	68,972	25.3	189

Peak Day Leachate Rates

Leachate Collection System (above top liner system)

Peak Day Leachate Rates are provided in the following tables.

LANDFILL CELL 8

Waste height	Peak Day Leachate Rates		
(ft)	(in)	(cf/sump)	(gal/sump)
0	0.13165	1,698.7	12,706
10	0.01934	249.5	1,867
30	0.01646	212.4	1,589
48	0.01546	199.5	1,492

LANDFILL CELLS 9-13

Waste height	Peak Day Leachate Rates		
(ft)	(in)	(cf/sump)	(gal/sump)
0	0.13165	1,739.8	13,014
10	0.01934	255.6	1,912
30	0.01646	217.5	1,627
48	0.01546	204.3	1,528

The predicted peak daily leachate rate conveyed through the geocomposite was predicted to be about 0.13165 in/day for all of the cells.

The resulting peak daily flow along a 1 foot wide strip is:

$q_{leachate}$ = (262 ft)(0.13165 in/day)(1 ft/ 12 in)
$q_{leachate}$ = 2.87 ft^3/ft-day

The slope of the cells east to west and north to south are both 2.3% slopes and the resultant slope of the flow path within the geocomposite is 3.25%. In order to accommodate differential settlement, a slope of 2.3% was used in the model. The resulting slope due to differential settlement is not expected to be less than 2.3% based on results provided by AGEC in the geotechnical investigation report.

The required transmissivity for the geocomposite is given by $q_{req'd}$ and is related to the leachate rate $q_{leachate}$ by applying necessary safety factors. The combination of all the necessary safety factors is a resulting safety factor (SF_{RES}). Therefore,

$$q_{req'd} = q_{leachate} \times SF_{RES}$$

"Designing with Geosynthetics" by Robert Koerner provides recommended safety factors in the design of geonets as follows:

SF_{IN} = Safety factor for intrusion of adjacent geosynthetic materials into the geonet (1.5)
SF_{CR} = Safety factor for creep deformation of the geonet (1.5)
SF_{BC} = Safety factor for biological (2.0)
SF_{cc} = Safety factor for chemical clogging (1.5)

Because geocomposite testing includes the intrusion of the adjacent geosynthetic materials SF_{IN} is not required.

Combining all of the remaining safety factors presented yields a resulting safety factor of:

$$SF_{RES} = 1.5 \times 2.0 \times 1.5 = 4.5$$

Using the information presented above, the required geocomposite transmissivity (Θ_{req}) in m^2/sec is:

$$(2.87\ ft^3/ft\text{-}day)(4.5) = (\Theta_{req}\ m^2/sec)(10.7639\ ft^2/m^2)(86400\ sec/day)(0.023)$$

$$\Theta_{req} = 6.0 \times 10^{-4}\ m^2/sec$$

The geocomposite shall be selected to provide the required hydraulic transmissivity at the loading and boundary conditions provided.

2. Determine the required diameters for the leachate collection pipe system.

a. Max pipe capacity:

Assume potential 4-inch, 6-inch, and 8-inch, corrugated polyethylene pipe. It was assumed for the purposes of this design that flow at 80% depth represents pipe capacity. The design slope for the leachate pipe is 2.3%. Applying this slope in Manning's equation and assuming capacity of the pipe is at 80% full the capacity of the pipe are as follows:

Manning's n = 0.016 ("ADS Specifier Manual - Civil Engineer", Advanced Drainage Systems, Inc.)

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

Pipe Capacity (80% flow depth assumed as full capacity)

Pipe Diameter	Flow Area	Hydraulic Radius	Flow Capacity	
(in.)	(ft^2)	(ft)	(cfs)	(gpm)
4	0.07	0.10	0.23	103
6	0.17	0.15	0.68	304
8	0.30	0.20	1.46	655

b. Pipe Sizing:

Predicted flows (Q) within the leachate collection pipes were calculated based on HELP model predicted peak daily leachate rates, 0.13165 in/day, applied over the contributing areas to each pipe. The leachate collection pipe system consists of a single pipe running down the the cell where the slopes of the floor converge. The Contributing area to the leachate pipe is 89,110 ft^2. The resulting flow in the leachate pipe is 5.1 gpm. A 4-in pipe should convey the required flow.

Adding a safety factor similar to that of the geocomposite of 4.5 and the required flow capacity is about 23 gpm. The minimum slope for a 4-inch pipe to have the capacity to convey 23 gpm was calculated to be about 0.12%. It is not expected that a slope resulting from differential settlement will be less than 0.12%.

3. Information for Leachate Storage and Operations Requirements

   a. The total capacity in pore spaces of the rock and leachate pipe within the leachate collection sumps is about 1,278 gallons at 1 foot of depth above the lowest point within the sumps, 3,651 gallons at 1.83 feet above the lowest point in the sumps and at the lowest point on the floor around the top perimeter of the sumps, and 4,379 gallons at the highest elevation around the top perimeter of the sumps (full sump capacity at 2.73 feet above the lowest point within the sumps), and 8,190 gallons at 2.83 feet above the lowest point in the sumps and 1 foot above the lowest point on the floor above the top perimeter of the sumps.

   b. The HELP model predicts various annual average lateral drainage rates collected from the geocomposite based on waste thickness or height placed within the cells as presented under section 1 of these calculations. Leachate volumes were then estimated based on the drainage area to each sump (154,839 ft^2 for Landfill Cell 8 and 158,586 ft^2 for Landfill Cells 9-13). Storage and operations requirements are conservatively based on the sump drainage areas associated with Landfill Cells 9-13.

c. Average accumulated Leachate Volumes over time are listed in the following table using 365 days per year and the leachate rates provided below as generated from the HELP model.

Waste height	Average Day Leachate Rates	Volume of Leachate Produced in Each Sump Over Time (Gallons)						
(ft)	(gal/sump)	1 Day	2 Days	3 Days	4 Days	5 Days	6 Days	1 Week
0	361	361	722	1083	1444	1805	2166	2527
10	388	388	776	1164	1552	1940	2328	2716
30	283	283	566	849	1132	1415	1698	1981
48	189	189	378	567	756	945	1134	1323

d. The number of days of average leachate production to fill the top sumps (leachate collection and removal system sumps) based on estimated leachate rates and depths are presented in the following table.

Sump Capacity	Leachate Depth		Maximum Number of Days Between Pumping From Sumps Based on Estimated Leachate Rates			
(gal)	(ft)	Description	361 (gal)	388 (gal)	283 (gal)	189 (gal)
1,278	1	Above lowest point in sumps.	3.5	3.3	4.5	6.8
3,651	1.83	Above lowest point in sumps and at lowest point on floor around top perimeter of sumps.	10.1	9.4	12.9	19.3
4,379	2.73	Above lowest point in sumps and at highest point on floor around top perimeter of sumps (full sump capacity).	12.1	11.2	15.5	23.1
8189	2.83	Above lowest point in sumps and one foot above lowest point on floor around top perimeter of sumps.	22.6	21.1	28.9	43.3

e. The HELP model predicts a peak day lateral drainage collected from the geocomposite to be 0.13165 in/day. Storage and operations requirements are conservatively based on the sump drainage areas associated with Landfill Cells 9-13. The peak day accumulated Leachate Volume is a temporary condition resulting from a short term precipitation event in the very early stages of waste placement prior to waste completely covering the floor of the cell. The peak day leachate volume using a leachate depth of 0.13165 in, and the area of 158,586 ft^2 is 12,706. The top sumps have insufficient capacity to contain leachate from a peak day condition. Should such a condition occur, pumping should occur quickly following the event and should continue as needed until the leachate volume to the sumps lowers to conditions that allow periodic or less frequent pumping.

I. Area Tributary to Each Secondary Sump

The area tributary to each secondary sump in Landfill Cell 8 is as follows:

Total Sump Drainage Area = 383' x 415' = 154,839 ft^2 = 3.55 acres
Floor Area (outside the sumps) = 108,520 sf = 2.49 acres
Sideslope Area Immediately Above the Sumps = 2,926 sf = 0.07 acre
Remaining Sideslope Area = 41,870 sf = 0.96 acre
Sump Area = 1,523 sf = 0.03 acre
Largest Area Contributing Flow to the Valley Edge of the Sumps = 89,237 sf = 2.05 acres

The area tributary to each secondary sump in Landfill Cells 9 – 13 is as follows:

Total Sump Drainage Area = 383' x 415' = 158,586 ft^2 = 3.64 acres
Floor Area (outside the sumps) = 111,896 sf = 2.57 acres
Sideslope Area Immediately Above the Sumps = 2,926 sf = 0.07 acre
Remaining Sideslope Area = 42,241 sf = 0.97 acre
Sump Area = 1,523 sf = 0.03 acre
Area Contributing Flow to the Valley Edge of the Sumps = 89,237 sf = 2.05 acres

II. HELP model results

EPA's Hydrologic Evaluation of Landfill Performance computer model was used to generate estimated leakage rates (in inches) into the leak detection system based on climate data in the general proximity of the site, design parameters for the liner systems, and construction quality assumptions. The area contributing flows within the leak detection systems was used to determine flow quantities to the sumps for average annual and average daily leakage rates (obtained by dividing the average annual rate by 365 days per year), and for peak day leakage rates. The following provides results of the models for the leak detection system.

Average Annual and Average Daily Leachate Rates

Leak Detection System (between the top and bottom liner systems)

Average Annual Leachate rates in the leak detection system and corresponding Average Day Leachate Rates based on the Average Annual Leachate Rates are provided in the following tables. Leakage volumes contributing to each sump is for the total sump drainage area.

LANDFILL CELL 8

Waste height	Average Annual Leakage Rates			Average Day Leakage Rates	
(ft)	(in)	(cf/sump)	(gal/sump)	(cf/sump)	(gal/sump)
0	0.44601	5,755.0	43,047	15.8	118
10	0.46899	6,051.5	45,265	16.6	124
30	0.35085	4,527.1	33,863	12.4	93
48	0.24477	3,158.3	23,624	8.7	65

LANDFILL CELLS 9-13

Waste height	Average Annual Leakage Rates			Average Day Leakage Rates	
(ft)	(in)	(cf/sump)	(gal/sump)	(cf/sump)	(gal/sump)
0	0.44601	5,894.2	44,089	16.1	121
10	0.46899	6,197.9	46,361	17.0	127
30	0.35085	4,636.7	34,682	12.7	95
48	0.24477	3,234.8	24,196	8.9	66

Peak Day Leachate Rates

Leak Detection System (between the top and bottom liner systems) - Peak Day Leachate Rates are provided in the following tables. Leakage volumes contributing to each sump is for the total sump drainage area.

LANDFILL CELL 8

Waste height	Peak Day Leakage Rates		
(ft)	(in)	(cf/sump)	(gal/sump)
0	0.00818	105.5	790
10	0.00309	39.9	298
30	0.00274	35.4	264
48	0.00268	34.6	259

LANDFILL CELLS 9-13

Waste height	Peak Day Leakage Rates		
(ft)	(in)	(cf/sump)	(gal/sump)
0	0.00818	108.1	809
10	0.00309	40.8	305
30	0.00274	36.2	271
48	0.00268	35.4	265

The largest area contributing flow to the edge of the sumps where the floor valley intersects the sumps is the same for all of Landfill Cells 8-13. Therefore, the leakage rates to sumps along the edge where the valley intersects the sumps is provided in the following tables.

LANDFILL CELL 8-13 AVERAGE DAY LEAKAGE RATE TO THE VALLEY SIDE OF THE SUMPS

Waste height	Average Annual Leakage Rates			Average Day Leakage Rates	
(ft)	(in)	(cf/sump)	(gal/sump)	(cf/sump)	(gal/sump)
0	0.44601	3,316.7	24,809	9.3	70
10	0.46899	3,487.6	26,087	9.6	72
30	0.35085	2,609.1	19,516	7.1	54
48	0.24477	1,820.2	13,615	5.0	37

LANDFILL CELLS 8-13 PEAK DAY LEAKAGE RATE
TO THE VALLEY SIDE OF THE SUMPS

Waste height	Peak Day Leakage Rates		
(ft)	(in)	(cf/sump)	(gal/sump)
0	0.00818	60.8	455
10	0.00309	23.0	172
30	0.00274	20.4	152
48	0.00268	19.9	149

III. Transmissivity of the Drainage Net
Maximum overburden load on the leak detection system is:

53' Depth above Liner

Gravel Armor Plating (4 in @ 110 pcf)	=	37 psf	
Closure Material (Soil) (2.5 ft @ 125 pcf)	=	313 psf	
Waste (48 ft @ 120 pcf)	=	5,760 psf	
Soil Cover (2 ft @ 125 pcf)	=	250 psf	
	=	6,360 psf	(use 6,400 psf)
TOTAL	=	44.4 psi	

The leak detection system consists of a double-sided geocomposite with HDPE geomembrane forming the upper and lower boundaries of the geocomposite. The floor has a design slope of 2.3% perpendicular to all sides of the perimeter of the sumps prior to differential settlement with a minimum slope of about 1.4% after estimated differential settlement occurs. The resultant design slope on each planar section of the floor is 3.25% and with a minimum slope of about 2.3% after differential settlement occurs.

Specification sheets were obtained for the transmissivity values for double sided geocomposite from two different manufacturers. Both manufacturers tested the geocomposite at a 10% gradient, under a normal loading of 10,000 psf, and using steel bearing plates for the upper and lower boundaries. Steel bearing plates approximately represent the boundary conditions of HDPE geomembrane. Using the test values of the manufacturers provides conservative results in design of the leak detection system and in evaluating the action leakage rate due to the higher loading and gradient used for testing. Manufacturers test values are presented in the following table for double-sided geocomposites using 8 oz. non-woven geotextile.

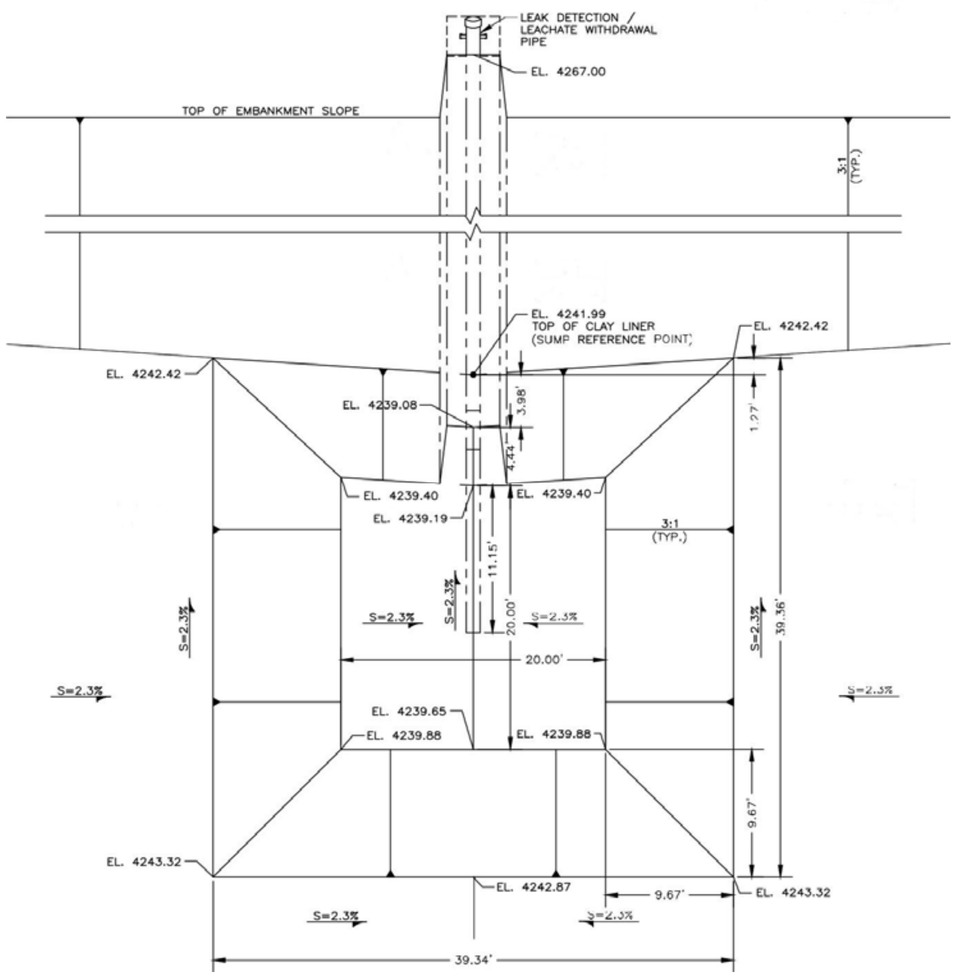
Double-Sided Geocomposite Thickness, mils	Transmissivity, gal/min/ft (m^2/sec)					
	GSE			AGRU America		
	gal/min/ft	ft^2/min	m^2/sec	gal/min/ft	ft^2/min	m^2/sec
175	0.4	0.058	$9.0x10^{-5}$	NA	NA	NA
200	0.5	0.065	$1.0x10^{-4}$	0.5	0.065	$1.0x10^{-4}$
225	1.3	0.174	$2.7x10^{-4}$	1.3	0.174	$2.7x10^{-4}$
250	2.4	0.323	$5.0x10^{-4}$	2.4	0.323	$5.0x10^{-4}$
275	3.4	0.452	$7.0x10^{-4}$	3.4	0.452	$7.0x10^{-4}$
300	4.3	0.581	$9.0x10^{-4}$	4.3	0.581	$9.0x10^{-4}$

Note: The transmissivity values for the two manufacturers are consistent.

III. Capacity of Secondary Drainage System into Secondary Sumps

Find: The capacity of the drainage net around the perimeter of the secondary sumps.

1. The worst case flow condition is in the valley formed at the intersection of the two planar slopes of the floor in each sump drainage area of the landfill cells. Flow will concentrate in the valley from a large portion of the floor area prior to entering the leak detection sumps. The following figure shows the plan view of the leak detection sumps (bottom sumps).



Assuming a maximum head of 1 foot above the lowest point on the bottom liner system around the leak detection sumps provides a maximum elevation for the leachate head of 4243.42. This is higher than any point around the perimeter of the sumps. Therefore, flow can enter into the sumps from the entire perimeter. The length around that portion of the sumps adjacent to the floor area is approximately 118 feet. The length of the top of the sump where the floor valley enters the sump is about 40 feet.

Equation governing the flow in the net is:

$$Q = \beta \cdot \theta \cdot i$$

Where: θ = Transmissivity of the net, ft^2/min
i = Gradient of the net, ft/ft
Q = Flow rate through the net, $ft^3/min/ft$
β = Width perpendicular to the flow, ft.

2. From the equation above for the 1.4% slopes, assuming only a 1-foot flow width (β = 1 ft.), and using varying thickness of geocomposite with the respective transmissivity values (θ= ft^2/min), determine the flow rate "q" per unit flow width and the flow width required for the peak day flow of 455 gpd and the average day flow of 72 gpm to enter the leak detection sump:

q $ft^3/min/ft$ = $\beta \cdot \theta \cdot i$ = (1)(0.065 ft^2/min)(i ft./ft.)

q gpd/ft = (q $ft^3/min/ft$)(7.48 gal/ft^3)(60 min/hr)(24 hr/d)

Flow Width = (Leachate Flow Rate, gpd)/(q, gpd/ft)

Double-Sided Geocomposite Thickness	**Geocomposite Transmissivity**	**Geocomposite Unit Flow Capacity**		**Peak Day Required Flow Width**	**Average Day Required Flow Width**
(mils)	**m^2/sec (ft^2/min)**	**($ft^3/min/ft$)**	**(gpd/ft)**	**(ft)**	**(ft)**
175	$9.0x10^{-5}$ (0.058)	0.0008	8.75	52	9
200	$1.0x10^{-4}$ (0.065)	0.0009	9.80	47	8
225	$2.7x10^{-4}$ (0.174)	0.0024	26.24	18	3
250	$5.0x10^{-4}$ (0.323)	0.0045	48.71	10	2
275	$7.0x10^{-4}$ (0.452)	0.0063	68.16	7	1
300	$9.0x10^{-4}$ (0.581)	0.0081	87.61	6	1

Use a geocomposite having a minimum transmissivity value of 2.7 $x10^{-4}$ m^2/sec (0.193 ft^2/min) which exceeds the Federal and State Regulations of 3 $x10^{-5}$ m^2/sec. Using the 118-foot perimeter around the line of intersection of the sumps with the floor provides a safety factor of 6.6 to provide sufficient capacity for the peak day leakage rate to enter the sumps while maintaining less than one-foot of head on the liner system on the floor of the cells. A safety factor of 39.3 is provided for the average day demand. The safety factors should be sufficient to account for creep deformation of the geonet, intrusion of the non-woven geotextile into the geonet, and for biological and chemical clogging.

IV. Action Leakage Rate (ALR) Based on Drainage System

The ALR for the drainage system can be determined by multiplying the unit flow rate derived above by the perimeter length around the top of the sumps (118 feet). This value is then divided by the area tributary to the secondary sumps to determine a gallon per day per acre (gpd/acre) figure required by EPA.

ALR = (26.24 gpd/ft) x 118 ft/3.55 ac = 872 gpd/acre for Landfill Cell 8
ALR = (26.24 gpd/ft) x 118 ft/3.64 ac = 850 gpd/acre for Landfill Cells 9-13

Applying a factor of safety of 4.5 to this figure, the ALR results in the following:

ALR = 872/4.5 = 194 gpd/acre or 688 gpd per sump drainage area for Landfill Cell 8
ALR = 850/4.5 = 189 gpd/acre or 688 gpd per sump drainage area for Landfill Cells 9-13

IV. Action Leakage Rate (ALR) Based on Sump and System Storage Capacity

The ALR associated with the capacity of the leak detection system to store leachate while maintaining a maximum liquid depth of 1 foot above the bottom liner system outside the sumps is directly related to the frequency that the sumps are checked and that leachate is removed from the bottom sumps. The discussion of pump operation versus sump capacity is provided later in these calculations.

V. Action Leakage Rate (ALR) Based on Pumping System Capacity and Operation

The pumps will have a minimum capacity of about 3 gallons per minute, but will most likely be between 15 and 60 gpm. The ALR for varying pumping rates and times are provided in the following tables.

Pump Operation	LANDFILL CELLS 8 ALR VALUES BASED ON VARIOUS PUMPING RATES					
	3 (gpm)		15 (gpm)		60 (gpm)	
(hrs/day)	(gpd/sump)	(gpd/acre)	(gpd/sump)	(gpd/acre)	(gpd/sump)	(gpd/acre)
4	720	203	3,600	1,014	14,400	4,056
6	1,080	304	5,400	1,484	21,600	6,085
12	2,160	608	10,800	1,521	43,200	12,169
24	4,320	1,217	21,600	6,085	86,400	24,388

The capacity of the leak detection system controls the ALR for all conditions except the assumption of pumping 4 hours with a 2.5 gpm pump.

Pump Operation	LANDFILL CELLS 9-13 ALR VALUES BASED ON VARIOUS PUMPING RATES					
	3 (gpm)		15 (gpm)		60 (gpm)	
(hrs/day)	(gpd/sump)	(gpd/acre)	(gpd/sump)	(gpd/acre)	(gpd/sump)	(gpd/acre)
4	720	198	3,600	989	14,400	3956
6	1,080	297	5,400	1484	21,600	5934
12	2,160	593	10,800	2967	43,200	11868
24	4,320	1,187	21,600	5934	86,400	23736

The capacity of the leak detection system 688 gpd/sump (189 gpd/acre) controls the ALR over the pump capacity and operation for all conditions presented herein.

Check the flow capacity within the sumps to the HDPE leachate withdrawal pipes in which the pumps are located. The leachate withdrawal pipe will have a minimum of about 30 perforations that are 3/8-inch diameter each or 0.03125 foot each (Area = 0.00077 ft^2). Using the orifice equation, $Q = CA\sqrt{2g\Delta h}$, assuming an orifice coefficient of 0.61, and using an average of 1 foot of head on the perforations, the flow through each orifice is $Q = (0.00077)(0.61)((2)(32.2)(1))^{0.5}$ = 0.00377 cfs = 1.7 gpm. With a total of 30 perforations, the total flowrate into the pipe is about 51 gpm. Therefore, the ALR for the capacity of the sump to supply flow to the pumps through the perforations and the HDPE pipe is 73,440 gpd/sump (20,687 gpd/acre for Landfill Cell 8 and 20,176 gpd/acre for Landfill Cells 9-13). This is much higher than the values in the above table except for the condition of pumping 24 hours per day at a rate of 15 gpm or higher. The leak detection system capacity controls the ALR over the capacity of the perforations and flow capacity within the HDPE leachate withdrawal pipe in the bottom of the sump.

VI. Action Leakage Rate Based on Storage Capacity and Operation of the Pumping System

Operationally, Clean Harbors current plan is to check the leak detection (bottom) sumps once a week. This becomes a limiting factor in determination of the ALR. The maximum action leakage rate which can be allowed, given the proposed weekly inspection and pumping plan, must be based on the amount of leachate which will fill the void volume within the sump and drainage layer without exceeding 1-foot of head on the lining system outside the perimeter edge of the sump.

1. The total capacity within the void space of the rock in the leak detection sumps is about 2,318

gallons assuming a porosity of 32% within the rock.

2. The capacity in leak detection system drainage layer (within a 225 mil geocomposite) outside the sumps is about 460 gallons. This is the capacity when limiting the head on the liner system outside the sumps to a maximum of 1 foot.

3. Total Capacity Associated with the Leak Detection (Bottom) Sumps = 2,318 + 460 = 2,778 gallons.

   If this 2,778 gallon volume is allowed to accumulate over 7 days, the daily volume will be 396 gallons.

   Therefore the ALR would be: 396 gpd/3.55 ac. = 111 gpd/acre for Cell 8;

   and the ALR would be: 396 gpd/3.64 ac. = 108 gpd/acre for Cells 9-13.

   If Clean Harbors were to modify the operational plan to check the leak detection (bottom) sumps more frequently that ALR will be as presented in the following table:

Frequency for Checking the Leak Detection Sumps	Resulting Action Leakage Rate (ALR)			
	Cell 8 – (sump drainage area = 3.55 acres)		Cells 9-13 – (sump drainage area = 3.64 acres)	
(days)	(gpd/acre)	(gal/sump)	(gpd/acre)	(gal/sump)
1	782	2,778	763	2,778
2	391	1,389	381	1,389
3	260	926	254	926
4	195	694	190	694
5	156	555	152	555
6	130	463	127	463
7	111	396	108	396

The maximum ALR that can be allowed from the table above is for about a 4 day frequency for checking the sumps since the ALR for the drainage system then controls the ALR at 194 gpd/acre (688 gal per sump) for Cell 8 and 189 gpd/acre (688 gal/sump) for Cells 9-13.

VI. ALR Summary and Conclusions

Summary

The ALR is dependent upon sump the leak detection system capacity at the discharge of the system into the bottom (leak detection) sump, the capacity and operation of the pumps for removing leachate from the bottom (leak detection) sump, and the capacity of the sump and leak detection system near the sump to provide leachate storage while limiting the depth of liquid on the bottom liner system to one foot or less. The calculations for Landfill Cells 9-13 provide lower ALR values than Landfill Cell 8 and will be used to establish the ALR for all of the cells. The following summarizes the various controlling ALR values:

System Controlling ALR = 189 gpd/acre or 688 gpd per sump drainage area

Pump Capacity and Operation Controlling ALR = 198 gpd/acre or 720 gpd per sump drainage area

Inspection and Pumping Frequency Controlling ALR Values are provided in the following table

Frequency for Checking the Leak Detection Sumps	Resulting Action Leakage Rate (ALR)			
	Cell 8 – (sump drainage area = 3.55 acres)		Cells 9-13 – (sump drainage area = 3.64 acres)	
(days)	(gpd/acre)	(gal/sump)	(gpd/acre)	(gal/sump)
1	782	2,778	763	2,778
2	391	1,389	381	1,389
3	260	926	254	926
4	195	694	189	688
5	156	555	152	555
6	130	463	127	463
7	111	396	108	396

Conclusions

The ALR = 108 gpd/acre (396 gpd per sump drainage area) for a 7 day inspection and pumping frequency. The action plan when this ALR is exceeded is to increase the frequency of inspection and pumping to 6 days.

The ALR = 127 gpd/acre (463 gpd per sump drainage area) for a 6 day inspection and pumping frequency. The action plan when this ALR is exceeded is to increase the frequency of inspection and pumping to 5 days.

The ALR = 152 gpd/acre (555 gpd per sump drainage area) for a 5 day inspection and pumping frequency. The action plan when this ALR is exceeded is to increase the frequency of inspection and pumping to 4 days.

The ALR = 189 gpd/acre (688 gpd per sump drainage area) for a 4 day inspection and pumping frequency. The action plan for exceeding this ALR is to repair the leaks, grade the waste and install an additional liner system in that sump drainage area, closure that area of the landfill, or prepare another written plan that is acceptable to the Director of the Utah Division of Waste Management and Radiation Control.

Client: Clean Harbors
Project: Landfill Cells 8 - 13 Design
Feature: Sump Capacities
Proj. No.: 064.85.100

Determine the capacities of the top and bottom sumps of the proposed landfill cells. The capacities will be used to evaluate the potential pumping frequency for leachate removal from the top sump and the ALR versus the leachate pumping frequency for the bottom sumps.

Sump Rock Porosity:	32%			
Geonet Porosity:	75%			
Geonet Thickness:	275	mil or	0.275	inch
Geonet Capacity,	0.017	cf/sf		
Protective Soil Cover Porosity:	20%			

TOP SUMPS

Elev. In Sump	Area in Sump (sf)	Interval Capacity (cf)	Volume of Sump (cf)	Capacity In Sump Rock (cf)	Area Above Sump (sf)	Geonet Volume (cf)	Geonet Capacity (cf)	PSC Interval Volume Above Sump (cf)	PSC Volume Above Sump (cf)	PSC Capacity Above Sump (cf)	Total Comb. Capacity (cf)	Total Comb. Capacity (gallons)	
4240.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**	empty
4240.91	220.07	35.11	35.11	11.24	0.00	0.00	0.00	0.00	0.00	0.00	11.24	**84**	
4241.26	719.30	163.87	198.99	63.68	0.00	0.00	0.00	0.00	0.00	0.00	63.68	**476**	
4241.60	1037.76	299.75	498.74	159.60	0.00	0.00	0.00	0.00	0.00	0.00	159.60	**1194**	1' of depth above low point
4241.99	1194.58	440.11	938.85	300.43	0.00	0.00	0.00	0.00	0.00	0.00	300.43	**2247**	
4242.42	988.27	461.89	1400.74	448.24	386.89	8.87	6.65	81.87	81.87	16.37	471.26	**3525**	
4242.87	336.95	300.10	1700.84	544.27	1658.05	38.00	28.50	463.08	544.94	108.99	681.75	**5100**	
4243.32	0.00	76.22	1777.05	568.66	3812.56	87.37	65.53	1237.45	1782.40	356.48	990.66	**7410**	Full Sump at highest point
4243.42	0.00	0.00	1777.05	568.66	4375.54	100.27	75.20	387.71	2170.10	434.02	1077.88	**8063**	

Leachate Withdrawal Pipe in Sump
Diameter: 18 inches
Length: 14 feet
Volume: 24.74 cubic feet = volume of gravel displaced or a gravel storage capacity of 7.92 cubic feet
Net capacity increase in the pipe space = 16.82 cubic feet 125.84 gallons

BOTTOM SUMPS

Elev. In Sump	Area in Sump (sf)	Interval Capacity (cf)	Volume of Sump (cf)	Capacity In Sump Rock (cf)	Area Above Sump (sf)	Geonet Volume (cf)	Geonet Capacity (cf)	Total Comb. Capacity (cf)	Total Comb. Capacity (gallons)	
4238.58	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0**	empty
4238.62	3.09	0.05	0.05	0.02	0.00	0.00	0.00	0.02	**0**	
4238.72	11.94	0.76	0.82	0.26	0.00	0.00	0.00	0.26	**2**	
4238.77	32.76	1.18	2.00	0.64	0.00	0.00	0.00	0.64	**5**	
4238.90	97.05	8.28	10.27	3.29	0.00	0.00	0.00	3.29	**25**	
4239.11	267.53	38.32	48.59	15.55	0.00	0.00	0.00	15.55	**116**	
4239.30	370.09	61.50	110.09	35.23	0.00	0.00	0.00	35.23	**264**	
4239.58	434.80	112.85	222.94	71.34	0.00	0.00	0.00	71.34	**534**	1' of depth above low point
4240.00	541.61	204.07	427.01	136.64	6.38	0.15	0.11	136.75	**1023**	
4240.59	686.61	362.02	789.02	252.49	220.07	5.04	3.78	256.27	**1917**	
4240.91	569.79	200.46	989.48	316.63	719.30	16.48	12.36	329.00	**2461**	
4241.26	191.66	132.83	1122.32	359.14	1037.76	23.78	17.84	376.98	**2820**	
4241.60	0.00	32.70	1155.02	369.60	1375.17	31.51	23.64	393.24	**2941**	full sump
4242.00	0.00	0.00	1155.02	369.60	1995.00	45.72	34.29	403.89	**3021**	
4242.50	0.00	0.00	1155.02	369.60	3812.56	87.37	65.53	435.13	**3255**	
4243.00	0.00	0.00	1155.02	369.60	4375.54	100.27	75.20	444.81	**3327**	

Leachate Withdrawal Pipe in Sump
Diameter: 18 inches
Length: 14 feet
Volume: 24.74 cubic feet = volume of gravel displaced or a gravel storage capacity of 7.92 cubic feet
Net capacity increase in the pipe space = 16.82 cubic feet 125.84 gallons

APPENDIX E

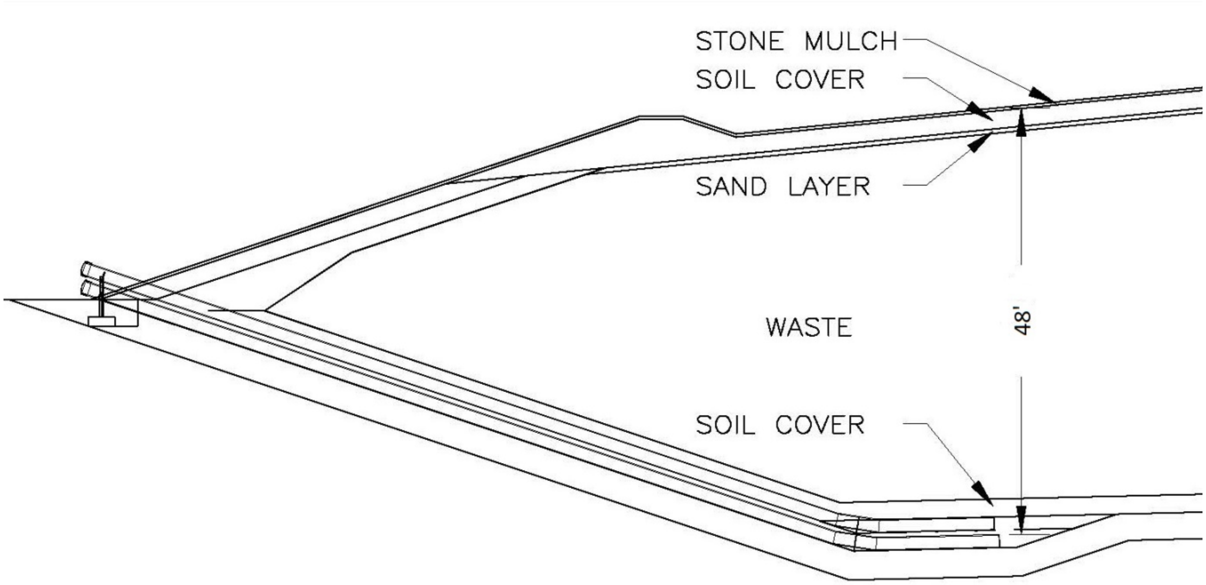
Leachate Withdrawal Pipe Calculations

I. Evaluate the long-term strength of the Polyethylene pipe against failure or significant loss of cross-sectional area.

Reference Manuals: Plastics Pipe Institute Handbook of Polyethylene Pipe

Design Criteria:

Pipe Diameter = 18 inches
Maximum Design Height of Overburden = 48 feet (See attached drawing)
This is the height of the soil, waste, and closure material above the pipe.



The height of the overburden above the bottom leachate withdrawal pipe is 48 feet.

2 feet of Protective Soil Cover @ 125 pcf
43.17 feet of Waste @ 120 pcf
6 inches of sand @ 125 pcf
2 feet of Soil Cover @ 125 pcf
4 inches of Stone Mulch (Gravel) @ 110 pcf

The attached spread sheet calculations show an 18-inch diameter HDPE Pipe (DR-17) has the strength characteristics needed to support the overburden load.

The pipe will be supported by 3/4-inch rounded washed rock (gravel) in the sump and will be backfilled using on-site clay soil compacted to 95% of maximum dry density as determined by ASTM D-698.

The pipe was evaluated for Ring Deflection and for Ring Compression in crushing and buckling using the design methodology in the Plastic Pipe Institute Handbook of Polyethylene Pipe.

Client: Clean Harbors
Project: Landfill Cells 8-13 Permit Design
Feature: Leachate Withdrawal Pipes
Proj. No.: 064.85.100

Determine the DR and installations requirements for the HDPE Leachate Withdrawal Pipes based on
Ring Deflection, Ring Compression, and Ring Buckling using the design methodology in the
PLASTIC PIPE INSTITUTE HANDBOOD OF POLYETHYLENE PIPE (CHAPTER 6)

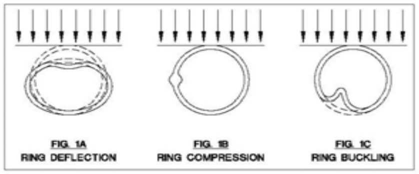


Figure 3-1 Performance Limits for Buried PE Pipe

Summary of Outputs

Ensure information in all gray cells is filled in correctly. If so, results are as follows:

Ring Deflection ok?	YES
Ring Compression - Crushing ok?	YES
Ring Compression - Buckling ok?	YES

References: http://plasticpipe.org/pdf/chapter-6_design_method.pdf

Soil Column Load

Burial depth to top of pipe	48	ft
Soil Cover	125	pcf
depth	4.5	ft
Gravel	110	pcf
depth	0.33	ft
Waste	120	pcf
depth	43.17	ft
Outside diameter of pipe, D_O	18	in
Avg. Inside diameter of pipe, D_I	15.88	in
Mean diameter, D_M	16.94	in
Soil column pressure, P_E	5779	psf
	40.13	psi

Live Load

Impact Factor, I_f	1	
Wheel Load, W_W	16000	lb
vertical depth, H	48	ft
Radius from point of load application, r	52.83	ft
Live Load, P_L	2.05	psf

(3-4)
$$P_L = \frac{3 I_f W_w H^3}{2\pi r^5}$$

WHERE

P_L = vertical soil pressure due to live load lb/ft²
W_W = wheel load, lb
H = vertical depth to pipe crown, ft
I_f = impact factor
r = distance from the point of load application to pipe crown, ft

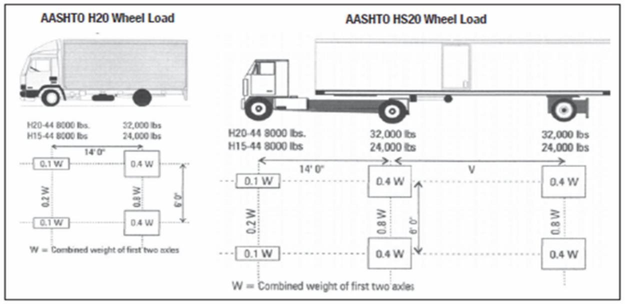


Figure 3-3 AASHTO H20 and HS20 Vehicle Loads

TABLE 3-2
Typical Impact Factors for Paved Roads

Cover Depth, ft	Impact Factor, I_f
1	1.35
2	1.30
3	1.25
4	1.20
6	1.10
8	1.00

Derived from Illinois DOT dynamic load formula (1996).

HANSEN ALLEN & LUCE INC ENGINEERS

Client: Clean Harbors
Project: Landfill Cells 8-13 Permit Design
Feature: Leachate Withdrawal Pipes
Proj. No.: 064.85.100

Ring Deflection

Bedding constant, K_{BED}	0.1	(assumed)	
Deflection lag factor, L_{DL}	1	(always 1 for this method)	
Soil column load, P_E	5779.17	psf	
Live load, P_L	2.05	psf	
Dimension Ratio, DR = OD/t	17		
Modulus of Elast. for pipe material, E	28000	psi	(tbl B.1.1)
Modulus of soil reaction, E'	700	psi	(tbl 3-7 or 3-8)
Modulus of soil reaction (native), E'_N	5000		(tbl 3-9)
E'_N/E' Ratio	7.14		
Trench Width, B_d	42		
B_d/D_O Ratio	2.33		
Soil Support factor, F_S	1.6		(tbls 3-10)
Horizontal Deflection, ΔX	0.93	in	
% Deflection	5.88		
Allowable Deflection as a % of ID	7.5%		(tbl 3-11, note)
Ring Deflection OK?	YES		

(3-10)

$$\frac{\Delta X}{D_M}=\frac{1}{144}\left(\frac{K_{BED}\,L_{DL}\,P_E+K_{BED}P_L}{\frac{2E}{3}\left(\frac{1}{DR-1}\right)^3+0.061F_SE'}\right)$$

WHERE

ΔX = Horizontal deflection, in
K_{BED} = Bedding factor, typically 0.1
L_{DL} = Deflection lag factor
P_E = Vertical soil pressure due to earth load, psf
P_L = Vertical soil pressure due to live load, psf
E = Apparent modulus of elasticity of pipe material, lb/in²
E' =Modulus of Soil reaction, psi
F_S = Soil Support Factor
RSC = Ring Stiffness Constant, lb/ft
DR = Dimension Ratio, OD/t
D_M = Mean diameter (D_I+2z or D_O-t), in
Z = Centroid of wall section, in
t = Minimum wall thickness, in
D_I = pipe inside diameter, in
D_O = pipe outside diameter, in

TABLE B.1.1
Apparent Elastic Modulus for 73°F (23°C)

Duration of Sustained Loading	Design Values For 73°F (23°C)(1,2,3)					
	PE 2XXX		PE3XXX		PE4XXX	
	psi	MPa	psi	MPa	psi	MPa
0.5hr	62,000	428	78,000	538	82,000	565
1hr	59,000	407	74,000	510	78,000	538
2hr	57,000	393	71,000	490	74,000	510
10hr	50,000	345	62,000	428	65,000	448
12hr	48,000	331	60,000	414	63,000	434
24hr	46,000	317	57,000	393	60,000	414
100hr	42,000	290	52,000	359	55,000	379
1,000hr	35,000	241	44,000	303	46,000	317
1 year	30,000	207	38,000	262	40,000	276
10 years	26,000	179	32,000	221	34,000	234
50 years	22,000	152	28,000	193	29,000	200
100 years	21,000	145	27,000	186	28,000	193

(1) Although there are various factors that determine the exact apparent modulus response of a PE, a major factor is its ratio of crystalline to amorphous content – a parameter that is reflected by a PE's density. Hence, the major headings PE2XXX, PE3XXX and, PE4XXX, which are based on PE's Standard Designation Code. The first numeral of this code denotes the PE's density category in accordance with ASTM D3350 (An explanation of this code is presented in Chapter 5).

(2) The values in this table are applicable to both the condition of sustained and constant loading (under which the resultant strain increases with increased duration of loading) and that of constant strain (under which an initially generated stress gradually relaxes with increased time).

(3) The design values in this table are based on results obtained under uni-axial loading, such as occurs in a test bar that is being subjected to a pulling load. When a PE is subjected to multi-axial stressing its strain response is inhibited, which results in a somewhat higher apparent modulus. For example, the apparent modulus of a PE pipe that is subjected to internal hydrostatic pressure – a condition that induces bi-axial stressing – is about 25% greater than that reported by this table. Thus, the Uni-axial condition represents a conservative estimate of the value that is achieved in most applications.

It should also be kept in mind that these values are for the condition of continually sustained loading. If there is an interruption or a decrease in the loading this, effectively, results in a somewhat larger modulus.

In addition, the values in this table apply to a stress intensity ranging up to about 400psi, a value that is seldom exceeded under normal service conditions.

TABLE 3-7
Values of E' for Pipe Embedment (See Howard (8))

Soil Type-pipe Embedment Material (Unified Classification System)[1]	E' for Degree of Embedment Compaction, lb/in²			
	Dumped	Slight, <85% Proctor, <40% Relative Density	Moderate, 85%-95% Proctor, 40%-70% Relative Density	High, >95% Proctor, >70% Relative Density
Fine-grained Soils (LL > 50)[2] Soils with medium to high plasticity; CH, MH, CH-MH	No data available: consult a competent soils engineer, otherwise, use E' = 0.			
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with less than 25% coarse grained particles.	50	200	400	1000
Fine-grained Soils (LL < 50) Soils with medium to no plasticity, CL, ML, ML-CL, with more than 25% coarse grained particles; Coarse-grained Soils with Fines, GM, GC, SM, SC[3] containing more than 12% fines.	100	400	1000	2000
Coarse-grained soils with Little or No Fines GW, GP, SW, SP[3] containing less than 12% fines	200	1000	2000	3000
Crushed Rock	1000	3000	3000	3000
Accuracy in Terms of Percentage Deflection[4]	±2%	±2%	±1%	±0.5%

[1] ASTM D-2487, USBR Designation E-3
[2] LL = Liquid Limit
[3] Or any borderline soil beginning with one of these symbols (i.e., GM-GC, GC-SC).
[4] For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note: Values applicable only for fills less than 50 ft (15 m). Table does not include any safety factor. For use in predicting initial deflections only; appropriate Deflection Lag Factor must be applied for long-term deflections. If embedment falls on the borderline between two compaction categories, select lower E' value, or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using 12,500 ft-lb/cu ft (598,000 J/m²) (ASTM D-698, AASHTO T-99, USBR Designation E-11). 1 psi = 6.9 KPa.

TABLE 3-9
Values of E'_N, Native Soil Modulus of Soil Reaction, Howard (8)

Native In Situ Soils				
Granular		Cohesive		E'_N (psi)
Std. Pentration ASTM D1586 Blows/ft	Description	Unconfined Compressive Strength (TSF)	Description	
> 0 - 1	very, very loose	> 0 - 0.125	very, very soft	50
1 - 2	very loose	0.125 - 0.25	very soft	200
2 - 4	very loose	0.25 - 0.50	soft	700
4 - 8	loose	0.50 - 1.00	medium	1,500
8 - 15	slightly compact	1.00 - 2.00	stiff	3,000
15 - 30	compact	2.00 - 4.00	very stiff	5,000
30 - 50	dense	4.00 - 6.00	hard	10,000
> 50	very dense	> 6.00	very hard	20,000
Rock	-	-	-	50,000

TABLE 3-8
Values of E' for Pipe Embedment (See Duncan and Hartley(10))

Type of Soil	Depth of Cover, ft	E' for Standard AASHTO Relative Compaction, lb/in²			
		85%	90%	95%	100%
Fine-grained soils with less than 25% sand content (CL, ML, CL-ML)	0-5	500	700	1000	1500
	5-10	600	1000	1400	2000
	10-15	700	1200	1600	2300
	15-20	800	1300	1800	2600
Coarse-grained soils with fines (SM, SC)	0-5	600	1000	1200	1900
	5-10	900	1400	1800	2700
	10-15	1000	1500	2100	3200
	15-20	1100	1600	2400	3700
Coarse-grained soils with little or no fines (SP, SW, GP, GW)	0-5	700	1000	1600	2500
	5-10	1000	1500	2200	3300
	10-15	1050	1600	2400	3600
	15-20	1100	1700	2500	3800

TABLE 3-10
Soil Support Factor, F_S

E'_N/E'	B_d/D_O 1.5	B_d/D_O 2.0	B_d/D_O 2.5	B_d/D_O 3.0	B_d/D_O 4.0	B_d/D_O 5.0
0.1	0.15	0.30	0.60	0.80	0.90	1.00
0.2	0.30	0.45	0.70	0.85	0.92	1.00
0.4	0.50	0.60	0.80	0.90	0.95	1.00
0.6	0.70	0.80	0.90	0.95	1.00	1.00
0.8	0.85	0.90	0.95	0.98	1.00	1.00
1.0	1.00	1.00	1.00	1.00	1.00	1.00
1.5	1.30	1.15	1.10	1.05	1.00	1.00
2.0	1.50	1.30	1.15	1.10	1.05	1.00
3.0	1.75	1.45	1.30	1.20	1.08	1.00
5.0	2.00	1.60	1.40	1.25	1.10	1.00

TABLE 3-11
Safe Deflection Limits for Pressurized Pipe

DR or SDR	Safe Deflection as % of Diameter
32.5	7.5
26	7.5
21	7.5
17	6.0
13.5	6.0
11	5.0
9	4.0
7.3	3.0

* Based on Long-Term Design Deflection of Buried Pressurized Pipe given in ASTM F1962.

Note: **7.5% Deflection provides a large safety factor for non-pressure applications (ch. 6, pg 218)**

Client: Clean Harbors
Project: Landfill Cells 8-13 Permit Design
Feature: Leachate Withdrawal Pipes
Proj. No.: 064.85.100

Ring Compression - Crushing

Soil column load, P_E	5779.2	psf	
	40.13	psi	
Live load, P_L	2.05	psf	
	0.014	psi	
Avg pipe wall thickness, t	1.059	in	
Avg wall cross-sectional area	1.059	in^2/in	
Dimension Ratio, DR = OD/t	17		
Pipe wall compressive stress, S	341.3	psi	
Allowable compressive stress, S_A	1000	psi	(tbl C.1)
Temperature compensating mult, T_M	0.94		(tbl A.2)
Allow. adjusted compressive stress, S_A	940		
Ring Compression - Crushing OK?	YES		

$$S = \frac{(P_E + P_L)D_O}{288A} \qquad S = \frac{(P_E + P_L)DR}{288}$$

WHERE

P_E = vertical soil pressure due to earth load, psf
P_L = vertical soil pressure due to live-load, psf
S = pipe wall compressive stress, lb/in2
DR = Dimension Ratio, D_O/t
D_O = pipe outside diameter (for profile pipe $D_O = D_I + 2H_P$), in
D_I = pipe inside diameter, in
H_P = profile wall height, in
A = profile wall average cross-sectional area, in2/in
(Obtain the profile wall area from the manufacturer of the profile pipe.)

(Note: These equations contain a factor of 144 in the denominator for correct units conversions.)

TABLE A.2
Temperature Compensating Multipliers for Converting a Base Temperature HDS or PR to HDS or PR for Another Temperature Between 40 and 100°F (4 and 38°C)

Maximum Sustained Temperature, °F (°C) (1)	Multiplier (2,3)
40 (4)	1.25
50 (10)	1.17
60 (16)	1.10
73 (23)	1.00
80 (27)	0.94
90 (32)	0.86
100 (38)	0.78

(1) Temporary and relatively minor increases in temperature beyond a sustained temperature have little effect on the long-term strength of a PE pipe material and thus, can be ignored.
(2) The multipliers in this table apply to a PE pipe that is made from a material having at least, an established hydrostatic design stress (HDS) for water, for 73°F (23°C). This HDS is designated by the last two numerals in the PE's standard designation code (e.g., the last two digits in PE4710 designate that the HDS for water, for 73°F (23°C), is 1,000psi – See Introduction and Chapter 5 for a more complete explanation.)
(3) For a temperature of interest that falls within any pair of listed temperatures the reader may apply an interpolation process to determine the appropriate multiplier.

Appendix C
Allowable Compressive Stress

Table C.1 lists allowable compressive stress values for 73°F (23°C). Values for allowable compressive stress for other temperatures may be determined by application of the same multipliers that are used for pipe pressure rating (See Table A.2).

TABLE C.1
Allowable Compressive Stress for 73°F (23°C)

	Pe Pipe Material Designation Code (1)					
	PE 2406		PE3408		PE 4710	
	PE 2708		PE 3608			
			PE 3708			
			PE 3710			
			PE 4708			
	psi	MPa	psi	MPa	psi	MPa
Allowable Compressive Stress	800	5.52	1000	6.90	1150	7.93

(1) See Chapter 5 for an explanation of the PE Pipe Material Designation Code.

Ring Compression - Buckling

Below Ground Water Level - Luscher Equation

Safety Factor, N	2	
Height of Groundwater above pipe, H_{GW}	0	ft
Depth of Cover, H	48	ft
Buoyancy Reduction Factor, R	1.0000	
Factor, B'	0.8499	
Soil Reaction Modulus, E'	700	psi
Apparent Modulus of Elasticity, E	28000	psi
Dimension Ratio, DR	17	
Allow. Constrained Buckling Pressure, P_{WC}	52.0	psi
	7489	psf
Soil column load, P_E	5779	psf
Ring Compression - Buckling, OK	YES	

$$P_{WC} = \frac{5.65}{N}\sqrt{RB'E'\frac{E}{12(DR-1)^3}}$$

$$P_{WC} = \frac{5.65}{N}\sqrt{RB'E'\frac{EI}{D_M{}^3}}$$

$$R = 1 - 0.33\frac{H_{GW}}{H}$$

$$B' = \frac{1}{1 + 4_e{}^{(-0.065H)}}$$

Where:
PWC = allowable constrained buckling pressure, psi
N = safety factor
R = buoyancy reduction factor
H_{GW} = height of ground water above pipe, ft
H = depth of cover, ft
e = natural log base number, 2.71828
E' = soil reaction modulus, psi
E = apparent modulus of elasticity, psi
DR = Dimension Ratio
I = pipe wall moment of interia, in4/in (t^3/12, if solid wall construction)
DM = mean pipe diameter (D_I + 2z or D_O - t), in
z = pipe section modulus

APPENDIX F

Storm Water Management Calculations

Purpose: To design the storm drainage facilities to convey runoff from the closure cap and cell embankments.

Method: The SCS curve number method was used in a HEC-HMS hydrology model.

Required: In order to calculate the runoff, the following steps and information are required:

- A delineation of the tributary area.
- A representative Soil Conservation Service (SCS) curve number (CN) for the tributary area.
- Lag time.
- Storm Distribution.
- 100-year 24-hour precipitation depth.

Delineation: The delineation of the subbasins, shown in Figure 1, was based on the landfill cell closure cap design. Each basin would drain into a channel which would convey the runoff to an inlet that conveys the water to an open ditch or an additional storm drain network (Shown on Figure 2).

Curve Numbers: In order to match the design for surrounding cells, a curve number of 83 was selected for the model. The cell cap will be a gravel cover over a silty sand layer over an impervious liner.

Precipitation: A 100-year 24-hour event was conservatively used for the design storm. The rainfall amount was taken from the “Point Precipitation Frequency Estimates from NOAA Atlas 14. The value for a 100-year 24-hour event was 1.85 inches.

Storm Distribution: The distribution used for the 24-hour event was the SCS Type II.

Lag Time: Lag time (T_L) for each subbasin was calculated by using the time of concentration (T_C) and the equation $T_L = 0.6T_C$. T_C was calculated using Worksheet 3 in TR-55. A minimum lag time of 3.6 minutes was used in the HEC-HMS model (as recommended in TR-55) since calculated lag times are less than 3.6 minutes.

Results: Results are summarized in Table 1 below. Runoff results can also be seen on Figure 1. The expected flows for each pipe, along with the design slope and recommended pipe diameter can be seen on Figure 3. The minimum pipe size is 18 inches in diameter, and the maximum proposed pipe size is 24 inches in diameter. The total volume of runoff for each tributary area can be seen on Figure 4. In general, peak flows are about 0.95 cfs/acre and runoff volume is about 0.05 ac-ft/acre.

North Channel: The peak design flow of the existing channel along the south side of Landfill Cells 4, 5, and 6 (located north of the access road for the proposed Landfill Cells 8, 10, and 12) is 16 cfs. This is a result of runoff from portions of Landfill Cells 3 through 6. Runoff from the north half of Landfill Cells 8, 10, and 12 and from the northeast quarter of Landfill Cell 7 will add an additional 29 cfs to the peak flow for a total peak design flow within the channel of 45 cfs at the pipes entering the containment pond east of Cell 12. The flow in the channel increases as each downspout pipe and the embankment side slopes contribute flow to the channel.

The channel has a slope of about 0.1% which is flat and acts similar to several retention ponds that buffer the flow to the containment pond. The retention ponds created by the channel are created by the mounds that extend from the access road to the monitoring wells along the road. The bottom width of the channel between the monitoring well mounds and the toe of the embankment slopes for Landfill Cells 4, 5, and 6 is about 5 feet or more.

Using Manning's equation for a bottom width of 5 feet, a 2.5H:1V slopes on one side, a 3H:1V slopes on the other side, and a hydraulic slope of 0.2% through the channel at the monitoring wells (a little steeper than the channel slope, but still very flat) results in a flow depth of 1.7 feet and a velocity of 2.8 fps. The channel bottom width upstream and downstream of the monitoring wells is about 22 feet and will result in a flow depth of about 1.0 foot and a velocity of about 1.8 fps using the bottom slope of 0.01%. Therefore, the flow depth around the monitoring wells is less than 2 feet and the depth will decrease in the upstream direction from the monitoring wells. The velocities are non-erosive.

Install 3 pipes, 24 inches in diameter, to convey the peak flow from the channel into the containment pond to the east. Each pipe, with inlet control, will convey 15 cfs at a headwater depth of 2.3 feet. Therefore, slope the bottom of the channel or install a concrete inlet that drops the inlet of the pipes to 3 feet below the road or the closest monitoring well to avoid flooding of the road or monitoring well.

East Channel: The channel east of Landfill Cells 12 and 13 has a project peak flow rate of about 29 cfs, a bottom width of about 13 feet, and a bottom slope of 0.1%. Assuming a hydraulic grade line equal to the bottom slope of the channel results in a flow depth of 1 foot and a velocity of 1.7 fps. The velocity is non-erosive so no erosion protection is required. The berm along the east side of the channel should be 2 feet above the bottom of the channel to maintain 1 foot of freeboard under peak flow conditions. The steep portion of the channel entering the containment pond has a slope of 2.6% resulting in a calculated flow depth of 0.4 foot and a velocity of 5.1 fps requiring 6 inches of rock (D50 = 3 inches) for erosion protection.

West Channels: The west channels consist of inlets to the west pond. The north inlet will have flow of about 25 cfs, a slope of about 2.1%, and a bottom width of about 10 feet. The calculated flow depth is 0.4 foot with a velocity of 4.8 fps requiring 6 inches of rock (D50 = 3 inches) for erosion protection. The south inlet will have flow of about 5.0 cfs, a slope of about 1.5%, and a bottom width of about 10 feet. The calculated flow depth is 0.2 foot with a velocity of 2.4 fps which is a non-erosive velocity requiring no erosion protection

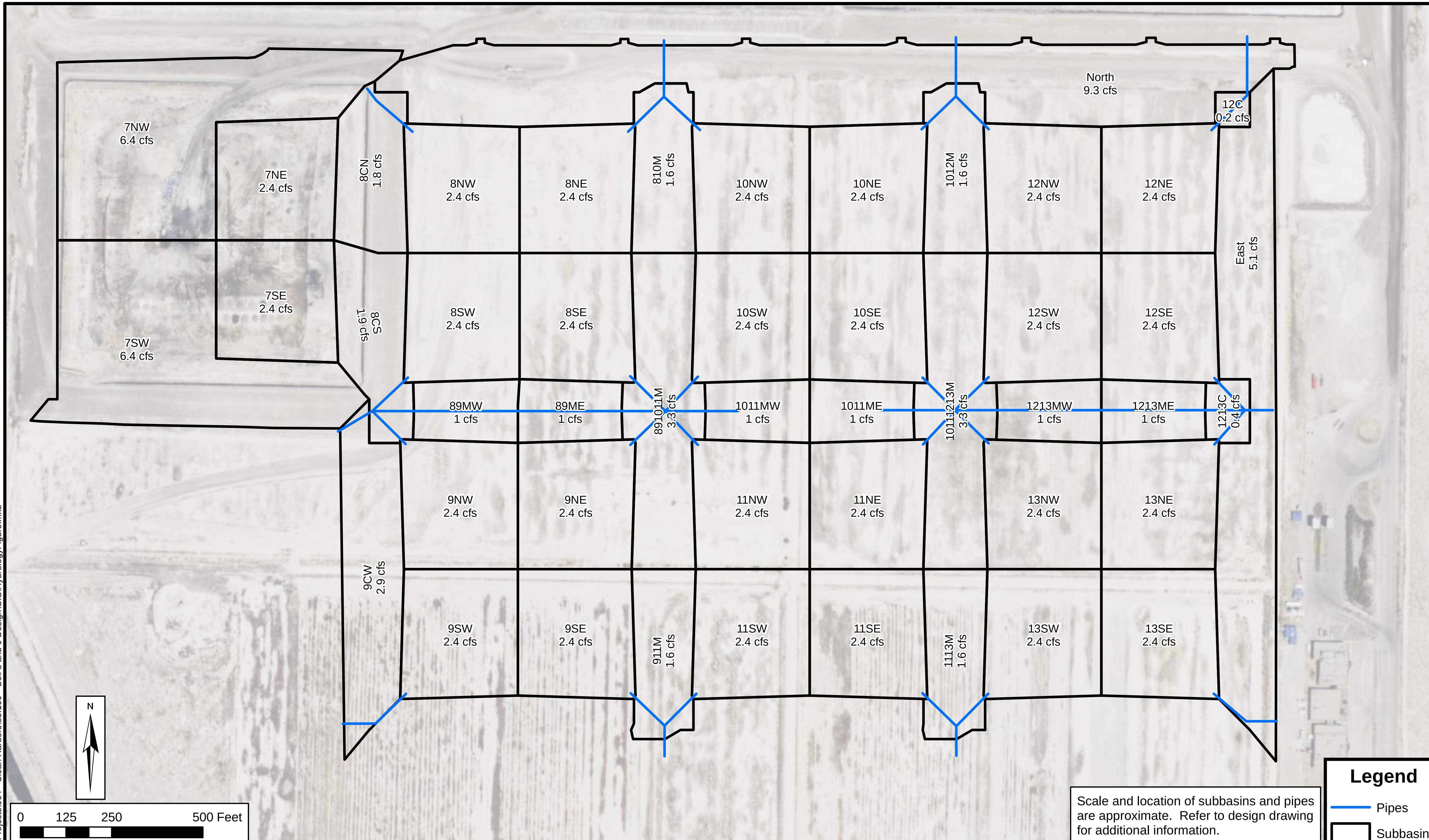
East Pond: The current capacity of the east containment pond is designed with a capacity of 9.0 acre-feet. This is to contain runoff volume from portions of Landfill Cells 3-5, Landfill Cell 6, Landfill Cells X, Y, and Z, and portions of the operations area and roads around the cells listed. The added area contributing storm water to the containment pond east of Cell 12 includes the north half of cells 8, 10, and 12, and the northeast quarter of Cell 7 which is about 34.7 acres. The pond needs to be enlarged an additional 1.74 acre feet for a total of 10.74 acre feet. The pond should be enlarged at the time any of the proposed cells (Cells 8-13) is closed. The bottom width of the pond is 196 feet. Assuming 3H:1V slopes, a bottom elevation of 4231.5, a water surface elevation of 4237, and a bottom length of 384 (using the short side of the pond), the pond will provide more than 10.74 acre feet of capacity.

South Pond: There is an existing containment pond located southeast of the existing Landfill Cell 7. That containment pond will provide sufficient capacity to contain storm water from the area after construction of Landfill Cell 8. However, at the time Cell 9 or Cell 10 are constructed, the area of containment will expand beyond the berm system for the current pond and the pond south of Cell 13 will need to be constructed. This pond will receive runoff from portions or Cells 9, 10, 11, 12, and 13. The potential drainage area to the pond south of Cell 13 is 67.4 acres and will need to have a capacity of 3.37 acre feet. Assuming the water depth in the pond to be 3 feet, 3H:1V side slopes, and a bottom area 212' x 212' will provide a capacity of more than 3.37 acre-feet.

West Pond: A new pond proposed to be constructed between the proposed Surface Impoundment B and the proposed Landfill Cell 9. This pond will receive runoff from portions of Landfill Cell 7, 8, 9, 10, and 11, from the top and outside slopes of proposed Surface Impoundment B, and area south of Cell 7 and west of Cell 9 (60.0 acres). The pond will need to provide 3.0 acre feet of storm water capacity. Assuming the water depth in the pond to be 3 feet, 3H:1V side slopes, and a bottom area 130' x 295' will provide a capacity of more than 3.0 acre-feet.

TABLE 1
MODELED RUNOFF RESULTS

Subbasin	Area (ac)	Peak Runoff (cfs)	Runoff Volume (ac-ft)
8NW	2.5536	2.4	0.126
8NE	2.5536	2.4	0.126
8SE	2.5536	2.4	0.126
8SW	2.5536	2.4	0.126
9NW	2.5536	2.4	0.126
9NE	2.5536	2.4	0.126
9SE	2.5536	2.4	0.126
9SW	2.5536	2.4	0.126
10NW	2.5536	2.4	0.126
10NE	2.5536	2.4	0.126
10SE	2.5536	2.4	0.126
10SW	2.5536	2.4	0.126
11NW	2.5536	2.4	0.126
11NE	2.5536	2.4	0.126
11SE	2.5536	2.4	0.126
11SW	2.5536	2.4	0.126
12NW	2.5536	2.4	0.126
12NE	2.5536	2.4	0.126
12SE	2.5536	2.4	0.126
12SW	2.5536	2.4	0.126
13NW	2.5536	2.4	0.126
13NE	2.5536	2.4	0.126
13SE	2.5536	2.4	0.126
13SW	2.5536	2.4	0.126
891011M	3.4944	3.3	0.172
10111213M	3.4944	3.3	0.172
810M	1.7344	1.6	0.085
1012M	1.7344	1.6	0.085
1113M	1.7344	1.6	0.085
911M	1.7344	1.6	0.085
1213ME	1.0816	1	0.053
1213MW	1.0816	1	0.053
1011ME	1.0816	1	0.053
1011MW	1.0816	1	0.053
89ME	1.0816	1	0.053
89MW	1.0816	1	0.053
8CN	1.8496	1.8	0.091
8CS	2.0352	1.9	0.100
12C	0.2048	0.2	0.010
1213C	0.4672	0.4	0.023
9CW	3.0656	2.9	0.151
North	11.008	9.3	0.541
East	5.8944	5.1	0.290
7NW	6.7264	6.4	0.331
7SW	6.688	6.4	0.329
7NE	2.5536	2.4	0.126
7SE	2.5536	2.4	0.126



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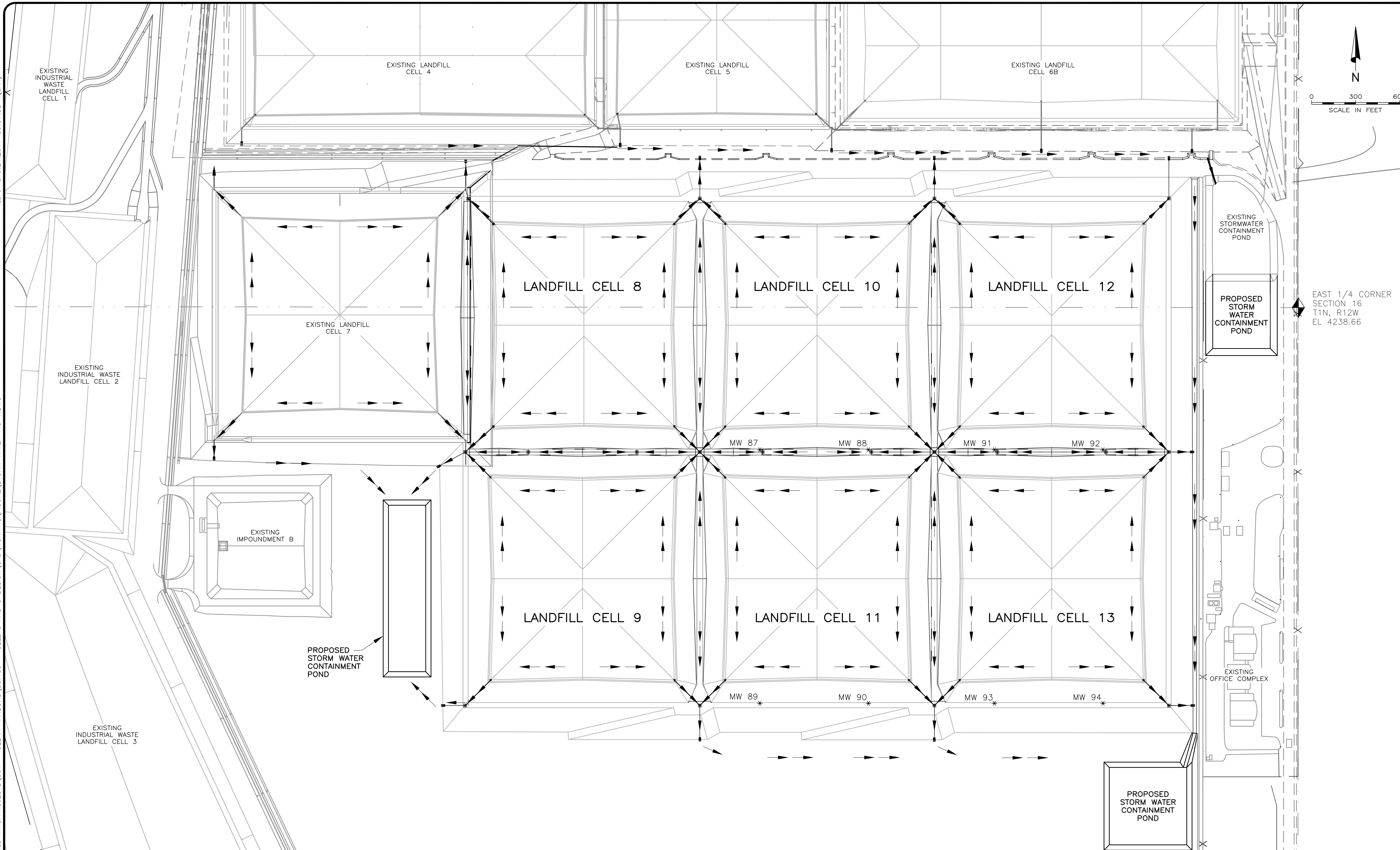
CLEAN HARBORS - GRASSY MOUNTAIN FACILITY
CELLS 8-13 HYDROLOGY

SUBBASIN PEAK RUNOFF

FIGURE 1



FILE NAME: PROJECTS\064 – CLEAN HARBORS\85.100 – CELL 8 AND 9 DESIGN\CAD\WORKING\FIGURE\STORM WATER FIG 1.DWG FILE DATE: 9.21.2017 09:07:58 (CAH)

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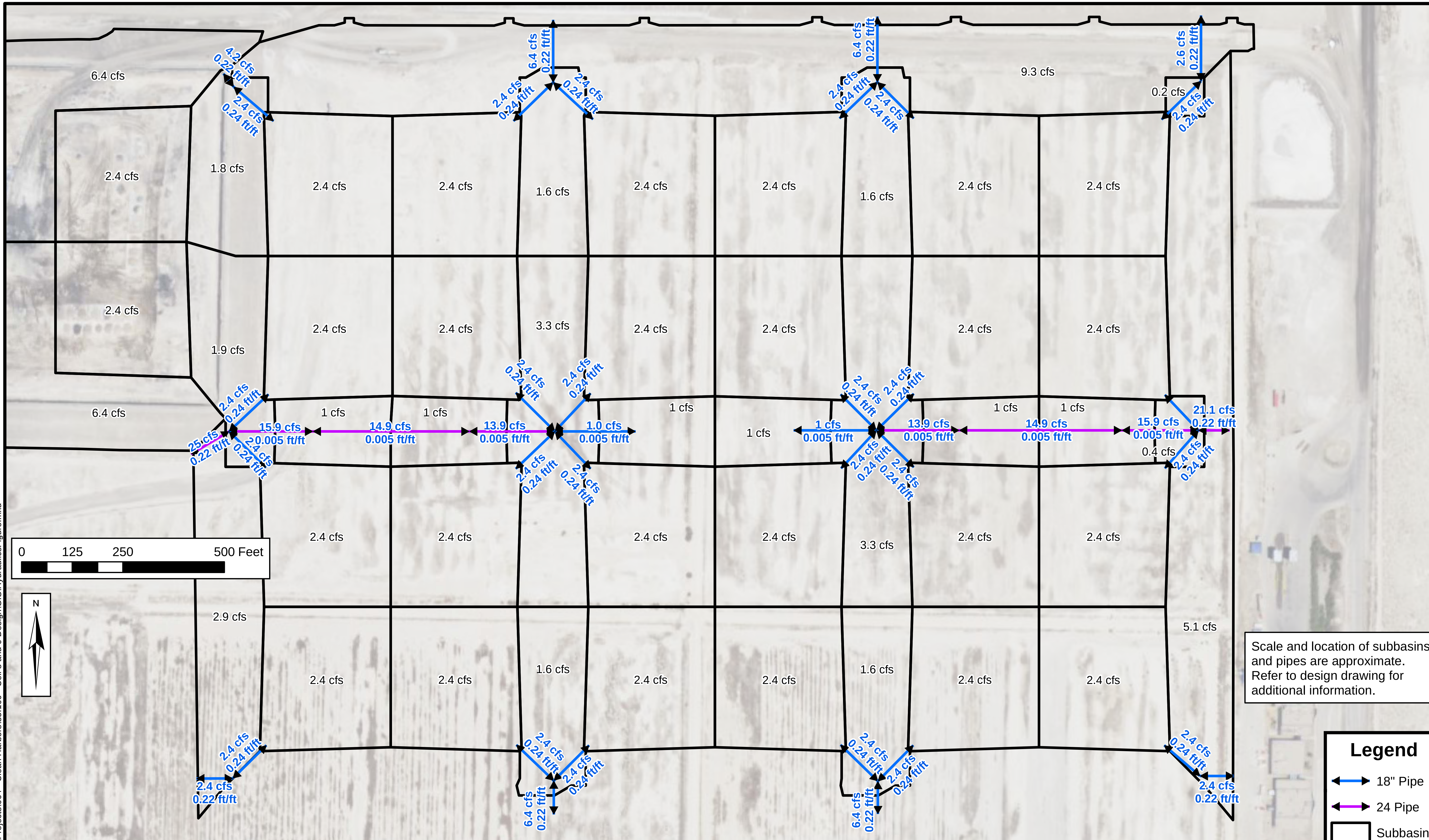
10/07

STORM WATER DRAINAGE

CleanHarbors® ENVIRONMENTAL SERVICES, INC.

FIGURE 2



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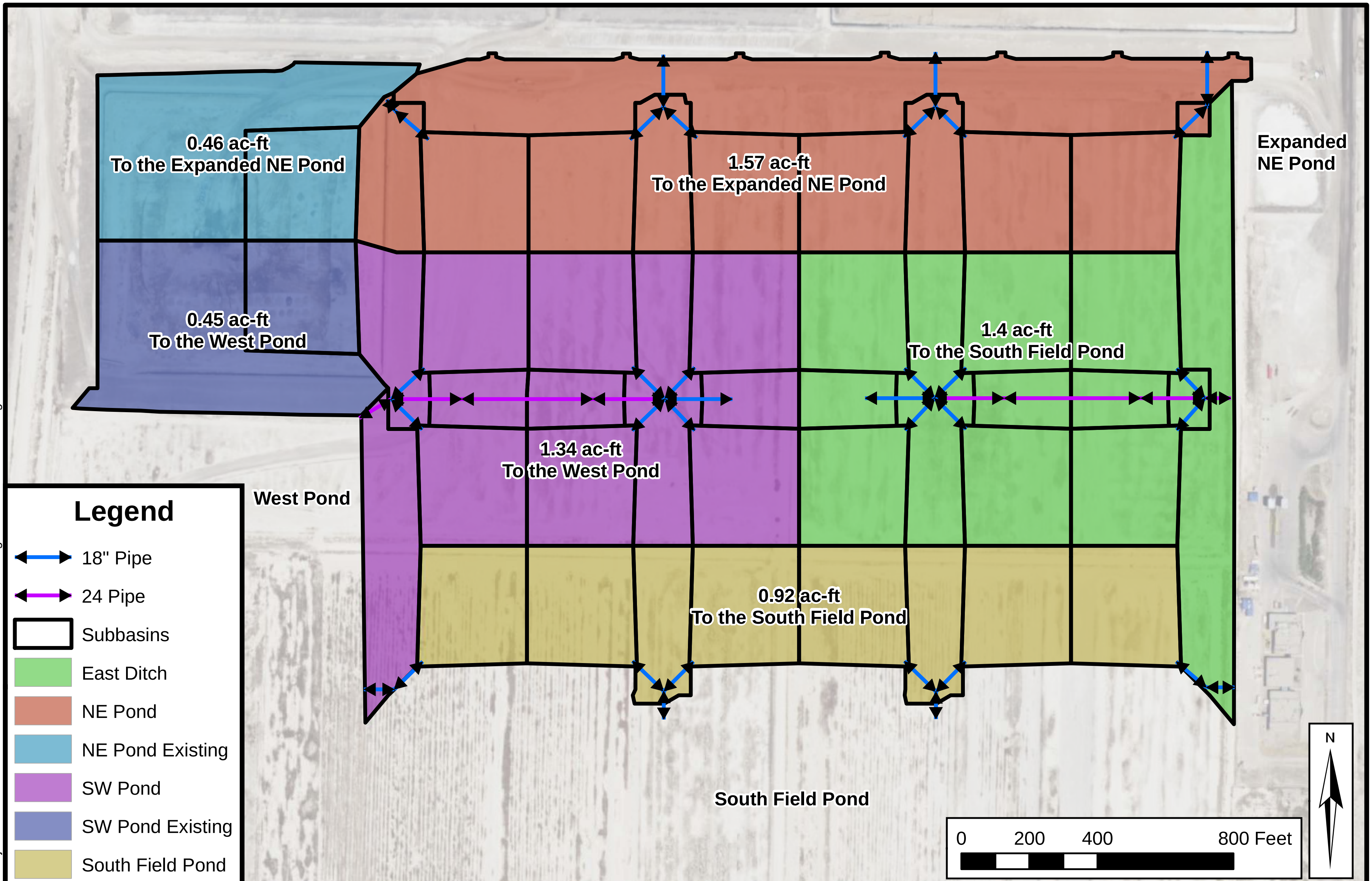
CLEAN HARBORS - GRASSY MOUNTAIN FACILITY
CELLS 8-13 HYDROLOGY

HYDRAULICS

FIGURE 3



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CLEAN HARBORS
GRASSY MOUNTAIN FACILITY
CELLS 8-13 HYDROLOGY

RUNOFF VOLUMES

FIGURE
4

Date: 9/27/2017
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Clean Harbors Cells 8 and 9
Lag Time Calculations
Computed: JGH
9/19/2017

Sheet flow

Subbasin Name	Manning N	Flow Length (ft)	Design rainfall (in)	High Elevation	Low Elevation	Slope (ft/ft)	Tt (hr)
Quadrants	0.015	300	0.9	4306.0	4290.9	0.05	0.080
Centers	0.015	81	0.9	4292.9	4267.0	0.32	0.013
NS Margins	0.015	81	0.9	4292.9	4267.0	0.32	0.013
North	0.015	160	0.9	4292.8	4244.0	0.31	0.024
Center Margins	0.015	81	0.9	4292.9	4267.0	0.32	0.013
East	0.015	162	0.9	4292.7	4244.0	0.30	0.024
9CW	0.015	169	0.9	4292.0	4240.0	0.31	0.025

Equation Used:

$$T_t = \frac{0.007(nL)^{0.8}}{(P_2)^{0.5} s^{0.4}} \qquad \text{[eq. 3-3]}$$

where:

T_t = travel time (hr),
n = Manning's roughness coefficient (table 3-1)
L = flow length (ft)
P_2 = 2-year, 24-hour rainfall (in)
s = slope of hydraulic grade line (land slope, ft/ft)

Channel Flow

Subbasin Name	Manning N*	Flow Length (ft)	High Elevation	Low Elevation	Slope (ft/ft)	Hydraulic Radius	Velocity (ft/s)	Tt (hr)
Quadrants	0.033	344.0	4290.9	4287.5	0.01	1.5	5.88	0.016
Centers	0.033	433	4,271	4,267	0.010	1.5	5.83	0.021
NS Margins	0.033	433	4,271	4,267	0.010	1.5	5.83	0.021
North	0.033	2,386	4244.2	4241.2	0.001	4.4	4.29	0.154
Center Margins	0.033	185	4268.8	4267.0	0.010	1.5	5.84	0.009
East	0.033	1,896	NA	NA	0.001	4.4	3.83	0.138
9CW	0.033	520	4240.0	NA	0.001	2	2.27	0.064

Equation used:

$$V = \frac{1.49 r^{\frac{2}{3}} s^{\frac{1}{2}}}{n} \qquad \text{[eq. 3-4]}$$

where:

V = average velocity (ft/s)
r = hydraulic radius (ft) and is equal to a/p_w
a = cross sectional flow area (ft^2)
p_w = wetted perimeter (ft)
s = slope of the hydraulic grade line (channel slope, ft/ft)
n = Manning's roughness coefficient for open channel flow.

Results:

Subbasin Name	Tc (hr)	Tl (hr)	Lag Time (min)	Model Lag Time (min)
Quadrants	0.097	0.058	3.48	3.60
Centers	0.034	0.020	1.23	3.60
NS Margins	0.034	0.020	1.23	3.60
North	0.178	0.107	6.41	6.41
Center Margins	0.022	0.013	0.80	3.60
East	0.162	0.097	5.82	5.82
9CW	0.088	0.053	3.18	3.60

Clean Harbors Cells 8 and 9
Pipe Capacity Calculations
Computed: JGH
9/21/2017

Pipe Capacity with Mannings Equation

Pipe	Description	Design Flow	Diameter		Pipe Capacity	Area	Wetted Perimeter	Slope	k	Mannings n*
					Q	A	P	S		
		cfs	in	ft	cfs	ft^2	ft	ft/ft		
P1	Cell Quadrants	**2.4**	18	1.5	**51.46**	1.77	4.71	0.24	1.486	0.013
P2	2 Quads and margin	**6.4**	18	1.5	**49.27**	1.77	4.71	0.22	1.486	0.013
P3	Center line 1	**1**	18	1.5	**7.43**	1.77	4.71	0.005	1.486	0.013
P4	Center line 2	**13.9**	24	2	**16.00**	3.14	6.28	0.005	1.486	0.013
P5	Center line 3	**14.9**	24	2	**16.00**	3.14	6.28	0.005	1.486	0.013
P6	Center line 4	**15.9**	24	2	**16.00**	3.14	6.28	0.005	1.486	0.013
P7	Center line 5	**25**	24	2	**106.11**	3.14	6.28	0.22	1.486	0.013
P8	East center	**21.1**	24	2	**106.11**	3.14	6.28	0.22	1.486	0.013
P9	South ditch	**6.4**	15	1.3	**30.30**	1.23	3.93	0.22	1.486	0.013

*Mannings n reflects values for cement pipe.

Mannings Equation: $Q = \frac{k}{n} A \left(\frac{A}{P}\right)^{2/3} S^{1/2}$

NOAA ATLAS 14 POINT PRECIPITATION FREQUENCY ESTIMATES: UT

Data description

Data type: Precipitation depth **Units:** English **Time series type:** Partial duration

Select location

1) Manually:

a) By location (decimal degrees, use "-" for S and W): Latitude: Longitude: Submit

b) By station (list of UT stations): Select station

c) By address Search

2) Use map (if ESRI interactive map is not loading, try adding the host: **https://js.arcgis.com/** to the firewall, or contact us at hdsc.questions@noaa.gov):

a) Select location
Move crosshair or double click

b) Click on station icon
Show stations on map

Location information:
Name: Wendover, Utah, USA*
Latitude: 40.8145°
Longitude: -113.2050°
Elevation: 4236.05 ft **

* Source: ESRI Maps
** Source: USGS

POINT PRECIPITATION FREQUENCY (PF) ESTIMATES

WITH 90% CONFIDENCE INTERVALS AND SUPPLEMENTARY INFORMATION
NOAA Atlas 14, Volume 1, Version 5

PF tabular PF graphical Supplementary information Print page

PDS-based precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	**0.093** (0.080-0.110)	**0.118** (0.102-0.140)	**0.165** (0.143-0.195)	**0.209** (0.179-0.246)	**0.283** (0.235-0.334)	**0.350** (0.284-0.417)	**0.432** (0.339-0.517)	**0.526** (0.398-0.640)	**0.677** (0.489-0.840)	**0.812** (0.563-1.02)
10-min	**0.142** (0.122-0.167)	**0.180** (0.156-0.212)	**0.252** (0.217-0.297)	**0.318** (0.272-0.375)	**0.430** (0.358-0.508)	**0.533** (0.432-0.634)	**0.656** (0.516-0.787)	**0.801** (0.606-0.974)	**1.03** (0.744-1.28)	**1.24** (0.857-1.56)
15-min	**0.176** (0.151-0.208)	**0.223** (0.193-0.263)	**0.312** (0.269-0.368)	**0.395** (0.337-0.465)	**0.533** (0.444-0.630)	**0.661** (0.536-0.786)	**0.814** (0.640-0.975)	**0.992** (0.752-1.21)	**1.28** (0.922-1.58)	**1.53** (1.06-1.93)
30-min	**0.237** (0.204-0.280)	**0.301** (0.260-0.355)	**0.420** (0.363-0.495)	**0.531** (0.454-0.626)	**0.718** (0.597-0.848)	**0.890** (0.721-1.06)	**1.10** (0.862-1.31)	**1.34** (1.01-1.63)	**1.72** (1.24-2.13)	**2.06** (1.43-2.60)
60-min	**0.293** (0.252-0.346)	**0.372** (0.322-0.439)	**0.519** (0.449-0.613)	**0.658** (0.562-0.774)	**0.889** (0.739-1.05)	**1.10** (0.892-1.31)	**1.36** (1.07-1.63)	**1.65** (1.25-2.01)	**2.13** (1.54-2.64)	**2.55** (1.77-3.21)
2-hr	**0.359** (0.319-0.415)	**0.451** (0.400-0.521)	**0.597** (0.527-0.689)	**0.735** (0.643-0.846)	**0.961** (0.819-1.11)	**1.17** (0.970-1.36)	**1.41** (1.14-1.67)	**1.70** (1.32-2.04)	**2.16** (1.60-2.65)	**2.58** (1.82-3.23)
3-hr	**0.405** (0.364-0.460)	**0.502** (0.449-0.574)	**0.648** (0.578-0.733)	**0.777** (0.689-0.879)	**0.987** (0.858-1.12)	**1.18** (0.999-1.38)	**1.43** (1.17-1.68)	**1.72** (1.36-2.06)	**2.18** (1.65-2.68)	**2.60** (1.89-3.26)
6-hr	**0.495** (0.451-0.548)	**0.608** (0.553-0.677)	**0.761** (0.692-0.846)	**0.895** (0.808-0.995)	**1.09** (0.973-1.22)	**1.26** (1.10-1.42)	**1.46** (1.25-1.70)	**1.74** (1.43-2.08)	**2.21** (1.73-2.71)	**2.63** (2.00-3.29)
12-hr	**0.582**	**0.716**	**0.885**	**1.02**	**1.22**	**1.38**	**1.55**	**1.75**	**2.23**	**2.66**

	(0.534-0.640)	(0.656-0.790)	(0.810-0.974)	(0.932-1.12)	(1.10-1.35)	(1.23-1.53)	(1.36-1.74)	(1.51-2.11)	(1.74-2.74)	(2.02-3.33)
24-hr	**0.743** (0.677-0.822)	**0.920** (0.837-1.02)	**1.13** (1.02-1.24)	**1.29** (1.17-1.42)	**1.51** (1.37-1.66)	**1.68** (1.52-1.85)	**1.85** (1.66-2.04)	**2.02** (1.81-2.24)	**2.25** (1.99-2.76)	**2.68** (2.13-3.36)
2-day	**0.803** (0.733-0.885)	**0.989** (0.905-1.09)	**1.20** (1.10-1.32)	**1.37** (1.25-1.50)	**1.59** (1.45-1.74)	**1.75** (1.59-1.93)	**1.92** (1.73-2.11)	**2.08** (1.88-2.30)	**2.29** (2.05-2.79)	**2.71** (2.18-3.39)
3-day	**0.863** (0.790-0.947)	**1.06** (0.974-1.16)	**1.28** (1.18-1.40)	**1.46** (1.34-1.60)	**1.70** (1.56-1.85)	**1.88** (1.71-2.05)	**2.06** (1.87-2.25)	**2.24** (2.02-2.46)	**2.48** (2.22-2.86)	**2.79** (2.36-3.41)
4-day	**0.923** (0.847-1.01)	**1.14** (1.04-1.24)	**1.37** (1.26-1.49)	**1.56** (1.43-1.69)	**1.81** (1.66-1.97)	**2.01** (1.83-2.18)	**2.21** (2.00-2.40)	**2.41** (2.17-2.62)	**2.67** (2.39-2.93)	**2.87** (2.55-3.43)
7-day	**1.02** (0.938-1.12)	**1.26** (1.15-1.37)	**1.51** (1.38-1.64)	**1.70** (1.56-1.85)	**1.96** (1.80-2.13)	**2.14** (1.96-2.33)	**2.33** (2.12-2.53)	**2.50** (2.28-2.73)	**2.72** (2.46-2.97)	**2.89** (2.59-3.46)
10-day	**1.11** (1.01-1.23)	**1.37** (1.25-1.51)	**1.64** (1.50-1.80)	**1.85** (1.69-2.03)	**2.12** (1.94-2.32)	**2.32** (2.12-2.54)	**2.50** (2.28-2.75)	**2.68** (2.44-2.95)	**2.89** (2.62-3.19)	**3.03** (2.74-3.50)
20-day	**1.33** (1.21-1.46)	**1.63** (1.49-1.80)	**1.96** (1.80-2.15)	**2.21** (2.02-2.41)	**2.51** (2.30-2.74)	**2.72** (2.49-2.98)	**2.92** (2.67-3.20)	**3.10** (2.83-3.39)	**3.30** (3.01-3.62)	**3.43** (3.13-3.77)
30-day	**1.49** (1.36-1.64)	**1.83** (1.67-2.01)	**2.19** (2.00-2.39)	**2.44** (2.24-2.67)	**2.77** (2.54-3.02)	**2.99** (2.74-3.26)	**3.21** (2.93-3.50)	**3.39** (3.09-3.71)	**3.61** (3.28-3.96)	**3.74** (3.40-4.12)
45-day	**1.76** (1.62-1.93)	**2.16** (1.98-2.35)	**2.55** (2.35-2.76)	**2.82** (2.61-3.05)	**3.14** (2.92-3.38)	**3.34** (3.12-3.59)	**3.51** (3.28-3.75)	**3.62** (3.40-3.86)	**3.68** (3.50-4.00)	**3.78** (3.53-4.16)
60-day	**2.01** (1.85-2.20)	**2.46** (2.26-2.68)	**2.89** (2.67-3.14)	**3.22** (2.97-3.47)	**3.60** (3.34-3.88)	**3.85** (3.58-4.14)	**4.07** (3.78-4.36)	**4.23** (3.95-4.53)	**4.36** (4.11-4.67)	**4.39** (4.17-4.69)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Estimates from the table in CSV format: Precipitation frequency estimates Submit

Client	*Clean Harbors*	Sheet	
Project	*Landfill Cells 8 - 13 Design*	Comp.	*KCS*
Feature	*North Storm Drainage Channel*	Chck'd	
Project #	*064.85.100*	Date	*30-Oct-17*

HANSEN ALLEN & LUCE INC ENGINEERS

Trapezoidal Channel Flow Calculations

GENERAL CRITERIA:

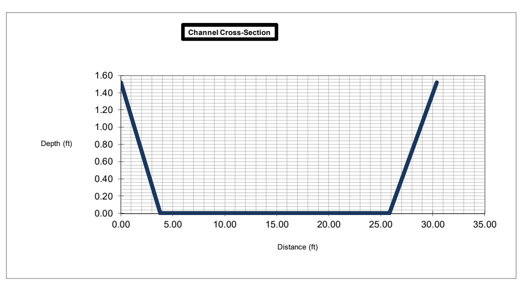
	Design Flow:	45.00	cfs
	Bottom Width:	22.0	feet
	Side Slope1:	2.5	m1
	Side Slope2:	3.0	m2
	Friction Factor:		
	Assumed D50:	0.1	
Anderson et al. (1970)	If X=1, n=0.0395(D50)^1/6		
Abt. et al. (1987, 1988)	If X=2, n=0.0456(D50*S)^0.0159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	Generally Applicable for R/D50 > 0.5		
Jarrett (1984)	If X=4, n=0.39*(S^0.38)*(R^0.16)		
	If X=5, n=input n value		
	X:	1	
	Input n Value when X=5:	0.025	
	Calc (used) n Value:	0.025	
	Min. Bottom Slope:	0.001	ft/ft
	Max. Bottom Slope:	0.001	ft/ft
	Freeboard:	0.5	feet

Depth (Min. Slope):	1.02	feet
Q-1.49AR(2/3)S(1/2)/n=	-0.114	Accuracy
Required Depth:	1.52	feet
Area:	25.30	ft2
Perimeter:	27.97	feet
Hydraulic Radius:	0.90	feet
Velocity:	1.78	ft/sec
Froude Number:	0.33	

Depth (Max. Slope):	0.43	feet
Q-1.49AR(2/3)S(1/2)/n=	34.507	Accuracy
Required Depth:	0.93	feet
Area:	10.01	ft2
Perimeter:	24.53	feet
Hydraulic Radius:	0.41	feet
Velocity:	4.50	ft/sec
Froude Number:	1.24	

Channel Design Summary:

Bottom Width:	22.00	feet
Side Slope1:	2.50	1/m1
Side Slope2:	3.00	1/m2
Min. Bottom Slope:	0.001	ft/ft
Max. Bottom Slope:	0.001	ft/ft
Min. Channel Depth:	1.52	feet
Channel Top Width:	30.36	feet



Channel Cross Section

HANSEN ALLEN & LUCE INC
ENGINEERS

Client	*Clean Harbors*	Sheet	
Project	*Landfill Cells 8 - 13 Design*	Comp.	*KCS*
Feature	*North Storm Drainage Channel*	Chck'd	
Project #	*064.85.100*	Date	*30-Oct-17*

Trapezoidal Channel Flow Calculations

GENERAL CRITERIA:

Design Flow:	45.00	cfs
Bottom Width:	5.0	feet
Side Slope1:	2.5	m1
Side Slope2:	3.0	m2
Friction Factor:		
Assumed D50:	0.1	

Anderson et al. (1970) If X=1, n=0.0395(D50)^1/6
Abt. et al. (1987, 1988) If X=2, n=0.0456(D50*S)^0.0159
If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}
Generally Applicable for R/D50 > 0.5
Jarrett (1984) If X=4, n=0.39*(S^0.38)*(R^0.16)
If X=5, n=input n value

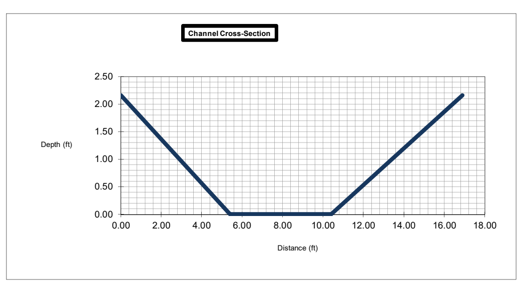
X:	1	
Input n Value when X=5:	0.025	
Calc (used) n Value:	0.025	
Min. Bottom Slope:	0.002	ft/ft
Max. Bottom Slope:	0.002	ft/ft
Freeboard:	0.5	feet

Depth (Min. Slope):	1.66	feet
Q-1.49AR(2/3)S(1/2)/n=	-0.028	Accuracy
Required Depth:	2.16	feet
Area:	15.88	ft2
Perimeter:	14.72	feet
Hydraulic Radius:	1.08	feet
Velocity:	2.83	ft/sec
Froude Number:	0.47	

Depth (Max. Slope):	1.66	feet
Q-1.49AR(2/3)S(1/2)/n=	-0.028	Accuracy
Required Depth:	2.16	feet
Area:	15.88	ft2
Perimeter:	14.72	feet
Hydraulic Radius:	1.08	feet
Velocity:	2.83	ft/sec
Froude Number:	0.47	

Channel Design Summary:

Bottom Width:	5.00	feet
Side Slope1:	2.50	1/m1
Side Slope2:	3.00	1/m2
Min. Bottom Slope:	0.002	ft/ft
Max. Bottom Slope:	0.002	ft/ft
Min. Channel Depth:	2.16	feet
Channel Top Width:	16.88	feet



Channel Cross Section

HANSEN ALLEN & LUCE INC ENGINEERS	Client *Clean Harbors*	Sheet	
	Project *Landfill Cells 8 - 13 Design*	Comp.	*KCS*
	Feature *East Storm Drainage Channel and Pond Inlet*	Chck'd	
	Project # *064.85.100*	Date	*30-Oct-17*

Trapezoidal Channel Flow Calculations

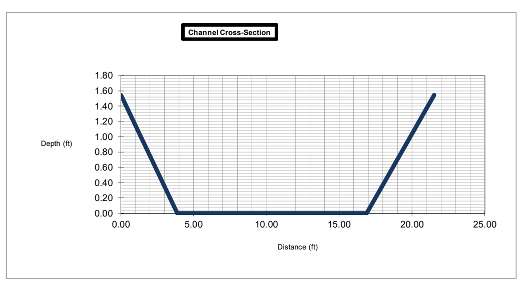
GENERAL CRITERIA:

	Design Flow:	29.00	cfs
	Bottom Width:	13.0	feet
	Side Slope1:	2.5	m1
	Side Slope2:	3.0	m2
	Friction Factor:		
	Assumed D50:	0.1	
Anderson et al. (1970)	If X=1, n=0.0395(D50)^1/6		
Abt. et al. (1987, 1988)	If X=2, n=0.0456(D50*S)^0.0159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	Generally Applicable for R/D50 > 0.5		
Jarrett (1984)	If X=4, n=0.39*(S^0.38)*(R^0.16)		
	If X=5, n=input n value		
	X:	1	
	Input n Value when X=5:	0.025	
	Calc (used) n Value:	0.025	
	Min. Bottom Slope:	0.001	ft/ft
	Max. Bottom Slope:	0.026	ft/ft
	Freeboard:	0.5	feet

Depth (Min. Slope):	1.05	feet
Q-1.49AR(2/3)S(1/2)/n=	-0.011	Accuracy
Required Depth:	1.55	feet
Area:	16.68	ft2
Perimeter:	19.15	feet
Hydraulic Radius:	0.87	feet
Velocity:	1.74	ft/sec
Froude Number:	0.33	
Depth (Max. Slope):	0.40	feet
Q-1.49AR(2/3)S(1/2)/n=	0.864	Accuracy
Required Depth:	0.90	feet
Area:	5.64	ft2
Perimeter:	15.34	feet
Hydraulic Radius:	0.37	feet
Velocity:	5.14	ft/sec
Froude Number:	1.49	

Channel Design Summary:

Bottom Width:	13.00	feet
Side Slope1:	2.50	1/m1
Side Slope2:	3.00	1/m2
Min. Bottom Slope:	0.001	ft/ft
Max. Bottom Slope:	0.026	ft/ft
Min. Channel Depth:	1.55	feet
Channel Top Width:	21.53	feet



Channel Cross Section

HANSEN ALLEN & LUCE INC ENGINEERS	Client *Clean Harbors*	Sheet	*of*
	Project *Landfill Cells 8 - 13 Design*	Comp.	*KCS*
	Feature *East Storm Drainage Channel and Pond Inlet*	Chck'd	
	Project # *064.85.100*	Date	*30-Oct-17*

DESIGN CRITERIA:

Design Flow:	29.00	cfs
Bottom Width:	13.00	feet
Side Slope1:	2.50	1/m1
Side Slope2:	3.00	1/m2
Friction Factor:	0.02	
Min. Bottom Slope:	0.1	%
Max. Bottom Slope:	2.6	%
Flow Depth (Min. S):	1.05	feet
Flow Depth (Max. S):	0.40	feet
Angle Repose (Ar):	42.0	degrees
Specific Gravity	2.65	

Reynolds No. = U*D50/v, where U=Shear Velocity, v=viscosity

U=(gRS)^0.5 for Smin	0.17	
Reynolds # for Smin	718	
U=(gRS)^0.5 for Smax	0.55	
Reynolds # for Smax	2,378	

T = G*d*S where G=Unit weight of Water

Nb = F*T/(G(SD-1)D50)

F=(1/0.047)=21.3 for flat slopes with Reynolds No. < 500

F=(1/0.062)=16.1 for 500 < Reynolds No. < 40,000

F=varies from (1/0.062)=16.1 for Reynolds No. = 40,000 to

(1/0,25)=4 for Reynolds No. = 500,000 or larger

K for S min (See K vs. R Chart)	0.047	
K for S max (See K vs. R Chart)	0.062	
F for S min	16.1	
F for S max	16.1	

SFb = (Cos a tan b)/(sin a + Nb tan b)

Tmax= Ks*G*d*S

Set Ks=0.75 for 1.5:1 slope, 0.76 for 2:1 slope, and 0.85 for 3:1 slope

Ks: 0.76

Ns = F*Tmax/(G(SG-1)D)

A = Atan(1/m)

B = Atan(Cos(Ar)/(2Sin(A)/NsTan)Ar))+Sin(Ar))

Nsp = Ns(1+Sin(Ar+B)/2)

SFs = Cos(A)Tan(Ar)/(nTan(Ar)+Sin(A)Cos(B))

RIPRAP DESIGN:

	Smin	Smax	
D50	0.02	0.25	feet
T	0.07	0.65	lb/ft2
Nb	0.51	0.41	
Tmax	0.05	0.49	lb/ft2
Ns	0.39	0.31	
m Critical	2.50	2.50	
A (m crit)	21.80	21.80	degrees
B	25.29	20.35	degrees
Nsp	0.28	0.21	
SFb	1.94	2.30	
SFs	1.43	1.55	

Client	*Clean Harbors*	Sheet	
Project	*Landfill Cells 8 - 13 Design*	Comp.	*KCS*
Feature	*West Storm Drainage North Pond Inlet Channel*	Chck'd	
Project #	*064.85.100*	Date	*30-Oct-17*

Trapezoidal Channel Flow Calculations

GENERAL CRITERIA:

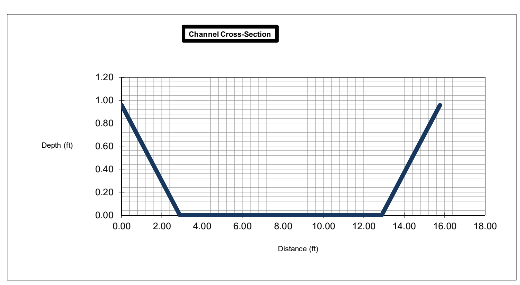
	Design Flow:	25.00	cfs
	Bottom Width:	10.0	feet
	Side Slope1:	3.0	m1
	Side Slope2:	3.0	m2
	Friction Factor:		
	Assumed D50:	0.1	
Anderson et al. (1970)	If X=1, n=0.0395(D50)^1/6		
Abt. et al. (1987, 1988)	If X=2, n=0.0456(D50*S)^0.0159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	Generally Applicable for R/D50 > 0.5		
Jarrett (1984)	If X=4, n=0.39*(S^0.38)*(R^0.16)		
	If X=5, n=input n value		
	X:	1	
	Input n Value when X=5:	0.025	
	Calc (used) n Value:	0.025	
	Min. Bottom Slope:	0.021	ft/ft
	Max. Bottom Slope:	0.021	ft/ft
	Freeboard:	0.5	feet

Depth (Min. Slope):	0.46	feet
Q-1.49AR(2/3)S(1/2)/n=	-0.056	Accuracy
Required Depth:	0.96	feet
Area:	5.23	ft2
Perimeter:	12.91	feet
Hydraulic Radius:	0.41	feet
Velocity:	4.78	ft/sec
Froude Number:	1.31	

Depth (Max. Slope):	0.46	feet
Q-1.49AR(2/3)S(1/2)/n=	-0.056	Accuracy
Required Depth:	0.96	feet
Area:	5.23	ft2
Perimeter:	12.91	feet
Hydraulic Radius:	0.41	feet
Velocity:	4.78	ft/sec
Froude Number:	1.31	

Channel Design Summary:

Bottom Width:	10.00	feet
Side Slope1:	3.00	1/m1
Side Slope2:	3.00	1/m2
Min. Bottom Slope:	0.021	ft/ft
Max. Bottom Slope:	0.021	ft/ft
Min. Channel Depth:	0.96	feet
Channel Top Width:	15.76	feet



Channel Cross Section

Client	*Clean Harbors*	Sheet	*of*
Project	*Landfill Cells 8 - 13 Design*	Comp.	*KCS*
Feature	*West Storm Drainage North Pond Inlet Channel*	Chck'd	
Project #	*064.85.100*	Date	*30-Oct-17*

DESIGN CRITERIA:

Design Flow:	25.00	cfs
Bottom Width:	10.00	feet
Side Slope1:	3.00	1/m1
Side Slope2:	3.00	1/m2
Friction Factor:	0.02	
Min. Bottom Slope:	2.1	%
Max. Bottom Slope:	2.1	%
Flow Depth (Min. S):	0.46	feet
Flow Depth (Max. S):	0.46	feet
Angle Repose (Ar):	42.0	degrees
Specific Gravity	2.65	

Reynolds No. = U*D50/v, where U=Shear Velocity, v=viscosity

U=(gRS)^0.5 for Smin	0.52	
Reynolds # for Smin	2,244	
U=(gRS)^0.5 for Smax	0.52	
Reynolds # for Smax	2,244	

T = G*d*S where G=Unit weight of Water

Nb = F*T/(G(SD-1)D50)

F=(1/0.047)=21.3 for flat slopes with Reynolds No. < 500

F=(1/0.062)=16.1 for 500 < Reynolds No. < 40,000

F=varies from (1/0.062)=16.1 for Reynolds No. = 40,000 to (1/0,25)=4 for Reynolds No. = 500,000 or larger

K for S min (See K vs. R Chart)	0.062
K for S max (See K vs. R Chart)	0.062
F for S min	16.1
F for S max	16.1

SFb = (Cos a tan b)/(sin a + Nb tan b)

Tmax= Ks*G*d*S

Set Ks=0.75 for 1.5:1 slope, 0.76 for 2:1 slope, and 0.85 for 3:1 slope

Ks: 0.85

Ns = F*Tmax/(G(SG-1)D)

A = Atan(1/m)

B = Atan(Cos(Ar)/(2Sin(A)/NsTan)Ar))+Sin(Ar))

Nsp = Ns(1+Sin(Ar+B)/2)

SFs = Cos(A)Tan(Ar)/(nTan(Ar)+Sin(A)Cos(B))

RIPRAP DESIGN:

	Smin	Smax	
D50	0.18	0.25	feet
T	0.60	0.60	lb/ft2
Nb	0.52	0.38	
Tmax	0.51	0.51	lb/ft2
Ns	0.45	0.32	
m Critical	3.00	3.00	
A (m crit)	18.44	18.44	degrees
B	32.06	24.35	degrees
Nsp	0.35	0.23	
SFb	1.82	2.49	
SFs	1.48	1.73	

Client	*Clean Harbors*	Sheet	
Project	*Landfill Cells 8 - 13 Design*	Comp.	*KCS*
Feature	*West Storm Drainage South Pond Inlet Channel*	Chck'd	
Project #	*064.85.100*	Date	*30-Oct-17*

HANSEN ALLEN & LUCE INC ENGINEERS

Trapezoidal Channel Flow Calculations

GENERAL CRITERIA:

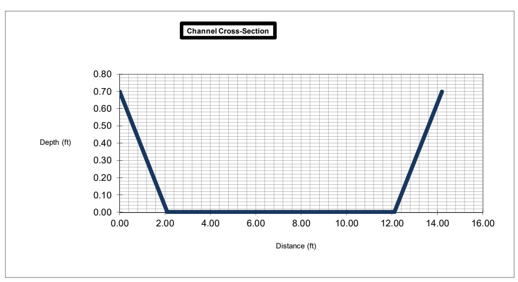
	Design Flow:	5.00	cfs
	Bottom Width:	10.0	feet
	Side Slope1:	3.0	m1
	Side Slope2:	3.0	m2
	Friction Factor:		
	Assumed D50:	0.1	
Anderson et al. (1970)	If X=1, n=0.0395(D50)^1/6		
Abt. et al. (1987, 1988)	If X=2, n=0.0456(D50*S)^0.0159		
	If X=3, n={D50^1/6*(R/D50)^1/6}/{3.82*[2.25+5.23*LOG(R/D50)]}		
	Generally Applicable for R/D50 > 0.5		
Jarrett (1984)	If X=4, n=0.39*(S^0.38)*(R^0.16)		
	If X=5, n=input n value		
	X:	1	
	Input n Value when X=5:	0.025	
	Calc (used) n Value:	0.025	
	Min. Bottom Slope:	0.015	ft/ft
	Max. Bottom Slope:	0.015	ft/ft
	Freeboard:	0.5	feet

Depth (Min. Slope):	0.20	feet
Q-1.49AR(2/3)S(1/2)/n=	-0.141	Accuracy
Required Depth:	0.70	feet
Area:	2.12	ft2
Perimeter:	11.26	feet
Hydraulic Radius:	0.19	feet
Velocity:	2.36	ft/sec
Froude Number:	0.96	

Depth (Max. Slope):	0.20	feet
Q-1.49AR(2/3)S(1/2)/n=	-0.141	Accuracy
Required Depth:	0.70	feet
Area:	2.12	ft2
Perimeter:	11.26	feet
Hydraulic Radius:	0.19	feet
Velocity:	2.36	ft/sec
Froude Number:	0.96	

Channel Design Summary:

Bottom Width:	10.00	feet
Side Slope1:	3.00	1/m1
Side Slope2:	3.00	1/m2
Min. Bottom Slope:	0.015	ft/ft
Max. Bottom Slope:	0.015	ft/ft
Min. Channel Depth:	0.70	feet
Channel Top Width:	14.20	feet



Channel Cross Section

HY-8 Culvert Analysis Report
NORTH CHANNEL TO EMPTY POND

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Design Flow: 45 cfs

Table 1 - Summary of Culvert Flows at Crossing: North Channel to East Pond

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
4240.53	45.00	45.00	0.00	1
4241.00	71.39	71.39	0.00	Overtopping

Rating Curve Plot for Crossing: North Channel to East Pond

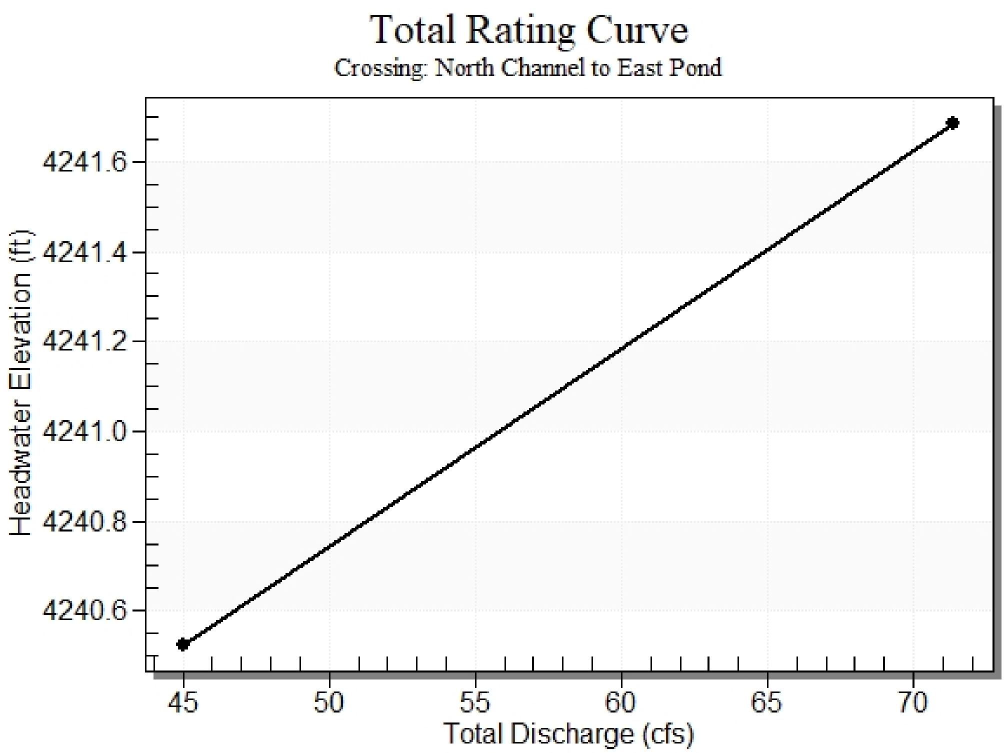


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
45.00	45.00	4240.53	2.181	3.026	4-FFf	0.973	1.392	2.000	1.013	4.775	2.222
45.00	45.00	4240.53	2.181	3.026	4-FFf	0.973	1.392	2.000	1.013	4.775	2.222

****

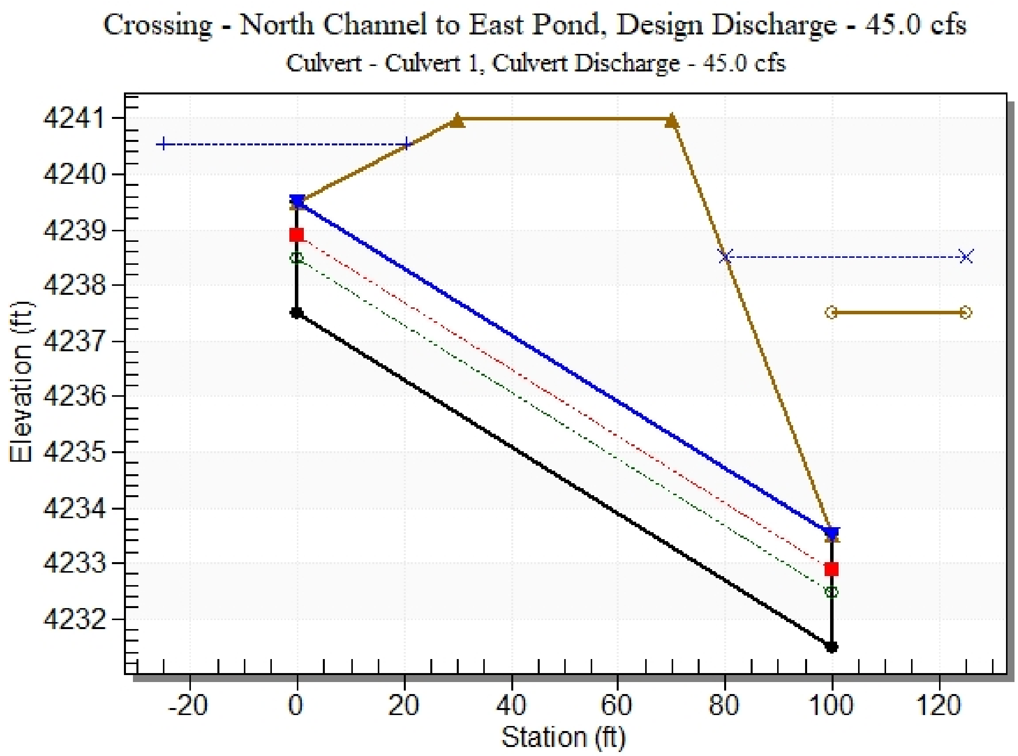
Straight Culvert

Inlet Elevation (invert): 4237.50 ft,   Outlet Elevation (invert): 4231.50 ft

Culvert Length: 100.18 ft,   Culvert Slope: 0.0600

****

Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4237.50 ft

Outlet Station: 100.00 ft

Outlet Elevation: 4231.50 ft

Number of Barrels: 3

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Corrugated PE

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: North Channel to East Pond)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
45.00	4238.51	1.01	2.22	0.06	0.39
45.00	4238.51	1.01	2.22	0.06	0.39

Tailwater Channel Data - North Channel to East Pond

Tailwater Channel Option: Rectangular Channel

Bottom Width: 20.00 ft

Channel Slope: 0.0010

Channel Manning's n: 0.0200

Channel Invert Elevation: 4237.50 ft

Roadway Data for Crossing: North Channel to East Pond

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 40.00 ft

Crest Elevation: 4241.00 ft

Roadway Surface: Gravel

Roadway Top Width: 40.00 ft

HY-8 Culvert Analysis Report
CULVERT FROM NORTH CHANNEL TO EAST CONTAINMENT POND

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Design Flow: 45 cfs

Table 1 - Summary of Culvert Flows at Crossing: North Channel to East Pond

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
4240.68	45.00	45.00	0.00	1
4241.00	48.03	48.03	0.00	Overtopping

Rating Curve Plot for Crossing: North Channel to East Pond

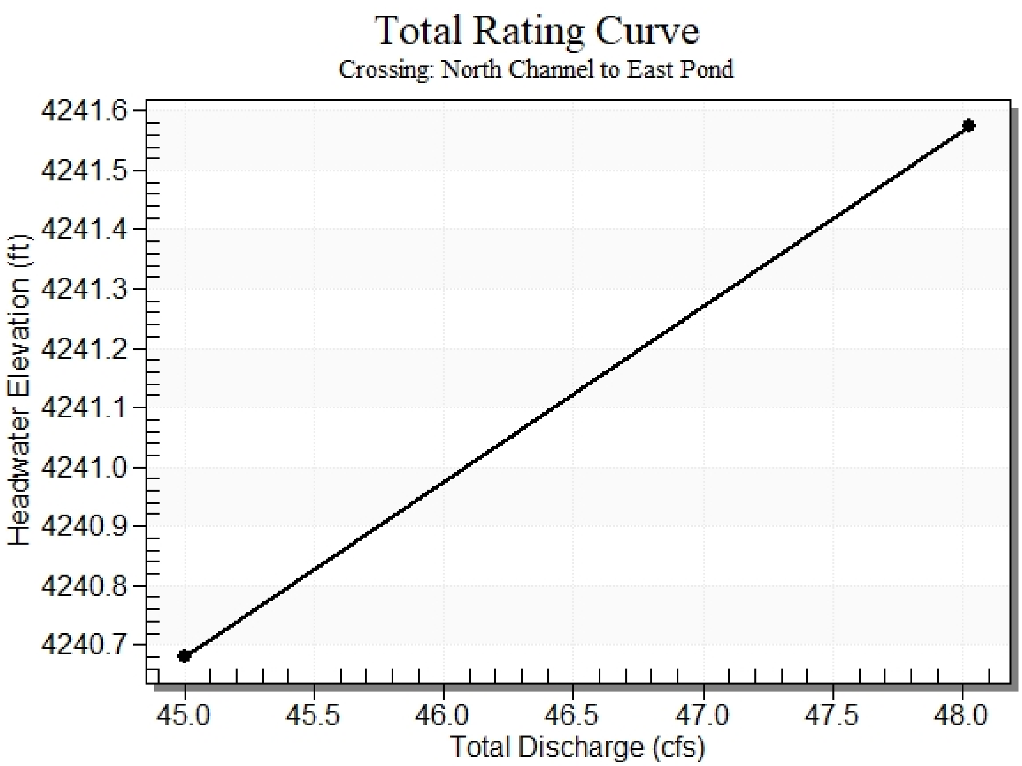


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
45.00	45.00	4240.68	2.236	3.181	7-M2t	2.000	1.392	1.513	1.013	5.884	2.222
45.00	45.00	4240.68	2.236	3.181	7-M2t	2.000	1.392	1.513	1.013	5.884	2.222

****

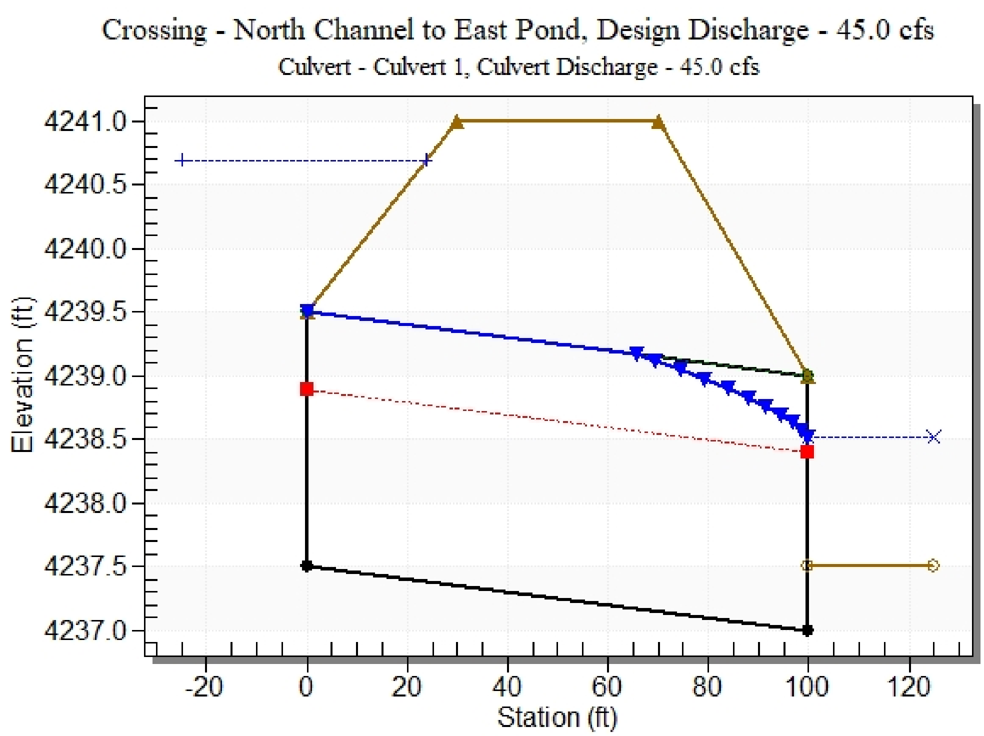
Straight Culvert

Inlet Elevation (invert): 4237.50 ft,   Outlet Elevation (invert): 4237.00 ft

Culvert Length: 100.00 ft,   Culvert Slope: 0.0050

****

Water Surface Profile Plot for Culvert: Culvert 1



Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4237.50 ft

Outlet Station: 100.00 ft

Outlet Elevation: 4237.00 ft

Number of Barrels: 3

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 2.00 ft

Barrel Material: Corrugated PE

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

Table 3 - Downstream Channel Rating Curve (Crossing: North Channel to East Pond)

Flow (cfs)	Water Surface Elev (ft)	Depth (ft)	Velocity (ft/s)	Shear (psf)	Froude Number
45.00	4238.51	1.01	2.22	0.06	0.39
45.00	4238.51	1.01	2.22	0.06	0.39

Roadway Data for Crossing: North Channel to East Pond

Roadway Profile Shape: Constant Roadway Elevation

Crest Length: 40.00 ft

Crest Elevation: 4241.00 ft

Roadway Surface: Gravel

Roadway Top Width: 40.00 ft

HY-8 Culvert Analysis Report
CLOSURE CAP DOWNSPOUTS

Crossing Discharge Data

Discharge Selection Method: Specify Minimum, Design, and Maximum Flow

Design Flow: 2.4 cfs

Table 1 - Summary of Culvert Flows at Crossing: Cap Downspouts

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
4287.19	2.40	2.40	0.00	1
4289.71	13.87	13.87	0.00	Overtopping

Rating Curve Plot for Crossing: Cap Downspouts

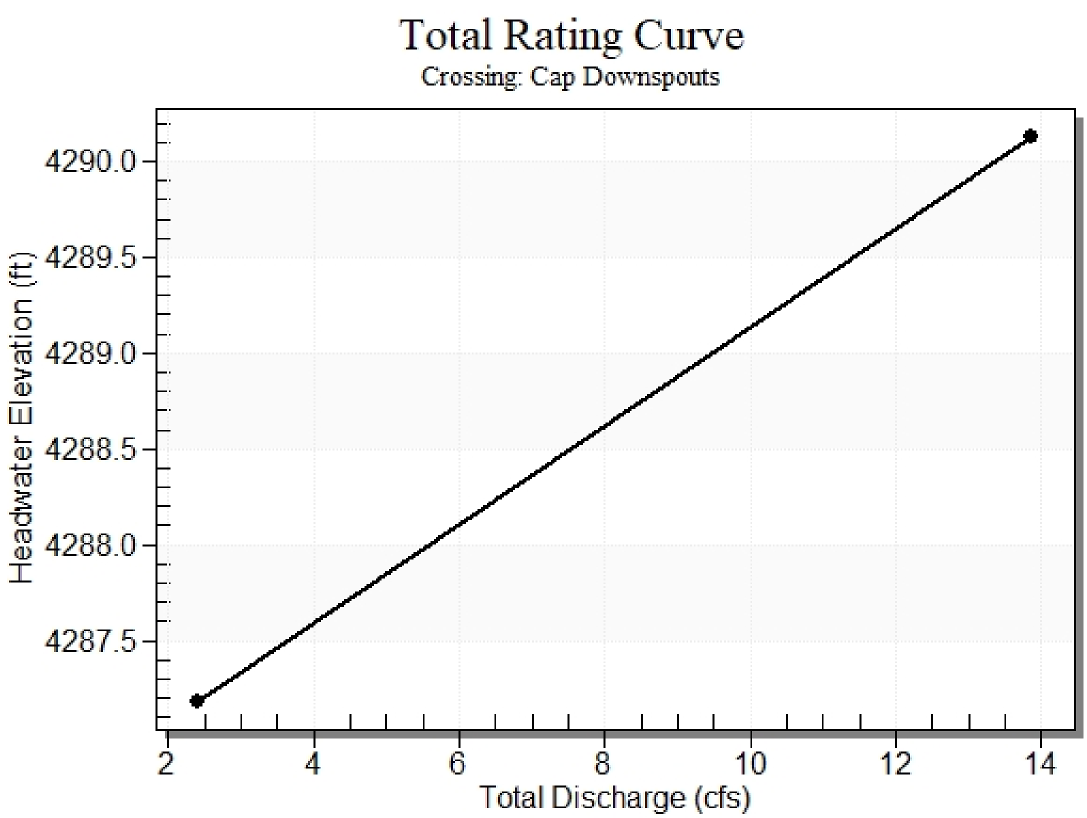


Table 2 - Culvert Summary Table: Culvert 1

Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Inlet Control Depth (ft)	Outlet Control Depth (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2.40	2.40	4287.19	0.647	0.0*	1-JS1f	0.278	0.582	1.500	0.568	1.358	2.480

* Full Flow Headwater elevation is below inlet invert.

****

Straight Culvert

Inlet Elevation (invert): 4286.54 ft,   Outlet Elevation (invert): 4264.00 ft

Culvert Length: 83.11 ft,   Culvert Slope: 0.2817

****

Site Data - Culvert 1

Site Data Option: Culvert Invert Data

Inlet Station: 0.00 ft

Inlet Elevation: 4286.54 ft

Outlet Station: 80.00 ft

Outlet Elevation: 4264.00 ft

Number of Barrels: 1

Culvert Data Summary - Culvert 1

Barrel Shape: Circular

Barrel Diameter: 1.50 ft

Barrel Material: Corrugated PE

Embedment: 0.00 in

Barrel Manning's n: 0.0240

Culvert Type: Straight

Inlet Configuration: Square Edge with Headwall

Inlet Depression: None

APPENDIX G

Erosion Protection Calculations

1. Purpose and Procedure.

The purpose of these calculations is determine which erosion protection to use for the proposed landfill Cells 8 – 13 and how to apply it. The closure cap will consist of a 3H:1V slope extending up from the top of the cell embankments. The embankments will consist of a 3H:1V slope from the top of the embankment down to the ground surface. The top of the closure cap will have a 5% slope.

The procedure used to determine the appropriate erosion protection is taken from the publication "Erosion and Sedimentation in Utah - A Guide for Control", Utah Water Research Laboratory, February 1984. This publication is specific to Utah. The cross-section and configuration the closure cap are shown in the drawings that accompany the Design Engineering Report and described herein. The degree of erosion protection required is based on the steepness and length of the slopes. Erosion protection measures will be determined for the longest slope length and the erosion control measures determined for the longest slope will be conservatively applied to all slopes. According to a 1991 Seminar Publication from the EPA entitled “Design and Construction of RCRA/CERCLA Final Covers”, the minimum criteria is a cover soil loss of less than 2 tons/acre/year. This same criteria will be applied to these calculations.

2. The procedure from the above publication uses the Universal Soil Loss Equation (in modified form to represent Utah's climatic and topographic conditions) to estimate the soil erosion potential of the surface soils assuming no application of erosion control measures. Erosion control measures to be implemented are based on the soil erosion potential calculated.

The universal soil loss equation used to calculate soil erosion potential is:

$$A = R * K * LS$$

where;

A	=	Computed amount of soil loss per unit area for the time interval represented by factor R, generally in tons per acre per year.
R	=	Rainfall (precipitation) factor.
K	=	Soil erodibility factor in tons per acre per year per unit of R.
LS	=	Topographic factor (length and steepness of slope).

Calculated erosion after applying erosion control measures is determined by applying and erosion control factor (VM) to the universal soil loss equation. The erosion control factor is dependent upon the type and extent to which the erosion control measure is used (ie. vegetative - type and density, mulches - type and thickness, chemical - type and application amount, mechanical - compactive effort, smoothness of surface, etc.).

a. The rainfall (precipitation) factor (*R*) is obtained from mean annual iso-erodent *R* value maps. The *R*-value for the facility as obtained from the Tooele area map is:

   R = 6

   Since R = 6 is based on an annual recurrence interval, a correction factor is obtained from the figure below for the 100-yr recurrence interval:

   R = 6(2.51) = 15.06

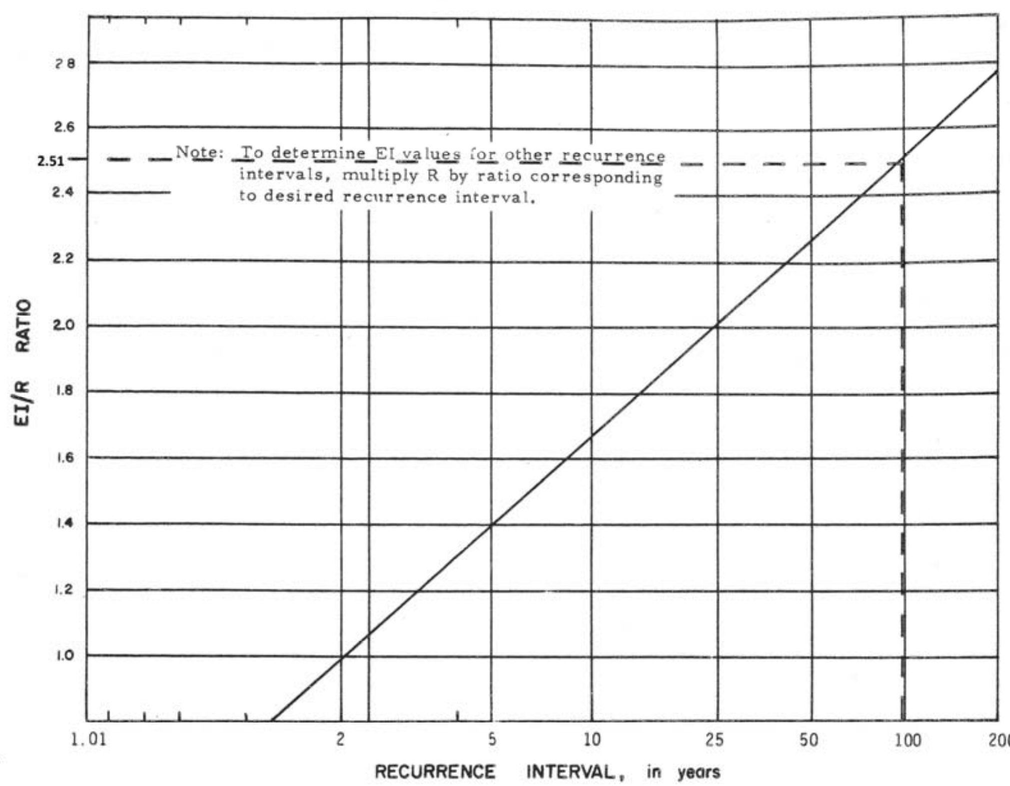
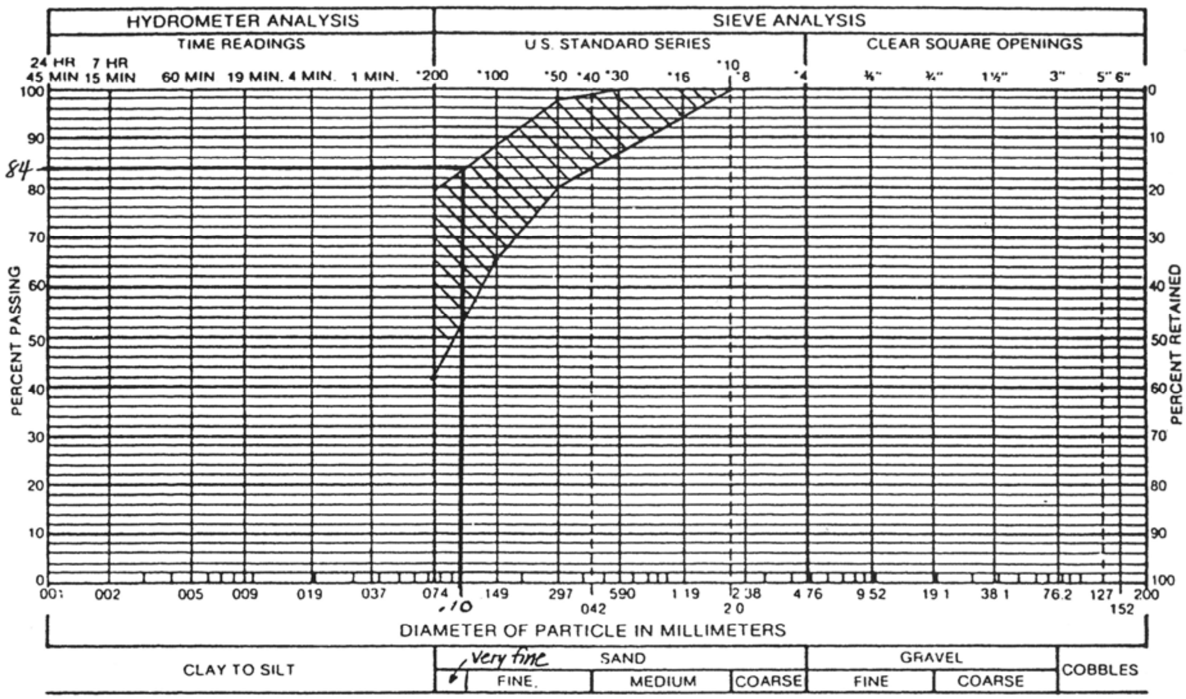


Figure 9. The relationship between the EI/R ratio and recurrence interval.

b. Soil erodibility factor (K) is determined using the figure on pages 3 and 4. The gradation of the materials is based on information from AGEC soil testing completed for a previous cell design project at the facility. Samples were taken at the borrow site and in depth hydrometer testing was performed. Information from the sample was used to determine K and is consistent with previous cell design at the facility.



Parameters obtained from the gradation envelopes of the sample and parameters assumed for use with the nomograph to determine K are:

- 84% silt + very fine sand
- 16% sand
- 0 % organic material assumed
- Very slow permeability assumed due to high clay content.

Applying the above parameters to the nomograph on Page 4 gives an average soil erodibility factor (K) equal to 0.72.

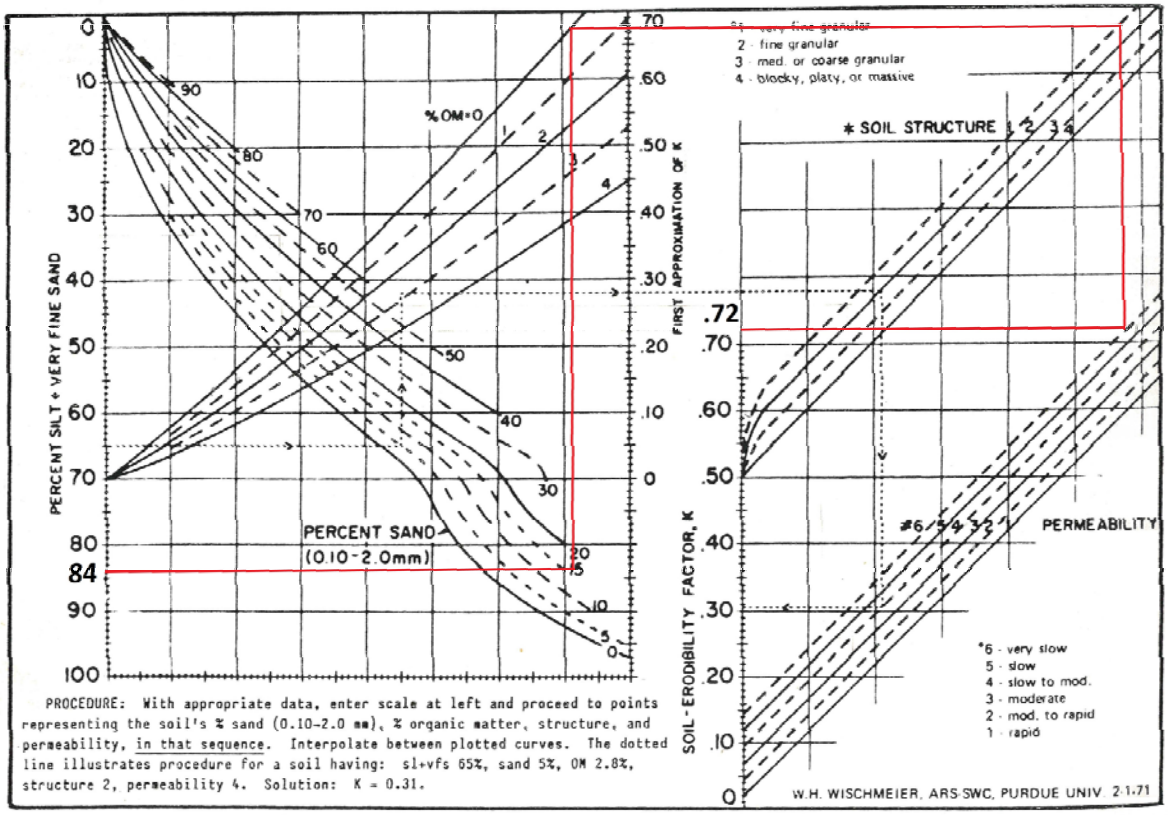


Figure 2. Nomograph for determining soil erodibility factor K.

c. The topographic factor (LS) is determined assuming single slopes. The closure cap slope is designed at 3H:1V. The LS factor is determined by the following equation:

$$LS = \left(\frac{65.41s^2}{s^2 + 10{,}000} + \frac{4.56s}{\sqrt{s^2 + 10{,}000}} + 0.065\right)\left(\frac{l}{72.6}\right)^m$$

where;

LS	=	topographic factor for slope segment n.
l	=	length of slope segment n.
s	=	slope gradient of segment n in percent.
m	=	slope gradient factor, which is: 0.2 for gradients of 0 to 1 percent 0.3 for gradients of 1 to 3 percent 0.4 for gradients of 3.5 to 4.5 percent 0.5 for gradients greater than 5 percent

The following table provides LS factor values for varying lengths of the 3H:1V slopes and potential erosion rates (A) assuming bare soils (without erosion protection measures) where R = 6 and K = 0.72.

SLOPE DESCRIPTION	HORIZONTAL DISTANCE ALONG SLOPE* (FT)	SLOPE LENGTH (FT)	SLOPE (%)	LS FACTOR	A (tons/ac/yr)
Top Slope	303.4	303.8	5	0.9	4.0
Side Slope	89.3	89.3	33.3	9.2	39.6

* The longest top slope and side slope, respectively, for Cells 8 – 13 was chosen for the erosion control basis for all cells.

In order to minimize erosion control protection required on the 3H:1V side slope due to continuous slope from the top slope a final cover a berm was designed along the perimeter of the top (5% slope) of the landfill closure to capture the runoff.

d. Required Stone Mulch Application Rates

Based on the established closure design used at Grassy Mountain in the past, a stone mulch was the only erosion control application that was considered. The amount of stone mulch material required to limit soil loss to one tone per acre per year is determined from the figure shown below. With no stone mulch cover the soil loss calculated above was 4 tons/ac/yr on the top slopes and 39.6 tons/ac/yr for the side slopes. These losses were reduced to 1 ton/ac/yr with the following application rates:

Top Slopes: The amount of soil loss associated with the top slopes of 4 tons/ac/yr is just off the graph of the figure shown below. Therefore, using the smallest value shown on the figure of 5 tons/ac/yr results in a total quantity of mulch of approximately 40 tons/acre. This is equivalent to:

T = (required tons/acre of gravel x 2,000 lbs/ton x 12 in/ft) / (43,560 sf/acre x gravel density lbs/cf)

Assume a gravel density of 110 lbs/cf

T = 40(2,000)(12)/(43,560)(110) = 0.2 inches

Clean Harbors has agreed with the Utah Division of Waste Management and Radiation Control to use 6 inches of stone mulch thickness in order to provide additional protection beyond the 4 inches provided in previous designs.

Side Slopes: The amount of soil loss associated with the side slopes of 39.6 tons/ac/yr is just off the graph of the figure shown below. Therefore, using the smallest value shown on the figure of 5 tons/ac/yr results in a total quantity of mulch of approximately 160 tons/acre. This is equivalent to:

T = (required tons/acre of gravel x 2,000 lbs/ton x 12 in/ft) / (43,560 sf/acre x gravel density lbs/cf)

Assume a gravel density of 110 lbs/cf

T = 160(2,000)(12)/(43,560)(110) = 0.8 inches

Clean Harbors has agreed with the Utah Division of Waste Management and Radiation Control to use 6 inches of stone mulch thickness in order to provide additional protection beyond the 4 inches provided in previous designs.

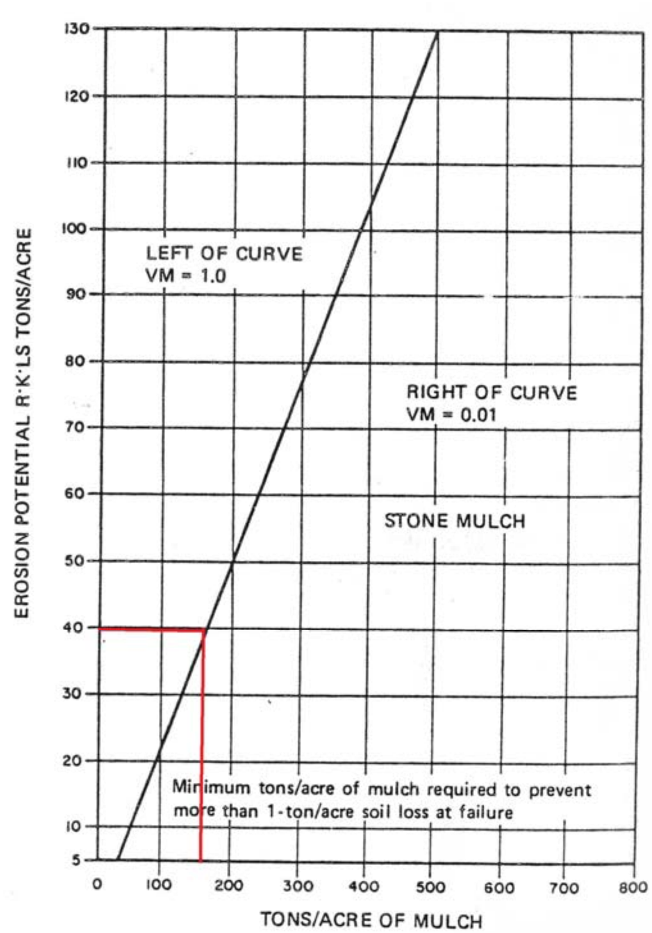


Figure 6. Stone mulch vs. R·K·LS.

APPENDIX H

Closure and Post-Closure Care Cost Estimates

Client: Clean Harbors - Grassy Mountain Facility
Project: Landfill Cells 8 - 13
Feature: Closure and Post-Closure Care Cost Estimate
Date: November 2017

(Factors Determined Using the Surface Area and Perimeter Lengths of Each Cell)

			Cells 8	Cells 9-13
Perimeter (feet)			3141	3158
Area (sq. ft.)			623953	631327
Item Description	**Qty. Factor**	**Apply Factor To:**		
Earthwork				
Imported Sand Material (Yd^3)	0.0130	Area	8132	8228
Clay Liner Placement (Yd^3)	6.6697	Perimeter	20950	21063
Clay Liner Finishing (Yd^2)	7.8610	Perimeter	24691	24825
Clay Soil Material (Yd^3)	8.8173	Perimeter	27695	27845
Anchor Trench (Linear Feet)	2.7106	Perimeter	8514	8560
Imported Soil Cover (Yd^3)	0.0562	Area	35043	35457
Gravel Armor Plating (Yd^3)	0.0131	Area	8169	8266
Road Base (Yd^3)	0.0500	Perimeter	727	727
Miscellaneous				
Drainage Pipe – 18# Dia. Linear Foot	0.3500	Perimeter	1099	1200
Inlet Boxes (Each)	0.0017	Perimeter	5	4
Manholes (Each)	0.0012	Perimeter	4	3
Outlet Structures (Each)	0.0003	Perimeter	1	1.7
Geosynthetics				
60-mil HDPE Liner (Sq. Ft.)	0.8343	Area	520547	526699.1
60-mil HDPE Textured Liner (Sq. Ft.)	20.0000	Perimeter	62820	256939.9
Drainage Net (Sq. Ft.)	0.8901	Area	555363	561926
Geotextile Fabric (Sq. Ft.)	1.7801	Area	1110725	1123852
Geosynthetic Clay Liner (Sq. Ft.)	0.8544	Area	533135	539436
8-mil Poly Membrane (Sq. Ft.)	20.0000	Perimeter	62820	34366

Quantities for Cells 9-13 were used for Cell 8 by applying the Qty. Factor listed for each item.

CDA - Landfill Closure	**Unit Cost**	**Unit**	**TSCA/RCRA Cell 8 (Closure)**		**TSCA/RCRA Celsl 9-13 (Closure)**	
			Qty[1]	**Total Cost**	**Qty[1]**	**Total Cost**
Mobilize/Demobilize	$229,605	EA	1	$229,605	1	$229,605
Subgrade Preparation	$1	SY				
Embankment	$6	CY				
Clay Liner-New Cell	$14	CY				
Clay Liner-Closure	$20	CY	20,950	$408,860.72	21,063	$411,074
Clay Soils Placement (Cost includes finishing.)	$13	CY	27,695	$349,740.68	27,845	$351,634
60 mil HDPE (Cost includes 8 mil liner.)	$4	SY	71,799	$262,115.90	87,071	$317,871
GCL	$5	SY	59,237	$277,463.28	59,937	$280,742
Geotextile	$2	SY	123,414	$204,022.02	124,872	$206,433
Geonet	$2	SY	61,707	$137,431.50	62,436	$139,056
Perimeter HDPE Weld	$3	LF	2,738	$7,071.48	2,770	$7,155
Excavate Anchor Trench	$8	LF	8,514	$68,419.21	8,560	$68,790
Leachate Collection	$57,401	EA	1	$57,401.13	1	$57,401
Imported Sand	$16	CY	8,132	$130,698.40	8,228	$132,243
Protective Soil Cover	$7	CY	35,043	$241,379.94	35,457	$244,233
Drainage (Covers Misc. from Quantity Estimates)	$86,102	LS	1	$86,101.69	1	$86,102
Road Base Placement	$9	CY	727	$6,263.85	727	$6,264
Gravel Armor	$10	CY	8,169	$79,719.08	8,266	$80,661
Subtotal				**$2,316,689**		**$2,619,264**
Design, QC, QA, PM, Survey	22%		22%	$509,671.55	22%	$576,238
Final Waste Grading	$86,102	EA	1	$86,101.69	1	$86,102
Security	$57,401	LS	1	$57,401.13	1	$57,401
TOTAL				**$2,969,863**		**$3,339,005**

Client: Clean Harbors - Grassy Mountain Facility
Project: Landfill Cells 8 - 13
Feature: Closure and Post-Closure Care Cost Estimate
Date: November 2017

CELLS 9-13 QUANTITIES

Top of Waste Mound			
Total Waste Mound Area (Bottom of 1.5H:1V Slopes)	581466.76 sf area	3035.1 ft perimeter	4264 Elev
Top of 1.5H:1V Perimeter Slopes	527832.75 sf area	2891.1 ft perimeter	4276 Elev
Top of 3H:1V Slopes (Area of 5% Slopes)	446765.29 sf area	2715.45 ft perimeter	
6-Inch Soil Layer (5% Sope)			
Bottom Area (Outside)	446674.03 sf area	2715.07 ft perimeter	
Top Area (Inside)	441891.5 sf area	2700.4 ft perimeter	
Average Area	444282.77 sf area		
Compacted Cap Clay (3H:1V) Slope			
Outside Toe of 3H:1V Slope) Top Inside of Cell	631327.00 sf area	3157.40 ft perimeter	4267.00 Elev
Bottom Outside of Runoff Containment Ditch	601918.75 sf area	3085.70 ft perimeter	4264.00 Elev
Bottom Inside of Runoff Containment Ditch	581466.76 sf area	3035.10 ft perimeter	4264.00 Elev
Top Inside of Runoff Containment Ditch	567815.26 sf area	2999.10 ft perimeter	4267.00 Elev
Outside intersection, 5% w/ 3H:1V Slopes (at Top of 1.5H:1V Slope)	551940.70 sf area	2950.62 ft perimeter	4275.63 Elev
Top of 1.5H:1V Bottom Slope (break line)	527832.75 sf area	2891.10 ft perimeter	4276.00 Elev
Top of 3H:1V Slope Outside	464928.35 sf area	2761.88 ft perimeter	4285.81 Avg Elev
Top of 3H:1V Slope Inside	441888.29 sf area	2700.19 ft perimeter	4286.22 Avg Elev
Top Area	23040.06 sf area		4286.02 Avg Elev
Area at Bottom Breakline from 1.5H:1V to 3H:1V Slope	23040.06 sf area		4275.82 Avg Elev
Area at Top of Containment Ditch	34103.49 sf area		4267.00 Elev
Area at Bottom of Containment Ditch	20451.99 sf area		4264.00 Elev
Compacted PSC Clay (3H:1V) Slope			
Bottom Outside Toe	653338.02 sf area	3195.68 ft perimeter	4267.00 Elev
Bottom Inside Toe	601918.75 sf area		4267.00 Elev
Top of 3H:1V Slope Outside	488628.25 sf area	2826.51 ft perimeter	4285.33 Avg Elev
Top of 3H:1V Slope Inside	464928.35 sf area		4285.81 Avg Elev
Top Area	23699.90 sf area		4285.57 Avg Elev
Bottom Area	51419.27 sf area		4267.00 Elev
Protective Soil Cover (5% Slope)			
Bottom Outside (5% Slope Intersect with 3H:1V Slope)	488628.25 sf area	2826.51 ft perimeter	
Top Outside (5% Slope Intersect with 3H:1V Slope)	468711.55 sf area	2772.72 ft perimeter	
Bottom Outside of Perimeter Berm	468711.55 sf area	2772.72 ft perimeter	4287.72 Avg Elev
Top Outside of Perimeter Berm	444507.56 sf area	2704.32 ft perimeter	4290.76 Avg Elev
Top Inside of Perimeter Berm	434121.08 sf area	2675.31 ft perimeter	4290.75 Avg Elev
Bottom Inside of Perimeter Berm	418305.53 sf area	2629.52 ft perimeter	4288.76 Avg Elev
Top Area of Perimeter Berm	10386.48 sf area		4288.24 Avg Elev
Bottom Area of Perimeter Berm	50406.02 sf area		4290.76 Avg Elev
Final Closure Surface			
Total Closure Cap Area	656710.69 sf area	3203.51 ft perimeter	
Area of 5% Closure Slope	418187.95 sf area	2631.04 ft perimeter	Inside Perimeter Berms
Area of 5% Liner Slope	492112.06 sf area	2836.14 ft perimeter	To geonet daylight into 3H:1V slope
Area to Outside Top of Perimeter Berm	444750.50 sf area	2704.73 ft perimeter	
Area of Inside Top of Perimeter Berm	434094.74 sf area	2674.86 ft perimeter	
Area at Top of Perimeter Berm	10655.76 sf area	2689.80 ft perimeter, Avg	
Inside 3H:1V slope of Perimeter Berm	15906.79 sf area	2652.95 ft perimeter, Avg	
Outside 3H:1V Perimeter Slopes	211960.19		
3H:1V Slope Multiplier from Plan to Slope Areas	1.0541		
5% Slope Multiplier from Plan to Slope Areas	1.0012		
Slope Area of 5% Slopes	418710.36 sf area		
Slope Area of 3H:1V Inside Perimeter Berm Slopes	16767.23 sf area		
Slope Area of 3H:1V Outside Perimeter Slopes	223425.66 sf area		
Total Final Closure Surface Area	669559.01 sf area		

Storm Drainage Grading Between Closure Caps

Cross-Section Area at High End of North/South Wedges	136.50	sf area
Length of North/South Wedges	418.00	lf
Soil Volume in Each North/South Wedge	1056.61	cy volume
Total Soil Volume for North/South Wedges (10)	10566.11	cy volume
Top Surface Area of North/South Wedges	15300.00	sf area
Total Surface Area of North/South Wedges (10)	153000.00	sf area
Cross-Section Area at High End of East/West Long Wedges	48.45	sf area
Length of East/West Long Wedges	185.00	lf
Soil Volume in Each Long East/West Wedge	165.99	cy volume
Total Soil Volume for Long East/West Wedges (6)	995.92	cy volume
Top Surface Area of Long East/West Wedges	4700.00	sf area
Total Top Surface Area of Long East/West Wedges (5)	28200.00	sf area
Cross-Section Area at High End of East/West Short Wedges	23.00	sf area
Length of East/West Short Wedges	100.00	lf
Soil Volume in Each Short East/West Wedge	42.59	cy volume
Total Soil Volume for Short East/West Wedges (12)	511.11	cy volume
Top Surface Area of East/West Short Wedges	2300.00	sf area
Total Top Surface Area of Short East/West Wedges (12)	27600.00	sf area
Total Area of Top of North Embankment	48376.00	sf area
Total Area of Top of South Embankment	48252.00	sf area
Total Area of Top of East Embankment	30453.00	sf area
Total Area of Top of West Embankment (not common)	17682.00	sf area
Total Surface Area on Embankments and Drainage Wedges	353563.00	sf area
Average Surface Area Per Cell	58927.17	sf area
Tota Soil Volume for Drainage on Top of Cell Embankments	12073.14	cy volume
Average Soil Volume per Cell for Drainage on Top of Embankments	2012.19	cy volume

Soil Construction Quantities

6-Inch Soil Layer	8227.46	cy volume
Compacted Cap Clay	21063.04	cy volume
Clay Protective Soil Cover on Perimeter Slopes	25832.65	cy volume
2-Foot Thick Protective Soil Cover	35457.03	cy volume
Perimeter Berm	2831.35	cy volume
Total Protective Soil Cover	38288.38	cy volume
4-inch Thick Stone Mulch (on cap)	8266.1606	cy volume
4-inch Thick Stone Mulch (on cap)	0	cy volume
Soil Fill Between Closure Caps		cy volume

Geosynthetics Construction Quantities

					Totals			
Geosynethetic Clay Liner (GCL)	469074	sf area	Lap and Scrap =	15%	539,436	sf material =	59937	sy material
60-mil Geomembrane (Textured)	681425	sf area	Lap and Scrap =	15%	783,639	sf material =	87071	sy material
8-mil Polyethylene Membrane	29883	sf area	Lap and Scrap =	15%	34,366	sf material =	3818	sy material
Double-Sided Geocomposite	488631	sf area	Lap and Scrap =	15%	561,926	sf material =	62436	sy material

Storm Drainage Control Surface Grading

Embankment Fill Between Closure Caps	12073	cy total	Divide Between Caps	6	2,012	cy average per cap
Stone Mulch Between Closure Caps	2578	cy total	Divide Between Caps	6	430	cy average per cap

Storm Drainage Control Structures

Concrete Inlets	4	ea	
18-Inch Diameter CPE Pipe (Inlet to Manhole)	500	lf	
5-Foot Diameter Concrete Manholes With Concrete Apron	1.5	ea	Avg per closure cap (shared between caps)
6-Foot Diameter Concrete Manholes With Concrete Apron	1.17	ea	Avg per closure cap (shared between caps)
8-Foot Diameter Concrete Manholes With Concrete Apron	0.33	ea	Avg per closure cap (shared between caps)
18-Inch Diameter CPE Pipe (Manhole to Outlet)	200	lf	Avg per closure cap (shared pipes between caps)
24-Inch Diameter CPE Pipe (Manhole to Manhole to Outlet)	300	lf	Avg per closure cap (shared pipes between caps)
Concrete Baffled Outlets	1.67	ea	Avg per closure cap (shared between caps)

Client: Clean Harbors - Grassy Mountain Facility
Project: Landfill Cells 8-13
Feature: Closure and Post-Closure Care Cost Estimate
Date: November 2017

POST-CLOSURE CARE

	GROUNDWATER MONITORING PER CELL				
a.	Assumed number of monitoring wells (each)	2	each		
b.	Unit cost to obtain samples, to obtain analyticals, and to complete statistical analysis ($/well/year)	$3,500.00	/well/year		
c.	**TOTAL ESTIMATED ANNUAL COST FOR GROUNDWATER MONITORING**	$7,000.00			
d.	**TOTAL ESTIMATED 30-YEAR POST CLOSURE COST FOR GROUNDWATER MONITORING**	**$210,000.00**			
	MONITORING WELL REMOVAL PER CELL				
a.	Assumed number of monitoring wells	2	each		
b.	Unit cost for removal of monitoring wells and plugging well holes ($/well)	$5,000.00	/well		
c.	**TOTAL ESTIMATED COST ASSOCIATED WITH AQUEOUS RESIDUAL WASH DOWN**	**$10,000.00**			
	LEACHATE PUIMPS PER CELL				
a.	Number of Leachate Pumps	8			
b.	Estimated Average pumps Replaced Per Year	1			
c.	Pump Replacement Cost (2 laborers for 3 hours @ $49.50/hour and $793 per pump)	$1,091.00			
d.	**ESTIMATED TOTAL POST CLOSURE PUMP REPLACEMENT COSTS**	**$32,730.00**			
	LEACHATE COLLECTION PER CELL				
	Assume the average leachate collected the first year of closure is equivalent to the estimated leachate rate provided from the HELP model using 48 feet of waste in the landfill cells. Assume the second year to be half the rate as the first, and then decrease each subsequent year at the rate of 25% per of the previous year resulting in insignificant leachate generation after 11 years of closure. Therefore, years 12-30 following closure, leachate management costs will only include inspection of the sumps and pump maintenance.				
a.	Average Leachate Collected (Gallons/Day/Sump Area) During First Year of Closure From HELP Model	189			
b.	Number of Sump Areas per Cell	4			
c.	Average Leachate Collected (Gallons/Day/Cell During First Year of Closure From Help Model	756			
d.	Annual Reduction in Leachate Production Following First Year of Closure	25%			
e.	Average Leachate Collected (Gallons/Year)	275,940			
f.	Leachate Collection And Disposal Costs ($/Gallon, est. 2017 costs projected from 2001 costs and 2.2%/year average inflation)	$1.40	Annual Leachate	Annual Leachate	Annual Sump
g.	Annual Cost for Sump Inspections ($/Cell), minimum. Annual Cost Will Be This Amount at a Minimum.	$9,600	Rates	Costs	Inspect.
h.	1st Year of Closure	756	275,940	$386,316	
i.	2nd Year of Closure	378	137,970	$193,158	
j.	3rd Year of Closure	189	68,985	$96,579	
k.	4th Year of Closure	95	34,493	$48,290	
l.	5th Year of Closure	47	17,246	$24,145	
m.	6th Year of Closure	24	8,623	$12,072	
n.	7th Year of Closure	12	4,312	$6,036	$3,564
o.	8th Year of Closure	6	2,156	$3,018	$6,582
p.	9th Year of Closure	3	1,078	$1,509	$8,091
q.	10th Year of Closure	1	539	$755	$8,845
r.	11th Year of Closure (<500 Gallons/Year), Average Daily Pumping Rate N/A. Facility Closure Plan	1	269	$0	$9,600
s.	12th Year of Closure	0	135	$0	$9,600
t.	13th Year of Closure	0	67	$0	$9,600
u.	14th Year of Closure	0	34	$0	$9,600
v.	15th Year of Closure	0	17	$0	$9,600
w.	16th Year of Closure	0	8	$0	$9,600
x.	17th Year of Closure	0	4	$0	$9,600
y.	18th Year of Closure	0	2	$0	$9,600
z.	19th Year of Closure	0	1	$0	$9,600
aa.	20th Year of Closure	0	1	$0	$9,600
ab.	21st Year through 30th Year				$86,400
ac.	Total Leachate Rate for the 30-Year Post-Closure Period		551,879	$771,877	$123,082
TOTAL POST-CLOSURE CARE LEACHATE MANAGEMENT COST			**$894,960**		

ANNUAL CLOSURE MAINTENANCE COST					
	Cap maintenance involves the routine maintenance of the erosion protection layer (stone mulch), for degradation of the landfill covers, or other required cover structures, including stormwater management facilities.				
a.	Crew Days Per Year (Days/Year)	8			
b.	Hourly Cost of Maintenance Crew ($/Hour), Adjusted From 2001 Costs at 2.2% Average Inflation	$163			
c.	Length of Day	10			
d.	Daily Cost of Maintenance Crew	$1,630			
e.	Annual Cost of Maintenance Crew	$13,040			
f.	**TOTAL POST-CLOSURE CARE MAINTENANCE COST**	**$391,200**			
ANNUAL ROUTINE CLOSURE INSPECTION COST					
	Security and site inspection is expected to be performed as a function of facility maintenance and is included in the overall post-closure cost estimate for the facility. Therefore, no separate cost is assessed for each individual unit of the facility.				
a.	**TOTAL POST-CLOSURE CARE COST PER CELL**	**$1,538,889.63**			