ENVIRONMENTAL SERVICES, INC.

Clean Harbors Environmental Services, LLC
Lone Mountain Facility
Waynoka, Oklahoma

RCRA/HSWA Permit Renewal Application

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Lone Mountain RCRA Permit Renewal

Volume 11A

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Appendix B

Design Engineering Report – Cell 15 Expansion Dated June 2014

ENGINEERING DESIGN REPORT

LANDFILL CELL 15 EXPANSION

LONE MOUNTAIN FACILITY

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June 2014

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ENGINEERING DESIGN REPORT

To Accompany:

PROPOSED CLASS 3 PERMIT MODIFICATION
LANDFILL CELL 15

LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

10/20/2014

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1. INTRODUCTION

1.1 Overview

The Lone Mountain Facility Landfill Cell 15 (Cell 15) is located near Waynoka, Major County, Oklahoma, in Section 28, T23N, R15W, adjacent to (north of) existing Cells 12 and 14 at the facility. Cell 15 is currently permitted as a Resource Conservation and Recovery Act (RCRA) landfill disposal cell, in accordance with Federal and State regulations including the design requirements of Code of Federal Regulations (CFR) 40 CFR 264 and Oklahoma Administrative Code (OAC) 252:205. As currently permitted, Cell 15 is designed to occupy a waste disposal plan footprint area of approximately 54.8 acres, and is composed of thirteen (13) subcells. Currently, Subcells 1 through 11 have been constructed. Subcells 1 through 4 have been filled to capacity, and Subcells 5 through 11 are active and in the process of being filled.

Clean Harbors Environmental Services, Inc. (CHES) is requesting a Class 3 Permit Modification to expand the lateral extent of Cell 15 to the west, thereby increasing the waste disposal capacity. The proposed expanded waste disposal footprint for Cell 15 will occupy approximately 95.2 acres, and will be composed of 22 subcells, (existing Subcells 1 through 13, plus new Subcells 14 through 22). The engineering design of the Cell 15 modification was prepared by Geosyntec Consultants, Inc. (Geosyntec), and is described in this report.

It is noted that a pre-application meeting was held with representatives from Oklahoma Department of Environmental Quality (ODEQ), CHES, and Geosyntec, on 17 December 2013. This Class 3 Permit Modification presents a revised Cell 15 design consistent with that presented during the pre-application meeting, as supported by the engineering drawings and calculations included in this report.

1.2 Report Organization

This Engineering Report describes the proposed Cell 15 revisions and addresses the technical issues associated with the new proposed Cell 15 layout. Since Cell 15 Subcells 1 through 11 have already been constructed in accordance with the approved permit design in effect at the time of their construction, calculations and drawings of existing subcell layout and liner system design are not included in this report except to the extent that the existing features need to be evaluated to assess whether Subcells 1 through 11 are compatible with the overall proposed Cell 15 changes. The remainder of this Engineering Report is organized as follows:

- additional details of the proposed Class 3 Permit Modification, as compared to the current permitted design, are presented in the remainder of Section 1;
- the landfill cell design is presented in Section 2;
- the final cover system and closure design is presented in Section 3;
- the storm water management system design is presented in Section 4; and
- the calculated Cell 15 waste disposal volume is presented in Appendix A.

Further detailed information on the proposed Landfill Cell 15 design is included as Exhibits which are attached to this report and are organized as follows:

- Exhibit A – Engineering Drawings;
- Exhibit B – Geotechnical Investigation and Design;
- Exhibit C – Operational Storm Water Management Design;
- Exhibit D – Liner Design (Anchor Trench);
- Exhibit E – Leachate Collection and Leak Detection System Design;
- Exhibit F – Final Closure Design;
- Exhibit G – Landfill Cell 15 Closure Plan; and
- Exhibit H – Landfill Cell 15 Construction Quality Assurance (CQA) Plan.

1.3 Cell 15 Design Overview

1.3.1 Landfill Cell 15 Layout (Base and Cover Grades) and Volume

As mentioned, for this modification it is proposed to laterally expand Cell 15. The resulting layout will be composed of existing Subcells 1 through 5, and new proposed Subcells 6 through 13. The proposed layout modifications, along with a comparison to the currently permitted landfill, are presented below in Table 1.

TABLE 1
PROPOSED CHANGES TO THE LANDFILL CELL 15 LAYOUT

Currently Permitted Cell 15	Proposed Cell 15
Lined Area = 54.8 Acres.	Lined Area = 95.2 Acres.
Waste Disposal Volume = 5,264,000 cubic yards (CY).	Waste Disposal Volume = 8,065,500 cubic yards (CY).
Maximum Final Cover System Elevation = 1496 ft, MSL.	Maximum Final Cover System Elevation = 1496 ft, MSL.

Inspection of Table 1 above reveals that, the proposed expansion will increase the lined area by 40.4 acres, and will increase the waste disposal volume by 2,801,500 CY. The engineering design and analyses associated with the layout modifications described above are contained in this report and in the attached exhibits. The Engineering Drawings presented in Exhibit A attached to this report show the revised Cell 15 layout. As shown on Drawing 2 in Exhibit A, the expansion will be towards the west compared to the current permitted extent of Cell 15. The west embankments of Cells 13 and 14 will be shared as the east embankments of Cell 15. The northern embankment of Cell 15 will be expanded westward until the limit of disturbance is 50-ft (min) from the north spillway berm. The western embankment of Cell 15 will run south and turn around a corner to run east where it will tie-in to the southwest corner of the embankment of existing Cell 13. Since Subcells 1 through 11 have been constructed and are in various stages of being filled (or already filled to capacity), no changes are proposed to the base (liner) grades of these subcells. Additionally, no changes are proposed to Subcells 12 and 13 which are part of the currently permitted Cell 15 configuration. The proposed base grades of the new subcells (Subcells 14 through 22) are shown on Drawing 4 in Exhibit A. Once complete, all subcell liner systems will be tied-in to each other such that the entire Cell 15 footprint is lined.

As shown on Drawing 4 of Exhibit A, the embankment forming the perimeter border of Cell 15 is at a constant elevation of 1420 feet above mean sea level (ft, MSL). The final cover grades extend upward, generally at a ten percent (10%) slope to form a general “triangular prism” cover layout with a “crest” or a “ridge” at the peak. Around the perimeter edges of Cell 15, a small portion of the final cover grades are sloped at 3 horizontal to 1 vertical (3H:1V), where the grades then transition to the 10% cover slope. The maximum top of final cover system elevation at this crest is at an elevation of approximately 1496 ft, MSL.

As shown in Table 1 above, the lateral expansion of Cell 15 results in a revised waste disposal capacity of 8,065,500 cubic yards (CY). Appendix A of this report contains a volume analysis detailing the methodology used to calculate the revised Cell 15 volume and presenting the results. Table 2, presented below, indicates the plan area of each subcell, along with the calculated waste disposal volumes provided by each subcell. It is noted that these waste disposal volumes are based on vertical projections of the subcell boundaries.

TABLE 2
SUBCELL AREAS AND WASTE DISPOSAL VOLUMES

Subcell #	**Plan Area** (acres)	**Waste Disposal Volume** (cubic yards)
1	4.5	315,000
2	3.3	298,000
3	2.7	236,700
4	3.7	338,000
5	5.1	565,000
6	4.6	604,400
7	3.5	445,200
8	7.0	622,500
9	4.9	502,400
10	3.0	373,700
11	2.6	301,800
12	4.5	492,700
13	3.6	407,200
14	5.8	578,900
15	5.9	348,900
16	4.8	371,500
17	4.8	280,400

Subcell #	Plan Area (acres)	Waste Disposal Volume (cubic yards)
18	4.2	234,800
19	4.2	239,000
20	4.2	216,800
21	4.2	183,900
22	3.7	108,700
Totals:	94.8	8,065,500

1.3.2 Base (Floor) Liner System

No changes are proposed to the current permitted base (i.e., floor of the landfill) liner system design. The base liner system for Subcells 14 through 22 will be the same as the base liner system currently permitted for Cell 15 Subcells 6 through 13. As shown in Table 3, the proposed base liner system remains a "triple liner". It is well documented that a composite liner system (i.e.; combination of geomembrane and GCL) is a far superior barrier system than a single liner system (i.e.; geomembrane alone).

TABLE 3
BASE LINER SYSTEM

Cell 15 Base Liner System (for existing Subcells 1 through 5; from bottom to top)	Cell 15 Base Liner System (for Subcells 6-13 and future Subcells 14-22; from bottom to top)
Layer 1 – 3-ft thick compacted clay liner having permeability of $1x10^{-7}$ cm/sec.	Layer 1 – 3-ft thick compacted clay liner having permeability of $1x10^{-7}$ cm/sec.
Layer 2 – 60 mil HDPE bottom liner.	Layer 2 – 60 mil textured HDPE bottom liner.
Layer 3 – Bottom drainage net (bottom leak detection drainage layer).	Layer 3 – Bottom geocomposite (bottom leak detection drainage layer).
Layer 4 – 60 mil HDPE middle liner.	Layer 4 – 60 mil textured HDPE middle liner.
Layer 5 – Middle drainage net (middle leak detection drainage layer) with non-woven geotextile fabric.	Layer 5 - Geosynthetic clay liner (GCL). GCL forms a composite upper liner system with proposed Layer 6.
Layer 6 –1.5-ft thick middle soil protective cover.	Layer 6 - 60 mil HDPE textured upper liner.
Layer 7 – 80 mil HDPE upper liner.	Layer 7 – Upper geocomposite (leachate collection system drainage layer).
Layer 8 – Upper drainage net (leachate collection system drainage layer) with non-woven geotextile fabric.	Layer 8 – 2-ft thick protective cover (screened waste).
Layer 9 – 2-ft thick protective cover (screened waste).	

1.3.3 Sideslope Liner System

No changes are proposed to the sideslope liner system. The sideslope liner system is the same as the proposed base liner system, except that the middle geomembrane is absent, resulting in an upper and a bottom geomembrane liner, both of which form composite liners with their underlying liner components.

1.3.4 Final Cover System

The final cover system components are presented below in Table 4.

TABLE 4
FINAL COVER SYSTEM

Final Cover System Components(from bottom to top)
Layer 1– 1-ft interim cover clay (bedding clay); layer will serve as interim cover soil prior to final cover system construction.
Layer 2 – Geosynthetic clay liner (GCL).
Layer 3 – 60 mil textured HDPE geomembrane.
Layer 4 – Geocomposite (net sandwiched between two geotextiles).
Layer 5 – 1.5-ft thick protective cover soil.
Layer 6 – 6-in. thick topsoil.
Layer 7 – Grassy vegetation on 10% cover slopes; and 6-in. thick riprap or grassy vegetation on 3H:1V cover slopes.

2. DESCRIPTION OF LANDFILL CELL 15 DESIGN EVALUATIONS

As previously noted, the layout and engineering details of the Cell 15 layout and liner system components are presented on the Engineering Drawings in Exhibit A. This section provides description of the engineering analyses and design calculations performed to support design of the landfill liner system and cell layout. The following engineering analyses and related information are discussed in the subsections indicated:

2.1 Liner System Description;
2.2 Groundwater Separation Distance;
2.3 Buffer Distance;
2.4 Geotechnical Site Investigation;
2.5 Slope Stability Analyses;
2.6 Settlement and Liner Stress Analyses;
2.7 Liner Anchor Trench Design;
2.8 Leachate Collection and Removal System Design;
2.9 Leak Detection System Design; and
2.10 Upper and Lower Sump Capacities.

2.1 Liner System Description

The existing and permitted liner system Cell 15 was discussed in Section 1.3 of this report. The proposed liner system is depicted in a cross-sectional engineering detail on Drawing 14 of Exhibit A. In summary, the proposed Cell 15 base liner system for the remaining (yet-to-be-constructed) subcells is composed of (from bottom to top):

- 3-ft thick compacted clay liner ($k \leq 1 \times 10^{-7}$ cm/s) ;
- bottom 60-mil HDPE textured geomembrane;
- bottom double-sided geocomposite leak detection drainage layer;
- middle 60-mil HDPE textured geomembrane;
- GCL;
- upper 60-mil HDPE textured geomembrane;
- upper double-sided geocomposite leachate collection drainage layer; and
- 2-ft thick protective cover layer (screened waste).

As mentioned in Section 1.3, the proposed sideslope liner system is the same as the proposed base liner system, except that the middle geomembrane is absent, resulting in an upper and a bottom geomembrane liner, both of which form composite liners with their underlying liner low-permeability components. The liner system components have been selected and designed to prevent migration of wastes out of the landfill, using materials with sufficient chemical properties, strength, and thickness to prevent failure due to anticipated pressures and stresses.

2.2 Groundwater Separation Distance

The new portion of Cell 15 being revised by this Class 3 Permit Modification (i.e., Subcells 14 through 22) is designed to maintain a 5-ft minimum separation distance between groundwater and the bottom most 60-mil geomembrane component of the liner system. The previously permitted Cell 15 subcells were also designed to maintain this separation distance. This layout was accomplished by using a "Highest Historical Groundwater Map" (Drawing 3 of Exhibit A) developed by the hydrogeology consulting firm involved at this facility, Cameron-Cole, Inc. This map shows groundwater contours developed using the highest groundwater readings that were recorded historically in each individual groundwater monitoring well at the facility, and therefore represents a conservatively-high surface (since not all readings occurred at the same time). The base grades were then designed accordingly such that a 5-ft minimum separation distance between the liner and groundwater is maintained, including at the lowest points of the landfill in the sumps.

2.3 Buffer Distance

Cell 15 is designed to maintain a minimum 300-ft buffer distance from the limit of liner to the facility boundary. This set back distance exceeds the minimum required distance of 200 feet specified in the Code of Federal Regulations (40 CFR Part 264). These buffers are shown on Drawing 2 in Exhibit A. As shown, the north and east portions of Cell 15 have an approximately 300-ft or slightly greater buffer distance. The southwestern portion of Cell 15 also has a buffer of just over 300-ft. Other portions of Cell 15 have a much larger distance to the facility boundary (off the map to the west and south on Drawing 2 in Exhibit A).

2.4 Geotechnical Site Investigation

Geotechnical (and hydrogeologic) conditions at the Lone Mountain Facility have been extensively investigated and characterized as part of previous permitting activities for the current Cell 15 design, and prior landfill cells.

Applied Geotechnical Engineering Consultants prepared the Cell 15 Engineering Report (dated April, 1993) which included the geotechnical site investigation report, titled, "*Geotechnical Investigation – Landfill Cell 15 – Lone Mountain Facility*." This report includes information on the geotechnical (soils) subsurface conditions (boring logs, identification of soil strata, and laboratory characterization of engineering properties).

In 2010, Geosyntec reviewed the prior geotechnical information and developed an investigation program to supplement the previous data with additional information. This program included additional soil borings and laboratory testing at a similar frequency and depth as with previous investigations. The 2010 geotechnical site investigation was performed in February 2010. Drilling services were provided by Envirotech Engineering and Consulting, Inc. (Envirotech). ODEQ and Geosyntec personnel were present during portions of the investigation. Eleven borings (B-22 through B-32) were drilled during this investigation and laboratory testing was conducted on representative samples.

Because this proposed Class 3 Permit Modification involves laterally expanding the Cell 15 boundary, further geotechnical investigation was performed in 2013 to define the subsurface conditions within the new landfill areas west and south of the current permitted Cell 15 limits. Geosyntec reviewed the historical data at the site and developed an investigation program to further supplement previous data. This subsurface investigation was performed in October 2013 by Envirotech. Geosyntec personnel were also present during portions of the investigation. Seven borings (B-33 through B-39) were drilled and laboratory testing on representative samples was conducted. The results of the 2013 and 2010 geotechnical site investigations, along with relevant data from previous investigations, are presented in Exhibit B-1 of this submittal.

2.5 Slope Stability Analyses

Part of the geotechnical evaluation and design of proposed Cell 15 includes analyzing the stability of the landfill and embankment slopes and the foundation beneath the landfill. These slope stability analyses are presented in Exhibit B-2. The calculations presented in Exhibit B-2 include a detailed discussion of the approach, sliding scenarios, critical cross sections, assumed parameters, and results. Comprehensive calculations are presented for the relevant sliding scenarios and critical landfill cross sections. The components of the landfill for which the slope stability analyses were performed are:

- embankment slopes and foundation soils (bearing capacity) prior to liner system construction;
- liner system slopes prior to waste placement (i.e., liner system veneer);
- interim landfill slopes during operation;
- final cover system slopes (i.e., final cover system veneer); and
- final landfill slopes and foundation soils (bearing capacity) at closure.

The slope stability factor of safety (FS) for each component and sliding scenario was evaluated for cross sections that represent critical combinations of geometry and shear strength. The slope stability of the landfill components except for veneer sliding of the liner and final cover system was analyzed using a method of slices coded in the computer program SLIDE, Version 6.026 by Rocscience, Inc. The computer program was used to generate circular and non-circular (block-type) shear surfaces and calculate the factors of safety of these surfaces using Spencer's (1967) method (see Exhibit B-2 for references).

Veneer stability refers to sliding of the liner or cover system layers along the weakest interface. Liner system and final cover system veneer stability was evaluated using the force equilibrium method presented by Giroud et al. (1995).

For shear surfaces that pass through the liner system or final cover system, the approach generally taken is to back-calculate the minimum secant effective-stress friction angle for the liner system or final cover system that yields the target calculated factor of safety for slope stability. The back-calculated minimum strength values for the liner system and final cover system are then incorporated into the material specifications for liner and final cover materials, which are part of the Construction Quality Assurance (CQA) Plan.

Refer to Exhibit B-2 for a detailed description of slope stability evaluation. In summary, the results indicate that the proposed Landfill Cell 15 has adequate calculated factor of safety against slope stability sliding for the modes analyzed at the critical cross sections.

2.6 Settlement and Liner Stress Analyses

Another component of the geotechnical analysis of Landfill Cell 15 is an evaluation of settlement to assess the magnitude of settlements and whether the liner system would be expected to withstand the associated grade changes and stresses from settlement. These settlement and liner stress analyses are presented in Exhibit B-3. The analyses evaluate the effect of one-dimensional compression of the foundation materials on the post-settlement grades of liner system of Cell 15. Specifically, the settlements of the most critical portion of the liner grades along the leachate collection system corridors (flattest slopes) were evaluated. The leachate corridors should be predicted to maintain positive drainage towards the leachate collection sumps after foundation settlements have occurred. Also, calculated tensile strains due to differential settlement should not exceed tolerable strains for the liner system components.

Foundation soils beneath the landfill base are expected to compress as the load increases (i.e., as waste is placed in the landfill followed by closure). The foundation settlements will be affected by: (i) the thickness and properties of the soil strata beneath the landfill; and (ii) the variable loading of the foundation by the landfill, from zero at the limits of the embankment, to a maximum near the center of the landfill where the waste and final cover elevation will be at a maximum. Settlement of the clayey foundation strata beneath the landfill was calculated using equations for conventional one-dimensional compression settlement due to loading based on consolidation.

Based on the analyses, the calculated settlements along the leachate collection corridors range from 0.17 to 2.93 feet. The calculated minimum post-settlement slope along the leachate collection corridor is slightly flatter than the pre-settlement slope, changing from 1.0% to 0.8%, which is minimal and considered acceptable. The stresses induced by predicted differential settlement of the foundation layers were also calculated. This was done by calculating the strains between adjacent points (i.e., difference in settlement divided by the length) due to differential settlement. Results show calculated liner tensile strains of less than 0.17%. This predicted elongation strain is less than the yield strain (13 percent) for an HDPE geomembrane, and is therefore considered acceptable.

Accordingly, the calculations show that the settlements are tolerable and the integrity of the geomembrane liner should not be adversely affected by total or differential settlement. Furthermore, the cover system is not expected to settle significantly for the reasons discussed in Exhibit B-3. Refer to Exhibit B-3 for a detailed description of the settlement and liner stress analyses.

2.7 Anchor Trench Design

The anchor trench design is presented in Exhibit D, and is similar in concept to that previously permitted. Loading of the geosynthetic materials are estimated, and the stresses transmitted by friction to the underlying geosynthetic materials are predicted based on a method presented in *Designing with Geosynthetics* by Koerner (1990 and 1998). The design is based on: (i) an evaluation of the anticipated stresses in the geosynthetic components of the liner system and resulting tensile forces (if any); and (ii) demonstration that the anchor trench configuration is adequately designed in the event excessive tensile loading is experienced. The prescribed anchor trench runout length, depth, and interface friction have been evaluated to verify that the geosynthetics will pull out of the anchor trench before tensile failure of the geosynthetics occurs, which is an appropriate condition.

2.8 Leachate Collection and Leak Detection System Design

The leachate collection and leak detection system (LCS and LDS, respectively) design is presented in Exhibit E. The LCS components have been designed to effectively collect and remove leachate. The LDS components have been designed to effectively collect and remove liquid collected by the bottom leak detection layer. The following LCS and LDS-related engineering analyses were performed and are presented in the sub-exhibits indicated:

- Exhibit E-1: Leachate Generation Rates (HELP Modeling) and Head on Liner;
- Exhibit E-2: Geotextile Filter Design;
- Exhibit E-3: LCS and LDS Drainage Layer Design;
- Exhibit E-4: LCS and LDS Pipe Design;
- Exhibit E-5: LCS Sump Capacity Calculations; and
- Exhibit E-6: LDS Sump Capacity Calculations.

The remainder of this section discusses each of the above aspects of the LCS and LDS design in more detail.

2.8.1 LCS and LDS Layout and Components

Cell 15 is divided into 22 Subcells which will be constructed sequentially over time. As mentioned, Subcells 1 through 11 are currently constructed and in varying stages of filling (or already filled to capacity). Subcells 14 through 22 are new proposed subcells, and their layout is shown on Drawing 4 of Exhibit A. Each of these new subcells are separated from each other with lined "inter-subcell" division berms which are designed to allow for a temporary storm-water storage area in the active subcell, to contain precipitation runoff from the active face waste surfaces. These division berms will be lined in the same manner as the floor of the subcells.

As shown on the liner system details on Drawing 13 and 17 of Exhibit A, the proposed liner system includes an LCS drainage layer above the upper geomembrane liner, to collect and convey leachate towards low spots (sumps) in each subcell. Similarly, the proposed liner system includes an LDS drainage layer above the bottom geomembrane liner, to collect and convey any liquid in the leak detection layer towards leak detection (bottom) sumps in each subcell. The LCS and LDS components are completely separate drainage systems that are not connected to each other. Each subcell will have an upper LCS sump and a lower LDS sump.

Thus, on the cell floor areas, the separate LCS and LDS drainage layers will each convey collected liquid towards a collection corridor located along the centerline of each subcell. Each cell floor is sloped at 2% towards the leachate collection corridor, which in turn slopes at 1% towards each collection sump. The LCS and LDS collection corridors each have a perforated collection pipe surrounded by gravel drainage material, surrounded by a geotextile filter. The sumps are filled with gravel drainage material, and have a perforated section of leachate riser pipe in the sumps, into which a submersible pump is operated to remove liquid from the sump. The riser pipe is solid wall on the sideslopes, and extends out of each sump area to the landfill perimeter (i.e., top of perimeter embankment).

2.8.2 Leachate Generation and Head on Upper Liner

The leachate collection rates and maximum leachate head on the upper liner system were estimated using the HELP computer model, Version 3.07, developed by the U.S. Environmental Protection Agency (USEPA). HELP simulates hydrologic processes for a landfill by performing daily, sequential water balance analyses using a quasi-two-dimensional, deterministic approach. The hydrologic processes considered in the HELP model include precipitation, surface-water evaporation, runoff, infiltration, plant transpiration, soil water evaporation, soil water storage, vertical drainage (saturated and unsaturated), lateral drainage (saturated), vertical drainage (saturated) through compacted soil liners and GCLs, and leakage through geomembranes.

Leachate generation rates were estimated for several operational scenarios expected in subcells. These scenarios range from initial conditions after a subcell has been recently opened, to final closure with a final cover system in-place. The leachate collection rate and maximum leachate head on the floor of the liner system were calculated for these typical operational conditions. Results from the HELP model show that the maximum peak daily leachate collection rate is calculated to be 1,916 gallons per acre per day (gpad), while the maximum annual average leachate collection rate is calculated to be 150 gpad. The maximum peak daily and the maximum annual average leachate collection rates are observed during the initial condition and the intermediate conditions, respectively, when the in-place waste thickness is minimal. For all operational cases evaluated, the calculated head of leachate on the liner is less than the regulatory maximum of 30 cm (12 in.). Refer to Exhibit E-1 for a detailed description of the analyses, including approach, parameter selection, scenarios evaluated, and results.

2.8.3 Geotextile Filter Design

The LCS and LDS layers are both composed of geocomposite drainage layers. A geocomposite refers to a geonet sandwiched between and bonded to two non-woven geotextiles. The geotextiles provide frictional strength against adjacent layers, and also serve as a filter or separator when adjacent to a soil layer. Since the LDS is located between geomembranes, filtration design is not applicable. However, for the LCS, the geocomposite is directly beneath the protective cover layer; therefore, the geotextile component on the upper side of the LCS geocomposite will serve to minimize the movement of fine-grained soils into the geocomposite's geonet component. The filtration characteristics of the geotextile were evaluated using a retention criterion, a permeability criterion, and an anti-clogging criterion, based on the methods presented in the technical literature. Survivability requirements (grab, tear, and puncture strengths) were also considered so that the geotextile will have adequate resistance to stresses applied on the geotextile during construction (i.e., when concentrated stresses should be the highest). This approach and the resulting specifications are presented in Exhibit E-2.

2.8.4 LCS Drainage Layer Design

The geonet core of the LCS drainage layer geocomposite will provide the hydraulic capacity (in-plane transmissivity) to properly drain the collected leachate. The geocomposite drainage layer hydraulic capacity design evaluation is performed using the design-by-function concept presented by Koerner (1998) and based on Darcy's equation (flow rate = hydraulic conductivity × hydraulic gradients × cross-sectional area of flow) for hydraulic flow in porous, saturated media. The approach then follows the design methodologies presented in technical literature to apply partial reduction factors and a global factor of safety to specify the required in-service transmissivity that accounts for factors such as creep, chemical clogging, biological clogging, intrusion, and long-term decrease in flow capacity behavior. The site-specific transmissivity design evaluation results showed a minimum required transmissivity for the LCS drainage layer of 4.2×10^{-4} m^2/s. According to 40 CFR §264.301, the minimum transmissivity for a geosynthetic material used as a drainage layer in the liner system of a landfill disposing hazardous waste is 3×10^{-5} m^2/s; as shown, the site-specific required transmissivity is larger than the regulatory specified value, and therefore, the site-specific calculation governs. Details of the approach, assumptions, parameters, calculations, and results are presented in Exhibit E-3.

2.8.5 LDS Drainage Layer Design

The transmissivity of the geocomposite in the LDS was selected to be equivalent to the minimum transmissivity of the geocomposite of the LCS calculated in Exhibit E-3. This is because the flows experienced by the LDS will be substantially less than those experienced by the LCS; therefore, the LDS transmissivity was specified without the need for a detailed analysis. With regard to filtration, as mentioned, the geocomposite of the LDS will be located between the middle and bottom geomembranes; hence there is no filtration requirement for the geotextiles of the geocomposite in the LDS. With regard to survivability, it is expected that the geocomposite of the LDS will be subjected to stresses similar to those acting on the geocomposite of the LCS. Therefore, the same survivability criterion outlined in Exhibit E-2 for the geocomposite of the LCS applies for the geocomposite of the LDS. Based on the above discussion, it is evident that geocomposites that meets the minimum criteria for the LCS (Exhibits E-2 and E-3) are adequate for use in the LDS.

2.8.6 LCS and LDS Pipe Design Hydraulic Capacity

2.8.6.1 Pipe Hydraulic Capacity

As mentioned, each new subcell will have a leachate collection corridor located along the centerline of the subcell, composed of a perforated pipe surrounded by gravel. The perforated LCS pipe will be 6-in. diameter, standard dimension ratio (SDR)-11 HDPE pipe. In Exhibit E-4, the hydraulic capacity of the proposed 6-in. diameter LCS pipe was evaluated and compared to the anticipated leachate flow rates. The maximum flow rate of leachate entering the leachate collection corridor was calculated using impingement rates provided in Exhibit E-1. The peak daily impingement rate for the most critical condition (maximum flows) is 1,916 gpad. The leachate collection corridor of Subcell 14, serving an area of 6.05 acres, was calculated to be the most critical with a peak daily flow rate of 11,588 gallons per day (gpd). The maximum flow rate expected from the largest cell was compared to the capacity of the leachate corridor collector pipe to ensure that the calculated collector pipe flow capacity is greater than the calculated maximum expected flow rates. The 6-in. diameter pipe sloped at 1% has a hydraulic capacity of 399,100 gpd using Manning’s equation to calculate gravity flow in a pipe. Thus, the 6-in. diameter LCS pipe has adequate hydraulic capacity, with a substantial factor of safety. Details of the approach, assumptions, parameters, calculations, and results of the LCS pipe hydraulic capacity evaluation are presented in Exhibit E-4.

The LDS collection corridor will be composed of a 4-in. diameter SDR-11 HDPE pipe. Since the flows experienced by the LDS will be substantially less than those experienced by the LCS, a detailed evaluation of LDS capacity was not necessary, and it can be concluded by inspection that the LDS pipe capacity will be adequate for the very small flows expected.

2.8.6.2 Pipe Structural Strength

The structural capacity of both the LCS and LDS pipes was evaluated to assess whether the pipes could withstand the stresses caused by the overlying loads. As mentioned, the LCS pipes will be perforated 6-in. diameter SDR-11 HDPE, and the LDS pipes will be perforated 4-in. diameter SDR-11 HDPE. The riser pipes within the sumps will be 18-in. diameter SDR-17 (maximum) HDPE. The stability and integrity of these various HDPE pipes was analyzed under the expected loads.

Four potential strength failure mechanisms for plastic pipes are: (i) wall crushing; (ii) wall buckling; (iii) excessive ring deflection; and (iv) excessive bending strain. These mechanisms were evaluated using methods presented in the technical literature for flexible plastic pipes. Stresses applied to the pipes are estimated for the post-closure condition. A maximum total waste height of 124 ft will be applied on top of the leachate collection and leak detection corridors. A maximum total waste height of 81 ft will be applied on top of the riser pipes.

The analyses indicate that the various specified HDPE pipe components of the LCS and LDS have sufficient strength to withstand the expected loads. Exhibit E-4 presents additional details on the approach, methods, parameters, assumptions, calculations, and results of the pipe structural capacity design evaluation.

2.8.7 LCS Sump Design

A calculation was performed to evaluate the storage capacity of the LCS sumps for Subcells 14 through 22, and to recommend submersible pump capacities that would provide adequate removal with reasonable cycle times (on-off pumping cycles). As noted, the LCS sumps for Subcells 1 through 11 have already been constructed and are in operation. Subcells 12 and 13 of the current Cell 15 permit have not yet been constructed. The engineering details for the Subcell 14 through 22 LCS sumps are presented on Drawings 18 and 19 of Exhibit A. As shown, these LCS sumps will have a typical, standard design layout. Based on the sump dimensions and assumed porosity of the gravel in the sump, each LCS sump has an estimated capacity of approximately 7,410 gallons. As an example, using an assumed submersible sump pump operation of 20 gallons per minute (gpm), the proposed leachate sump has adequate storage capacity to provide acceptable pump cycle times considering peak and average daily operation rates. The LCS sump pump flow rate is not intended to be a limiting parameter and is merely an example to give an estimate of the magnitude of typical operations; other pump operation flow rates can also provide adequate cycle times and prompt leachate removal. Details of the approach, assumptions, parameters, calculations, and results of the LCS sump design evaluation are presented in Exhibit E-5.

2.8.8 LDS Sump Design

Similar to the LCS sump design approach, a calculation was performed to evaluate the storage capacity of the LDS sumps for Subcells 14 through 22 based on the geometry of the typical LDS sump, the assumed porosity of the gravel, and the operating levels. However, the design procedure for the LDS sumps was somewhat different. For the LDS sumps, not only was the maximum capacity calculated, but also the liquid height that would develop between daily pumping cycles was calculated assuming certain inflow rates corresponding to the tiered Action Leakage Rate (ALR) thresholds identified by ODEQ. Details of the approach, assumptions, parameters, calculations, and results of the LDS sump design, and the calculated liquid head buildup in each LDS sump between daily pumping events, are presented in Exhibit E-6.

Table 5, presented below, summarizes the liquid storage capacities of both the LCS and LDS sumps. It is noted that (i) the sump capacities for existing Subcells 1 through 4 was taken from the October 1997 Engineering Report by HA&L Engineering;(ii) the sump capacities for existing Subcell 5 was taken from the January 2007 Envirotech Design Modification Report; (iii) the sump capacities for existing Subcells 6 through 13 were taken from the July 2010 Engineering Design Report by Geosyntec. The sump capacities for future Subcells 14 through 22 were calculated by Geosyntec as described in Exhibits E-5 and E-6 of this Engineering Report.

TABLE 5
LCS SUMP AND LDS SUMP CAPACITIES

Subcell #	**Tributary Area** (acres)	**Upper (LCS) Sump Capacity** (gallons)	**Bottom (LDS) Sump Capacity** (gallons)
1	4.5	19,320	1,575
2	3.1	20,470	1,575
3	3.2	9,650	1,558
4	2.6	9,980	1,558
5	5.1	21,236	1,993
6	4.6	8,503	3,587
7	3.5	8,503	3,587
8	7.0	8,503	3,587
9	4.9	8,503	3,587
10	3.0	8,503	3,587
11	2.6	8,503	3,587
12	4.5	8,503	3,587
13	3.6	8,503	3,587
14	6.1	8,503	3,587
15	6.0	8,503	3,587
16	4.9	8,503	3,587
17	5.0	8,503	3,587
18	4.3	8,503	3,587
19	4.3	8,503	3,587
20	4.3	8,503	3,587
21	4.3	8,503	3,587
22	3.9	8,503	3,587

3. DESCRIPTION OF CELL 15 WASTE FILLING AND CLOSURE DESIGN

The layout and engineering details of the Cell 15 interim waste filling grades, final waste grades, final cover grades, and details of related components are presented on the Engineering Drawings in Exhibit A. This section provides description of the engineering analyses and design calculations performed to support design of Cell 15 filling and closure. The following items are addressed in the subsections indicated:

- 3.1 Final Cover System Description;
- 3.2 Phased Waste Filling and Closure;
- 3.3 Final Cover Stability;
- 3.4 Final Cover System Drainage Layer Design;
- 3.5 Final Cover System Erosion Analysis;
- 3.6 Exterior Embankment Slope Erosion Protection; and
- 3.7 Closure Plan.

3.1 Final Cover System Description

The proposed Cell 15 final cover system was discussed in Section 1.3 of this report, and is depicted in a cross-sectional engineering detail on Drawing 21 of Exhibit A. In summary, the proposed Cell 15 final cover system is composed of (from bottom to top):

- 12-in. thick interim cover clay (bedding clay);
- GCL;
- 60-mil HDPE textured geomembrane;
- double-sided geocomposite drainage layer;
- 1.5-ft thick protective cover soil layer;
- 6-in. thick topsoil; and
- grassy vegetation on 10% cover slopes; and 6-in. thick riprap or grassy vegetation on 3H:1V cover slopes.

The final cover components have been selected to: (i) provide long-term minimization of liquid migration into and through the closed landfill; (ii) function with minimal maintenance; (iii) promote drainage and minimize erosion or abrasion of the cover; (iv) accommodate settling and subsidence so that the cover's integrity is maintained; and (v) have a barrier layer with a hydraulic conductivity less than or equal to the hydraulic conductivity of the bottom liner at the landfill.

3.2 Phased Waste Filling and Closure

Waste filling of Cell 15 is currently in progress in accordance with the currently permitted design features. A series of drawings showing the planned continued progression of waste filling over time are presented on Drawings 5 through 8 of Exhibit A. It should be recognized that landfill development is a constantly-changing process as waste filling progresses, and therefore the interim filling plans presented are intended to provide typical "snap-shots" with a general level of detail of the interim landfill configuration at different points in time in the future. The waste filling plan is summarized below.

- Subcells 1 through 4 of Cell 15 are currently filled to final waste grades.
- Subcells 5 through 8 and Subcell 10 are near final waste grades.
- Subcell 11 is currently active and in the process of being filled. In general, the active waste slope is in west face of Subcell 11.
- Subcell 9 is currently under construction.
- Subcells 12 through 22 will be constructed and filled to final waste grades over time in sequential order (see Drawing 8 in Exhibit A).

Since waste filling will take place incrementally, Cell 15 closure through construction of the final cover system will also occur incrementally in phases, as portions reach final waste grades. Subcells 1 through 4 have been filled to final waste grades and are mostly capped with final cover. Based on the waste filling plan described above, Subcells 5 through 8 are near final waste grades, and it is anticipated that construction of final cover system will occur in these areas next. Then, it is projected that the waste overlying Subcells 9 and 11 will reach final grades. Therefore, it is anticipated that construction of the final cover system will start on the eastern portion of Cell 15. Filling to final waste grades will then progress westward and southward, with the area in the southwest corner of Cell 15 (overlying Subcell 22) being the last area to reach final waste grades. Construction of the final cover system is anticipated to continue in a similar manner, in regular increments. The limits of each phase of closure have been delineated, and are shown on a figure and discussed in more detail in the revised Landfill Cell 15 Closure Plan that accompanies this Class 3 Permit Modification.

3.3 Final Cover and Overall Landfill Slope Stability

The slope stability of Cell 15 at final grades was evaluated as part of the geotechnical design analyses presented in Exhibit B-2. Final cover scenarios analyzed include the cover system components (i.e., "veneer stability"), along with the final landfill and embankment slopes. Refer to Exhibit B-2 for a detailed description of slope stability evaluation, including methodology, cross sections analyzed, parameters, and results. In summary, the results indicate that each of the critical cross sections, which were based on the proposed Landfill Cell 15 final slopes and final cover system, has an adequate minimum calculated factor of safety against slope stability sliding for the modes analyzed.

3.4 Final Cover Drainage Layer Design

The final cover drainage layer design is presented in Exhibit F-2. The design is for the double-sided geocomposite (non-woven geotextiles bonded to geonet) drainage layer component of the final cover system. The items evaluated in the design evaluation include: (i) filtration capability and specifications for the geotextile component of the geocomposite drainage layer; (ii) survivability specifications for the geotextiles; and (iii) hydraulic capacities of the geosynthetic drainage layers and testing conditions for verifying that the required capacities are achieved.

The drainage layer hydraulic capacity design evaluation was performed using the design-by-function concept presented by Koerner (1998) and based on Darcy's equation (flow rate = hydraulic conductivity × hydraulic gradient × cross-sectional area of flow) for hydraulic flow in porous, saturated media. The predicted flow rates were obtained using the USEPA Hydrologic Evaluation of Landfill Performance (HELP) model. The resulting required transmissivity was then calculated to be 2.8×10^{-4} m^2/sec. Refer to Exhibit F-2 for a detailed discussion of the approach, HELP model, input parameters, assumptions, and the results of the final cover drainage layer design.

3.5 Final Cover Erosion Analyses

The final cover erosion analysis of the vegetated topsoil surface of the final cover system is presented in Exhibit F-3. The erosion analysis of the final cover system to evaluate whether the design provides adequate resistance to erosion was performed using the Revised Universal Soil Loss Equation (RUSLE). The majority of the final cover system is sloped at ten percent (10%). As shown on Drawing 22 of Exhibit A, a small portion of the perimeter of the final cover system around Cell 15 is sloped more steeply, at 3 horizontal to 1 vertical (3H:1V). Both of these slopes were evaluated. Based on the erosion analysis, the calculated soil loss for the 10% slopes of the final cover system is 0.45 tons per acre per year. The calculated soil loss for the 3H:1V slopes of the final cover system, when vegetated (worst case for soil erosion) is 0.70 tons per acre per year. Both of these values are less than the allowable 2 tons/acre/year soil loss recommended by USEPA for landfill final covers. Therefore, the final cover system design provides adequate erosion loss resistance and is expected to need relatively minimal maintenance during the closure and post closure period. Refer to Exhibit F-3 for a detailed discussion of the approach, input parameters, assumptions, and the results of the erosion analysis.

3.6 Perimeter Embankment Erosion Protection System

The perimeter embankment is sloped at 2 horizontal to 1 vertical (2H:1V), and is proposed to use the same granular and riprap-based erosion protection system as is currently permitted (and that has been successfully constructed on 2H:1V embankments at the Facility). No changes are proposed, and the previously submitted and permitted design analyses remain applicable and valid.

3.7 Closure Plan

A revised Landfill Cell 15 Closure Plan has been developed as part of this Class 3 Permit Modification. This Closure Plan is presented in Exhibit G, and incorporates the Cell 15-specific phased closure approach, along with other relevant information on the closure activities and schedule.

4. DESCRIPTION OF CELL 15 STORM WATER MANAGEMENT SYSTEM

This section provides description of the engineering analyses and calculations performed to support design of the Cell 15 storm water management features. The Cell 15 storm water management system includes a system to store run-off from active areas during landfill operations, and features to control and manage run-off from the landfill and adjoining embankment slopes after closure. The following engineering analyses and related information are discussed in the subsections indicated:

4.1 Storm Water Management During Operations; and
4.2 Storm Water Management Plan for Final Conditions.

4.1 Storm Water Management During Operations

4.1.1 Contaminated Stormwater – Temporary Storage Areas

Design calculations for sizing of the temporary storage areas of contaminated stormwater during operations are provided in Exhibit C. The storm water management design during operations refers to the features used to control and store run-off from precipitation that falls on the waste in active areas of Cell 15. This water is assumed to be treated as contaminated and require treatment, and will therefore be directed to a temporary holding area inside of the lined limits of the currently-active subcell. Conveyance channels around the perimeter of Cell 15, along with other interim diversion berms/ditches on the interior of the active areas, will direct runoff that falls on active areas, towards the temporary storage area. The temporary storage area will be located at the west end of the active cells for Subcells 9 through 13 and on the south end of the active cells for Subcells 14 through 22. The storage area will be relocated to the next subcell as the landfill development progresses.

As described in Exhibit C, the storm water storage areas have been sized to collect and temporarily store storm water resulting from a 100-year, 24-hour storm event (6.3-inches). The runoff volume was calculated assuming 100 percent runoff from the waste. Evapotranspiration and infiltration was not considered. This is a very conservative assumption but is considered appropriate for sizing the storm water storage areas. The resulting runoff volume represents the required storage capacity. Storm water storage requirements for each subcell and contributing active areas were evaluated separately. The results, presented in Exhibit C, were used to calculate the required set-back areas and division berm heights in each subcell to provide the required storage volume. Waste shall not be placed in a subcell any closer than the set-back distance specified in each subcell (see Exhibit C), so that the required storm water storage area is maintained until the next subcell is opened and its storm water storage area is made ready.

4.1.2 Uncontaminated Stormwater From Interim Cover Areas

The waste filling plan was previously described in Section 3.2 of this Engineering Report, and is also shown on Drawings 5 through 8 of the Engineering Drawings in Exhibit A. As discussed, the first part of the filling sequence will be to progressively construct each subcell over time and then fill Subcells 14 through 22 to final waste grades. As the subcells are filled, stormwater runoff from the active waste areas will continue to be managed using a combination of diversions and conveyances to route the stormwater to holding areas for collection and treatment as contaminated water.

When final waste grades are reached in an area, a 1-ft thick interim cover layer will be installed on top of the final waste grades, thereby allowing stormwater runoff from these areas to be managed as uncontaminated water. The interim cover soil layer on final waste grades will also remain in place to serve as the bottom layer of the final cover system (bedding layer on which the GCL will be installed). A cross section depicting this situation is presented on Drawing 12 of the Engineering Drawings in Exhibit A.

4.2 Storm Water Management Plan – Final Conditions

The storm water management design for final landfill conditions is presented in Exhibit F-1. The layout of the drainage features on the Cell 15 cover and perimeter embankment is presented on Drawing 21 of Exhibit A. Engineering details of these drainage features are presented on Drawings 22 and 23 of Exhibit A. The storm water management features for Cell 15 are designed to efficiently remove storm water and minimize erosion and infiltration resulting from the peak 10 minute intensity of a 100-yr design storm. The surface water management system is composed of the following components which will collect and convey storm water from the final cover system and embankments to the perimeter facility drainage system:

- On the final cover surface of Cell 15, a mid-slope and toe-of-slope drainage berm will intercept surface water runoff (i.e., sheet flow) from the final cover and will convey runoff to several low points along these berms.
- At the low points of the mid-slope drainage berm, “drainage down-channels” will convey the collected water towards drop inlets located at various points around the Cell 15 final cover toe-of-slope.
- These drop inlets will receive water from the toe-of-slope drainage berms and drainage down-channels, and will convey the water down the perimeter embankment slope via “downspout” pipes, which will outlet at the toe-of-slope of the perimeter embankments and flow into the facility perimeter drainage system.

Hydrology calculations were performed using the rainfall intensity based on calculations for times of concentration outlined in the TR-55 Urban Hydrology for Small Watersheds manual (USDA, 1986). Then, peak design intensity and peak discharges were calculated based on the rational method as described in *Applied Hydraulics* (Chow et al., 1988) and Hydro-35 (NOAA, 1977), as described further in Exhibit F-1. Once the volume of storm water was calculated, Manning's equation for open-channel flow was used to calculate velocities within the drainage conveyances and to size their dimensions. Results from calculations performed indicate that the surface water management system for the proposed Cell 15 will collect and control the runoff resulting from a 100-year, 24-hour storm event (conservatively, including that from the 10-minute peak intensity of the 100-year event).

Refer to Exhibit F-1 for a detailed discussion of the approach, input parameters, assumptions, and the results of the final storm water management system design, including the required size and location of the drainage features.

5. LANDFILL CELL 15 CQA PLAN

Minor changes are proposed to the Landfill Cell 15 "*Construction Quality Assurance Plan for Landfill Construction and Closure*" (CQA Plan) as part of this Class 3 Permit Modification. The changes are very minor, to incorporate and make the plan consistent with recent construction change procedures (CCPs) implemented during liner construction projects. This updated CQA Plan is included in Exhibit H of this report, to replace the previous version of the Landfill Cell 15 CQA Plan. The CQA Plan establishes the quality assurance and quality control monitoring, testing, and documentation activities that shall be implemented during construction of liner and final cover systems and related facilities (e.g., leak detection and leachate collection systems, etc.). Required material properties of the liner and final cover system components are also presented in the CQA Plan.

Appendix A

Landfill Cell 15 Waste Disposal Volume Calculation

Written by: **Y. Bholat** Date: **2/17/2014** Reviewed by: **Scott Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

LANDFILL CELL 15 WASTE VOLUME CALCULATION

This Class 3 permit modification is proposed to laterally expand Cell 15 of the Lone Mountain Facility to the west of its currently permitted footprint. As part of the currently permitted design, Subcells 1 through 11 have been constructed and are in various stages of filling (or have already been filled to capacity). Subcells 12 and 13 are permitted but have not yet been constructed, and Subcells 14 through 22 are proposed. This volume calculation is based on the footprints for the existing as-constructed or permitted Subcells 1 through 11 and the proposed Subcells 12 through 22.

The volume of waste was calculated using three-dimensional digital terrain model (3D DTM) surfaces produced for the top of clay liner and the top of waste elevations along with CIVIL 3D® tools in AutoCAD®. The volume between the top of clay liner surface and the top of waste surface, which is the volume available for waste disposal, was calculated to be 8,065,500 yd^3. Representative output from the CIVIL 3D® tool is shown in Figure A1.

It is noted that the waste disposal volume of the currently-permitted Cell 15 (Subcells 1 through 13) is 5,264,000 yd^3. Therefore, this proposed Class 3 permit modification would provide a 2,801,500 yd^3 increase in waste disposal capacity.

Written by:	Y. Bholat	Date:	2/17/2014	Reviewed by:	Scott Graves	Date:	3/4/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

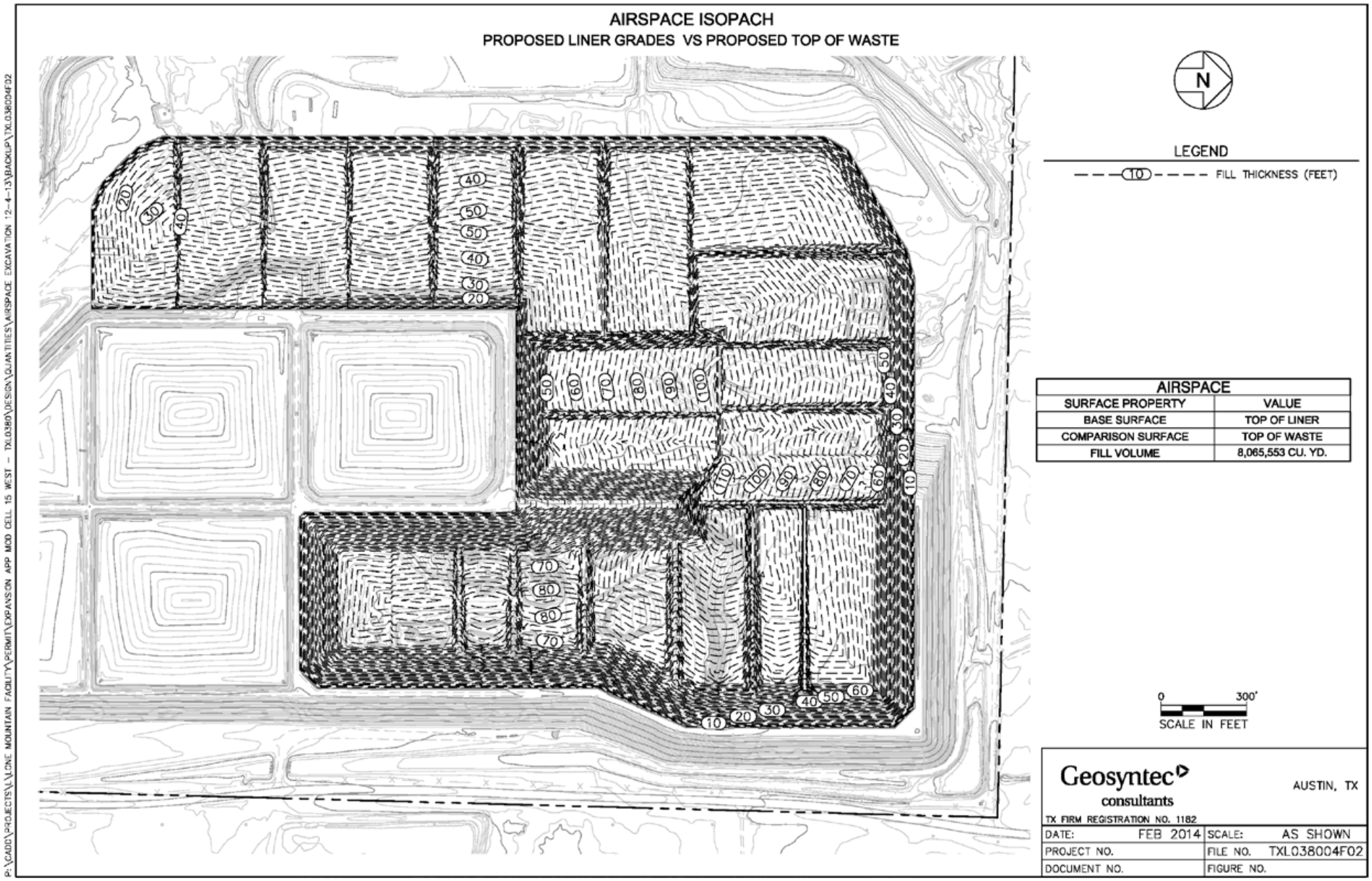
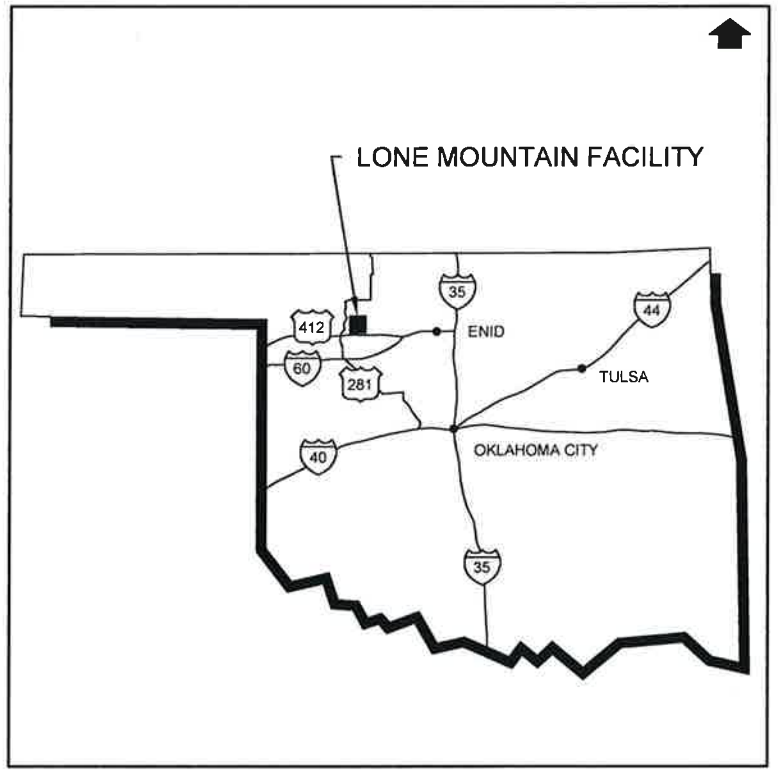


Figure A1. Airspace Isopach for Landfill Cell 15.

EXHIBIT A

ENGINEERING DRAWINGS

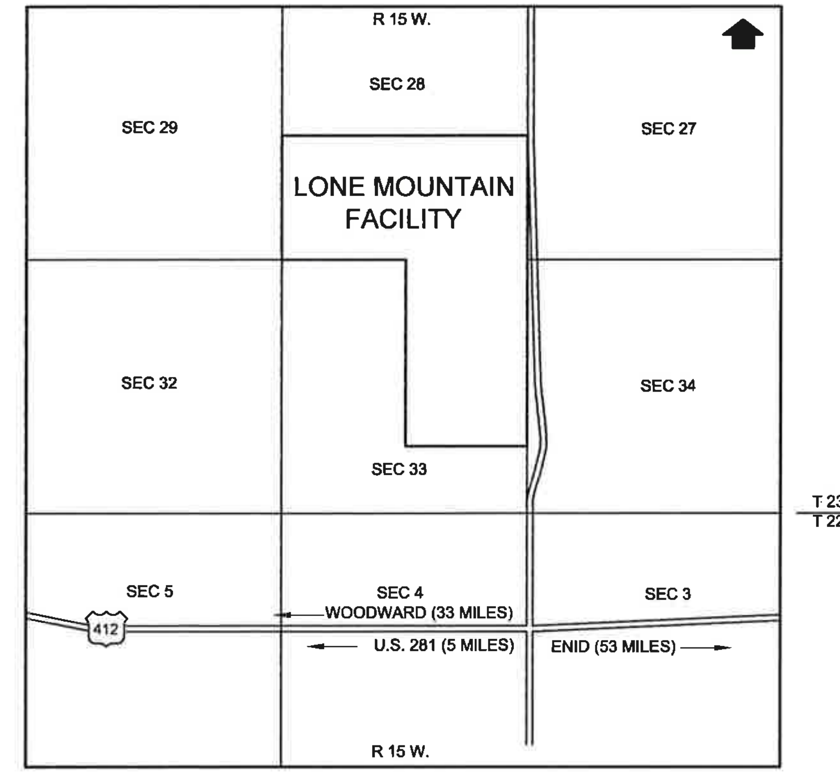
LONE MOUNTAIN FACILITY
LANDFILL CELL 15 WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION
JUNE 2014



LOCATION MAP
NOT TO SCALE

DRAWING NUMBER	DRAWING TITLE	LATEST REVISION	DATE
1	TITLE SHEET	–	JUNE 2014
2	SITE PLAN	–	JUNE 2014
3	HIGHEST HISTORICAL GROUNDWATER MAP	–	JUNE 2014
4	OVERALL CELL 15 TOP OF CLAY LINER GRADING PLAN	–	JUNE 2014
5	INTERIM FILLING PLAN – SUBCELL 11	–	JUNE 2014
6	INTERIM FILLING PLAN – SUBCELL 17	–	JUNE 2014
7	INTERIM FILLING PLAN – SUBCELL 21	–	JUNE 2014
8	TOP OF FINAL WASTE GRADING PLAN	–	JUNE 2014
9	TOP OF FINAL COVER GRADING PLAN	–	JUNE 2014
10	FINAL LANDFILL CROSS SECTION A	–	JUNE 2014
11	FINAL LANDFILL CROSS SECTION B	–	JUNE 2014
12	FINAL LANDFILL CROSS SECTIONS C AND D	–	JUNE 2014
13	LINER SYSTEM DETAILS I	–	JUNE 2014
14	LINER SYSTEM DETAILS II	–	JUNE 2014
15	EMBANKMENT AND LINER PERIMETER DETAILS	–	JUNE 2014
16	LEACHATE COLLECTION AND LEAK DETECTION PLAN	–	JUNE 2014
17	LEACHATE COLLECTION AND LEAK DETECTION SYSTEM DETAILS	–	JUNE 2014
18	SUMP DETAILS I	–	JUNE 2014
19	SUMP DETAILS II	–	JUNE 2014
20	FINAL COVER SYSTEM DETAILS	–	JUNE 2014
21	FINAL CELL 15 STORM WATER MANAGEMENT PLAN	–	JUNE 2014
22	STORM WATER MANAGEMENT DETAILS I	–	JUNE 2014
23	STORM WATER MANAGEMENT DETAILS II	–	JUNE 2014

DRAWING INDEX



VICINITY MAP
NOT TO SCALE

PREPARED FOR:

Clean Harbors® ENVIRONMENTAL SERVICES, INC.

ROUTE 2, BOX 170
WAYNOKA, OKLAHOMA 73860-9622
TELEPHONE: 405.697.3500

PREPARED BY:

Geosyntec consultants

8217 SHOAL CREEK BLVD, SUITE 200
AUSTIN, TEXAS 78757
TELEPHONE: 512.451.4003

DETAIL NUMBER
4
6
SHEET ON WHICH ABOVE DETAIL IS PRESENTED

DETAIL NUMBER
4
3
SHEET ON WHICH ABOVE DETAIL WAS FIRST REFERENCED
DETAIL
TITLE OF DETAIL
SCALE: 1"=2'

EXAMPLE: DETAIL NUMBER 4 PRESENTED ON SHEET NO. 6 WAS REFERENCED FOR THE FIRST TIME ON SHEET NO.3.

ABOVE SYSTEM ALSO APPLIES TO SECTION IDENTIFICATIONS.

DETAIL IDENTIFICATION LEGEND

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

PERMIT DRAWING

REV	DATE	DESCRIPTION	DRN	APP

Clean Harbors ENVIRONMENTAL SERVICES, INC.
CLEAN HARBORS ENVIRONMENTAL SERVICES, INC.
ROUTE 2, BOX 170
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Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
8217 SHOAL CREEK BLVD, SUITE 200
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PHONE: 512.451.4003

TITLE: TITLE SHEET

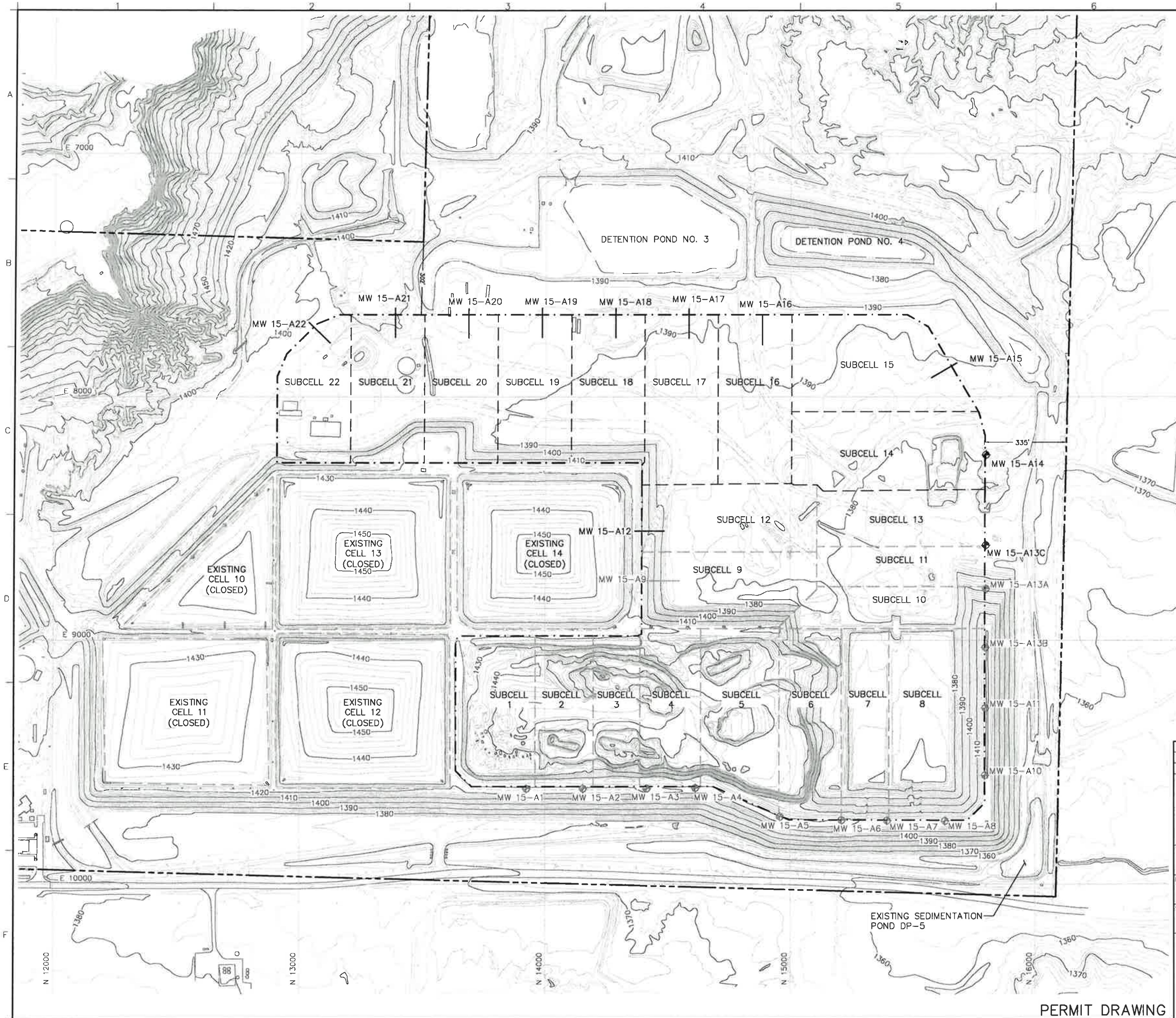
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY:	YB	DATE:	JUNE 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-P-1
REVIEWED BY:	SMG	DRAWING NO.:	
APPROVED BY:	–		1 OF 23

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST – TXL0380\DRAWINGS\TXL038004-P-1.dwg PLOTTED: Jun 02, 2014 – 2:42pm



PERMIT DRAWING

N

LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTE 1, 4)
	EXISTING ROAD
	EXISTING BUILDING OR TANK
	EXISTING FENCE
E 8000 N 15000	HORIZONTAL COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
	PROPOSED LIMIT OF WASTE (CELL 15) (NOTE 4)
	PROPOSED PHASE BOUNDARY
MW 15-A5	EXISTING CELL 15 MONITORING WELL
MW 15-A6	PROPOSED CELL 15 MONITORING WELL
MW 15-A9	EXISTING CELL 15 INCLINED MONITORING WELL
MW 15-A12	PROPOSED CELL 15 INCLINED MONITORING WELL

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. EXISTING MONITORING WELL LOCATIONS AND PROPOSED NEW MONITORING WELLS ASSOCIATED WITH THIS CELL 15 EXPANSION WERE PROVIDED BY CAMERON-COLE, INC., BOULDER, COLORADO.
4. WITHIN THE LIMIT OF WASTE, CELL 15 SUBCELLS 1 THROUGH 11 ARE EXISTING SUBCELLS THAT HAVE BEEN CONSTRUCTED. TOP OF LINER ELEVATIONS IN THESE SUBCELLS ARE AS-BUILT GRADES. CELL 15 SUBCELLS 12 AND 13 ARE PERMITTED BUT NOT YET CONSTRUCTED. TOP OF LINER ELEVATIONS IN THESE SUBCELLS ARE PERMITTED GRADES.

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors ENVIRONMENTAL SERVICES, INC.
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AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: SITE PLAN

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY:	YB	DATE:	JUNE 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-P-2
REVIEWED BY:	SMG	DRAWING NO.:	2 OF 23
APPROVED BY:	–		

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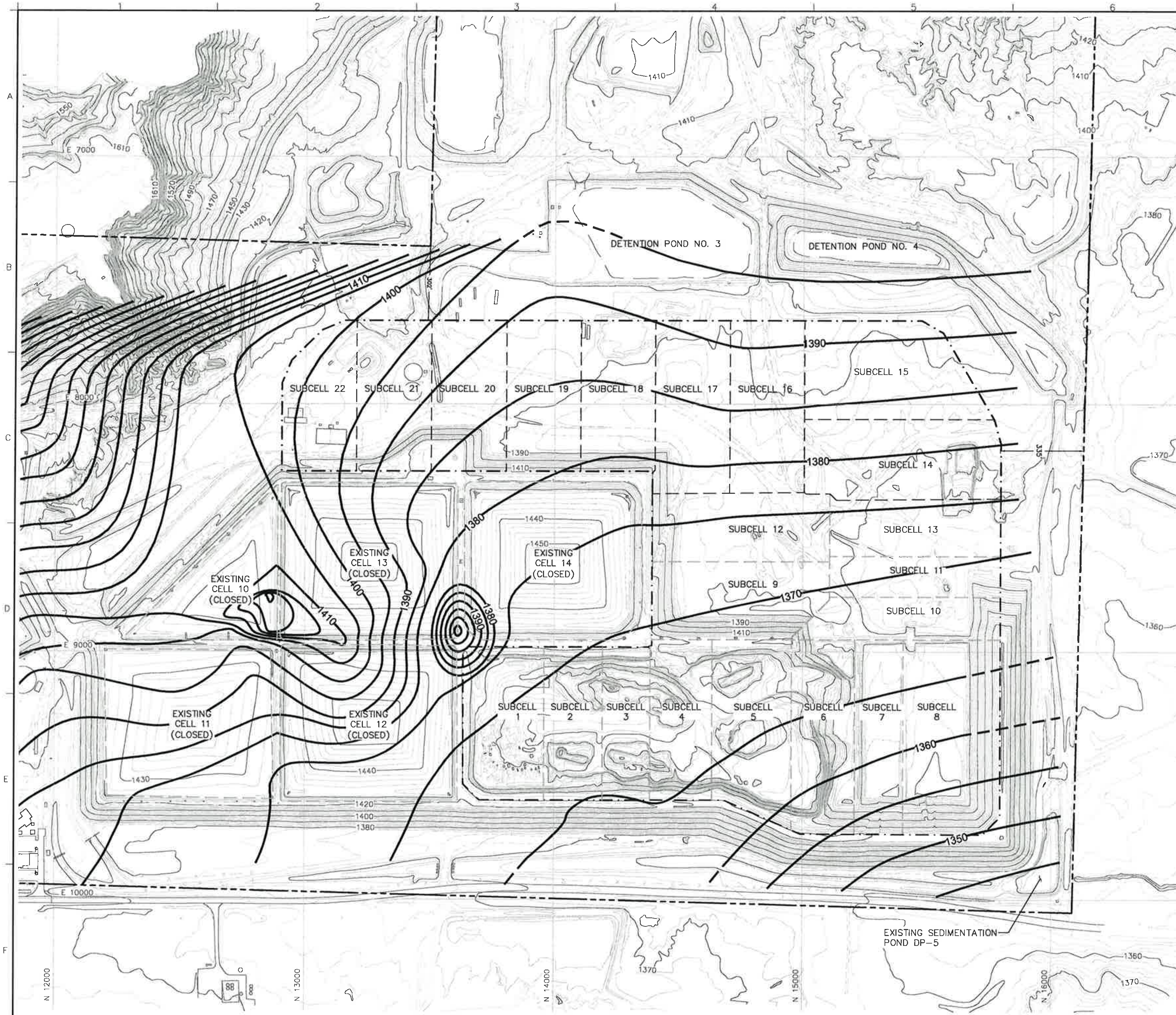

PERMIT DRAWING

N

LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTE 1, 4)
	EXISTING ROAD
	EXISTING FENCE
E 8000 N 15000	HORIZONTAL COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
	PROPOSED LIMIT OF WASTE (CELL 15) (NOTE 4)
	PROPOSED PHASE BOUNDARY
1380	HIGHEST HISTORICAL GROUNDWATER ELEVATION (FEET, MSL) (NOTE 3)

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. HISTORICAL HIGH GROUNDWATER CONTOURS PROVIDED BY CAMERON-COLE, INC. CONTOURS REPRESENT THE COMPOSITE SURFACE RESULTING FROM COMBINING THE HIGHEST GROUNDWATER ELEVATIONS RECORDED IN EACH WELL BETWEEN APPROXIMATELY 9/1987 TO 12/2013. THESE CONTOURS ARE THEREFORE CONSERVATIVELY HIGH SINCE NOT ALL HIGHEST WATER LEVELS OCCURRED AT THE SAME TIME.
4. WITHIN THE LIMIT OF WASTE, CELL 15 SUBCELLS 1 THROUGH 11 ARE EXISTING SUBCELLS THAT HAVE BEEN CONSTRUCTED. TOP OF LINER ELEVATIONS IN THESE SUBCELLS ARE AS-BUILT GRADES. CELL 15 SUBCELLS 12 AND 13 ARE PERMITTED BUT NOT YET CONSTRUCTED. TOP OF LINER ELEVATIONS IN THESE SUBCELLS ARE PERMITTED GRADES.

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors
ENVIRONMENTAL SERVICES, INC.
CLEAN HARBORS ENVIRONMENTAL SERVICES, INC.
ROUTE 2, BOX 170
WAYNOKA, OKLAHOMA 73860-9622
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Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
8217 SHOAL CREEK BLVD, SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: HIGHEST HISTORICAL GROUNDWATER MAP

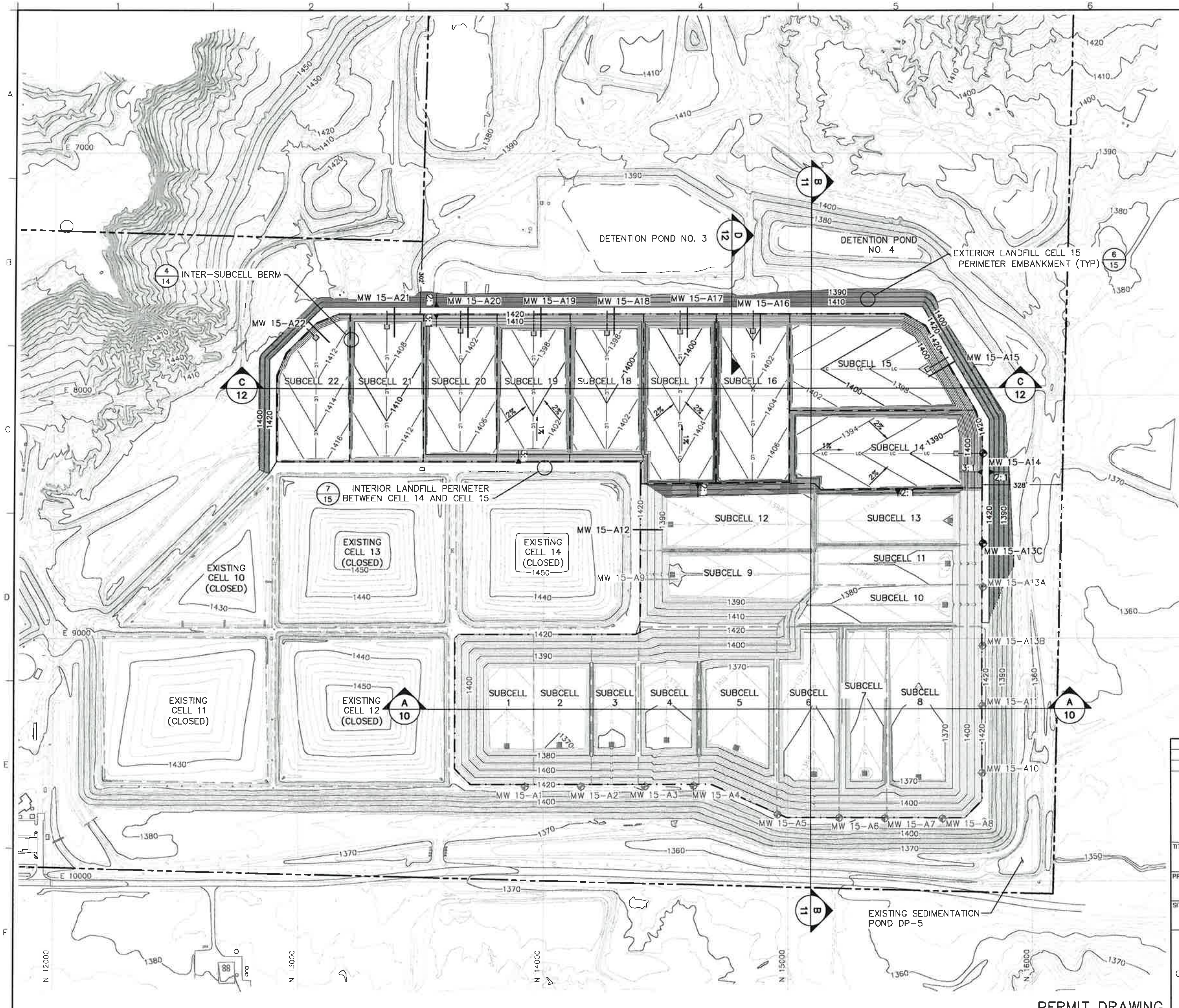
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY:	YB	DATE:	JUNE 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-P-3
REVIEWED BY:	SMG	DRAWING NO.:	3 OF 23
APPROVED BY:	–		

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST - TXL0380\DRAWINGS\TXL038004-P-3.dwg PLOTTED: Jun 02, 2014 - 2:43pm



LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTES 1, 4)
	EXISTING ROAD
	EXISTING FENCE
E 8000 N 15000	HORIZONTAL COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
	PROPOSED LIMIT OF WASTE (CELL 15) (NOTE 3)
	PROPOSED PHASE BOUNDARY
1380	PROPOSED TOP OF LINER ELEVATION (FEET) (NOTE 3)
LC	PROPOSED LEACHATE COLLECTION CORRIDOR
	PROPOSED LEACHATE COLLECTION SUMP
MW 15-A5	EXISTING CELL 15 MONITORING WELL
MW 15-A6	PROPOSED CELL 15 MONITORING WELL
MW 15-A9	EXISTING CELL 15 INCLINED MONITORING WELL
MW 15-A12	PROPOSED CELL 15 INCLINED MONITORING WELL

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. WITHIN THE LIMIT OF WASTE, CONTOURS REFER TO THE TOP OF LINER ELEVATIONS, WHICH IS THE TOP OF COMPACTED CLAY LINER (i.e. SURFACE ON WHICH THE BOTTOM GEOMEMBRANE LINER WILL BE INSTALLED). CONTOURS IN EXISTING SUBCELLS REFER TO AS-BUILT OR PERMITTED LINER GRADES AND CONTOURS IN FUTURE SUBCELLS REFER TO PROPOSED LINER GRADES. OUTSIDE THE LIMIT OF LINER, THE PROPOSED CONTOURS REFER TO FINISHED GRADE.
4. WITHIN THE LIMIT OF WASTE, CELL 15 SUBCELLS 1 THROUGH 11 ARE EXISTING SUBCELLS THAT HAVE BEEN CONSTRUCTED. TOP OF LINER ELEVATIONS IN THESE SUBCELLS ARE AS-BUILT GRADES. CELL 15 SUBCELLS 12 AND 13 ARE PERMITTED BUT NOT YET CONSTRUCTED. TOP OF LINER ELEVATIONS IN THESE SUBCELLS ARE PERMITTED GRADES.
5. EXISTING MONITORING WELL LOCATIONS AND PROPOSED NEW MONITORING WELLS ASSOCIATED WITH CELL 15 WERE PROVIDED BY CAMERON-COLE, INC., BOULDER, COLORADO.

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

REV	DATE	DESCRIPTION	DRN	APP

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8217 SHOAL CREEK BLVD, SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: OVERALL CELL 15 TOP OF CLAY LINER GRADING PLAN

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION CLASS 3 PERMIT MODIFICATION

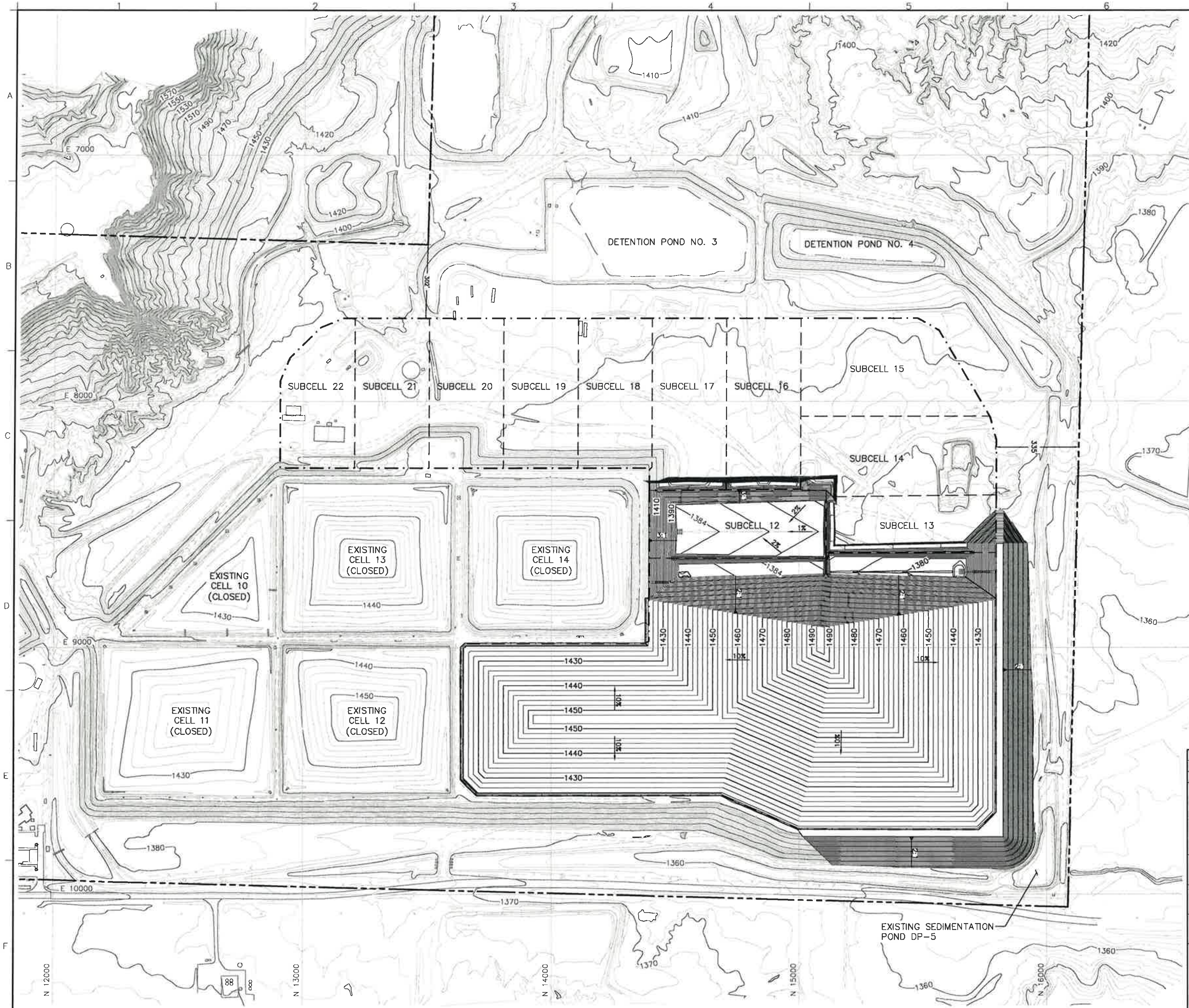
SITE: LONE MOUNTAIN FACILITY WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY:	YB	DATE:	JUNE 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-P-4
REVIEWED BY:	SMG	DRAWING NO.:	
APPROVED BY:	–		4 OF 23

PERMIT DRAWING

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST - TXL0380\DRAWINGS\TXL038004-P-4.dwg PLOTTED: Jun 02, 2014 - 2:44pm



N

LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTE 1)
	EXISTING ROAD
	EXISTING FENCE
E 8000 N 15000	HORIZONTAL COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
	PROPOSED LIMIT OF WASTE
	PROPOSED PHASE BOUNDARY
1400	PROPOSED CONTOUR ELEVATION (FEET)
	EXISTING LEACHATE COLLECTION CORRIDOR
	EXISTING LEACHATE COLLECTION SUMP

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. THE PURPOSE OF THIS DRAWING IS TO ILLUSTRATE A CONCEPTUAL "SNAP-SHOT" OF THE APPROXIMATE FUTURE CELL 15 CONFIGURATION WHEN SUBCELLS 9 AND 11 ARE FILLED TO INTERIM CAPACITY WITH WASTE, AND SUBCELL 12 LINER IS CONSTRUCTED. KEY FEATURES SHOWN INCLUDE:
   - EAST PORTION OF CELL 15 BUILT TO FINAL WASTE GRADES
   - SUBCELLS 9 AND 11 MOSTLY FILLED TO INTERIM GRADES (LOWER THAN FINAL)
   - INTERIM WASTE SET-BACKS IN SUBCELLS 9 AND 11 FOR TEMPORARY STORM WATER HOLDING AREA
   - SUBCELL 12 LINER SYSTEM CONSTRUCTED AND READY FOR WASTE PLACEMENT
   - FUTURE SUBCELL 13 THROUGH 22 NOT YET CONSTRUCTED
4. ACTIVE WASTE FACE SHALL BE SLOPED AT A MAXIMUM STEEPNESS OF 2H:1V.

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

REV	DATE	DESCRIPTION	DRN	APP

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Geosyntec consultants
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PHONE: 512.451.4003

TITLE: INTERIM FILLING PLAN – SUBCELL 11

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

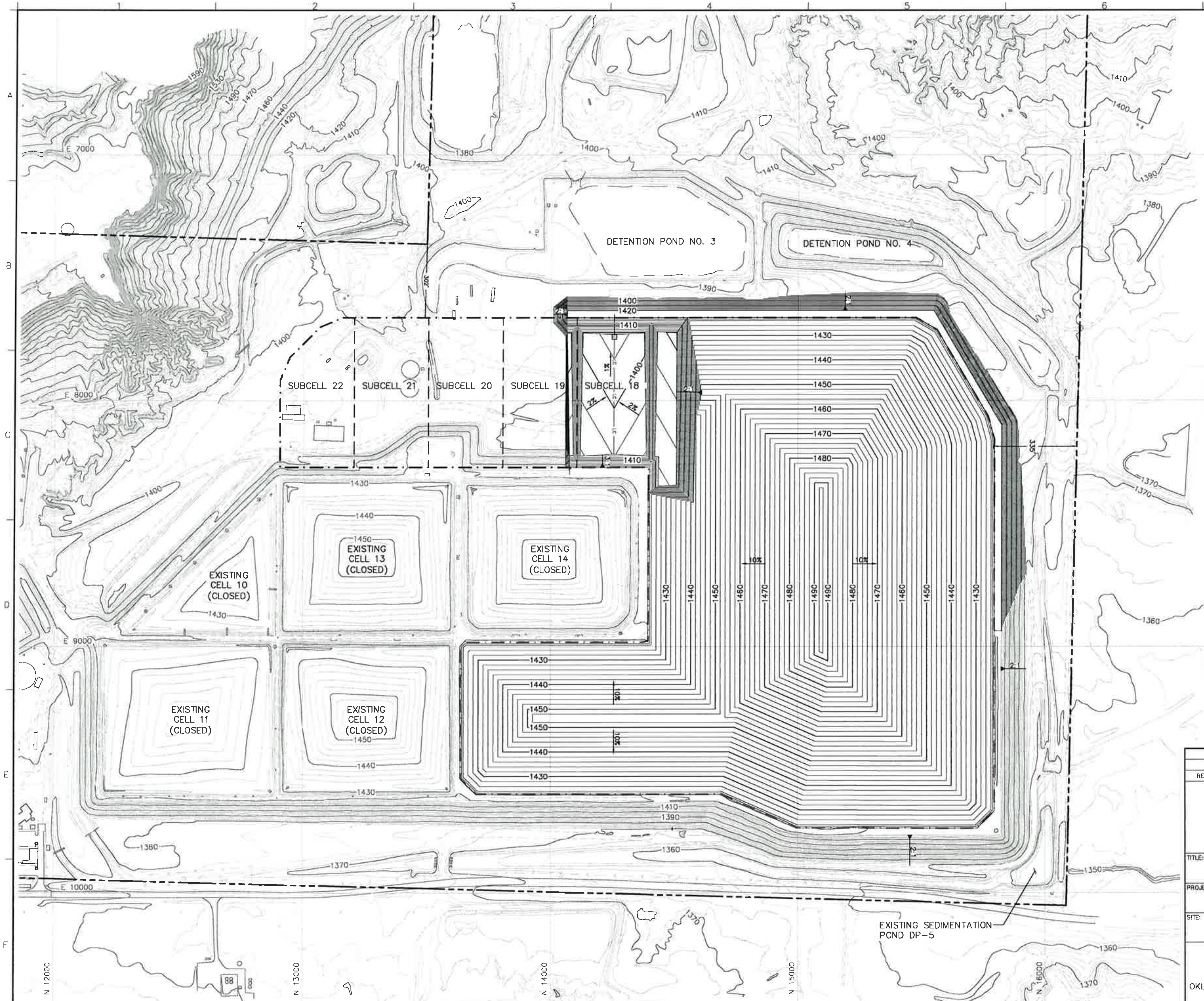
SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY:	YB	DATE:	JUNE 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-P-6
REVIEWED BY:	SMG	DRAWING NO.:	5 OF 23
APPROVED BY:	–		

PERMIT DRAWING

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST – TXL0380\DRAWINGS\TXL038004-P-6.dwg PLOTTED: Jun 02, 2014 – 2:44pm



N

LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTE 1)
	EXISTING ROAD
	EXISTING FENCE
E 8000 N 15000	HORIZONTAL COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
	PROPOSED LIMIT OF WASTE
	PROPOSED PHASE BOUNDARY
1400	PROPOSED CONTOUR ELEVATION (FEET)
LC	PROPOSED LEACHATE COLLECTION CORRIDOR
	PROPOSED LEACHATE COLLECTION SUMP

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. THE PURPOSE OF THIS DRAWING IS TO ILLUSTRATE A CONCEPTUAL "SNAP-SHOT" OF THE APPROXIMATE FUTURE CELL 15 CONFIGURATION WHEN SUBCELL 17 IS FILLED TO INTERIM CAPACITY WITH WASTE, AND SUBCELL 18 LINER IS CONSTRUCTED. KEY FEATURES SHOWN INCLUDE:
   - NORTH AND EAST PORTION OF CELL 15 BUILT TO FINAL WASTE GRADES
   - SUBCELL 17 MOSTLY FILLED
   - INTERIM WASTE SET-BACK IN SUBCELL 17 FOR TEMPORARY STORM WATER HOLDING AREA
   - SUBCELL 18 LINER SYSTEM CONSTRUCTED AND READY FOR WASTE PLACEMENT
   - FUTURE SUBCELLS 19 THROUGH 22 NOT YET CONSTRUCTED
4. ACTIVE WASTE FACE SHALL BE SLOPED AT A MAXIMUM STEEPNESS OF 2H:1V.

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

REV	DATE	DESCRIPTION	DRN	APP

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TITLE: INTERIM FILLING PLAN – SUBCELL 17

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

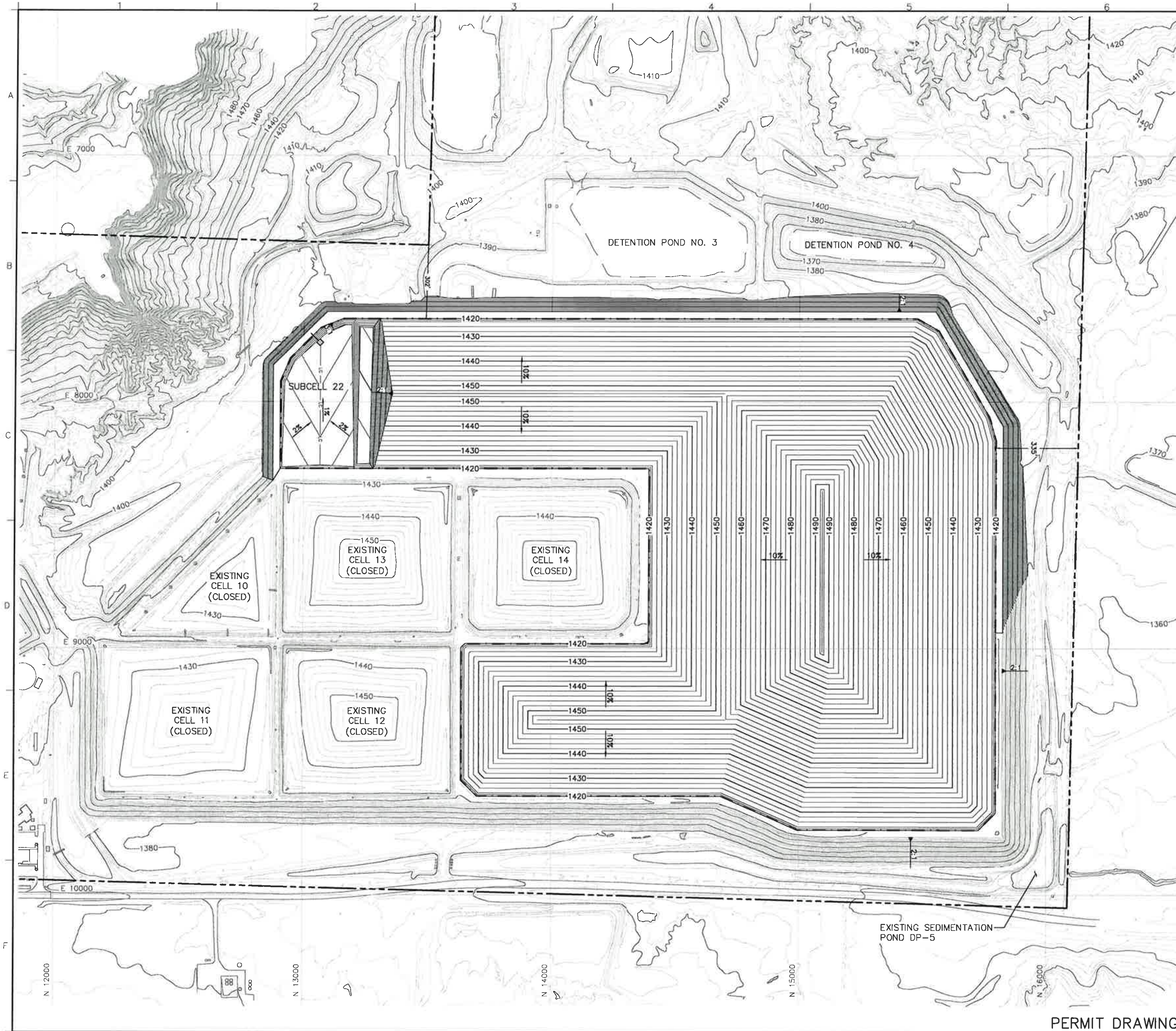
SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY:	YB	DATE:	JUNE 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-P-5A
REVIEWED BY:	SMG	DRAWING NO.:	
APPROVED BY:	–	6 OF 23	

PERMIT DRAWING

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST – TXL0380\DRAWINGS\TXL038004-P-5a.dwg PLOTTED: Jun 02, 2014 – 2:45pm



LEGEND

—1400—	EXISTING GROUND ELEVATION (FEET) (NOTE 1)
	EXISTING ROAD
	EXISTING FENCE
E 8000 N 15000	HORIZONTAL COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
	PROPOSED LIMIT OF WASTE
	PROPOSED PHASE BOUNDARY
—1400—	PROPOSED CONTOUR ELEVATION (FEET)
LC	PROPOSED LEACHATE COLLECTION CORRIDOR
	PROPOSED LEACHATE COLLECTION SUMP

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP WAS COMPILED USING AN AERIAL SURVEY DATED 11 FEBRUARY 2005 AND A GROUND SURVEY DATED 30 JUNE 2010 WITHIN THE ACTIVE WASTE PLACEMENT AREAS OF CELL 15, PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ALONG WITH INFORMATION FROM PREVIOUS CONSTRUCTION AND AS-BUILT DRAWINGS FOR SUBCELL 15. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. THE PURPOSE OF THIS DRAWING IS TO ILLUSTRATE A CONCEPTUAL "SNAP-SHOT" OF THE APPROXIMATE FUTURE CELL 15 CONFIGURATION WHEN SUBCELL 21 IS FILLED TO INTERIM CAPACITY WITH WASTE, AND SUBCELL 22 LINER IS CONSTRUCTED.
   KEY FEATURES SHOWN INCLUDE:
   - ALMOST ALL OF CELL 15 BUILT TO FINAL WASTE GRADES
   - SUBCELL 21 MOSTLY FILLED
   - INTERIM WASTE SET-BACK IN SUBCELL 21 FOR TEMPORARY STORM WATER HOLDING AREA
   - SUBCELL 22 LINER SYSTEM CONSTRUCTED AND READY FOR WASTE PLACEMENT
4. ACTIVE WASTE FACE SHALL BE SLOPED AT A MAXIMUM STEEPNESS OF 2H:1V.

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors
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Geosyntec consultants
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8217 SHOAL CREEK BLVD, SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: INTERIM FILLING PLAN – SUBCELL 21

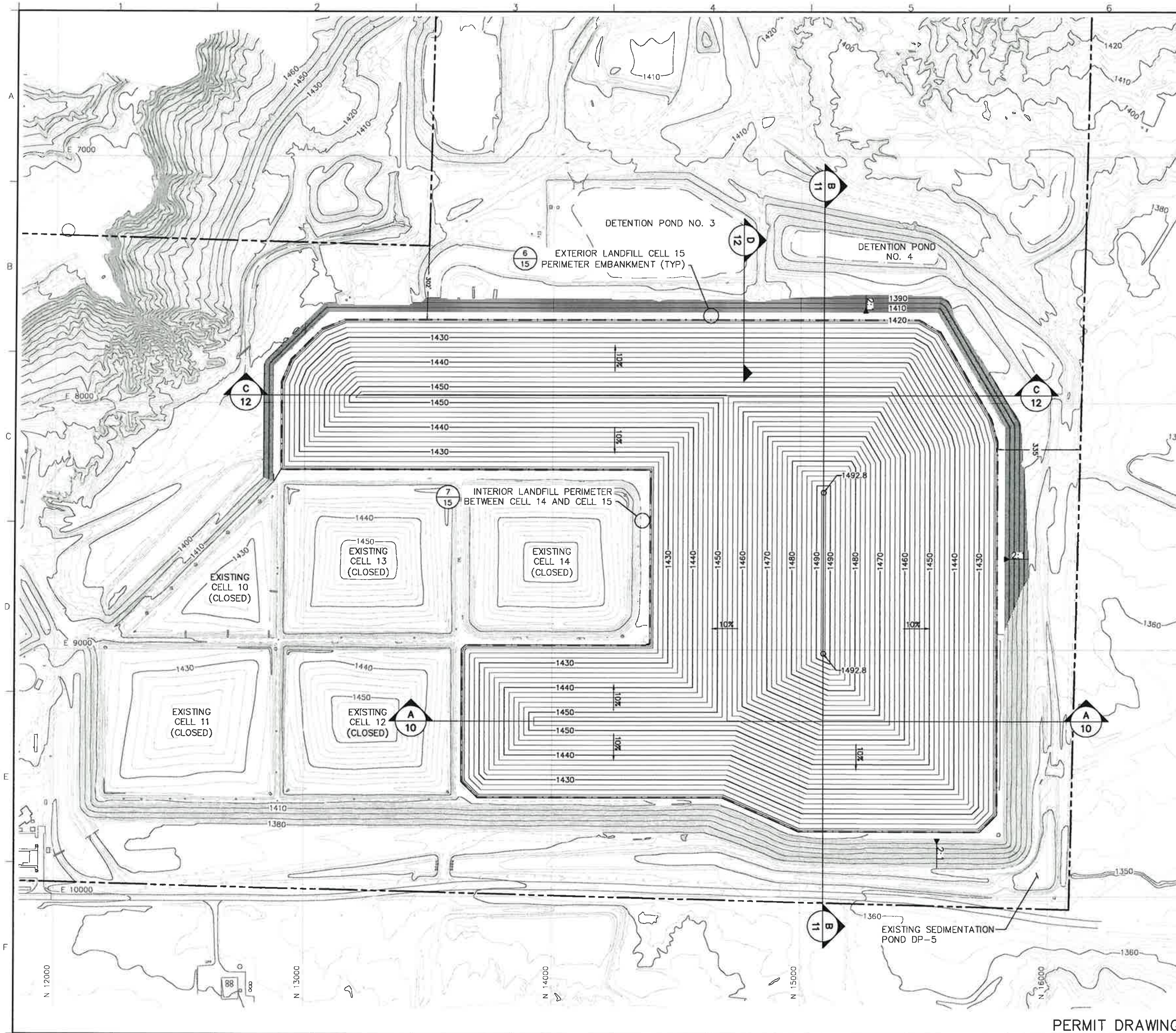
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY:	YB	DATE:	JUNE 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-P-6B
REVIEWED BY:	SMG	DRAWING NO.:	
APPROVED BY:	–		7 OF 23

PERMIT DRAWING



LEGEND

—1400—	EXISTING GROUND ELEVATION (FEET) (NOTE 1)
	EXISTING ROAD
	EXISTING FENCE
E 8000 N 15000	HORIZONTAL COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
	PROPOSED LIMIT OF WASTE
—1400—	PROPOSED TOP OF WASTE ELEVATION (FEET) (NOTE 3)

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. WITHIN THE LIMIT OF WASTE, PROPOSED CONTOURS REFER TO TOP OF WASTE ELEVATIONS OR THE PROPOSED FINISHED WASTE GRADE, REPRESENTING THE SURFACE ON WHICH THE FINAL COVER SYSTEM WILL BE CONSTRUCTED. OUTSIDE THE LIMIT OF LINER, THE PROPOSED CONTOURS REFER TO FINISHED GRADE.
4. IT IS ANTICIPATED THAT FINAL COVER SYSTEM WILL BE CONSTRUCTED INCREMENTALLY IN PHASES. SEE CELL 15 CLOSURE PLAN FOR ADDITIONAL INFORMATION.

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors
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TITLE: TOP OF FINAL WASTE GRADING PLAN

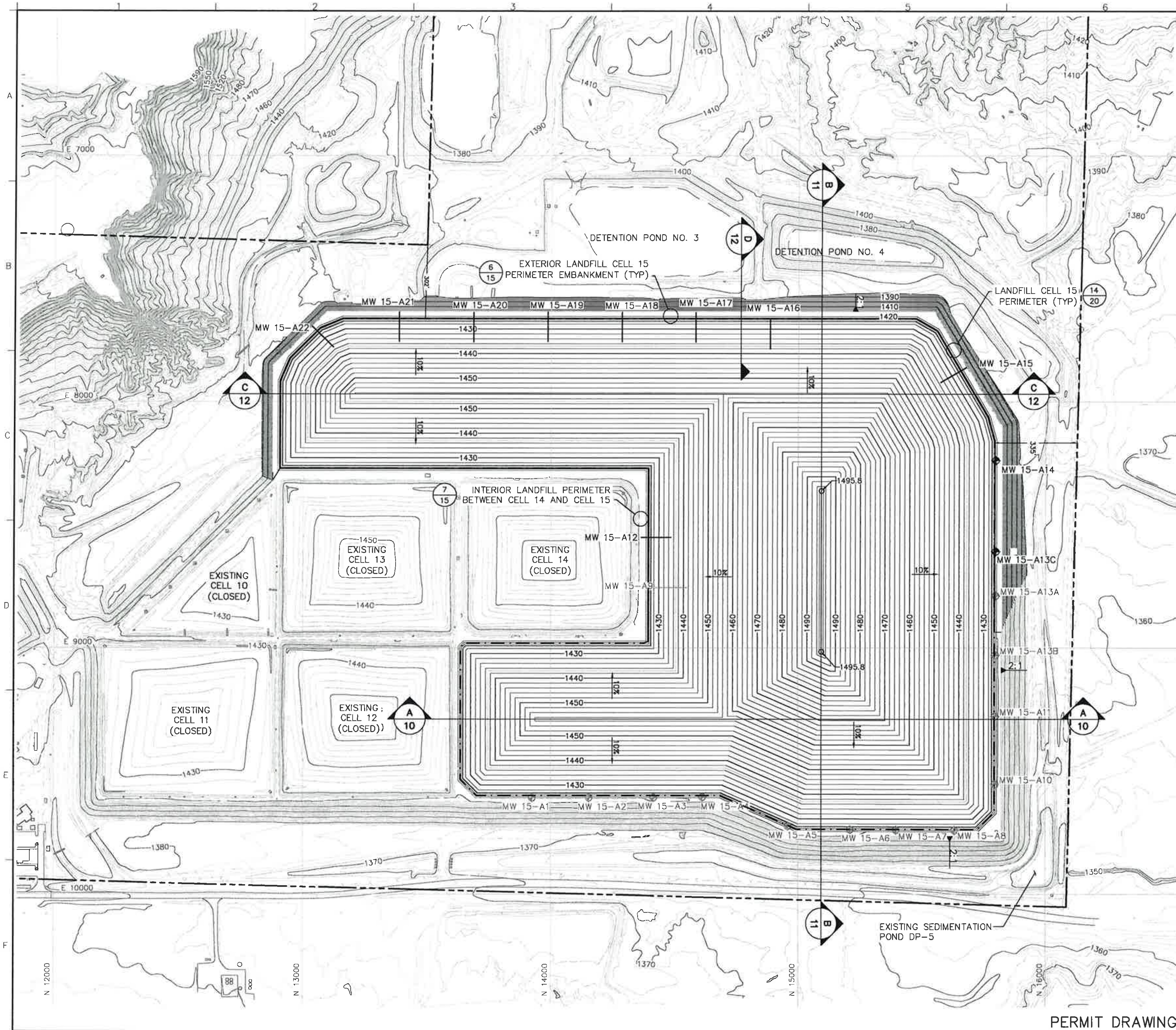
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-P-7
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	8 OF 23

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST – TXL0380\DRAWINGS\TXL038004-P-7.dwg PLOTTED: Jun 02, 2014 – 2:46pm



LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTE 1)
	EXISTING ROAD
	EXISTING FENCE
E 8000 N 15000	HORIZONTAL COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
	PROPOSED LIMIT OF WASTE
1400	PROPOSED TOP OF FINAL COVER ELEVATION (FEET) (NOTE 3)
MW 15-A5	EXISTING MONITORING WELL
MW 15-A6	PROPOSED MONITORING WELL

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. WITHIN THE LIMIT OF WASTE, TOP OF FINAL COVER ELEVATIONS REFER TO PROPOSED FINISHED GRADE (TOP OF THE TOPSOIL COMPONENT OF FINAL COVER SYSTEM). OUTSIDE THE LIMIT OF LINER, THE PROPOSED CONTOURS REFER TO FINISHED GRADE.
4. REFER TO DRAWING 21 FOR FINAL STORM WATER MANAGEMENT PLAN, INCLUDING LOCATIONS OF DRAINAGE FEATURES ON THE FINAL COVER (NOT SHOWN HERE FOR CLARITY).
5. EXISTING MONITORING WELL LOCATIONS AND PROPOSED NEW MONITORING WELLS ASSOCIATED WITH THIS CELL 15 EXPANSION WERE PROVIDED BY CAMERON-COLE, INC., BOULDER, COLORADO.

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors ENVIRONMENTAL SERVICES, INC.
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PHONE: 512.451.4003

TITLE: TOP OF FINAL COVER GRADING PLAN

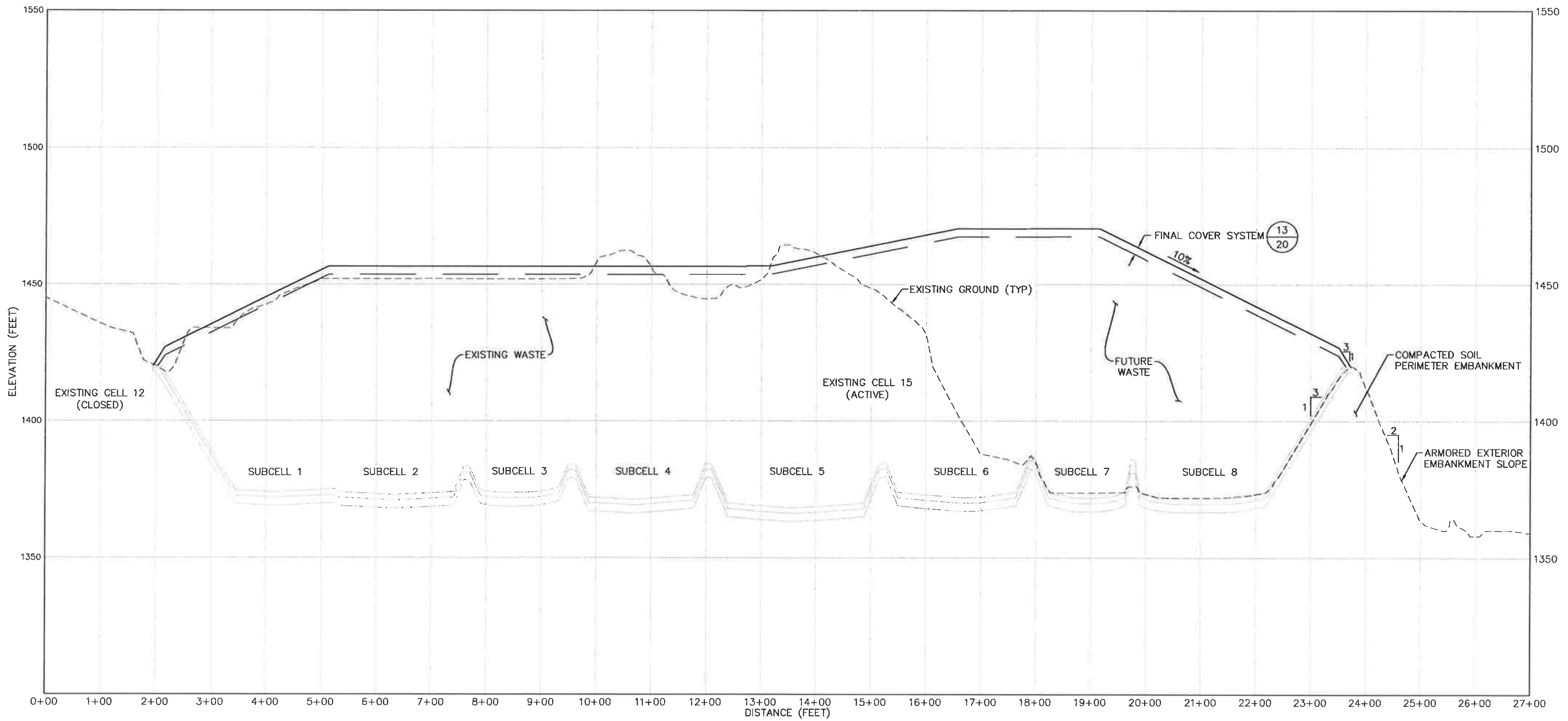
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

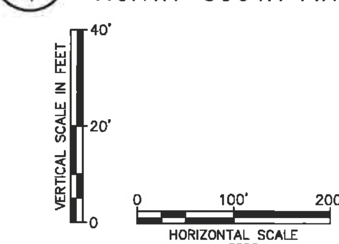
GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY:	YB	DATE:	JUNE 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-P-8
REVIEWED BY:	SMG	DRAWING NO.:	
APPROVED BY:	–	9 OF 23	

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST - TXL0380\DRAWINGS\TXL038004-P-8.dwg PLOTTED: Jun 02, 2014 - 2:46pm



A
4
SECTION
NORTH–SOUTH FINAL LANDFILL CROSS SECTION



6/13/2014

REGISTERED PROFESSIONAL ENGINEER
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OKLAHOMA

PERMIT DRAWING

REV	DATE	DESCRIPTION	DRN	APP

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Geosyntec
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PHONE: 512.451.4003

TITLE: FINAL LANDFILL CROSS SECTION A

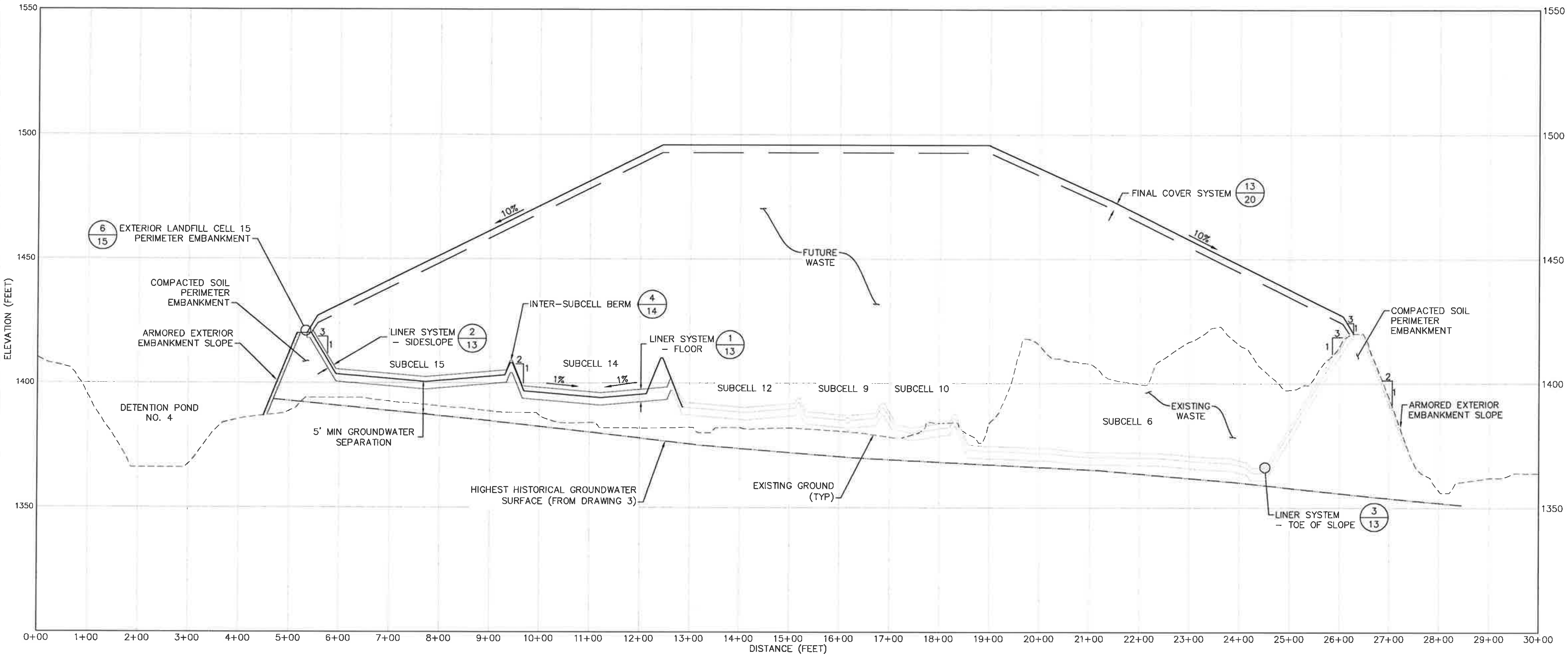
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

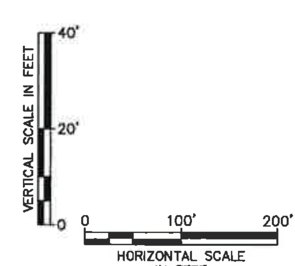
GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-P-9
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	10 OF 23

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST - TXL0380\DRAWINGS\TXL038004-P-9.dwg PLOTTED: Jun 02, 2014 - 2:47pm



B/4 SECTION
WEST-EAST FINAL LANDFILL CROSS SECTION



6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

PERMIT DRAWING

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors ENVIRONMENTAL SERVICES, INC.
CLEAN HARBORS ENVIRONMENTAL SERVICES, INC.
ROUTE 2, BOX 170
WAYNOKA, OKLAHOMA 73860-9622
PHONE: 405.697.3500

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
8217 SHOAL CREEK BLVD, SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: FINAL LANDFILL CROSS SECTION B

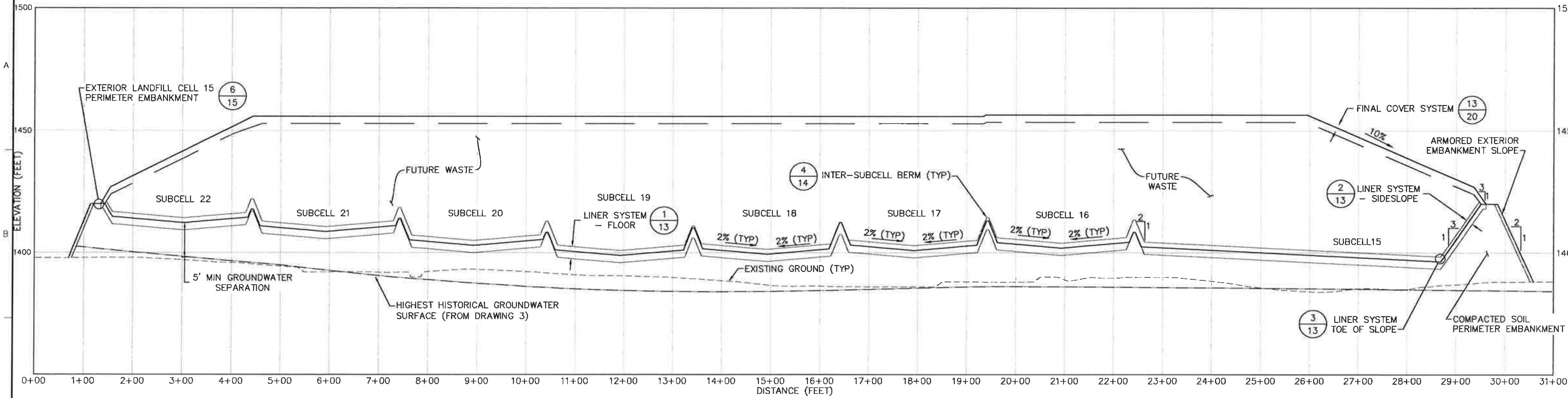
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-P-9A
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	11 OF 23

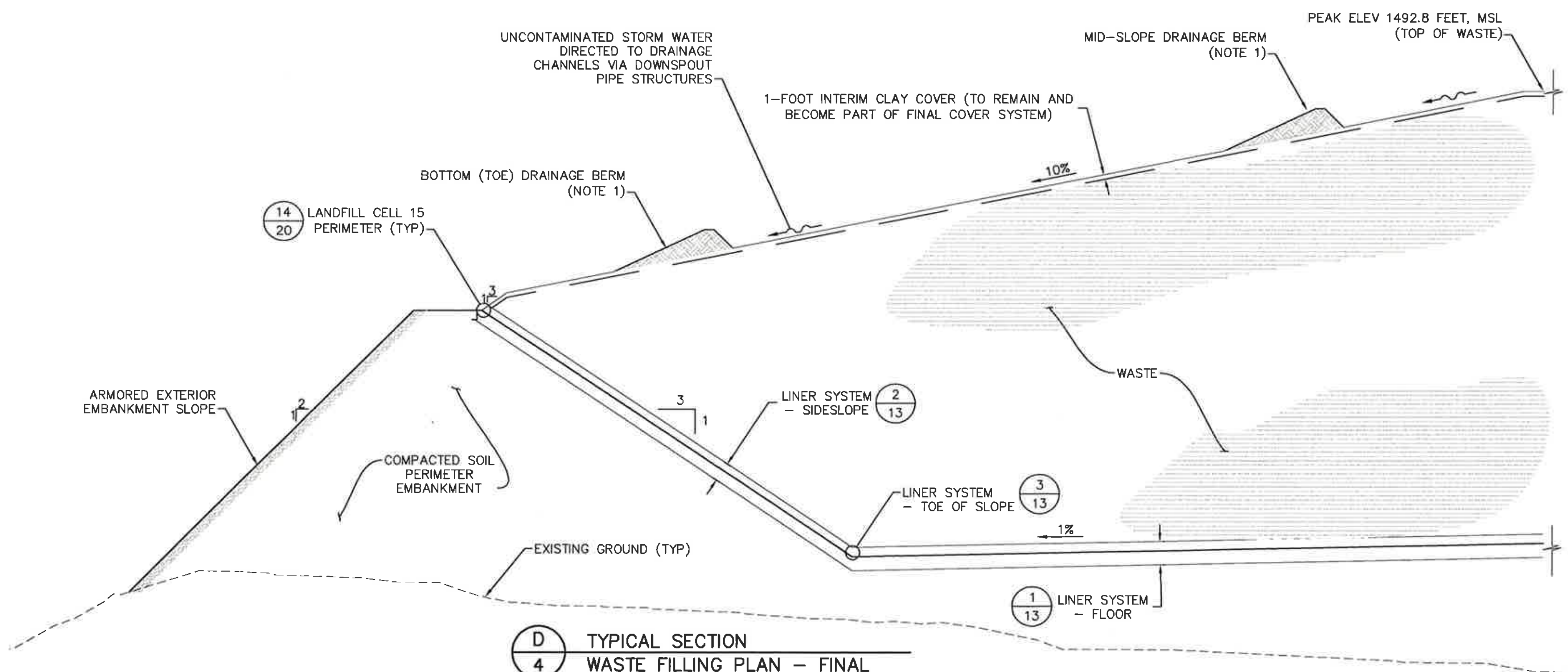
DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST - TXL0380\DRAWINGS\TXL038004-P-9A.dwg PLOTTED: Jun 02, 2014 - 2:47pm



SECTION (C/4)
NORTH–SOUTH FINAL LANDFILL CROSS SECTION

0 20' 40' VERTICAL SCALE IN FEET

0 100' 200' HORIZONTAL SCALE IN FEET



TYPICAL SECTION (D/4)
WASTE FILLING PLAN – FINAL (PRE–FINAL COVER INSTALLATION)
SCALE: N.T.S.

NOTES:

1. MID–SLOPE AND TOE DRAINAGE BERMS SHALL BE LOCATED IN THE SAME GENERAL LOCATIONS AS SPECIFIED FOR THE FINAL STORM WATER MANAGEMENT PLAN (DRAWING 21). BERM DIMENSIONS SHALL ALSO BE AS SPECIFIED FOR THESE FINAL FEATURES (DRAWING 22).

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
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8217 SHOAL CREEK BLVD, SUITE 200
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TITLE: FINAL LANDFILL CROSS SECTIONS C AND D

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004–P–11
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	12 OF 23

PERMIT DRAWING

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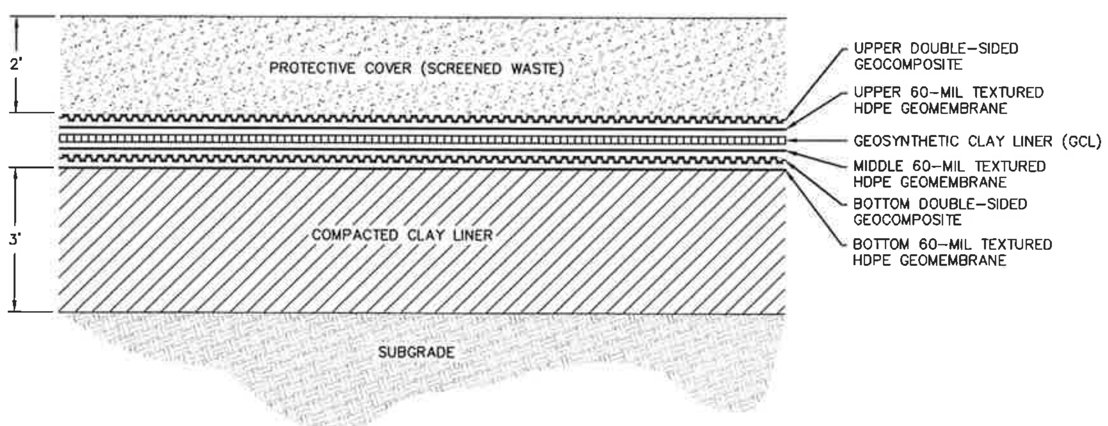
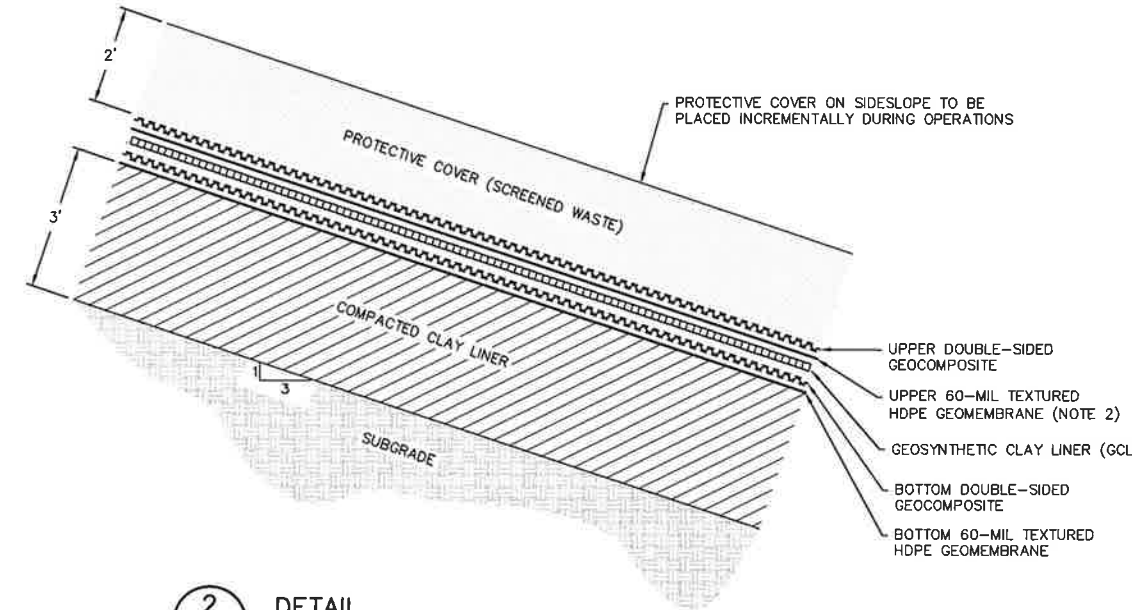


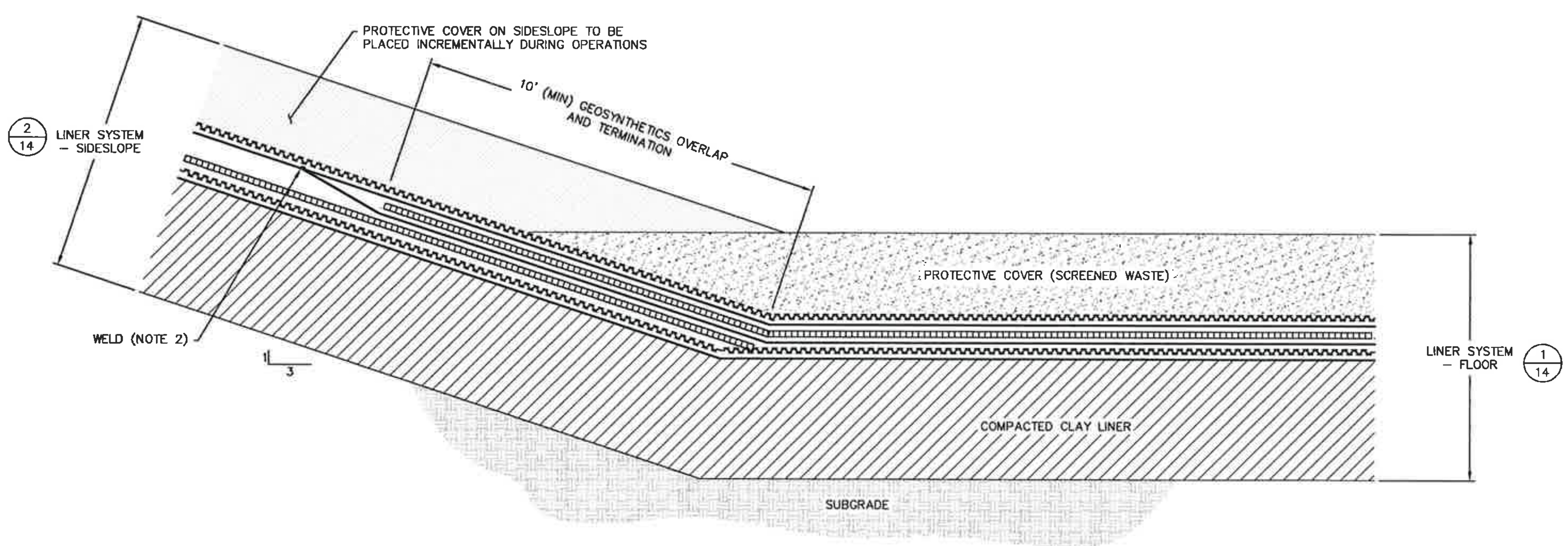
1/12 DETAIL
LINER SYSTEM – FLOOR
SCALE: N.T.S.



2/12 DETAIL
LINER SYSTEM – SIDESLOPE
SCALE: N.T.S.

NOTES:

1. REFER TO THE CQA PLAN FOR ADDITIONAL SPECIFICATIONS AND CONSTRUCTION REQUIREMENTS.
2. UPPER GEOMEMBRANE ON SIDESLOPE IS A CONTINUATION OF THE MIDDLE GEOMEMBRANE ON THE FLOOR.
3. GEOSYNTHETIC COMPONENTS ARE EXAGGERATED FOR CLARITY.



3/12 DETAIL
LINER SYSTEM – TOE OF SLOPE
SCALE: N.T.S.

REGISTERED PROFESSIONAL ENGINEER
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6/13/2014

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PHONE: 512.451.4003

TITLE: LINER SYSTEM DETAILS I

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

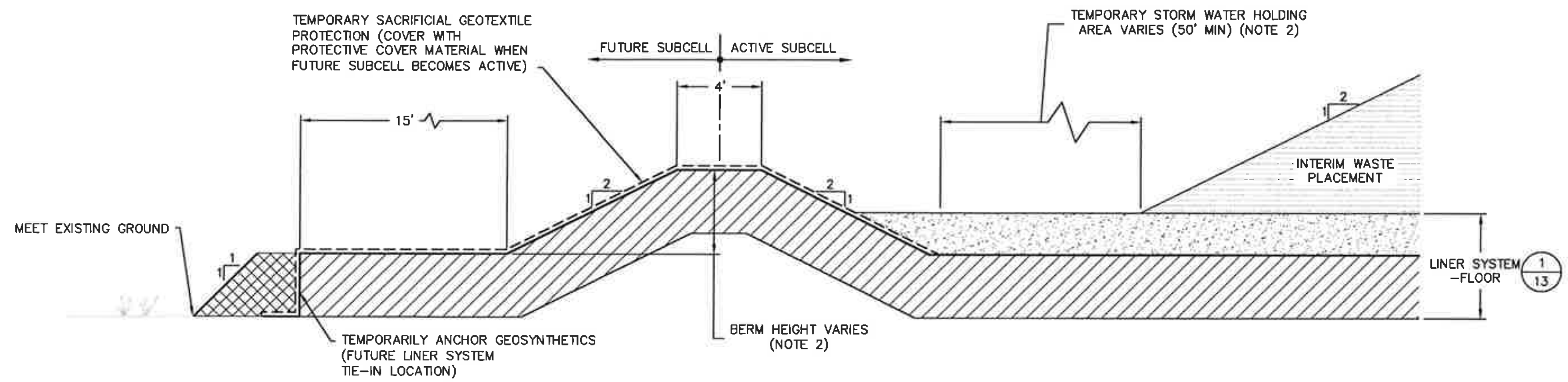
SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-P-12
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	13 OF 23

PERMIT DRAWING

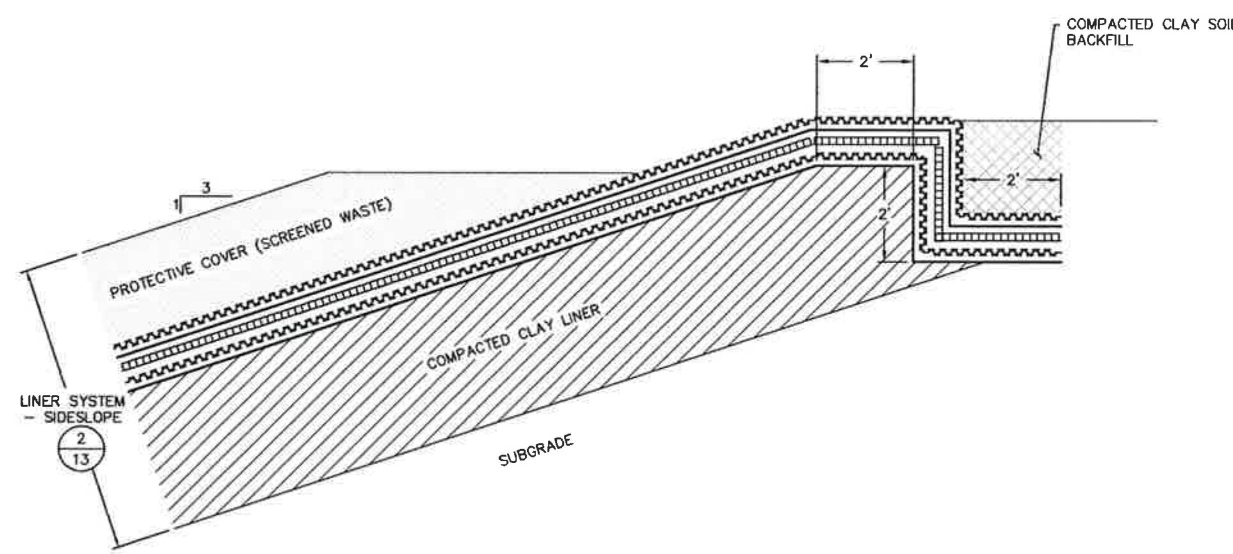
DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST - TXL0380\DRAWINGS\TXL038004-P-12.dwg PLOTTED: Jun 02, 2014 - 2:47pm



4/4 DETAIL
INTER-SUBCELL BERM
SCALE: N.T.S.

NOTES:

1. REFER TO THE CQA PLAN FOR ADDITIONAL SPECIFICATIONS AND CONSTRUCTION REQUIREMENTS.
2. INTER-SUBCELL BERM HEIGHTS AND TEMPORARY STORM WATER HOLDING AREA DIMENSIONS VARY AND SHALL BE AS SPECIFIED IN EXHIBIT C OF THE LANDFILL CELL 15 ENGINEERING REPORT.
3. GEOSYNTHETIC COMPONENTS ARE EXAGGERATED FOR CLARITY.



5/15 DETAIL
LINER SYSTEM – ANCHOR TRENCH
SCALE: N.T.S.

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
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OKLAHOMA

6/13/2014

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PHONE: 512.451.4003

TITLE: LINER SYSTEM DETAILS II

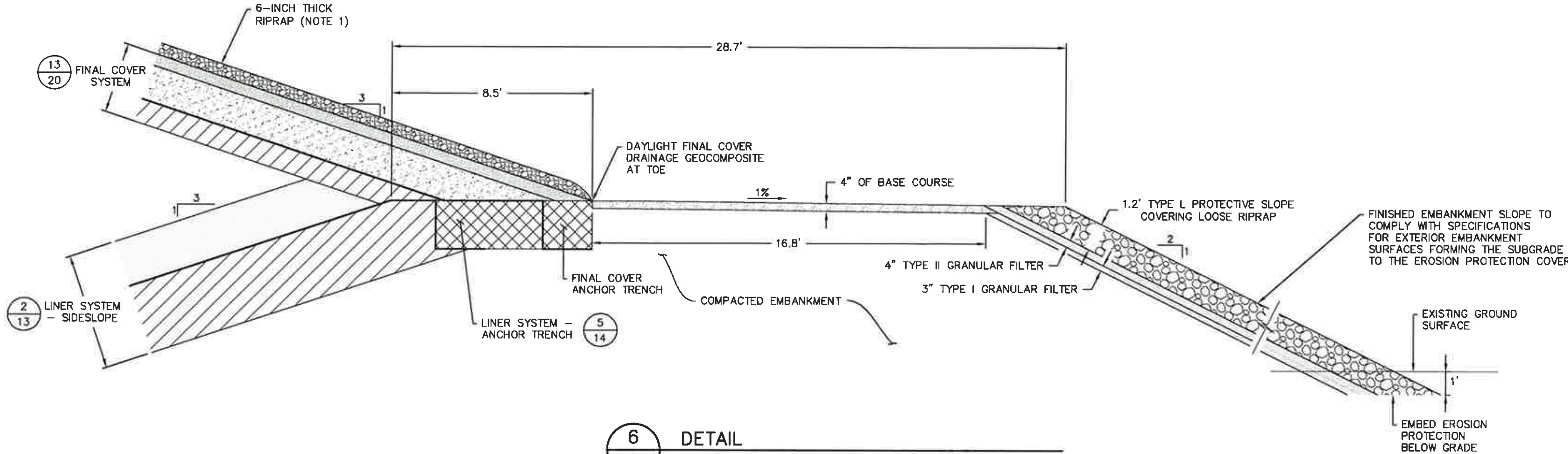
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-P-13
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	14 OF 23

PERMIT DRAWING

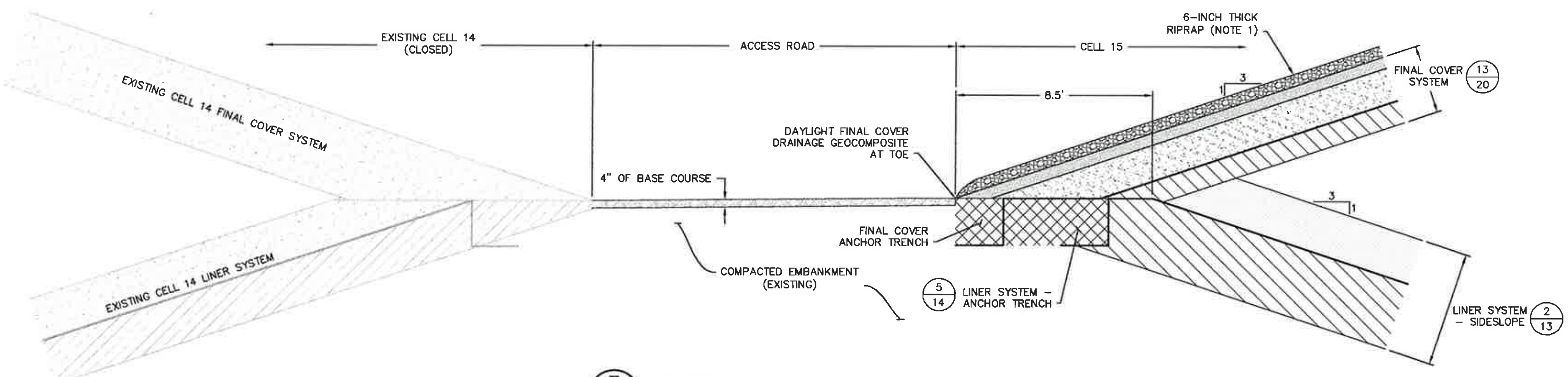


6/4 DETAIL
EXTERIOR LANDFILL CELL 15 PERIMETER EMBANKMENT (TYP)

0 3' 6'
SCALE IN FEET

NOTE:

1. ON THE 3 HORIZONTAL TO 1 VERTICAL (3H:1V) PORTIONS OF THE FINAL COVER SIDESLOPES, THE VEGETATION MAY BE SUBSTITUTED WITH A 6-INCH LAYER OF TYPE V RIPRAP.



7/4 DETAIL
INTERIOR LANDFILL PERIMETER BETWEEN CELL 14 AND CELL 15

0 3' 6'
SCALE IN FEET

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

6/13/2014

REV	DATE	DESCRIPTION	DRN	APP

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PHONE: 512.451.4003

TITLE: EMBANKMENT AND LINER PERIMETER DETAILS

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-P-14
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	15 OF 23

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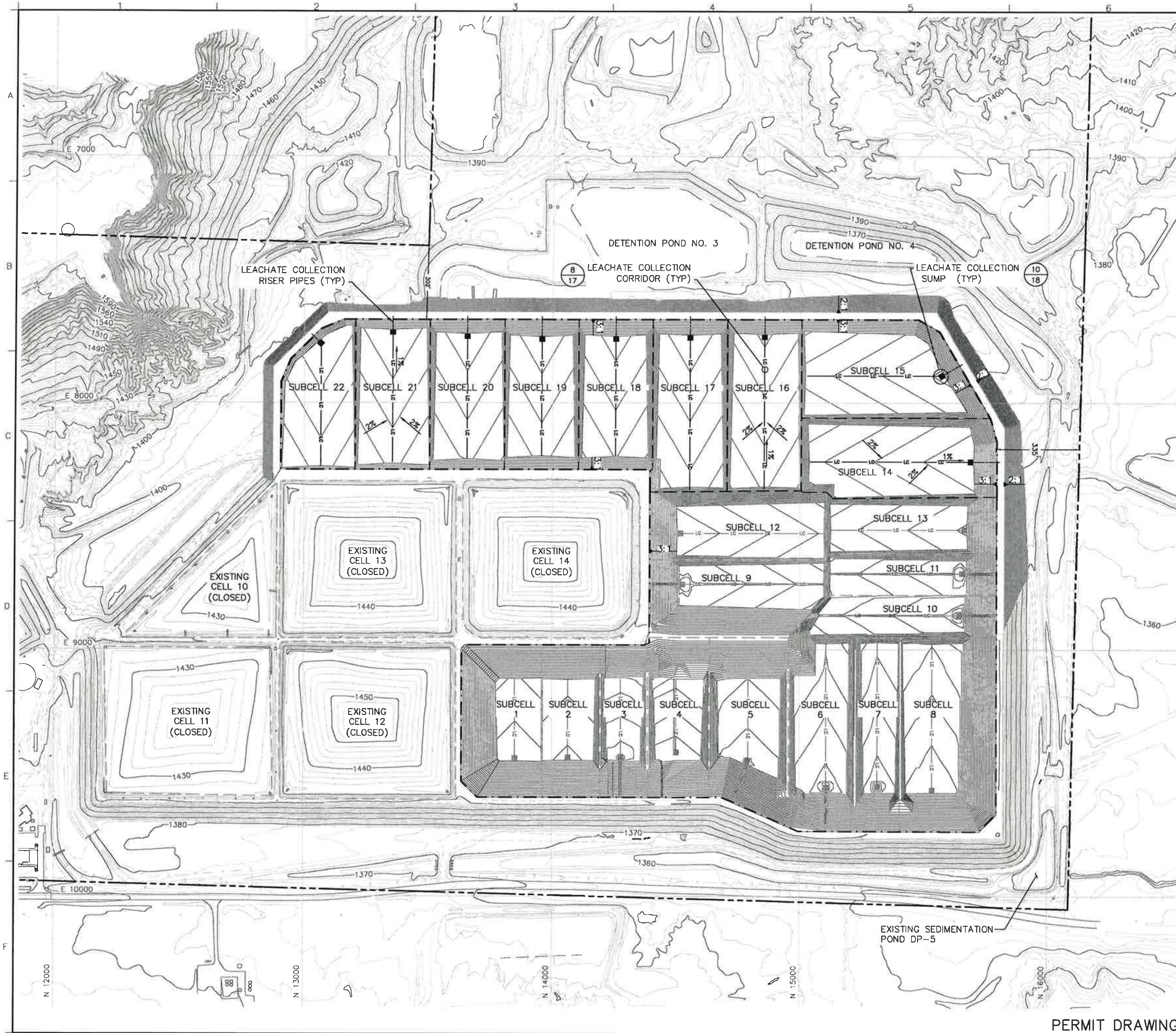

LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTE 1)
	EXISTING ROAD
	EXISTING FENCE
E 8000 N 15000	HORIZONTAL COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
	PROPOSED LIMIT OF WASTE
	PROPOSED PHASE BOUNDARY
LC	PROPOSED LEACHATE COLLECTION CORRIDOR
■	PROPOSED LEACHATE COLLECTION SUMP
	PROPOSED LEACHATE COLLECTION RISER PIPES

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
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OKLAHOMA

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8217 SHOAL CREEK BLVD., SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: LEACHATE COLLECTION AND LEAK DETECTION PLAN

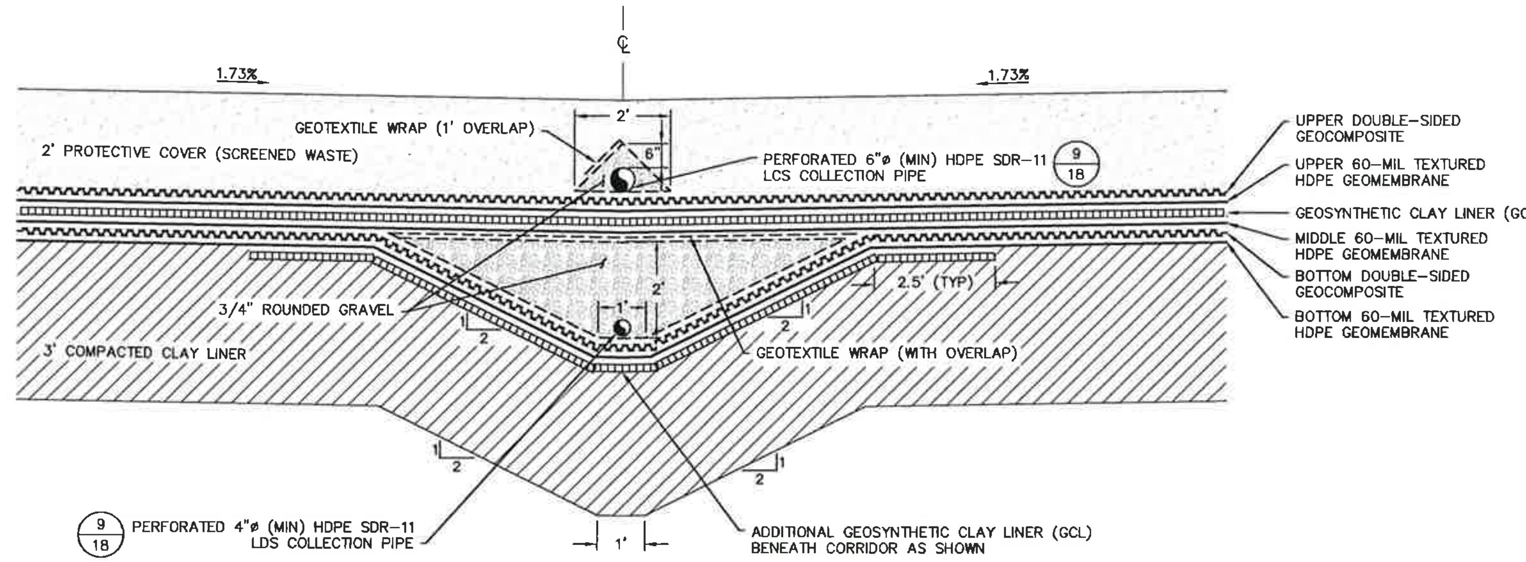
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY WAYNOKA, OKLAHOMA

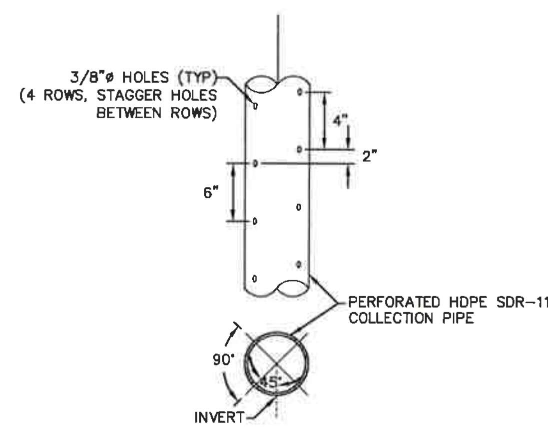
GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY:	YB	DATE:	JUNE 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-P-15
REVIEWED BY:	SMG	DRAWING NO.:	
APPROVED BY:	–	16 OF 23	

PERMIT DRAWING



8/17 DETAIL
LEACHATE COLLECTION CORRIDOR (TYP)
SCALE: N.T.S.



9/18 DETAIL
LEACHATE COLLECTION PIPE PERFORATIONS
SCALE: N.T.S.

NOTE:

1. GEOSYNTHETIC COMPONENTS ARE EXAGGERATED FOR CLARITY.

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

6/13/2014

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors ENVIRONMENTAL SERVICES, INC.
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AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: LEACHATE COLLECTION AND LEAK DETECTION SYSTEM DETAILS

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
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REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	17 OF 23

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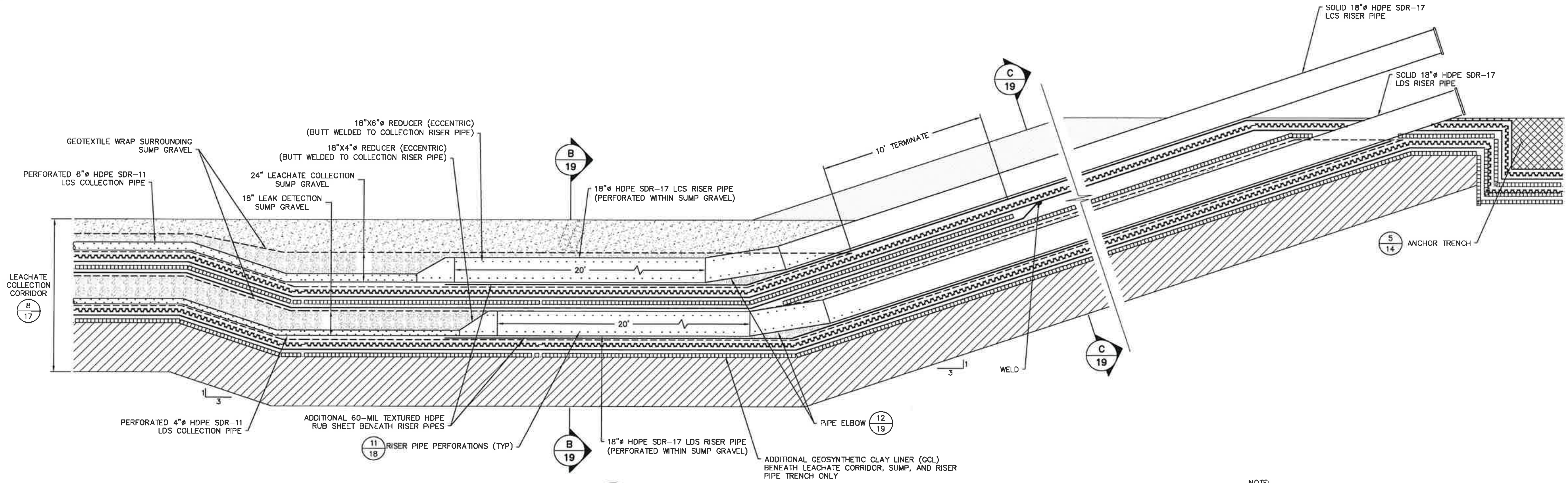
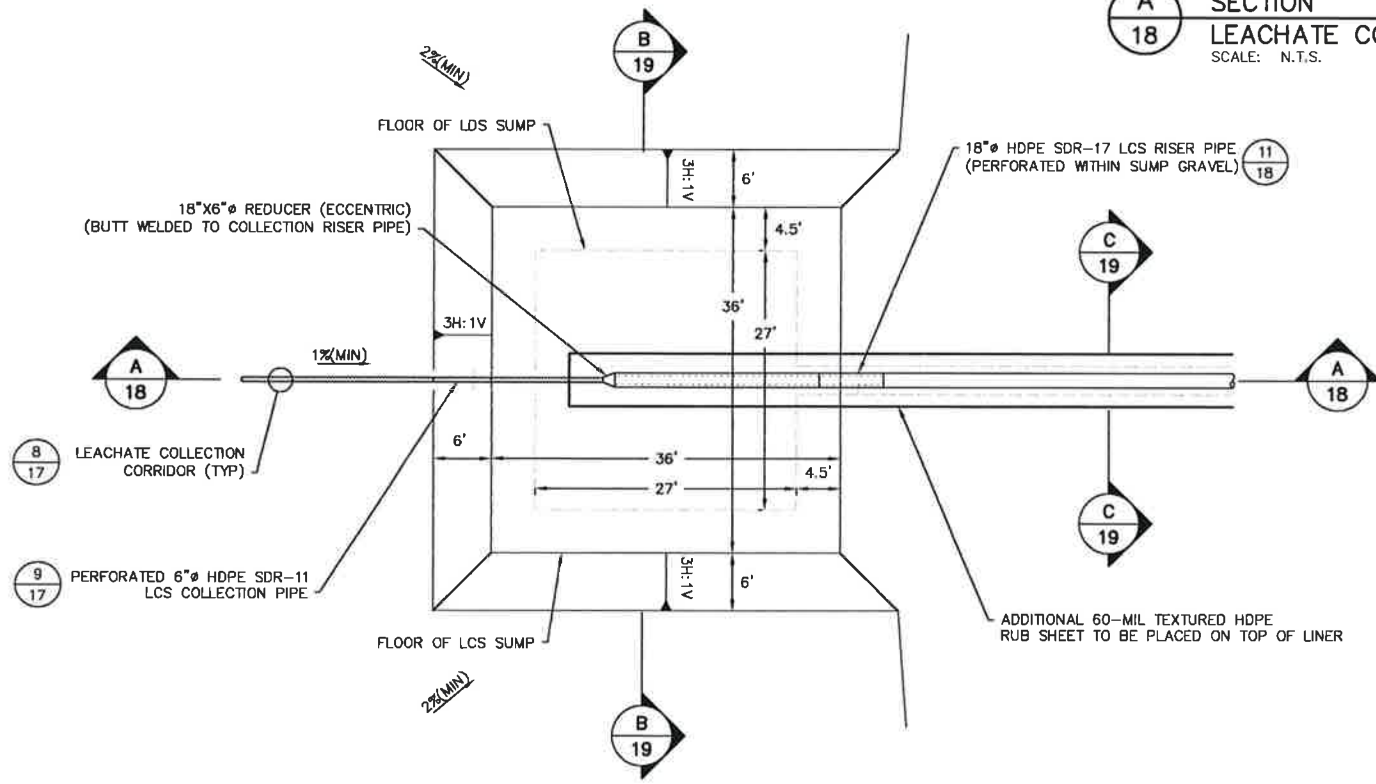


A
18

SECTION
LEACHATE COLLECTION SUMP
SCALE: N.T.S.

NOTE:

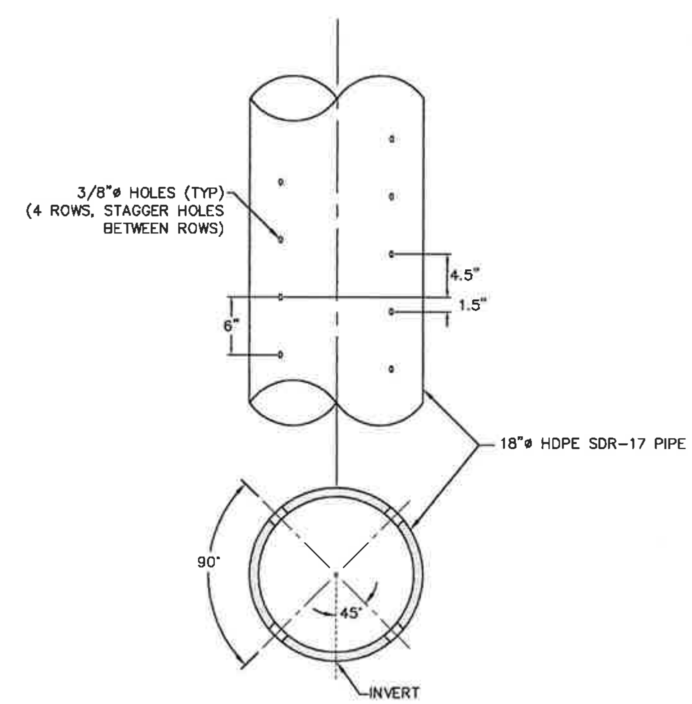
1. GEOSYNTHETIC COMPONENTS ARE EXAGGERATED FOR CLARITY.



10
16

DETAIL (PLAN)
LEACHATE COLLECTION SUMP

0 10' 20'
SCALE IN FEET



11
19

DETAIL
RISER PIPE PERFORATIONS
SCALE: N.T.S.

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
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OKLAHOMA

6/13/2014

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TITLE: SUMP DETAILS I

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-P-18
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	18 OF 23

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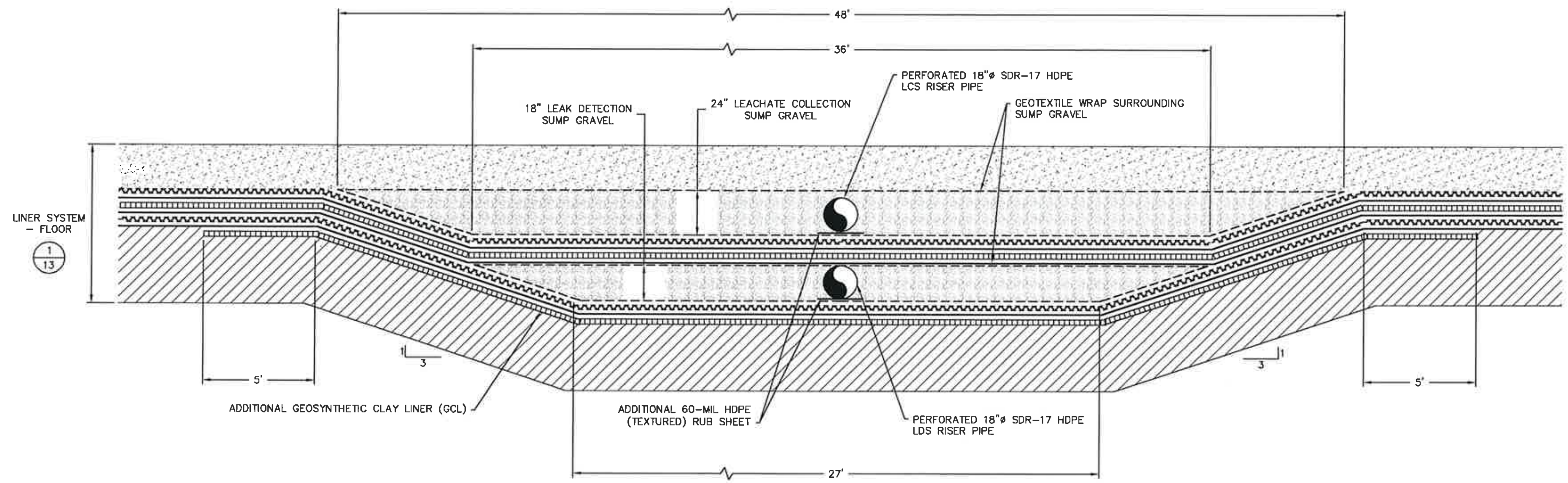
DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST - TXL0380\DRAWINGS\TXL038004-P-18.dwg PLOTTED: Jun 02, 2014 - 2:49pm



B / 18 SECTION
LEACHATE COLLECTION SUMP
SCALE: N.T.S.

NOTE:

1. GEOSYNTHETIC COMPONENTS ARE EXAGGERATED FOR CLARITY.

REGISTERED PROFESSIONAL ENGINEER
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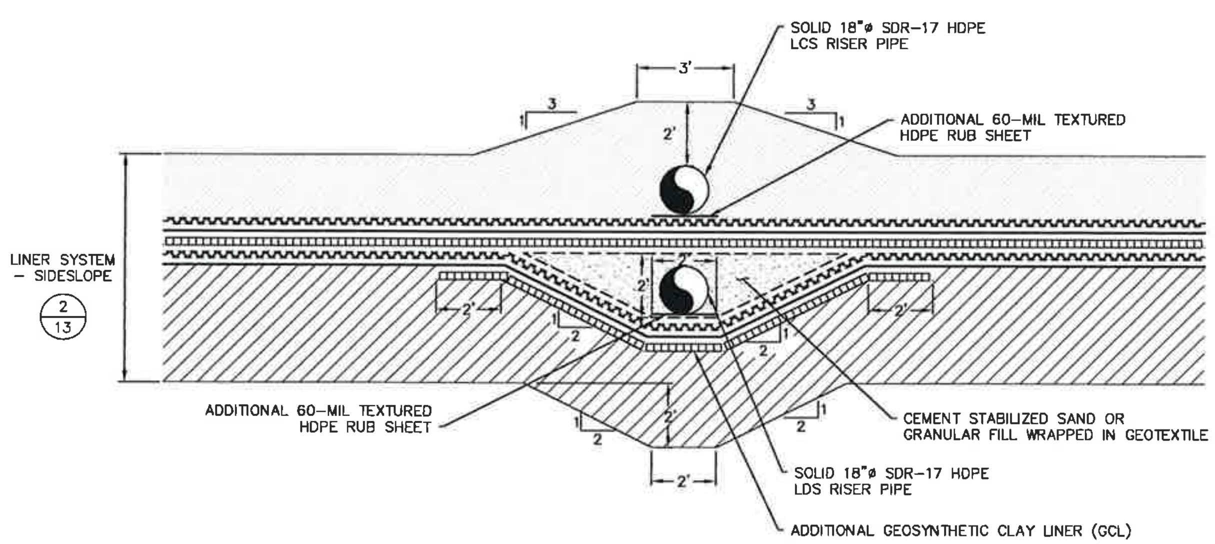
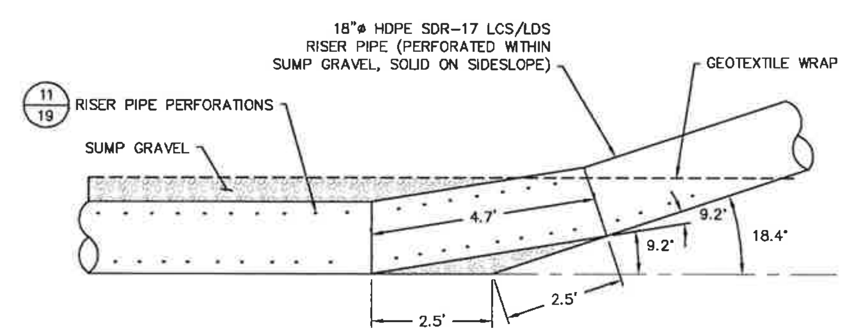
OKLAHOMA

6/13/2014



C / 18 SECTION
SIDESLOPE LEACHATE RISER SYSTEM
SCALE: N.T.S.



12 / 19 DETAIL
PIPE ELBOW
SCALE: N.T.S.

PERMIT DRAWING

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors ENVIRONMENTAL SERVICES, INC.
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PHONE: 512.451.4003

TITLE: SUMP DETAILS II

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
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DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-P-19
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	19 OF 23

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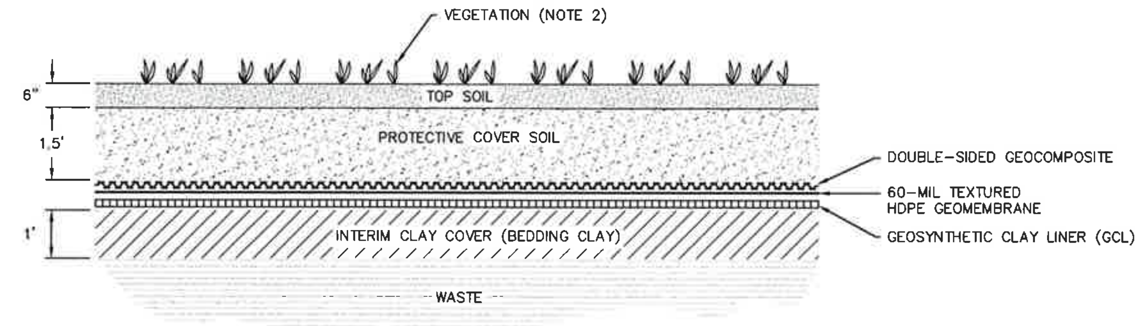
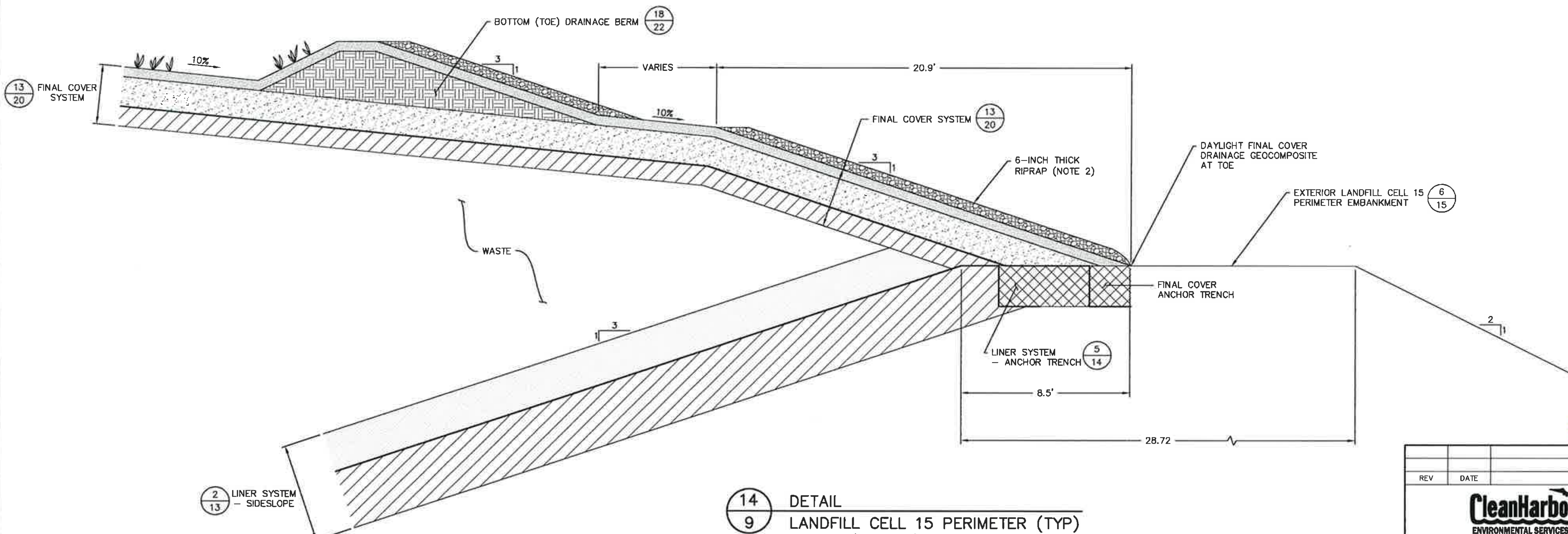


13/10 DETAIL
FINAL COVER SYSTEM
SCALE: N.T.S.

NOTE:

1. GEOSYNTHETIC COMPONENTS ARE EXAGGERATED FOR CLARITY.
2. VEGETATION WILL BE ESTABLISHED ON 10% FINAL COVER SLOPES. ON THE 3 HORIZONTAL TO 1 VERTICAL (3H:1V) PORTIONS OF THE FINAL COVER SIDESLOPES, THE VEGETATION MAY BE SUBSTITUTED WITH A 6-INCH LAYER OF TYPE V RIPRAP



14/9 DETAIL
LANDFILL CELL 15 PERIMETER (TYP)
0 3' 6'
SCALE IN FEET

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
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OKLAHOMA

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PHONE: 512.451.4003

TITLE: FINAL COVER SYSTEM DETAILS

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
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NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-P-20
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	20 OF 23

PERMIT DRAWING

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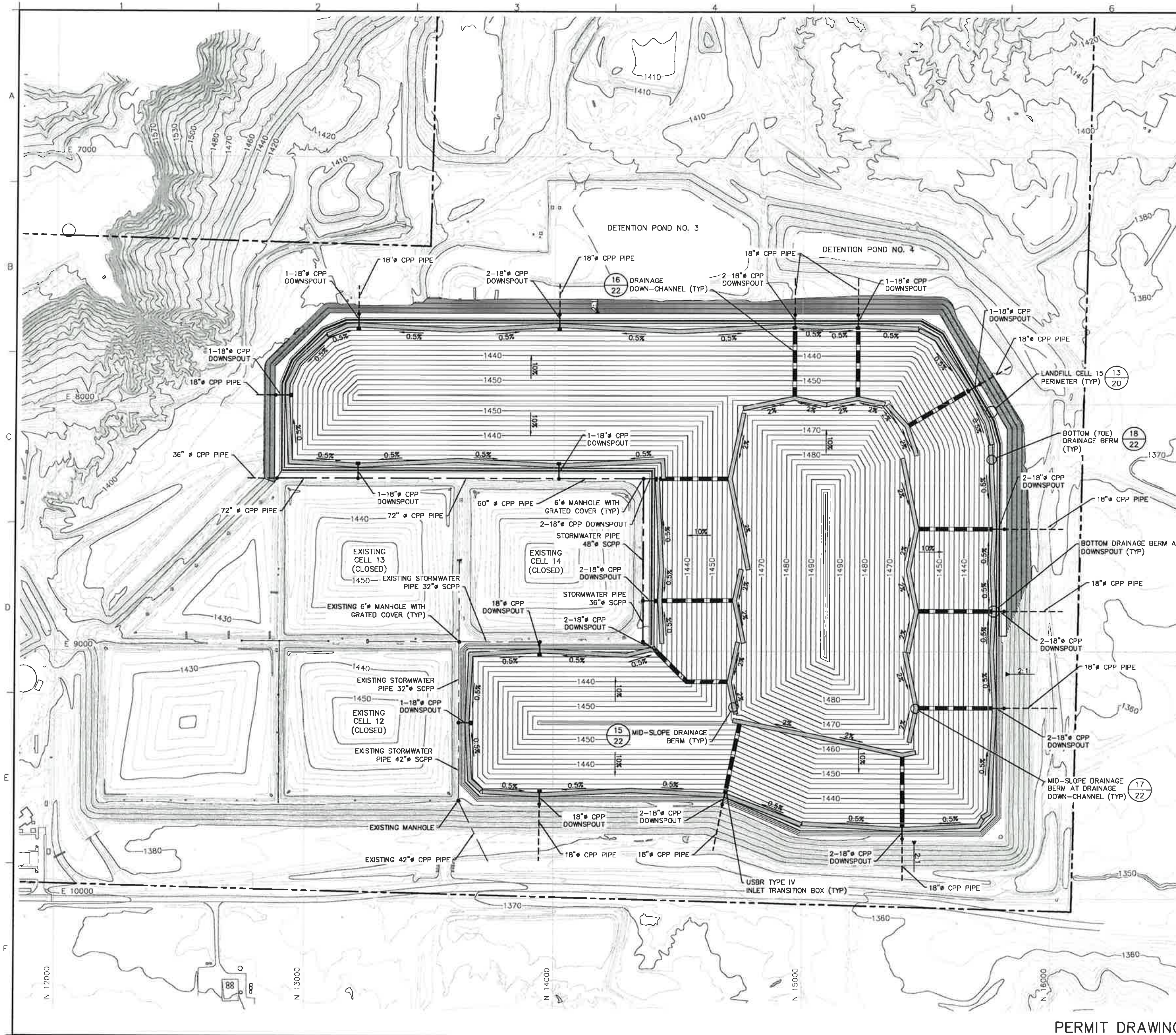

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LEGEND

- 1400 — EXISTING GROUND ELEVATION (FEET) (NOTE 1)
- EXISTING ROAD
- EXISTING FENCE
- E 8000 / N 15000 — STATE PLANE COORDINATES (NOTE 2)
- PROPERTY BOUNDARY
- 1400 — PROPOSED TOP OF FINAL COVER ELEVATION (FEET) (NOTE 3)
- PROPOSED DRAINAGE BERM
- PROPOSED DRAINAGE DOWN-CHANNEL

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. WITHIN THE LIMIT OF WASTE, TOP OF FINAL COVER ELEVATIONS REFER TO PROPOSED FINISHED GRADE (TOP OF THE TOPSOIL COMPONENT OF FINAL COVER SYSTEM). OUTSIDE THE LIMIT OF LINER, THE PROPOSED CONTOURS REFER TO FINISHED GRADE.
4. REFER TO EXHIBIT E1 OF THE CELL 15 ENGINEERING REPORT FOR DESIGNATIONS AND DESIGN CALCULATIONS OF THE STORM WATER CONVEYANCES SHOWN ON THIS DRAWING.

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors ENVIRONMENTAL SERVICES, INC.
CLEAN HARBORS ENVIRONMENTAL SERVICES, INC.
ROUTE 2, BOX 170
WAYNOKA, OKLAHOMA 73860-9622
PHONE: 405.697.3500

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
8217 SHOAL CREEK BLVD, SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: FINAL CELL 15 STORM WATER MANAGEMENT PLAN

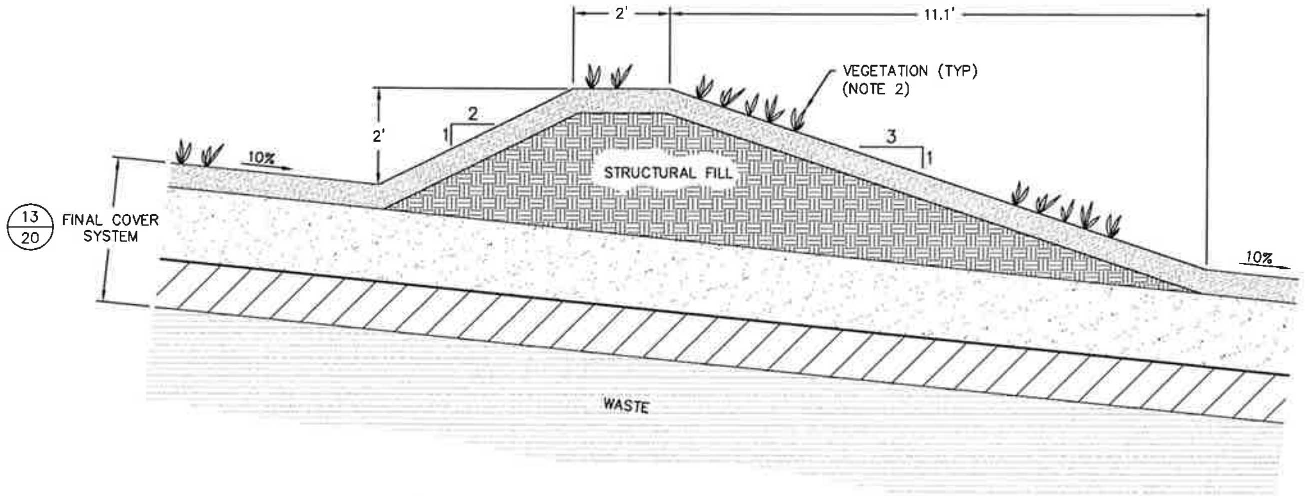
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION NO. 1996 EXP. 06/30/2014

DESIGN BY:	YB	DATE:	JUNE 2014
DRAWN BY:	JJV / KH	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-P-22
REVIEWED BY:	SMG	DRAWING NO.:	
APPROVED BY:	--	21 OF 23	

PERMIT DRAWING



15/21 DETAIL
MID–SLOPE DRAINAGE BERM (TYP)

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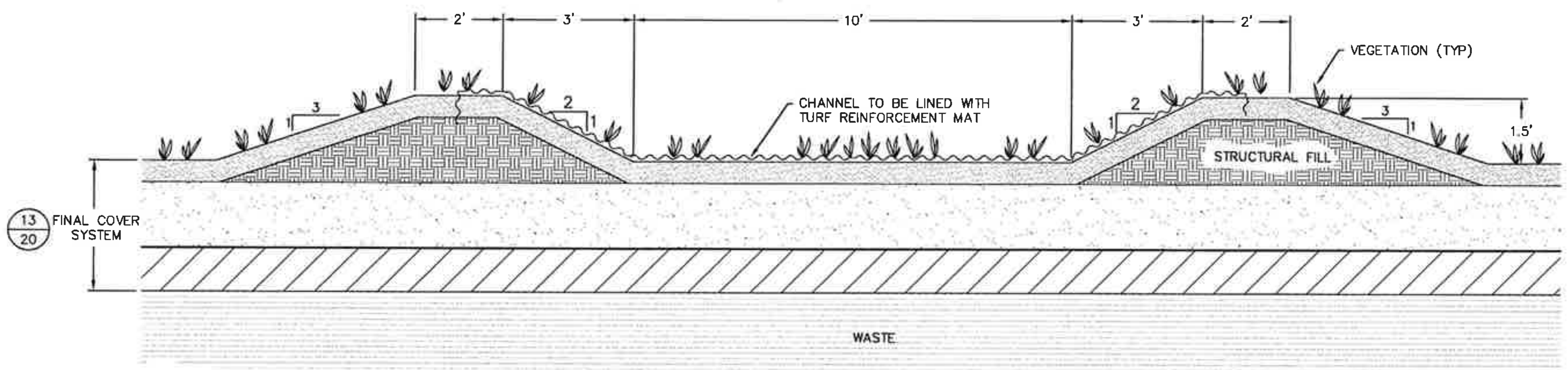
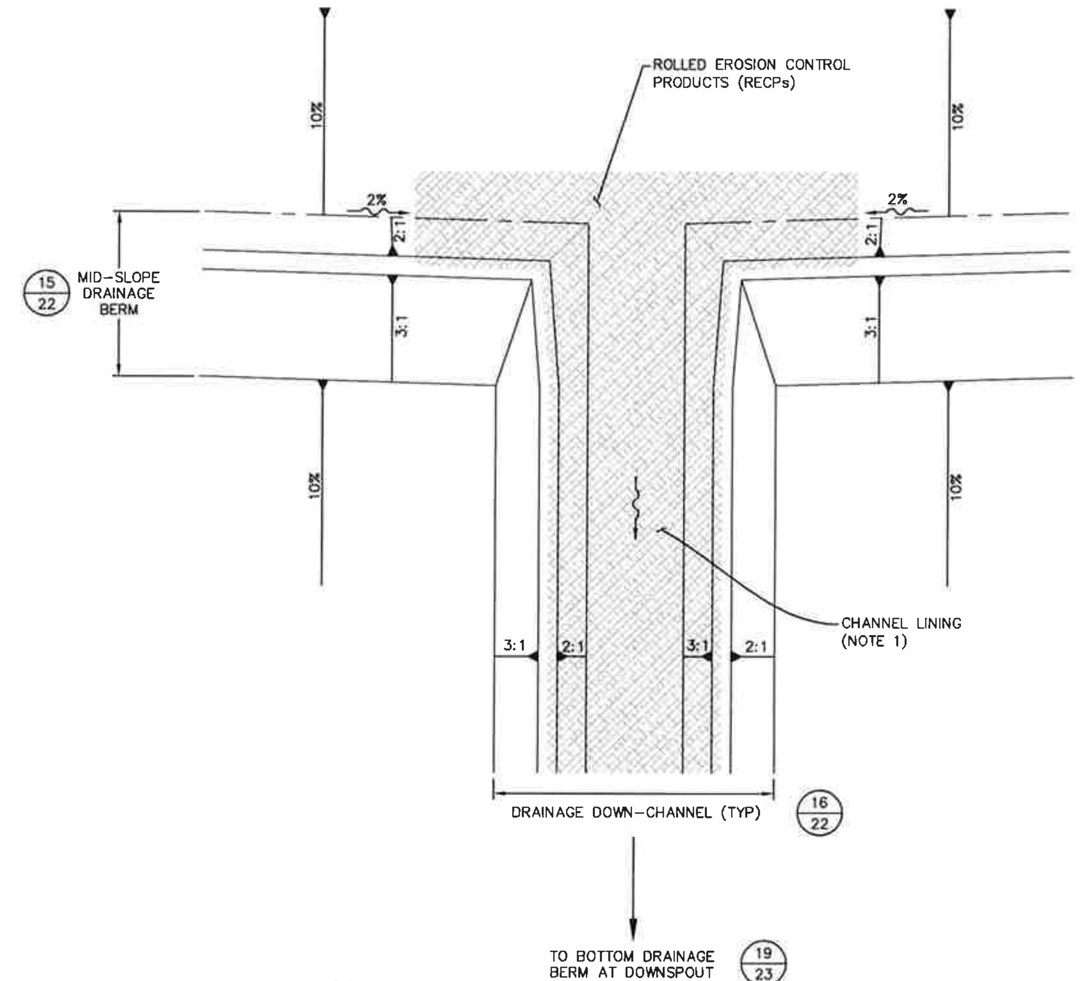
SCALE IN FEET

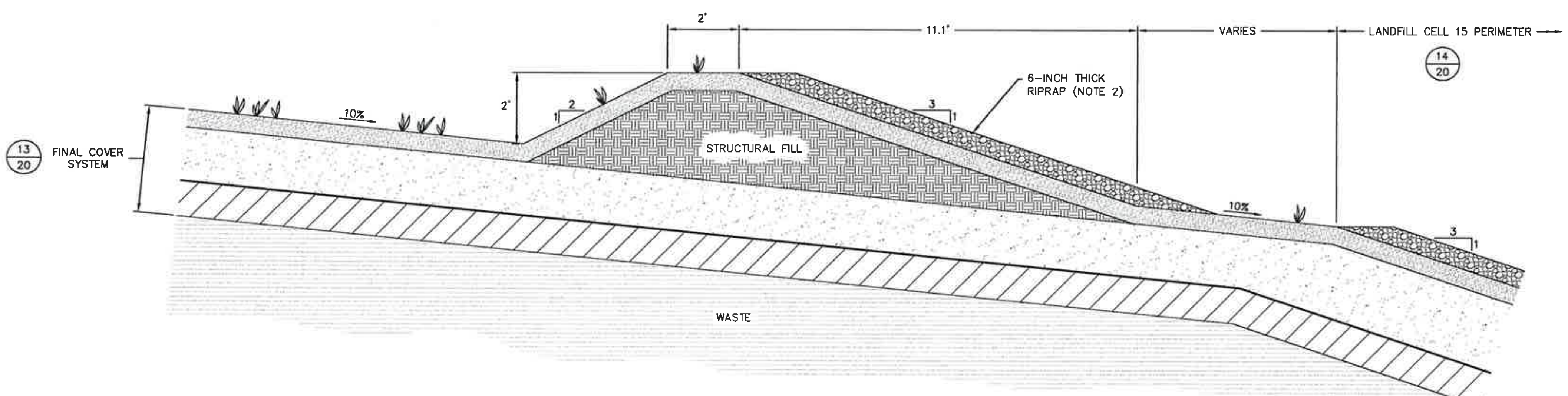


16/21 DETAIL
DRAINAGE DOWN–CHANNEL (TYP)

0 2' 4'
SCALE IN FEET



17/21 DETAIL
MID–SLOPE DRAINAGE BERM AT DRAINAGE DOWN–CHANNEL (TYP)
SCALE: N.T.S.



18/20 DETAIL
BOTTOM (TOE) DRAINAGE BERM (TYP)

0 2' 4'
SCALE IN FEET

NOTE:

1. RIP–RAP MAY BE USED IN–LIEU OF TURF REINFORCEMENT MAT WHEREVER SPECIFIED IN THE DRAWING.
2. VEGETATION WILL BE ESTABLISHED ON 10% FINAL COVER SLOPES. ON THE 3 HORIZONTAL TO 1 VERTICAL (3H:1V) PORTIONS OF THE FINAL COVER SIDESLOPES, THE VEGETATION MAY BE SUBSTITUTED WITH A 6–INCH LAYER OF TYPE V RIPRAP

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA
6/13/2014

PERMIT DRAWING

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors
ENVIRONMENTAL SERVICES, INC.
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TITLE: STORM WATER MANAGEMENT DETAILS I

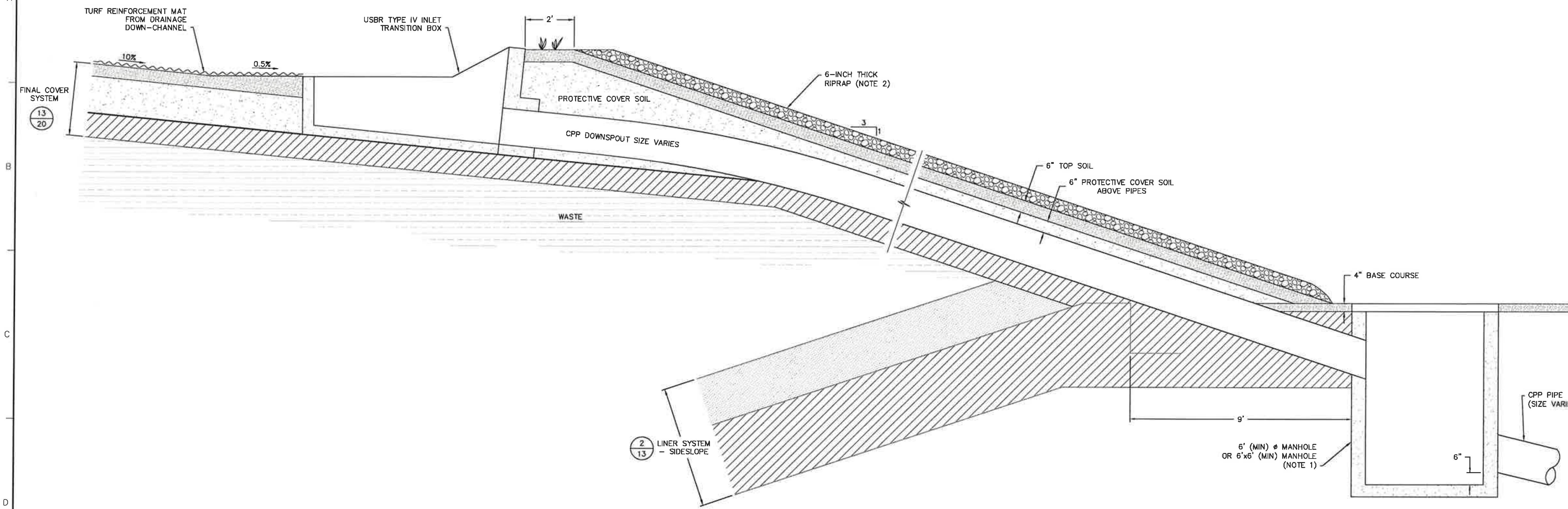
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004–P–23
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: –	22 OF 23

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST – TXL0380\DRAWINGS\TXL038004–P–23.dwg PLOTTED: Jun 02, 2014 – 3:00pm



19/21 DETAIL
BOTTOM DRAINAGE BERM AT DOWNSPOUT (TYP)

0 2' 4'
SCALE IN FEET

NOTE:

1. WHERE MANHOLES INCLUDE CONNECTION TO PERIMETER CULVERT, THE MANHOLE SHALL BE SIZED LARGER AS NEEDED TO ACCOMMODATE THE SPECIFIED CULVERT.
2. VEGETATION WILL BE ESTABLISHED ON 10% FINAL COVER SLOPES. ON THE 3 HORIZONTAL TO 1 VERTICAL (3H:1V) PORTIONS OF THE FINAL COVER SIDESLOPES, THE VEGETATION MAY BE SUBSTITUTED WITH A 6-INCH LAYER OF TYPE V RIPRAP

6/13/20A

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

PERMIT DRAWING

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors ENVIRONMENTAL SERVICES, INC.
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AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: STORM WATER MANAGEMENT DETAILS II

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION
CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: YB	DATE: JUNE 2014
DRAWN BY: JJV / KH	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-P-24
REVIEWED BY: SMG	DRAWING NO.:
APPROVED BY: --	23 OF 23

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST - TXL0380\DRAWINGS\TXL038004-P-24.dwg PLOTTED: Jun 02, 2014 - 2:50pm

EXHIBIT B

GEOTECHNICAL INVESTIGATION AND DESIGN

Exhibit B-1

Geotechnical Site Characterization Summary

Prepared for:

Clean Harbors Environmental Services, Inc.
Lone Mountain Facility
Route 2, Box 170
Waynoka, OK 73860-9622

EXHIBIT B-1: GEOTECHNICAL SITE CHARACTERIZATION SUMMARY

PROPOSED CLASS 3 PERMIT MODIFICATION
LANDFILL CELL 15
LONE MOUNTAIN FACILITY
WAYNOKA, OKLAHOMA

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

Scott M. Graves, P.E.
State of Oklahoma Registration # 19710
Geosyntec Consultants
Oklahoma Certificate of Authorization No. 1996
Exp. 06/30/2014

Prepared by:

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8217 Shoal Creek Blvd, Suite 200
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May 2014

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6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

TABLES

6/13/2014

FIGURES

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

APPENDICES

1. INTRODUCTION

1.1 Background

Clean Harbors Environmental Services, Inc. (CHES) owns and operates the Lone Mountain Facility (LMF), a hazardous waste processing and disposal facility located in Major County, Oklahoma near the town of Waynoka. The LMF includes several landfill cells, some of which are filled to capacity and have final cover installed and are closed. Landfill Cell 15 is a Resource Conservation and Recovery Act (RCRA) Subtitle "C" landfill, currently permitted with thirteen (13) subcells. Subcells 1 through 11 of Landfill Cell 15 have been constructed and are in various stages of filling (or have been already filled to capacity). The proposed waste disposal footprint for the Landfill Cell 15 will be composed of 22 subcells, (currently permitted Subcells 1 through 13, plus proposed Subcells 14 through 22).

The acreage of Landfill Cell 15 waste disposal limits will be increased from 54.8 acres to approximately 95.2 acres by laterally expanding Landfill Cell 15 in a general westward and southwestward direction. Since the area is laterally expanding by 40.4 acres beyond the currently permitted cell limits, a Geotechnical Site Investigation was conducted in the year 2013 to supplement the prior site investigations, characterize the subsurface conditions in the expansion area, and obtain geotechnical parameters for use in engineering design.

1.2 Purpose

This Geotechnical Site Characterization Summary was prepared by Geosyntec Consultants (Geosyntec) as part of the Class 3 Permit Modification Application for the Lone Mountain Facility Landfill Cell 15. The report describes the geotechnical information gathered during the October 2013 and February 2010 site investigation programs conducted by Envirotech Engineering (Envirotech). The report also includes relevant geotechnical information from past studies, as presented in the 1993 Permit Modification Application for Landfill Cell 15 prepared by HA&L Engineering and in the 2010 Permit Modification Application for Landfill Cell 15 prepared by Geosyntec.

1.3 Report Organization

The remainder of this exhibit is organized as follows:

- The past and current geotechnical site investigations are described in Section 2; and
- laboratory test results are presented in Section 3.

Tables, figures, and appendices containing supporting information are included at the end of this report.

2. GEOTECHNICAL INVESTIGATIONS

2.1 Previous Site Investigations (1985, 1991, 1992)

Geotechnical site investigations associated with Landfill Cell 15 and nearby cells at the Lone Mountain Facility were previously conducted by Chen and Associates, Inc and Applied Geotechnical Engineering Consultants (AGEC), Inc. Chen and Associates, Inc. performed a subsurface investigation in January/February 1985, and reported the results in Project No. 511685-2. Three of the Chen and Associates soil borings (B-4, B-8, and B-12) were located in the vicinity of the Landfill Cell 15 area of the site, and provided relevant geotechnical information for this Class 3 Permit Modification design. AGEC performed subsurface investigations in November 1991 and November 1992, and the results are reported in Project Nos. 19091 and 24292, respectively. Nine of the AGEC soil borings (B-13 through B-21) were located in the vicinity of the Landfill Cell 15 area of the site and provided relevant geotechnical information for this Class 3 Permit Modification design.

During their geotechnical investigations, Chen and Associates and AGEC performed periodic standard penetration tests to evaluate soil consistency. They also collected representative samples of soil for geotechnical testing when a change in lithology was encountered. A brief summary of the findings reported by these investigations is presented below.

- The soil stratigraphy beneath the LMF site was divided into two layers: (i) upper clay; and (ii) claystone/siltstone.
- The upper clay soil was found to be silty and red in color. This layer was moist to wet and medium stiff to very stiff in consistency. The unconfined compressive strength of upper clay soil ranged from 560 to 5,460 psf.
- The claystone/siltstone soil was reported to be firm to very hard with occasional gypsum mix. This layer was slightly moist and primarily red in color with some turquoise areas. The unconfined compressive strength of claystone/siltstone soil ranged from 8,050 to 36,500 psf.

Soil boring locations, boring logs, and relevant testing reports from these previous studies that are in the vicinity of Landfill Cell 15 are included in Appendix B1-1.

2.2 Recent Geotechnical Investigations

February 2010 Investigation

Envirotech Engineering (Envirotech) performed a subsurface exploration program in February 2010 in support of an expansion of Landfill Cell 15 up to Subcell 13. As mentioned, these additional borings were advanced in order to supplement the information from past site investigations in the vicinity of Landfill Cell 15.

Envirotech's February 2010 subsurface exploration program consisted of logging and sampling of 11 hollow-stem auger borings to depths ranging from 4 to 26 feet. Based on the field observation and the laboratory testing results, the subsurface at the proposed expansion area was divided into two layers, which is consistent with past investigations: (i) upper clay; and (ii) claystone/siltstone. The termination depths of each boring were determined in the field in consultation with ODEQ staff, when the underlying green shale material was encountered, since the objective of the investigation was to characterize the clayey layers above this shale material without penetrating into the shale formation. Select samples of the investigated layers were tested in the laboratory to characterize their geotechnical engineering properties. Also, test-pit excavations were performed in select areas, with the excavated soils visually classified in the field, and representative samples tested in the laboratory.

Boring logs and laboratory results from this investigation are presented in Appendix B1-2 and Appendix B1-3, respectively.

<u>October 2013 Investigation</u>

In October 2013, Envirotech performed an additional subsurface exploration program in support of the proposed Landfill Cell 15 expansion. Envirotech's subsurface exploration program consisted of logging and sampling seven (7) hollow stem auger borings to depths ranging from 8 to 20 feet. These borings were performed to supplement the information obtained during the February 2010 site investigation, and to obtain samples beneath the footprint of the proposed Subcells 14-22 for additional testing.

Boring logs and laboratory results from this investigation are presented in Appendix B1-4 and Appendix B1-5, respectively. The approximate locations of the exploratory borings discussed in this section are presented in Figure B1-1.

3. LABORATORY TEST RESULTS

As part of the geotechnical investigations discussed in Section 2, laboratory testing was performed on representative samples to evaluate the following properties:

- natural water content (ASTM D 2216);
- dry density (ASTM D 2937);
- Atterberg limits (ASTM D 4318);
- grain size distribution (ASTM D 422);
- standard Proctor moisture density relations (ASTM D 698A);
- hydraulic conductivity (ASTM D 5084);
- one-dimensional consolidation test (ASTM D2435);
- unconsolidated undrained triaxial compression test (ASTM D2850); and
- consolidated undrained triaxial compression test (ASTM D4767).

The laboratory tests were performed in accordance with industry practice and standard ASTM procedures referenced above.

A summary of the geotechnical laboratory test results are presented in Tables B1-1 through B1-6. Boring logs and geotechnical test data are provided in the appendices. When applicable, comparisons are made to the previous laboratory test results that are available. The remainder of this section discusses the results for each laboratory test.

3.1 Natural Water Content

The moisture content for the soil was measured using standard laboratory test methods according to ASTM D2216. The average natural water content in the upper clay and the claystone/siltstone soils were found to be approximately 20.6% and 20.1%, respectively (Table B1-1 and B1-2). No clear trend was apparent relative to variation of moisture content with depth.

3.2 Dry Density

The dry density for the soil was measured using standard laboratory test methods in accordance with ASTM D2937, and the results are summarized in Table B1-1. The average dry density values were 102.8 and 104.2 lb/ft^3, respectively, for the upper clay and the claystone/siltstone soils.

3.3 Grain Size Distribution and Atterberg Limits

The grain size distribution test results are used in conjunction with the Atterberg limit results to classify the soil samples using the Unified Soil Classification System (USCS) method (ASTM D2487). The soil classification results based on the USCS method are included in Tables B1-1 and B1-2. Both the upper clay and the claystone/siltstone soils were generally classified as lean clay (CL). Similar soil was identified during the previous site investigations.

3.4 Standard Proctor Moisture Density Relations

The relationship between water content and dry unit weight was evaluated in accordance with ASTM D 698A. Two standard Proctor tests were conducted on the composite upper clay soils. The first sample was prepared by mixing soils collected from borings B-23, B-27, and B-30; and the second was prepared by mixing soils collected from borings B-22, B-24, and B-25. The results of these tests were used to develop compaction curves for the soil. The maximum dry density and the optimum moisture content of the first composite sample (Borings 23, 27, 30 composite) were calculated to be 96.8 pcf and 25.7%, respectively. For the second composite sample (Borings 22, 24, 25 composite), the maximum dry density and the optimum moisture content were 103 pcf and 21.5%, respectively.

3.5 Hydraulic Conductivity

The hydraulic conductivity test was conducted in accordance with ASTM D 5084 using the falling head method (Method F). A total of four hydraulic conductivity tests were performed on remolded samples of the composite upper clay soils. The composite samples were similar to the samples used for the standard Proctor testing described above. The results of the hydraulic conductivity test are summarized in Table B1-3. The average hydraulic conductivity values were 3.5×10^{-8} and 2.2×10^{-8} cm/sec for the composite samples collected from Borings B-23, B-27, and B-30; and B-22, B-24, and B-25; respectively.

3.6 One-Dimensional Consolidation Test

Three one-dimensional (1-D) consolidation tests were performed as part of the recent site investigation programs; two were conducted on Shelby tube samples taken during the February 2010 site investigation, and one was performed on a Shelby tube sample from the October 2013 site investigation. The tests were performed on the following specimens: one sample from boring B-25 at a depth of about 8-8.5 ft below ground surface (bgs), one sample from boring B-29 at a depth of about 4-5 ft bgs and one from boring B-35 at a depth of approximately 6-7 feet bgs. The results of the 1-D consolidation tests are summarized in Table B1-4 and the laboratory testing data sheets are provided in Appendices B1-3 and B1-5.

A summary of the one-dimensional consolidation test results from the past geotechnical investigations is also provided in Table B1-4. It can be seen that the calculated modified compression and recompression indices for the B-25, B-29, and B-35 samples are consistent with the values reported for the upper clay soil in the previous geotechnical data report (Table B1-4 and Appendix B1-1). These results were used in the settlement analysis presented in Exhibit B-3.

3.7 Unconsolidated Undrained Triaxial Compression Test

Unconsolidated undrained (UU) triaxial compression tests were conducted on undisturbed samples to evaluate the undrained strengths of the soils underlying Lone Mountain Landfill Cell 15. Five samples were collected from the upper clay layer, and two samples were collected from the claystone/siltstone layer. The undrained shear strength values for the upper clay soil varied in the range from 576 to 7,661 psf with an average value of 3,047 psf. The relatively lower strength of 576 psf was obtained from Boring B-28 which was located at the northeast corner of Landfill Cell 15. To evaluate whether this relatively lower strength was isolated, three test pits (TP-1 through TP-3) were excavated within an approximately 100-ft radius from Boring B-28 (Figure B1-1). Undisturbed samples were collected by pushing Shelby tubes in the test pits at specified depths. The undrained shear strength values of 1,397 psf, 2,894 psf, and 7,661 psf were obtained for samples TP-1, TP-2, and TP-3, respectively. These results show that the lower strength of 576 psf obtained at boring B-28 was isolated to one small location and not representative of the stratum as a whole. The undrained shear strength values for the two claystone/siltstone samples were calculated to be 4,334 and 7,272 psf with an average value of 5,803 psf. These results were used in slope stability analysis presented in Exhibit B-2.

3.8 Consolidated Undrained Triaxial Compression Test

Consolidated undrained (CU) triaxial tests were conducted to evaluate the drained strength of the underlying soil at the Lone Mountain Facility Landfill Cell 15. Two samples from the upper clay layer and one sample from the claystone/siltstone layer were collected; the results of the CU tests are summarized in Table B1-6. The first sample from the upper clay (boring B-28: 8-9 feet bgs) had a measured effective stress friction angle of 25.4° and an effective stress cohesion of 634 psf. The second CU test on the upper clay material was performed on a series of three samples from borings B-33, B-35, and B-36, and indicated a measured effective stress friction angle of 14.9° and an effective stress cohesion of 1700 psf. The sample from the claystone/siltstone layer (boring B-24: 4-6 feet bgs) had a measured effective stress friction angle of 30.8° and an effective stress cohesion of 547 psf. These results were used in the slope stability analysis presented in Exhibit B-2.

TABLES

TABLE B1-1. SUMMARY OF INDEX PROPERTY AND SOIL CLASSIFICATION DATA FROM FEBRUARY 2010.

Boring Number	Sample Depth (ft)	Underlying Soil Layer	Water Content (%)	Atterberg Limits			USCS[1]	Grain Size Distribution	Dry Density (lb/ft^3)
				LL (%)	PL (%)	PI (%)		Fines (<0.075 mm)[2] (%)	
B-22	0-2	Upper Clay	18.0	36	16	20	CL	86.8	94.9
	2-16.5	Claystone/Siltstone	18.7	49	22	27	CL	88.5	97.4
B-23	0-1	Upper Clay	14.4	38	20	18	CL	74.4	104.3
	1-4	Claystone/Siltstone	18.0	36	20	16	CL	99.8	113.0
B-24	0-2	Upper Clay	21.8	40	16	24	CL	92.6	98.0
	2-12	Claystone/Siltstone	17.4	55	24	31	CH	55.6	94.9
B-25	0-6.5	Upper Clay	22.4	37	20	17	CL	81.3	104.3
	6.5-13	Claystone/Siltstone	18.2	40	20	20	CL	90.2	104.9
B-26	0-10	Upper Clay	19.4	42	22	20	CL	91.3	106.8
	10-26	Claystone/Siltstone	23.3	47	27	20	CL	99.1	99.9
B-27	0-1	Upper Clay	22.3	35	18	17	CL	95.9	101.1
	1-5	Claystone/Siltstone	21.3	39	23	16	CL	99.4	105.5
B-28	0-9	Upper Clay	24.7	38	20	18	CL	93.4	108.6
	9-23	Claystone/Siltstone	21.2	39	25	14	CL	90.4	106.8
B-29	0-3.5	Upper Clay	20.0	35	20	15	CL	85.9	106.8
	3.5-9	Claystone/Siltstone	20.5	36	22	14	CL	84.9	108.6
B-30	0-3.5	Upper Clay	24.4	38	23	15	CL	87.7	99.9
	3.5-8	Claystone/Siltstone	20.8	39	22	17	CL	95.2	104.9
B-31	0-3.5	Upper Clay	18.8	36	22	14	CL	88.8	99.9
	3.5-14	Claystone/Siltstone	19.7	37	22	15	CL	99.6	103.6
B-32	0-4.5	Upper Clay	19.5	35	19	16	CL	95.9	105.5
	4.5-10	Claystone/Siltstone	18.3	38	21	17	CL	88	106.8

Notes:
1. USCS = Unified Soil Classification System
2. Fines = Particles finer than #200 sieve (0.075 mm)

TABLE B1-2. SUMMARY OF INDEX PROPERTY AND SOIL CLASSIFICATION DATA FROM OCTOBER 2013.

Boring Number	Sample Depth (ft)	Soil Layer	Water Content (%)	Atterberg Limits			USCS[1]	Grain Size Distribution
				LL (%)	PL (%)	PI (%)		Fines (<0.075 mm)[2] (%)
B-33	4-5.5	Upper Clay	21.8	38	21	17	CL	74
B-34	0-1	Upper Clay	18.5	36	18	18	CL	83.6
	9-10.5	Claystone/Siltstone	20.7	40	23	17	CL	94
	11-13	Claystone/Siltstone	19.4	42	19	23	CL	99.1
B-35	13.5-15	Claystone/Siltstone	18.5	33	18	15	CL	99.1
B-36	9-10.5	Claystone/Siltstone	27.7	36	21	15	CH	89.3
B-37	3.5-5	Upper Clay	21.7	42	22	20	CL	91.4
	18.5-20	Claystone/Siltstone	18.3	39	21	18	CL	99.8

TABLE B1-3. SUMMARY OF REMOLDED HYDRAULIC CONDUCTIVITY TEST RESULTS.

Soil Layer	Sample No	Remolded Hydraulic Conductivity (cm/sec)
Upper Clay	Composite B-23, B-27, and B-30; Perm 1	2.57E-08
	Composite B-23, B-27, and B-30; Perm 2	4.45E-08
	Average	**3.51E-08**
	Composite B-22, B-24, and B-25; Perm 3	2.20E-08
	Composite B-22, B-24, and B-25; Perm 3	2.25E-08
	Average	**2.23E-08**

TABLE B1-4. ONE-DIMENSIONAL CONSOLIDATION TEST RESULTS.

Soil Layer	Sample No	Sampling Depth	Modified Compression Index, C_c'	Modified Recompression Index, C_r'	Comment
Upper Clay	B-25	8-8.5	0.067	0.012	February 2010 Envirotech Site Investigation Data
	B-29	4-5	0.075	0.010	
	B-4	2	0.055	0.015	Previous Data Submitted with Permit Modification Application for Landfill Cell 15 on 15 June 1993
	B-21	4	0.079	0.006	
	B-35	6-7	0.055		October 2013 Envirotech Site Investigation Data
	Average		**0.066**	**0.011**	
Claystone/Siltstone	B-1	7	0.014	0.002	Previous Data Submitted with Permit Modification Application for Landfill Cell 15 on 15 June 1993
	B-2	22	0.013		
	B-4	22	0.038	0.013	
	B-5	7	0.020	0.005	
	B-9	15	0.027	0.005	
	B-11	5	0.015	0.005	
	B-13	12	0.015		
	B-16	7	0.013		
	B-18	1	0.029		
	B-19	9	0.030		
	B-19	17	0.016		
	B-20	24	0.019	0.010	
	Average		**0.021**	**0.007**	

TABLE B1-5. UNCONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST RESULTS.

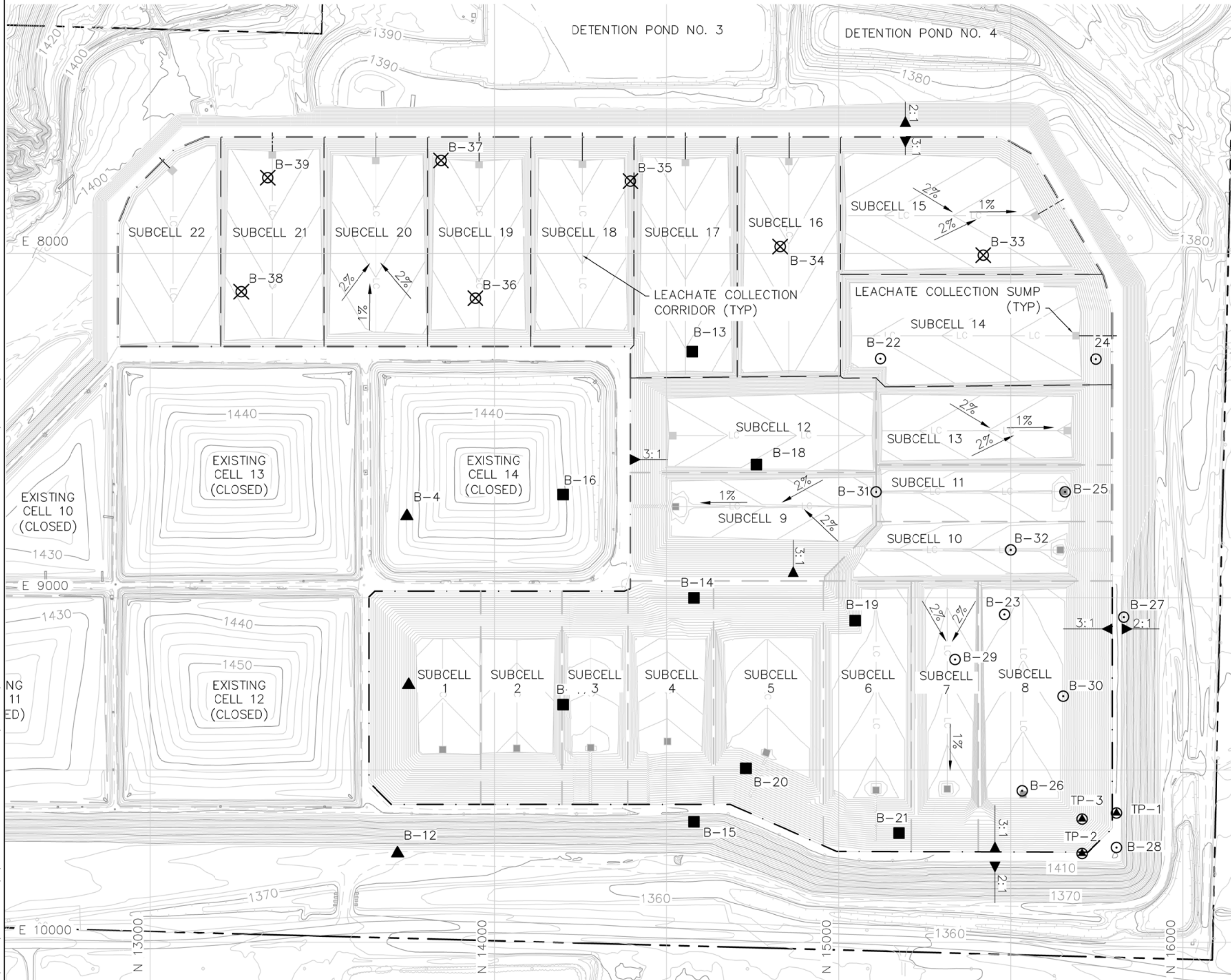
Soil Layer	Sample No	Sampling Depth (ft)	Undrained Shear Strength (S_u) (psf)
Upper Clay	B-26	4-5.5	2,707
	B-28	4-6	576
	TP-1	3-5	1,397
	TP-2	7-9	2,894
	TP-3	4-6	7,661
		Average	**3,047**
Claystone/Siltstone	B-24	4-6	4,334
	B-24	8-10	7,272
		Average	**5,803**

TABLE B1-6. CONSOLIDATED UNDRAINED TRIAXIAL COMPRESSION TEST RESULTS.

Soil Layer	Sample No	Sampling Depth	Drained Shear Strength	
			Effective Steess Cohesion, c' (psf)	Effective Stress Friction Angle, Φ' (degree)
Upper Clay	B-28	8-9	634	25.4
Upper Clay	B-33	5.5	1700	14.9
	B-36	11		
	B-35	6.5		
Claystone/Siltstone	B-24	4-6	547	30.8

FIGURES

BORING LOCATION MAP
LONE MOUNTAIN FACILITY LANDFILL CELL 15



LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTE 1)
E 8000 N 15000	STATE PLANE COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
	PROPOSED LIMIT OF WASTE
	PROPOSED PHASE BOUNDARY
▲ B-8	1985 CHEN AND ASSOCIATES BORING LOCATION
■ B-13	1991/1992 AGEC BORING LOCATION
⊙ B-25	2010 ENVIROTECH BORING LOCATION (NOTE 3)
TP-3	2010 ENVIROTECH TEST PIT LOCATION
B-33	2013 ENVIROTECH BORING LOCATION (NOTE 3)

NOTES:

1. AERIAL TOPOGRAPHIC BASE MAP WAS COMPILED USING AN AERIAL SURVEY PROVIDED BY JIVIDENS LAND SURVEY CO., INC. DATED 2013 AND PREVIOUS CONSTRUCTION DRAWINGS FOR CELL 15. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. LOCATIONS ARE APPROXIMATE. SEE BORING LOGS FOR EXACT LOCATIONS.
4. CELL 15 SUBCELLS 1 THROUGH 11 ARE EXISTING SUBCELLS THAT HAVE BEEN CONSTRUCTED. CELL 15 SUBCELLS 12 AND 13 ARE PERMITTED BUT NOT YET CONSTRUCTED. CELL 15 SUBCELLS 14 THROUGH 22 ARE PROPOSED.

0 300'
SCALE IN FEET

Geosyntec consultants

AUSTIN, TX

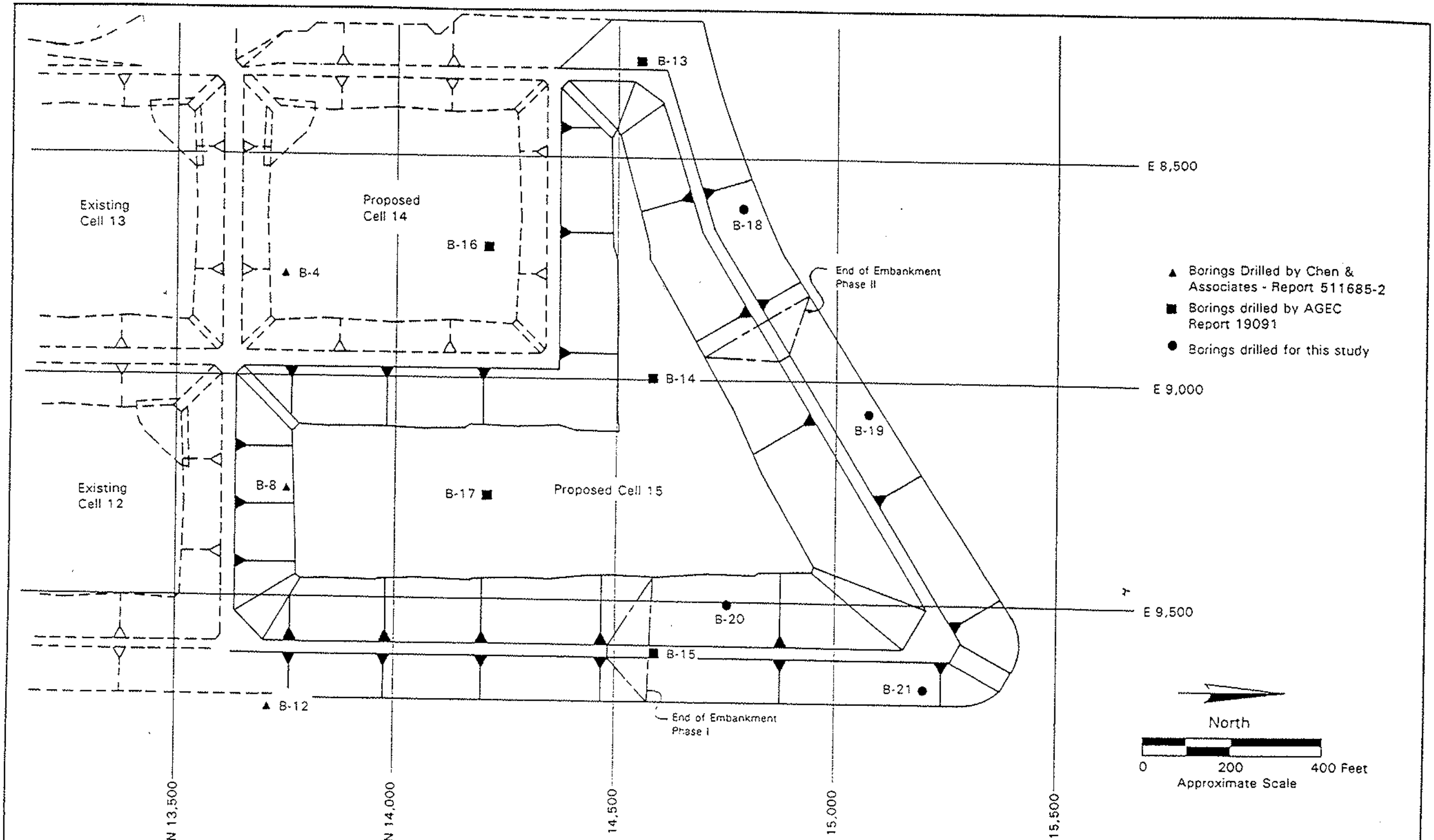
DATE:	MAY 2014	SCALE:	1" = 300'
PROJECT NO.	TXL0380	FILE NO.	038004F-B1-1
DOCUMENT NO.		FIGURE NO.	B1-1

P:\CADD\PROJECTS\L\LONE MOUNTAIN FACILITY\PERMIT\EXPANSION APP MOD CELL 15 WEST - TXL0380\FIGURES\038004F-B1-1

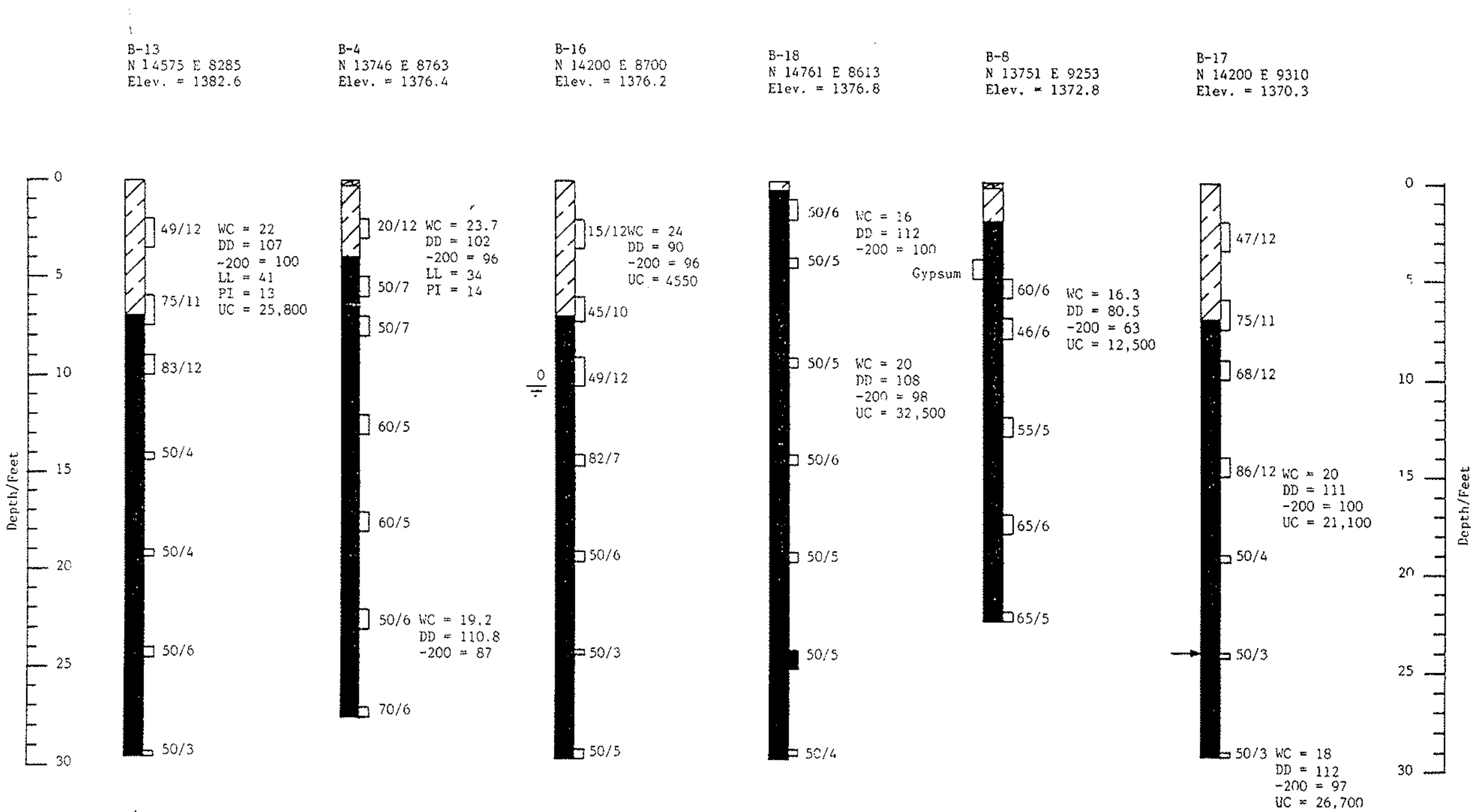
APPENDICES

APPENDIX B1-1

PREVIOUS GEOTECHNICAL TEST DATA (BORINGS B-4, B-8, AND B-12 THROUGH B-21)

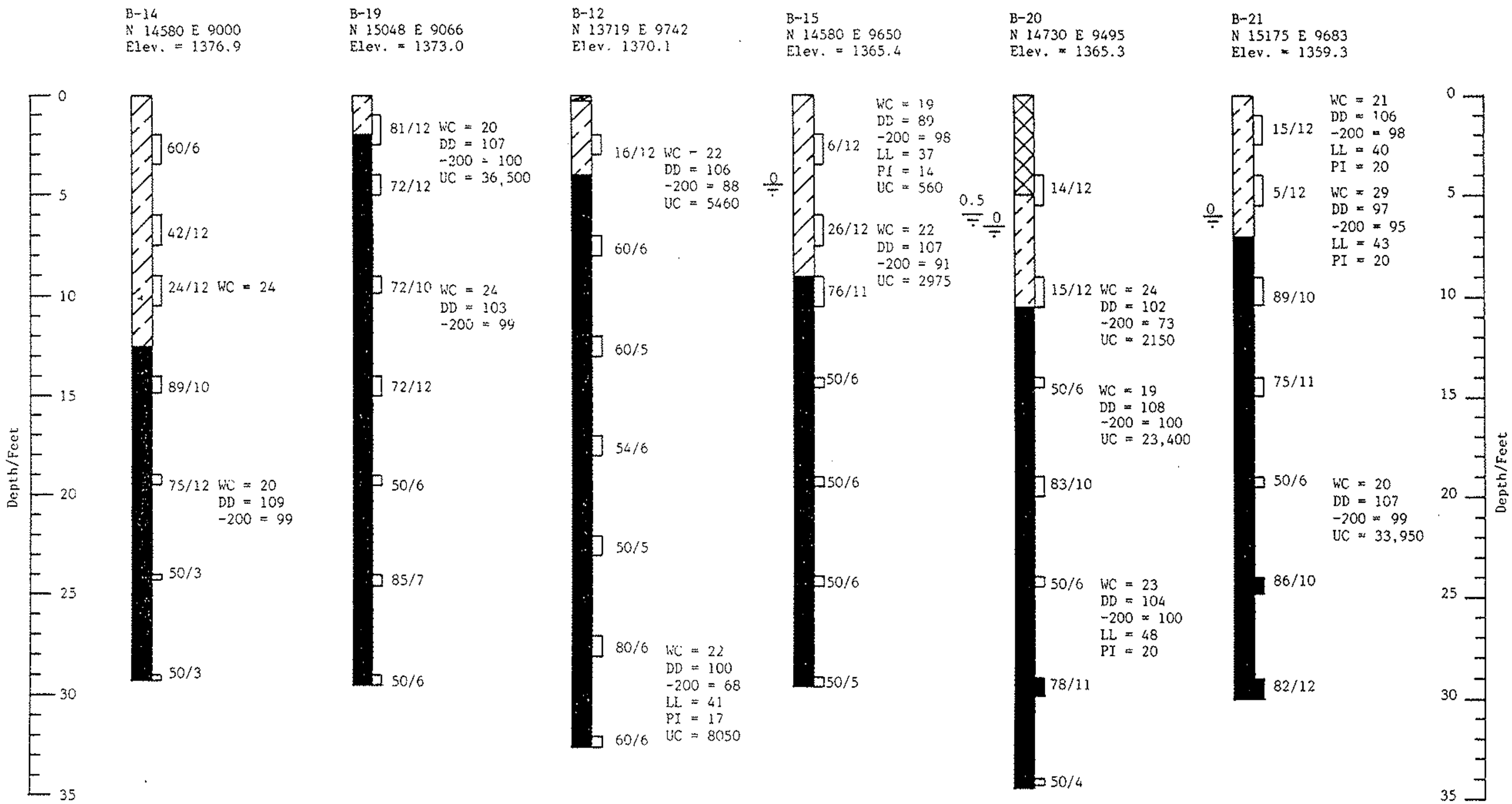


24292	AGEC	Location of Exploratory Borings	Figure 1



See Figure 4 for Legend and Notes

24292	AGEC	Logs of Exploratory Borings	Figure 2



See Figure 4 for Legend and Notes

24292	AGEC	Logs of Exploratory Borings	Figure 3

NOTES:

1. Listed below are the dates that the borings were drilled and the report in which they first were reported.

Borings	Date Drilled	Report
B-4, B-8, B-12	1/29/85 - 2/2/85	Chen & Associates 511685-2
B-13 through B-17	11/4/91 - 11/5/91	AGEC 19091
B-18 through B-21	11/13/92	This Report

2. Locations of exploratory borings were survey located by others.

3. Elevations of exploratory borings were surveyed by others.

4. The exploratory boring locations and elevations 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).

LEGEND:

Fill; clay and silt, sandy, slightly moist, red.

Topsoil; clay, silty, dry to moist, red.

Clay (CL); silty, stiff, moist to wet, red.

Clay and Silt (CL-ML); medium stiff to very stiff, moist to wet, red.

Claystone/Siltstone; firm to very hard, slightly moist, gravel sized gypsum, red and turquoise.

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.

Standard Drive Sample.

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

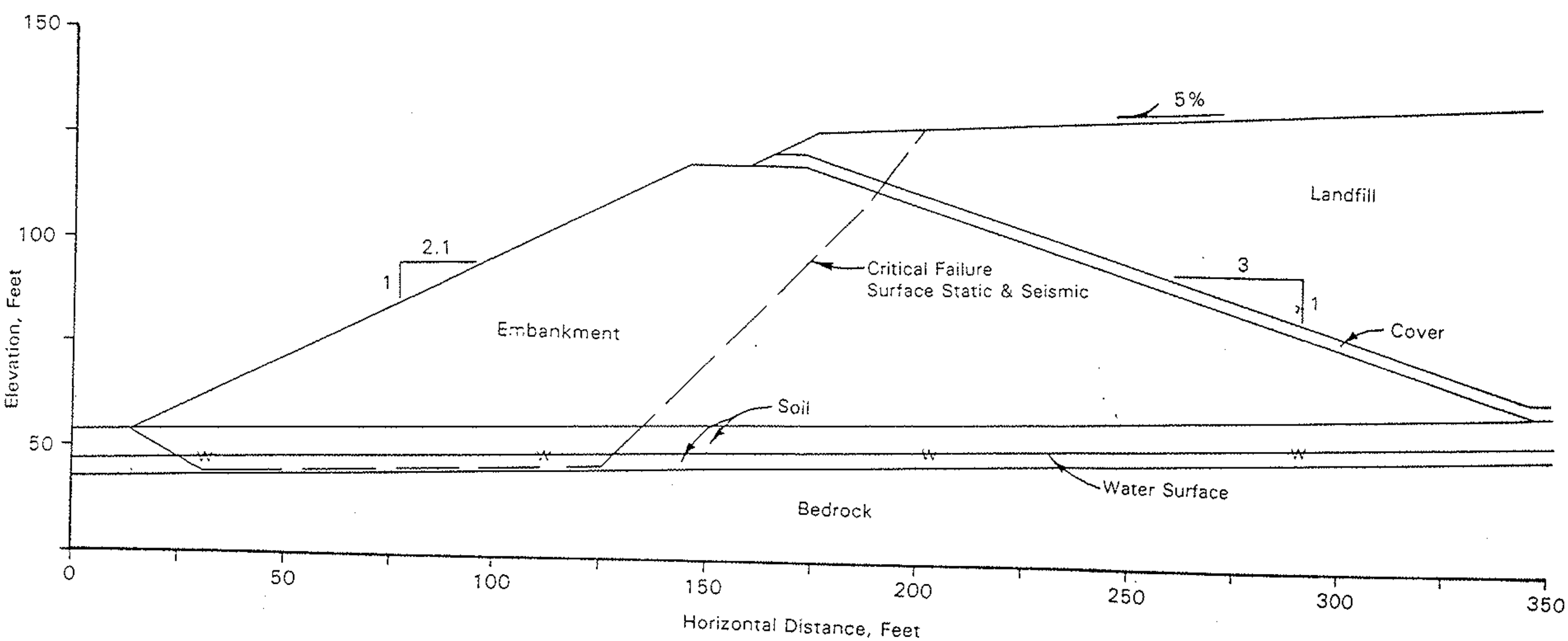
Indicates depth at which boring caved.

24292	AGEC	Legend and Notes of Exploratory Borings	Figure 4

Long Term Safety Factors

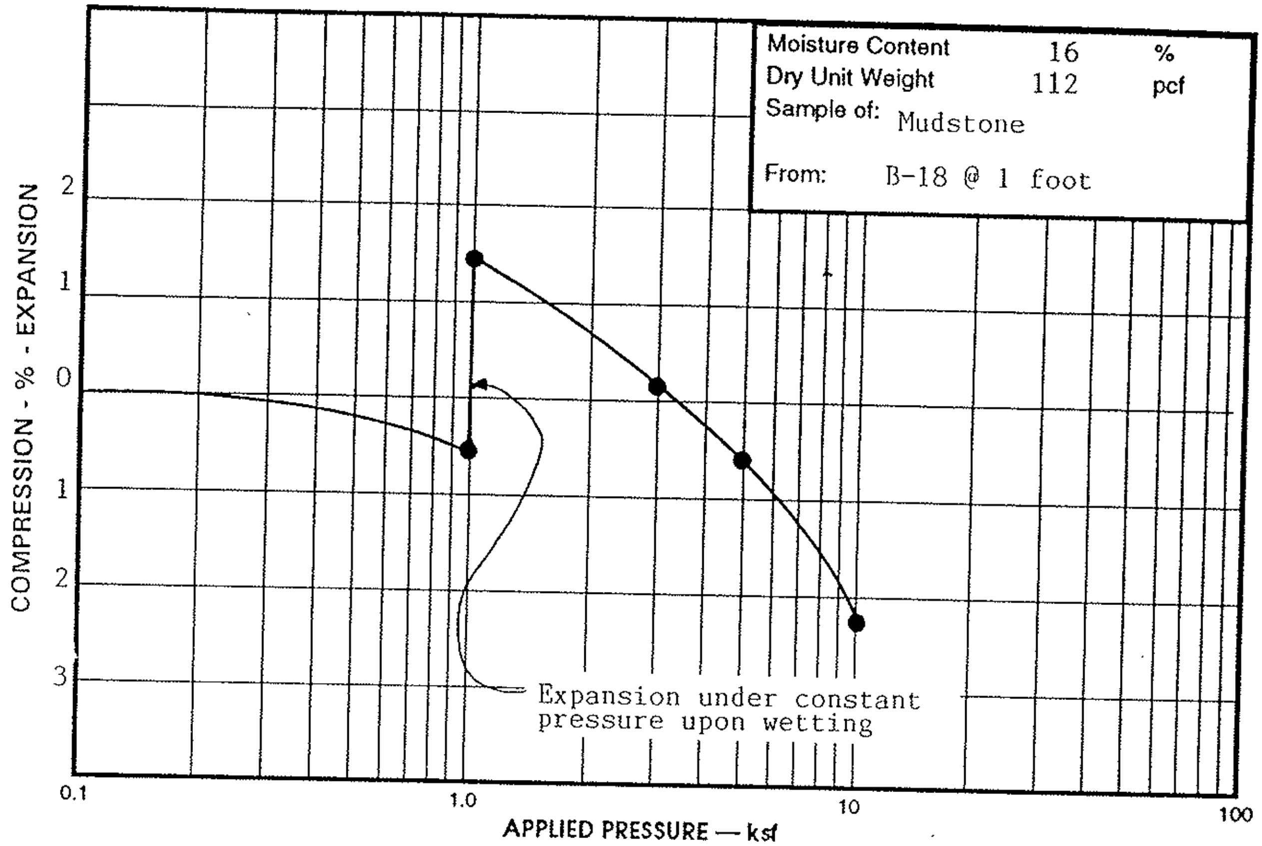
1.8 Static
1.6 Seismic - 0.04g acceleration

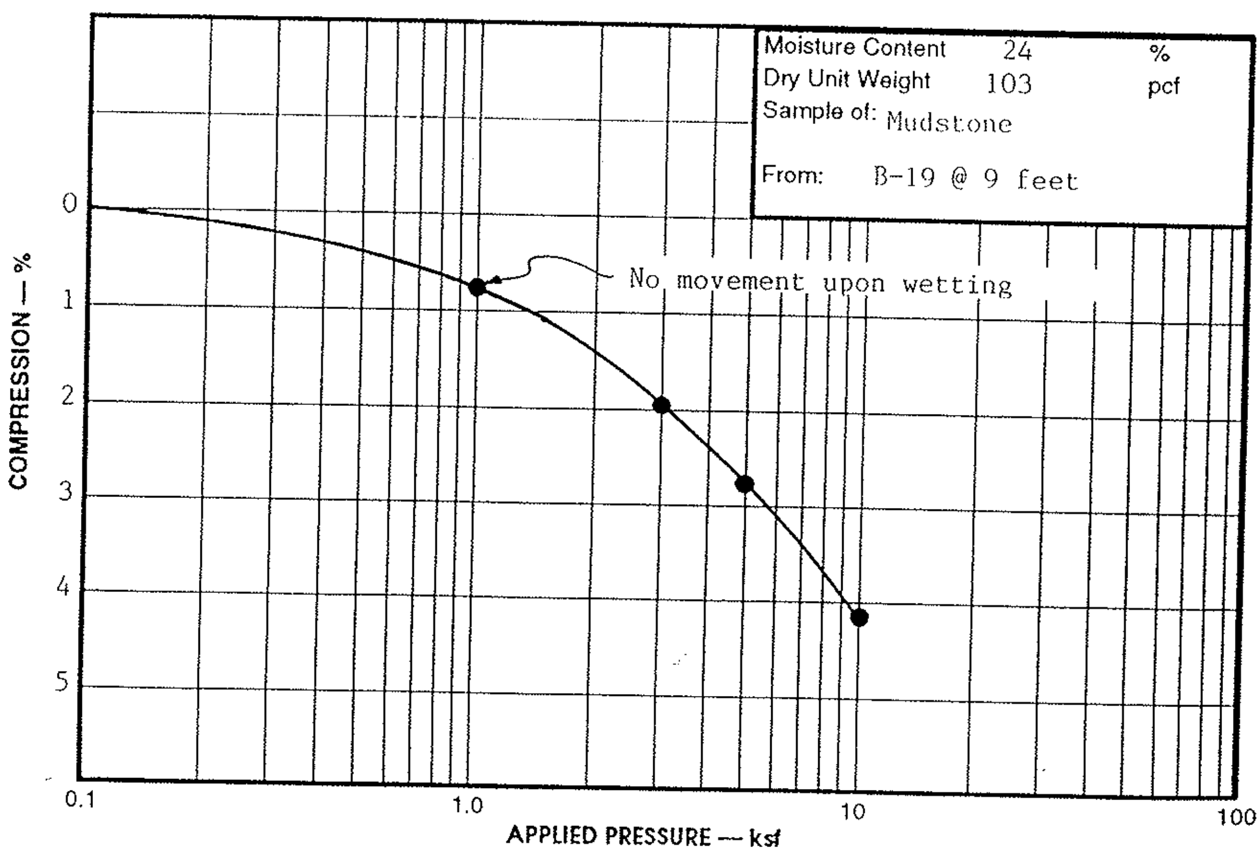
SOIL PARAMETERS			
Material	Density, pcf	ϕ, degrees	c, psf
Landfill	120	10	50
Cover	110	28	0
Embankment & Liner	120	23	550
Soil (CL-ML)	125	10	1800
Bedrock	128	10	5000



24293	AGEC	STABILITY ANALYSIS SUMMARY	FIGURE 5

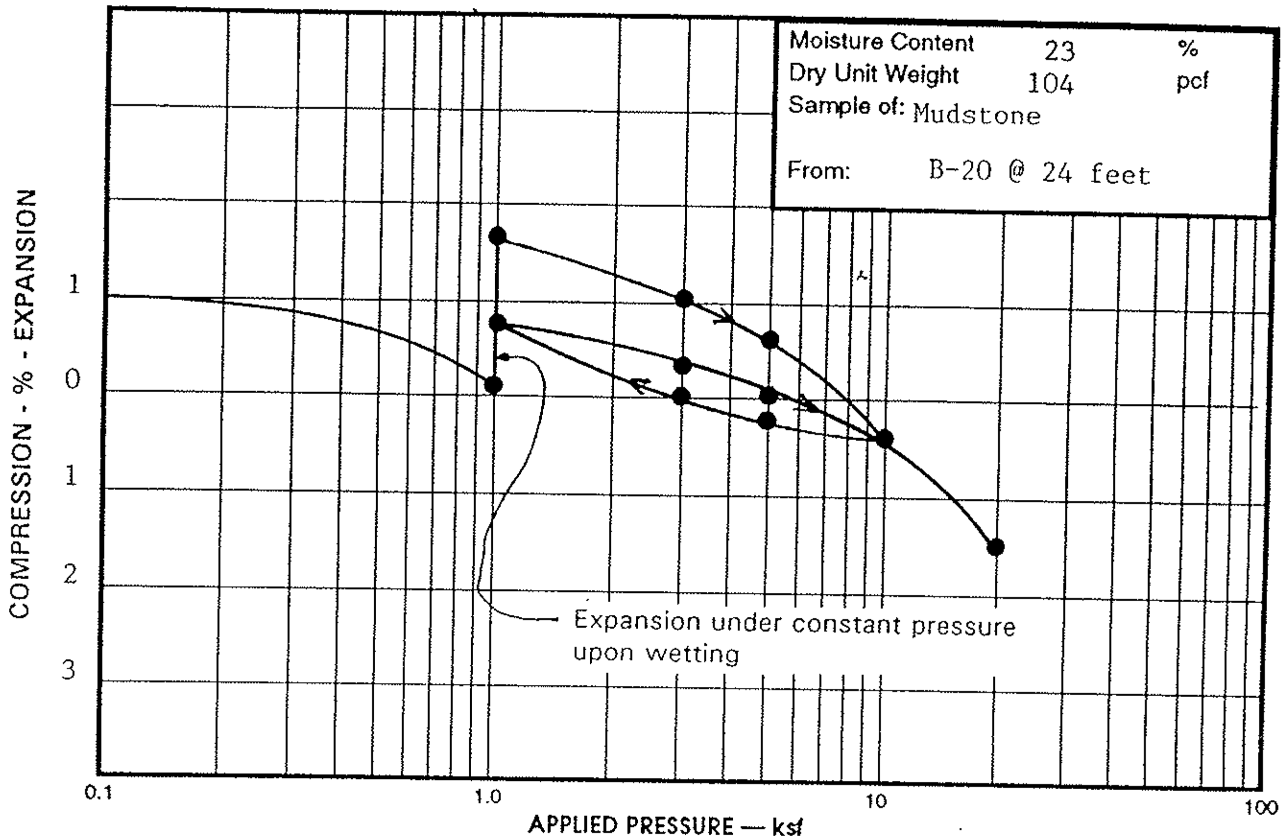
Applied Geotechnical Engineering Consultants, Inc.

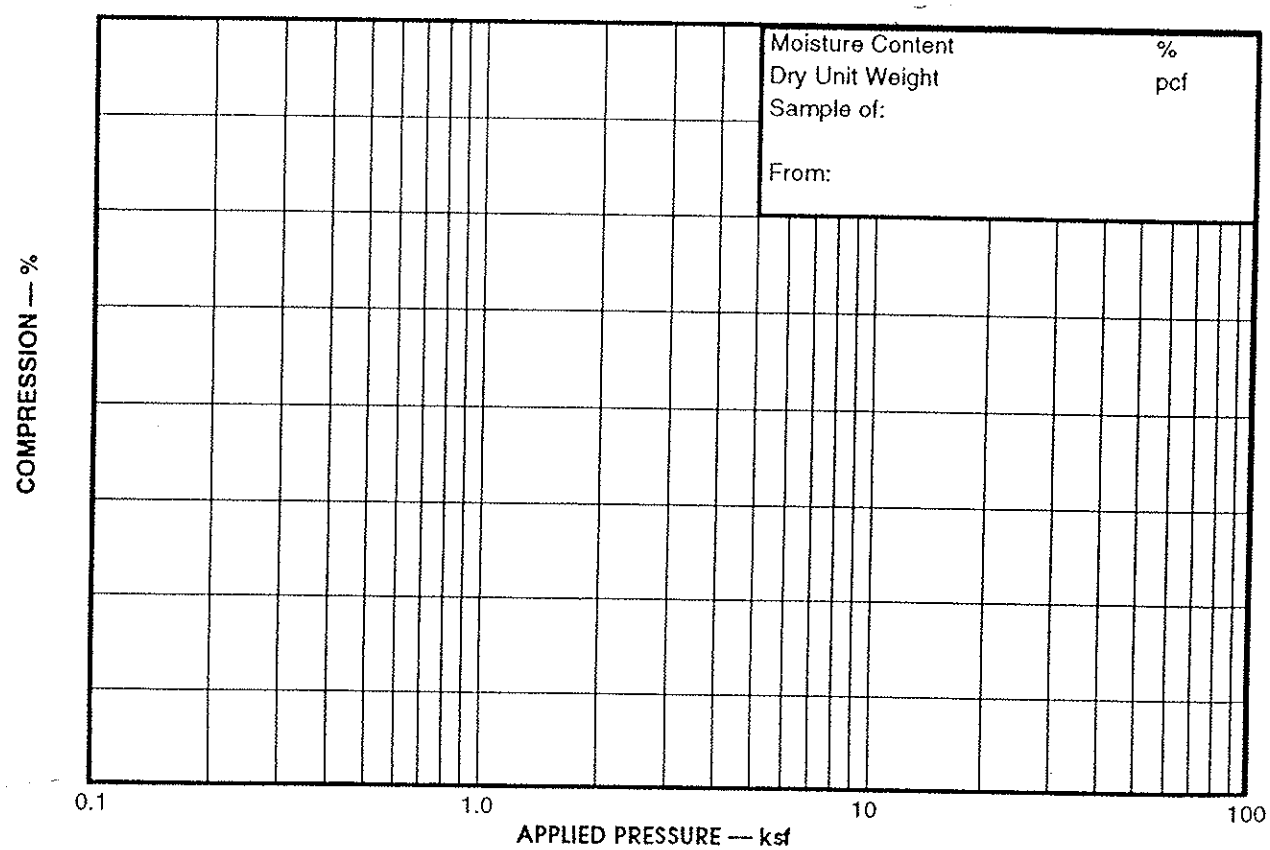




Project No. 24292 **CONSOLIDATION TEST RESULTS** Figure 6

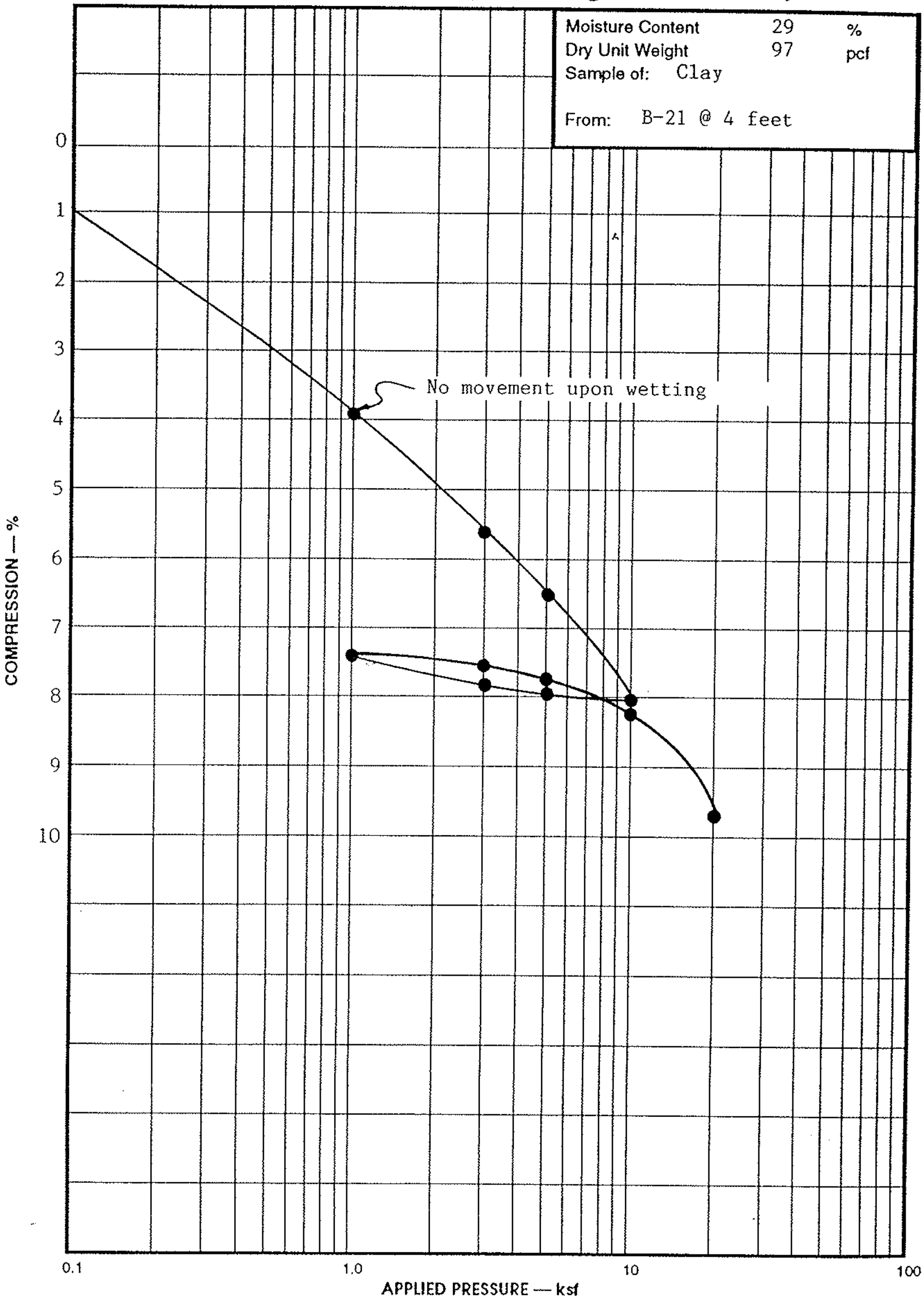
Applied Geotechnical Engineering Consultants, Inc.



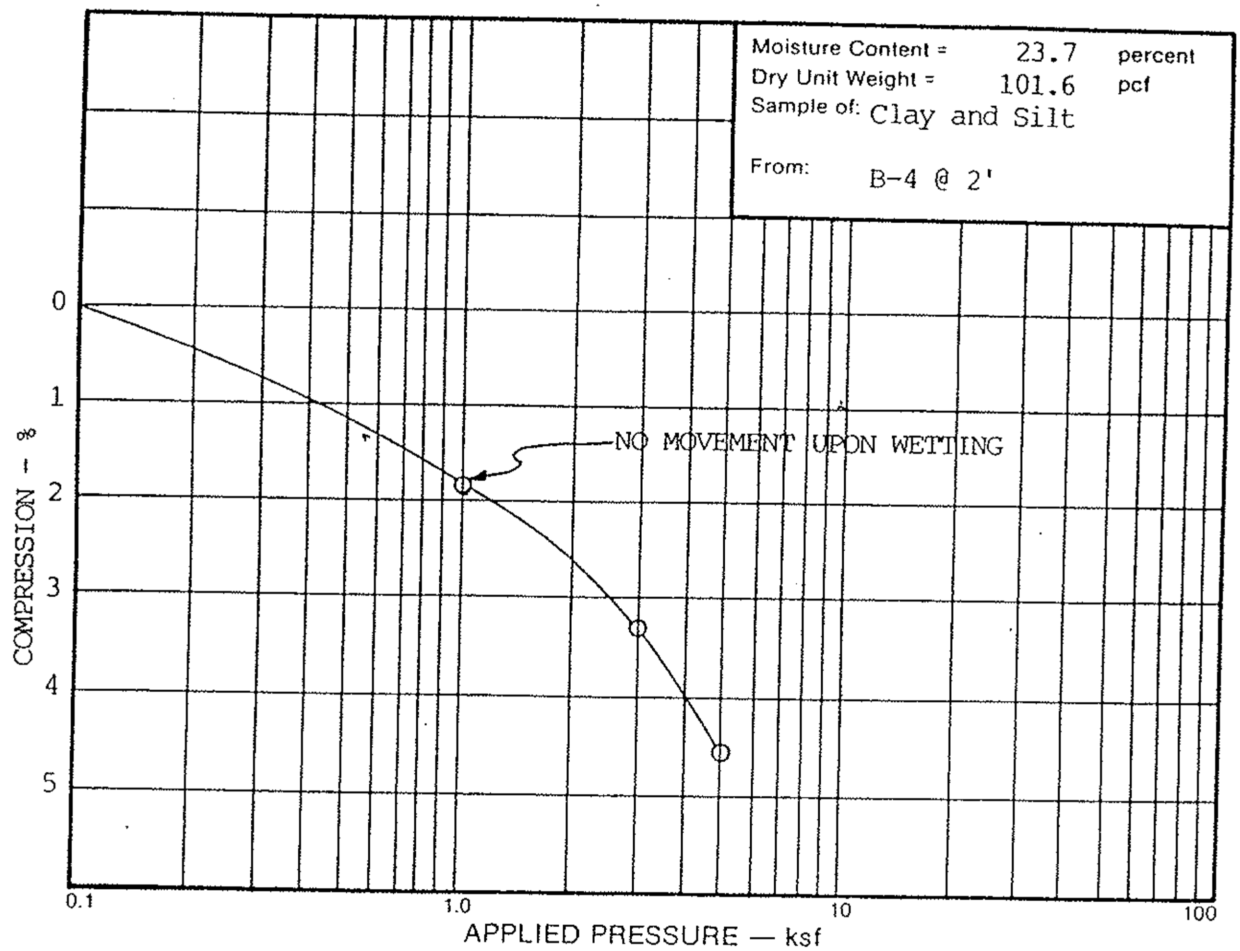


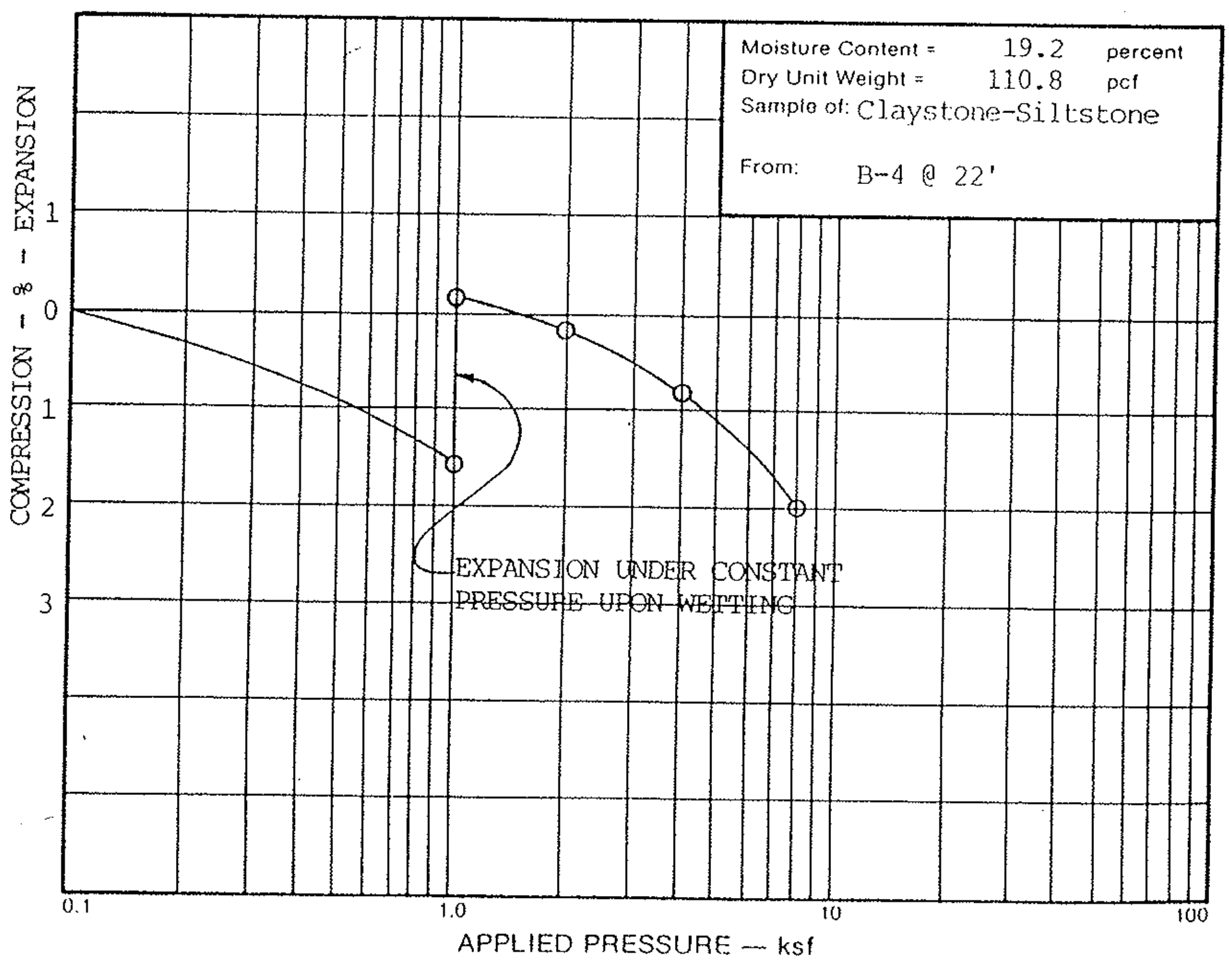
Project No. 24292 **CONSOLIDATION TEST RESULTS** Figure 7

Applied Geotechnical Engineering Consultants, Inc.



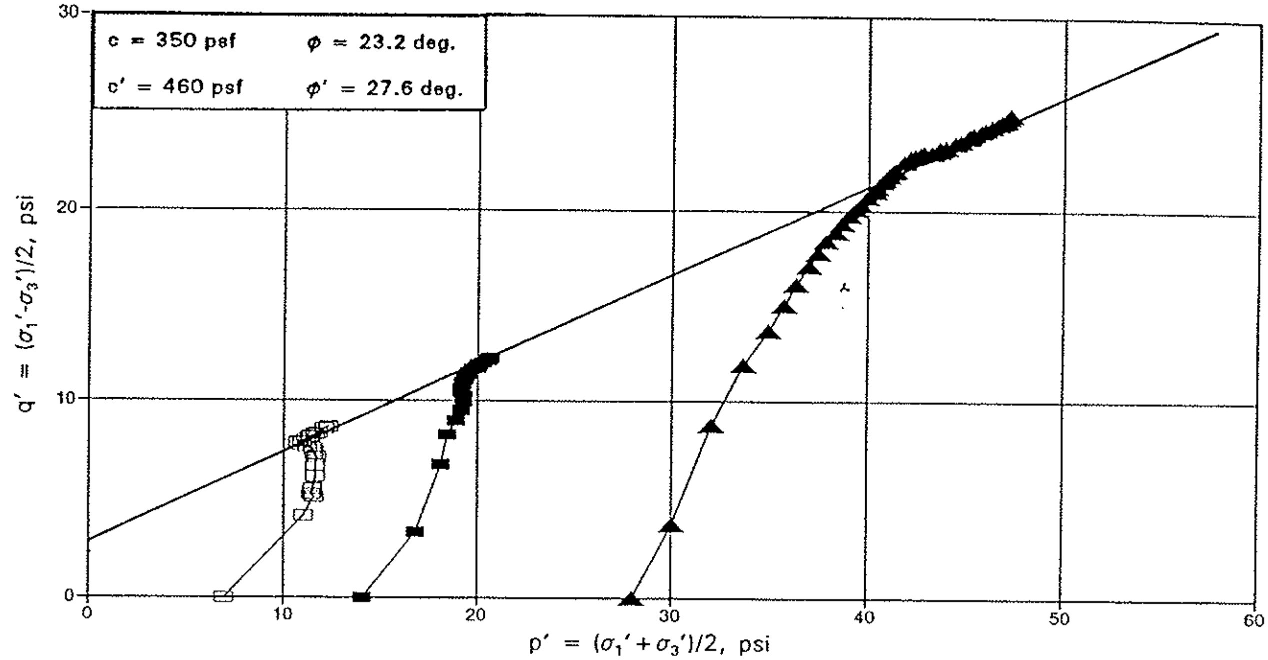
Project No. 24292 **CONSOLIDATION TEST RESULTS** Figure 8

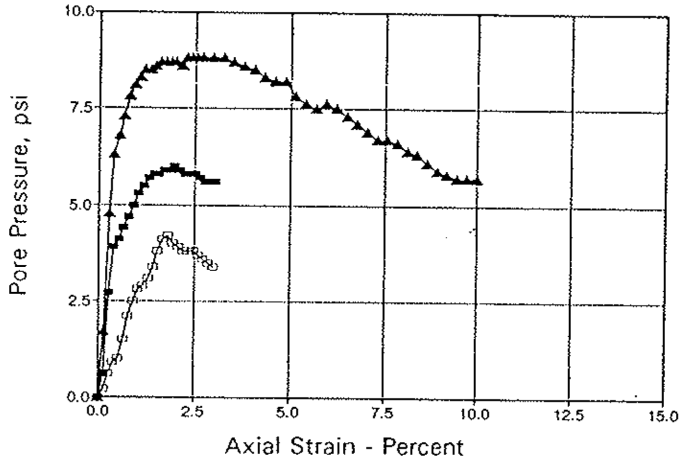




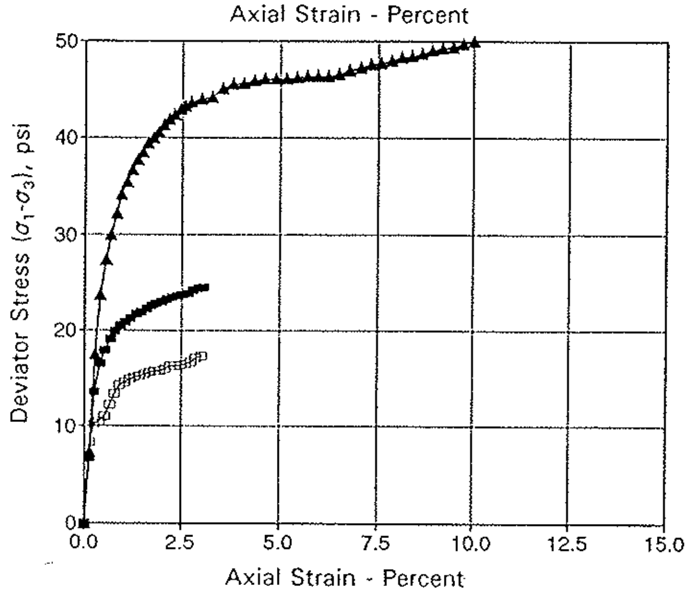
#511685-2 SWELL-CONSOLIDATION TEST RESULTS Fig. 9

Applied Geotechnical Engineering Consultants, Inc.





Test No.(Symbol)	1(□)	2(■)	3(▲)
Sample Type	undisturbed		
Length, in.	3.85	3.77	3.70
Diameter, in.	1.93	1.95	1.97
Dry Density, pcf	106.4		
Moisture Content, %	21.0		
Consol. Pressure, psi	7.0	14.0	28.0
"B" Parameter	1.00	1.00	1.00
Total Conf. Stress(σ_3), psi	7.0	14.0	28.0
Total Axial Stress(σ_1), psi	24.3	38.5	72.0
Deviator Stress(σ_1-σ_3), psi	17.3	24.5	44.0
Eff. Lateral Stress(σ_3'),	3.6	8.4	19.2
Eff. Axial Stress(σ_1'), psi	20.9	32.9	63.2
Pore Pressure(μ), psi	3.4	5.6	8.8
Strain(ϵ), %	3.0	6.0	9.0
Remarks	Test Type: (CIU) Consolidated Undrained with pore pressure measurements. Sample was back pressure saturated.		



Sample Index Properties	
Natural Dry Density, pcf	106.4
Natural Moisture Content, %	21.0
Liquid Limit, %	40
Plasticity Index, %	20
Percent Gravel	-
Percent Sand	-
Percent Passing No. 200 Sieve	98

Sample Description: Red, Lean Clay (CL)

From: Boring B-21 @ 1 foot

Project No.24292 **TRIAXIAL COMPRESSION TEST RESULTS** Figure 10

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

PROJECT NUMBER 24292

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 (%)		
B-4	2	23.7	102			96	34	14		Lean Clay
	22	19.2	110.8			87				Mudstone
B-8	5	16.3	80.5			63			12,500	Mudstone
B-12	2	22	106			88			5,460	Clay-Silt
	27	22	100			68	41	17	8,050	Mudstone
B-13	2	22	107			100	41	13	25,800	Clay
B-14	9	24								Clay-Silt
	19	20	109			99				Mudstone
B-15	2	19	80			98	37	14	560	Clay-Silt
	6	22	107			91			2,975	Clay-Silt
B-16	2	24	90			96			4,550	Clay-Silt
B-17	14	20	111			100			21,100	Mudstone

APPLIED GEOTECHNICAL ENGINEERING CONSULTANTS, INC.

TABLE I

SUMMARY OF LABORATORY TEST RESULTS

PROJECT NUMBER 2429

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 (%)		
B-18	1	16	112			100				Mudstone
	9	20	108			98			32,500	Mudstone
B-19	1	20	107			100			36,500	Mudstone
	9	24	103			99				Mudstone
B-20	9	24	102			73			2,150	Clay-Silt
	14	19	108			100			23,400	Mudstone
	24	23	104			100	48	20		Mudstone
B-21	1	21	106			98	40	20		Clay
	4	29	97			95	43	20		Clay
	19	20	107			99			33,950	Mudstone

PROJECT NO. 24292 TITLE Landfill Cell 15 DATE 1/20/93 BY JRM
SUBJECT Settlement Anlaysis SHEET 2 OF 7

Consolidation Test Results

Boring	Depth	Cc′	Cr′	Swell	Material
4	2′	0.055	0.015	---	clay
4	22′	0.038	0.013	1.7	claystone
13	12′	0.015	---	1.0	claystone
16	7′	0.013	---	0	claystone
18	1′	0.029	---	2.0	mudstone
19	9′	0.030	---	0	mudstone
20	24′	0.019	0.010	1.6	mudstone
21	4′	0.079	0.006	---	clay
1	7′	0.014	0.002	0.3	claystone
2	22′	0.0125	---	0.3	claystone
5	7′	0.02	0.005	0.7	claystone
9	15′	0.027	0.005	1.4	claystone
11	5′	0.015	0.005	1.3	claystone
19	17′	0.016	---	1.3	claystone
Average		0.024	0.006	1.16	

Extraplate expansion into results and assume all samples are under recompression.

	Cr′
B-1 @ 7	0.005
B-2 @ 22	0.006
B-4 @ 22	0.005
B-5 @ 7	0.004
B-9 @ 15	0.006
B-11 @ 5	0.005
B-13 @ 15	0.003
B-19 @ 17	0.005
Average	0.00049

APPENDIX B1-2

2010 GEOTECHNICAL SITE INVESTIGATION BORING LOGS (BORINGS B-22 THROUGH B-32)

Envirotech Engineering

PROJECT: *Lone Mountain Facility Geotech*
CLIENT: *Clean Harbors, Inc.*
DRILLING DATE: *February 25, 2010*
DRILLING METHOD: *8" Hollow Stem -Standard Penetration*

BORING NO. *22*
LOGGED BY: *J. Stovall*
DRILLED BY: *C. Butcher*
LOCATION: *N-36, 26.299 / W-98, 48.395*
ELEVATION: *N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N Value.)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0		CL	Brownish Red Clay, **CL**	N/A	Upper	18.0	36.0	16.0	20.0	1.52	86.8
	Split-Spoon	CL	Brownish Red Clay, **CL** (Bearing Capacity = 5500 psf)	26	Lower	18.7	49.0	22.0	27.0	1.56	88.5
5		CL									
	Split-Spoon	CL	Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	42	Lower	18.7	49.0	22.0	27.0	1.56	88.5
10		CL									
	Split-Spoon	CL	Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	18.7	49.0	22.0	27.0	1.56	88.5
15		CL	Green Shale								
			Terminated Drilling @ 16.5 ft. ***No Water Encountered*** ***(Thin layers of Gypsum present throughout the boring)***								
20											

Strata Symbols

- Low-Plasticity Clay (CL)
- High-Plasticity Silt (MH)
- Low-Plasticity Silt (ML)
- Well Graded Sand (SW)
- Clayey Sand (SC)
- Silty Sand (SM)
- High-Plasticity Clay (CH)

Soil Sampler

- Split-Spoon Sampler

Envirotech Engineering

PROJECT: *Lone Mountain Facility Geotech*
CLIENT: *Clean Harbors, Inc.*
DRILLING DATE: *February 27, 2010*
DRILLING METHOD: *8" Hollow Stem -Standard Penetration*

BORING NO. *23*
LOGGED BY: *J. Stovall*
DRILLED BY: *C. Butcher*
LOCATION: *N-36, 26.383 / W-98, 48.201*
ELEVATION: *N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N Value.)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0			Brownish Red Clay with Gravel, **CL**	N/A	Upper	14.4	38.0	20.0	18.0	1.67	74.4
			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf) Green Shale	46	Lower	18.0	36.0	20.0	16.0	1.81	99.8
5			***Terminated Drilling @ 4 ft.*** ***No Water Encountered***								
10											
15											
20											

Strata Symbols

Low-Plasticity Clay (CL)
High-Plasticity Silt (MH)
Low-Plasticity Silt (ML)
Well Graded Sand (SW)
Clayey Sand (SC)
Silty Sand (SM)
High-Plasticity Clay (CH)

Soil Sampler

Split-Spoon Sampler

Envirotech Engineering

PROJECT: *Lone Mountain Facility Geotech*
CLIENT: *Clean Harbors, Inc.*
DRILLING DATE: *February 25, 2010*
DRILLING METHOD: *8" Hollow Stem -Standard Penetration*

BORING NO. *24*
LOGGED BY: *J. Stovall*
DRILLED BY: *C. Butcher*
LOCATION: *N-36, 26.399 / W-98, 48.397*
ELEVATION: *N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N Value.)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0			Brown Clay, **CL**	N/A	Upper	21.8	40.0	16.0	24.0	1.57	92.6
5			Brownish Red Gravely Clay, **CH** (Bearing Capacity = 7500 psf)	46	Lower	17.4	55.0	24.0	31.0	1.52	55.6
			Water Level								
10			Brownish Red Gravely Clay, **CH** (Bearing Capacity = 7500 psf) Green Shale	46	Lower	17.4	55.0	24.0	31.0	1.52	55.6
15			***Terminated Drilling @ 12 ft.*** ***Water Encountered @ 10 ft.*** ***(Thin layers of Gypsum present throughout the boring)***								
20											

Strata Symbols

- Low-Plasticity Clay (CL)
- High-Plasticity Silt (MH)
- Low-Plasticity Silt (ML)
- Well Graded Sand (SW)
- Clayey Sand (SC)
- Silty Sand (SM)
- High-Plasticity Clay (CH)

Soil Sampler

- Split-Spoon Sampler

Envirotech Engineering

PROJECT:	*Lone Mountain Facility Geotech*	BORING NO.	*25*
CLIENT:	*Clean Harbors, Inc.*	LOGGED BY:	*J. Stovall*
DRILLING DATE:	*February 25, 2010*	DRILLED BY:	*C. Butcher*
DRILLING METHOD:	*8" Hollow Stem -Standard Penetration*	LOCATION:	*N-36, 26.402 / W-98, 48.318*
		ELEVATION:	*N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N Value.)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0			Brown Clay with Sand, **CL** (Bearing Capacity = 5000 psf)	20	Upper	22.4	37.0	20.0	17.0	1.67	81.3
			Brown/Light Brown Clay, **CL** (Bearing Capacity = 1500 psf)	6	Upper	22.4	37.0	20.0	17.0	1.67	81.3
			Water								
5											
			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	18.2	40.0	20.0	20.0	1.68	90.2
			1" water vein								
10			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf) Green Shale	45	Lower	18.2	40.0	20.0	20.0	1.68	90.2
			Terminated Drilling @ 13 ft. ***Water Encountered @ 4.7 ft.*** ***Water Encountered @ 9 ft.*** ***(Thin layers of Gypsum present throughout the boring)***								
15											
20											

Strata Symbols

- Low-Plasticity Clay (CL)
- High-Plasticity Silt (MH)
- Low-Plasticity Silt (ML)
- Well Graded Sand (SW)
- Clayey Sand (SC)
- Silty Sand (SM)
- High-Plasticity Clay (CH)

Soil Sampler

- Split-Spoon Sampler

Revision 1- 04/2002

Envirotech Engineering

PROJECT: *Lone Mountain Facility Geotech*
CLIENT: *Clean Harbors, Inc.*
DRILLING DATE: *February 26, 2010*
DRILLING METHOD: *8" Hollow Stem -Standard Penetration*

BORING NO. *26*
LOGGED BY: *J. Stovall*
DRILLED BY: *C. Butcher*
LOCATION: *N-36, 26.411 / W-98, 48.104*
ELEVATION: *N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N Value.)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0			Brownish Red Clay, **CL**	N/A	Upper	19.4	42.0	22.0	20.0	1.71	91.3
			Water								
5			Brownish Red Clay, **CL** (Bearing Capacity = 2500 psf)	10	Upper	19.4	42.0	22.0	20.0	1.71	91.3
10			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	23.3	47.0	27.0	20.0	1.60	99.1
15			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	23.3	47.0	27.0	20.0	1.60	99.1
20			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	23.3	47.0	27.0	20.0	1.60	99.1
25			Green Shale								
			Terminated Drilling @ 26 ft.								
			Water Encountered @ 5 ft.								
			(Thin layers of Gypsum present throughout the boring)								
30											
35											

Strata Symbols

- Low-Plasticity Clay (CL)
- High-Plasticity Silt (MH)
- Low-Plasticity Silt (ML)
- Well Graded Sand (SW)
- Clayey Sand (SC)
- Silty Sand (SM)
- High-Plasticity Clay (CH)

Soil Sampler

- Split-Spoon Sampler

Envirotech Engineering

PROJECT: *Lone Mountain Facility Geotech*
CLIENT: *Clean Harbors, Inc.*
DRILLING DATE: *February 27, 2010*
DRILLING METHOD: *8" Hollow Stem -Standard Penetration*

BORING NO. *27*
LOGGED BY: *J. Stovall*
DRILLED BY: *C. Butcher*
LOCATION: *N-36, 26.431 / W-98, 48.190*
ELEVATION: *N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N-Value)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0			Brown Clay, **CL**	N/A	Upper	22.3	35.0	18.0	17.0	1.62	95.9
			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	21.3	39.0	23.0	16.0	1.69	99.4
5			***Terminated Drilling @ 5 ft.*** ***No Water Encountered***								
10											
15											
20											

Strata Symbols

Low-Plasticity Clay (CL)
High-Plasticity Silt (MH)
Low-Plasticity Silt (ML)
Well Graded Sand (SW)
Clayey Sand (SC)
Silty Sand (SM)
High-Plasticity Clay (CH)

Soil Sampler

Split-Spoon Sampler

Envirotech Engineering

PROJECT: *Lone Mountain Facility Geotech*
CLIENT: *Clean Harbors, Inc.*
DRILLING DATE: *February 26, 2010*
DRILLING METHOD: *8" Hollow Stem -Standard Penetration*

BORING NO. *28*
LOGGED BY: *J. Stovall*
DRILLED BY: *C. Butcher*
LOCATION: *N-36, 26.434 / W-98, 48.095*
ELEVATION: *N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N Value.)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0			Clayey Gravel Brownish Red Clay, **CL**	N/A	Upper	24.7	38.0	20.0	18.0	1.74	93.4
			Water								
5			Brownish Red Clay, **CL** (Bearing Capacity = 5500 psf)	26	Upper	24.7	38.0	20.0	18.0	1.74	93.4
10			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	21.2	39.0	25.0	14.0	1.71	90.4
15			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	21.2	39.0	25.0	14.0	1.71	90.4
20			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	21.2	39.0	25.0	14.0	1.71	90.4
			Green Shale								
25			***Terminated Drilling @ 23 ft.*** ***Water Encountered @ 3.9 ft.*** ***(Thin layers of Gypsum present throughout the boring)***								
30											
35											

Strata Symbols

Low-Plasticity Clay (CL)
High-Plasticity Silt (MH)
Low-Plasticity Silt (ML)
Well Graded Sand (SW)
Clayey Sand (SC)
Silty Sand (SM)
High-Plasticity Clay (CH)

Soil Sampler

Split-Spoon Sampler

Envirotech Engineering

PROJECT: *Lone Mountain Facility Geotech*
CLIENT: *Clean Harbors, Inc.*
DRILLING DATE: *February 25, 2010*
DRILLING METHOD: *8" Hollow Stem -Standard Penetration*

BORING NO. *29*
LOGGED BY: *J. Stovall*
DRILLED BY: *C. Butcher*
LOCATION: *N-36, 26.372 / W-98, 48.172*
ELEVATION: *N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N Value.)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0			Brownish Red Clay with Rock, **CL**	N/A	Upper	20.0	35.0	20.0	15.0	1.71	85.9
5			Brownish Red Clay with Shale (Bearing Capacity = 7500 psf)	46	Lower	20.5	36.0	22.0	14.0	1.75	84.9
			Water								
			Green Shale								
10			***Terminated Drilling @ 9 ft.*** ***Water Encountered @ 8 ft.*** ***(Thin layers of Gypsum present throughout the boring)***								
15											
20											

Strata Symbols

- Low-Plasticity Clay (CL)
- High-Plasticity Silt (MH)
- Low-Plasticity Silt (ML)
- Well Graded Sand (SW)
- Clayey Sand (SC)
- Silty Sand (SM)
- High-Plasticity Clay (CH)

Soil Sampler

- Split-Spoon Sampler

Envirotech Engineering

PROJECT: *Lone Mountain Facility Geotech*
CLIENT: *Clean Harbors, Inc.*
DRILLING DATE: *February 27, 2010*
DRILLING METHOD: *8" Hollow Stem -Standard Penetration*

BORING NO. *30*
LOGGED BY: *J. Stovall*
DRILLED BY: *C. Butcher*
LOCATION: *N-36, 26.407 / W-98, 48.175*
ELEVATION: *N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N Value.)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0			Brownish Red Clay, **CL** (some grey shale)	N/A	Upper	24.4	38.0	23.0	15.0	1.60	87.7
5			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	20.8	39.0	22.0	17.0	1.68	95.2
			Green Shale								
10			***Terminated Drilling @ 8 ft.*** ***No Water Encountered*** ***(Thin layers of Gypsum present throughout the boring)***								
15											
20											

Strata Symbols

- Low-Plasticity Clay (CL)
- High-Plasticity Silt (MH)
- Low-Plasticity Silt (ML)
- Well Graded Sand (SW)
- Clayey Sand (SC)
- Silty Sand (SM)
- High-Plasticity Clay (CH)

Soil Sampler

- Split-Spoon Sampler

Revision 1- 04/2002

Envirotech Engineering

PROJECT: *Lone Mountain Facility Geotech*
CLIENT: *Clean Harbors, Inc.*
DRILLING DATE: *February 26, 2010*
DRILLING METHOD: *8" Hollow Stem -Standard Penetration*

BORING NO. *31*
LOGGED BY: *J. Stovall*
DRILLED BY: *C. Butcher*
LOCATION: *N-36, 26.321 / W-98, 48.300*
ELEVATION: *N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N-Value.)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0			Clayey Gravel Brownish Red Clay, **CL**	N/A	Upper	18.8	36.0	22.0	14.0	1.60	88.8
5			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	19.7	37.0	22.0	15.0	1.66	99.6
10			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	19.7	37.0	22.0	15.0	1.66	99.6
			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf) Green Shale	46	Lower	19.7	37.0	22.0	15.0	1.66	99.6
15			***Terminated Drilling @ 14 ft.*** ***No Water Encountered*** ***(Thin layers of Gypsum present throughout the boring)***								
20											

Strata Symbols

Low-Plasticity Clay (CL) · High-Plasticity Silt (MH) · Low-Plasticity Silt (ML) · Well Graded Sand (SW) · Clayey Sand (SC) · Silty Sand (SM) · High-Plasticity Clay (CH)

Soil Sampler

Split-Spoon Sampler

Envirotech Engineering

PROJECT: *Lone Mountain Facility Geotech*	BORING NO. *32*
CLIENT: *Clean Harbors, Inc.*	LOGGED BY: *J. Stovall*
DRILLING DATE: *February 27, 2010*	DRILLED BY: *C. Butcher*
DRILLING METHOD: *8" Hollow Stem -Standard Penetration*	LOCATION: *N-36, 26.383 / W-98, 48.234*
	ELEVATION: *N/A*

Depth (Ft.)	Sample	Soil Log	Description	SPT (N Value.)	Sample ID	Moisture (%)	LL	PL	PI	Dry Unit Weight (g/cc)	Passing 200 Sieve (%)
0			Brownish Red Clay, **CL**	N/A	Uppper	19.5	35.0	19.0	16.0	1.69	95.9
			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Upper	19.5	35.0	19.0	16.0	1.69	95.9
5			*Thin layer of Green Shale* Brownish Red Clay, **CL**	N/A	Lower	18.3	38.0	21.0	17.0	1.71	88.0
			Brownish Red Clay, **CL** (Bearing Capacity = 7500 psf)	46	Lower	18.3	38.0	21.0	17.0	1.71	88.0
10			***Terminated Drilling @ 10 ft.*** ***No Water Encountered*** ***(Thin layers of Gypsum present throughout the boring)***								
15											
20											

Strata Symbols

Low-Plasticity Clay (CL)
High-Plasticity Silt (MH)
Low-Plasticity Silt (ML)
Well Graded Sand (SW)
Clayey Sand (SC)
Silty Sand (SM)
High-Plasticity Clay (CH)

Soil Sampler

Split-Spoon Sampler

APPENDIX B1-3

2010 GEOTECHNICAL SITE INVESTIGATION LABORATORY TEST DATA

SOIL CLASSIFICATION (ASTM D-2487)

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 22 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/25/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	18.7%

% Passing No. 200 (ASTM D-1140)

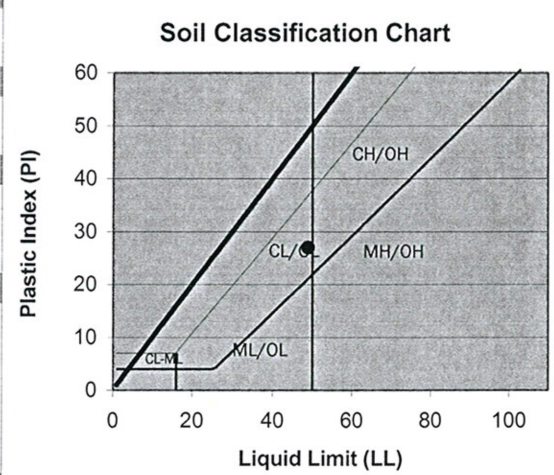
% Passing No. 200	88.5%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.56	g/cc
Specific Gravity	N/A	

Atterberg Limits (ASTM D-4318)

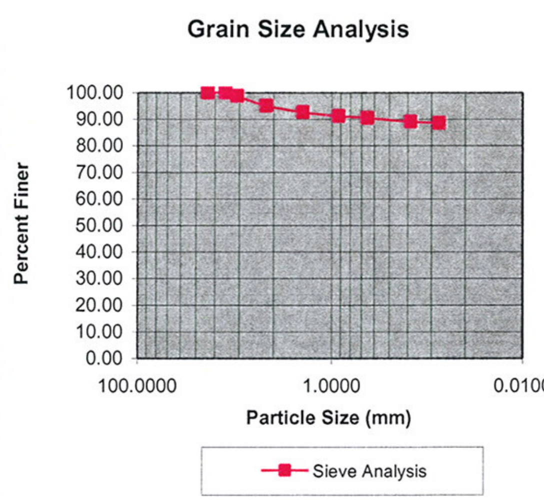
Flow Index	-8	Spec
Liquid Limit	49	
Plastic Limit	22	
Plasticity Index	27	



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	98.80	
No. 4	4.750	95.05	
No. 10	2.000	92.61	
No. 20	0.850	91.27	
No. 40	0.425	90.55	
No. 100	0.150	89.12	
No. 200	0.075	88.54	

Cu	N/A
Cc	N/A



Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate. Dry Unit Weight samples were remolded

Envirotech - Project Manager

3/12/10

Date

SOIL CLASSIFICATION (ASTM D-2487)

ENVIROTECH ENGINEERING & CONSULTING, INC.
2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 22 - Upper Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/25/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	18.0%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	86.8%

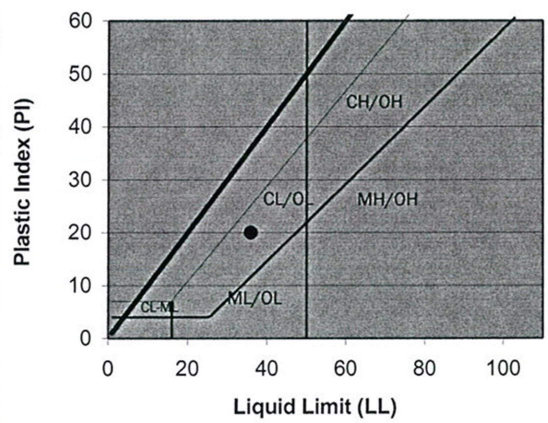
Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.52	g/cc
Specific Gravity	N/A	

Atterberg Limits (ASTM D-4318)

Flow Index	-4	Spec
Liquid Limit	36	
Plastic Limit	16	
Plasticity Index	20	

Soil Classification Chart

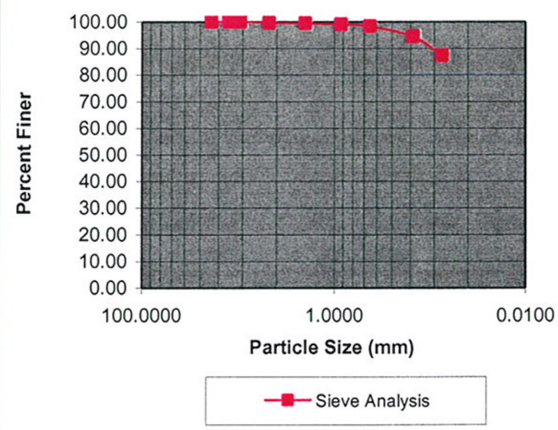


Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	99.65	
No. 10	2.000	99.37	
No. 20	0.850	99.04	
No. 40	0.425	98.35	
No. 100	0.150	94.48	
No. 200	0.075	87.43	

Cu	N/A
Cc	N/A

Grain Size Analysis



Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate. Dry Unit Weight samples were remolded

Envirotech - Project Manager

3/12/10

Date

SOIL CLASSIFICATION (ASTM D-2487)

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

ENVIROTECH ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 23 - Upper Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay with Rock
Project Location:	Lone Mountain Facility			Sampling Date:	2/27/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	14.4%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	74.4%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.67	g/cc
Specific Gravity	N/A	

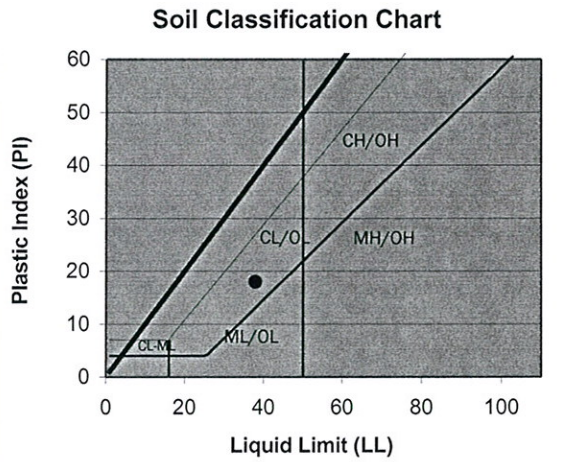
Atterberg Limits (ASTM D-4318)

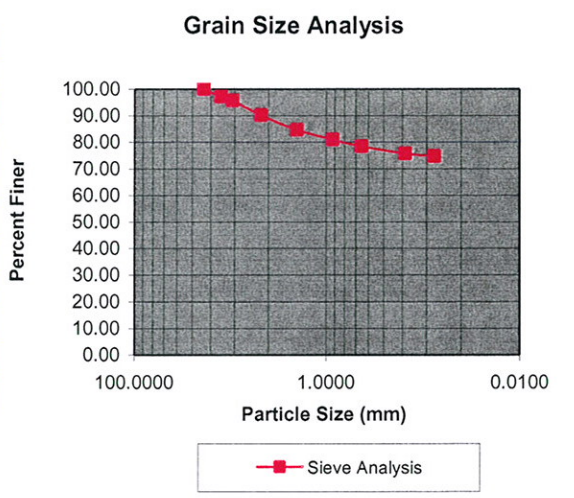
Flow Index	-4	Spec
Liquid Limit	38	
Plastic Limit	20	
Plasticity Index	18	

Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	97.17	
3/8	9.500	95.73	
No. 4	4.750	90.14	
No. 10	2.000	84.65	
No. 20	0.850	80.90	
No. 40	0.425	78.41	
No. 100	0.150	75.58	
No. 200	0.075	74.58	

Cu	N/A
Cc	N/A





Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

[signature]
Envirotech - Project Manager

3/12/10
Date

SOIL CLASSIFICATION (ASTM D-2487)

ENVIROTECH ENGINEERING & CONSULTING, INC.
2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 23 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/27/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	18.0%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	99.8%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.81	g/cc
Specific Gravity	N/A	

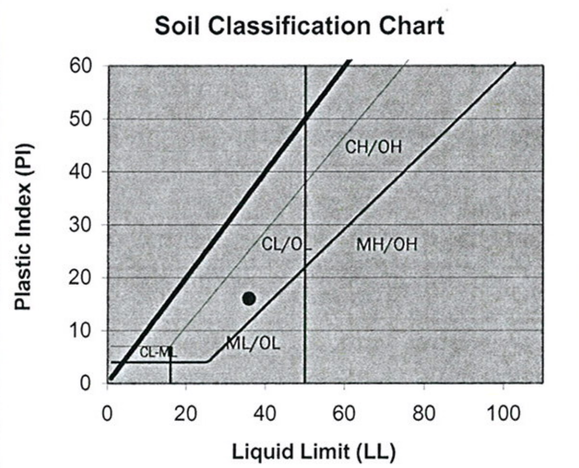
Atterberg Limits (ASTM D-4318)

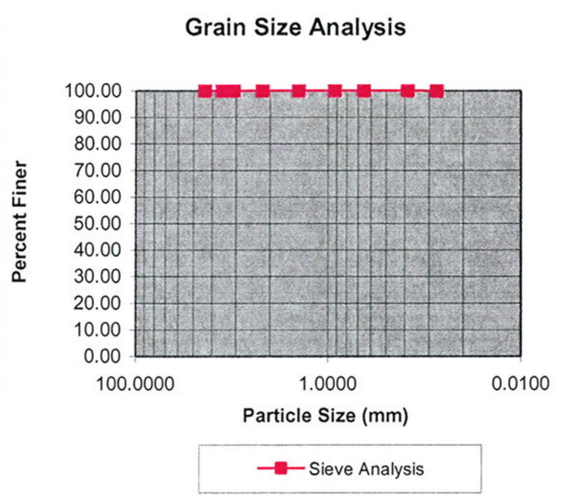
Flow Index	-4	Spec
Liquid Limit	36	
Plastic Limit	20	
Plasticity Index	16	

Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	100.00	
No. 10	2.000	100.00	
No. 20	0.850	99.97	
No. 40	0.425	99.96	
No. 100	0.150	99.95	
No. 200	0.075	99.87	

Cu	N/A
Cc	N/A





Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10
Date

SOIL CLASSIFICATION (ASTM D-2487)

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 24 - Upper Stratum
Project:	010039/010046			Sample Description:	Brown Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/25/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	21.8%

% Passing No. 200 (ASTM D-1140)

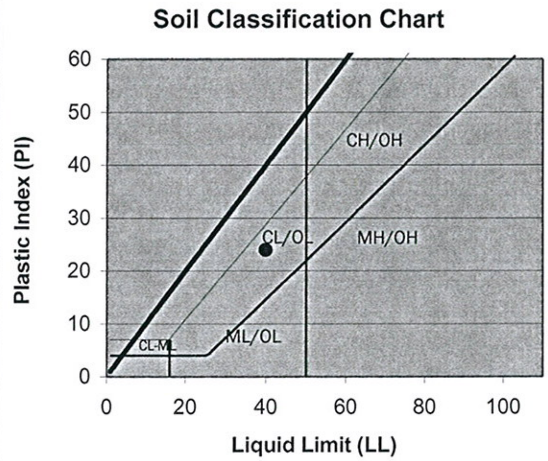
% Passing No. 200	92.6%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.57	g/cc
Specific Gravity	2.60	

Atterberg Limits (ASTM D-4318)

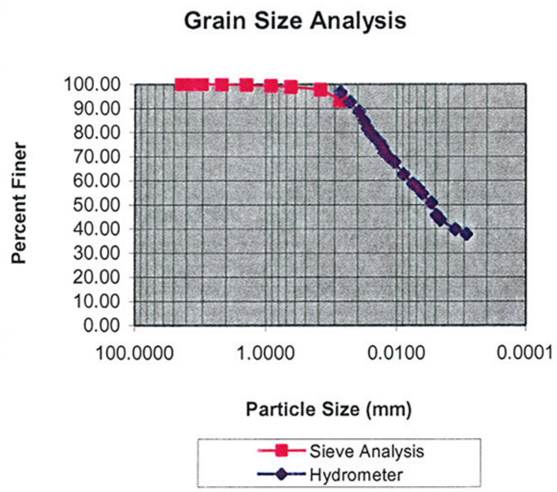
Flow Index	-8	Spec
Liquid Limit	40	
Plastic Limit	16	
Plasticity Index	24	



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	99.87	
No. 10	2.000	99.71	
No. 20	0.850	99.25	
No. 40	0.425	98.82	
No. 100	0.150	97.59	
No. 200	0.075	93.10	
Hydrometer	0.010	66.21	
Hydrometer	0.001	38.57	

Cu	N/A
Cc	N/A



Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10

Date

SOIL CLASSIFICATION (ASTM D-2487)

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 24 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay with Rock
Project Location:	Lone Mountain Facility			Sampling Date:	2/25/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	17.4%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	55.6%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.52	g/cc
Specific Gravity	N/A	

Atterberg Limits (ASTM D-4318)

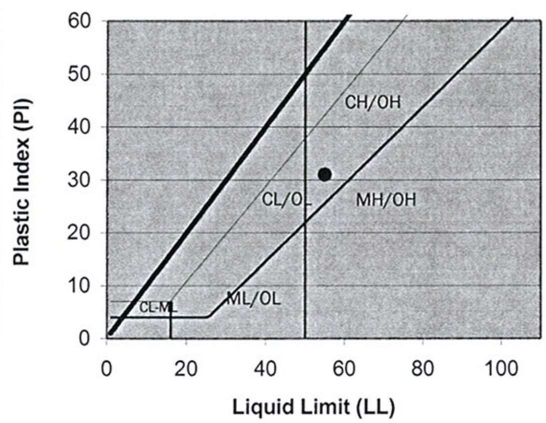
Flow Index	-5	Spec
Liquid Limit	55	
Plastic Limit	24	
Plasticity Index	31	

Particle Size Anaylsis (ASTM D-422)

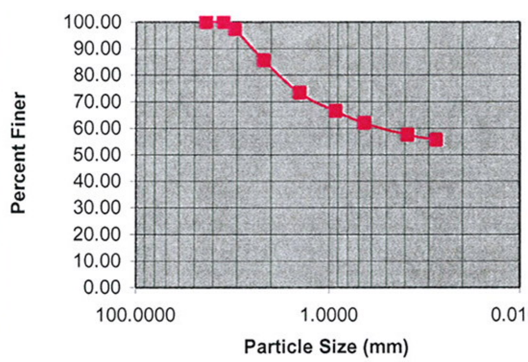
Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	97.40	
No. 4	4.750	85.57	
No. 10	2.000	73.37	
No. 20	0.850	66.46	
No. 40	0.425	61.86	
No. 100	0.150	57.40	
No. 200	0.075	55.59	

Cu	N/A
Cc	N/A

Soil Classification Chart



Grain Size Analysis



Unified Soil Classification (ASTM D-2487)

CH - Fat Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate. Dry Unit Weight samples were remolded

Envirotech - Project Manager

3/12/10

Date

SOIL CLASSIFICATION (ASTM D-2487)

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 25 - Upper Stratum
Project:	010039/010046			Sample Description:	Brown Clay with Sand
Project Location:	Lone Mountain Facility			Sampling Date:	2/25/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	22.4%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	81.3%

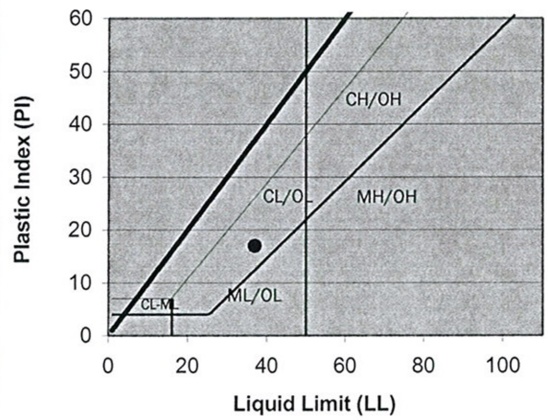
Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.67	g/cc
Specific Gravity	N/A	

Atterberg Limits (ASTM D-4318)

Flow Index	-6	Spec
Liquid Limit	37	
Plastic Limit	20	
Plasticity Index	17	

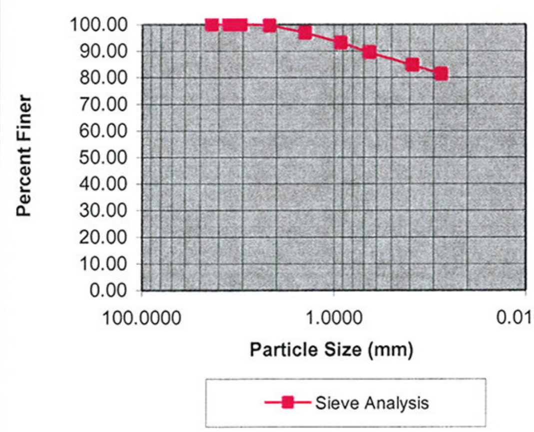
Soil Classification Chart



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	99.64	
No. 10	2.000	96.86	
No. 20	0.850	93.09	
No. 40	0.425	89.58	
No. 100	0.150	84.71	
No. 200	0.075	81.41	

Grain Size Analysis



Cu	N/A
Cc	N/A

Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate. Dry Unit Weight samples were remolded

Envirotech - Project Manager

3/12/10

Date

SOIL CLASSIFICATION (ASTM D-2487)

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 25 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/25/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	18.2%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	90.2%

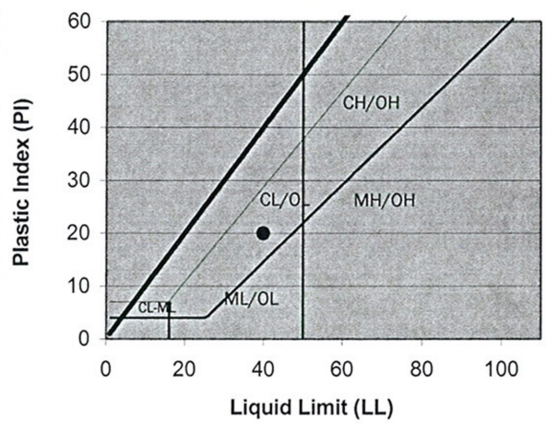
Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.68	g/cc
Specific Gravity	N/A	

Atterberg Limits (ASTM D-4318)

Flow Index	-6	Spec
Liquid Limit	40	
Plastic Limit	20	
Plasticity Index	20	

Soil Classification Chart

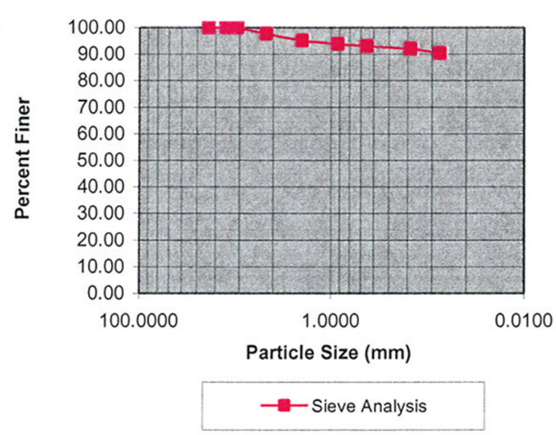


Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	97.75	
No. 10	2.000	95.15	
No. 20	0.850	93.82	
No. 40	0.425	93.00	
No. 100	0.150	92.01	
No. 200	0.075	90.37	

Cu	N/A
Cc	N/A

Grain Size Analysis



Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate. Dry Unit Weight samples were remolded

Envirotech - Project Manager

3/12/10

Date

SOIL CLASSIFICATION (ASTM D-2487)

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2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 26 - Upper Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/26/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	19.4%

% Passing No. 200 (ASTM D-1140)

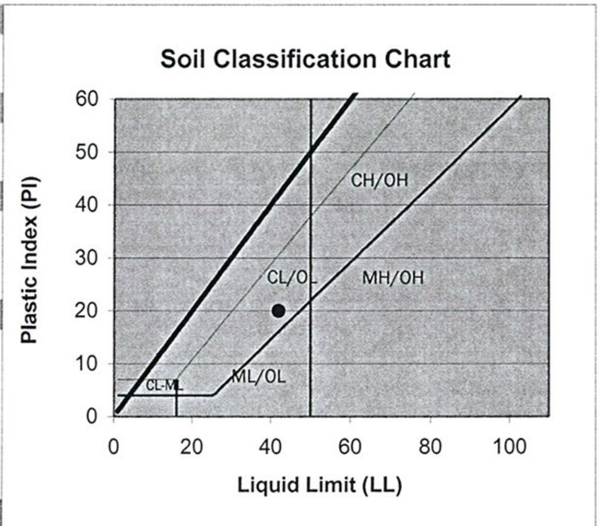
% Passing No. 200	91.3%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.71	g/cc
Specific Gravity	N/A	

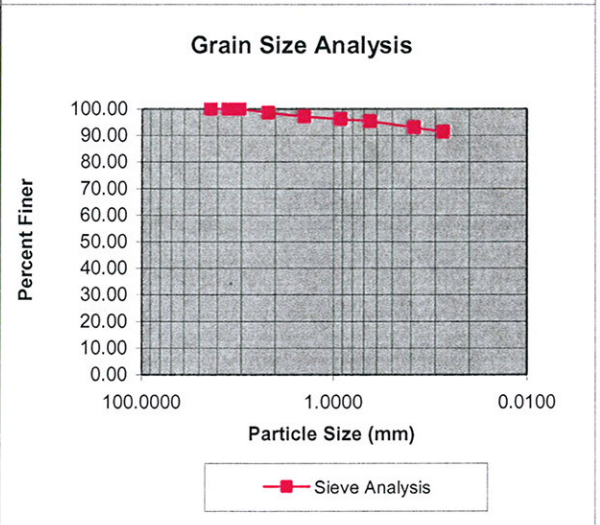
Atterberg Limits (ASTM D-4318)

Flow Index	-4	Spec
Liquid Limit	42	
Plastic Limit	22	
Plasticity Index	20	



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	98.53	
No. 10	2.000	97.16	
No. 20	0.850	96.21	
No. 40	0.425	95.34	
No. 100	0.150	92.99	
No. 200	0.075	91.38	



Cu	N/A
Cc	N/A

Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10
Date

SOIL CLASSIFICATION (ASTM D-2487)

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(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 26 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/26/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	23.3%

% Passing No. 200 (ASTM D-1140)

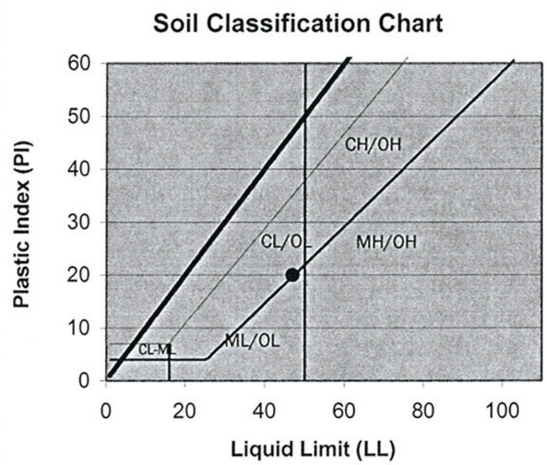
% Passing No. 200	99.1%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.60 g/cc
Specific Gravity	N/A

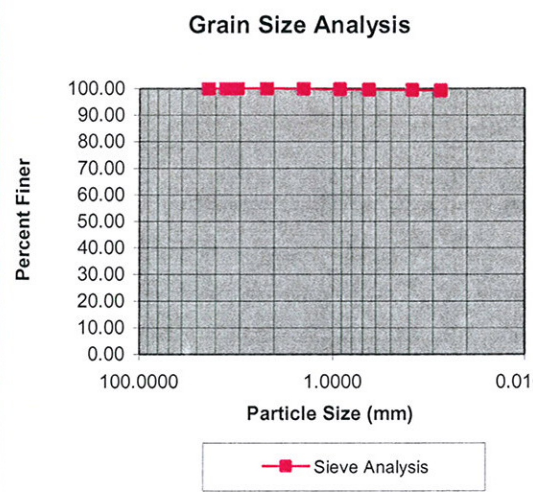
Atterberg Limits (ASTM D-4318)

		Spec
Flow Index	-6	
Liquid Limit	47	
Plastic Limit	27	
Plasticity Index	20	



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	100.00	
No. 10	2.000	99.88	
No. 20	0.850	99.68	
No. 40	0.425	99.56	
No. 100	0.150	99.40	
No. 200	0.075	99.12	



Cu	N/A
Cc	N/A

Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10

Date

SOIL CLASSIFICATION (ASTM D-2487)

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

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ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 27 - Upper Stratum
Project:	010039/010046			Sample Description:	Brown Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/27/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	22.3%

% Passing No. 200 (ASTM D-1140)

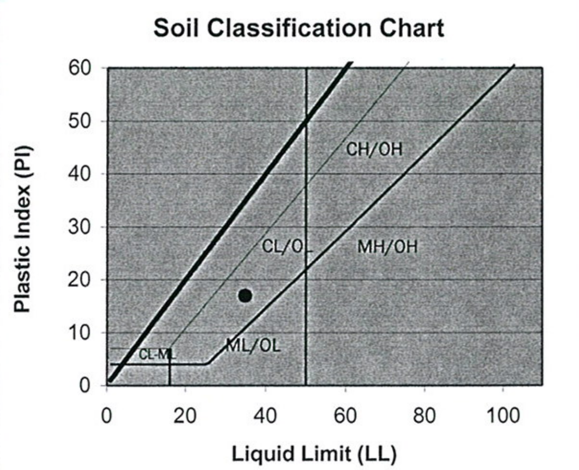
% Passing No. 200	95.9%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.62	g/cc
Specific Gravity	N/A	

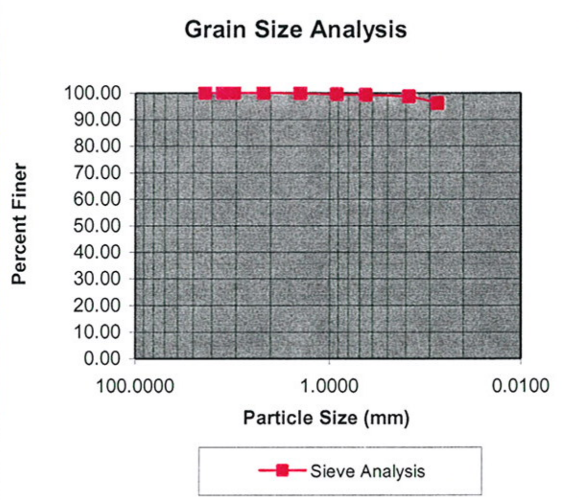
Atterberg Limits (ASTM D-4318)

Flow Index	-5	Spec
Liquid Limit	35	
Plastic Limit	18	
Plasticity Index	17	



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	100.00	
No. 10	2.000	99.85	
No. 20	0.850	99.53	
No. 40	0.425	99.26	
No. 100	0.150	98.70	
No. 200	0.075	96.17	



Cu	N/A
Cc	N/A

Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10

Date

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2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 27 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/27/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	21.3%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	99.4%

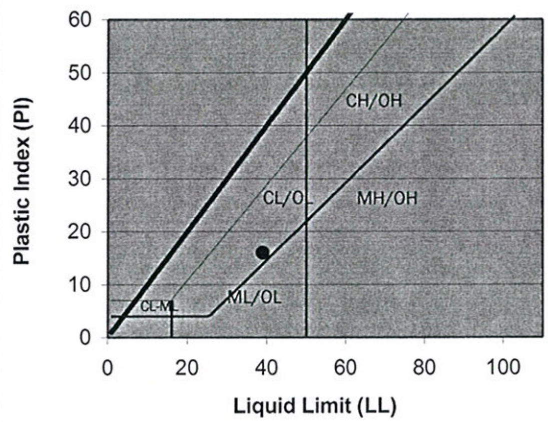
Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.69 g/cc
Specific Gravity	N/A

Atterberg Limits (ASTM D-4318)

Flow Index	-6	Spec
Liquid Limit	39	
Plastic Limit	23	
Plasticity Index	16	

Soil Classification Chart

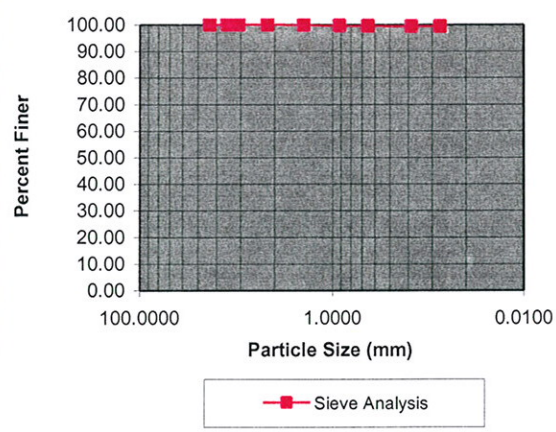


Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	100.00	
No. 10	2.000	99.91	
No. 20	0.850	99.65	
No. 40	0.425	99.52	
No. 100	0.150	99.43	
No. 200	0.075	99.39	

Cu	N/A
Cc	N/A

Grain Size Analysis



Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10
Date

SOIL CLASSIFICATION (ASTM D-2487)

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 28 - Upper Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/26/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	24.7%

% Passing No. 200 (ASTM D-1140)

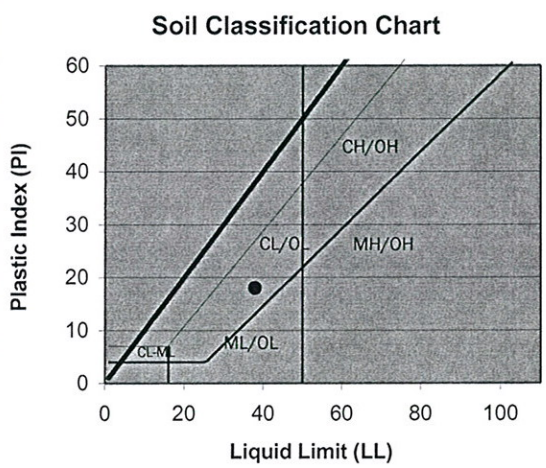
% Passing No. 200	93.4%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.74	g/cc
Specific Gravity	2.69	

Atterberg Limits (ASTM D-4318)

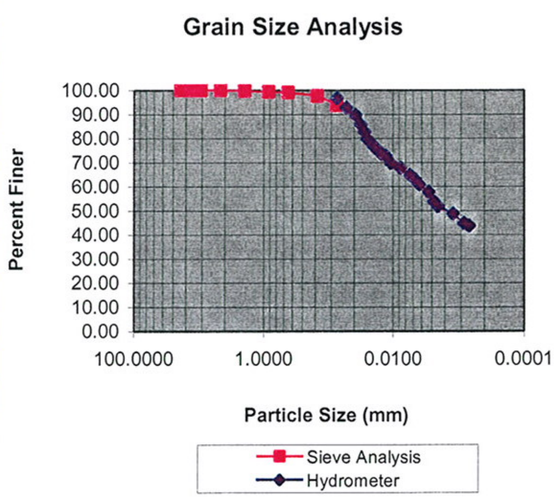
Flow Index	-4	Spec
Liquid Limit	38	
Plastic Limit	20	
Plasticity Index	18	



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	99.94	
No. 10	2.000	99.80	
No. 20	0.850	99.39	
No. 40	0.425	99.04	
No. 100	0.150	97.66	
No. 200	0.075	93.72	
Hydrometer	0.010	70.89	
Hydrometer	0.001	46.09	

Cu	N/A
Cc	N/A



Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate. Dry Unit Weight samples were remolded

Envirotech - Project Manager

3/12/10
Date

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2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 28 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/26/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	21.2%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	90.4%

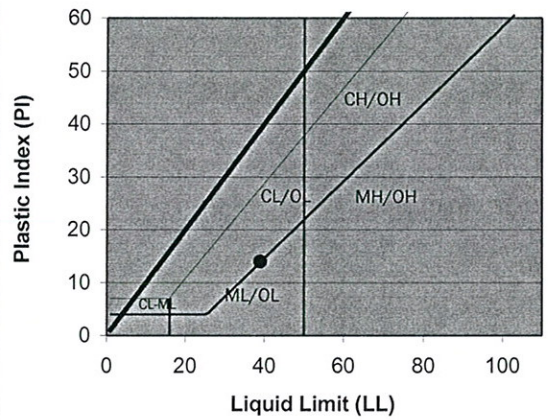
Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.71	g/cc
Specific Gravity	N/A	

Atterberg Limits (ASTM D-4318)

Flow Index	-6	Spec
Liquid Limit	39	
Plastic Limit	25	
Plasticity Index	14	

Soil Classification Chart

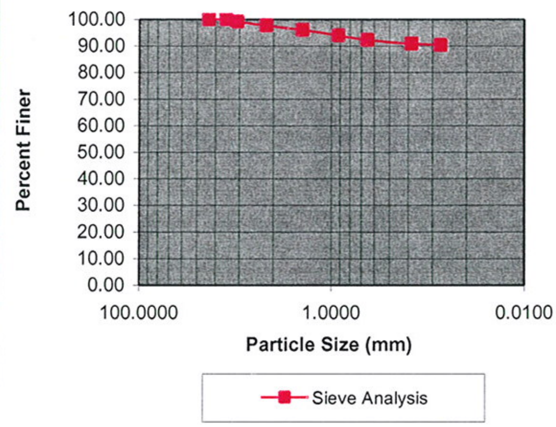


Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	99.14	
No. 4	4.750	97.75	
No. 10	2.000	96.03	
No. 20	0.850	93.99	
No. 40	0.425	92.36	
No. 100	0.150	90.83	
No. 200	0.075	90.41	

Cu	N/A
Cc	N/A

Grain Size Analysis



Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10
Date

SOIL CLASSIFICATION (ASTM D-2487)

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 29 - Upper Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay with Rock
Project Location:	Lone Mountain Facility			Sampling Date:	2/25/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	20.0%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	85.9%

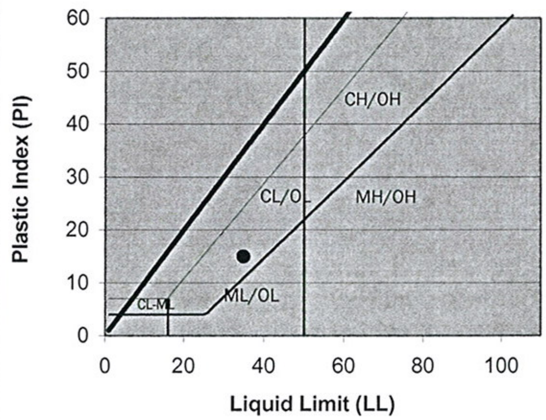
Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.71	g/cc
Specific Gravity	N/A	

Atterberg Limits (ASTM D-4318)

Flow Index	-5	Spec
Liquid Limit	35	
Plastic Limit	20	
Plasticity Index	15	

Soil Classification Chart

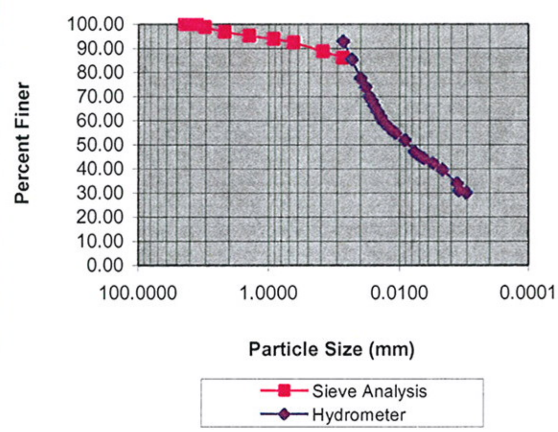


Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	98.78	
No. 4	4.750	96.82	
No. 10	2.000	95.23	
No. 20	0.850	93.88	
No. 40	0.425	92.45	
No. 100	0.150	88.73	
No. 200	0.075	86.03	
Hydrometer	0.010	53.56	
Hydrometer	0.001	30.38	

Cu	N/A
Cc	N/A

Grain Size Analysis



Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10

Date

SOIL CLASSIFICATION (ASTM D-2487)

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2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 29 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay with Shale
Project Location:	Lone Mountain Facility			Sampling Date:	2/25/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	20.5%

% Passing No. 200 (ASTM D-1140)

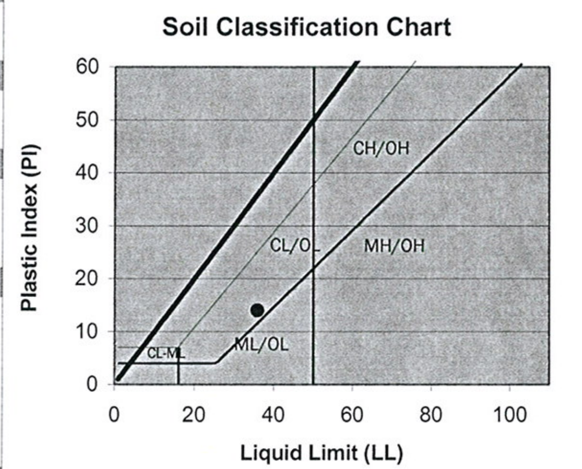
% Passing No. 200	84.9%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.75	g/cc
Specific Gravity	N/A	

Atterberg Limits (ASTM D-4318)

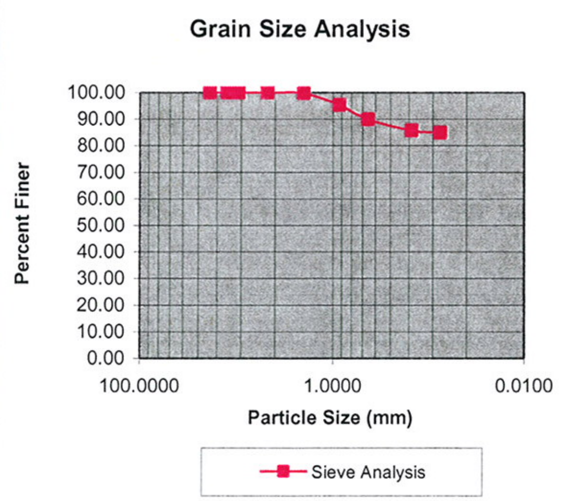
Flow Index	-4	Spec
Liquid Limit	36	
Plastic Limit	22	
Plasticity Index	14	



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	100.00	
No. 10	2.000	99.72	
No. 20	0.850	95.37	
No. 40	0.425	89.90	
No. 100	0.150	85.71	
No. 200	0.075	84.85	

Cu	N/A
Cc	N/A



Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10
Date

SOIL CLASSIFICATION (ASTM D-2487)

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 30 - Upper Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/27/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	24.4%

% Passing No. 200 (ASTM D-1140)

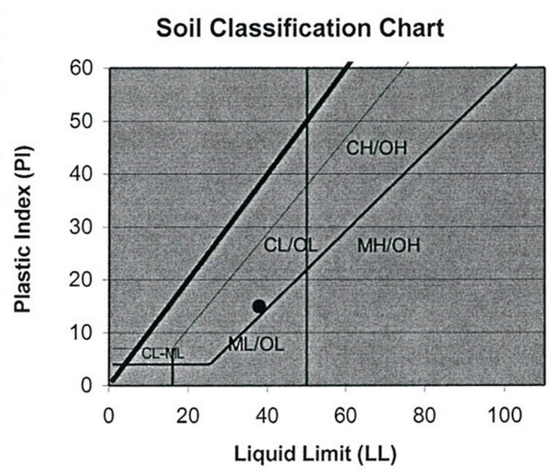
% Passing No. 200	87.7%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.60	g/cc
Specific Gravity	N/A	

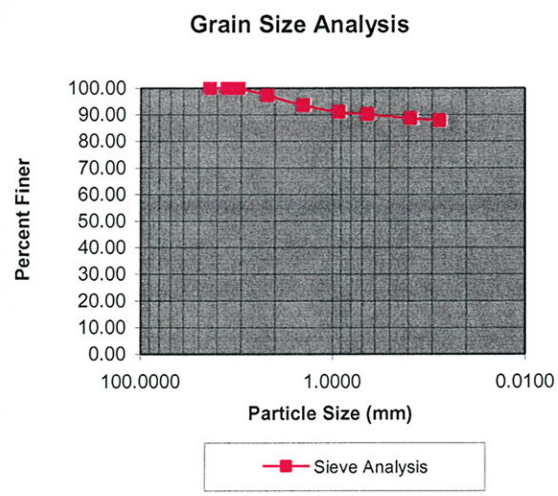
Atterberg Limits (ASTM D-4318)

Flow Index	-7	Spec
Liquid Limit	38	
Plastic Limit	23	
Plasticity Index	15	



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	97.26	
No. 10	2.000	93.46	
No. 20	0.850	91.03	
No. 40	0.425	90.17	
No. 100	0.150	88.61	
No. 200	0.075	87.69	



Cu	N/A
Cc	N/A

Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10
Date

SOIL CLASSIFICATION (ASTM D-2487)

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 30 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/27/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	20.8%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	95.2%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.68	g/cc
Specific Gravity	N/A	

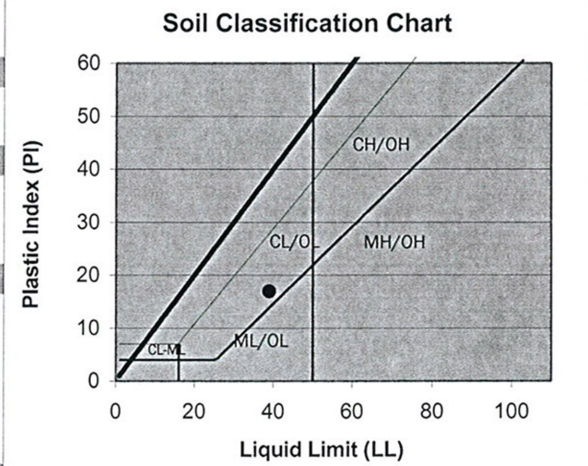
Atterberg Limits (ASTM D-4318)

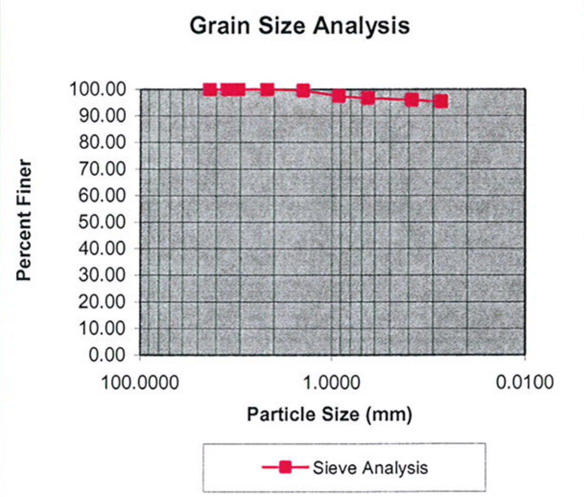
Flow Index	-7	Spec
Liquid Limit	39	
Plastic Limit	22	
Plasticity Index	17	

Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	100.00	
No. 10	2.000	99.57	
No. 20	0.850	97.50	
No. 40	0.425	96.74	
No. 100	0.150	96.02	
No. 200	0.075	95.41	

Cu	N/A
Cc	N/A





Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10
Date

SOIL CLASSIFICATION (ASTM D-2487)

ENVIROTECH ENGINEERING & CONSULTING, INC.
2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 31 - Upper Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/26/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	18.8%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	88.8%

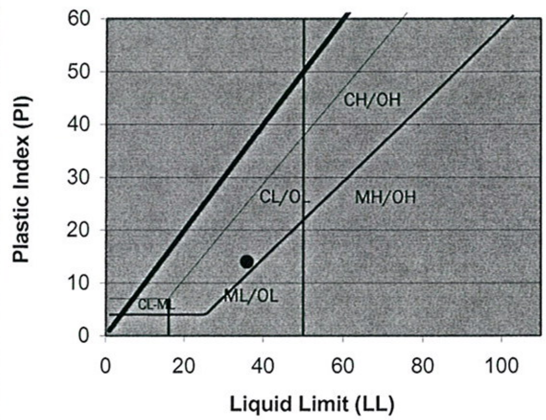
Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.60	g/cc
Specific Gravity	N/A	

Atterberg Limits (ASTM D-4318)

Flow Index	-6	Spec
Liquid Limit	36	
Plastic Limit	22	
Plasticity Index	14	

Soil Classification Chart

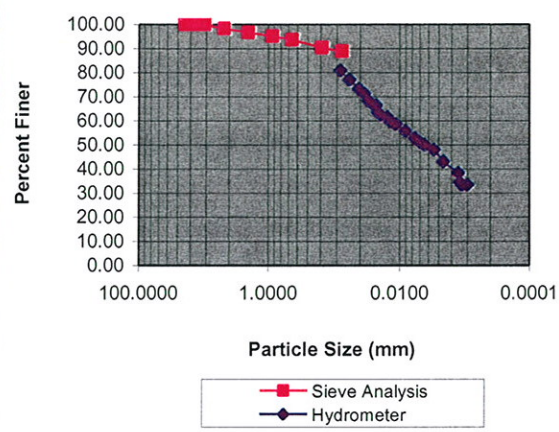


Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	98.32	
No. 10	2.000	96.70	
No. 20	0.850	95.15	
No. 40	0.425	93.58	
No. 100	0.150	90.34	
No. 200	0.075	88.94	
Hydrometer	0.010	57.40	
Hydrometer	0.001	33.43	

Cu	N/A
Cc	N/A

Grain Size Analysis



Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

[signature]
Envirotech - Project Manager

3/12/10
Date

SOIL CLASSIFICATION (ASTM D-2487)

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 31 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/26/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	19.7%

% Passing No. 200 (ASTM D-1140)

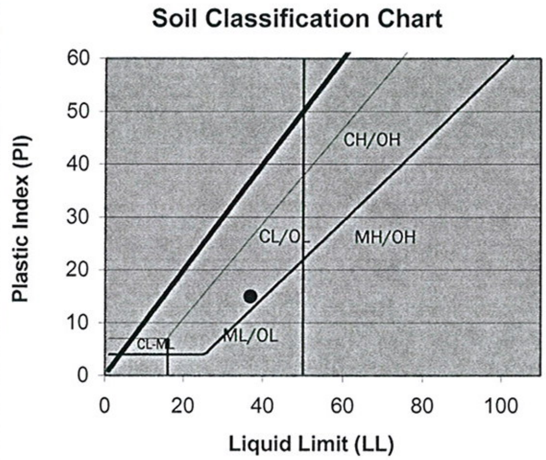
% Passing No. 200	99.6%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.66	g/cc
Specific Gravity	N/A	

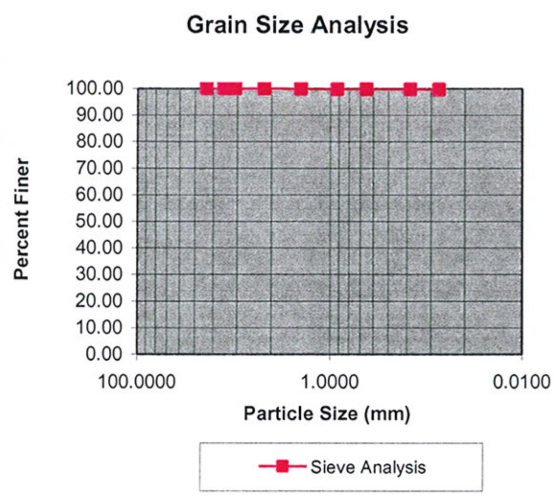
Atterberg Limits (ASTM D-4318)

Flow Index	-5	Spec
Liquid Limit	37	
Plastic Limit	22	
Plasticity Index	15	



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	100.00	
No. 10	2.000	99.91	
No. 20	0.850	99.81	
No. 40	0.425	99.76	
No. 100	0.150	99.72	
No. 200	0.075	99.62	



Cu	N/A
Cc	N/A

Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

[signature]
Envirotech - Project Manager

3/12/10
Date

SOIL CLASSIFICATION (ASTM D-2487)

ENVIROTECH ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 32 - Upper Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/27/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	19.5%

% Passing No. 200 (ASTM D-1140)

% Passing No. 200	95.9%

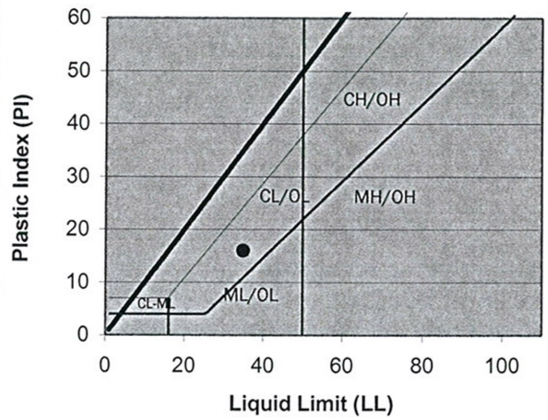
Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.69	g/cc
Specific Gravity	N/A	

Atterberg Limits (ASTM D-4318)

Flow Index	-6	Spec
Liquid Limit	35	
Plastic Limit	19	
Plasticity Index	16	

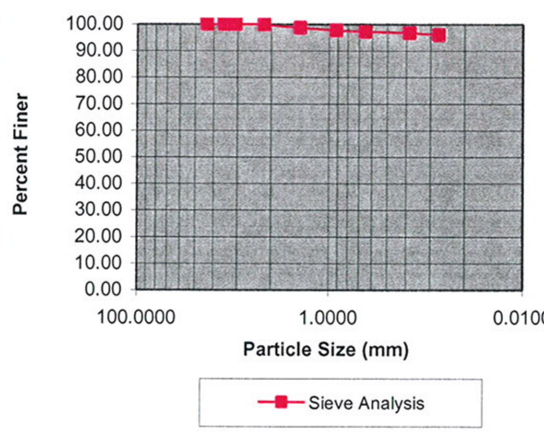
Soil Classification Chart



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	99.89	
No. 10	2.000	98.63	
No. 20	0.850	97.66	
No. 40	0.425	97.23	
No. 100	0.150	96.72	
No. 200	0.075	96.04	

Grain Size Analysis



Cu	N/A
Cc	N/A

Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10

Date

SOIL CLASSIFICATION (ASTM D-2487)

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Client:	Clean Harbors, Inc.
Address:	Route 2 Box 170 Waynoka, OK. 73860

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Boring 32 - Lower Stratum
Project:	010039/010046			Sample Description:	Brownish Red Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/27/2010
Tested By:	K. Richards	Date:	3/5/2010	Sampled By:	C. Butcher
Reviewed By:	J. Voss	Date:	3/12/2010	Date Received:	3/1/2010

Natural Moisture Content (ASTM D-2216)

Natural Moisture	18.3%

% Passing No. 200 (ASTM D-1140)

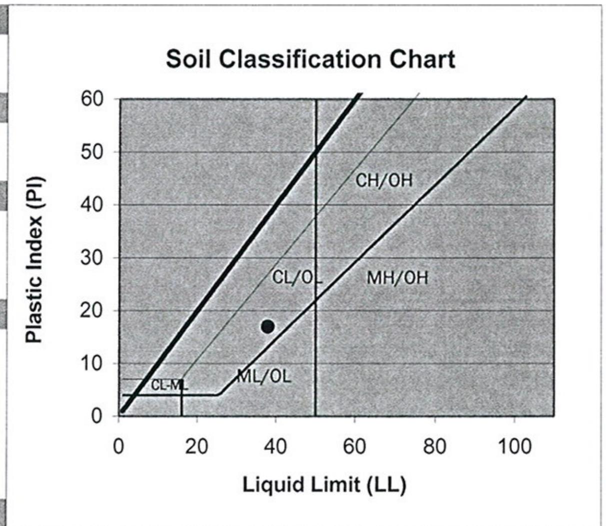
% Passing No. 200	88.0%

Bulk Density, Specific Gravity (ASTM D-854, D-2937)

Dry Bulk Density	1.71	g/cc
Specific Gravity	N/A	

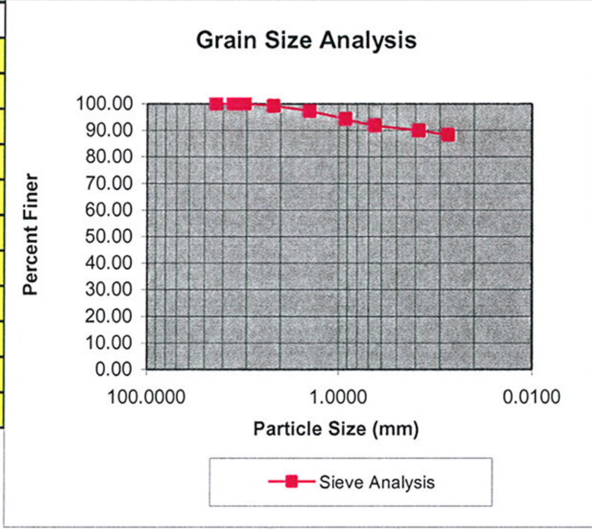
Atterberg Limits (ASTM D-4318)

Flow Index	-7	Spec
Liquid Limit	38	
Plastic Limit	21	
Plasticity Index	17	



Particle Size Anaylsis (ASTM D-422)

Sieve No	Sieve Opening	% Passing	Spec
3/4	19.000	100.00	
1/2	12.500	100.00	
3/8	9.500	100.00	
No. 4	4.750	99.20	
No. 10	2.000	97.19	
No. 20	0.850	94.27	
No. 40	0.425	91.85	
No. 100	0.150	89.92	
No. 200	0.075	88.29	



Cu	N/A
Cc	N/A

Unified Soil Classification (ASTM D-2487)

CL - Lean Clay

Deviations from ASTM or Notes:
200 wash samples were saturated for 24 hours with Sodium Hexametaphosphate

Envirotech - Project Manager

3/12/10

Date

Standard Proctor (ASTM D 698)

Client: Clean Harbors, Inc.
Address: Route 2 Box 170 Waynoka, OK. 73860

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Borings 23,27,30 Composite
Project:	010039/010046			Sample Des:	Reddish Brown Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/25/10 through 2/27/10
Tested By:	J. Stovall	Date:	3/4/2010	Sampled By:	K. Richards
Reviewed By:	J. Voss	Date:	3/5/2010	Date Received:	3/1/2010

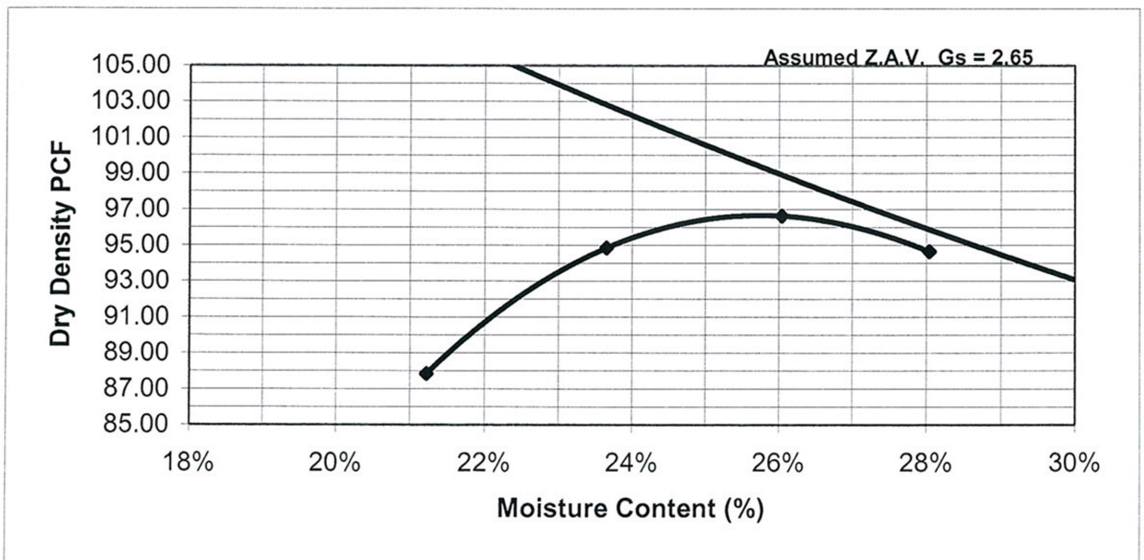
DENSITY DATA (lbs)

Mold + Wet Soil	12.59	12.74	12.72	12.23	
Mold Wt.	8.68	8.68	8.68	8.68	
Wet Soil	3.91	4.06	4.04	3.55	
lbs/cu. ft. (wet)	117.30	121.80	121.20	106.50	
lbs/cu. ft. (dry)	94.86	96.64	94.66	87.85	

MOISTURE DATA (grams)

Tin No.	KLM	BBB	IO	IS	
Wet Soil + Tin	307.00	228.85	274.97	363.03	
Dry Soil + Tin	279.10	202.60	235.08	328.45	
Tin Wt.	161.15	101.78	92.81	165.52	
Dry Soil	117.95	100.82	142.27	162.93	
% Moisture	23.7%	26.0%	28.0%	21.2%	

MAXIMUM DRY DENSITY (PCF)	OPTIMUM MOISTURE CONTENT (%)
96.8	**25.7%**



Project Manager

3/12/10

Date

 Revision 3- 08/2003

HYDRAULIC CONDUCTIVITY TEST
ASTM 5084, METHOD F
Constant volume, Falling Head Hydraulic System

ENVIROTECH ENGINEERING & CONSULTING, INC.

Project Name:	Clean Harbors	**Cell No.:**	7
Project Number:	10039/10046		
Date:	3/8/2010		
Sample ID	Composite 23,27,30 Perm 1		
Soil Description	Reddish Brown Clay		

L_i =	7.90	cm
L_f =	7.85	cm
Dia =	10.2	cm
Temp =	17.8	C
R_t =	1.058091	

Hydraulic System Constants	
Mercury U-Tube Manometer	
Area annulus, a_a (cm^2)	0.76712
Area permometer tube, a_p (cm^2)	0.031416
Delta Hg at equilibrium (cm)	1.70

Mercury Head Setting			
Estimated k_t (cm/sec)	Max Gradient i_o=h/L	Permometer Setting (cm)	Min. Cell Pressure (psi)
10^{-4} - 10^{-5}	5	4.70	60
10^{-5} - 10^{-6}	10	7.70	60
10^{-6} - 10^{-7}	20	13.70	60
< 10^{-7}	30	19.69	60

B Coefficient	0.95
Effective Stress	5

Specific Gravity of Water, Gw	1

Test No.	Readings by:	Date:	Time mins	Cumulative t secs	Pressure Cell psi	Pressure Back psi	Mercury Head Tail cm Hg	Mercury Head Head cm Hg	Total Head Loss cm H_2O	Hyd Gradient Prel/final	Hydraulic Conductivity K cm/sec	Hydraulic Conductivity K_{20} cm/sec
	KR	3/8/2010	0				21.80	1.70	273.56	34.9		
1	KR	3/8/2010	20	1200	60	65	21.00	1.67	263.12	33.5	2.06E-08	2.18E-08
			20				21.00	1.67	263.12	33.5		
2	KR	3/8/2010	30	1800	60	65	20.40	1.64	255.29	32.5	2.4441E-08	2.59E-08
			30				20.40	1.64	255.29	32.5		
3	KR	3/8/2010	40	2400	60	65	19.90	1.62	248.76	31.7	2.5227E-08	2.67E-08
			40				19.90	1.62	248.76	31.7		
4	KR	3/8/2010	50	3000	60	65	19.40	1.60	242.23	30.9	2.5859E-08	2.74E-08
			50				19.40	1.60	242.23	30.9		
5	KR	3/8/2010	60	3600	60	65	19.00	1.59	237.01	30.2	2.5436E-08	2.69E-08

Average K:	2.4315E-08	2.5727E-08
Specification:		N/A

[signature]
Project Manager

3/12/10
Date

HYDRAULIC CONDUCTIVITY TEST
ASTM 5084, METHOD F
Constant volume, Falling Head Hydraulic System

ENVIROTECH ENGINEERING & CONSULTING, INC.

Project Name:	Clean Harbors	**Cell No.:**	7
Project Number:	10039/10046		
Date:	3/8/2010		
Sample ID	Composite 23,27,30 Perm 1		
Soil Description	Reddish Brown Clay		

Item	**Initial**		**Final**	
Sample Diameter (cm)	10.21		10.21	
Sample Length (cm)	7.90		7.85	
Sample Volume (cm^3)	646.8		642.7	
Tare Number	FF		lol	
Tare Weight (gm)	49.95		49.5	
Wet Soil + Tare (gm)	399.18		281.1	
Dry Soil + Tare (gm)	323.79		231.19	
Water Weight (gm)		75.4		49.91
Dry Soil Weight (gm)		273.84		181.69
Moisture Content (%)		27.5%		27.5%
Wet Weight Sample (gm)	1234		1244.8	
Wet Density Sample (pcf)		118.86		120.66
Dry Density Sample (pcf)		93.20		94.66
Saturation %		92.0%		95.1%

Specific Gravity	2.7		Tested		Assumed	x
Soil Sample:	**No Required Specification**					

HYDRAULIC CONDUCTIVITY TEST
ASTM 5084, METHOD F
Constant volume, Falling Head Hydraulic System

ENVIROTECH ENGINEERING & CONSULTING, INC.

Project Name:	Clean Harbors	**Cell No.:**	8
Project Number:	10039/10046		
Date:	3/8/2010		
Sample ID	Composite 23,27,30 Perm 2		
Soil Description	Reddish Brown Clay		

L_i =	7.85	cm
L_f =	7.80	cm
Dia =	10.2	cm
Temp =	17.8	C
R_t =	1.058091	

Hydraulic System Constants	
Mercury U-Tube Manometer	
Area annulus, a_a (cm^2)	0.76712
Area permometer tube, a_p (cm^2)	0.031416
Delta Hg at equilibrium (cm)	1.70

B Coefficient	0.95
Effective Stress	5

Specific Gravity of Water, Gw	1

Mercury Head Setting

Estimated k_t (cm/sec)	Max Gradient i_o=h/L	Permometer Setting (cm)	Min. Cell Pressure (psi)
10^{-4} - 10^{-5}	5	4.68	60
10^{-5} - 10^{-6}	10	7.66	60
10^{-6} - 10^{-7}	20	13.63	60
< 10^{-7}	30	19.59	60

Test No.	Readings by:	Date:	Time mins	Cumulative t secs	Pressure Cell psi	Pressure Back psi	Mercury Head Tail cm Hg	Mercury Head Head cm Hg	Total Head Loss cm H_2O	Hyd Gradient Prel/final	Hydraulic Conductivity K cm/sec	Hydraulic Conductivity K_{20} cm/sec
	KR	3/8/2010	0				20.40	1.70	254.51	32.6		
1	KR	3/8/2010	20	1200	60	65	19.10	1.65	237.54	30.4	3.64E-08	3.85E-08
			20				19.10	1.65	237.54	30.4		
2	KR	3/8/2010	30	1800	60	65	18.20	1.61	225.79	28.9	4.217E-08	4.46E-08
			30				18.20	1.61	225.79	28.9		
3	KR	3/8/2010	40	2400	60	65	17.40	1.58	215.35	27.6	4.4236E-08	4.68E-08
			40				17.40	1.58	215.35	27.6		
4	KR	3/8/2010	50	3000	60	65	16.70	1.55	206.21	26.4	4.4667E-08	4.73E-08
			50				16.70	1.55	206.21	26.4		
5	KR	3/8/2010	60	3600	60	65	16.10	1.52	198.38	25.4	4.4159E-08	4.67E-08

Project Manager

3/12/10
Date

Average K:	4.2321E-08	4.4779E-08
Specification:		N/A

HYDRAULIC CONDUCTIVITY TEST
ASTM 5084, METHOD F
Constant volume, Falling Head Hydraulic System

ENVIROTECH ENGINEERING & CONSULTING, INC.

Project Name:	Clean Harbors	**Cell No.:**	8
Project Number:	10039/10046		
Date:	3/8/2010		
Sample ID	Composite 23,27,30 Perm 2		
Soil Description	Reddish Brown Clay		

Item	Initial		Final	
Sample Diameter (cm)	10.21		10.21	
Sample Length (cm)	7.85		7.80	
Sample Volume (cm^3)	643.1		638.9	
Tare Number	CC		V	
Tare Weight (gm)	49.83		49.6	
Wet Soil + Tare (gm)	366.63		370.1	
Dry Soil + Tare (gm)	304.19		304.1	
Water Weight (gm)		62.4		66
Dry Soil Weight (gm)		254.36		254.5
Moisture Content (%)		24.5%		25.9%
Wet Weight Sample (gm)	1249		1266.5	
Wet Density Sample (pcf)		121.00		123.50
Dry Density Sample (pcf)		97.15		98.07
Saturation %		90.3%		97.5%

Specific Gravity	2.7		Tested		Assumed	x
Soil Sample:	**No Required Specification**					

Standard Proctor (ASTM D 698)

Client: Clean Harbors, Inc.
Address: Route 2 Box 170 Waynoka, OK. 73860

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street | Enid, OK 73701
(580) 234-8780 | Fax (580) 237-4302

Sample Information

Contact Name:	Faizur Khan			Sample ID:	Borings 22,24,25 Composite
Project:	010039/010046			Sample Des:	Brown Clay
Project Location:	Lone Mountain Facility			Sampling Date:	2/25/10 through 2/27/10
Tested By:	J. Stovall	Date:	3/4/2010	Sampled By:	K. Richards
Reviewed By:	J. Voss	Date:	3/5/2010	Date Received:	3/1/2010

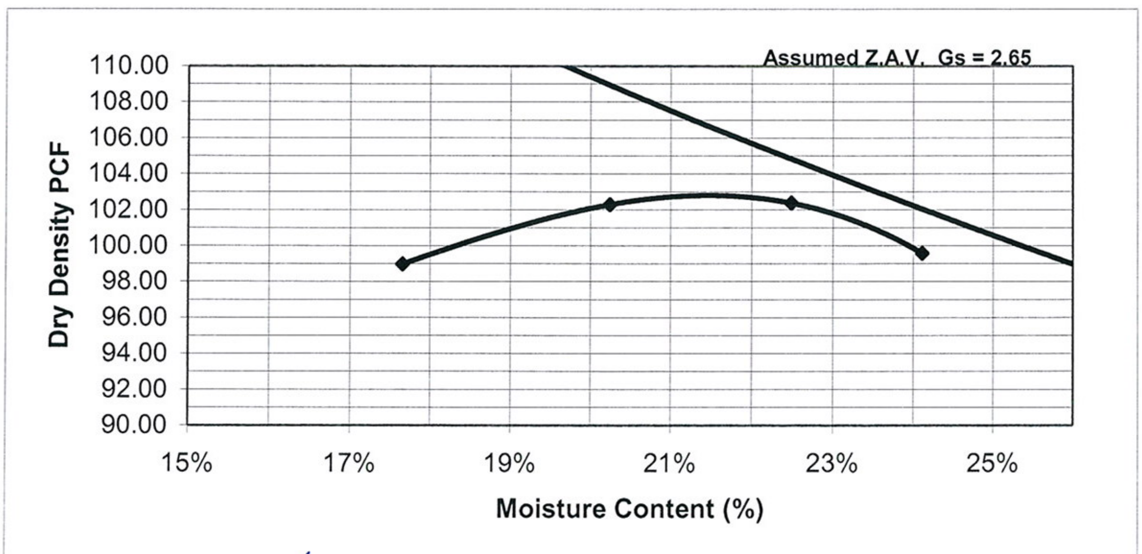
DENSITY DATA (lbs)

Mold + Wet Soil	12.56	12.78	12.86	12.80	
Mold Wt.	8.68	8.68	8.68	8.68	
Wet Soil	3.88	4.10	4.18	4.12	
lbs/cu. ft. (wet)	116.46	123.00	125.40	123.60	
lbs/cu. ft. (dry)	98.99	102.29	102.38	99.59	

MOISTURE DATA (grams)

Tin No.	QAT	V	MM	X	
Wet Soil + Tin	371.16	280.29	362.04	440.47	
Dry Soil + Tin	335.42	255.49	319.97	397.48	
Tin Wt.	132.97	132.97	132.88	219.16	
Dry Soil	202.45	122.52	187.09	178.32	
% Moisture	17.7%	20.2%	22.5%	24.1%	

MAXIMUM DRY DENSITY (PCF)	OPTIMUM MOISTURE CONTENT (%)
103.0	21.5%



Project Manager

Date 3/12/10

HYDRAULIC CONDUCTIVITY TEST
ASTM 5084, METHOD F
Constant volume, Falling Head Hydraulic System

ENVIROTECH ENGINEERING & CONSULTING, INC.

Project Name:	Clean Harbors	**Cell No.:**	1
Project Number:	10039/10046		
Date:	3/8/2010		
Sample ID	Composite 22,24,25 Perm 3		
Soil Description	Brown Clay		

L_i =	7.87	cm
L_f =	7.77	cm
Dia =	10.2	cm
Temp =	17.8	C
R_t =	1.058091	

Hydraulic System Constants	
Mercury U-Tube Manometer	
Area annulus, a_a (cm^2)	0.76712
Area permometer tube, a_p (cm^2)	0.031416
Delta Hg at equilibrium (cm)	1.70

B Coefficient	0.95
Effective Stress	5

Specific Gravity of Water, Gw	1

Mercury Head Setting			
Estimated k_t (cm/sec)	Max Gradient i_o=h/L	Permometer Setting (cm)	Min. Cell Pressure (psi)
10^{-4} - 10^{-5}	5	4.67	60
10^{-5} - 10^{-6}	10	7.64	60
10^{-6} - 10^{-7}	20	13.57	60
< 10^{-7}	30	19.51	60

Test No.	Readings by:	Date:	Time mins	Cumulative t secs	Pressure Cell psi	Pressure Back psi	Mercury Head Tail cm Hg	Mercury Head Head cm Hg	Total Head Loss cm H_2O	Hyd Gradient Prel/final	Hydraulic Conductivity K cm/sec	Hydraulic Conductivity K_{20} cm/sec
1	KR	3/8/2010	0				22.20	1.70	279.01	35.9		
	KR	3/8/2010	20	1200	60	65	21.50	1.67	269.87	34.7	1.74E-08	1.85E-08
2			20				21.50	1.67	269.87	34.7		
	KR	3/8/2010	30	1800	60	65	21.00	1.65	263.34	33.9	2.0208E-08	2.14E-08
3			30				21.00	1.65	263.34	33.9		
	KR	3/8/2010	40	2400	60	65	20.50	1.63	256.82	33.1	2.1764E-08	2.30E-08
4			40				20.50	1.63	256.82	33.1		
	KR	3/8/2010	50	3000	60	65	20.00	1.61	250.29	32.2	2.2846E-08	2.42E-08
5			50				20.00	1.61	250.29	32.2		
	KR	3/8/2010	60	3600	60	65	19.70	1.60	246.37	31.7	2.1818E-08	2.31E-08

Average K:	2.0817E-08	2.2026E-08
Specification:		N/A

Project Manager

3/12/10
Date

HYDRAULIC CONDUCTIVITY TEST
ASTM 5084, METHOD F
Constant volume, Falling Head Hydraulic System

ENVIROTECH ENGINEERING & CONSULTING, INC.

Project Name:	Clean Harbors	**Cell No.:**	1
Project Number:	10039/10046		
Date:	3/8/2010		
Sample ID	Composite 22,24,25 Perm 3		
Soil Description	Brown Clay		

Item	Initial		Final	
Sample Diameter (cm)	10.21		10.21	
Sample Length (cm)	7.87		7.77	
Sample Volume (cm^3)	644.4		636.2	
Tare Number	G		F	
Tare Weight (gm)	49.96		50.1	
Wet Soil + Tare (gm)	392.23		349.5	
Dry Soil + Tare (gm)	330.53		295.21	
Water Weight (gm)		61.7		54.29
Dry Soil Weight (gm)		280.57		245.11
Moisture Content (%)		22.0%		22.1%
Wet Weight Sample (gm)	1272		1290.2	
Wet Density Sample (pcf)		122.98		126.34
Dry Density Sample (pcf)		100.81		103.43
Saturation %		88.5%		95.1%

Specific Gravity	2.7		Tested		Assumed	x
Soil Sample:	**No Required Specification**					

HYDRAULIC CONDUCTIVITY TEST
ASTM 5084, METHOD F
Constant volume, Falling Head Hydraulic System

ENVIROTECH ENGINEERING & CONSULTING, INC.

Project Name:	Clean Harbors	**Cell No.:**	3
Project Number:	10039/10046		
Date:	3/8/2010		
Sample ID	Composite 22,24,25 Perm 4		
Soil Description	Brown Clay		

L_i =	7.75	cm
L_f =	7.67	cm
Dia =	10.2	cm
Temp =	17.8	C
R_t =	1.058091	

Hydraulic System Constants	
Mercury U-Tube Manometer	
Area annulus, a_a (cm^2)	0.76712
Area permometer tube, a_p (cm^2)	0.031416
Delta Hg at equilibrium (cm)	1.70

Mercury Head Setting			
Estimated k_t (cm/sec)	Max Gradient i_o=h/L	Permometer Setting (cm)	Min. Cell Pressure (psi)
10^{-4} - 10^{-5}	5	4.63	60
10^{-5} - 10^{-6}	10	7.56	60
10^{-6} - 10^{-7}	20	13.42	60
< 10^{-7}	30	19.28	60

B Coefficient	0.95
Effective Stress	5

Specific Gravity of Water, Gw	1

Test No.	Readings by:	Date:	Time mins	Cumulative t secs	Pressure Cell psi	Pressure Back psi	Mercury Head Tail cm Hg	Mercury Head Head cm Hg	Total Head Loss cm H_2O	Hyd Gradient Prel/final	Hydraulic Conductivity K cm/sec	Hydraulic Conductivity K_{20} cm/sec
	KR	3/8/2010	0				20.90	1.70	261.31	34.1		
1	KR	3/8/2010	20	1200	60	65	20.20	1.67	252.18	32.9	1.84E-08	1.95E-08
			20				20.20	1.67	252.18	32.9		
2	KR	3/8/2010	30	1800	60	65	19.60	1.65	244.34	31.9	2.3186E-08	2.45E-08
			30				19.60	1.65	244.34	31.9		
3	KR	3/8/2010	40	2400	60	65	19.30	1.63	240.43	31.4	2.1589E-08	2.28E-08
			40				19.30	1.63	240.43	31.4		
4	KR	3/8/2010	50	3000	60	65	18.90	1.62	235.21	30.7	2.1846E-08	2.31E-08
			50				18.90	1.62	235.21	30.7		
5	KR	3/8/2010	60	3600	60	65	18.60	1.61	231.29	30.2	2.1125E-08	2.24E-08

[signature]
Project Manager

3/12/10
Date

Average K:	2.1231E-08	2.2465E-08
Specification:		N/A

HYDRAULIC CONDUCTIVITY TEST
ASTM 5084, METHOD F
Constant volume, Falling Head Hydraulic System

ENVIROTECH ENGINEERING & CONSULTING, INC.

Project Name:	Clean Harbors	**Cell No.:**	3
Project Number:	10039/10046		
Date:	3/8/2010		
Sample ID	Composite 22,24,25 Perm 4		
Soil Description	Brown Clay		

Item	Initial		Final	
Sample Diameter (cm)	10.21		10.21	
Sample Length (cm)	7.75		7.67	
Sample Volume (cm^3)	635.0		627.9	
Tare Number	EZ		EE	
Tare Weight (gm)	50.29		50.2	
Wet Soil + Tare (gm)	411.96		334.9	
Dry Soil + Tare (gm)	341.4		279.49	
Water Weight (gm)		70.6		55.41
Dry Soil Weight (gm)		291.11		229.29
Moisture Content (%)		24.2%		24.2%
Wet Weight Sample (gm)	1246.9		1254.2	
Wet Density Sample (pcf)		122.33		124.45
Dry Density Sample (pcf)		98.46		100.23
Saturation %		92.0%		95.8%

Specific Gravity	2.7		Tested		Assumed	x
Soil Sample:	**No Required Specification**					

One-Dimensional Consolidation Properties of Soil

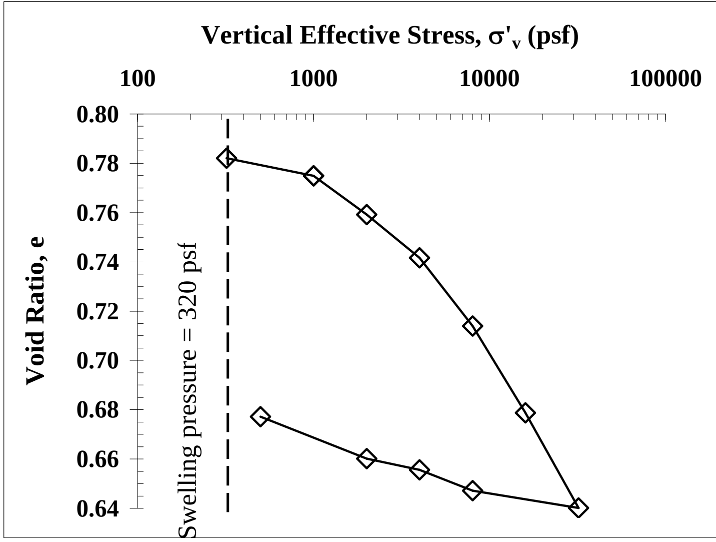
Client: EnviroTech Engineering & Consulting, Inc.
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotech
Specimen: B-25, depth = 8'-8.5'

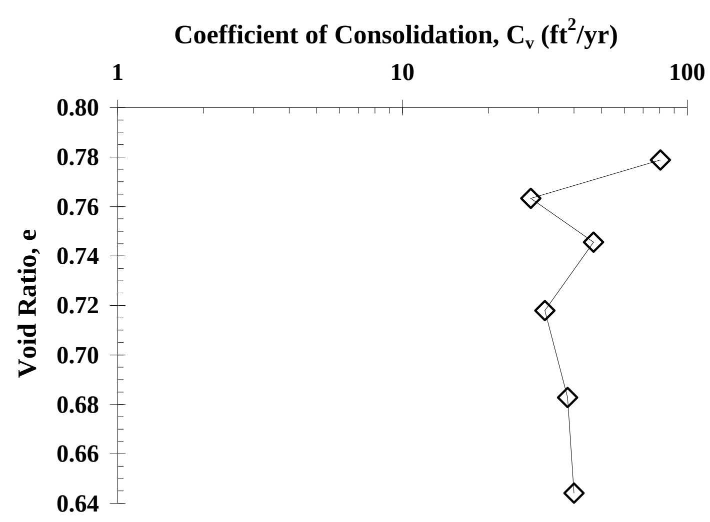
TRI Log No. E2337-21-04
Test Method: ASTM D 2435, Method A
Test Date: 03/10/10

Soil Specimen Properties	
Average Water Content of Trimmings (%)	24.1
Initial Specimen Water Content (%)	24.1
Final Specimen Water Content (%)	27.6
Initial Specimen Height (in)	1.003
Final Specimen Height (in)	0.946
Initial Dry Unit Weight, γ_o lb_f/ft^3	92.6
Final Dry Unit Weight, γ_f lb_f/ft^3	98.1
Initial Void Ratio, e_o	0.787
Final Void Ratio, e_f	0.687
Initial Degree of Saturation (%)	81.1
Final Degree of Saturation (%)	100
Preconsolidation Pressure (psf)	≈ 2950
Maximum Swell Pressure Recorded (psf)	320
Seating Load (psf)	500

The undisturbed specimens was provided by the client. Specimen was trimmed using a trimming turntable. Specimen was inundated with tap water during testing. Coefficient of Consolidation was determined using the Square Root of Time Method. Loading increment duration was 24 hours. G_s assumed to be 2.65.
Preconsolidation pressurewas determined by using the Casagrande construction technique.

Specimen Diameter: 2.497 inches



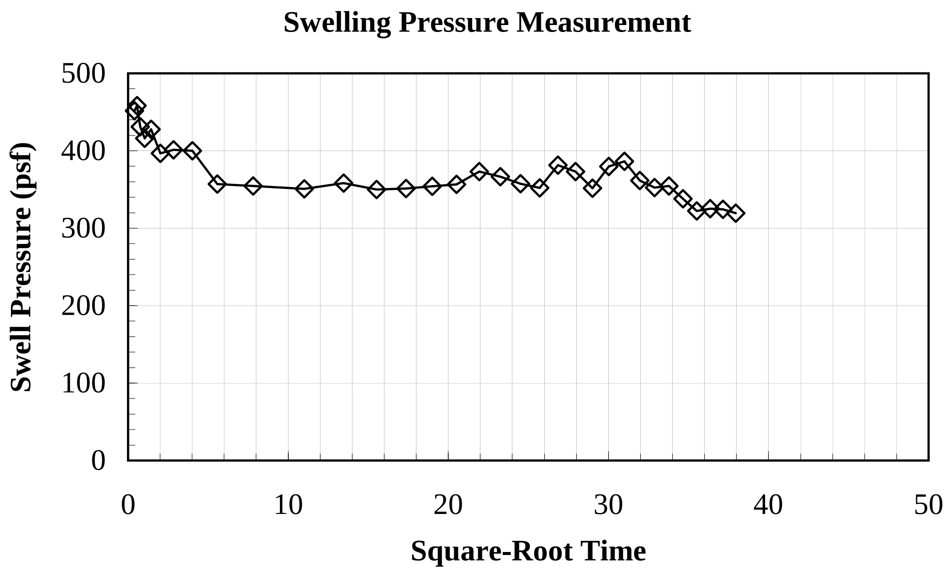


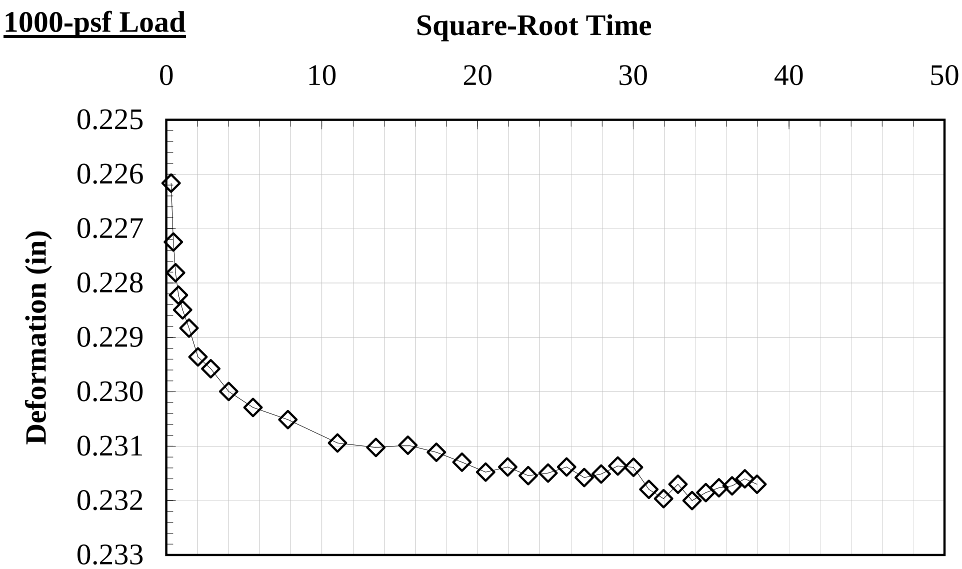
σ'_v (psf)	1000	2000	4000	8000	16000	32000	8000	4000	2000	500
C_v (ft^2/yr)	80.49	28.25	46.84	31.64	38.01	40.03	34.10	19.85	70.05	87.10
e	0.779	0.763	0.746	0.718	0.683	0.644	0.651	0.660	0.664	0.681

Cheng-Wei Chen, 03/30/10
Quality Review/Date
Specimen Prepared by: Caleb McCord

One-Dimensional Consolidation Properties of Soil Appendix

Client: EnviroTech Engineering & Consulting, Inc. TRI Log No. E2337-21-04
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotec Test Method: ASTM D 2435, Method A
Specimen: B-25, depth = 8'-8.5' Test Date: 03/10/10



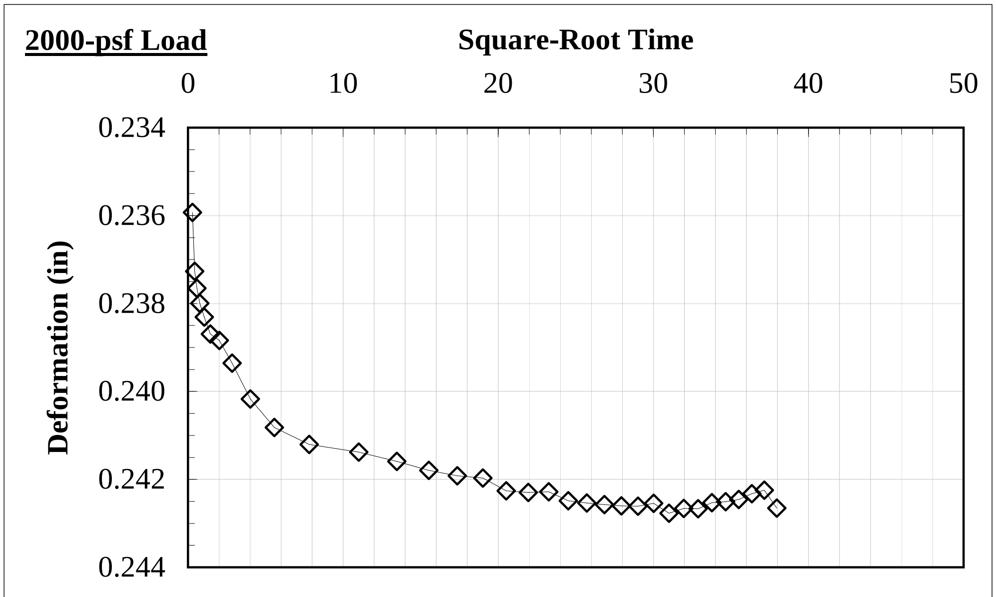


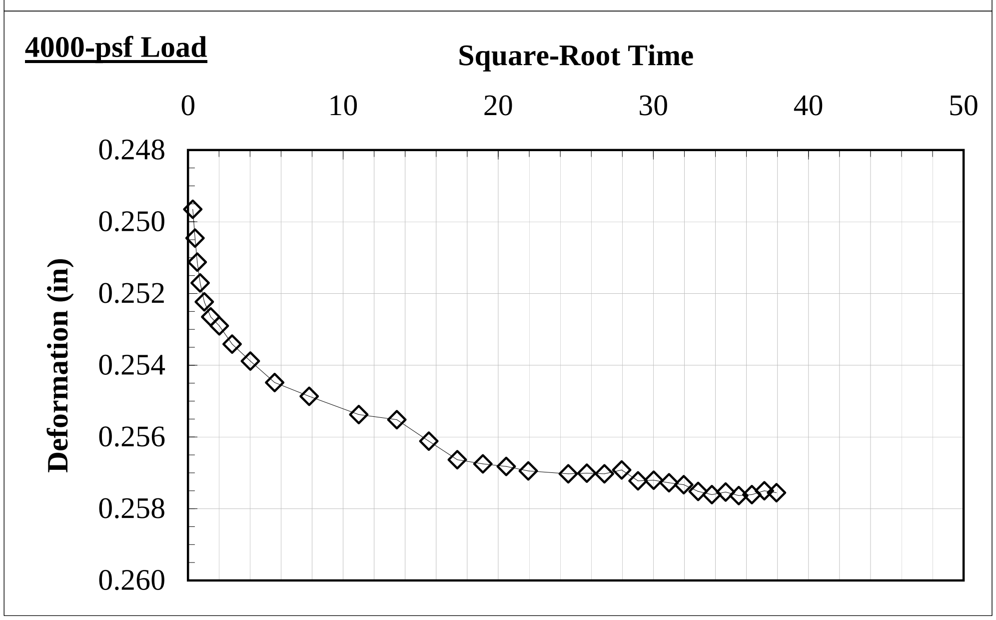
TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

One-Dimensional Consolidation Properties of Soil Appendix

Client:	EnviroTech Engineering & Consulting, Inc.	TRI Log No.	E2337-21-04
Project:	010039/010046 Clean Harbors-Lone Mountain Facility Geotec	Test Method:	ASTM D 2435, Method A
Specimen:	B-25, depth = 8'-8.5'	Test Date:	03/10/10





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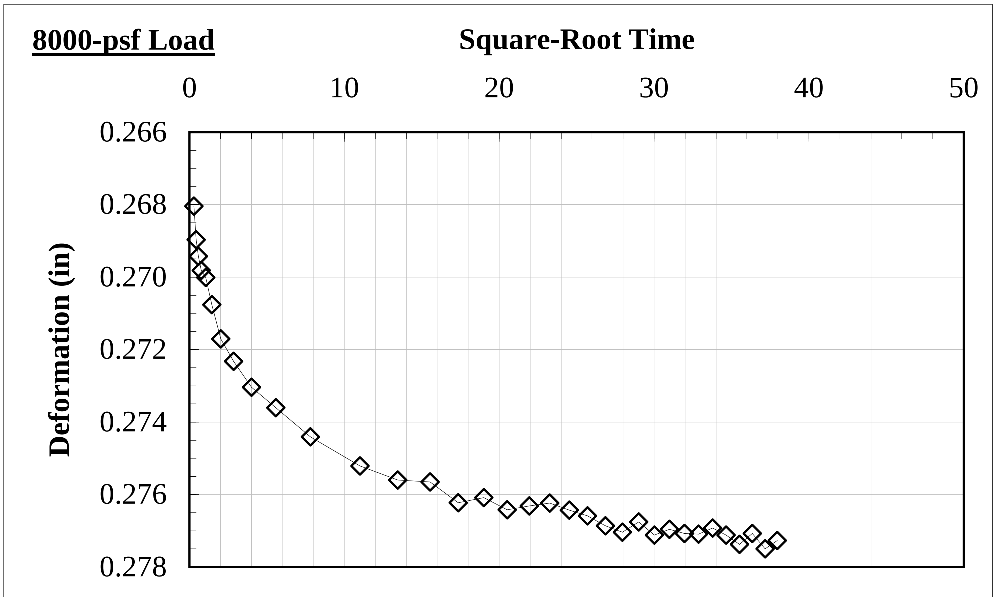
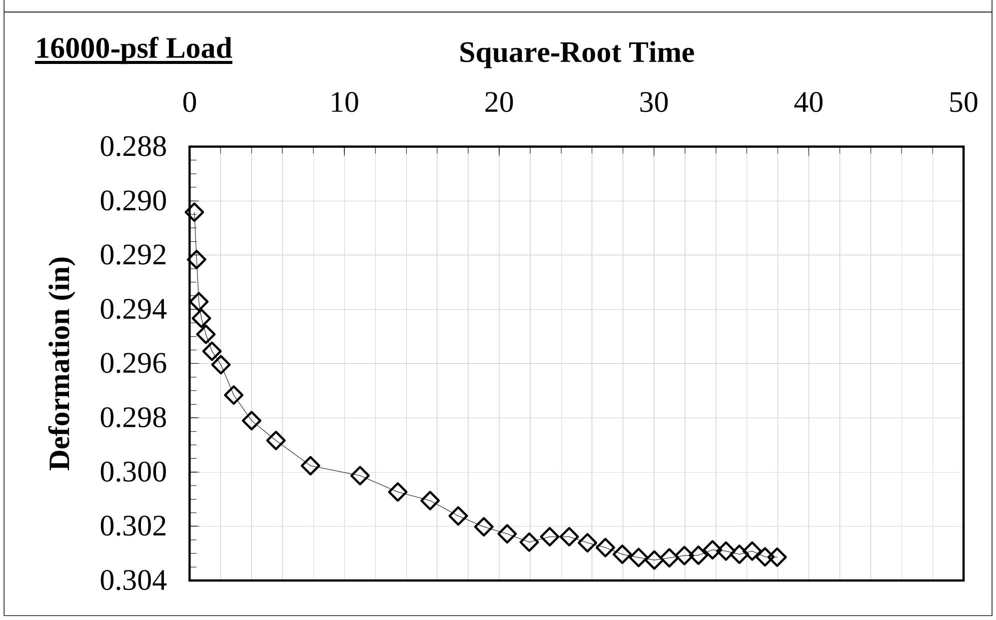
One-Dimensional Consolidation Properties of Soil Appendix

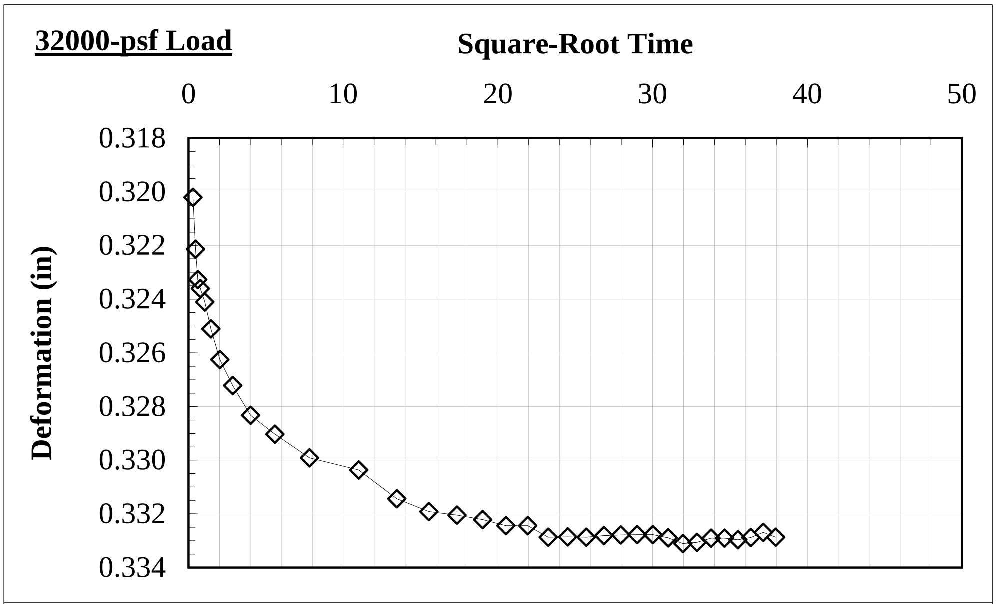
Client: EnviroTech Engineering & Consulting, Inc. TRI Log No. E2337-21-04
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotec Test Method: ASTM D 2435, Method A
Specimen: B-25, depth = 8'-8.5' Test Date: 03/10/10

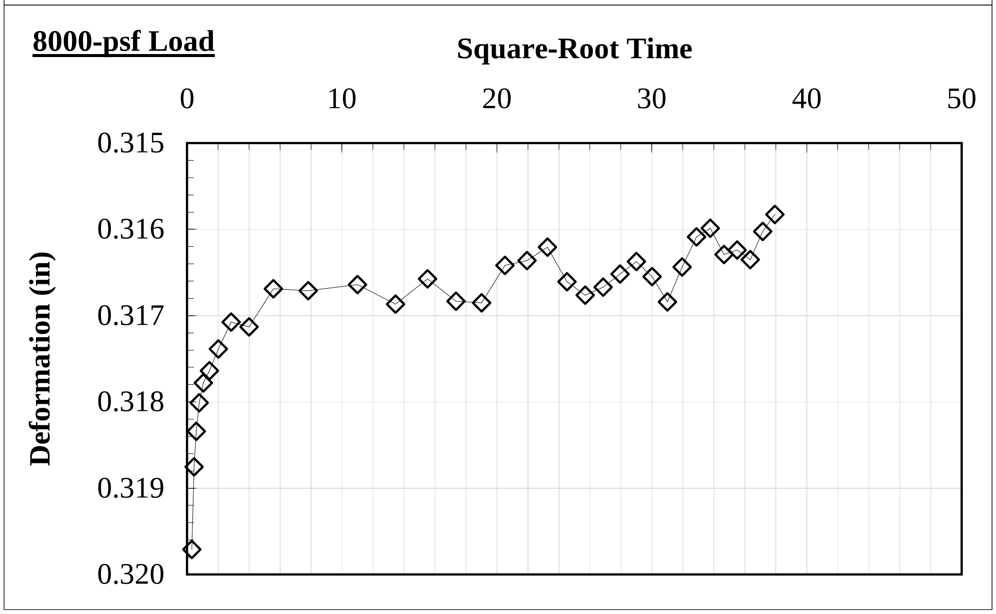




One-Dimensional Consolidation Properties of Soil Appendix

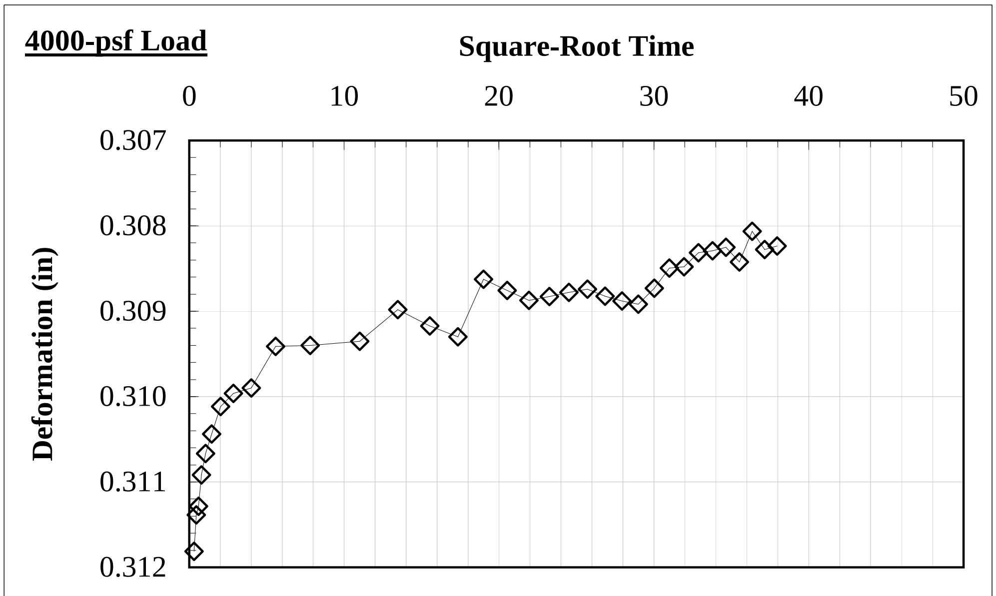
Client: EnviroTech Engineering & Consulting, Inc. TRI Log No. E2337-21-04
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotec Test Method: ASTM D 2435, Method A
Specimen: B-25, depth = 8'-8.5' Test Date: 03/10/10

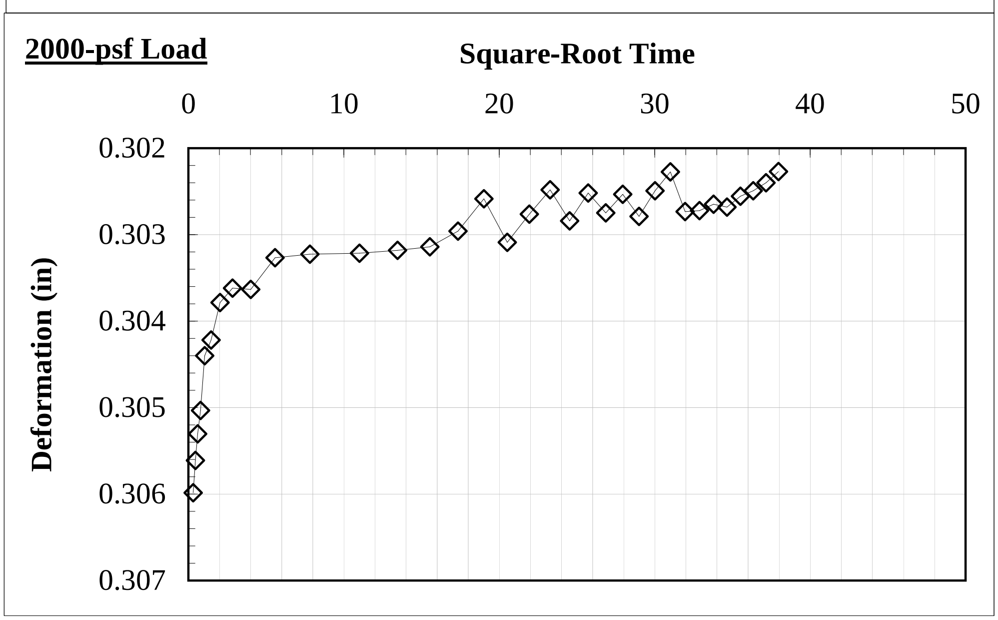




One-Dimensional Consolidation Properties of Soil Appendix

Client: EnviroTech Engineering & Consulting, Inc. TRI Log No. E2337-21-04
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotec Test Method: ASTM D 2435, Method A
Specimen: B-25, depth = 8'-8.5' Test Date: 03/10/10





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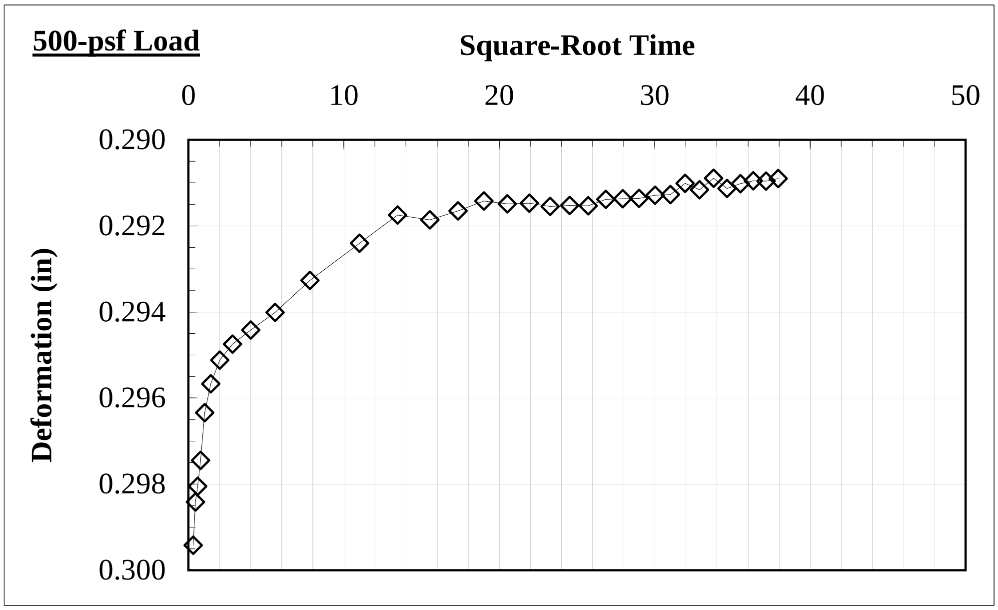
One-Dimensional Consolidation Properties of Soil Appendix

Client: EnviroTech Engineering & Consulting, Inc. TRI Log No. E2337-21-04
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotec Test Method: ASTM D 2435, Method A
Specimen: B-25, depth = 8'-8.5' Test Date: 03/10/10



TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

One-Dimensional Consolidation Properties of Soil

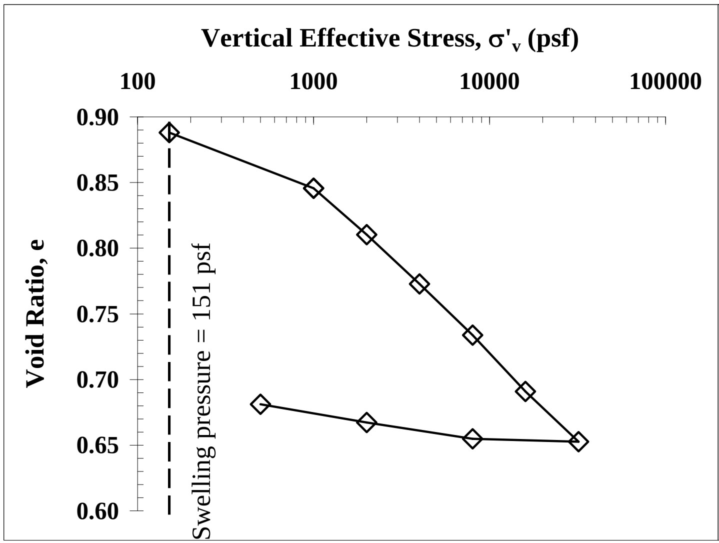
Client: EnviroTech Engineering & Consulting, Inc.
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotech
Specimen: B-29, depth = 4'-5'

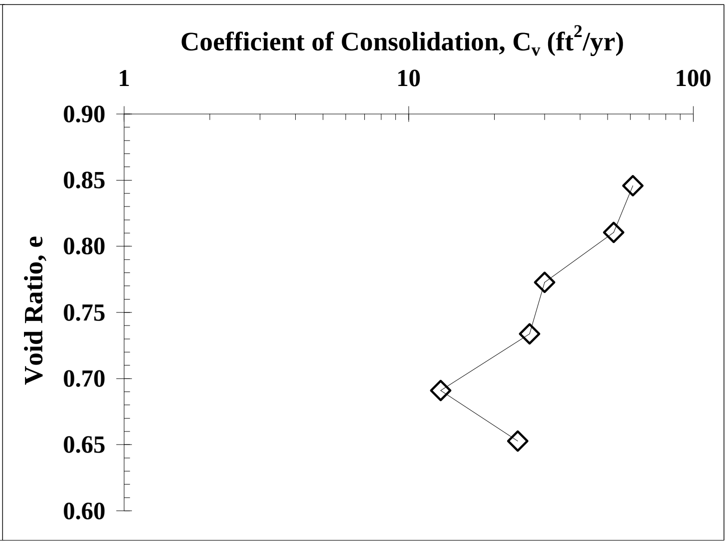
TRI Log No. E2337-21-04
Test Method: ASTM D 2435, Method A
Test Date: 03/10/10

Soil Specimen Properties	
Average Water Content of Trimmings (%)	23.8
Initial Specimen Water Content (%)	23.8
Final Specimen Water Content (%)	27.3
Initial Specimen Height (in)	1.000
Final Specimen Height (in)	0.891
Initial Dry Unit Weight, γ_o lb_f/ft^3	87.6
Final Dry Unit Weight, γ_f lb_f/ft^3	98.2
Initial Void Ratio, e_o	0.889
Final Void Ratio, e_f	0.684
Initial Degree of Saturation (%)	71.0
Final Degree of Saturation (%)	100
Preconsolidation Pressure (psf)	≈ 1400
Maximum Swell Pressure Recorded (psf)	151
Seating Load (psf)	500

The undisturbed specimens was provided by the client. Specimen was trimmed using a trimming turntable. Specimen was inundated with tap water during testing. Coefficient of Consolidation was determined using the Square Root of Time Method. Loading increment duration was 24 hours. G_s assumed to be 2.65.
Preconsolidation pressurewas determined by using the Casagrande construction technique.

Specimen Diameter: 2.497 inches



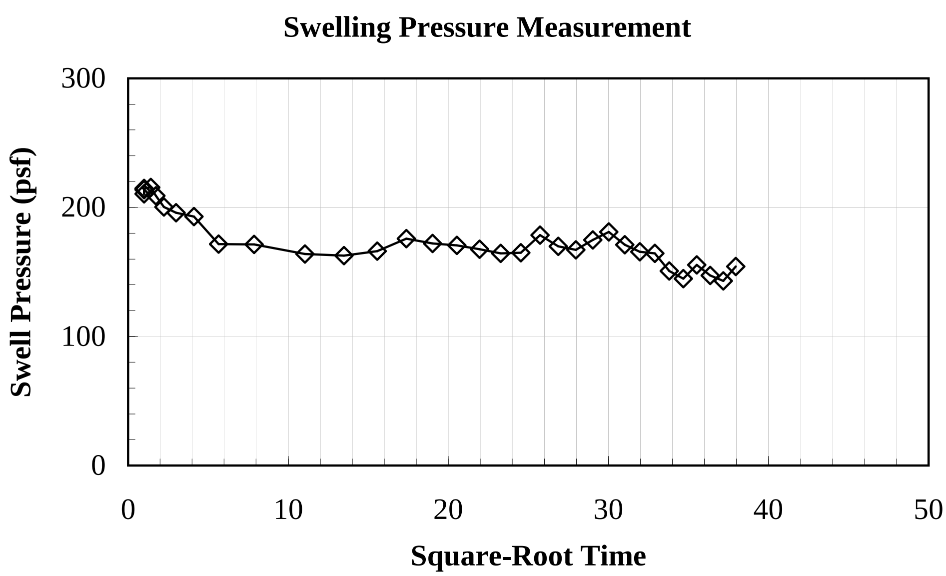


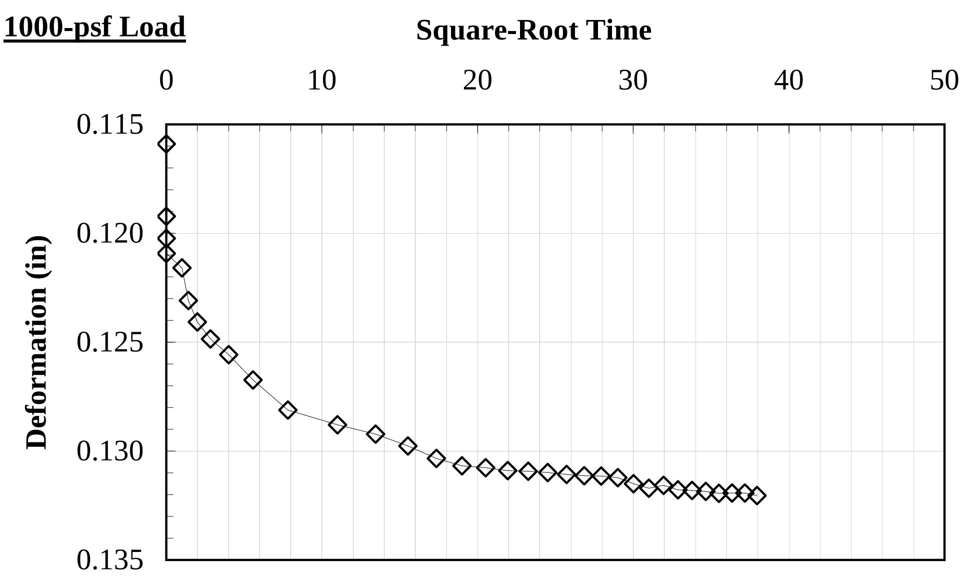
σ'_v (psf)	1000	2000	4000	8000	16000	32000	8000	2000	500
C_v (ft^2/yr)	61.40	52.52	30.06	26.62	12.96	24.15	23.67	10.37	16.36
e	0.846	0.810	0.773	0.734	0.691	0.653	0.655	0.667	0.681

Cheng-Wei Chen, 03/30/10
Quality Review/Date
Specimen Prepared by: Caleb McCord

One-Dimensional Consolidation Properties of Soil Appendix

Client:	EnviroTech Engineering & Consulting, Inc.	TRI Log No.	E2337-21-04
Project:	010039/010046 Clean Harbors-Lone Mountain Facility Geotec	Test Method:	ASTM D 2435, Method A
Specimen:	B-29, depth = 4'-5'	Test Date:	03/10/10





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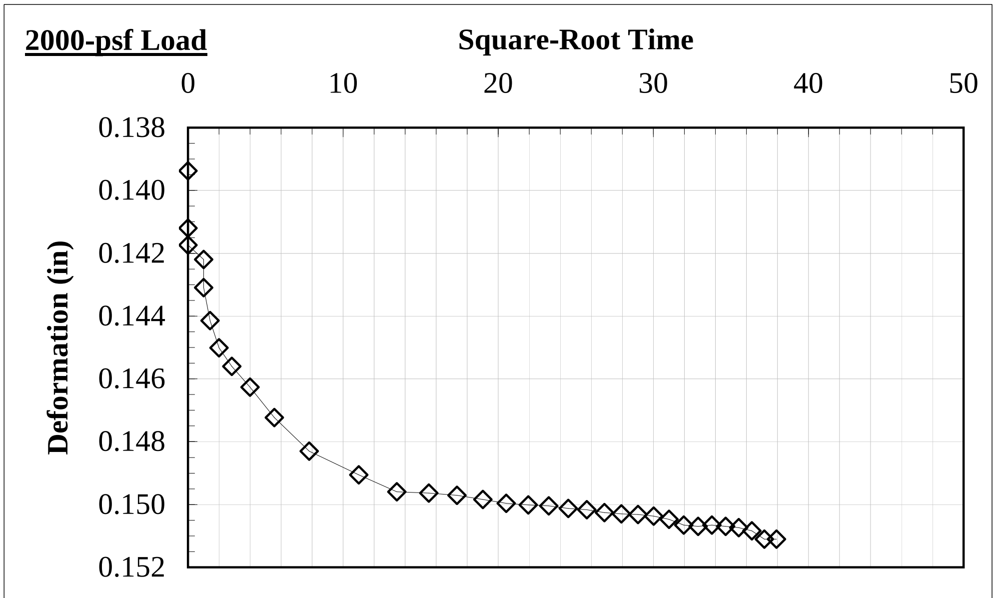
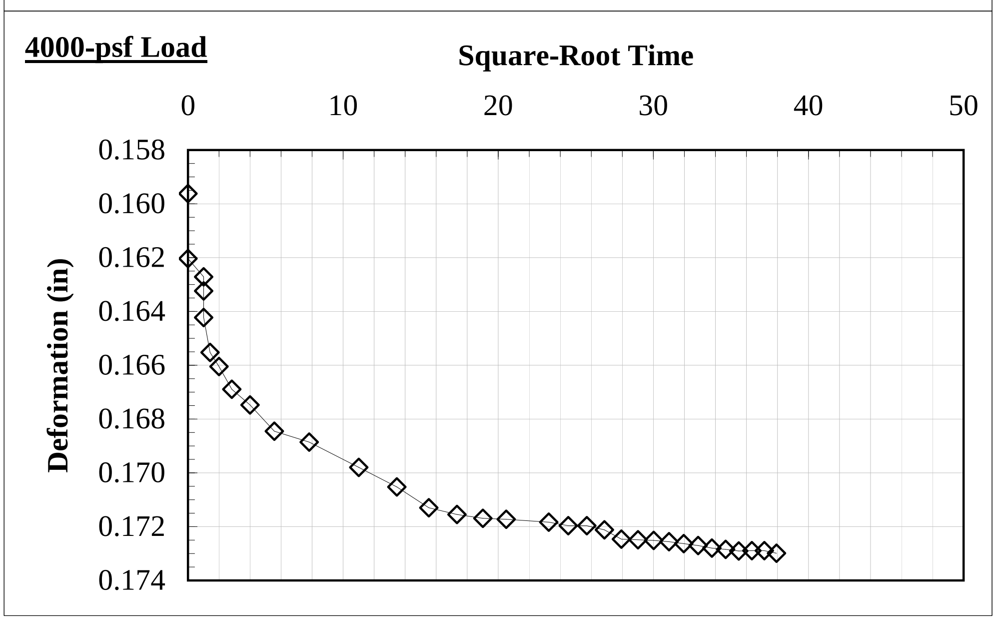
One-Dimensional Consolidation Properties of Soil Appendix

Client: EnviroTech Engineering & Consulting, Inc. TRI Log No. E2337-21-04
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotec Test Method: ASTM D 2435, Method A
Specimen: B-29, depth = 4'-5' Test Date: 03/10/10





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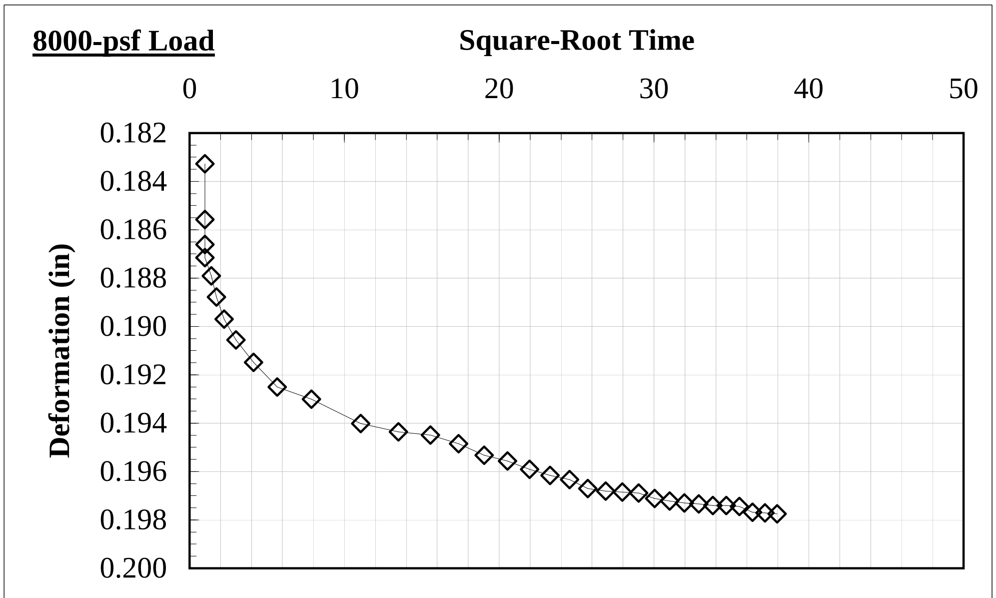
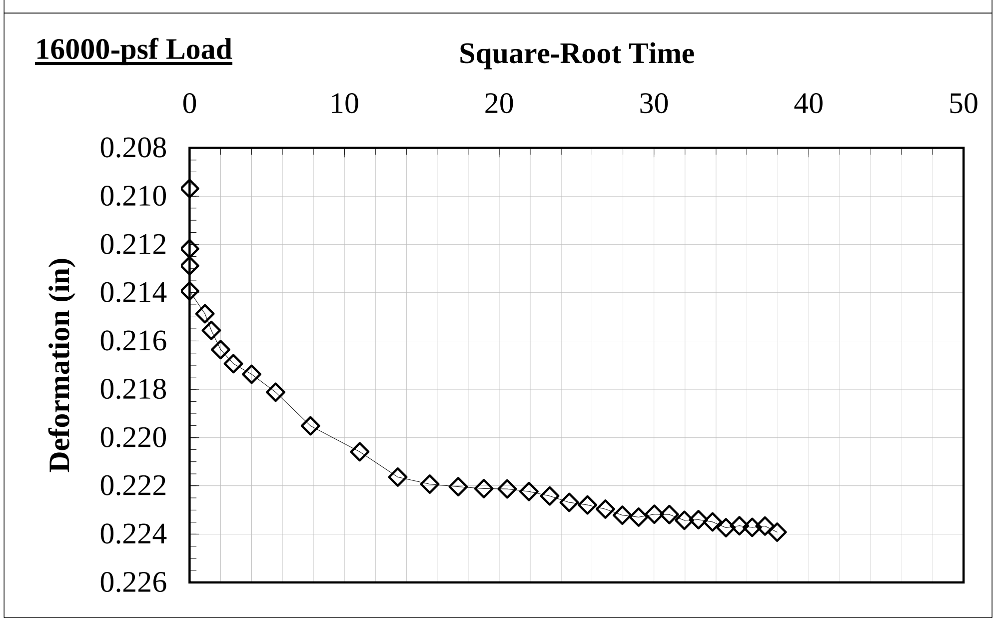
One-Dimensional Consolidation Properties of Soil Appendix

Client: EnviroTech Engineering & Consulting, Inc. TRI Log No. E2337-21-04

Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotec Test Method: ASTM D 2435, Method A

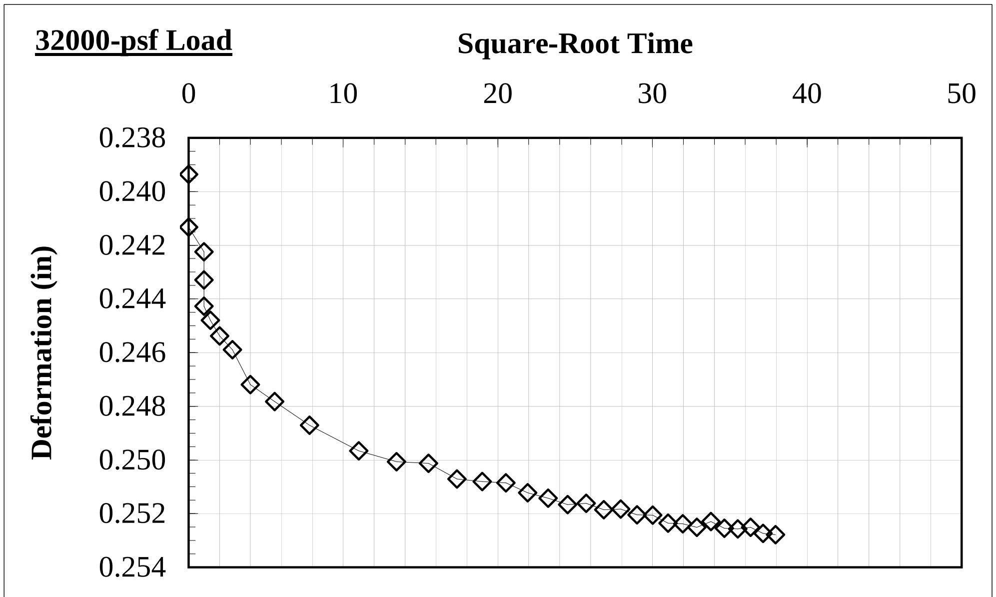
Specimen: B-29, depth = 4'-5' Test Date: 03/10/10

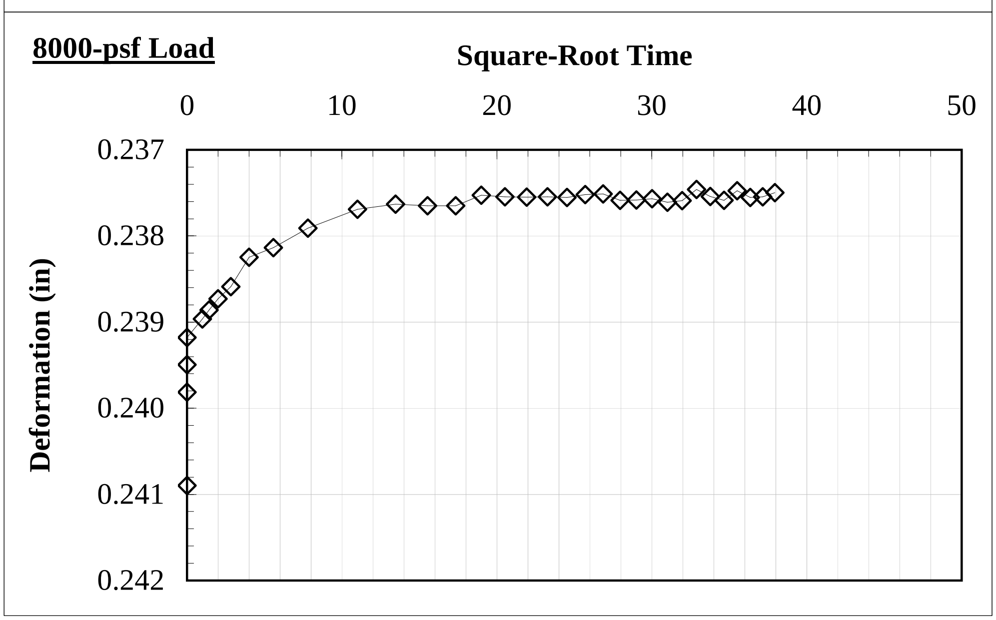




One-Dimensional Consolidation Properties of Soil Appendix

Client: EnviroTech Engineering & Consulting, Inc. TRI Log No. E2337-21-04
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotec Test Method: ASTM D 2435, Method A
Specimen: B-29, depth = 4'-5' Test Date: 03/10/10





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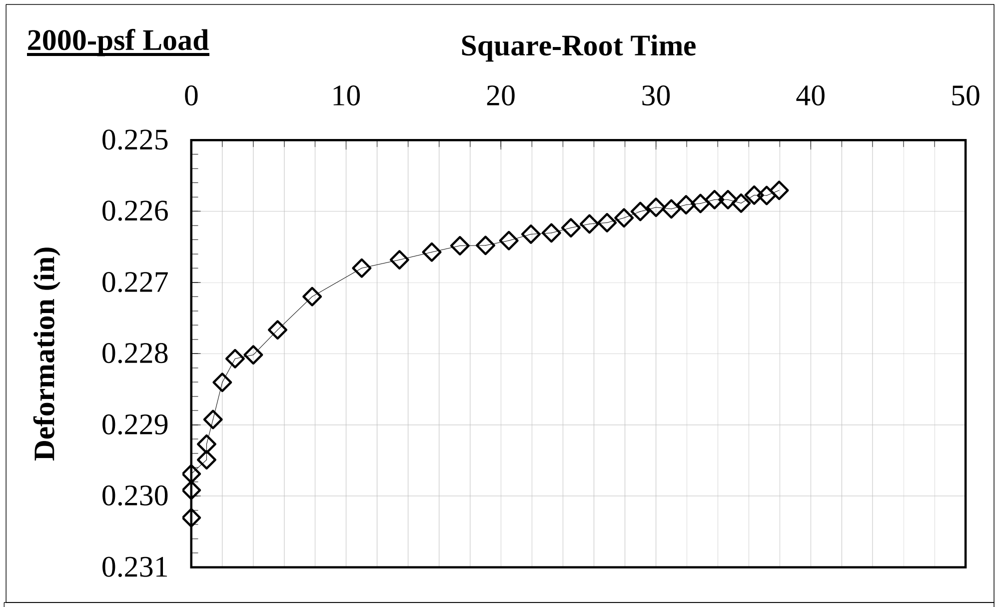
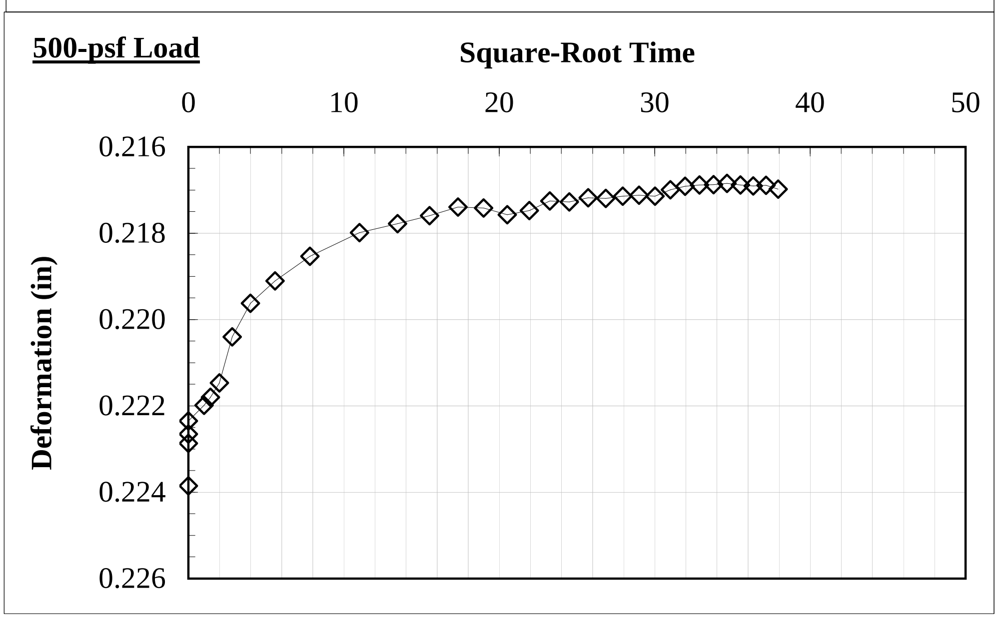
A Texas Research International Company

One-Dimensional Consolidation Properties of Soil Appendix

Client: EnviroTech Engineering & Consulting, Inc.
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotec
Specimen: B-29, depth = 4'-5'

TRI Log No. E2337-21-04
Test Method: ASTM D 2435, Method A
Test Date: 03/10/10



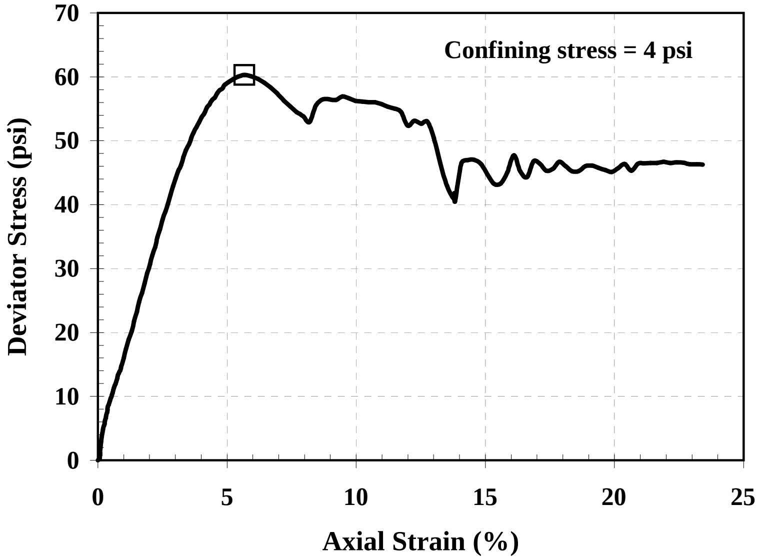


Unconsolidated-Undrained Triaxial Compression Test Report

Client: EnviroTech Engineering &
Project: 010039/010046 Clean Harbors-
Lone Mountain Facility
Sample No.: B-24 (4'-6')

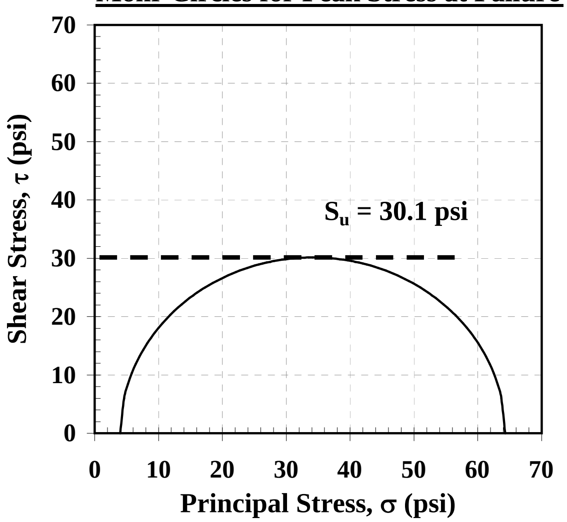
TRI Log No.: E2337-21-04
Test Method: ASTM D 2850
Test Date: 3/9/2010

Type of Specimen: Undisturbed
Strain Rate (%/min): 1 % / min
Type of Test: Q-Test



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psi)		4
Depth/Elev (ft):		4-6
Avg. Diameter (in)	D_o	2.85
Avg. Height (in)	H_o	5.63
Avg. Water Content (%)	w_o	22.9
Bulk Density (pcf)	γ_{total}	127.7
Dry Density (pcf)	γ_{dry}	103.9
Saturation (%)	S_r	100.0
Void Ratio	e_o	0.59
Assumed Specific Gravity	G_s	2.65

Mohr Circles for Peak Stress at Failure



Stresses at Failure	
Maximum Deviator Stress (psi)	60.3
Axial Strain at Failure (%)	5.7
Total Stresses at Failure	
Minor Principal Stress, σ_1 (psi)	64.3
Major Principal Stress, σ_3 (psi)	4.0
Friction Angle, ϕ_u (^{o}):	- -
Undrained Shear Strength, S_u (psi):	30.1

Note: The test specimen was nearly saturated, the Mohr failure envelope was taken as a horizontal straight line. Failure is taken to correspond to the peak deviator stress.

Cheng-Wei Chen, 03/29/10
Quality Review/Date
Tested by: Caleb McCord

Unconsolidated-Undrained Triaxial Compression Test Appendix

Client:	EnviroTech Engineering & Consulting, Inc.	TRI Log No.:	E2337-21-04
Project:	010039/010046 Clean Harbors-Lone Mountain Facility Geotech	Test Method:	ASTM D 2850
		Test Date:	03/09/10

Sample No.B-24 (4-6 ft)
Confining Pressure = 4 psi

The testing herein is based upon accepted industry practice as well as the test method listed. Test results reported herein do not apply to samples other than those tested. TRI neither accepts responsibility for nor makes claim as to the final use and purpose of the material. TRI observes and maintains client confidentiality. TRI limits reproduction of this report, except in full, without prior approval of TRI.

TRI/Environmental, Inc.
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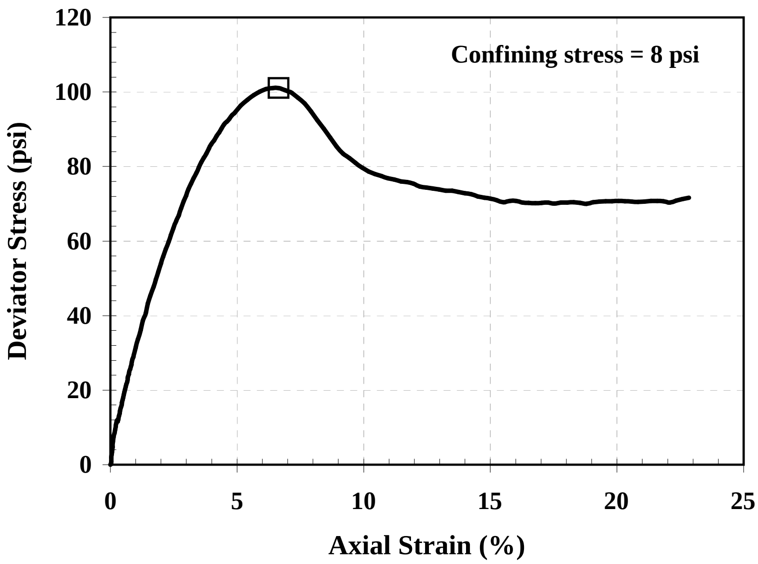
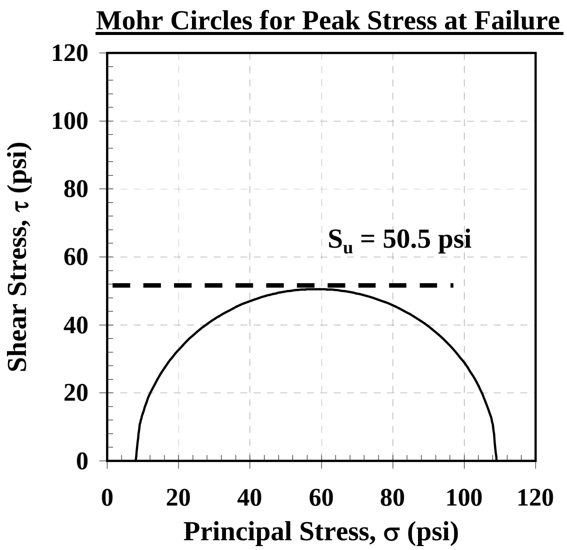
Unconsolidated-Undrained Triaxial Compression Test Report

Client:	EnviroTech Engineering &	TRI Log No.:	E2337-21-04	Type of Specimen:	Undisturbed
Project:	010039/010046 Clean Harbors-Lone Mountain Facility	Test Method:	ASTM D 2850	Strain Rate (%/min):	1 % / min
		Test Date:	3/9/2010	Type of Test:	Q-Test

Sample No.: B-24 (8'-10')



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psi)		8
Depth/Elev (ft):		8-10
Avg. Diameter (in)	D_o	2.84
Avg. Height (in)	H_o	5.64
Avg. Water Content (%)	w_o	19.7
Bulk Density (pcf)	γ_{total}	127.5
Dry Density (pcf)	γ_{dry}	106.5
Saturation (%)	S_r	96.0
Void Ratio	e_o	0.55
Assumed Specific Gravity	G_s	2.65



Stresses at Failure	
Maximum Deviator Stress (psi)	101.1
Axial Strain at Failure (%)	6.6
Total Stresses at Failure	
Minor Principal Stress, σ_1 (psi)	109.1
Major Principal Stress, σ_3 (psi)	8.0
Friction Angle, ϕ_u (^{o}):	- -
Undrained Shear Strength, S_u (psi):	50.5

Note: The test specimen was nearly saturated, the Mohr failure envelope was taken as a horizontal straight line. Failure is taken to correspond to the ppeak deviator stress.

Cheng-Wei Chen, 03/29/10
Quality Review/Date
Tested by: Caleb McCord

Unconsolidated-Undrained Triaxial Compression Test Appendix

Client:	EnviroTech Engineering & Consulting, Inc.	TRI Log No.:	E2337-21-04
Project:	010039/010046 Clean Harbors-Lone Mountain Facility Geotech	Test Method:	ASTM D 2850
		Test Date:	03/09/10

Sample No.B-24 (8-10 ft)
Confining Pressure = 8 psi

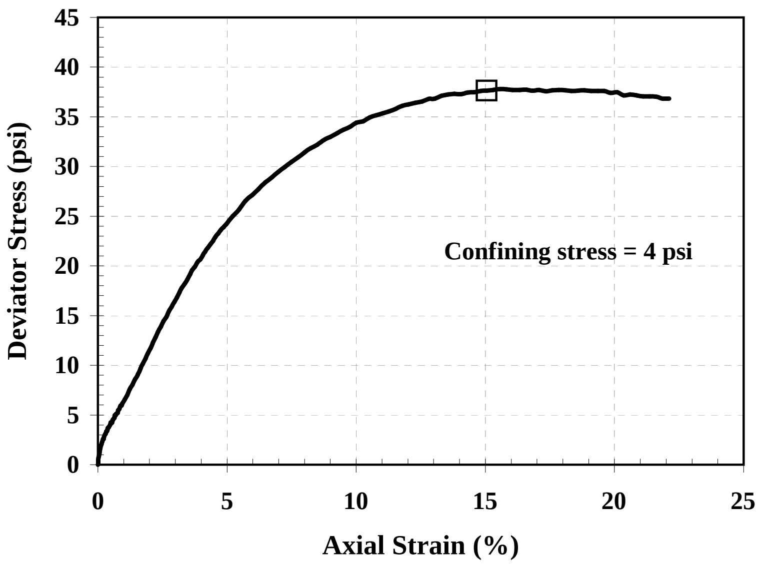
TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

Unconsolidated-Undrained Triaxial Compression Test Report

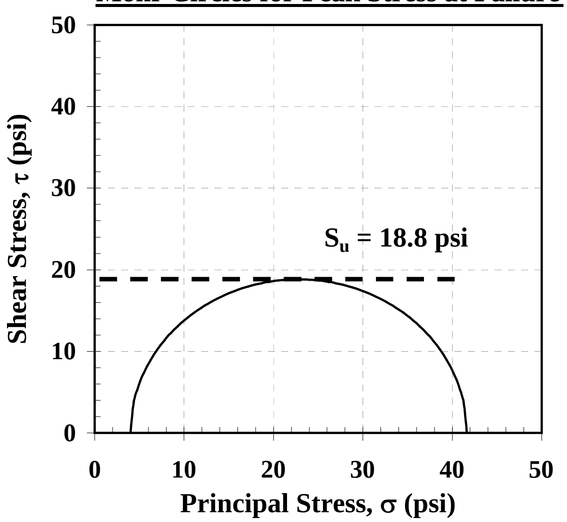
Client:	EnviroTech Engineering &	TRI Log No.:	E2337-21-04	Type of Specimen:	Undisturbed
Project:	010039/010046 Clean Harbors-Lone Mountain Facility	Test Method:	ASTM D 2850	Strain Rate (%/min):	1 % / min
		Test Date:	3/10/2010	Type of Test:	Q-Test

Sample No.: B-26 (4'-5.5')



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psi)		4
Depth/Elev (ft):		4-5.5
Avg. Diameter (in)	D_o	2.84
Avg. Height (in)	H_o	5.61
Avg. Water Content (%)	w_o	23.7
Bulk Density (pcf)	γ_{total}	127.0
Dry Density (pcf)	γ_{dry}	102.7
Saturation (%)	S_r	100.0
Void Ratio	e_o	0.61
Assumed Specific Gravity	G_s	2.65

Mohr Circles for Peak Stress at Failure



Stresses at Failure	
Maximum Deviator Stress (psi)	37.6
Axial Strain at Failure (%)	15.1
Total Stresses at Failure	
Minor Principal Stress, σ_1 (psi)	41.6
Major Principal Stress, σ_3 (psi)	4.0
Friction Angle, ϕ_u (^{o}):	- -
Undrained Shear Strength, S_u (psi):	18.8

Note: The test specimen was nearly saturated, the Mohr failure envelope was taken as a horizontal straight line. Failure is taken to correspond to the deviator stress at 15 % axial strain.

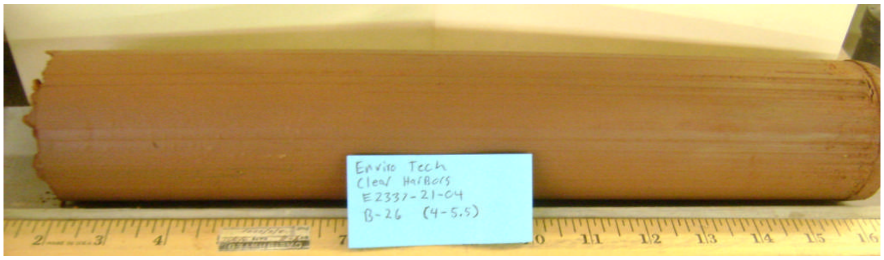
Cheng-Wei Chen, 03/30/10
Quality Review/Date
Tested by: Caleb McCord

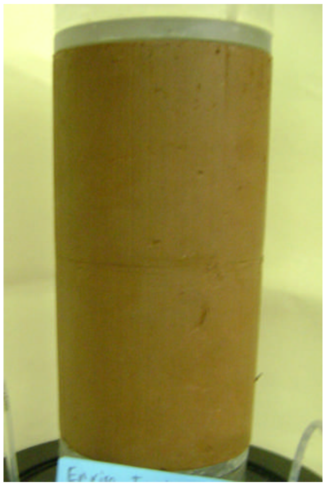
TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

Unconsolidated-Undrained Triaxial Compression Test Appendix

Client:	EnviroTech Engineering & Consulting, Inc.	TRI Log No.:	E2337-21-04
Project:	010039/010046 Clean Harbors-Lone Mountain Facility Geotech	Test Method:	ASTM D 2850
		Test Date:	03/10/10





Sample No.B-26 (4-5.5 ft)
Confining Pressure = 4 psi

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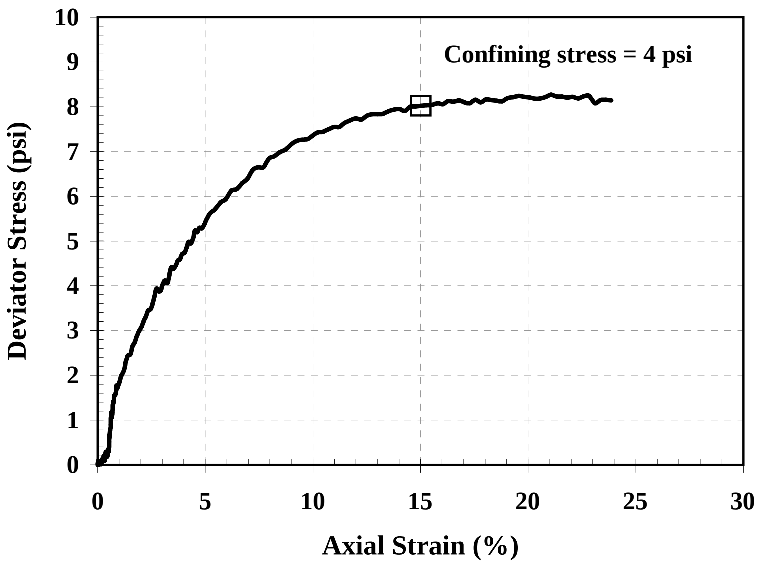
Unconsolidated-Undrained Triaxial Compression Test Report

Client: EnviroTech Engineering &
Project: 010039/010046 Clean Harbors-Lone Mountain Facility
Sample No.: B-28 (4'-6')

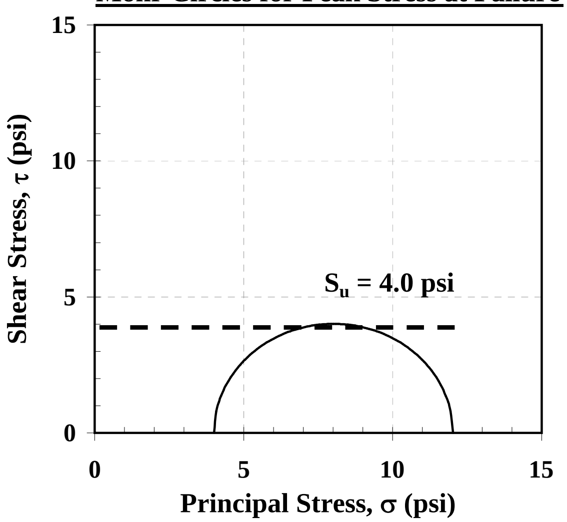
TRI Log No.: E2337-21-04
Test Method: ASTM D 2850
Test Date: 3/10/2010

Type of Specimen: Undisturbed
Strain Rate (%/min): 1 % / min
Type of Test: Q-Test



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psi)		4
Depth/Elev (ft):		- -
Avg. Diameter (in)	D_o	2.82
Avg. Height (in)	H_o	5.61
Avg. Water Content (%)	w_o	27.0
Bulk Density (pcf)	γ_{total}	120.7
Dry Density (pcf)	γ_{dry}	95.0
Saturation (%)	S_r	95.0
Void Ratio	e_o	0.74
Assumed Specific Gravity	G_s	2.65

Mohr Circles for Peak Stress at Failure



Stresses at Failure	
Maximum Deviator Stress (psi)	8.0
Axial Strain at Failure (%)	15.0
Total Stresses at Failure	
Minor Principal Stress, σ_1 (psi)	12.0
Major Principal Stress, σ_3 (psi)	4.0
Friction Angle, ϕ_u (^{o}):	- -
Undrained Shear Strength, S_u (psi):	4.0

Note: The test specimen was nearly saturated, the Mohr failure envelope was taken as a horizontal straight line. Failure is taken to correspond to the deviator stress at 15 % axial strain.

Cheng-Wei Chen, 03/30/10
Quality Review/Date
Tested by: Caleb McCord

TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

Unconsolidated-Undrained Triaxial Compression Test Appendix

Client: EnviroTech Engineering & Consulting, Inc.
Project: 010039/010046 Clean Harbors-Lone Mountain Facility Geotech

TRI Log No.: E2337-21-04
Test Method: ASTM D 2850
Test Date: 03/10/10

Sample No.B-28 (4-6 ft)
Confining Pressure = 4 psi

TRI/ENVIRONMENTAL, INC.

A Texas Research International Company

Unconsolidated-Undrained Triaxial Compression Test Report

Client: EnviroTech Engineering & Consulting, Inc.

Project: 010046-02 Clean Harbors-Lone Mountain Facility

Sample No.: TP-1 (3'-5')

TRI Log No.: E2337-32-04

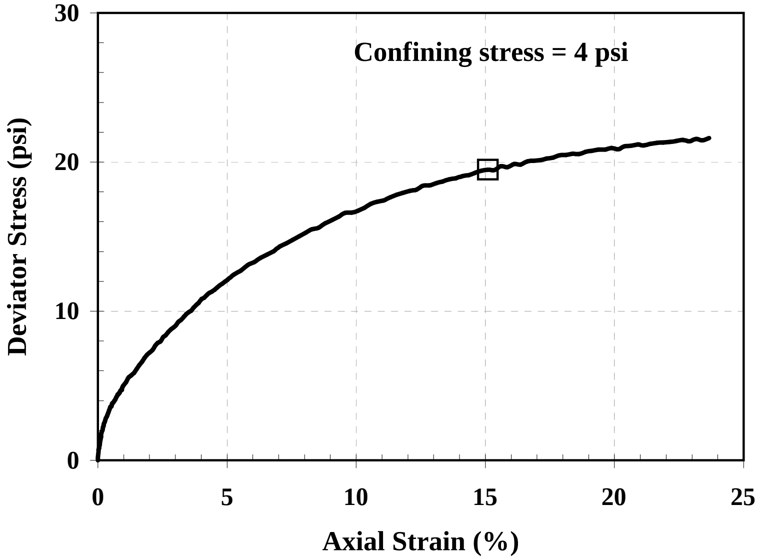
Test Method: ASTM D 2850

Test Date: 4/16/2010

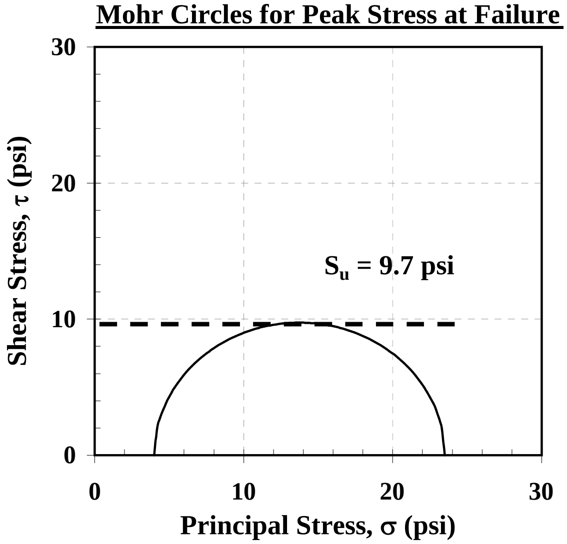
Type of Specimen: Undisturbed

Strain Rate (%/min): 1 % / min

Type of Test: Q-Test



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psi)		4
Depth/Elev (ft):		3-5
Avg. Diameter (in)	D_o	2.82
Avg. Height (in)	H_o	5.63
Avg. Water Content (%)	w_o	20.8
Bulk Density (pcf)	γ_{total}	127.0
Dry Density (pcf)	γ_{dry}	105.1
Saturation (%)	S_r	95.4
Void Ratio	e_o	0.57
Assumed Specific Gravity	G_s	2.65



Stresses at Failure	
Maximum Deviator Stress (psi)	19.5
Axial Strain at Failure (%)	15.1
Total Stresses at Failure	
Minor Principal Stress, σ_1 (psi)	23.5
Major Principal Stress, σ_3 (psi)	4.0
Friction Angle, ϕ_u (^{o}):	- -
Undrained Shear Strength, S_u (psi):	9.7

Note: The test specimen was nearly saturated, the Mohr failure envelope was taken as a horizontal straight line. Failure is taken to correspond to the peak deviator stress.

Cheng-Wei Chen, 04/19/10
Quality Review/Date
Tested by: Caleb McCord

TRI/ENVIRONMENTAL, INC.
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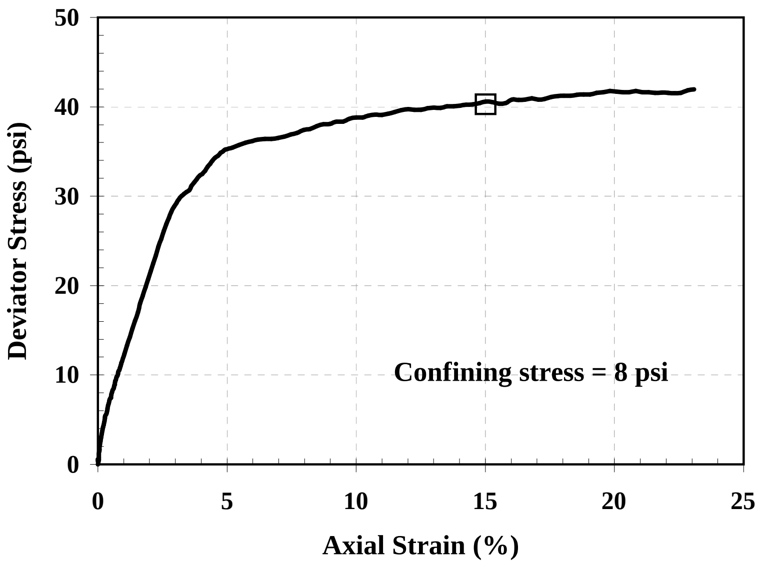
Unconsolidated-Undrained Triaxial Compression Test Report

Client: EnviroTech Engineering & Consulting, Inc.
Project: 010046-02 Clean Harbors-Lone Mountain Facility
Sample No.: TP-2 (7'-9')

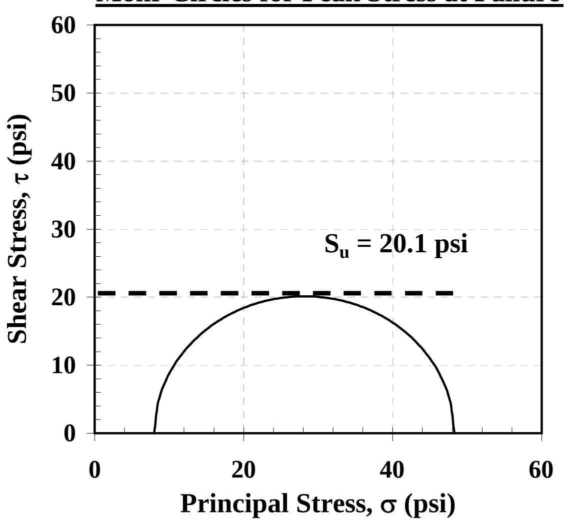
TRI Log No.: E2337-33-05
Test Method: ASTM D 2850
Test Date: 4/20/2010

Type of Specimen: Undisturbed
Strain Rate (%/min): 1 % / min
Type of Test: Q-Test



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psi)		8
Depth/Elev (ft):		7 - 9
Avg. Diameter (in)	D_o	2.86
Avg. Height (in)	H_o	5.64
Avg. Water Content (%)	w_o	27.8
Bulk Density (pcf)	γ_{total}	122.7
Dry Density (pcf)	γ_{dry}	96.0
Saturation (%)	S_r	98.0
Void Ratio	e_o	0.72
Assumed Specific Gravity	G_s	2.65

Mohr Circles for Peak Stress at Failure



Stresses at Failure	
Maximum Deviator Stress (psi)	40.3
Axial Strain at Failure (%)	15.0
Total Stresses at Failure	
Minor Principal Stress, σ_1 (psi)	48.3
Major Principal Stress, σ_3 (psi)	8.0
Friction Angle, ϕ_u (^{o}):	- -
Undrained Shear Strength, S_u (psi):	20.1

Note: The test specimen was nearly saturated, the Mohr failure envelope was taken as a horizontal straight line. Failure is taken to correspond to the peak deviator stress.

Cheng-Wei Chen, 04/21/10
Quality Review/Date
Tested by: Caleb McCord

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

Unconsolidated-Undrained Triaxial Compression Test Appendix

Client: EnviroTech Engineering & Consulting, Inc.
Project: 010046-02 Clean Harbors-Lone Mountain Facility Geotech

TRI Log No.: E2337-33-05
Test Method: ASTM D 2850
Test Date: 04/20/10

Sample No.TP-2 (7-9 ft)
Confining Pressure = 8 psi

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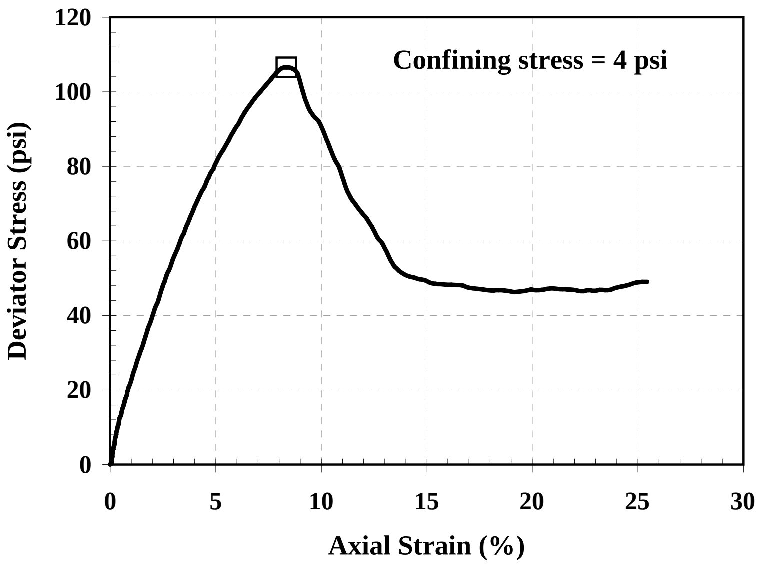
Unconsolidated-Undrained Triaxial Compression Test Report

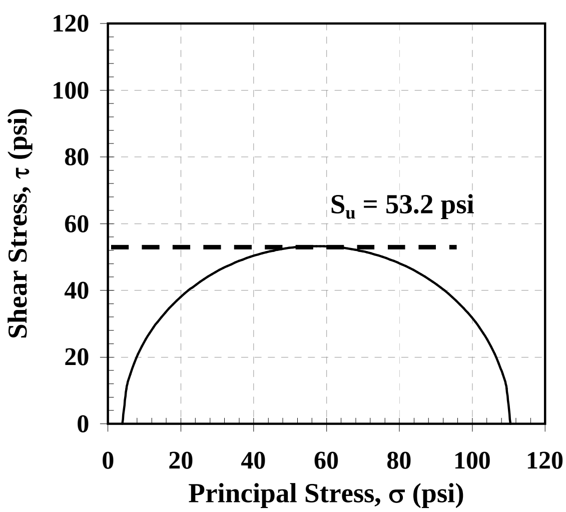
Client:	EnviroTech Engineering & Consulting, Inc.	TRI Log No.:	E2337-33-05	Type of Specimen:	Undisturbed
		Test Method:	ASTM D 2850	Strain Rate (%/min):	1 % / min
Project:	010046-02 Clean Harbors-Lone Mountain Facility	Test Date:	4/20/2010	Type of Test:	Q-Test

Sample No.: TP-3 (4'-6')



Initial Specimen Conditions		
Specimen No.		1
Confining Stress (psi)		4
Depth/Elev (ft):		4 - 6
Avg. Diameter (in)	D_o	2.82
Avg. Height (in)	H_o	5.61
Avg. Water Content (%)	w_o	19.8
Bulk Density (pcf)	γ_{total}	128.6
Dry Density (pcf)	γ_{dry}	107.3
Saturation (%)	S_r	98.2
Void Ratio	e_o	0.54
Assumed Specific Gravity	G_s	2.65

Mohr Circles for Peak Stress at Failure



Stresses at Failure	
Maximum Deviator Stress (psi)	106.5
Axial Strain at Failure (%)	8.4
Total Stresses at Failure	
Minor Principal Stress, σ_1 (psi)	110.5
Major Principal Stress, σ_3 (psi)	4.0
Friction Angle, ϕ_u (^{o}):	- -
Undrained Shear Strength, S_u (psi):	53.2

Note: The test specimen was nearly saturated, the Mohr failure envelope was taken as a horizontal straight line. Failure is taken to correspond to the peak deviator stress.

Cheng-Wei Chen, 04/21/10
Quality Review/Date
Tested by: Caleb McCord

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

Unconsolidated-Undrained Triaxial Compression Test Appendix

Client: EnviroTech Engineering & Consulting, Inc.
Project: 010046-02 Clean Harbors-Lone Mountain Facility Geotech

TRI Log No.: E2337-33-05
Test Method: ASTM D 2850
Test Date: 04/20/10

Sample No.TP-3 (4-6 ft)
Confining Pressure = 4 psi

APPENDIX B1-4

2013 GEOTECHNICAL SITE INVESTIGATION BORING LOGS (BORINGS B-33 THROUGH B-39)

Boring			
33	**CLIENT :** Clean Harbors	**WEATHER :** Partly Cloudy, Windy	ENVIROTECH ENGINEERING & CONSULTING, INC.
	PROJECT : Geotech Investigation, Subcells	**LOCATION :** N-15420, E-8005	
	PROJECT # : 013334-00	**ELEVATION :** 1383.69	
	DATE START : 10/22/2013 **FINISH :** 10/22/2013	**LOGGED BY :** J. Stovall	2500 N. 11th Street I Enid, OK 73701
	TIME START : 14:15 **FINISH :** 15:30	**DRILLED BY :** TJ Horner	(580) 234-8780 I Fax (580) 237-4302
	AUGER SIZE : 8" Hollow Stem **RIG ID :** F-6	**METHOD B :** SPT &@ 5' Intervals	

Depth (Ft.)	Sample Type	Soil Log	Visual Description	USCS	SPT "N" Value	Bearing Capacity (lbs/sq.ft)	Sample ID	Moisture (%)	LL	PL	PI	Passing 200 Sieve (%)
0–3			Brown Clay with some Vegetation	CL								
3–4			Reddish Brown Shaley Clay with ~1% Gypsum	CL								
4–5.5			Reddish Brown Shaley Clay with ~1% Gypsum *Water Encountered at 5.5 ft.*	CL	16		Sample A	21.8	38	21	17	74.0
5.5–6			Saturated Reddish Brown Shaley Clay	CL								
6–6.5			*Shelby Tube Pushed, 100% Recovery*									
6.5–7			Sat. Reddish Brown Shaley Clay with ~1% Gypsum	CL								
7–8			Sat. Gray/Green Shaley Clay	CL								

Terminated Drilling at 8.0 ft
Water Encountered at 5.5 ft.

Note: Missed the Gray Lense. Offset 2 ft and drilled down to take shelby tube. Terminated drilling per client.

Strata Symbol: Low-Plasticity Clay (CL); High-Plasticity Clay (CH); Low-Plasticity Silt (ML); High-Plasticity Silt (MH); Clayey Sand (SC); Silty Sand (SM); Well Graded Sand (SW); Poorly Graded Sand (SP)

Soil Sampler: Shelby Tube (in-situ); 2" Split-Spoon Sampler; Grab Sample

Boring				
34	**CLIENT :** Clean Harbors		**WEATHER :** Partly Cloudy, Windy	ENVIROTECH ENGINEERING & CONSULTING, INC.
	PROJECT : Geotech Investigation, Subcells		**LOCATION :** N-14830, E-7980	
	PROJECT # : 013334-00		**ELEVATION :** 1388.77	
	DATE START : 10/22/2013	**FINISH :** 10/22/2013	**LOGGED BY :** J. Stovall	
	TIME START : 15:45	**FINISH :** 16:15	**DRILLED BY :** TJ Horner	2500 N. 11th Street I Enid, OK 73701
	AUGER SIZE : 8" Hollow Stem	**RIG ID :** F-6	**METHOD B :** SPT &@ 5' Intervals	(580) 234-8780 I Fax (580) 237-4302

Depth (Ft.)	Sample Type	Soil Log	Visual Description	USCS	SPT "N" Value	Bearing Capacity (lbs/sq.ft)	Sample ID	Moisture (%)	LL	PL	PI	Passing 200 Sieve (%)
0	Grab Sample	CL	Brown Clay with some Vegetation	CL			Sample D	18.5	36	18	18	83.6
1	Grab Sample	CL	Brown/Gray Clay with Sand & Gravel	CL								
2–4	Grab Sample	CL	Reddish Brown Shaley Clay	CL								
4–5.5	2" Split-Spoon Sampler	CL	Reddish Brown Shaley Clay *(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
5.5–9	Grab Sample	CL	Reddish Brown Shaley Clay	CL								
9–10.5	2" Split-Spoon Sampler	CL	Reddish Brown Shaley Clay / Gray Shaley Clay	CL	55		Sample C	20.7	40	23	17	94.0
10.5–11	Grab Sample	CL	Gray Shaley Clay	CL								
11–13	Grab Sample	CL	Red & Gray Shaley Clay	CL			Sample B	19.4	42	19	23	99.1
13–15.5	Grab Sample / 2" Split-Spoon Sampler	CL	Gray Shaley Clay	CL	60							
15.5–20	2" Split-Spoon Sampler	CL	Reddish Brown Shaley Clay with Gray Specks *(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
			(Refusal Met, 10 blows with no Advancement)	CL	Ref							
			Reddish Brown Shaley Clay with Gray Specks *(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
20–30			***Terminated Drilling at 20 ft*** ***No Water Encountered***									
			Note: At 15 ft went to continuous STPP to ensure the wet zone was not missed, per client.									

Strata Symbol: Low-Plasticity Clay (CL); High-Plasticity Clay (CH); Low-Plasticity Silt (ML); High-Plasticity Silt (MH); Clayey Sand (SC); Silty Sand (SM); Well Graded Sand (SW); Poorly Graded Sand (SP)

Soil Sampler: Shelby Tube (in-situ); 2" Split-Spoon Sampler; Grab Sample

Borings are backfilled and sealed per Oklahoma Water Resource Board regulations unless otherwise noted.

Boring 35	
CLIENT : Clean Harbors	WEATHER : Partly Cloudy, Windy
PROJECT : Geotech Investigation, Subcells	LOCATION : N-14395, E-7790
PROJECT # : 013334-00	ELEVATION : 1391.57
DATE START : 10/23/2013 FINISH : 10/23/2013	LOGGED BY : J. Stovall
TIME START : 14:05 FINISH : 15:40	DRILLED BY : TJ Horner
AUGER SIZE : 6" Hollow Stem RIG ID : F-6	METHOD B : SPT &@ 5' Intervals

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2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Depth (Ft.)	Visual Description	USCS	SPT "N" Value	Bearing Capacity (lbs/sq.ft)	Sample ID	Moisture (%)	LL	PL	PI	Passing 200 Sieve (%)
0	Dark Brown Clay (some gravel) Dark Brown Clay	CL	30							
4	Brown Clay with some Gypsum and Vegetation	CL	45							
5	Reddish Brown Shaley Clay	CL								
6	Reddish Brown Shaley Clay *Shelby Tube Pushed, 100% Recovery*	CL								
7	Reddish Brown Shaley Clay *Refusal Met with Shelby Tube, No Recovery*	CL								
8	*Refusal Met with Shelby Tube, No Recovery*									
9	Reddish Brown Shaley Clay *(Refusal Met, 10 blows with no Advancement)*	CL	Ref		Sample E	18.5	33	18	15	99.1
14	Gray Shaley Clay	CL	62							
19	Gray Shaley Clay *(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
19.5	Reddish Brown Shaley Clay	CL								
20	***Terminated Drilling at 20 ft. No Water Encountered***									

Strata Symbol: Low-Plasticity Clay (CL); High-Plasticity Clay (CH); Low-Plasticity Silt (ML); High-Plasticity Silt (MH); Clayey Sand (SC); Silty Sand (SM); Well Graded Sand (SW); Poorly Graded Sand (SP)

Soil Sampler: Shelby Tube (in-situ); 2" Split-Spoon Sampler; Grab Sample

Borings are backfilled and sealed per Oklahoma Water Resource Board regulations unless otherwise noted.

Boring			
36	**CLIENT :** Clean Harbors	**WEATHER :** Partly Cloudy, Windy	ENVIROTECH ENGINEERING & CONSULTING, INC.
	PROJECT : Geotech Investigation, Subcells	**LOCATION :** N-13945, E-8130	
	PROJECT # : 013334-00	**ELEVATION :** 1387.9	
	DATE START : 10/22/2013 **FINISH :** 10/22/2013	**LOGGED BY :** J. Stovall	
	TIME START : 8:25 **FINISH :** 10:30	**DRILLED BY :** TJ Horner	2500 N. 11th Street I Enid, OK 73701
	AUGER SIZE : 6" Hollow Stem **RIG ID :** F-6	**METHOD B :** SPT &@ 5' Intervals	(580) 234-8780 I Fax (580) 237-4302

Depth (Ft.)	Sample Type	Soil Log	Visual Description	USCS	SPT "N" Value	Bearing Capacity (lbs/sq.ft)	Sample ID	Moisture (%)	LL	PL	PI	Passing 200 Sieve (%)
0			Red Shaley Clay with some Gravel	CL								
1			Red with Turquoise Specks Shaley Clay with 1% Gypsum	CL	30							
2			Red with Turquoise Specks Shaley Clay	CL	23							
3–4			Red with Turquoise Specks Shaley Clay	CL	18							
5			Red with Turquoise Shaley Clay, 10% Gypsum	CL	*37*							
6–7			Brown Clay with Vegetation	CL	21							
8					13							
			3" of Pure Gypsum									
9			*Water Encountered at 9.5 ft.*				Sample F	27.7	36	21	15	89.3
			Saturated Brown Clay	CL	7							
10												
11			Saturated Brown Clay	CL								
			Shelby Tube Pushed, 75% Recovery									
			Saturated Brown Clay	CL								
12			Sat. Brown/Red Weathered Shale	CL	52							
13–14			Sat. Green Weathered Shale	CL	52							
15–16			***Terminated Drilling at 15 ft.*** ***Water Encountered at 9.5 ft.***									
17												
18												
19												
20												
21												
22												
23												
24												
25												
26												
27												
28												
29												
30												

Strata Symbol				Soil Sampler
	Low-Plasticity Clay (CL)	Low-Plasticity Silt (ML)	Clayey Sand (SC) / Well Graded Sand (SW)	Shelby Tube (in-situ)
	High-Plasticity Clay (CH)	High-Plasticity Silt (MH)	Silty Sand (SM) / Poorly Graded Sand (SP)	2" Split-Spoon Sampler
				Grab Sample

Borings are backfilled and sealed per Oklahoma Water Resource Board regulations unless otherwise noted.

Boring 37		
CLIENT : Clean Harbors	WEATHER : Partly Cloudy, Windy	
PROJECT : Geotech Investigation, Subcells	LOCATION : N-13845, E-7730	
PROJECT # : 013334-00	ELEVATION : 1391.95	
DATE START : 10/23/2013 FINISH : 10/23/2013	LOGGED BY : J. Stovall	
TIME START : 12:45 FINISH : 13:45	DRILLED BY : TJ Horner	
AUGER SIZE : 6" Hollow Stem RIG ID : F-6	METHOD B : SPT &@ 5' Intervals	

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Depth (Ft.)	Visual Description	USCS	SPT "N" Value	Bearing Capacity (lbs/sq.ft)	Sample ID	Moisture (%)	LL	PL	PI	Passing 200 Sieve (%)
0	Brown Clay with some Gypsum & Sand	CL	58							
4	Brown Clay	CL	36		Sample H	21.7	42	22	20	91.4
5	Brown/Gray Clay *Refusal Met with Shelby Tube, No Recovery*	CL								
6	Gray Clay	CL								
7.5	Reddish Brown Shaley Clay	CL								
9	Reddish Brown Shaley Clay *(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
14	Reddish Brown Shaley Clay with 25% Gypsum *(Refusal Met, 50 blows in 6")*	CL	Ref							
19	Reddish Brown Shaley Clay *(Refusal Met, 10 blows with no Advancement)*	CL	Ref		Sample G	18.3	39	21	18	99.8
20	***Terminated Drilling at 20 ft. No Water Encountered***									

Depth scale: 0 – 30 ft.

Strata Symbol: Low-Plasticity Clay (CL); High-Plasticity Clay (CH); Low-Plasticity Silt (ML); High-Plasticity Silt (MH); Clayey Sand (SC); Silty Sand (SM); Well Graded Sand (SW); Poorly Graded Sand (SP)

Soil Sampler: Shelby Tube (in-situ); 2" Split-Spoon Sampler; Grab Sample

Borings are backfilled and sealed per Oklahoma Water Resource Board regulations unless otherwise noted.

Boring 38	
CLIENT :	Clean Harbors
PROJECT :	Geotech Investigation, Subcells
PROJECT # :	013334-00
DATE START :	10/23/2013
FINISH :	10/23/2013
TIME START :	8:20
FINISH :	11:35
AUGER SIZE :	6" Hollow Stem
RIG ID :	F-6
WEATHER :	Partly Cloudy, Windy
LOCATION :	N-13265, E-8111
ELEVATION :	1392.97
LOGGED BY :	J. Stovall
DRILLED BY :	TJ Horner
METHOD B :	SPT &@ 5' Intervals

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(580) 234-8780 I Fax (580) 237-4302

Depth (Ft.)	Sample Type	Soil Log	Visual Description	USCS	SPT "N" Value	Bearing Capacity (lbs/sq.ft)	Sample ID	Moisture (%)	LL	PL	PI	Passing 200 Sieve (%)
0–2			Brown Clay with Gravel	CL	64							
2–3			Brown Clay	CL	26		Sample I	24.3	39	22	17	80.3
3			*Refusal Met with Shelby Tube, No Recovery*									
4			Reddish Brown Shaley Clay with Gray Specks	CL	44							
5–6			Reddish Brown Shaley Clay with 10% Gypsum	CL	72							
7			*(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
8			Reddish Brown Shaley Clay	CL	60							
9			Gray Shaley Clay									
10			Reddish Brown Shaley Clay with Gray Specks *(Refusal Met, 50 blows in last 6")*	CL	Ref							
11–12			Reddish Brown Shaley Clay with 10% Gypsum	CL	Ref							
13			*(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
14–15			Reddish Brown Shaley Clay with 10% Gypsum *(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
16					Ref							
17–18			Reddish Brown Shlaey Clay with 20% Gypsum	CL	Ref							
19			*(Refusal Met, 10 blows with no Advancement)*		Ref							
20			***Terminated Drilling at 20 ft. No Water Encountered***									

Strata Symbol: Low-Plasticity Clay (CL); High-Plasticity Clay (CH); Low-Plasticity Silt (ML); High-Plasticity Silt (MH); Clayey Sand (SC); Silty Sand (SM); Well Graded Sand (SW); Poorly Graded Sand (SP)

Soil Sampler: Shelby Tube (in-situ); 2" Split-Spoon Sampler; Grab Sample

Borings are backfilled and sealed per Oklahoma Water Resource Board regulations unless otherwise noted.

Boring 39	
CLIENT :	Clean Harbors
PROJECT :	Geotech Investigation, Subcells
PROJECT # :	013334-00
DATE START :	10/22/2013
FINISH :	10/22/2013
TIME START :	11:00
FINISH :	13:20
AUGER SIZE :	8" Hollow Stem
RIG ID :	F-6
WEATHER :	Partly Cloudy, Windy
LOCATION :	N13342, E-7780
ELEVATION :	1390.95
LOGGED BY :	J. Stovall
DRILLED BY :	TJ Horner
METHOD B :	SPT &@ 5' Intervals

ENVIROTECH
ENGINEERING & CONSULTING, INC.
2500 N. 11th Street I Enid, OK 73701
(580) 234-8780 I Fax (580) 237-4302

Depth (Ft.)	Visual Description	USCS	SPT "N" Value	Bearing Capacity (lbs/sq.ft)	Sample ID	Moisture (%)	LL	PL	PI	Passing 200 Sieve (%)
0	Brown Clay	CL								
1–4	Reddish Brown Shaley Clay	CL								
4–5	*(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
5	Red/Gray Shaley Clay	CL								
6	Red Shaley Clay	CL			Sample J	20.8	37	22	15	83.1
7	*Refusal Met with Shelby Tube, No Recovery*									
8	Gray (Turquoise) Shaley Clay	CL								
9–10	Red with Gray Specks Shaley Clay *(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
14–15	Red with Gray Specks Shaley Clay *(Refusal Met, 10 blows with no Advancement)*	CL	Ref							
18	Red with Gray Specks Shaley Clay with 15% Gypsum	CL								
20	***Terminated Drilling at 19.5 ft. Auger Refusal No Water Encountered***									

Strata Symbol: Low-Plasticity Clay (CL); High-Plasticity Clay (CH); Low-Plasticity Silt (ML); High-Plasticity Silt (MH); Clayey Sand (SC); Silty Sand (SM); Well Graded Sand (SW); Poorly Graded Sand (SP)

Soil Sampler: ▭ Shelby Tube (in-situ); ■ 2" Split-Spoon Sampler; ▨ Grab Sample

APPENDIX B1-5

2013 GEOTECHNICAL SITE INVESTIGATION LABORATORY TEST DATA

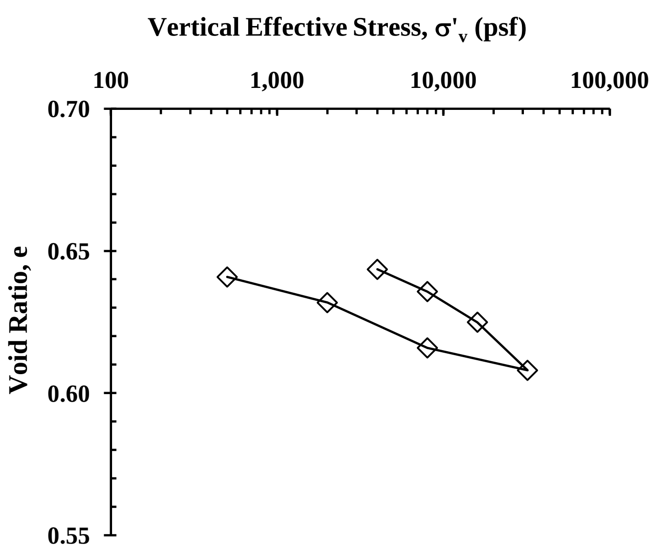
One-Dimensional Consolidation Properties of Soil

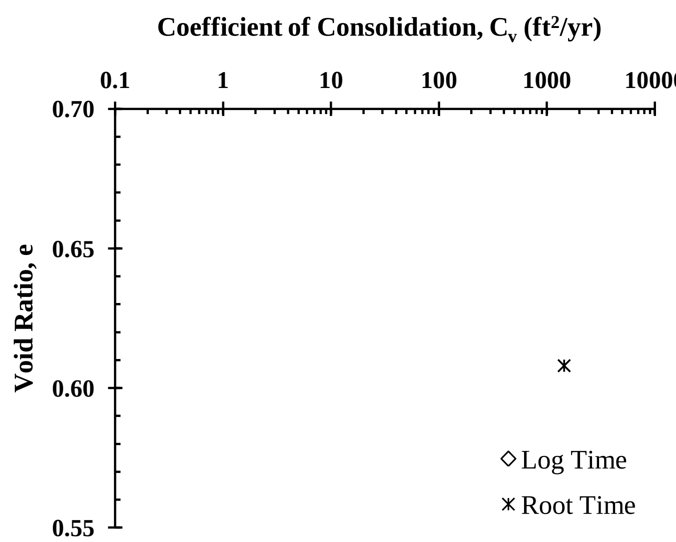
Client: Envirotech Engineering and Consulting
Project: Clean Harbors Geotech. - Lone Mountain
Specimen: B-35 (6-7 ft)

TRI Log No.: E2377-51-05
Test Method: ASTM D 2435, Method B
Test Date: 11/12/13

Soil Specimen Properties	
Initial Specimen Water Content (%)	22.7
Final Specimen Water Content (%)	22.6
Specimen Diameter (in)	2.497
Initial Specimen Height (in)	0.992
Final Specimen Height (in)	0.988
Final Differential Height (in)	0.004
Initial Dry Unit Weight, γ_o lb_f/ft^3	100.3
Final Dry Unit Weight, γ_f lb_f/ft^3	100.8
Initial Void Ratio, e_o	0.648
Final Void Ratio, e_f	0.641
Initial Degree of Saturation (%)	92.7
Preconsolidation Pressure (psf)	-
Swell Pressure (psf), Maximum Measured	1597
Compression Index, C_c	0.055
Recompression Index, C_r	-

σ'_v	e	Strain, ε	C_v (ft^2/year)	
(psf)	(-)	(%)	Log Time	Root Time
Initial	0.648	0.0	-	-
4,000	0.643	0.3	-	-
8,000	0.636	0.8	-	-
16,000	0.625	1.4	-	-
32,000	0.608	2.4	-	1400
8,000	0.616	2.0	-	-
2,000	0.632	1.0	-	-
500	0.641	0.5	-	-





The undisturbed specimen was provided by the client. Specimen was trimmed using a trimming turntable and mounted. Specimen was inundated with tap water during testing. Coefficient of Consolidation was determined using the Log Time and Root Time Methods. Gs was assumed to be 2.65. Calculations include machine deflections measured at each loading step. The preconsolidation was not evident from the test results.

Jeffrey A. Kuhn, Ph.D., P.E., 12/3/2013
Quality Review/Date
Specimen Prepared by: Mark Fountain, Ph.D.

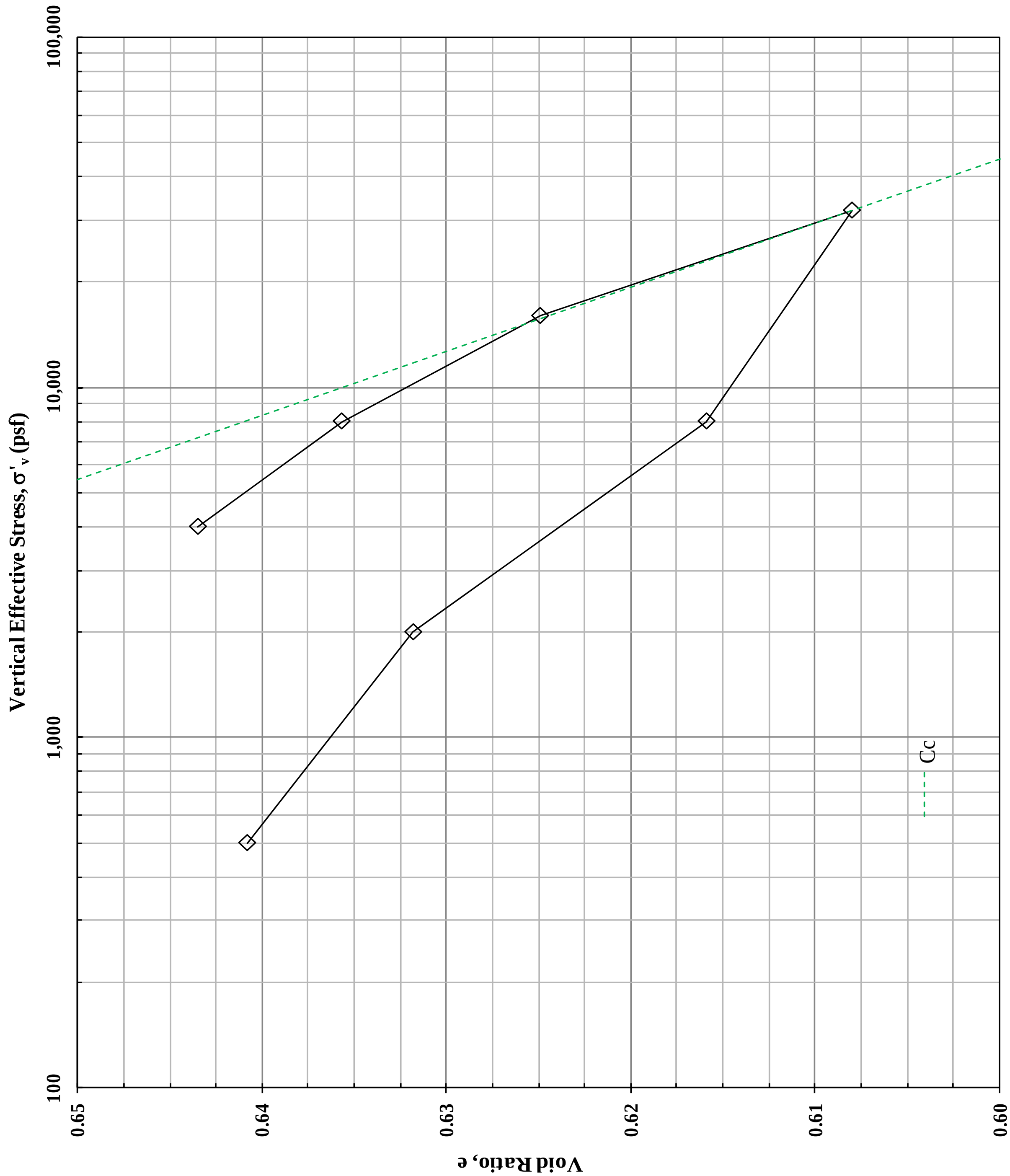
One-Dimensional Consolidation Properties of Soil

Client: Envirotech Engineering and Consulting

TRI Log No.: E2377-51-05

Project: Clean Harbors Geotech. - Lone Mountain

Specimen: B-35 (6-7 ft)



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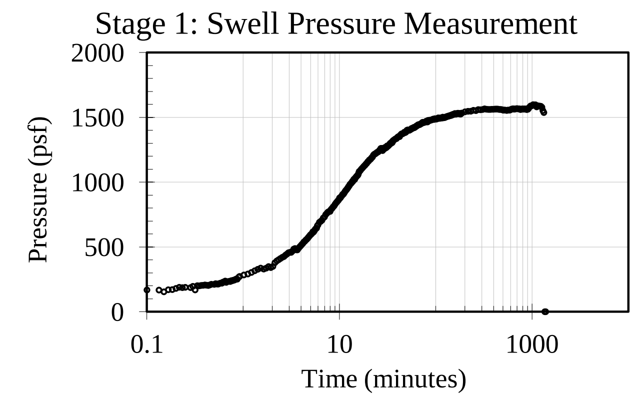
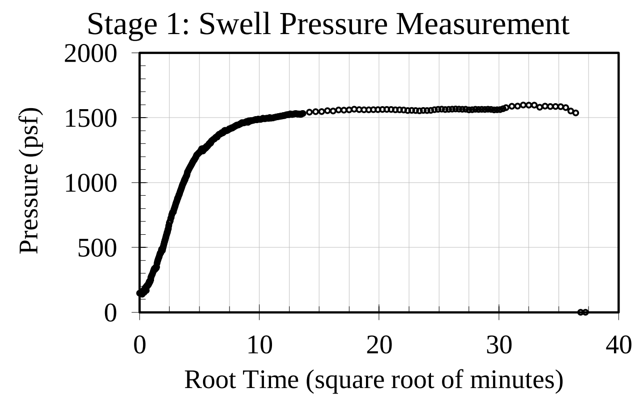
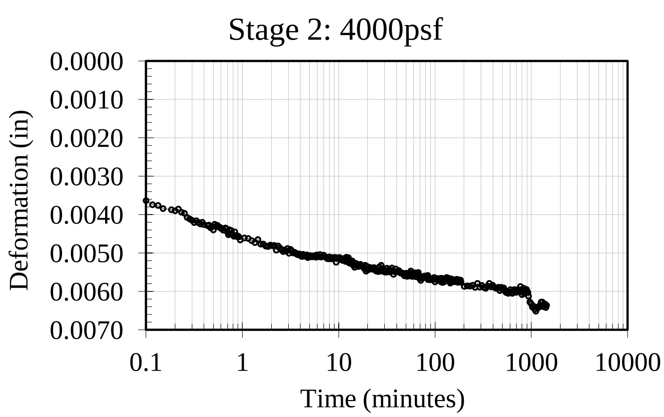
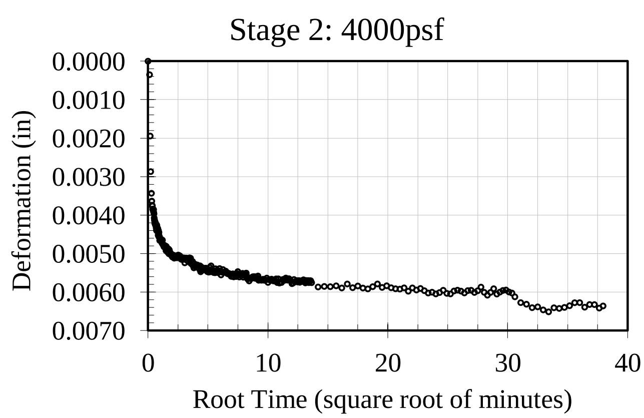
One-Dimensional Consolidation Properties of Soil

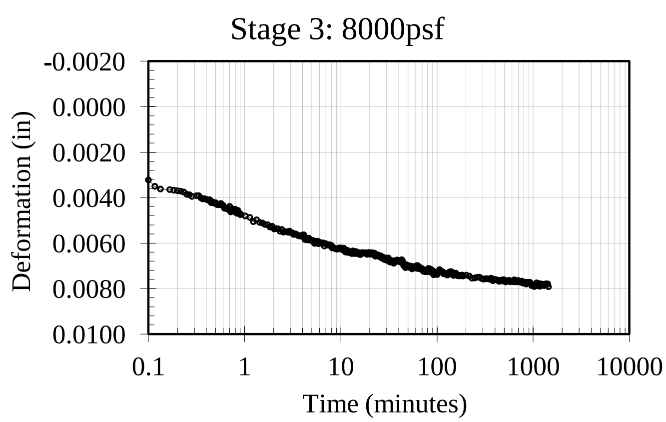
TRI Log No.: E2377-51-05

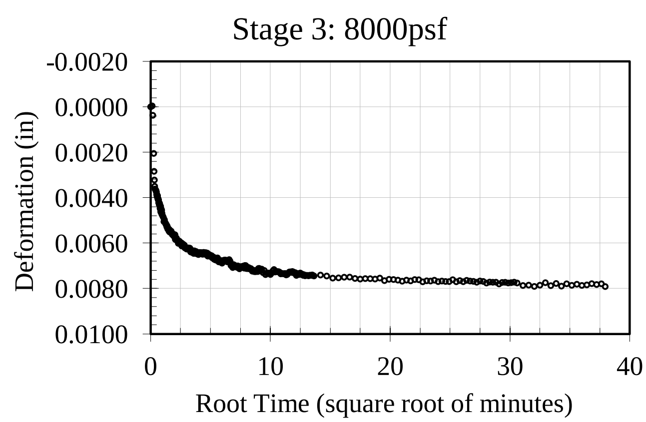






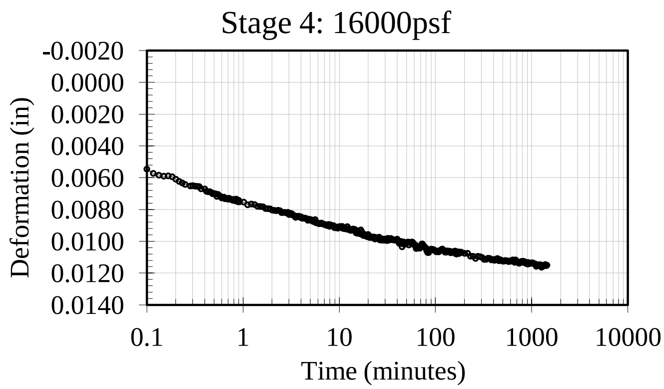


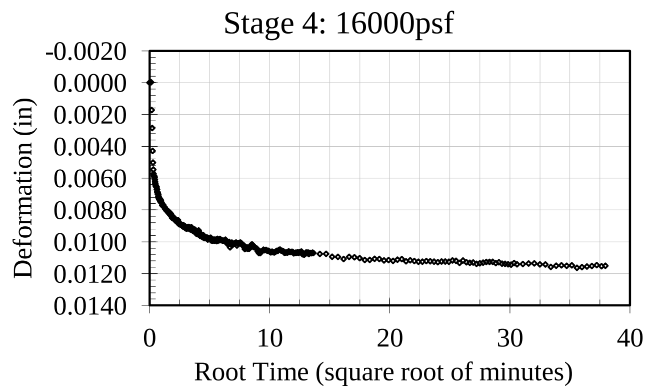


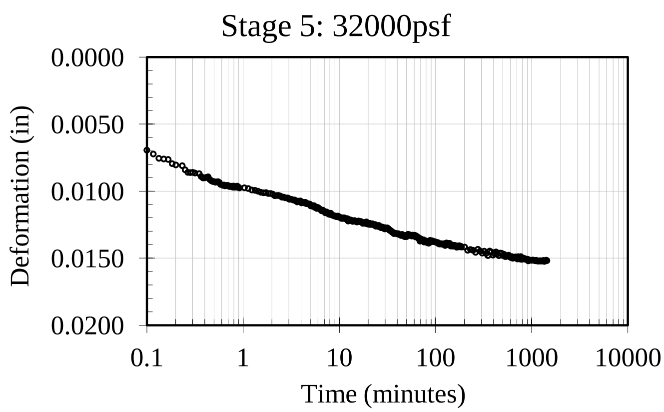


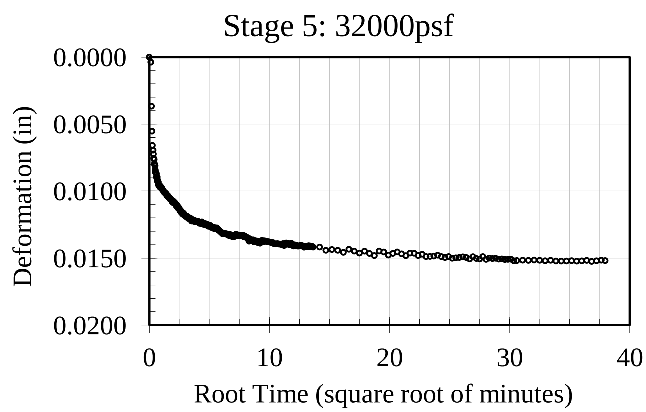
One-Dimensional Consolidation Properties of Soil

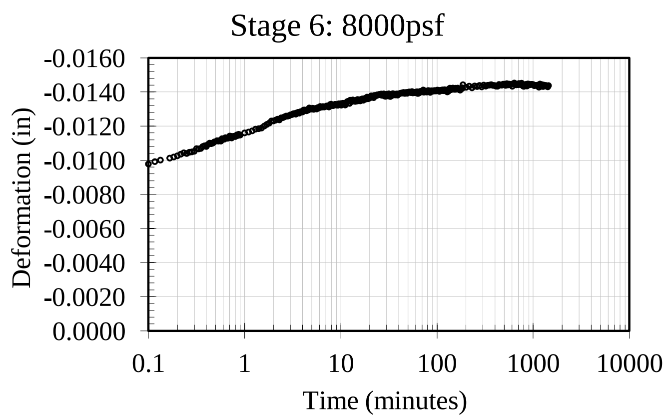
TRI Log No.: E2377-51-05

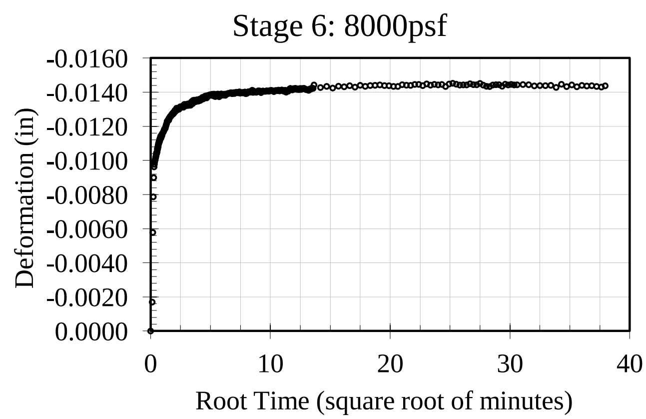






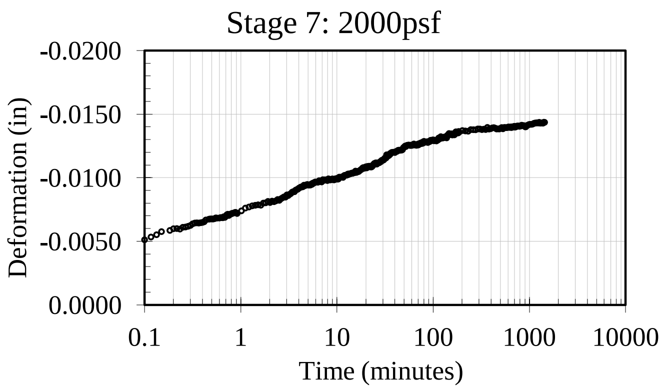


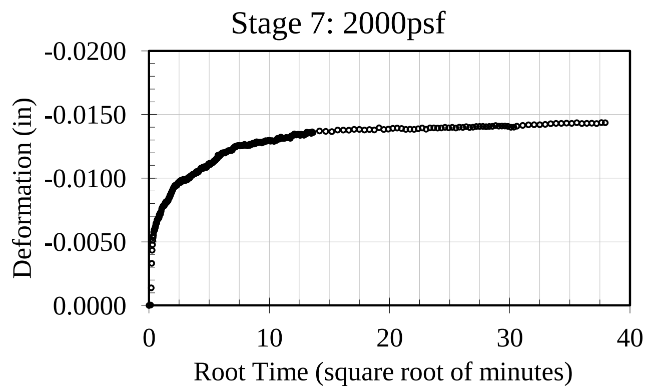


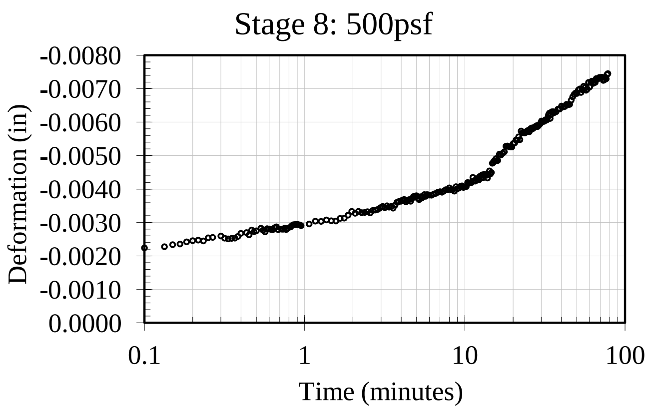


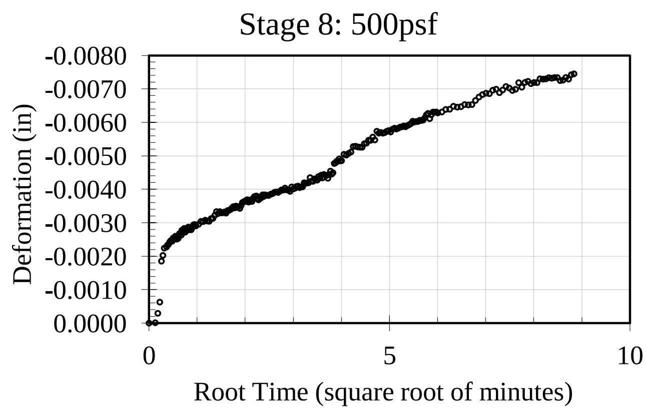
One-Dimensional Consolidation Properties of Soil

TRI Log No.: E2377-51-05









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Consolidated-Undrained ($\bar{R}$) Triaxial Compression

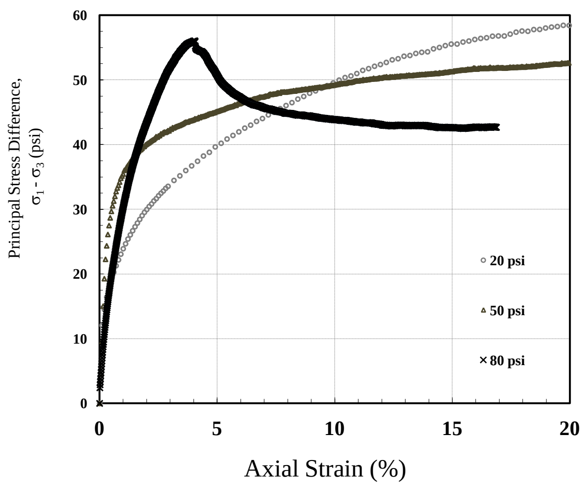
Client:	Envirotech Engineering and Consulting	TRI Log #:	E2377-51-05
Project:	Clean Harbors Geotech. - Lone Mountain	Test Method:	ASTM D4767
Sample:	B-33 (5-6 ft), B-35 (6-7 ft), and B-36 (10.5-11.5 ft)	Test Date:	11/12/2013

$\bar{R}$-Envelope, Effective Stress	
Effective Friction Angle (deg)	14.9
Effective Cohesion (psi)	11.8

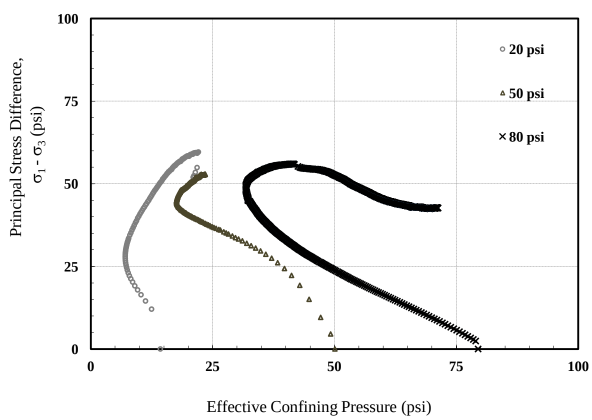
R-Envelope, "Total" Stress	
Friction Angle (deg)	7.0
Cohesion (psi)	13.7

Samples			
Sample I.D.	B-33	B-36	B-35
Depth/Elev. (ft)	5.5	11	6.5
Eff. Consol. Stress (psi)	20.0	50.0	80.0
Initial Properties			
Avg. Diameter (in)	2.84	2.67	2.85
Avg. Height (in)	5.68	5.57	5.72
Avg. Water Content (%)	22.2	28.1	20.1
Bulk Density (pcf)	129.8	129.2	126.2
Dry Density (pcf)	106.2	100.9	105.1
Saturation (%)	100.0	100.0	92.7
Void Ratio	0.56	0.64	0.57
Specific Gravity (Assumed)	2.65	2.65	2.65
Total Back-Pressure (psi)	85.9	59.9	80.5
B-Value, End of Saturation	0.95	0.96	0.96
Post-Consolidation			
Void Ratio	0.54	0.54	0.52
Area (in^2)	6.28	5.35	6.25
At Failure			
Failure Criterion	Peak Principal Stress Ratio		
Rate of Strain (%/hr)	0.50	0.48	1.20
Axial Strain at Failure (%)	2.9	7.3	2.9
Minor Total Stress (psi)	14.3	50.1	79.5
Major Total Stress (psi)	47.8	97.9	130.7
Minor Effective Stress (psi)	7.8	18.3	32.3
Major Effective Stress (psi)	41.3	66.1	83.6
Principal Stress Diff. (psi)	33.5	47.8	51.2

Stress-Strain



Modified Mohr-Coulomb



Jeffrey A. Kuhn , Ph.D., P.E., 12/3/2013

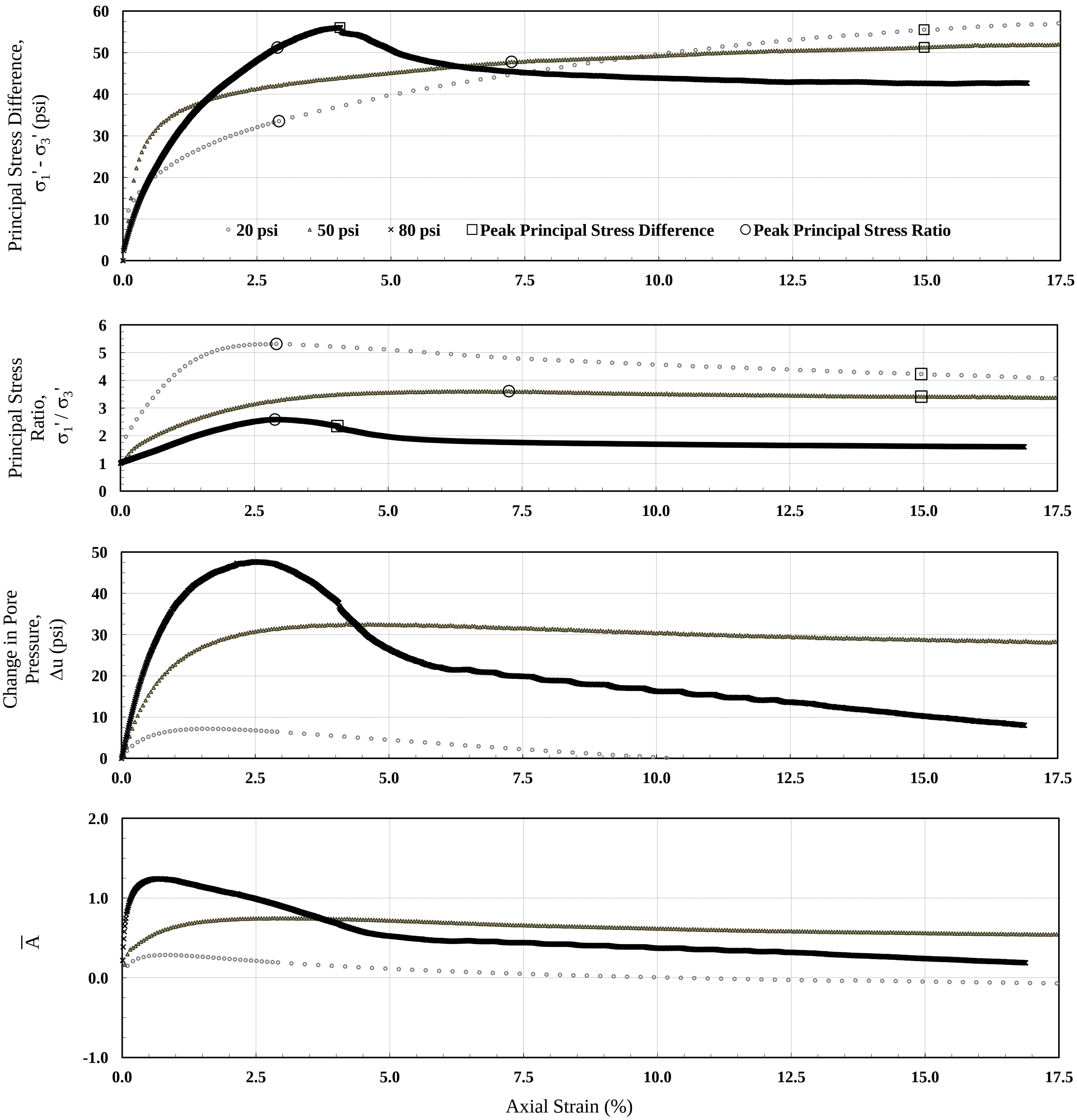
Analysis & Quality Review/Date

pecimens Prepared By: Mark Fountain, Ph.I

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

Consolidated-Undrained ($\bar{R}$) Triaxial Compression

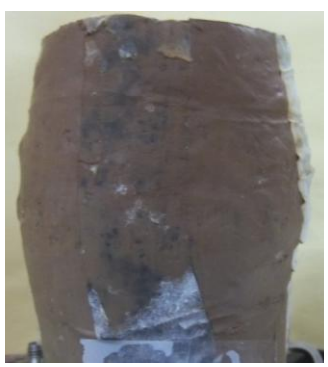
Client:	Envirotech Engineering and Consulting	TRI Log #:	E2377-51-05
Project:	Clean Harbors Geotech. - Lone Mountain	Test Method:	ASTM D4767
Sample:	B-33 (5-6 ft), B-35 (6-7 ft), and B-36 (10.5-11.5 ft)	Test Date:	11/12/2013



Consolidated-Undrained ($\bar{R}$) Triaxial Compression

Client: Envirotech Engineering and Consulting
Project: Clean Harbors Geotech. - Lone Mountain
Sample: B-33 (5-6 ft), B-35 (6-7 ft), and B-36 (10.5-11.5 ft)

TRI Log #: E2377-51-05
Test Method: ASTM D4767
Test Date: 11/12/2013

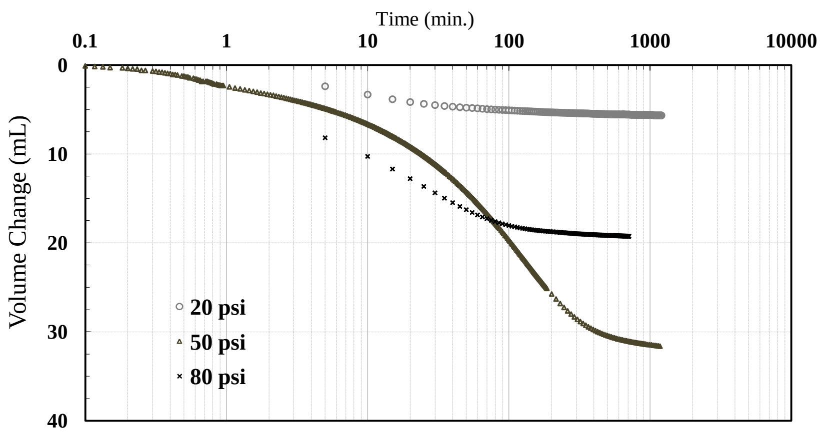
			Samples		
Sample I.D.			B-33	B-36	B-35
Depth/Elev. (ft)			5.5	11	6.5
Eff. Consol. Stress (psi)			20.0	50.0	80.0
Pre-Test Specimen Image					
Post-Test Specimen Image					
Final Water Content (%)	Top	1	21.5	23.8	22.9
		2	21.5	24.1	21.1
		3	22.5	24.4	21.6
	Bottom	4	22.8	23.6	25.8

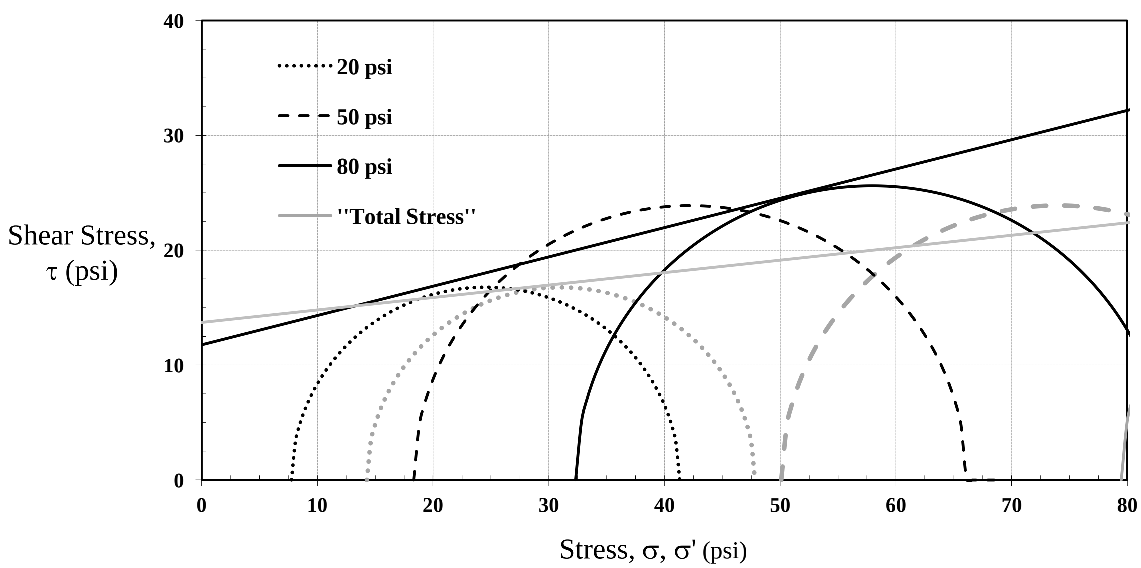
9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

Consolidated-Undrained ($\bar{R}$) Triaxial Compression

Client:	Envirotech Engineering and Consulting	TRI Log #:	E2377-51-05
Project:	Clean Harbors Geotech. - Lone Mountain	Test Method:	ASTM D4767
Sample:	B-33 (5-6 ft), B-35 (6-7 ft), and B-36 (10.5-11.5 ft)	Test Date:	11/12/2013

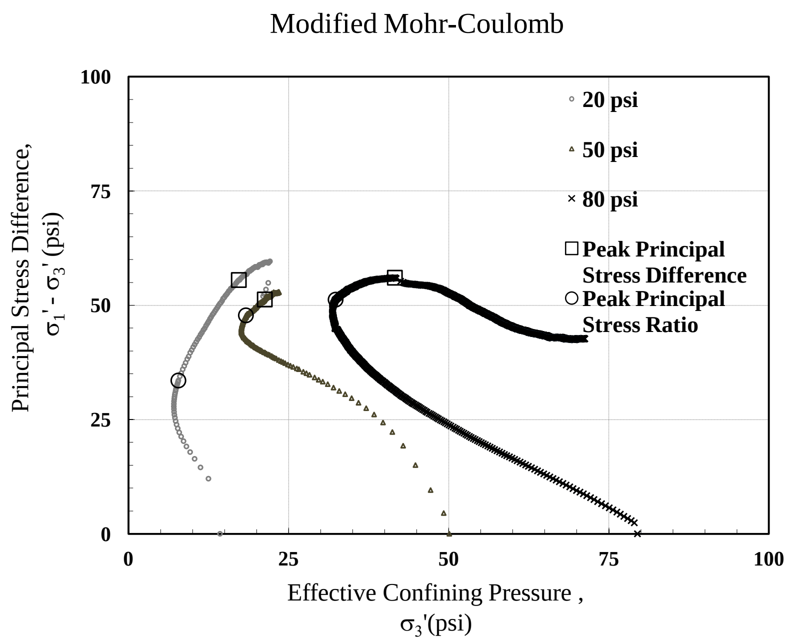
Isotropic Consolidation

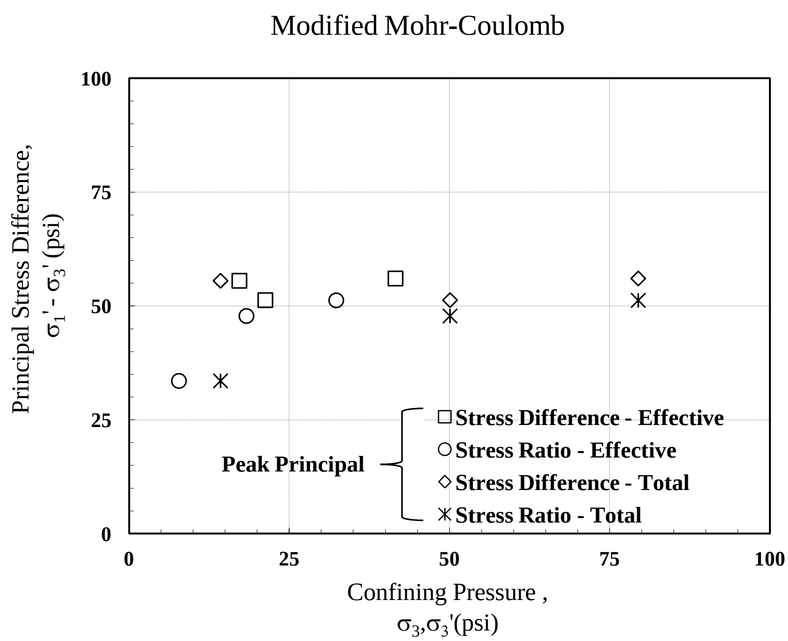




Consolidated-Undrained ($\bar{R}$) Triaxial Compression

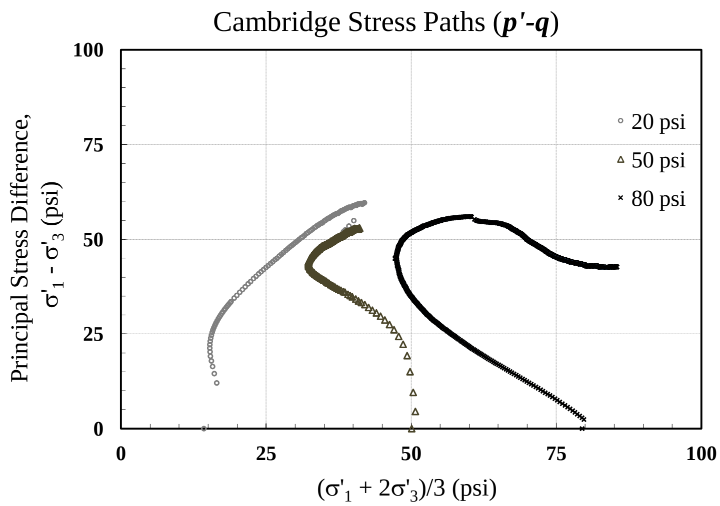
Client:	Envirotech Engineering and Consulting	TRI Log #:	E2377-51-05
Project:	Clean Harbors Geotech. - Lone Mountain	Test Method:	ASTM D4767
Sample:	B-33 (5-6 ft), B-35 (6-7 ft), and B-36 (10.5-11.5 ft)	Test Date:	11/12/2013





Consolidated-Undrained ($\bar{R}$) Triaxial Compression

Client:	Envirotech Engineering and Consulting	TRI Log #:	E2377-51-05
Project:	Clean Harbors Geotech. - Lone Mountain	Test Method:	ASTM D4767
Sample:	B-33 (5-6 ft), B-35 (6-7 ft), and B-36 (10.5-11.5 ft)	Test Date:	11/12/2013



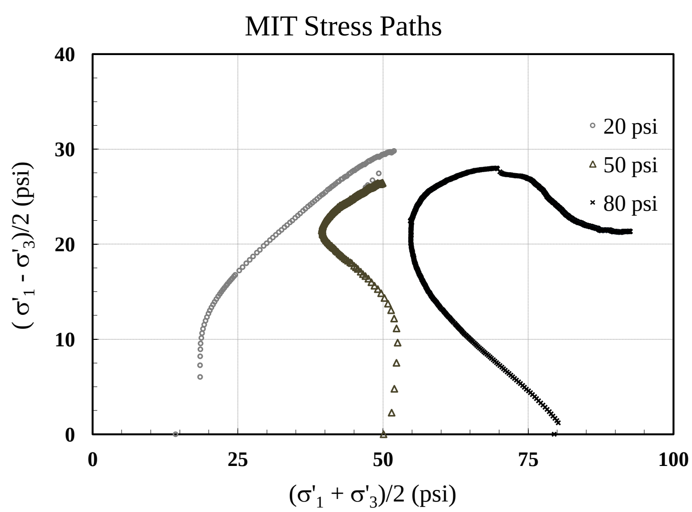


Exhibit B-2

Slope Stability Analysis

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

SLOPE STABILITY ANALYSIS

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6/13/2014

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Exp. 06/30/2014

SEALED FOR CALCULATION PAGES
B2-1 THROUGH B2-70

1. INTRODUCTION

The purpose of this calculation package is to present the slope stability analysis for the proposed Landfill Cell 15 expansion at the Clean Harbors Lone Mountain Facility. The components of Landfill Cell 15 for which the static slope stability analysis were performed are:

- perimeter embankment slopes and foundation soils after construction but before waste placement;
- liner system slopes prior to waste placement (i.e., liner system veneer);
- interim landfill slopes during waste placement operations;
- final cover system slopes (i.e., final cover system veneer); and
- final landfill slopes and foundation soils at the final closure condition.

The slope stability factor of safety (FS) is evaluated herein for cross sections that represent critical combinations of geometry and shear strength. For shear surfaces that pass through the liner system or final cover system, the approach generally taken is to back-calculate the minimum secant effective-stress friction angle for the liner system or final cover system that yields the target calculated factor of safety for slope stability. The back-calculated minimum strength values for the liner system and final cover system should be incorporated into the material specifications for liner and final cover materials.

Minimum acceptable factors of safety for landfill slope stability depend on project-specific conditions and uncertainties. The target calculated factor of safety for interim conditions (i.e., perimeter embankment slopes prior to liner system construction, liner system veneer, and interim landfill slopes during operation) is 1.25 using peak shear strength parameters. The target calculated factor of safety for final conditions (i.e., final cover veneer, final liner and foundation conditions, and final landfill slopes at the end of operation) is 1.5 using peak shear strength parameters. . To provide additional confidence in the reliability of the design, for all cases considered herein with shear surfaces that pass along a liner or final cover system interface, target factors of safety using large-displacement strengths are also set. The target minimum calculated factor of safety using large-displacement strengths is 1.0 for interim conditions and 1.15 for final conditions.

2. EVALUATION OF SITE SEISMICITY

Geosyntec performed an evaluation of the seismicity of the site area to assess whether seismic slope stability analyses were necessary. Although Landfill Cell 15 is a Subtitle "C", hazardous waste facility, for which 40 CFR §264 does not specify the need for seismic analyses, Geosyntec adopted the criterion used for municipal solid waste (MSW) landfills (40 CFR §258.14), as an appropriate standard. This Federal regulation defines a seismic impact zone as an area with a 10% or greater probability that the MHA in lithified earth material exceeds 0.10g in 250 years. The regulation further requires that landfills located in a seismic impact zone should be designed to resist the maximum horizontal acceleration (MHA) occurring in bedrock (i.e., lithified material) at the site.

Accordingly, Geosyntec evaluated whether the Lone Mountain Facility is in an area that would meet the definition of a "seismic impact zone" as described above. Values of MHA having a certain probability of exceedance (P_e) are generally determined from United States Geologic Survey (USGS) National Seismic Hazard Maps. Note that current National Seismic Hazard Maps present MHA values for a seismic risk level of 2% probability that the MHA will be exceeded in 50 years (i.e., P_e = 2% in 50 years); however, a seismic risk level of P_e = 2% in 50 years is approximately statistically equivalent to P_e = 10% in 250 years. According to the most recent (2008) USGS National Seismic Hazard Maps, the MHA at the Lone Mountain Facility Landfill site (98.81° W, 36.44° N) corresponding to P_e = 2% in 50 years is 0.065g (Figure B2-1). Based on the low seismicity of the area and the MHA of less than 0.10g in 250 years, it is concluded that, the Lone Mountain Facility Landfill Cell 15 is not located in a seismic impact zone and does not require seismic stability analyses. The remainder of this calculation package presents the static slope stability analyses.

3. METHOD

The slope stability of the landfill components except for veneer sliding of the liner and final cover system was analyzed using a method of slices coded in the computer program SLIDE, Version 6.026 [Rocscience, 1998-2014]. The computer program was used to generate circular and non-circular (block-type) shear surfaces and to calculate the factors of safety of these surfaces using Spencer's (1967) method.

Liner system and final cover system veneer stability was evaluated using the force equilibrium method presented by Giroud et al. (1995). Veneer stability refers to sliding of the liner or cover system layers along the weakest interface. The veneer stability analysis is presented in Appendix B-1 of this calculation package.

4. CRITICAL CROSS SECTIONS

Slope stability analyses were performed for several cross sections to evaluate the different critical configurations of the various components of the landfill for each sliding scenario. The following engineering drawings were used to select the critical slope stability cross sections:

- top of clay liner grading plan (Drawing 4 in Exhibit A of the Landfill Cell 15 Engineering Report);
- interim waste filling grading plans (Drawings 5 to 7 in Exhibit A of the Landfill Cell 15 Engineering Report);
- overall final cover grading plan (Drawing 9 in Exhibit A of the Landfill Cell 15 Engineering Report); and
- typical post closure cross sections (Drawing 10-12 in Exhibit A of the Landfill Cell 15 Engineering Report).

Also, the liner system and final cover system materials were considered when selecting the critical cross sections. The top of clay liner grading plan and final cover grading plan for the landfill – taken from the engineering drawings in Exhibit A of the Engineering Report – are shown on Figures B2-2 and B2-3, respectively, of this calculation package. The specific critical cross sections are identified on these figures and are described in more detail below.

4.1 Perimeter Embankment Slopes and Foundation

This case refers to stability of the compacted earthen perimeter embankment and underlying foundation soils of the facility after construction and prior to waste placement (i.e., when the perimeter embankment is un-buttressed by waste, and therefore more critical). The critical cross sections for perimeter embankment slope stability and related deep-seated foundation "bearing capacity" mode of stability occur along the highest and steepest slopes. The perimeter embankment cross section selected for stability analysis is identified as Section C, and the location of this cross section is shown on Figure B2-2 of these calculations. As shown on Figure B2-2, the earthen perimeter embankment incorporates 2 horizontal: 1 vertical (2H:1V) external slopes and 3H:1V internal slopes. The 2H:1V exterior slope was analyzed for both short-term and long-term stability assuming circular slip surfaces. The long term stability of the exterior slope is important in case waste placement is delayed for a period of time that is sufficient to allow soil drainage of the perimeter embankment and foundation. By inspection, the flatter 3H:1V interior slope is considered stable if the steeper 2H:1V slope is found to be stable. Therefore, separate analysis of the 3H:1V perimeter embankment slope is not necessary.

4.2 Liner System and Final Cover System Veneer

These cases refer to stability of the relatively thin veneer of liner system and final cover system layers. For these cases, the potential for sliding to occur within the components of the liner or cover system materials or along interfaces between the components (e.g., clay liner-to-geomembrane interface) is evaluated. The cross sections considered for the veneer stability analysis are described in Appendix B2-1 of this calculation package.

4.3 Interim Landfill Slopes

These cases refer to stability of interim landfill conditions (including the liner and the waste mass slopes) as waste placement is progressing. For this analysis the interim waste slopes are assumed to be inclined at 2H:1V slopes in interior portions of the landfill as filling occurs. The interior interim waste slope is assumed un-buttressed during these interim conditions, since the slope will be set-back from the edge of the subcell for the operational storm water storage area.

According to the phasing plan presented on Drawing 5 of Exhibit A of the Engineering Report, waste will be placed in lifts spanning across Subcells 9 and 11 up to an interim configuration with a maximum waste elevation of approximately 1493 ft above mean sea level (ft, MSL) before waste placement starts in Subcells 12 through 22. For this waste filling progression, the critical interim slope would be expected to occur when there is the highest un-buttressed slope of interim waste. Accordingly, the critical interim cross section selected for stability analysis is that when waste filling is occurring in Subcells 9 and 11, up to an elevation of approximately 1493 ft, MSL. The location of this cross section, which is identified as Section A, is shown on Figures B2-2 and B2-3. The stability of the interim slopes was evaluated using circular and block slip surfaces passing through the waste and/or the weakest liner material or interface of the liner system.

4.4 Final Landfill Slopes

This case refers to stability of the overall landfill (including the perimeter embankment, waste mass, and foundation) when constructed to final conditions. The critical case for stability of the Lone Mountain Facility Landfill Cell 15 at final grades was evaluated for Section B (Figures B2-2 and B2-3). This section was evaluated for both short-term conditions (representing the time of closure when landfilling has just been completed) and long-term (representing post-closure) conditions. The stability of the landfill at final grades was evaluated using circular and block-type slip surfaces that pass through or along the weakest material and interface of the liner system, through foundation materials, through the waste mass, and/or through the perimeter embankment.

5. LINER SYSTEM AND FINAL COVER SYSTEM MATERIALS

5.1 Liner System

The liner system for the Lone Mountain Facility Landfill Cell 15 consists of the following components, from top to bottom:

- 2-ft thick protective cover;
- upper geocomposite drainage layer;
- upper 60-mil thick high density polyethylene (HDPE) geomembrane liner;
- geosynthetic clay liner (GCL);
- middle 60-mil thick HDPE geomembrane liner (only on floor);
- bottom geocomposite drainage layer;
- bottom 60-mil thick HDPE geomembrane liner; and
- 3-ft thick compacted soil liner.

It is noted that in terms of these slope stability analyses, there is no distinction or limitation made regarding whether the geomembranes are textured or smooth, nor whether the geocomposite drainage layers are single or double-sided. Instead, the minimum required interface strength is back-calculated, and as long as the site-specific liner materials meet or exceed these strengths, they would be allowable for use in terms of slope stability performance. In all cases, however, the liner system construction must meet the other requirements specified elsewhere in the Landfill Cell 15 Engineering Report and permit.

5.2 Final Cover System

The final cover system cross section consists of the following components from top to bottom:

- 6-in. thick topsoil with vegetation;
- 1.5-ft thick protective cover soil;
- geocomposite drainage layer;
- 60-mil thick high density polyethylene (HDPE) geomembrane liner;
- geosynthetic clay liner (GCL); and
- 12-in. thick interim cover soil (bedding clay).

As with the liner system, it is noted that no distinction or limitation is made regarding whether the final cover system geomembrane is textured or smooth, nor whether the geocomposite drainage layer is single or double-sided. Instead, the minimum required interface strength is back-calculated, and as long as the site-specific final cover system materials meet or exceed these strengths, they would be allowable for use in terms of slope stability performance. In all cases, however, the final cover system construction must meet the other requirements specified elsewhere in the Landfill Cell 15 Engineering Report and permit.

6. MATERIAL PARAMETERS

6.1 Foundation Soils

The geotechnical site characterization of the foundation soils beneath Landfill Cell 15 is presented in Exhibit B-1 of the Landfill Cell 15 Engineering Report. As discussed in Exhibit B-1, the foundation soils beneath the site have been investigated as part of past site permitting efforts, and also in 2013 as part of this Landfill Cell 15 permit modification application effort. The subsurface soils are divided into two layers: (i) Upper Clay; and (ii) Claystone/Siltstone.

Geotechnical laboratory tests conducted during the February 2010 and October 2013 site investigation programs included water content and dry unit weight tests, one-dimensional (1-D) consolidation tests, unconsolidated undrained (UU) triaxial compression tests, and consolidated undrained (CU) triaxial compression tests (see Exhibit B-1 of the Landfill Cell 15 Engineering Report). The results from these tests were used to estimate the unit weight (γ), and the shear strength (drained cohesion and friction angle, c' and ϕ', as well as the undrained cohesion and friction angle, c and ϕ) of the foundation strata.

The foundation soil parameters selected for use in these stability analyses are summarized below. For the upper clay material, a conservative effective stress failure envelope, consisting of the minimum measured ϕ' and minimum measured c' from two separate CU tests, was selected for analysis.

Stratum	Total Unit Weight γ (pcf)	Drained Strength		Undrained Strength	
		c' (psf)	ϕ' (degrees)	c (psf)	ϕ (degrees)
Upper Clay	124	634	14.9	3,000	0
Claystone/Siltstone	125	547	30.8	5,800	0

6.2 Perimeter Embankment Soil

On-site soil (generally classified as CL) will likely be used to construct the perimeter embankments. Tables B2-1 and B2-2 present typical unit weights and strength properties for compacted soils. The moist unit weight of the compacted perimeter embankment soil was assumed to be 120 pcf. This value falls within the range of moist unit weights calculated for lightly to moderately compacted clays using the maximum dry unit weight and optimum moisture content values in Table B2-1.

The undrained shear strength (i.e. cohesion) of compacted perimeter embankment soil was assumed to be 1,600 psf. This assumed value is lower than the typical shear strength reported (i.e., 1,800 psf) for as-compacted CL soil in literature (Table B2-1) and is, therefore, considered conservative.

Average reported values by Duncan et al. (1989; see Table B2-2) were used for the drained shear strength of the perimeter embankment soil (i.e., a drained friction angle, ϕ', of 28° and a cohesion, c', of 285 psf).

6.3 Liner and Final Cover System

Both the liner system and final cover system have two soil components (i.e., cover soil and soil liner/bedding clay) and two geosynthetic components (i.e., drainage geocomposite, and geomembrane). The shear strength of the soil components of the liner system and final cover system were estimated from published values for compacted soils. Tables B2-1 and B2-2 present typical strength properties for compacted soils. Table B2-3 presents typical interface friction values for common geosynthetic and soil interfaces; these values were used to assess the reasonableness of the back-calculated minimum strength values. A discussion of the selection of the unit weight and shear strength values used for the veneer slope stability analysis is provided below.

6.3.1 Final Cover Soil

On-site soil (generally classified as CL) will likely be used as cover soil for the final cover system (with a layer of topsoil placed above that). The moist unit weight of the compacted cover soil and topsoil was assumed to be 120 pcf, as previously assumed for the perimeter embankment soil. For analysis of final cover system veneer stability, the drained strength of the cover soil will be used. A drained strength analysis is appropriate as the cover soil will be exposed for many years after the final cover system is constructed. The short-term stability right after construction of the final cover will also be checked using an undrained strength analysis.

Typical undrained shear strength (i.e. cohesion) for CL soils range from 270 psf for saturated conditions to 1,800 psf for as-compacted conditions (Table B2-1). Since the protective cover soil may be only lightly to moderately compacted, the protective cover may not achieve the full "as-compacted" strengths indicated in Table B2-1. Also, the presence of the drainage layer beneath the protective cover should prevent the soil from becoming saturated at the toe of the slope where the buttress effect occurs. Based on the above rationale, an undrained shear strength of 400 psf was selected for the protective cover. This value is believed to be a reasonable yet conservative strength to presume for design since it is substantially lower than the typical strength that is achieved by "as-compacted" soils as indicated in Table B2-1.

The drained shear strength parameters for the final cover CL soil were assumed to be the same as for the perimeter embankment soils. Accordingly, the compacted clay of the final cover system was assumed to have an average drained friction angle, ϕ', of 28° and a cohesion, c', of 285 psf.

6.3.2 Liner Soil

The properties of the protective cover soil for the liner system were assumed to be the same as for the final cover soil. Consequently, the undrained shear strength of the compacted soil liner was assumed to be 400 psf, and the drained friction angle, ϕ', and a cohesion, c', were assumed to be 28° of 285 psf, respectively. The moist unit weight of the protective cover soil was assumed to be 120 pcf.

The compacted soil liner will likely be constructed from on-site soil generally classified as CL. The properties of the compacted soil liner were assumed to be the same as for the compacted perimeter embankment soils. Accordingly, the compacted soil liner was assumed to have an average drained friction angle, ϕ', of 28° and a cohesion, c', of 285 psf. The undrained shear strength of the compacted soil liner was assumed to be 1,600 psf and the moist unit weight was assumed to be 120 pcf.

6.3.3 Interface Shear Strength

Typical peak strengths of the different liner system and final cover system interfaces are discussed in this section. These values are not used in the stability analysis *per se*, but are presented to assess whether the required interface friction angles back-calculated from the stability analyses are reasonable. It should be noted that the use of values close to the upper end of the range of values is acceptable in design for veneer stability because the failure envelopes for interface testing are generally curved, with higher interface friction angles at lower stresses representative of veneer stability conditions.

The peak shear strength between the soil component of the liner system and the final cover system, and the geomembrane liner and geotextile filter component of the geocomposite was estimated using the information presented in Tables B2-1 through B2-3, and assuming drained conditions at the interface. Assuming an effective-stress friction angle of 28º for the CL soil of the liner system and $\tan\delta$ / $\tan\phi$ = 0.4 to 0.8 for a geomembrane (smooth or textured) / clayey soil interface, δ = 11º to 23º. Assuming an effective-stress friction angle of 28º for the CL soil of the final cover system and $\tan\delta$ / $\tan\phi$ = 0.8 to 0.9 for a geotextile / clayey soil interface, δ = 23º to 25.5º. The GCL/compacted soil liner interface was assumed to have the same strength as the soil/geotextile interface (i.e. 23º to 25.5º).

Based on Table B2-3, the secant peak interface friction angle for the geotextile/geomembrane interface could range between 7º and 35º depending on whether the geomembrane is textured or not. The large-displacement secant friction angle for the same interface ranges between 6º and 11º, based on available data. The secant interface friction angle for a geonet/geomembrane is on the same order, ranging between 7º and 29º for the peak and between 10º and 20º for the large-displacement friction angles.

Based on Table B2-3, the peak secant interface friction angle for the geomembrane/GCL interface may be on the order of 8° to 37° while the large displacement friction angle may be on the order of 6° to 10°.

With extended periods of loading, stitching that brings together the geosynthetic components of a GCL and acts as reinforcement might break due to creep. In this case, the drained strength of the GCL might drop to the drained strength of the bentonite clay component of the GCL. Based on a study by Bonaparte et al. (1996), the angle of friction for hydrated GCL under drained conditions is about 12° for stresses up to 2,000 psf, and decreases to a value of 6° at stresses of about 10,000 psf and above. It is noted that for the Landfill Cell 15 liner system, it is considered unlikely that the GCL would hydrate, since it is sandwiched between geomembranes. Nevertheless, a conservative approach was taken by using these lower hydrated GCL strengths and by accounting for potential creep effects.

Based on available data, the interfaces that could potentially have the most critical interface friction angle are the geotextile/geomembrane or geonet/geomembrane on the side slope liner and final cover systems, and the geomembrane/GCL interface on the side slope liner system.

6.4 Waste

Based on visual observation of the waste placed in the Lone Mountain Facility Landfill Cell 15, and discussions with facility personnel, the waste stream can be described as being similar in physical appearance to a construction and demolition type of waste mixed with other industrial and hazardous types of soils and debris. Typical friction angle in the range of 40° to 60° was reported by Sarsby (2000) for demolition wastes. A friction angle of 45° under both undrained and drained shearing conditions was assumed in the stability analyses. Based on the observation of the currently existing very steep waste slope at the site, a friction angle of 45° is considered conservative and reasonable. The average unit weight of the waste was assumed to be 120 pcf, as assumed in the previously submitted permit application and considered reasonable for these analyses.

6.5 Summary of Material Parameters Used in Stability Analysis

The table presented below summarizes the material parameters used in the stability analysis.

Layer	γ (pcf)	Drained Strength		Undrained Strength	
		c' (psf)	ϕ' (degrees)	c (psf)	ϕ (degrees)
Upper Clay	124	634	14.9	3,000	0
Claystone/Siltstone	125	547	30.8	5,800	0
Perimeter Embankment	120	285	28	1600	0
Protective Cover Soil	120	285	28	400	0
Compacted Soil Liner	120	285	28	1600	0
Waste	120	0	45	0	45
Liner and cover interface	-	$\delta_{interface}$ Back calculated			

Note: γ = moist unit weight; c' = effective-stress cohesion; ϕ' = effective-stress friction angle; c = undrained cohesion; ϕ = undrained friction angle; and δ = secant effective-stress interface friction angle.

7. GROUNDWATER ELEVATION

A historical-high groundwater contour map was prepared by Cameron-Cole, Inc. in December 2013 and is presented on Drawing 3 in Exhibit A of the Engineering Report. In general, the data shows that groundwater is located at a relatively shallow depth beneath the ground surface and in a manner that generally mimics the natural surface topography. The Landfill Cell 15 subcells designed as part of this evaluation are configured with a 5-ft minimum separation distance between the top of the compacted clay liner elevation and the highest historical groundwater table; this water level was also used in the slope stability calculations to be conservative.

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

8. RESULTS

8.1 Perimeter Embankment Slopes and Foundation

A summary of the evaluated perimeter embankment stability scenarios and calculated factors of safety is presented in the following table. The SLIDE computer output and figure with the critical failure surface are presented in Appendix B2-2.

Perimeter Embankment Slopes Shear Surface Scenario	**Calculated Factor of Safety (✓ if ≥ Target)**	**Target Minimum Calculated Factor of Safety**
2H:1V slope: Circular shear surfaces through the perimeter embankment and foundation (short-term stability)	2.16✓	1.25
2H:1V slope: Circular shear surfaces through the perimeter embankment (long-term stability of temporary slope)	1.62✓	1.50

As shown above, the calculated factors of safety (FS) for the 2H:1V perimeter embankment slopes and foundation are 2.16 and 1.62, respectively for the short-term and long-term stability. These factors of safety are greater than the target factors of safety of 1.25 and 1.50, respectively, for short-term and long-term conditions. Therefore, the calculated factors of safety are considered acceptable.

8.2 Liner System and Final Cover System Veneer

The veneer stability analyses are presented in Appendix B2-1. The results are summarized below.

Liner system and final cover system Veneer Scenario	Calculated Factor of Safety (✓ if ≥ Target)	Target Minimum Calculated Factor of Safety
Liner System (short-term)		
back-calculated peak interface friction angle ($\delta_{interface}$ = 9.7°)	1.254✓	1.25
back-calculated large-displacement interface friction angle ($\delta_{interface,LD}$ = 5.0°)	1.003✓	1.00
Liner System (long-term)		
back-calculated peak interface friction angle ($\delta_{interface}$ = 9.7°)	1.31✓	1.25
back-calculated large-displacement interface friction angle ($\delta_{interface,LD}$ = 5.0°)	1.055✓	1.00
Final Cover System (short-term)		
back-calculated peak interface friction angle ($\delta_{interface}$ = 6.4°)	1.54✓	1.50
back-calculated large-displacement interface friction angle ($\delta_{interface,LD}$ = 4.4°)	1.19✓	1.15
Final Cover System (long-term)		
back-calculated peak interface friction angle ($\delta_{interface}$ = 6.4°)	1.51✓	1.50
back-calculated large-displacement interface friction angle ($\delta_{interface,LD}$ = 4.4°)	1.16✓	1.15

8.3 Interim Landfill Slopes

As previously mentioned, the interim scenario considered one interim slope located at the critical cross section A. Also, for sliding along the liner system, the analyses back-calculated the minimum allowable liner interface shear strength that would yield acceptable factors of safety. These analyzed scenarios are summarized as follows:

- block-type shear surfaces along the liner system with waste placed across Subcells 9 and 11 and up to an elevation of 1493 ft, MSL:
  - the back-calculated peak interface friction angle needed to achieve a FS=1.25 was evaluated;
  - the back-calculated large-displacement interface friction angle needed to achieve a FS=1.0 was evaluated; and
- circular shear surfaces through the waste mass.

The results of the analysis are summarized below. The SLIDE computer output and figures that illustrate each of the shear surface scenarios and show the critical failure surface for each scenario are presented in Appendix B2-2.

Interim Landfill Slopes Shear Surface Scenario	**Calculated Factor of Safety (✓ if ≥ Target)**	**Target Minimum Calculated Factor of Safety**
Block-type shear surface along the liner system with waste placed across Subcells 9 and 11 and up to an elevation of 1,493 ft		
back-calculated peak interface friction angle ($\delta_{interface}$ = 9.8°)	1.26✓	1.25
back-calculated large-displacement interface friction angle ($\delta_{interface,LD}$ = 6.0°)	1.02✓	1.00
Circular shear surfaces through the waste	1.91✓	1.25

As shown above, block-type shear surfaces extending along the liner system have calculated factors of safety that are greater than or equal to the target when the liner system components meet certain minimum shear strength criteria. The minimum required liner interface shear strengths for all of the scenarios evaluated are presented in Section 9. Also, the circular shear surface through the waste slope has a calculated factor of safety (1.91) that is well above the target factor of safety of 1.25

Written by:	A. Brown	Date:	2/24/2014	Reviewed by:	S. Graves	Date:	3/5/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

8.4 Final Landfill Slopes and Foundation

As previously mentioned, two shear surface scenarios were considered for the final landfill slopes at the time of closure (short-term stability) and for post-closure (long-term stability):

- block-type shear surfaces through the waste and along the liner system; and
- circular shear surfaces through the waste, liner system, and foundation soils.

The results of the analysis are summarized below. The SLIDE computer output and figures that illustrate each of the shear surface scenarios and show the critical failure surface for each scenario are presented in Appendix B2-2.

Final Landfill Slopes Shear Surface Scenario	Calculated Factor of Safety (✓ if ≥ Target)	Target Minimum Calculated Factor of Safety
Stability at closure (short-term)		
block-type shear surfaces through the waste and along the liner system (peak interface friction angle $\delta_{interface}$ = 9.8°)	1.91✓	1.50
block-type shear surfaces through the waste and along the liner system (large displacement interface friction angle $\delta_{interface,LD}$ = 6.0°)	1.88✓	1.15
circular shear surfaces through the waste, liner system, and foundation soils	2.22✓	1.50
Post-closure stability (long-term)		
block-type shear surfaces through the waste and along the liner system (peak interface friction angle $\delta_{interface}$ = 9.8°)	3.51✓	1.50
block-type shear surfaces through the waste and along the liner system (large displacement interface friction angle $\delta_{interface,LD}$ = 6.0°)	2.68 ✓	1.15
circular shear surfaces through the waste, liner system, and foundation soils	1.93✓	1.50

As shown above, for each considered shear surface scenario, the calculated factor of safety of the final landfill configuration is greater than or equal to the target minimum calculated factor of safety. The previously calculated minimum interface friction angles of 9.8^{o} (peak strengths) and 6.0^{o} (large displacement strengths) were assumed in these calculations.

9. LINER AND FINAL COVER MINIMUM INTERFACE STRENGTH VALUES

The table presented below summarizes the back-calculated minimum required peak and large-displacement shear strengths of the liner system and final cover system components. These incorporate the results of the interim and final slope stability analyses presented herein, as well as the results of the veneer stability analyses presented in Appendix B2-1 of this calculation package.

	Normal Stress (psf)	Peak Effective-Stress Interface Strength		Large-Displacement Effective-Stress Interface Strength	
		Shear Strength (psf)	Equivalent Secant Friction Angle (°)	Shear Strength (psf)	Equivalent Secant Friction Angle (°)
Liner System and GCL (internal)	240	40.4	9.7	20.9	5.0
	6,000	1,021.3	9.8	627.2	6.0
Final Cover System	240	26.8	6.4	18.4	4.4

The above values should be specified as material specifications for the selected liner and final cover system components, and should be verified by laboratory testing using site specific materials and interfaces prior to construction. As previously mentioned, the results of this stability analysis do not necessarily limit the geomembrane required for the liner and final cover systems to textured, nor do they limit the type of geocomposite or geotextile needed as long as the minimum interface friction angles are exceeded.

It is noted that a comparison of typical interface and GCL internal shear strengths that can usually be achieved (as reported in technical literature and from Geosyntec's project experience as shown in Table B2-3) versus the above required strengths shows that the required strengths can likely be achieved. Moreover, a 2010 site specific interface friction test between textured geomembrane and compacted clay resulted a peak interface friction angle of 22.5^{o} and a large-displacement friction angle of 16^{o} (Appendix B2-3). These demonstrate the reasonableness of the design.

10. REFERENCES

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TABLES

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Table B2-1. Typical Properties of Compacted Soils (after NAVFAC, 1986).

Group Symbol	Soil Type	Range of Maximum Dry Unit Weight (pcf)	Range of Optimum Moisture Content (%)	Typical Strength Characteristics			
				Cohesion (as compacted) (psf)	Cohesion (saturated) (psf)	ϕ, Effective-Stress Envelope (degrees)	Tanϕ
SP	Poorly graded clean sands, sand-gravel mix.	100 - 120	12-21	0	0	37	0.74
SM	Silty sands, poorly graded sand-silt mix.	110 - 125	11 - 16	1,050	420	34	0.67
SM-SC	Sand-silt clay mix. with slightly plastic fines	110 - 130	11 - 15	1,050	300	33	0.66
SC	Clayey sands, poorly-graded sand-clay mix.	105 - 125	11 - 19	1,550	230	31	0.60
ML	Inorganic silts and clayey silts	95 - 120	12 - 24	1,400	190	32	0.62
CL	Inorganic clays of low to medium plasticity	95 - 120	12 - 24	1,800	270	28	0.54
CH	Inorganic clays of high plasticity	75 - 105	19 - 36	2,150	230	19	0.35

Table B2-2. Effective-Stress Shear Strength Properties of Compacted Soils (Duncan et al., 1989)

Group Symbol	Soil Type	Maximum Dry Unit Weight (pcf)	Optimum Moisture Content (%)	Typical Strength Characteristics	
				ϕ' (degrees)	c' (psf)
CL	Inorganic clays of low to medium plasticity	108 ± 1	17 - 18	28 ± 2	285 ± 40
CH	Inorganic clays of high plasticity	94 ± 2	24 - 27	19 ± 5	245 ± 120

Table B2-3. Summary of Documented Interface Friction Values. (Adapted from tests by Martin et al. (1984), Williams and Houlihan (1986), Koerner et al. (1986), Williams and Houlihan (1987),Williams and Luna (1987), Eid and Stark (1997), Sabatini et al. (1998), Stark et al. (1998), manufacturer's literature, and unpublished results from GeoSyntec Consultants.)

GEOSYNTHETIC / GEOSYNTHETIC	δ_p (1) (degrees)	δ_{ld} (1) (degrees)
Smooth HDPE Geomembrane / Nonwoven Geotextile	7 - 12	6 - 11
Smooth LLDPE Geomembrane / Nonwoven Geotextile	10 - 12	
Textured HDPE Geomembrane / Nonwoven Geotextile	22 - 35	
Smooth HDPE Geomembrane / Geonet	7 - 15	
Textured HDPE Geomembrane / Geonet	7 - 16	10 - 12
Textured HDPE Geomembrane / Geocomposite	17 - 29	13 - 20
Geonet / Nonwoven Geotextile	13 - 22	
Smooth HDPE Geomembrane / GCL (hydrated)	8 - 12	
Textured HDPE Geomembrane / GCL (hydrated)	18 - 37	6 - 10
GEOSYNTHETIC / SOIL	$\tan\delta_p/\tan\phi_p$ (1)	$\tan\delta_{ld}/\tan\phi_{ld}$ (1)
Smooth HDPE Geomembrane / Clay	0.4 - 0.7	0.3 - 0.7
Textured HDPE Geomembrane / Clay	0.8 - 0.9	0.6 - 0.9
Smooth HDPE Geomembrane / Sand	0.5 - 0.6	
Textured HDPE Geomembrane / Sand	0.7 - 0.8	
Needlepunched Nonwoven Geotextile / Sand	0.8 - 1.0	
Needlepunched Nonwoven Geotextile / Angular Gravel	0.7 - 0.9	
Needlepunched Nonwoven Geotextile / Rounded Gravel	0.6 - 0.8	

Note: (1) δ = interface friction angle; ϕ = soil internal friction angle; subscript p = peak and subscript ld = large displacement

FIGURES

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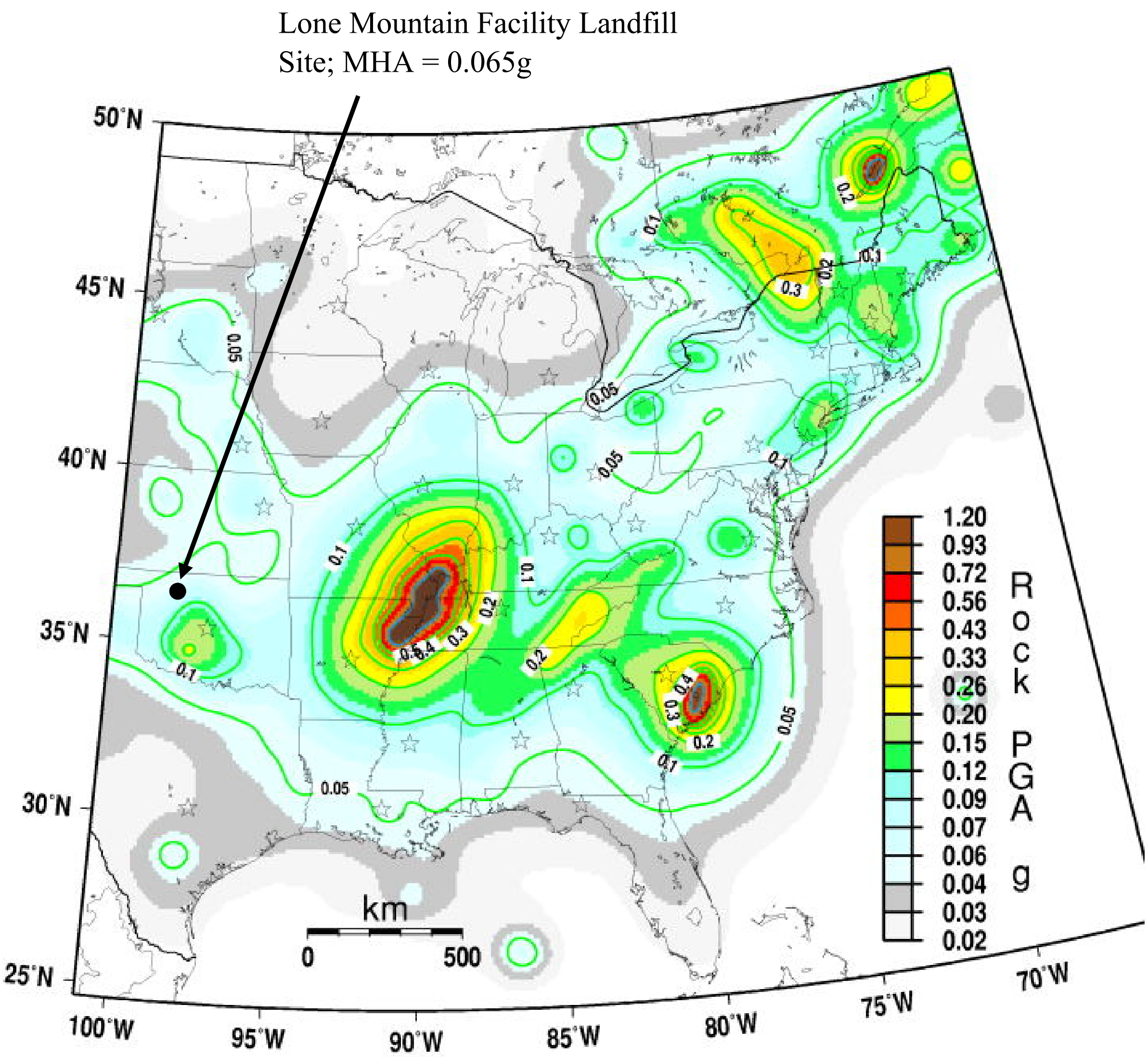

Figure B2-1. 2008 USGS National Seismic Hazard Map showing Maximum Horizontal Acceleration (%g) with 2% Probability of Exceedance in 50 years.

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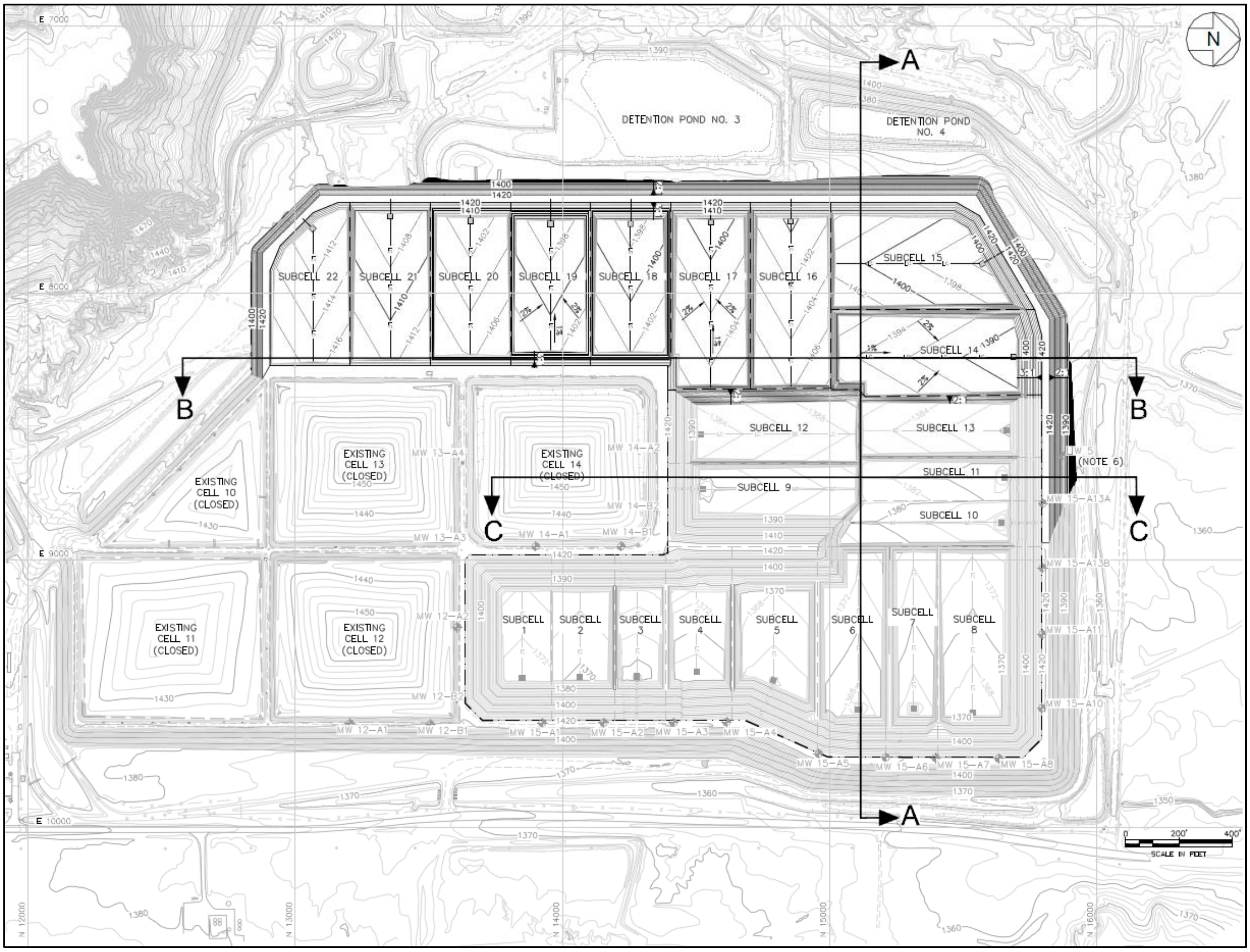

Figure B2-2. Locations of the Stability Cross Sections in Relation to Overall Base Grading Plan.

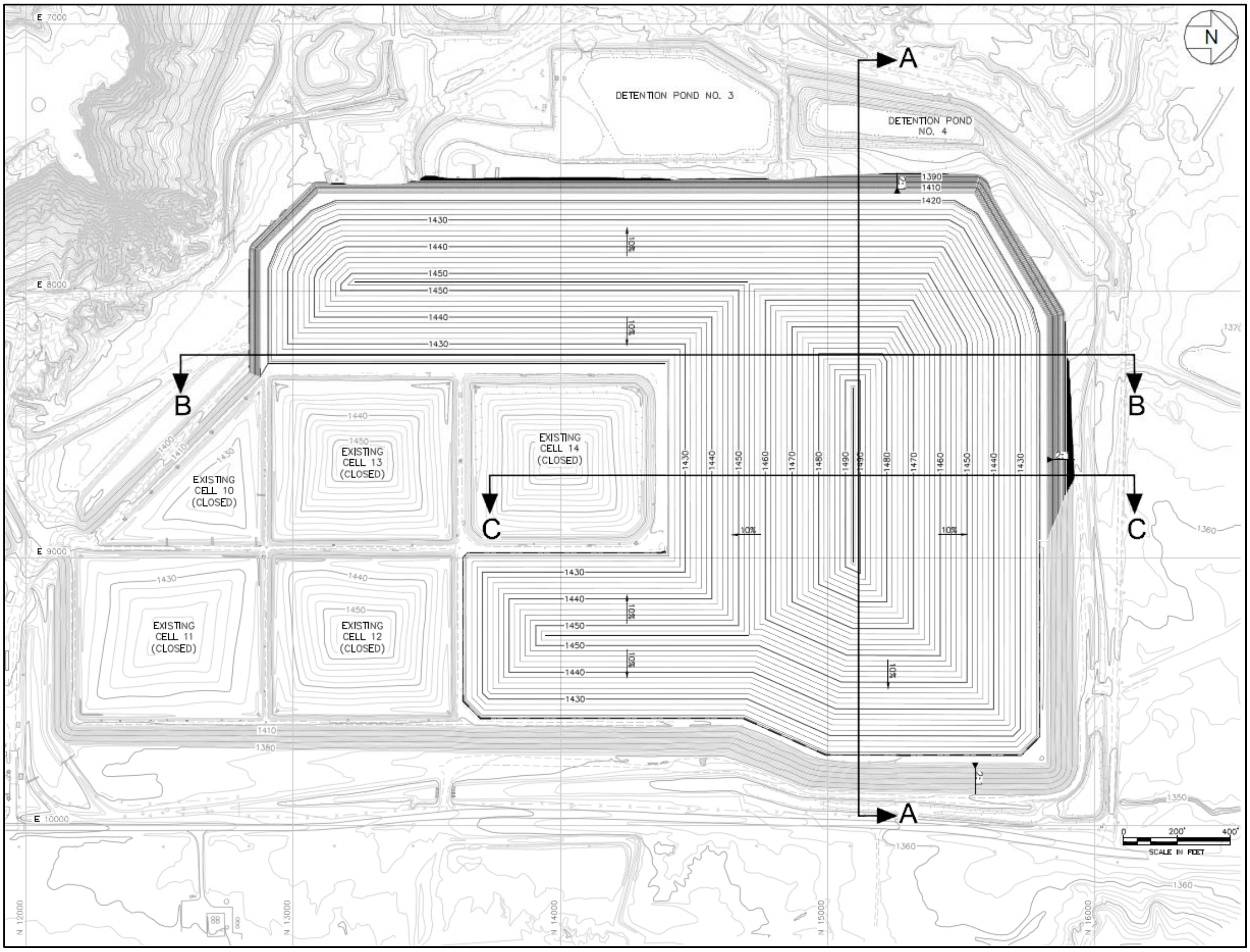

Figure B2-3. Locations of the Stability Cross Sections in Relation to Overall Top of Waste Grading Plan.

APPENDICES

APPENDIX B2-1

VENEER SLOPE STABILITY ANALYSIS

VENEER SLOPE STABILITY ANALYSIS

1. INTRODUCTION

The purpose of this section of the calculation package is to present the veneer slope stability analysis of the sideslope liner system of the Lone Mountain Facility Landfill Cell 15 expansion, for subcells yet-to-be constructed. The liner system will be constructed on the base of the landfill and on 3 horizontal to 1 vertical (3H:1V) side slopes of the perimeter embankment. Since liner system stability represents an interim condition for the period of time between the liner system installation and waste placement against the liner system, the target minimum calculated factor of safety is 1.25. The final cover system will be constructed on the top of final waste side slopes of the landfill. Since final cover system stability represents a long-term condition, the target minimum calculated factor of safety is 1.5. For all cases of veneer stability considered herein, the target minimum calculated factor of safety using large-displacement strengths is 1.0 for liner systems and 1.15 for final cover systems.

The approach taken herein is to back-calculate the minimum peak and large displacement secant effective-stress friction angles for the liner system and final cover system interfaces for a specified maximum height that the protective cover can be placed on the liner or cover system and for a selected target factor of safety. The maximum height that the protective cover can be placed on the liner or cover system was selected to be 15-ft tall vertically (equivalent to 47 ft length along the 3H:1V slope).

2. METHOD

An analysis of veneer stability considers noncircular wedge-type potential slip surfaces that extend along a liner system or final cover system. The critical interface for a liner system or cover system that incorporates geosynthetics typically occurs along an interface between a geosynthetic and an adjacent geosynthetic or soil.

The finite slope factor of safety equation, as formulated by Giroud et al. (1995), is:

$$FS = \left[\frac{\gamma_t(t-t_w)+\gamma_b t_w}{\gamma_t(t-t_w)+\gamma_{sat} t_w}\right]\frac{\tan\delta}{\tan\beta} + \frac{a/\sin\beta}{\gamma_t(t-t_w)+\gamma_{sat} t_w}$$

$$+\left[\frac{\gamma_t(t-t^*_w)+\gamma_b t^*_w}{\gamma_t(t-t_w)+\gamma_{sat} t_w}\right]\left[\frac{\tan\phi/(2\sin\beta\cos^2\beta)}{1-\tan\beta\tan\phi}\right]\frac{t}{h} + \left[\frac{1}{\gamma_t(t-t_w)+\gamma_{sat} t_w}\right]\left[\frac{1/(\sin\beta\cos\beta)}{1-\tan\beta\tan\phi}\right]\frac{ct}{h}$$

where: FS = factor of safety;

δ = interface friction angle;

a = apparent interface adhesion;

ϕ = soil internal friction angle;

c = apparent soil cohesion;

γ_t = moist soil unit weight;

γ_b = buoyant soil unit weight;

γ_{sat} = saturated soil unit weight;

t = depth of cover soil above critical interface;

t_w = water depth above critical interface on the sidewall;

t^*_w = water depth at slope toe;

β = sidewall slope angle; and

h = vertical height of slope.

It should be noted that while the above equation specifically applies to an interface above a geomembrane or similar liquid barrier layer, it could also be applied to interfaces below the geomembrane by changing the coefficient of the first term to 1.0 (i.e., the coefficient of $\tan\delta$ / $\tan\beta$ to 1.0).

The finite slope method is used herein to evaluate the factor of safety for veneer slope stability of the liner system and final cover system for the Lone Mountain Facility Landfill Cell 15 expansion.

It is assumed that the geocomposite drainage layer in the liner system and the geocomposite drainage layer in the final cover system have sufficient hydraulic capacity to convey all liquid percolating into them, and that the peak heads in the drainage layers are less than the thickness of the layers (i.e., $t_w \leq 0.2$ in. at the geocomposite/geomembrane interface). This value of t_w is very small and has negligible impact on the calculated slope stability factor of safety. Thus, the assumption of $t_w = 0$ can be used in the above equation. It is further assumed that leachate collected in the drainage layer at the toe of the liner system side slope will be allowed to outlet without the buildup of excessive hydraulic head at the slope toe (i.e., $t^*_w \leq 0.2$ in.). For the final cover system, it is assumed that drainage layer outlets at the toe of the side slope will be maintained to preclude the buildup of excessive hydraulic head at the slope toe (i.e., $t^*_w \leq 0.2$ in.). With $t_w = 0$ and $t^*_w \approx 0$, the finite slope equation simplifies to:

$$FS = \frac{\tan\delta}{\tan\beta} + \frac{a/\sin\beta}{\gamma_t t} + \left[\frac{\tan\phi/(2\sin\beta\cos^2\beta)}{1-\tan\beta\tan\phi}\right]\frac{t}{h} + \left[\frac{1}{\gamma_t t}\right]\left[\frac{1/(\sin\beta\cos\beta)}{1-\tan\beta\tan\phi}\right]\frac{ct}{h}$$

As discussed, the waste placed in the landfill will be hazardous wastes that have been described by facility personnel as similar to construction and demolition and other industrial-type debris in appearance and physical properties. Therefore, it is considered reasonable to assume the waste will not generate landfill gas (i.e., the waste is non-degradable). Accordingly, the analysis assumes that gas pressures beneath the final cover system are negligible.

3. CRITICAL CROSS SECTION

The critical cases for veneer stability occur along the longest and steepest slopes. The liner grading plan, shown on Drawing 4 in Exhibit A of the Landfill Cell 15 Engineering Report, incorporates 3 horizontal to 1 vertical (3H:1V) side slopes. As previously mentioned, the protective cover height will be limited to 15 ft vertical placement increments.

The final cover grading plan, shown on Drawing 9 in Exhibit A of the Landfill Cell 15 Engineering Report, has 10% side slopes that reach a maximum height of approximately 76 ft at the highest point on the landfill cover (i.e., landfill top deck elevation of 1496 ft above mean sea level (ft, MSL) vs. perimeter embankment elevation of 1420 ft, MSL). Along the perimeter of the final cover system, there is a short slope section with steeper 3H:1V side slopes, as shown on Drawing 20 in Exhibit A of the Landfill Cell 15 Engineering Report. The short perimeter section of 3H:1V slopes was analyzed and found to be less critical than the longer, taller slopes along the main sections of the final cover system. Consequently, for the final cover system, only the analysis for the more critical 10% side slopes is presented.

4. LINER SYSTEM AND FINAL COVER SYSTEM MATERIALS

4.1 Liner System on Side Slopes

As shown on Drawing 13 in Exhibit A of the Landfill Cell 15 Engineering Report, the side slope liner system cross section consists of the following components from top to bottom:

- 2-ft thick protective cover;
- upper geocomposite drainage layer;
- upper 60-mil thick high density polyethylene (HDPE) geomembrane liner;
- geosynthetic clay liner (GCL);
- middle 60-mil thick HDPE geomembrane liner (only on floor);
- bottom geocomposite drainage layer;
- bottom 60-mil thick HDPE geomembrane liner; and
- 3-ft thick compacted soil liner.

4.2 Final Cover System on Side Slopes

The standard final cover system cross section, as shown on the permit draawings in Exhibit A of the Landfill Cell 15 Engineering Report, consists of the following components from top to bottom:

- 6-in. thick topsoil with vegetation;
- 1.5-ft thick protective cover soil;
- geocomposite drainage layer;
- 60-mil thick high density polyethylene (HDPE) geomembrane liner;
- geosynthetic clay liner (GCL); and
- 12-in. thick interim cover soil (bedding clay).

5. MATERIAL PARAMETERS

The liner system and final cover system material parameters were described in Section 6.3 of the main narrative of the Slope Stability Analysis. In summary, the following material parameters were selected for the veneer stability analyses:

Layer	γ (pcf)	Drained Strength		Undrained Strength	
		c' (psf)	ϕ' (degrees)	c (psf)	ϕ (degrees)
Protective Cover Soil	120	285	28	400	0
Compacted Soil Liner	120	285	28	1600	0
Liner and Cover Interface	-	$\delta_{interface}$ Back calculated			

6. RESULTS OF ANALYSES

6.1 Liner System (3H:1V Side Slopes, δ_{peak}=9.7°, $\delta_{Large\ disp}$=5.0°, β=18.4°, h = 15')

Calculated factors of safety for both short-term and long-term stability of the liner system are presented below.

1. Using peak interface friction angle:

1.i. Undrained soil condition:

$$FS = \frac{\tan 9.7^\circ}{\tan 18.4^\circ} + \left[\frac{1}{(120)(2)}\right]\left[\frac{1/(\sin 18.4^\circ \cos 18.4^\circ)}{1 - \tan 18.4^\circ \tan 0^\circ}\right]\frac{(400)(2)}{(15)}$$

FS = 0.513 + 0.741 = 1.254 (stable (FS = 1.254 >1.25))

1.ii. Drained soil condition:

$$FS = \frac{\tan 9.7^\circ}{\tan 18.4^\circ} + \left[\frac{\tan 28^o /(2\sin 18.4^o \cos^2 18.4^o)}{1 - \tan 18.4^o \tan 28^o}\right]\frac{2}{15} + \left[\frac{1}{120 \times 2}\right]\left[\frac{1/(\sin 18.4^o \cos 18.4^o)}{1 - \tan 18.4^o \tan 28^o}\right]\frac{285 \times 2}{15}$$

FS = 0.51 + 0.15 + 0.64 = 1.31 (stable (FS = 1.31 >1.25))

2. Using large-displacement interface friction angle:

2.i. Undrained soil condition:

$$FS = \frac{\tan 5.0^\circ}{\tan 18.4^\circ} + \left[\frac{1}{(120)(2)}\right]\left[\frac{1/(\sin 18.4^\circ \cos 18.4^\circ)}{1 - \tan 18.4^\circ \tan 0^\circ}\right]\frac{(400)(2)}{(15)}$$

FS = 0.262 + 0.741 = 1.003 (stable (FS = 1.003 >1.0))

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2.ii. Drained soil condition:

$$FS = \frac{\tan 5.0^\circ}{\tan 18.4^\circ} + \left[\frac{\tan 28^o\ /(2\sin 18.4^o\ \cos^2 18.4^o)}{1 - \tan 18.4^o\ \tan 28^o}\right]\frac{2}{15} + \left[\frac{1}{120\times 2}\right]\left[\frac{1/(\sin 18.4^o\ \cos 18.4^o)}{1 - \tan 18.4^o\ \tan 28^o}\right]\frac{285\times 2}{15}$$

FS = 0.262 + 0.151 + 0.641 = 1.055 (stable (FS = 1.055 >1.0))

As shown above, (back-calculated interface strengths), a minimum peak secant interface friction angle of 9.7° and a large displacement secant friction angle of 5.0° at the corresponding normal stress is required to achieve an adequate factor of safety against sliding.

6.2 Final Cover System (10% Slopes, δ_{peak}=6.4°, $\delta_{Large\ disp}$=4.4°, β=5.7°, h = 80')

Calculated factors of safety for both short-term and long-term stability of the final cover system are presented below.

1. Using peak interface friction angle:

1.i. Undrained soil condition:

$$FS = \frac{\tan 6.4^\circ}{\tan 5.7^\circ} + \left[\frac{1}{(120)(2)}\right]\left[\frac{1/(\sin 5.7^\circ\ \cos 5.7^\circ)}{1 - \tan 5.7^\circ\ \tan 0^\circ}\right]\frac{(400)(2)}{(80)}$$

FS = 1.12 + 0.42 = 1.54 (stable (FS = 1.54 >1.5))

1.ii. Drained soil condition:

$$FS = \frac{\tan 6.4^\circ}{\tan 5.7^\circ} + \left[\frac{\tan 28^o\ /(2\sin 5.7^o\ \cos^2 5.7^o)}{1 - \tan 5.7^o\ \tan 28^o}\right]\frac{2}{80} + \left[\frac{1}{(120)(2)}\right]\left[\frac{1/(\sin 5.7^\circ\ \cos 5.7^\circ)}{1 - \tan 5.7^\circ\ \tan 28^\circ}\right]\frac{(285)(2)}{(80)}$$

FS = 1.12 + 0.07 + 0.32 = 1.51 (stable (FS = 1.51 >1.5))

2. Using large-displacement interface friction angle

2.i. Undrained soil condition:

$$FS = \frac{\tan 4.4^\circ}{\tan 5.7^\circ} + \left[\frac{1}{(120)(2)}\right]\left[\frac{1/(\sin 5.7^\circ\ \cos 5.7^\circ)}{1 - \tan 5.7^\circ\ \tan 0^\circ}\right]\frac{(400)(2)}{(80)}$$

FS = 0.77 + 0.42 = 1.19 (stable (FS = 1.19 >1.15))

2.ii. Drained soil condition:

$$FS = \frac{\tan 4.4^\circ}{\tan 5.7^\circ} + \left[\frac{\tan 28^o /(2\sin 5.7^o \cos^2 5.7^o)}{1-\tan 5.7^o \tan 28^o}\right]\frac{2}{80} + \left[\frac{1}{(120)(2)}\right]\left[\frac{1/(\sin 5.7^\circ \cos 5.7^\circ)}{1-\tan 5.7^\circ \tan 28^\circ}\right]\frac{(285)(2)}{(80)}$$

FS = 0.77 + 0.07 + 0.32 = 1.16 (stable (FS = 1.16 >1.15))

Based on the results of the calculations as shown above, a minimum peak secant interface friction angle of 6.4° and a large displacement secant friction angle of 4.4° at the corresponding normal stress is required to achieve the target factors of safety.

7. CONCLUSIONS

For the analyses herein, Geosyntec selected target calculated factors of safety of 1.25 for the liner system and 1.5 for the final cover system when using peak interface friction angles, and factors of safety of 1.0 for the liner system and 1.15 for the final cover system when using large-displacement interface friction angles. Specified minimum interface friction angles needed to achieve the target factors of safety were back-calculated as follows:

For the liner system (assuming a maximum incremental cover placement height of 15 ft.):

- minimum peak secant interface friction angle of 9.7º was back-calculated to achieve a factor of safety of 1.25 for the short-term stability and 1.31 for the long-term stability (at a normal stress of 240 psf); and
- minimum large-displacement secant interface friction angle of 5.0° was back-calculated to achieve a factor of safety 1.00 for the short-term stability and 1.06 for the long-term stability (at a normal stress of 240 psf).

For the final cover system:

- minimum peak secant interface friction angle of 6.4º was back-calculated to achieve a factor of safety of 1.54 for the short-term stability and 1.51 for the long-term stability (at a normal stress of 240 psf); and
- minimum large-displacement secant interface friction angle of 4.4° was back-calculated to achieve a factor of safety 1.19 for the short-term stability and 1.16 for the long-term stability (at a normal stress of 240 psf).

As previously mentioned, the interfaces that could potentially have the most critical interface friction angle are the ones that incorporate a geomembrane (i.e., geotextile/geomembrane, geonet/geomembrane, or geomembrane/GCL). Product specific interface friction angles need to be assessed prior to installation. Site-specific interface testing is recommended prior to construction of the liner system and final cover system. The results of the tests need to exceed the minimum back-calculated interface friction angles to meet the target factor of safety. The maximum incremental height that soil protective cover can be placed against the liner system will be limited to a vertical height of 15 ft to achieve the target calculated factors of safety.

8. REFERENCES

Giroud, J.P., Bachus, R.C., and Bonaparte, R. (1995). "Influence of Water Flow on the Stability of Geosynthetic-Soil Layered Systems on Slopes", *Geosynthetics International*, Vol. 2, No. 6, pp. 1149-1180.

APPENDIX B2-2

SLIDE OUTPUT
Perimeter Embankment Slopes and Foundation
Interim Landfill Slopes
Final Landfill Slopes and Foundation

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Perimeter Embankment Slopes

Perimeter Embankment, 2:1 Slope, Undrained Condition

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section C - Dike - Undrained
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/3/2013, 5:19:16 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Surface Options

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 10
- Circles per division: 10
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Claystone	Upper Clay	Dike
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120
Cohesion [psf]	5800	3000	1600
Friction Angle [deg]	0	0	0
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

Global Minimums

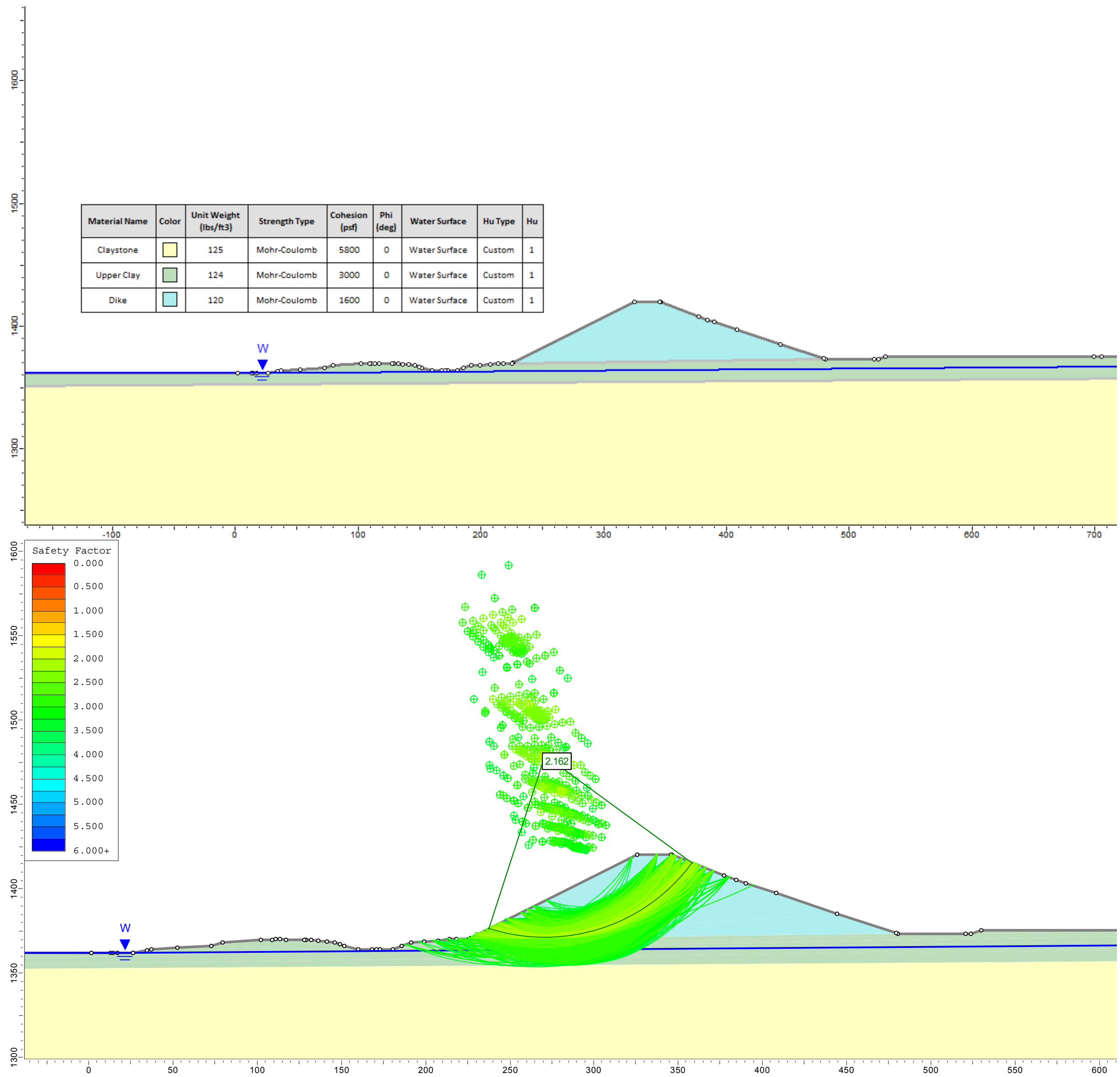
Method: spencer

- FS: 2.161880
- Center: 271.045, 1478.940
- Radius: 108.473
- Left Slip Surface Endpoint: 237.307, 1375.847
- Right Slip Surface Endpoint: 358.757, 1415.119
- Resisting Moment=2.36815e+007 lb-ft
- Driving Moment=1.09541e+007 lb-ft
- Resisting Horizontal Force=194319 lb
- Driving Horizontal Force=89884.1 lb
- Total Slice Area=2804.8 ft2

Geosyntec consultants

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	5800	0	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	3000	0	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1

Perimeter Embankment, 2:1 Slope, Drained Condition

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section C - Dike - Drained
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/3/2013, 5:19:16 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

  - Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Surface Options

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 10
- Circles per division: 10
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Claystone	Upper Clay	Dike
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120
Cohesion [psf]	547	634	285
Friction Angle [deg]	30.8	14.9	28
Water Surface	Water Table	Water Table	Water Table
Hu Value	1	1	1

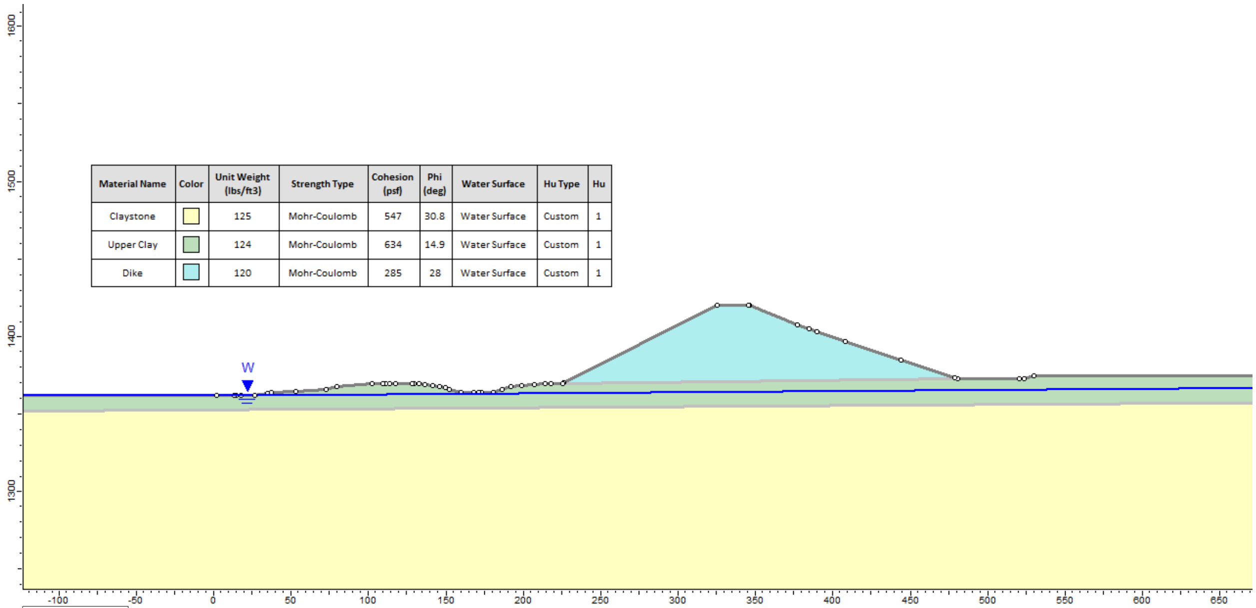
Global Minimums

Method: spencer

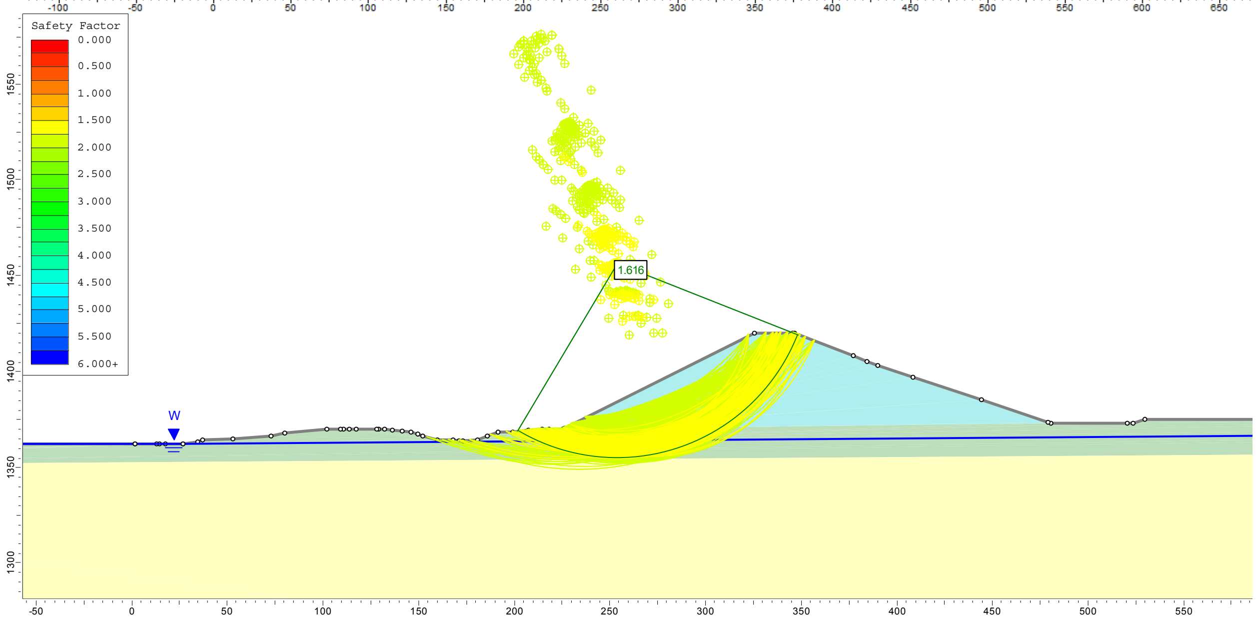
- FS: 1.615720
- Center: 253.791, 1456.086
- Radius: 101.843
- Left Slip Surface Endpoint: 201.677, 1368.586
- Right Slip Surface Endpoint: 348.668, 1419.068
- Resisting Moment=2.49165e+007 lb-ft
- Driving Moment=1.54213e+007 lb-ft
- Resisting Horizontal Force=210900 lb
- Driving Horizontal Force=130530 lb
- Total Slice Area=4022.39 ft2

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	547	30.8	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	634	14.9	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	285	28	Water Surface	Custom	1



Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Interim Slopes

Block-type Shear Surfaces along Liner; Waste Placed across Subcells 9 and 11; Undrained Condition; Peak Interface Friction

Back-calculated δinterface=9.8° for FS = 1.25

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section A - Interim - Undrained Block Peak
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/3/2013, 5:11:12 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 95
- Left Projection Angle (End Angle): 180
- Right Projection Angle (Start Angle): 0
- Right Projection Angle (End Angle): 85
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Claystone	Upper Clay	Clay Liner	Protective Cover	Waste	Dike	Geosynthetic Liner
Color							
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120	120	120	120	120
Cohesion [psf]	5800	3000	1600	400	0	1600	0
Friction Angle [deg]	0	0	0	0	45	0	9.8
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1

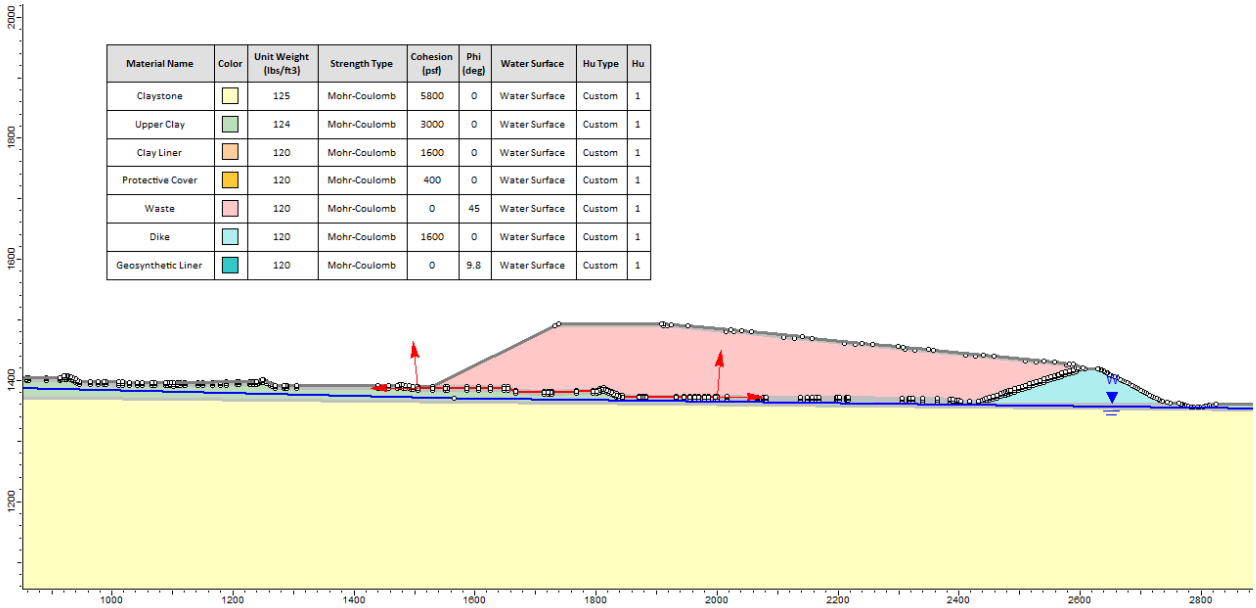
Global Minimums

Method: spencer

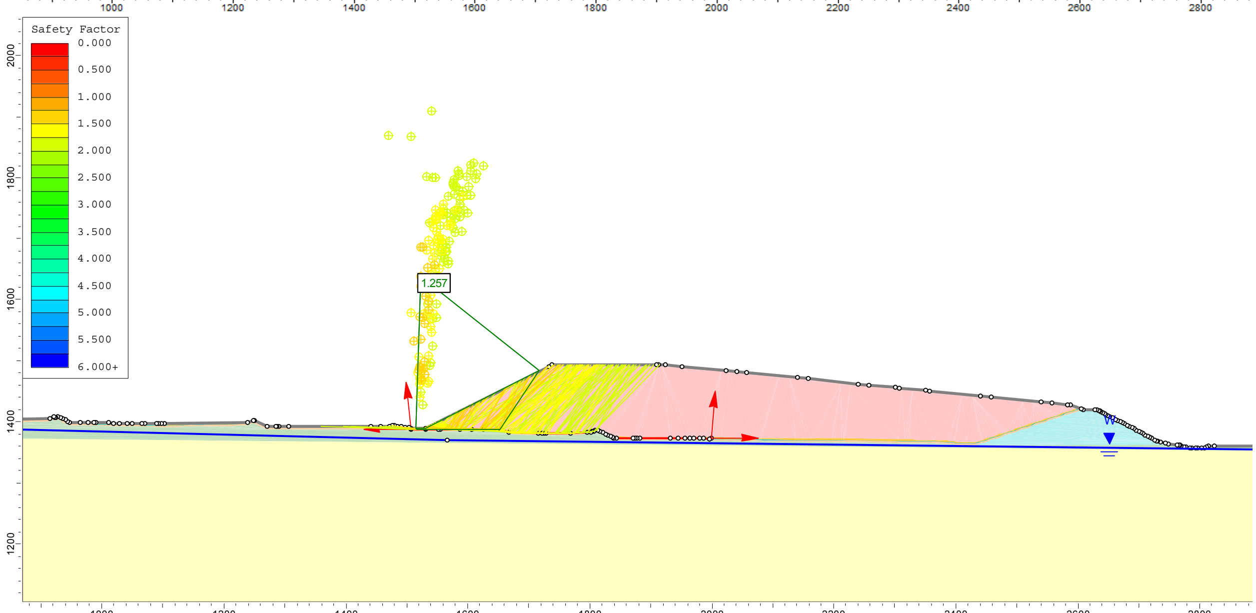
- FS: 1.256730
- Axis Location: 1522.121, 1638.218
- Left Slip Surface Endpoint: 1514.486, 1389.406
- Right Slip Surface Endpoint: 1716.590, 1482.822
- Resisting Moment=6.47419e+007 lb-ft
- Driving Moment=5.15162e+007 lb-ft

Written by:	A. Brown	Date:	2/24/2014	Reviewed by:	S. Graves	Date:	3/5/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

- Resisting Horizontal Force=184848 lb
- Driving Horizontal Force=147087 lb
- Total Slice Area=6082.02 ft2



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	5800	0	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	3000	0	Water Surface	Custom	1
Clay Liner		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Protective Cover		120	Mohr-Coulomb	400	0	Water Surface	Custom	1
Waste		120	Mohr-Coulomb	0	45	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Geosynthetic Liner		120	Mohr-Coulomb	0	9.8	Water Surface	Custom	1



Written by:	A. Brown	Date:	2/24/2014	Reviewed by:	S. Graves	Date:	3/5/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

Block-type Shear Surfaces along Liner; Waste Placed across Subcells 9 and 11; Undrained Condition; Large Displacement Interface Friction

Back-calculated δinterface=6.0° for FS = 1.0

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section A - Interim - Undrained Block LD
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/3/2013, 5:11:12 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Random Numbers

Written by:	A. Brown	Date:	2/24/2014	Reviewed by:	S. Graves	Date:	3/5/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 95
- Left Projection Angle (End Angle): 180
- Right Projection Angle (Start Angle): 0
- Right Projection Angle (End Angle): 85
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Claystone	Upper Clay	Clay Liner	Protective Cover	Waste	Dike	Geosynthetic Liner
Color							
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120	120	120	120	120
Cohesion [psf]	5800	3000	1600	400	0	1600	0
Friction Angle [deg]	0	0	0	0	45	0	6
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1

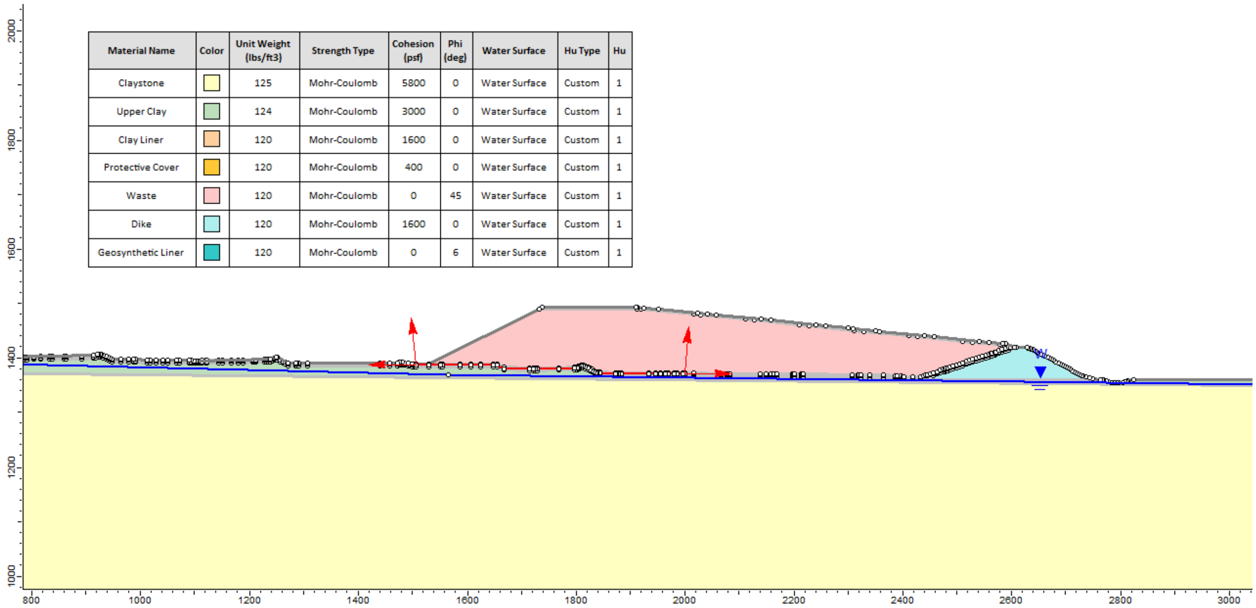
Global Minimums

Method: spencer

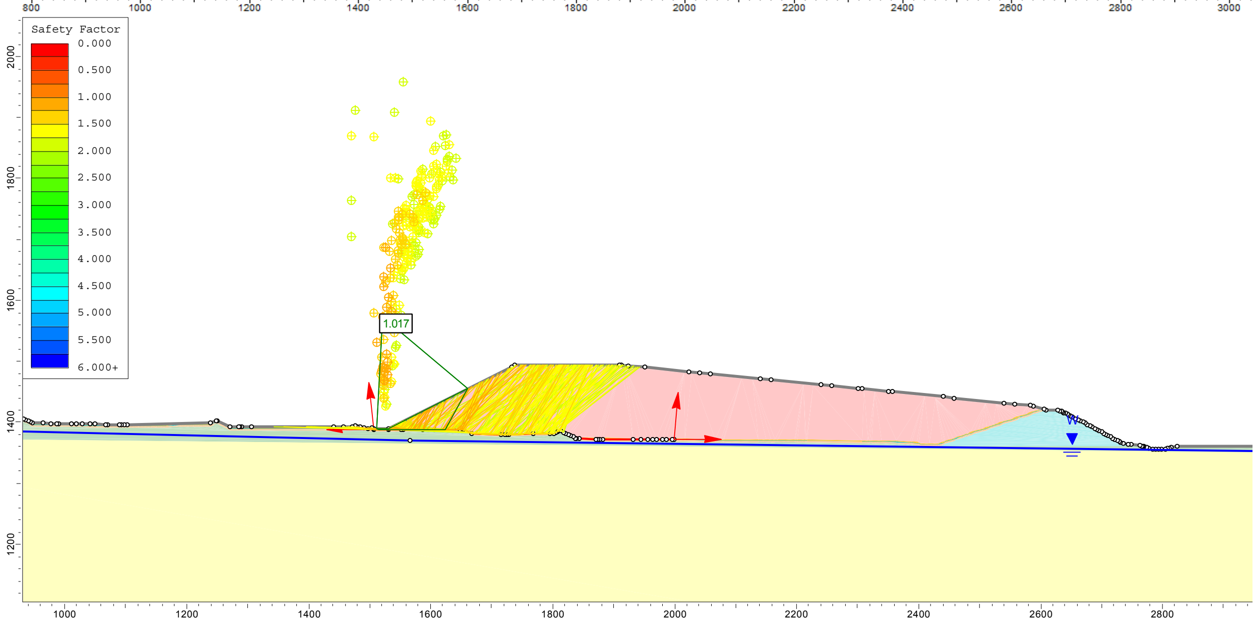
- FS: 1.016940
- Axis Location: 1520.431, 1572.090
- Left Slip Surface Endpoint: 1511.074, 1389.406
- Right Slip Surface Endpoint: 1660.964, 1454.993
- Resisting Moment=1.87365e+007 lb-ft
- Driving Moment=1.84243e+007 lb-ft
- Resisting Horizontal Force=66967.5 lb
- Driving Horizontal Force=65851.7 lb
- Total Slice Area=3362.61 ft2

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	5800	0	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	3000	0	Water Surface	Custom	1
Clay Liner		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Protective Cover		120	Mohr-Coulomb	400	0	Water Surface	Custom	1
Waste		120	Mohr-Coulomb	0	45	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Geosynthetic Liner		120	Mohr-Coulomb	0	6	Water Surface	Custom	1



WASTE STABILITY

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section A - Interim - Undrained Circular Slope Search
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/3/2013, 5:11:12 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

  - Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Surface Options

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

- Surface Type: Circular
- Search Method: Slope Search
- Number of Surfaces: 5000
- Upper Angle: Not Defined
- Lower Angle: Not Defined
- Composite Surfaces: Disabled
- Reverse Curvature: Create Tension Crack
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Claystone	Upper Clay	Clay Liner	Protective Cover	Waste	Top Soil	Dike	Geosynthetic Liner	Structural Fill
Color									
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120	120	120	120	120	120	120
Cohesion [psf]	547	634	285	285	0	285	285	0	285
Friction Angle [deg]	30.8	14.9	28	28	45	28	28	9.8	28
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1	1	1

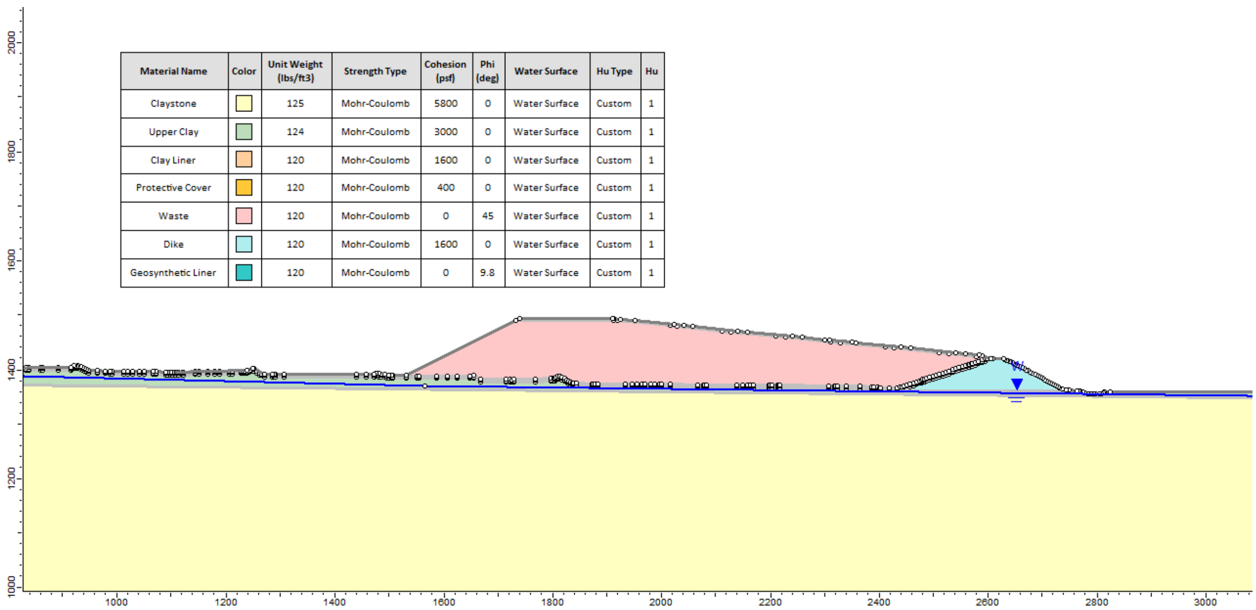
Global Minimums

Method: spencer

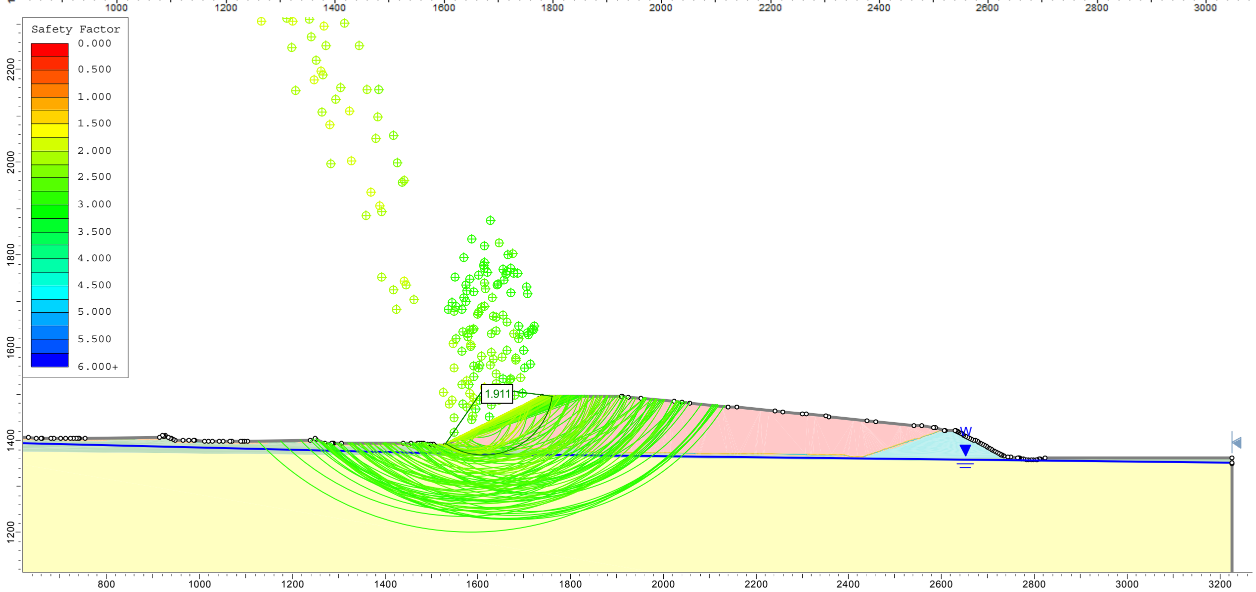
- FS: 1.910870
- Center: 1613.542, 1514.039
- Radius: 149.752
- Left Slip Surface Endpoint: 1530.241, 1389.594
- Right Slip Surface Endpoint: 1761.897, 1493.635
- Resisting Moment=1.43939e+008 lb-ft
- Driving Moment=7.53263e+007 lb-ft
- Resisting Horizontal Force=781467 lb
- Driving Horizontal Force=408959 lb
- Total Slice Area=13764 ft2

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	5800	0	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	3000	0	Water Surface	Custom	1
Clay Liner		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Protective Cover		120	Mohr-Coulomb	400	0	Water Surface	Custom	1
Waste		120	Mohr-Coulomb	0	45	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Geosynthetic Liner		120	Mohr-Coulomb	0	9.8	Water Surface	Custom	1



Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Final Landfill Slopes

(a) Closure

Block-type Shear Surface along Liner; Undrained Condition; Peak Interface Friction

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section B - Final - Undrained Block
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/11/2013, 1:17:00 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces

- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 95
- Left Projection Angle (End Angle): 162
- Right Projection Angle (Start Angle): 0
- Right Projection Angle (End Angle): 85
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Claystone	Upper Clay	Clay Liner	Protective Cover	Waste	Top Soil	Dike	Geosynthetic Liner	Structural Fill
Color									
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120	120	120	120	120	120	120
Cohesion [psf]	5800	3000	1600	400	0	400	1600	0	1600
Friction Angle [deg]	0	0	0	0	45	0	0	9.8	0
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1	1	1

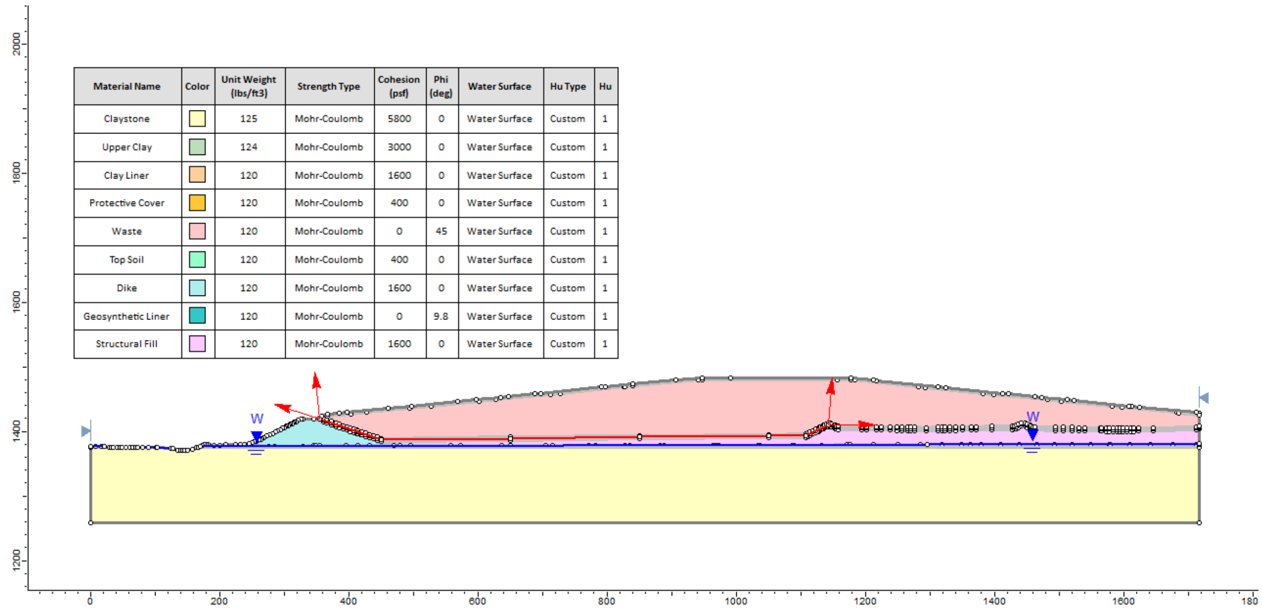
Global Minimums

Method: spencer

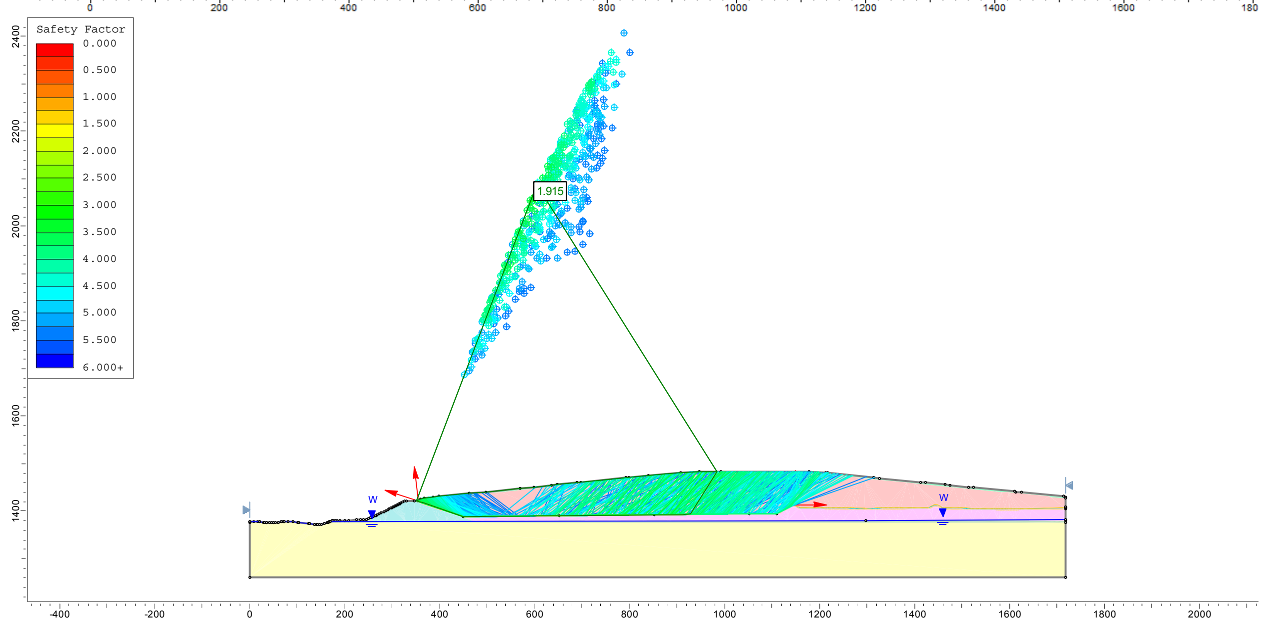
- FS: 1.914530
- Axis Location: 604.174, 2085.758
- Left Slip Surface Endpoint: 349.635, 1421.373

Written by:	A. Brown	Date:	2/24/2014	Reviewed by:	S. Graves	Date:	3/5/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

- Right Slip Surface Endpoint: 982.958, 1483.496
- Resisting Moment=3.51036e+008 lb-ft
- Driving Moment=1.83353e+008 lb-ft
- Resisting Horizontal Force=386961 lb
- Driving Horizontal Force=202118 lb
- Total Slice Area=37587 ft2



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	5800	0	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	3000	0	Water Surface	Custom	1
Clay Liner		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Protective Cover		120	Mohr-Coulomb	400	0	Water Surface	Custom	1
Waste		120	Mohr-Coulomb	0	45	Water Surface	Custom	1
Top Soil		120	Mohr-Coulomb	400	0	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Geosynthetic Liner		120	Mohr-Coulomb	0	9.8	Water Surface	Custom	1
Structural Fill		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1



Written by:	**A. Brown**	Date:	**2/24/2014**	Reviewed by:	**S. Graves**	Date:	**3/5/2014**
Client:	**Clean Harbors**	Project:	**Lone Mountain Facility**	Project No.:	**TXL0380**	Phase No.:	**04**

Block-type Shear Surface along Liner; Undrained Condition; Large Displacement Interface Friction

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section B - Final - Undrained Block LD
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/11/2013, 1:17:00 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used
  - Spencer
- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 95
- Left Projection Angle (End Angle): 162
- Right Projection Angle (Start Angle): 0
- Right Projection Angle (End Angle): 85
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Claystone	Upper Clay	Clay Liner	Protective Cover	Waste	Top Soil	Dike	Geosynthetic Liner	Structural Fill
Color									
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120	120	120	120	120	120	120
Cohesion [psf]	5800	3000	1600	400	0	400	1600	0	1600
Friction Angle [deg]	0	0	0	0	45	0	0	6	0
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1	1	1

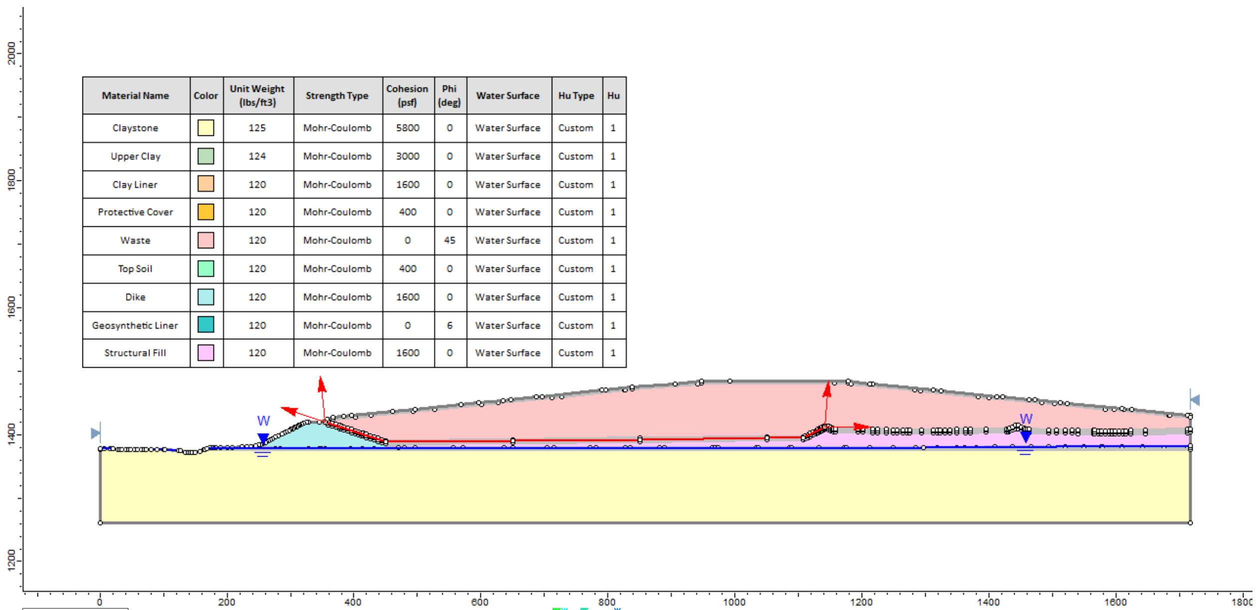
Global Minimums

Method: spencer

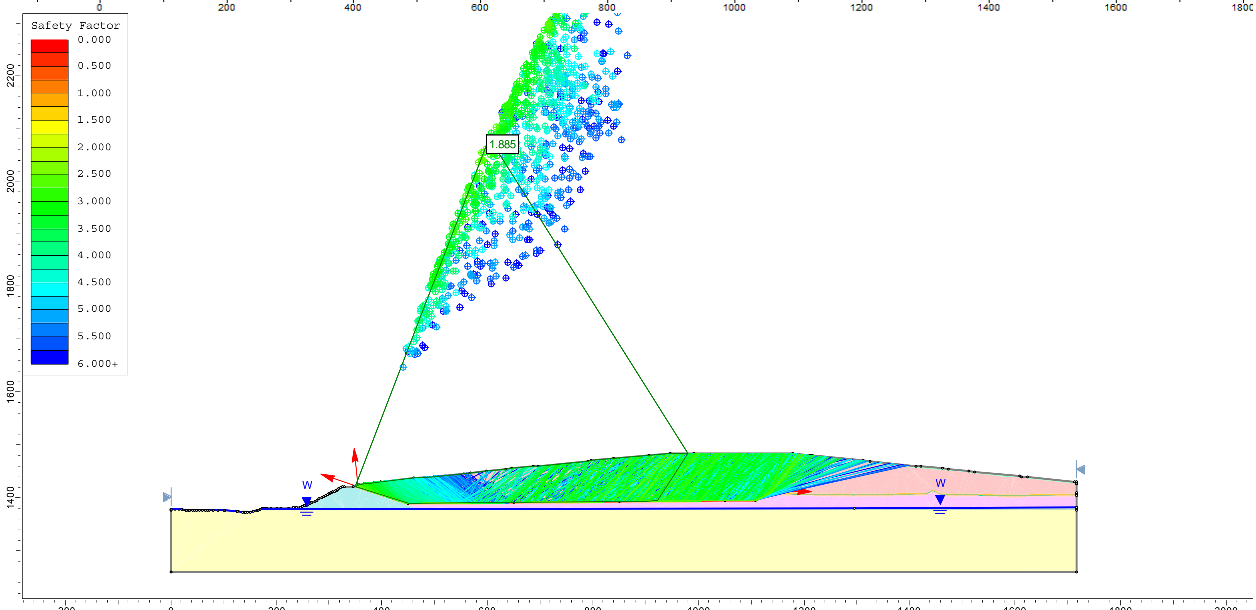
- FS: 1.884550
- Axis Location: 602.525, 2081.827
- Left Slip Surface Endpoint: 349.888, 1421.457
- Right Slip Surface Endpoint: 979.238, 1483.496
- Resisting Moment=3.39712e+008 lb-ft
- Driving Moment=1.80262e+008 lb-ft
- Resisting Horizontal Force=375435 lb
- Driving Horizontal Force=199218 lb
- Total Slice Area=37266.7 ft2

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	5800	0	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	3000	0	Water Surface	Custom	1
Clay Liner		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Protective Cover		120	Mohr-Coulomb	400	0	Water Surface	Custom	1
Waste		120	Mohr-Coulomb	0	45	Water Surface	Custom	1
Top Soil		120	Mohr-Coulomb	400	0	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Geosynthetic Liner		120	Mohr-Coulomb	0	6	Water Surface	Custom	1
Structural Fill		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1



Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Circular Shear Surface; Undrained Condition

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section B - Final - Undrained Circular
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/11/2013, 1:17:00 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Surface Options

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 10
- Circles per division: 10
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Claystone	Upper Clay	Clay Liner	Protective Cover	Waste	Top Soil	Dike	Geosynthetic Liner	Structural Fill
Color									
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120	120	120	120	120	120	120
Cohesion [psf]	5800	3000	1600	400	0	400	1600	0	1600
Friction Angle [deg]	0	0	0	0	45	0	0	9.8	0
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1	1	1

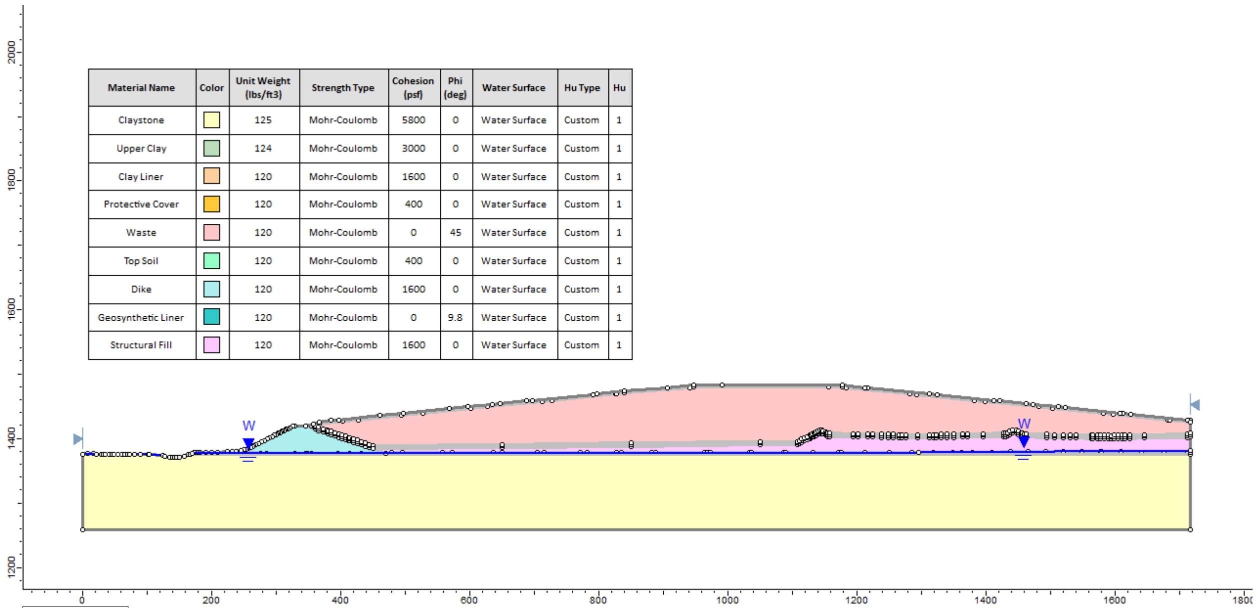
Global Minimums

Method: spencer

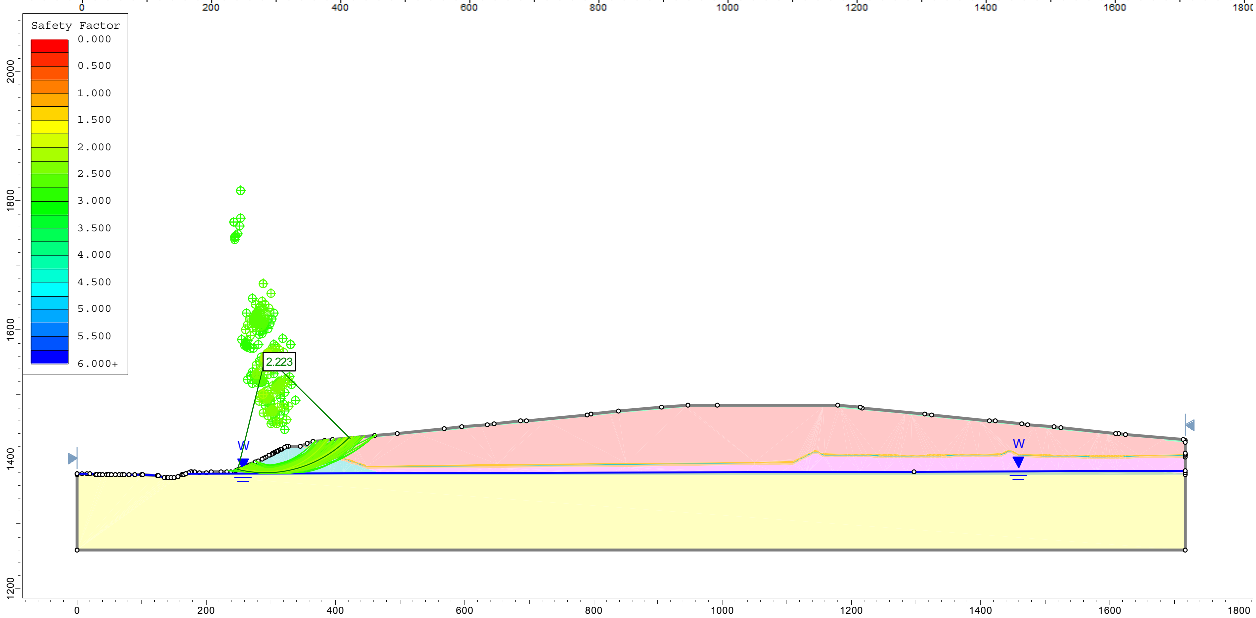
- FS: 2.222510
- Center: 292.723, 1560.436
- Radius: 182.322
- Left Slip Surface Endpoint: 248.978, 1383.440
- Right Slip Surface Endpoint: 422.717, 1432.597
- Resisting Moment=5.01758e+007 lb-ft
- Driving Moment=2.25762e+007 lb-ft
- Resisting Horizontal Force=257641 lb
- Driving Horizontal Force=115924 lb
- Total Slice Area=4168.4 ft2

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	5800	0	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	3000	0	Water Surface	Custom	1
Clay Liner		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Protective Cover		120	Mohr-Coulomb	400	0	Water Surface	Custom	1
Waste		120	Mohr-Coulomb	0	45	Water Surface	Custom	1
Top Soil		120	Mohr-Coulomb	400	0	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1
Geosynthetic Liner		120	Mohr-Coulomb	0	9.8	Water Surface	Custom	1
Structural Fill		120	Mohr-Coulomb	1600	0	Water Surface	Custom	1



Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

(b) Post-Closure

Block-type Shear Surface along Liner; Drained Condition, Peak Interface Friction

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section B - Final - Drained Block
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/11/2013, 1:17:00 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116

- Random Number Generation Method: Park and Miller v.3

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 95
- Left Projection Angle (End Angle): 180
- Right Projection Angle (Start Angle): 0
- Right Projection Angle (End Angle): 85
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Claystone	Upper Clay	Clay Liner	Protective Cover	Waste	Top Soil	Dike	Geosynthetic Liner	Structural Fill
Color									
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120	120	120	120	120	120	120
Cohesion [psf]	547	634	285	285	0	285	285	0	285
Friction Angle [deg]	30.8	14.9	28	28	45	28	28	9.8	28
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1	1	1

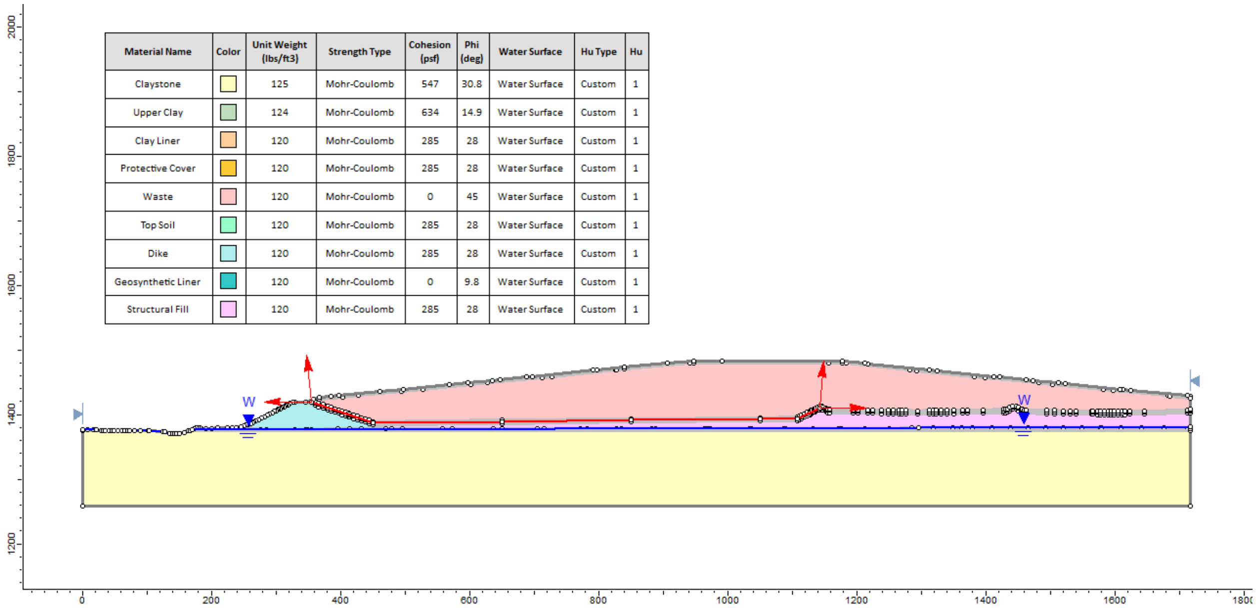
Global Minimums

Method: spencer

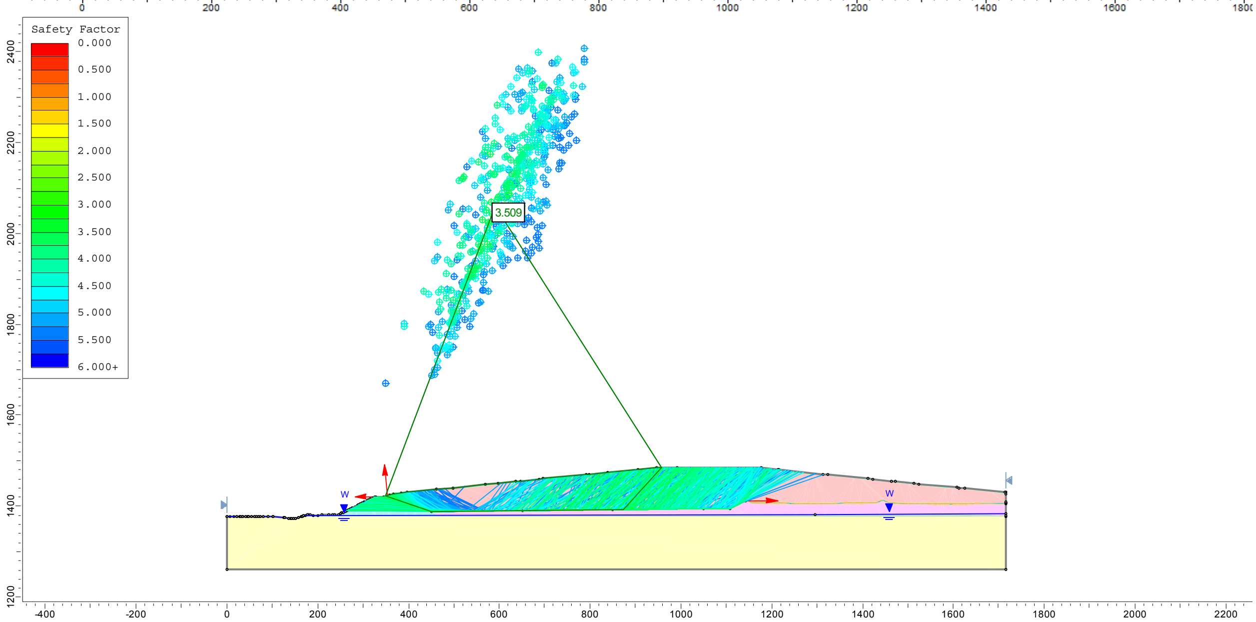
- FS: 3.508590
- Axis Location: 591.465, 2060.102
- Left Slip Surface Endpoint: 349.731, 1421.405
- Right Slip Surface Endpoint: 957.382, 1483.496
- Resisting Moment=7.34488e+008 lb-ft
- Driving Moment=2.0934e+008 lb-ft

Written by:	A. Brown	Date:	2/24/2014	Reviewed by:	S. Graves	Date:	3/5/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

- Resisting Horizontal Force=951543 lb
- Driving Horizontal Force=271204 lb
- Total Slice Area=34177.6 ft2



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	547	30.8	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	634	14.9	Water Surface	Custom	1
Clay Liner		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Protective Cover		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Waste		120	Mohr-Coulomb	0	45	Water Surface	Custom	1
Top Soil		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Geosynthetic Liner		120	Mohr-Coulomb	0	9.8	Water Surface	Custom	1
Structural Fill		120	Mohr-Coulomb	285	28	Water Surface	Custom	1



Written by:	**A. Brown**	Date:	**2/24/2014**	Reviewed by:	**S. Graves**	Date:	**3/5/2014**
Client:	**Clean Harbors**	Project:	**Lone Mountain Facility**	Project No.:	**TXL0380**	Phase No.:	**04**

Block-type Shear Surface along Liner; Drained Condition, Large Displacement Interface Friction

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section B - Final - Drained Block LD
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/11/2013, 1:17:00 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

  - Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Written by:	A. Brown	Date:	2/24/2014	Reviewed by:	S. Graves	Date:	3/5/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

Surface Options

- Surface Type: Non-Circular Block Search
- Number of Surfaces: 5000
- Pseudo-Random Surfaces: Enabled
- Convex Surfaces Only: Disabled
- Left Projection Angle (Start Angle): 95
- Left Projection Angle (End Angle): 180
- Right Projection Angle (Start Angle): 0
- Right Projection Angle (End Angle): 85
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

Property	Claystone	Upper Clay	Clay Liner	Protective Cover	Waste	Top Soil	Dike	Geosynthetic Liner	Structural Fill
Color									
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120	120	120	120	120	120	120
Cohesion [psf]	547	634	285	285	0	285	285	0	285
Friction Angle [deg]	30.8	14.9	28	28	45	28	28	6.0	28
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1	1	1

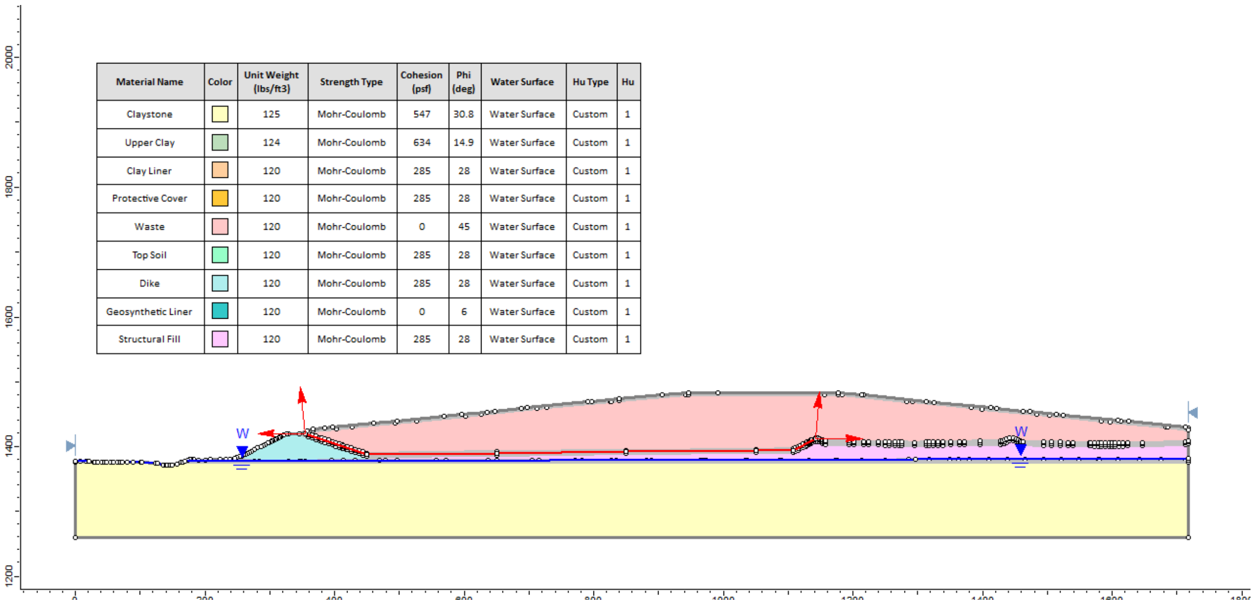
Global Minimums

Method: spencer

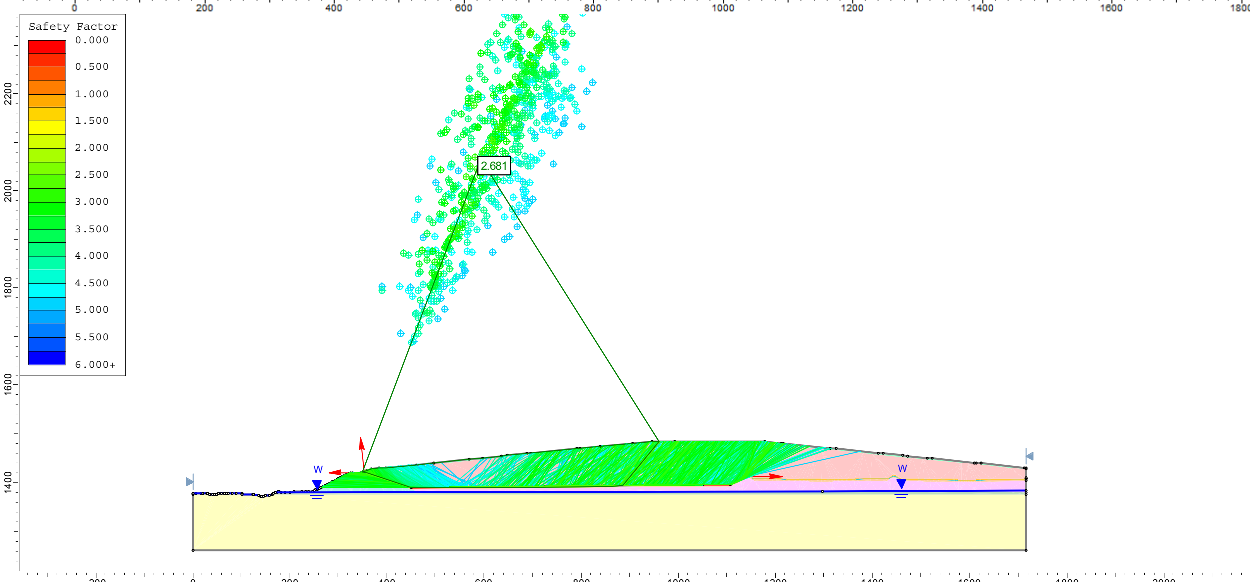
- FS: 2.681430
- Axis Location: 593.191, 2063.626
- Left Slip Surface Endpoint: 349.702, 1421.395
- Right Slip Surface Endpoint: 960.882, 1483.496
- Resisting Moment=5.33299e+008 lb-ft
- Driving Moment=1.98886e+008 lb-ft
- Resisting Horizontal Force=655937 lb

Written by:	A. Brown	Date:	2/24/2014	Reviewed by:	S. Graves	Date:	3/5/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

- Driving Horizontal Force=244622 lb
- Total Slice Area=34944.9 ft2



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	547	30.8	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	634	14.9	Water Surface	Custom	1
Clay Liner		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Protective Cover		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Waste		120	Mohr-Coulomb	0	45	Water Surface	Custom	1
Top Soil		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Geosynthetic Liner		120	Mohr-Coulomb	0	6	Water Surface	Custom	1
Structural Fill		120	Mohr-Coulomb	285	28	Water Surface	Custom	1



Circular Shear Surface; Drained Condition

Slide Analysis Information
SLIDE - An Interactive Slope Stability Program

Project Summary

- File Name: Section B - Final - Drained Circular
- Slide Modeler Version: 6.026
- Project Title: SLIDE - An Interactive Slope Stability Program
- Date Created: 12/11/2013, 1:17:00 PM

General Settings

- Units of Measurement: Imperial Units
- Time Units: days
- Permeability Units: feet/second
- Failure Direction: Right to Left
- Data Output: Standard
- Maximum Material Properties: 20
- Maximum Support Properties: 20

Analysis Options

Analysis Methods Used

- Spencer

- Number of slices: 25
- Tolerance: 0.005
- Maximum number of iterations: 50
- Check malpha < 0.2: Yes
- Initial trial value of FS: 1
- Steffensen Iteration: Yes

Groundwater Analysis

- Groundwater Method: Water Surfaces
- Pore Fluid Unit Weight: 62.4 lbs/ft3
- Advanced Groundwater Method: None

Random Numbers

- Pseudo-random Seed: 10116
- Random Number Generation Method: Park and Miller v.3

Surface Options

Written by: **A. Brown** Date: **2/24/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

- Surface Type: Circular
- Search Method: Auto Refine Search
- Divisions along slope: 10
- Circles per division: 10
- Number of iterations: 10
- Divisions to use in next iteration: 50%
- Composite Surfaces: Disabled
- Minimum Elevation: Not Defined
- Minimum Depth: Not Defined

Material Properties

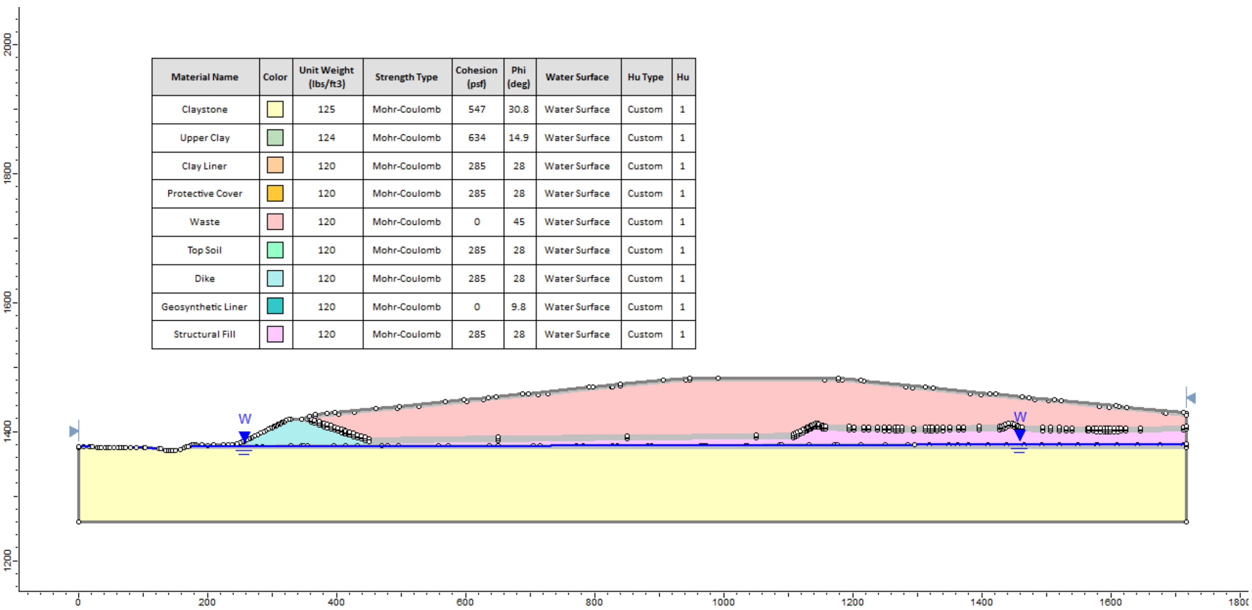
Property	Claystone	Upper Clay	Clay Liner	Protective Cover	Waste	Top Soil	Dike	Geosynthetic Liner	Structural Fill
Color									
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unit Weight [lbs/ft3]	125	124	120	120	120	120	120	120	120
Cohesion [psf]	547	634	285	285	0	285	285	0	285
Friction Angle [deg]	30.8	14.9	28	28	45	28	28	9.8	28
Water Surface	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table	Water Table
Hu Value	1	1	1	1	1	1	1	1	1

Global Minimums

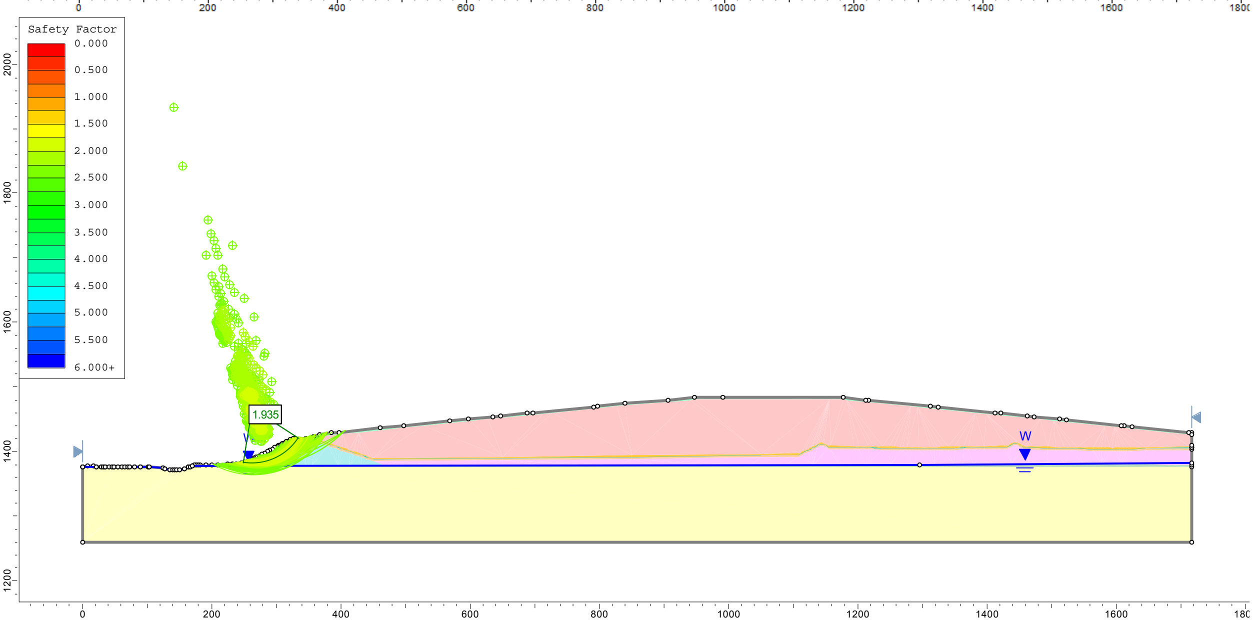
Method: spencer

- FS: 1.934800
- Center: 262.544, 1467.166
- Radius: 85.735
- Left Slip Surface Endpoint: 247.465, 1382.768
- Right Slip Surface Endpoint: 334.139, 1420.000
- Resisting Moment=7.72458e+006 lb-ft
- Driving Moment=3.99244e+006 lb-ft
- Resisting Horizontal Force=80252.8 lb
- Driving Horizontal Force=41478.6 lb
- Total Slice Area=1011.03 ft2

Written by:	A. Brown	Date:	2/24/2014	Reviewed by:	S. Graves	Date:	3/5/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04



Material Name	Color	Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Water Surface	Hu Type	Hu
Claystone		125	Mohr-Coulomb	547	30.8	Water Surface	Custom	1
Upper Clay		124	Mohr-Coulomb	634	14.9	Water Surface	Custom	1
Clay Liner		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Protective Cover		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Waste		120	Mohr-Coulomb	0	45	Water Surface	Custom	1
Top Soil		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Dike		120	Mohr-Coulomb	285	28	Water Surface	Custom	1
Geosynthetic Liner		120	Mohr-Coulomb	0	9.8	Water Surface	Custom	1
Structural Fill		120	Mohr-Coulomb	285	28	Water Surface	Custom	1



APPENDIX B2-3

INTERFACE FRICTION TEST RESULTS

Written by:	**A. Brown**	Date:	**2/24/2014**	Reviewed by:	**S. Graves**	Date:	**3/5/2014**
Client:	**Clean Harbors**	Project:	**Lone Mountain Facility**	Project No.:	**TXL0380**	Phase No.:	**04**

TRI/ENVIRONMENTAL, INC.
A Texas Research International Company

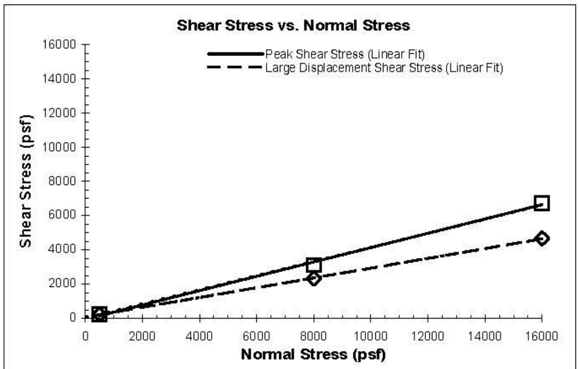
Interface Friction Test Report

Client: **Envirotech**
Project: **Clean Harbors - Lone Mountain**
Test Date: 04/16/10-04/22/10

TRI Log#: E2337-32-06
Test Method: ASTM D 5321

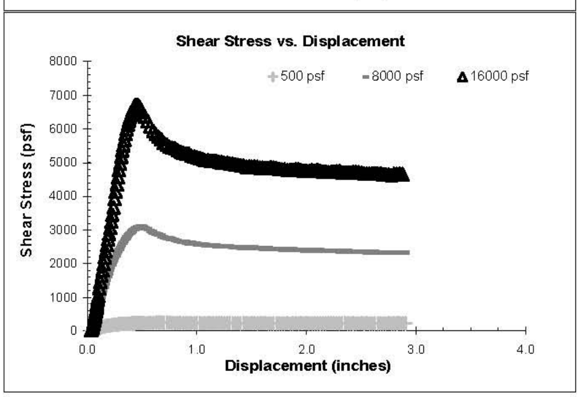
John M. Allen, P.E., 04/22/2010
Quality Review/Date

Tested Interface: Clay Borrow Soil (CB-01, 3'-5') vs. Agru 60 mil HDPE Microspike Geomembrane (no label)



Test Results	Peak	Large Displacement (@ 3.0 in.)
Friction Angle (degrees):	22.5	16.0
Y-intercept or Adhesion (psf):	0	56

Shearing occurred at the clay/geomembrane interface. The peak friction angle regression analysis was adjusted to fit a zero y-intercept.



Test Conditions

Upper Box &	Clay Borrow Soil (CB-01, 3'-5') remolded to 101 pcf at 22.5% moisture content
Lower Box	Agru 60 mil HDPE Microspike geomembrane (shiny side)
Box Dimensions:	12"x12"x4"
Interface Conditioning:	Interface soaked and loading applied for a minimum of 16 hours prior to shear.
Test Condition:	Wet
Shearing Rate:	0.001 inches/minute

Test Data

Specimen No.	1	2	3
Bearing Slide Resistance (lbs)	13	84	160
Normal Stress (psf)	500	8000	16000
Corrected Peak Shear Stress (psf)	247	3096	6721
Corrected Large Displacement Shear Stress (psf)	213	2323	4655
Peak Secant Angle (degrees)	26.3	21.2	22.8
Large Displacement Secant Angle (degrees)	23.1	16.2	16.2
Asperity (mils)	31.6	31.6	30.2

9063 Bee Caves Road □ Austin, TX 78733-6201 □ (512) 263-2101 □ (512) 263-2558 □ 1-800-880-TEST

Exhibit B-3

Settlement Analysis

Written by: A. Brown Date: 2/17/2014 Reviewed by: S. Graves Date: 3/5/2014

Client: Clean Harbors Project: Lone Mountain Facility Project No.: TXL0380 Phase No.: 04

SETTLEMENT AND LINER STRESS ANALYSIS

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA
6/13/2014

Scott M. Graves, P.E.
State of Oklahoma Registration # 19710
Geosyntec Consultants
Oklahoma Certificate of Authorization No. 1996
Exp. 06/30/2014

SEALED FOR CALCULATION PAGES
B3-1 THROUGH B3-17

1. INTRODUCTION

The purpose of this calculation package is to evaluate the effect of loading and the resulting compression of the foundation materials on the post-settlement grades of the liner system of the Lone Mountain Facility Landfill Cell 15 westward expansion. Specifically, the settlement of the most critical portions of the liner grades, which are along the leachate collection system corridor for Subcell 6 in the currently permitted facility and along the leachate collection system corridor for Subcell 14 in the westward expansion, were evaluated. The design criteria used for these evaluations is that the leachate corridor should maintain positive drainage towards the leachate collection sump after the predicted foundation settlements have occurred. Also, calculated tensile strains due to differential settlement should not exceed tolerable strains for the liner system components.

Soils beneath the landfill base are expected to compress as they are loaded through construction of the overlying liner system, waste placement, and closure. The foundation settlements will be affected by: (i) the variable thickness of the foundation layers (Upper Clay and Claystone/Siltstone layers) beneath the landfill; and (ii) the variable loading of the foundation by the landfill, from zero at the exterior limits of the perimeter embankment to a maximum near the center of the landfill where the waste and final cover elevation will be at a maximum.

2. BASIS OF SETTLEMENT ANALYSIS

Settlement of the foundation soils under the Lone Mountain Facility Landfill Cell 15 is calculated using equations for conventional one-dimensional (1-D) compression settlement due to embankment loading. The settlement analysis is modeled on the behavior of one-dimensional consolidation of clay soils.

One-dimensional consolidation of clay soils is divided into two phases: primary consolidation and secondary compression. According to the theory of consolidation, primary consolidation of a soil layer (and the associated settlement) is caused by an increase in effective vertical stress

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resulting from loading of the layer leading to expulsion of water (drainage) and a decrease in void ratio.

Settlements resulting from primary consolidation of waste were calculated using the general form of the settlement equation as given below [Holtz and Kovacs, 1981]:

$$S_p = \frac{C_r}{1+e_o} H \log\left(\frac{\sigma'_{vo} + \Delta\sigma}{\sigma'_{vo}}\right), \quad \text{for } (\sigma'_{vo} + \Delta\sigma) < p_c' \tag{1}$$

$$S_p = \frac{C_c}{1+e_o} H \log\left(\frac{\sigma'_{vo} + \Delta\sigma}{\sigma'_{vo}}\right), \quad \text{for } (\sigma'_{vo} > p_c') \text{ and } (\sigma'_{vo} + \Delta\sigma) > p_c' \tag{2}$$

$$S_p = \frac{C_c}{1+e_o} H \log\left(\frac{\sigma'_{vo} + \Delta\sigma}{p_c'}\right) + \frac{C_r}{1+e_o} H \log\left(\frac{p_c'}{\sigma'_{vo}}\right), \quad \text{for } (\sigma'_{vo} < p_c') \text{ and } (\sigma'_{vo} + \Delta\sigma) > p_c' \tag{3}$$

where: S_p = primary settlement;
C_c = compression index;
C_r = recompression index;
e_o = initial void ratio;
H = initial thickness of compressible layer;
σ'_{vo} = initial vertical effective stress;
p_c' = preconsolidation pressure; and
$\Delta\sigma$ = increment of vertical effective stress.

The increase in vertical stress due to landfill loads, $\Delta\sigma$, was evaluated at the midpoint of each layer. Also, the terms "modified compression index", $C_{c\varepsilon}$, and the "modified recompression index", $C_{r\varepsilon}$, can be defined and used in Equations 1 to 3. These parameters are defined below [Holtz and Kovacs, 1981]:

$$C_{c\varepsilon} = \frac{C_c}{1+e_o} \tag{4}$$

$$C_{r\varepsilon} = \frac{C_r}{1+e_o} \tag{5}$$

Settlements resulting from secondary compression were calculated using equation 6 [Holtz and Kovacs, 1981]:

$$S_t = C_{\alpha\varepsilon} H \log\left(\frac{t_2}{t_1}\right) \tag{6}$$

$$C_{\alpha\varepsilon} = \frac{C_\alpha}{1+e_o} \tag{7}$$

where: S_t = time dependent secondary settlement;

$C_{\alpha\varepsilon}$ = modified secondary compression index;

H = initial thickness of compressible layer;

t_1 = time when secondary compression is assumed to begin (assumed to be 1 year); and

t_2 = time for which secondary settlements are calculated (assumed to be 30 years).

3. DEVELOPMENT OF CROSS SECTIONS FOR ANALYSIS

The minimum slope of the leachate collection system is 1% and occurs along the leachate collection corridor of each cell. Two critical cross sections were used to evaluate the settlement underneath the leachate collection corridors in Subcell 6 (Section A) and Subcell 14 (Section B). The locations of the cross sections are shown on Figures B3-1 and B3-2 of this calculation package; the locations are shown in relation to the base (liner system) grading plan and the overall final grading plan, respectively. The highest differential settlements along a leachate collection corridor are expected to occur where the corridor is underlain by the thickest, most compressible materials and the differential loads along the corridor are the greatest. Therefore, the selected cross sections were chosen to incorporate the steepest/tallest slope, to include the representative foundation soils beneath the site, and to provide a broad variation of waste thickness throughout the cross section. Additionally, groundwater data was used to approximate the groundwater elevation at each of the analyzed points along the critical cross section to determine the effective stress at each point.

Twelve critical locations along each selected cross section were chosen for settlement analysis. The elevations of the selected points along each cross section, in addition to the corresponding elevations of the overburden materials and subsurface layer boundaries, were used as input to the settlement analysis. The elevations of the leachate collection system corridor and final cover system were obtained from the base and final cover grading plans (as shown in Figures B3-1 and B3-2, respectively). The elevations of the subsurface layer boundaries were determined from the cross sections shown in Figure B3-3. Settlement was estimated based on the expected compressibility of approximately the top 100-ft of subsurface soil. It is assumed that compressibility of lower soil layers beneath 100-ft below ground surface will be negligible because the influence of a load (the landfill) decreases with depth.

4. MATERIAL PROPERTIES USED FOR ANALYSIS

The typical landfill and subsurface profile is composed of materials able to compress beneath the landfill foundation and fill materials above the landfill foundation that impart stress to the foundation soils and cause compression. The subsurface at Lone Mountain Facility is divided into two general layers, from top to bottom:

- Upper Clay; and
- Claystone/Siltstone.

The fill materials that load and cause compression of the foundation soils are:

- perimeter embankment soil;
- liner system soils;
- waste; and
- final cover system soils.

The material parameters that are input to the model or that are used to calculate input parameters include:

- total unit weight;
- void ratio;
- preconsolidation pressure;
- primary compression index;
- recompression index;
- secondary compression index; and

The properties for each material used in the analysis, and the basis for their selection, are presented in Table B3-1.

5. CALCULATIONS AND RESULTS OF ANALYSIS

Settlement calculations for the selected cross-sections are presented in Appendix B3-1 of this calculation package. As shown in Spreadsheet 1, calculated settlements along Section A range from 0.18 to 2.93 feet, while the maximum difference between pre-settlement and post-settlement slopes is 2.3%. As shown in Spreadsheet 2, along Section B, settlements range from 0.17 to 2.61 feet, with a maximum calculated difference between the pre-settlement and post-settlement slopes of 0.9%.

The calculated strains between adjacent points (i.e., difference in settlement divided by the length) due to differential settlement are also calculated in the spreadsheet. Results show calculated liner tensile strains of about 0.02% in Section A and 0.17% in Section B.

The results are also presented in graphical format on Figures B3-4 and B3-5 for Section A and B, respectively. These figures show the pre-settlement and post-settlement grades on each cross section. As shown, settlement is relatively uniform between adjacent points (i.e., no significant differential settlement and no resulting grade reversals).

6. SUMMARY AND CONCLUSIONS

Calculations presented herein indicate that foundation settlement along the leachate collection corridors will occur as a result of the proposed waste loads. However, the calculated post-settlement slopes along the leachate corridors will provide adequate positive drainage to the leachate collection sumps.

The calculated tensile strains in the liner system due to differential settlement are small – about 0.02% along Section A and about 0.17% along Section B. This amount of strain is well below the amount of strain that can be tolerated by compacted clay and is well below the 12 percent yield strain for high density geomembranes reported by Koerner (1998); and is therefore considered acceptable.

7. DISCUSSION ON FINAL COVER SETTLEMENT

The waste will be placed in lifts and compacted. Therefore, the waste placed in the landfill is expected to experience negligible settlement. Furthermore, this negligible settlement will take place as filling progresses, so that by the time the final cover system will be installed, compression due to the self-weight of the underlying waste is expected to have already taken place. As a result, it is reasonable to conclude that the final cover system will experience negligible settlement due to settlement of underlying waste.

The perimeter embankment and final cover system may experience some settlement due to compression of the underlying foundation strata. A considerable fraction of the foundation settlement will take place during waste placement and prior to final cover construction. The final cover system would only be expected to settle a small fraction of the total foundation settlement. Inspection of the liner settlement calculations reveals relatively little differential settlement between adjacent points at maximum values of 0.94 feet over a distance of approximately 153 feet in Section A, and 0.94 ft over a distance of approximately 496 ft in Section B. Since only a fraction of this differential amount would be expected to be experienced at the final cover system, these minor differential settlements are even more negligible with respect to effect on final cover system slopes. Given that the settlement calculations presented herein demonstrate that the liner system will not be adversely affected by the total and differential settlements, it is not expected that the final cover system will be adversely affected by the minor amounts of anticipated settlement.

8. REFERENCES

Das, B.M. *Principles of Foundation Engineering*, PWS Publishing Company, Boston, Massachusetts, 1995.

Holtz, R.D., and Kovacs, W.D. *An Introduction to Geotechnical Engineering*, Prentice-Hall, Englewood Cliffs, New Jersey, 1981.

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TABLES

TABLE B3-1. MATERIAL PARAMETERS USED IN SETTLEMENT ANALYSIS.

Material and Parameter	Parameter Value	Basis
Embankment, Final Cover System, and Liner System		
• Unit Weight (γ_{cover} and γ_{liner})	120 pcf	• Assumed average values for on-site soils.
Waste		
• Unit Weight (γ_{waste})	120 pcf	• Assumed average value representative of the Cell 15 waste stream, containing construction and demolition-type waste and other industrial and hazardous-type soil and debris.
Sub Layer 1 - Upper Clay		
• Unit Weight (γ) • Void Ratio (e) • Preconsolidation Pressure (σ'_p)	124 pcf 0.89 1400 psf	• Based on laboratory tests conducted for on-site soils in February 2010 and October 2013.
• Modified Compression Index ($C_{c\varepsilon}$) • Modified Recompression Index ($C_{r\varepsilon}$)	0.066 0.011	• Based on laboratory tests conducted for on-site soils in February 2010 and October 2013 as well as values reported in the Permit Modification Application for Cell 15 dated June 1993.
• Modified Secondary Compression Index ($C_{\alpha\varepsilon}$)	0.003	• Assumed to be 5% of $C_{c\varepsilon}$ from Holtz and Kovacs (1981).
Sub Layer 2 - Claystone/Siltstone		
• Unit Weight (γ) • Void Ratio (e) • Preconsolidation Pressure (σ'_p)	125 pcf 0.79 3,100 psf	• Based on laboratory tests conducted for on-site soils in February 2010.
• Modified Compression Index ($C_{c\varepsilon}$) • Modified Recompression Index ($C_{r\varepsilon}$)	0.021 0.007	• Based on laboratory tests conducted for on-site soils in February 2010 and values reported in the Permit Modification Application for Cell 15 dated June 1993.
• Modified Secondary Compression Index ($C_{\alpha\varepsilon}$)	0.001	• Assumed to be 5% of $C_{c\varepsilon}$ from Holtz and Kovacs (1981).

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FIGURES

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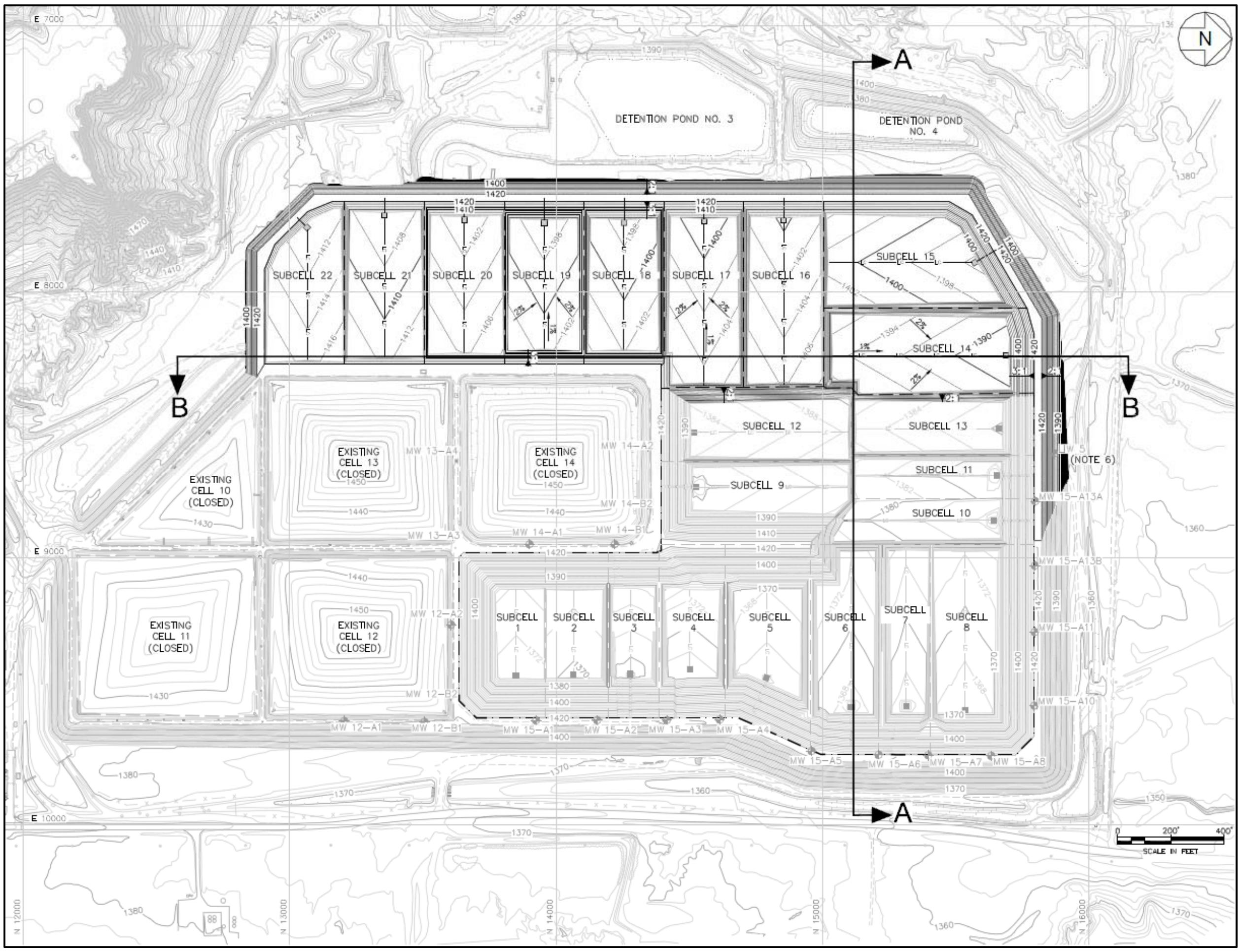

Figure B3-1. Location of the Cross Sections in Relation to Overall Base Grading Plan.

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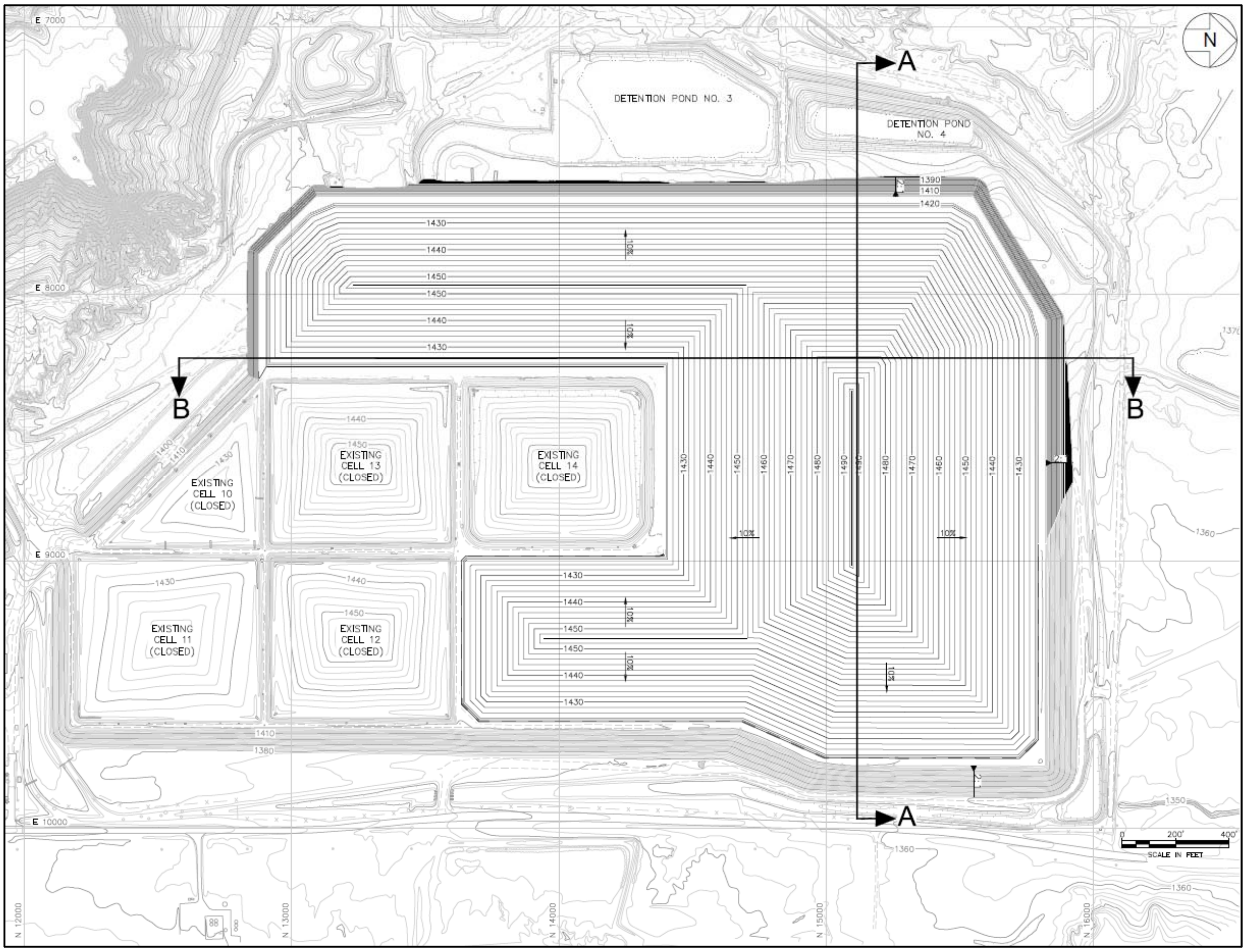

Figure B3-2. Location of the Cross Sections in Relation to Overall Final Grading Plan.

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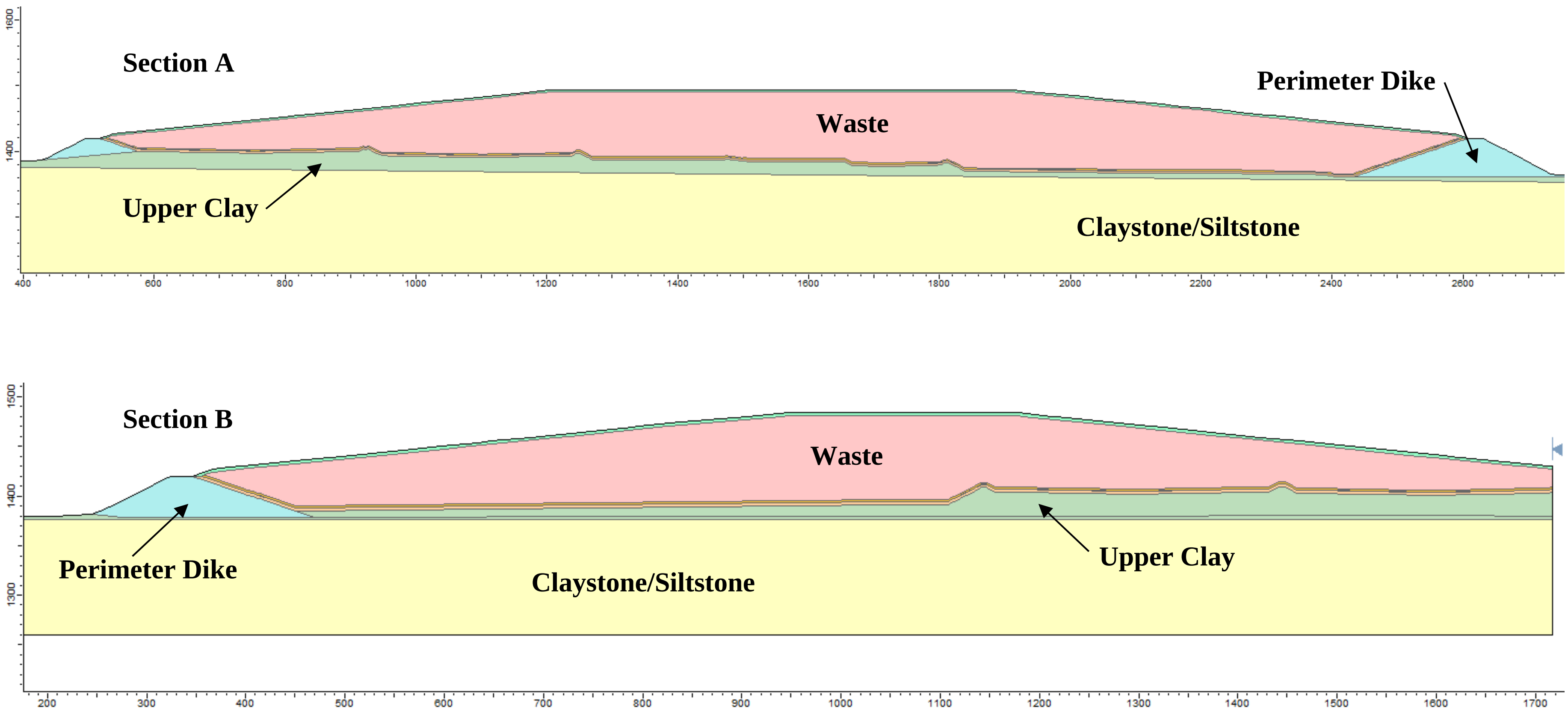

Figure B3-3. Critical Sections Used in the Settlement Analyses.

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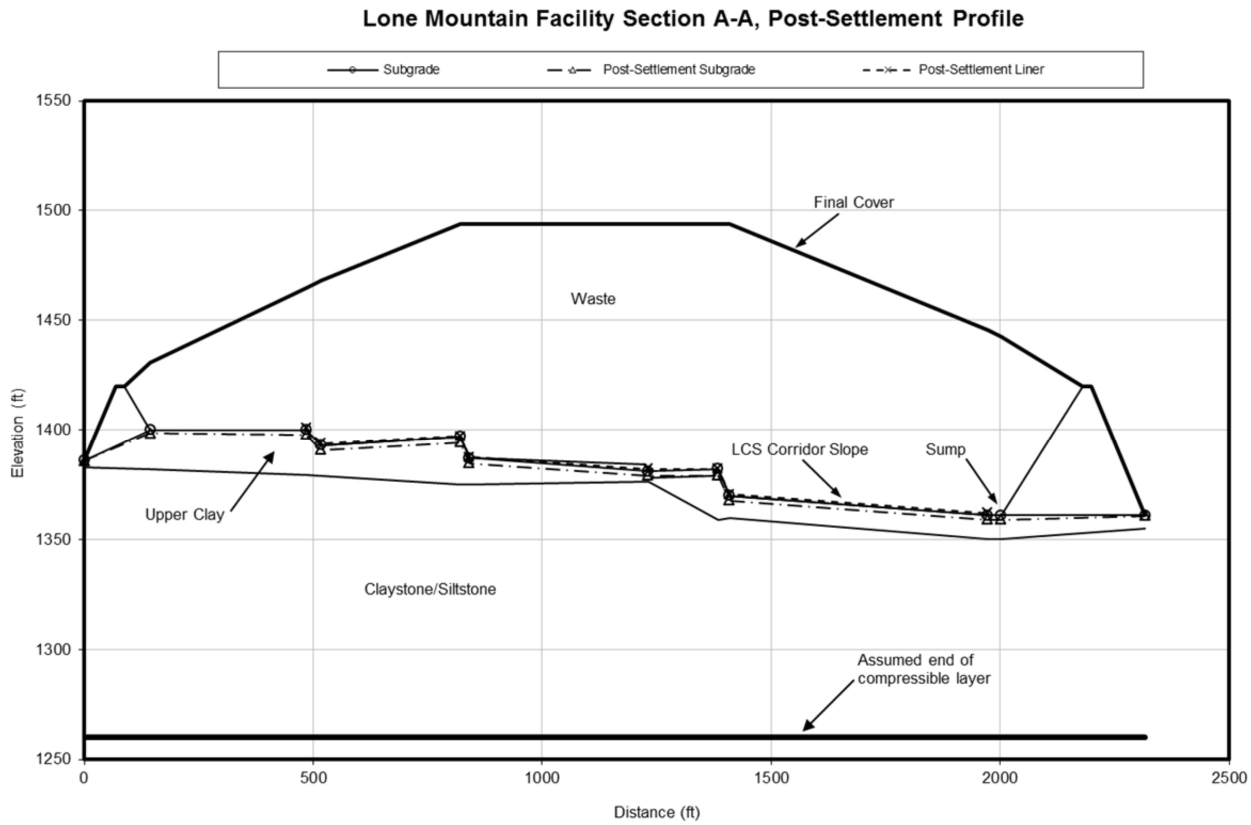

Figure B3-4. Post-Settlement Profile along Section A.

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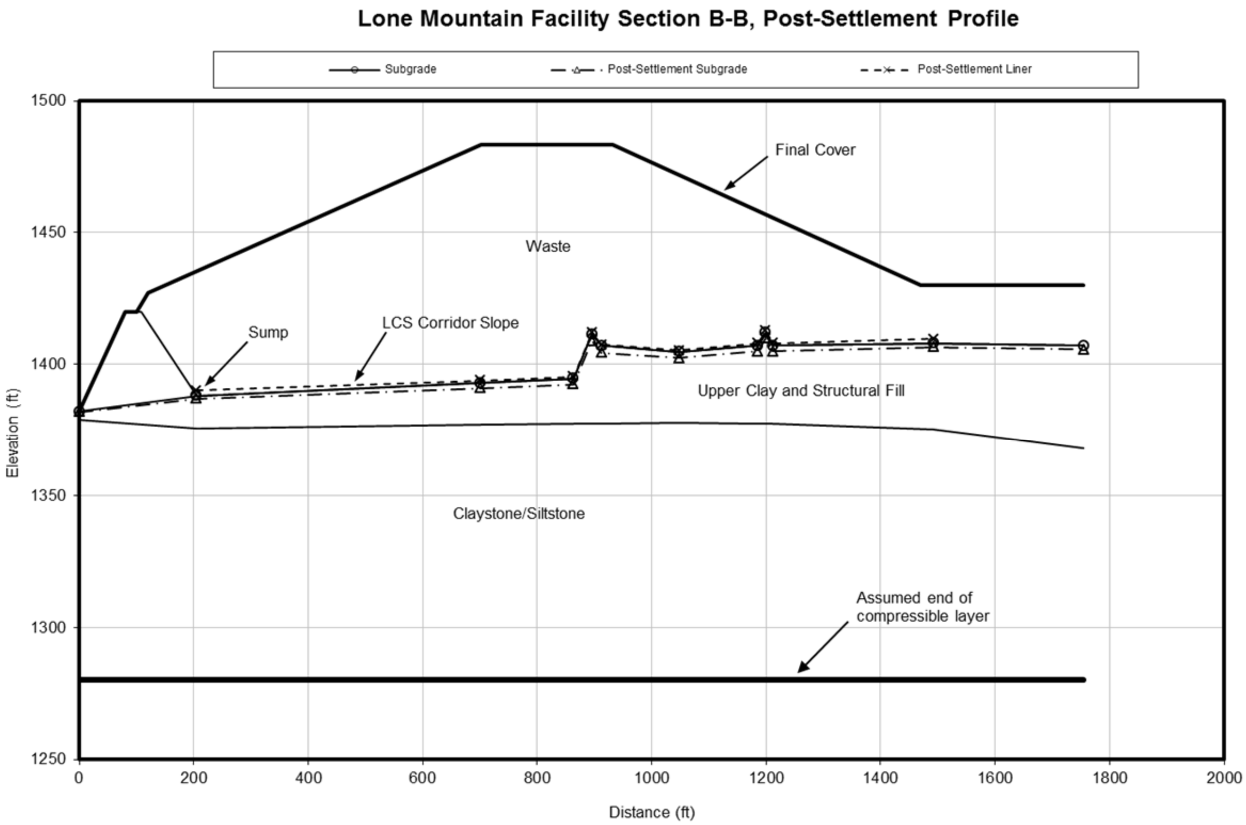

Figure B3-5. Post-Settlement Profile along Section B.

APPENDIX B3-1
SETTLEMENT ANALYSIS

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SPREADSHEET 1

Lone Mountain Facility - SECTION A-A

		1	2	3	4	5	6	7	8	9	10	11	12
	Point #	1	2	3	4	5	6	7	8	9	10	11	12
	Distance (ft)	0.0	145.0	485.0	517.0	821.0	841.0	1231.5	1384.0	1409.0	1973.0	2002.0	2317
Unit Weights	Final Cover, γ_{cover} (pcf)	120	120	120	120	120	120	120	120	120	120	120	120
	Waste, γ_{waste} (pcf)	120	120	100	120	120	120	120	120	120	120	120	120
	Liner, γ_{liner} (pcf)	120	120	120	120	120	120	120	120	120	120	120	120
	Soil, γ_{res} (pcf)												
	Sub Layer 1, Upper Clay 1	124	124	124	124	124	124	124	124	124	124	124	124
	Sub Layer 2, Claystone/Siltstone 2	125	125	125	125	125	125	125	125	125	125	125	125
Elevations Initial	Top of Soil (ft msl)	1386.0	1400.0	1400.0	1393.0	1397.0	1387.0	1381.0	1382.0	1370.0	1361.0	1361.0	1361.0
	Top of Bedrock (ft msl)	1260.0	1260.0	1260.0	1260.0	1260.0	1260.0	1260.0	1260.0	1260.0	1260.0	1260.0	1260.0
Elevations Final	Water Table Elevation (ft msl)	1386.0	1386.0	1385.8	1385.0	1377.6	1377.1	1368.9	1367.0	1366.7	1359.9	1359.6	1355.8
	Top of Final Cover (ft msl)	1386.0	1430.7	1464.9	1468.1	1494.0	1494.0	1494.0	1494.0	1494.0	1445.4	1442.6	1361.0
	top of waste elevation	1386.0	1428.7	1462.9	1466.1	1492.0	1492.0	1492.0	1492.0	1492.0	1443.4	1440.6	1361.0
	Subgrade (ft msl)	1386.0	1400.0	1400.0	1393.0	1397.0	1387.0	1381.0	1382.0	1370.0	1361.0	1361.0	1361.0
	top of liner elevation	1386.0	1403.0	1403.0	1396.0	1400.0	1390.0	1384.0	1385.0	1373.0	1364.0	1364.0	1361.0
Thicknesses	Intial Soil (ft)	126.0	140.0	140.0	133.0	137.0	127.0	121.0	122.0	110.0	101.0	101.0	101.0
	Final Cover (ft)	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0
	Waste (ft)	0.0	25.7	59.9	70.1	92.0	102.0	108.0	107.0	119.0	79.4	76.6	0.0
	Liner (ft)	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0
	Fill (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Final Soil (ft)	126.0	140.0	140.0	133.0	137.0	127.0	121.0	122.0	110.0	101.0	101.0	101.0
Sublayer Thicknesses	Soil												
	Sub Layer 1 (ft), Upper Clay 1	3.0	18.1	20.8	14.0	21.9	11.9	4.7	22.9	10.0	11.0	11.0	6.0
	Sub Layer 2 (ft), Claystone/Siltstone 2	123.0	121.9	119.2	119.0	115.15	115.07	116.3	99.1	100.0	90.0	90.0	95.0
	Total (ft)	126.0	140.0	140.0	133.0	137.0	127.0	121.0	122.0	110.0	101.0	101.0	101.0
	Thickness Check	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Stresses	Sub Layer 1												
	Final Midpoint Elevation, yres-mf (ft)	1384.5	1390.9	1389.6	1386.0	1386.1	1381.0	1378.7	1370.6	1365.0	1355.5	1355.5	1358.0
	Initial Total Stress, σ_i (psf)	186	1,124	1,287	869	1,355	740	290	1,419	621	682	679	372
	Final Total Stress, σ_f (psf)	186	4,810	7,880	9,886	12,995	13,580	13,850	14,859	15,501	10,814	10,467	372
	Initial Effective Stress, σ'_i (psf)	92	1,124	1,287	869	1,355	740	290	1,419	513	406	426	372
	Final Effective Stress, σ'_f (psf)	92	4,810	7,880	9,886	12,995	13,580	13,850	14,859	15,393	10,538	10,214	372
1-D Consolidation Theory (Plastic Method)	Consolidation Properties												
	Preconsolidation pressure, σ'_p (psf)	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
	Modified Primary Compression Index, $C_{c\varepsilon}$	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
	Modified Recompression Index, $C_{r\varepsilon}$	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
	Modified Secondary Compression Index, C_{α}	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Settlements	Primary Settlement, (ft)	0.000	0.660	1.037	0.817	1.399	0.814	0.343	1.541	0.737	0.702	0.686	0.000
	Secondary Settlement (30 Years) (ft)	0.015	0.088	0.101	0.068	0.107	0.058	0.023	0.112	0.049	0.054	0.053	0.029
	Total Settlement (ft)	0.015	0.749	1.138	0.885	1.506	0.872	0.366	1.652	0.785	0.755	0.740	0.029
	Elastic or Plastic (E/P)	P	P	P	P	P	P	P	P	P	P	P	P
		1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D
	Settlement of Sublayer (ft)	0.015	0.749	1.138	0.885	1.506	0.872	0.366	1.652	0.785	0.755	0.740	0.029
Stresses	Sub Layer 2												
	Final Midpoint Elevation, yres-mf (ft)	1321.5	1320.9	1319.6	1319.5	1317.6	1317.5	1318.2	1309.6	1310.0	1305.0	1305.0	1307.5
	Initial Total Stress, σ_i (psf)	8,060	9,865	10,027	9,174	9,907	8,671	7,850	9,033	7,491	6,989	6,986	6,682
	Final Total Stress, σ_f (psf)	8,060	13,551	16,620	18,192	21,547	21,511	21,410	22,473	22,371	17,121	16,774	6,682
	Initial Effective Stress, σ'_i (psf)	4,035	5,805	5,900	5,088	6,159	4,952	4,687	5,447	3,951	3,562	3,582	3,669
	Final Effective Stress, σ'_f (psf)	4,035	9,491	12,493	14,106	17,799	17,792	18,247	18,887	18,831	13,694	13,369	3,669
1-D Consolidation Theory (Plastic Method)	Consolidation Properties												
	Preconsolidation pressure, σ'_p (psf)	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100
	Modified Primary Compression Index, $C_{c\varepsilon}$	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
	Modified Recompression Index, $C_{r\varepsilon}$	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
	Modified Secondary Compression Index, $C_{\alpha\varepsilon}$	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Settlements	Primary Settlement, (ft)	0.000	0.547	0.816	1.107	1.114	1.342	1.442	1.124	1.424	1.105	1.082	0.000
	Secondary Settlement (30 Years) (ft)	0.191	0.189	0.185	0.185	0.179	0.178	0.180	0.154	0.155	0.140	0.140	0.147
	Total Settlement (ft)	0.191	0.736	1.001	1.291	1.293	1.521	1.622	1.278	1.579	1.245	1.221	0.147
	Elastic or Plastic (E/P)	P	P	P	P	P	P	P	P	P	P	P	P
		1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D
	Settlement of Sublayer (ft)	0.191	0.736	1.001	1.291	1.293	1.521	1.622	1.278	1.579	1.245	1.221	0.147
TOTAL SETTLEMENT	Total Settlement (ft)	0.21	1.48	2.14	2.18	2.80	2.39	1.99	2.93	2.36	2.00	1.96	0.18
	Post settlement subgrade elev. (ft msl)	1,385.8	1,398.5	1,397.9	1,390.8	1,394.2	1,384.6	1,379.0	1,379.1	1,367.6	1,359.0	1,359.0	1,360.8
	Post settlement liner elev. (ft msl)		1401.5	1400.9	1393.8	1397.2	1387.6	1382.0	1382.1	1370.6	1362.0	1362.0	
GRADES AND STRAINS BASED ON CALCULATED SETTLEMENT	Intial Liner Segment Length, L_o (ft)		146.0	340.0	32.8	304.0	22.4	390.5	152.5	27.7	564.1	29.0	315.0
	Post Settle. Liner Segment Length, L_o (ft)		145.8	340.0	32.8	304.0	22.2	390.5	152.5	27.5	564.1	29.0	315.0
	Post Settlement Liner Strain (+ comp, - tension)		0.10%	0.00%	-0.02%	0.00%	0.80%	0.00%	0.00%	0.87%	0.00%	0.00%	0.00%
	PreSettlement Slope (+ up, - down)		9.7%	0.0%	-21.9%	1.3%	-50.0%	-1.5%	0.7%	-48.0%	-1.6%	0.0%	0.0%
	Post Settlement Slope		8.8%	-0.2%	-22.0%	1.1%	-48.0%	-1.4%	0.0%	-45.7%	-1.5%	0.1%	0.6%
	Grade Difference (+ steeper, - milder)		-0.9%	0.2%	0.1%	-0.2%	-2.0%	-0.1%	-0.6%	-2.3%	-0.1%	0.1%	0.6%

Written by: **A. Brown** Date: **2/17/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

SPREADSHEET 2

Lone Mountain Facility - SECTION B-B

Point #	1	2	3	4	5	6	7	8	9	10	11	12
Distance (ft)	0.0	205.0	701.0	863.0	896.0	913.0	1048.0	1186.0	1199.0	1212.0	1492.0	1755
Unit Weights												
Final Cover, γ_{cover} (pcf)	120	120	120	120	120	120	120	120	120	120	120	120
Waste, γ_{waste} (pcf)	120	120	100	120	120	120	120	120	120	120	120	120
Liner, γ_{liner} (pcf)	120	120	120	120	120	120	120	120	120	120	120	120
Soil, γ_{res} (pcf)												
Sub Layer 1, Upper Clay 1	124	124	124	124	124	124	124	124	124	124	124	124
Sub Layer 2, Claystone/Siltstone 2	125	125	125	125	125	125	125	125	125	125	125	125
Elevations – Initial												
Top of Soil (ft msl)	1382.0	1388.1	1393.0	1394.6	1411.5	1407.0	1404.7	1407.1	1412.0	1407.0	1408.0	1407.0
Top of Bedrock (ft msl)	1280.0	1280.0	1280.0	1280.0	1280.0	1280.0	1280.0	1280.0	1280.0	1280.0	1280.0	1280.0
Elevations – Final												
Water Table Elevation (ft msl)	1378.1	1378.5	1379.4	1379.7	1379.7	1379.8	1380.0	1380.9	1381.0	1381.1	1382.9	1384.6
Top of Final Cover (ft msl)	1382.0	1435.2	1483.5	1483.5	1483.5	1483.5	1472.1	1458.3	1457.0	1455.8	1430.0	1430.0
top of waste elevation	1382.0	1433.2	1481.5	1481.5	1481.5	1481.5	1470.1	1456.3	1455.0	1453.8	1428.0	1430.0
Subgrade (ft msl)	1382.0	1388.1	1393.0	1394.6	1411.5	1407.0	1404.7	1407.1	1412.0	1407.0	1408.0	1407.0
top of liner elevation	1382.0	1391.1	1396.0	1397.6	1414.5	1410.0	1407.7	1410.1	1415.0	1410.0	1411.0	1407.0
Thicknesses												
Intial Soil (ft)	102.0	108.1	113.0	114.6	131.5	127.0	124.7	127.1	132.0	127.0	128.0	127.0
Final Cover (ft)	0.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.0
Waste (ft)	0.0	42.1	85.5	83.9	67.0	71.5	62.4	46.2	40.0	43.8	17.0	23.0
Liner (ft)	0.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	0.0
Fill (ft)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Final Soil (ft)	102.0	108.1	113.0	114.6	131.5	127.0	124.7	127.1	132.0	127.0	128.0	127.0
Sublayer Thicknesses – Soil												
Sub Layer 1 (ft), Upper Clay 1	3.0	3.0	16.1	17.2	34.0	29.5	26.8	29.7	34.7	29.7	32.8	39.2
Sub Layer 2 (ft), Claystone/Siltstone 2	99.0	105.1	96.9	97.4	97.50	97.54	97.9	97.4	97.3	97.3	95.2	87.8
Total (ft)	102.0	108.1	113.0	114.6	131.5	127.0	124.7	127.1	132.0	127.0	128.0	127.0
Thickness Check	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
Stresses – Sub Layer 1												
Final Midpoint Elevation, yres-mf (ft)	1380.5	1386.6	1385.0	1386.0	1394.5	1392.3	1391.3	1392.3	1394.7	1392.1	1391.6	1387.4
Initial Total Stress, σ_i (psf)	186	186	997	1,065	2,108	1,826	1,663	1,841	2,149	1,842	2,036	2,428
Final Total Stress, σ_f (psf)	186	5,836	10,147	11,733	10,748	11,006	9,746	7,990	7,554	7,693	4,676	5,188
Initial Effective Stress, σ'_i (psf)	186	186	997	1,065	2,108	1,826	1,663	1,841	2,149	1,842	2,036	2,428
Final Effective Stress, σ'_f (psf)	186	5,836	10,147	11,733	10,748	11,006	9,746	7,990	7,554	7,693	4,676	5,188
1-D Consolidation Theory (Plastic Method) – Consolidation Properties												
Preconsolidation pressure, σ'_p (psf)	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400
Modified Primary Compression Index, $C_{c\varepsilon}$	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066	0.066
Modified Recompression Index, $C_{r\varepsilon}$	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011
Modified Secondary Compression Index, C_α	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Settlements												
Primary Settlement, (ft)	0.000	0.152	0.939	1.070	1.587	1.517	1.359	1.249	1.249	1.217	0.783	0.852
Secondary Settlement (30 Years) (ft)	0.015	0.015	0.078	0.084	0.166	0.144	0.131	0.145	0.169	0.145	0.160	0.191
Total Settlement (ft)	0.015	0.166	1.017	1.153	1.753	1.660	1.490	1.394	1.418	1.362	0.943	1.043
Elastic or Plastic (E/P)	P	P	P	P	P	P	P	P	P	P	P	P
	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D
Settlement of Sublayer (ft)	0.015	0.166	1.017	1.153	1.753	1.660	1.490	1.394	1.418	1.362	0.943	1.043
Stresses – Sub Layer 2												
Final Midpoint Elevation, yres-mf (ft)	1329.5	1332.6	1328.5	1328.7	1328.8	1328.8	1328.9	1328.7	1328.7	1328.6	1327.6	1323.9
Initial Total Stress, σ_i (psf)	6,560	6,941	8,051	8,219	10,310	9,749	9,443	9,770	10,381	9,765	10,020	10,346
Final Total Stress, σ_f (psf)	6,560	12,591	17,201	18,887	18,950	18,929	17,527	15,919	15,787	15,615	12,660	13,106
Initial Effective Stress, σ'_i (psf)	3,525	4,074	4,874	5,040	7,129	6,568	6,257	6,514	7,118	6,494	6,567	6,557
Final Effective Stress, σ'_f (psf)	3,525	9,723	14,024	15,708	15,769	15,748	14,341	12,663	12,523	12,345	9,207	9,317
1-D Consolidation Theory (Plastic Method) – Consolidation Properties												
Preconsolidation pressure, σ'_p (psf)	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100	3100
Modified Primary Compression Index, $C_{c\varepsilon}$	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021	0.021
Modified Recompression Index, $C_{r\varepsilon}$	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007
Modified Secondary Compression Index, $C_{\alpha\varepsilon}$	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Settlements												
Primary Settlement, (ft)	0.000	0.834	0.934	1.010	0.706	0.778	0.740	0.591	0.502	0.570	0.293	0.281
Secondary Settlement (30 Years) (ft)	0.154	0.163	0.150	0.151	0.151	0.151	0.152	0.151	0.151	0.151	0.148	0.136
Total Settlement (ft)	0.154	0.997	1.085	1.161	0.857	0.929	0.892	0.742	0.653	0.721	0.441	0.418
Elastic or Plastic (E/P)	P	P	P	P	P	P	P	P	P	P	P	P
	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D	1-D
Settlement of Sublayer (ft)	0.154	0.997	1.085	1.161	0.857	0.929	0.892	0.742	0.653	0.721	0.441	0.418
TOTAL SETTLEMENT Total Settlement (ft)	0.17	1.16	2.10	2.31	2.61	2.59	2.38	2.14	2.07	2.08	1.38	1.46
Post settlement subgrade elev. (ft msl)	1,381.8	1,386.9	1,390.9	1,392.3	1,408.9	1,404.4	1,402.3	1,405.0	1,409.9	1,404.9	1,406.6	1,405.5
Post settlement liner elev. (ft msl)		1389.9	1393.9	1395.3	1411.9	1407.4	1405.3	1408.0	1412.9	1407.9	1409.6	
GRADES AND STRAINS BASED ON CALCULATED SETTLEMENT												
Intial Liner Segment Length, L_o (ft)		205.2	496.0	162.0	37.1	17.6	135.0	138.0	13.9	13.9	280.0	263.0
Post Settle. Liner Segment Length, L_o (ft)		205.2	496.0	162.0	36.9	17.6	135.0	138.0	13.9	13.9	280.0	263.0
Post Settlement Liner Strain (+ comp, - tension)		0.02%	0.00%	0.00%	0.36%	0.03%	0.00%	0.00%	-0.17%	-0.03%	0.00%	0.00%
PreSettlement Slope (+ up, - down)		3.0%	1.0%	1.0%	51.2%	-26.5%	-1.7%	1.7%	37.7%	-38.5%	0.4%	-0.4%
Post Settlement Slope		2.5%	0.8%	0.9%	50.3%	-26.3%	-1.6%	1.9%	38.2%	-38.6%	0.6%	-0.4%
Grade Difference (+ steeper, - milder)		-0.5%	-0.2%	-0.1%	-0.9%	-0.1%	-0.2%	0.2%	0.5%	0.1%	0.2%	0.0%

EXHIBIT C

OPERATIONAL STORM WATER MANAGEMENT DESIGN

Written by: Y. Bholat	Date: 2/5/2014	Reviewed & Revised by: S. Graves	Date: 10/10/2014
Client: Clean Harbors	Project: Lone Mountain Facility	Project No.: TXL0380	Phase No.: 04

OPERATIONAL STORM WATER MANAGEMENT DESIGN

10/20/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

Scott M. Graves, P.E.
State of Oklahoma Registration # 19710
Geosyntec Consultants
Oklahoma Certificate of Authorization No. 1996
Exp. 06/30/2016

SEALED FOR CALCULATION PAGES
C-1 THROUGH C-32

1. INTRODUCTION

The purpose of this calculation package is to present the analysis and design of the operational storm water storage areas that will be provided for the proposed Lone Mountain Facility Cell 15. This package provides calculations for the design storm runoff volume and the design of the operational storm water storage areas that will be provided as development progresses.

2. PROJECT BACKGROUND

An operational storm water storage area for the proposed Cell 15 will be provided during filling operations prior to construction of the final cover system. This calculation package is for the current and future conditions (i.e., the currently active areas, and for yet-to-be-constructed subcells). Accordingly, this calculation package begins with Subcell 9. The storage area will be located at the west end of the active cells for Subcells 9 through 13 and at the south end of the active cells for Subcells 14 through 22. The storage area will be relocated to the next cell as the landfill development progresses. The storage area will be within the lined cell in-between the toe of the waste and the operational berm or above grade dike.

3. CALCULATION METHODOLOGY

3.1 Return Period for Design Storm

The operational storm water storage area is designed for the calculated runoff volume from a 100-year, 24-hour design storm event.

3.2 Runoff Volume

The rainfall depth from the 100-year, 24-hour design storm was selected using the U.S. Department of the Interior and US Geological Survey Water-Resources Investigations Report 99-4232 (USGS, 1999). For Major County (Oklahoma), the 100-year, 24-hour rainfall depth is approximately 6.3 inches. The runoff volume is calculated by multiplying the rainfall depth by the active waste filling area. For design purposes, it is assumed that 100% of the rainfall will become runoff (i.e., no infiltration or evapotranspiration will occur). This is a very conservative assumption.

3.3 Storage Area Capacity

The proposed storage area has a trapezoidal cross-sectional shape that extends along the length of the cell, as shown in Figure C-1 at the end of this document. The storage area capacity is calculated using the following equation:

$$V = H * \left(\frac{A_1 + A_2}{2}\right) \qquad \text{(Eqn. 1)}$$

where:

V = volume (storage capacity);

A_1 = area of base (floor area) = length of floor × width of floor;

A_2 = area of top (top surface area of storm water at maximum depth) = length of surface × width of surface; and

H = maximum depth of storm water = average height of operational berm minus one foot of freeboard.

It is noted that the width of floor is measured from the toe-of-slope of the interim waste, to the toe-of-slope of the cell division berm, along the top of protective cover material layer of the liner system, as shown in Figure C-1.

The maximum depth of storm water, H, is calculated such that the calculated storage capacity, V, is equal to the runoff volume (Section 3.2). Next, one foot is added for freeboard. Therefore, the minimum average height of operational berm is then equal to H + 1 foot. The minimum berm elevation is then calculated by adding the minimum average berm height to the elevation at the midpoint of the cell floor (Equation 2).

$$E_{berm-storm\,water} = E_{midpoint\ cell\ floor} + (H + 1) \qquad \text{(Eqn. 2)}$$

where:

$E_{berm\text{-}stormwater}$ = minimum required berm elevation for storm water storage;

$E_{\text{midpoint cell floor}}$ = elevation at the midpoint of the cell floor at the toe of the berm;
$(H + 1)$ = minimum average berm height (inclusive of freeboard).

Due to the three-dimensional geometry of the landfill, it is noted that the minimum required berm elevation for storm water storage may be superseded by a greater value. The methodology for this is out of the scope of the storm water storage calculations; however, for clarity, the minimum required berm elevations are listed in Table C-1.

4. CALCULATIONS

4.1 Storage Area for Subcell 9

It is anticipated that the operational storm water storage area for Subcell 9 will collect runoff from 100% of Subcell 9, 50% of Subcells 4 and 5, and 25% of Subcell 6. As shown in Figure C-2, this drainage area is measured to be approximately 459,558 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 241,268 ft^3.

The proposed floor width for the storm water storage area for Subcell 9 is 50 feet and the minimum average height of operational berm is 7.3 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1390.9 feet above mean sea level (ft, MSL).

4.2 Storage Area for Subcell 10

Subcell 10 is constructed together with Subcell 11 and will not have its own operational storm water storage area, but rather, is accounted for below with Subcell 11.

4.3 Storage Area for Subcell 11

It is anticipated that the operational storm water storage area for Subcell 11 will collect runoff from 100% of Subcells 10 and 11, 50% of Subcells 7 and 8, and 25% of Subcell 6. As shown in Figure C-3, this drainage area is measured to be approximately 520,542 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 273,285 ft^3.

The proposed floor width for the storm water storage area for Subcell 11 is 50 feet and the average height of operational berm is 8.4 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1390.4 ft, MSL.

4.4 Storage Area for Subcell 12

It is anticipated that the operational storm water storage area for Subcell 12 will collect runoff from 100% of Subcells 9 and 12. As shown in Figure C-4, this drainage area is measured to be approximately 448,668 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 235,551 ft^3.

The proposed floor width for the storm water storage area for Subcell 12 is 50 feet and the average height of operational berm is 7.1 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1394.4 ft, MSL.

4.5 Storage Area for Subcell 13

It is anticipated that the operational storm water storage area for Subcell 13 will collect runoff from 100% of Subcells 10, 11, and 13. As shown in Figure C-5, this drainage area is measured to be approximately 444,312 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 233,264 ft^3.

The proposed floor width for the storm water storage area for Subcell 13 is 50 feet and the average height of operational berm is 7.4 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1391.4 ft, MSL.

4.6 Storage Area for Subcell 14

It is anticipated that the operational storm water storage area for Subcell 14 will collect runoff from 100% of Subcells 11, 13, and 14. As shown in Figure C-6, this drainage area is measured to be approximately 577,170 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 303,014 ft^3.

The proposed floor width for the storm water storage area for Subcell 14 is 100 feet and the average height of operational berm is 9.4 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1404.2 ft, MSL.

4.7 Storage Area for Subcell 15

It is anticipated that the operational storm water storage area for Subcell 15 will collect runoff from 100% of Subcell 15. As shown in Figure C-7, this drainage area is measured to be approximately 262,667 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 137,900 ft^3.

The proposed floor width for the storm water storage area for Subcell 15 is 50 feet and the average height of operational berm is 7.2 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1408.4 ft, MSL.

4.8 Storage Area for Subcell 16

It is anticipated that the operational storm water storage area for Subcell 16 will collect runoff from 100% of Subcells 12 and 16 and 50% of Subcells 13, 14, and 15. As shown in Figure C-8, this drainage area is measured to be approximately 807,167 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 423,763 ft^3.

The proposed floor width for the storm water storage area for Subcell 16 is 75 feet and the average height of operational berm is 8.2 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1413.1 ft, MSL.

4.9 Storage Area for Subcell 17

It is anticipated that the operational storm water storage area for Subcell 17 will collect runoff from 100% of Subcells 12, 16, and 17 and 25% of Subcells 13, 14, and 15. As shown in Figure C-9, this drainage area is measured to be approximately 841,579 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 441,829 ft^3.

The proposed floor width for the storm water storage area for Subcell 17 is 75 feet and the average height of operational berm is 8.4 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1412.4 ft, MSL.

4.10 Storage Area for Subcell 18

It is anticipated that the operational storm water storage area for Subcell 18 will collect runoff from 100% of Subcells 17 and 18 and one-third of Subcell 12. As shown in Figure C-10, this drainage area is measured to be approximately 481,628 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 252,855 ft^3.

The proposed floor width for the storm water storage area for Subcell 18 is 50 feet and the average height of operational berm is 8.4 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1410.2 ft, MSL.

4.11 Storage Area for Subcell 19

It is anticipated that the operational storm water storage area for Subcell 19 will collect runoff from 100% of Subcells 18 and 19. As shown in Figure C-11, this drainage area is measured to be approximately 377,665 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 198,274 ft^3.

The proposed floor width for the storm water storage area for Subcell 19 is 50 feet and the average height of operational berm is 7.1 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1408.3 ft, MSL.

4.12 Storage Area for Subcell 20

It is anticipated that the operational storm water storage area for Subcell 20 will collect runoff from 100% of Subcells 19 and 20. As shown in Figure C-12, this drainage area is measured to be approximately 377,665 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 198,274 ft^3.

The proposed floor width for the storm water storage area for Subcell 20 is 50 feet and the average height of operational berm is 6.9 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1412.2 ft, MSL.

4.13 Storage Area for Subcell 21

It is anticipated that the operational storm water storage area for Subcell 21 will collect runoff from 100% of Subcells 20 and 21. As shown in Figure C-13, this drainage area is measured to be approximately 376,358 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 197,588 ft^3.

The proposed floor width for the storm water storage area for Subcell 21 is 50 feet and the average height of operational berm is 6.6 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1417.6 ft, MSL.

4.14 Storage Area for Subcell 22

It is anticipated that the operational storm water storage area for Subcell 22 will collect runoff from 100% of Subcell 22 and 50% of Subcell 21. As shown in Figure C-14, this drainage area is measured to be approximately 262,449 ft^2. As shown in Table C-1, this drainage area results in a required storm water storage capacity of 137,786 ft^3.

The proposed floor width for the storm water storage area for Subcell 22 is 100 feet and the average height of operational berm is 4 feet. As shown in Table C-1, this minimum average berm height results in a calculated minimum berm elevation of 1420 ft, MSL.

5. CONCLUSIONS

Calculations presented herein indicate that the operational storm water areas for the proposed Lone Mountain Facility Cell 15 will provide capacity to store runoff from a 100-year, 24-hour storm.

In particular, refer to Table C-1 for the required interim waste set-back distance for each subcell, for the required minimum average height of each inter-subcell (operational) berm, and for the required minimum top elevation of each inter-subcell (operational) berm. It is noted that in many instances, the minimum calculated berm elevation to meet the storm water storage capacity was further increased due to three-dimensional effects of landfill geometry. Thus, the proposed management plan is a conservative approach for stormwater storage.

6. REFERENCES

United States Geological Survey (USGS), "Depth-Duration Frequency of Precipitation for Oklahoma", R.L. Tortorelli, A. Rea, and W.H. Asquith, Water-Resources Investigations Report 99-4232, 1999.

U.S. Weather Bureau, "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years," *Technical Paper No. 40*, Washington D.C., May 1961, 56 pp.

TABLES

- Table C-1. Summary of Required Storm Water Storage and Calculated Berm Heights and Elevations.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Table C-1. Summary of Required Storm Water Storage and Minimum Calculated Berm Heights and Elevations.

Subcell	Required Storage	Offset	Berm Height	Floor Elevation at Midpoint of the Cell Floor	Minimum Required Berm Elevation for Storm Water Storage	Minimum Required Berm Elevation (Note 4)
	ft^3	ft	ft	ft, MSL	ft, MSL	ft, MSL
9	241,268	50	7.3	1383.6	1390.9	1392.0
11 (Note 3)	273,285	50	8.4	1382.0	1390.4	1391.1
12	235,551	50	7.1	1387.3	1394.4	1413.1
13	233,264	50	7.4	1384.0	1391.4	1397.0
14	303,014	100	9.4	1394.8	1404.2	1410.0
15	137,900	50	7.2	1401.2	1408.4	1408.4
16	423,763	75	8.2	1404.9	1413.1	1413.1
17	441,829	75	8.4	1404.0	1412.4	1412.4
18	252,855	50	8.4	1401.8	1410.2	1410.2
19	198,274	50	7.1	1401.2	1408.3	1408.4
20	198,274	50	6.9	1405.3	1412.2	1414.1
21	197,588	50	6.6	1411.0	1417.6	1417.8
22	137,786	100	4	1416	1420.0	1420.0

Notes:

1. This table provides a summary of the full spreadsheet calculations which are presented in Appendix C-1.
2. The storage area in the subcells is provided between the waste and the above grade dike (operational berm).
3. Subcell 10 and 11 are constructed together and will share a storm water storage area.
4. The Minimum Required Berm Elevation is equal to or slightly greater than the Minimum Required Berm Elevation for Storm Water Storage. Due to the three-dimensional landfill geometry, various inter-subcell (operational) berm elevations were increased as shown to provide adequate separation between adjacent subcells (which was the governing condition, rather than the storm water storage calculated herein). This is a conservative approach for stormwater storage, as it will provide even more stormwater storage capacity.

FIGURES

Written by:	Y. Bholat	Date:	2/5/2014	Reviewed by:	S. Graves	Date:	3/4/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

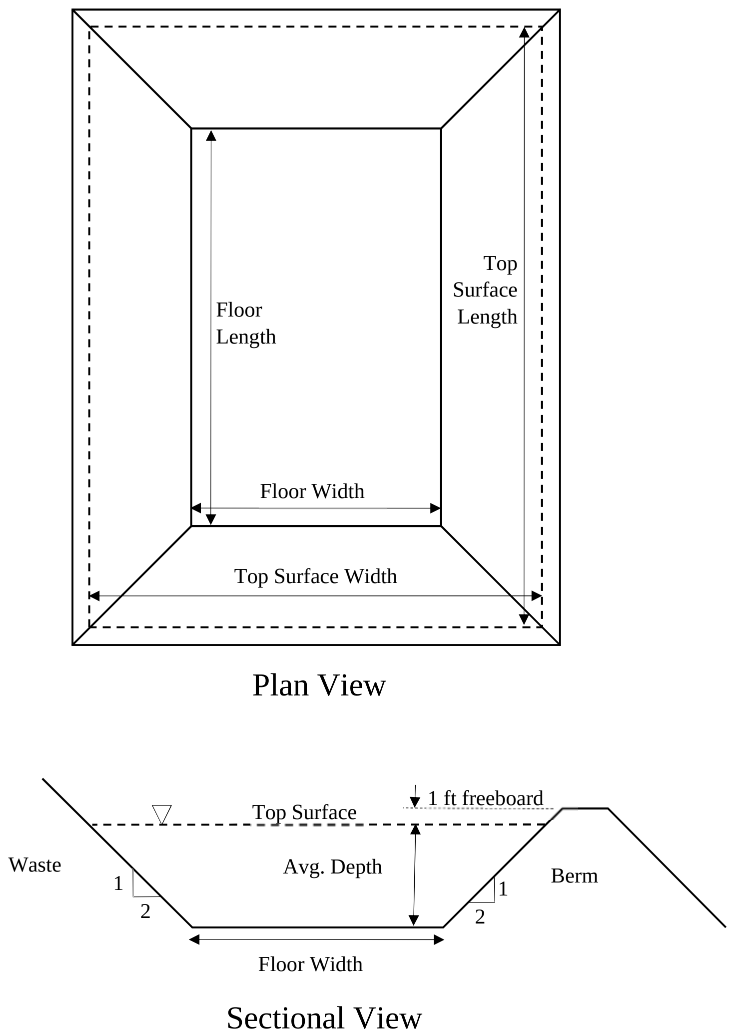


Figure C-1. Operational Storm Water Storage Area Configuration.

Written by: **Y. Bholat**	Date: **2/5/2014**	Reviewed & Revised by: **S. Graves**	Date: **10/10/2014**
Client: **Clean Harbors**	Project: **Lone Mountain Facility**	Project No.: **TXL0380**	Phase No.: **04**

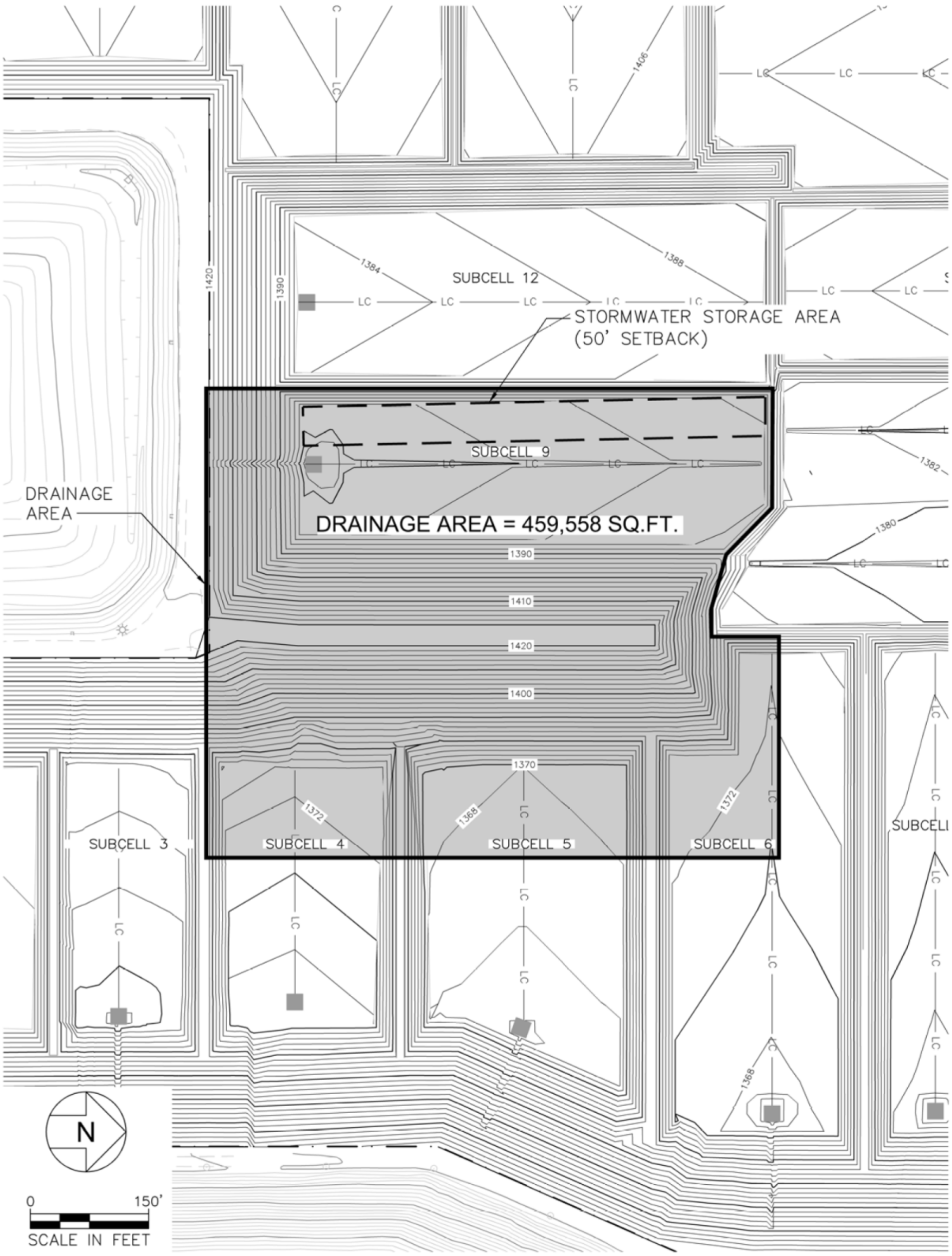


Figure C-2. Drainage Area for Subcell 9 Operational Storm Water Storage Area.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

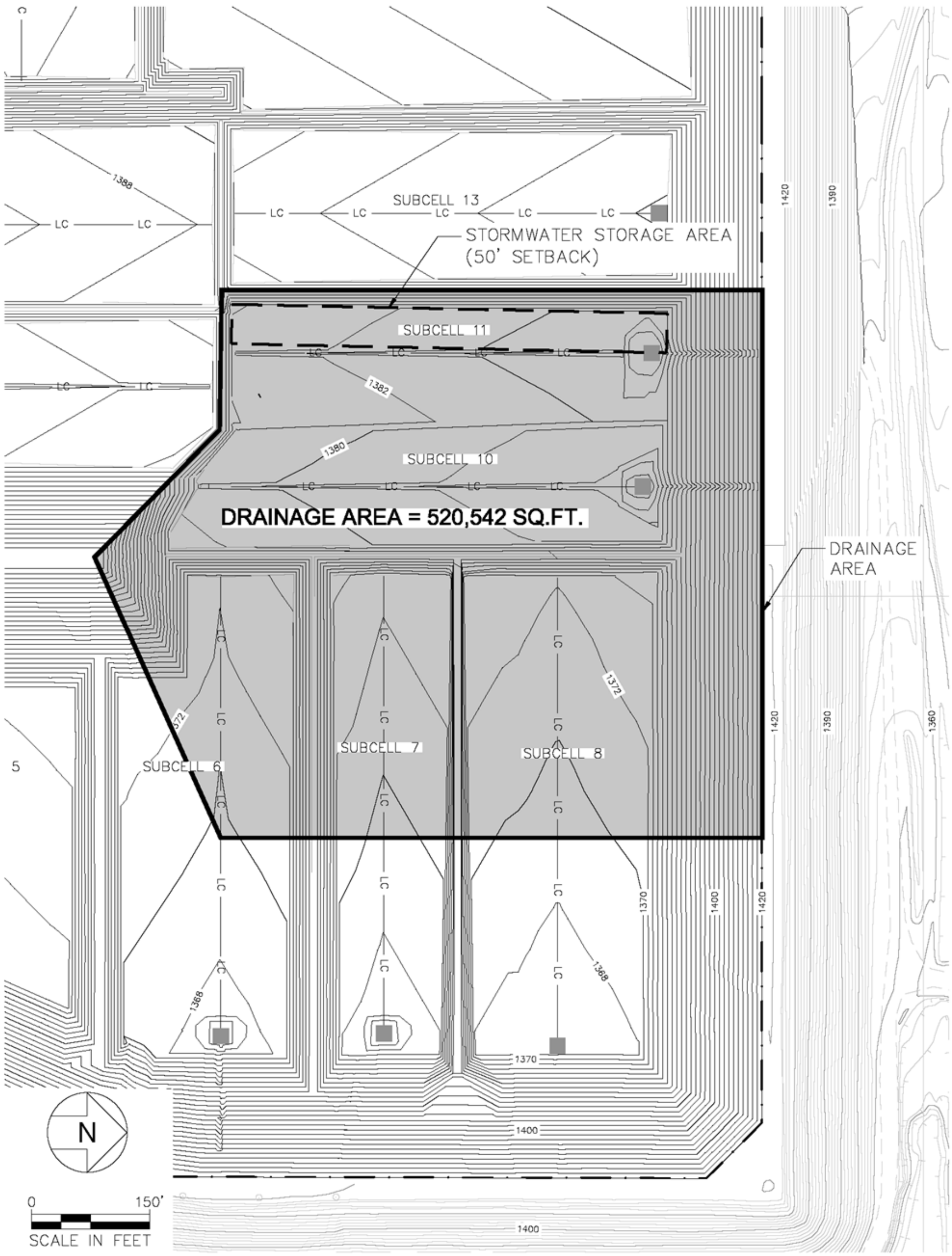


Figure C-3. Drainage Area for Subcell 11 Operational Storm Water Storage Area.

Written by: **Y. Bholat**	Date: **2/5/2014**	Reviewed by: **S. Graves**	Date: **3/4/2014**
Client: **Clean Harbors**	Project: **Lone Mountain Facility**	Project No.: **TXL0380**	Phase No.: **04**

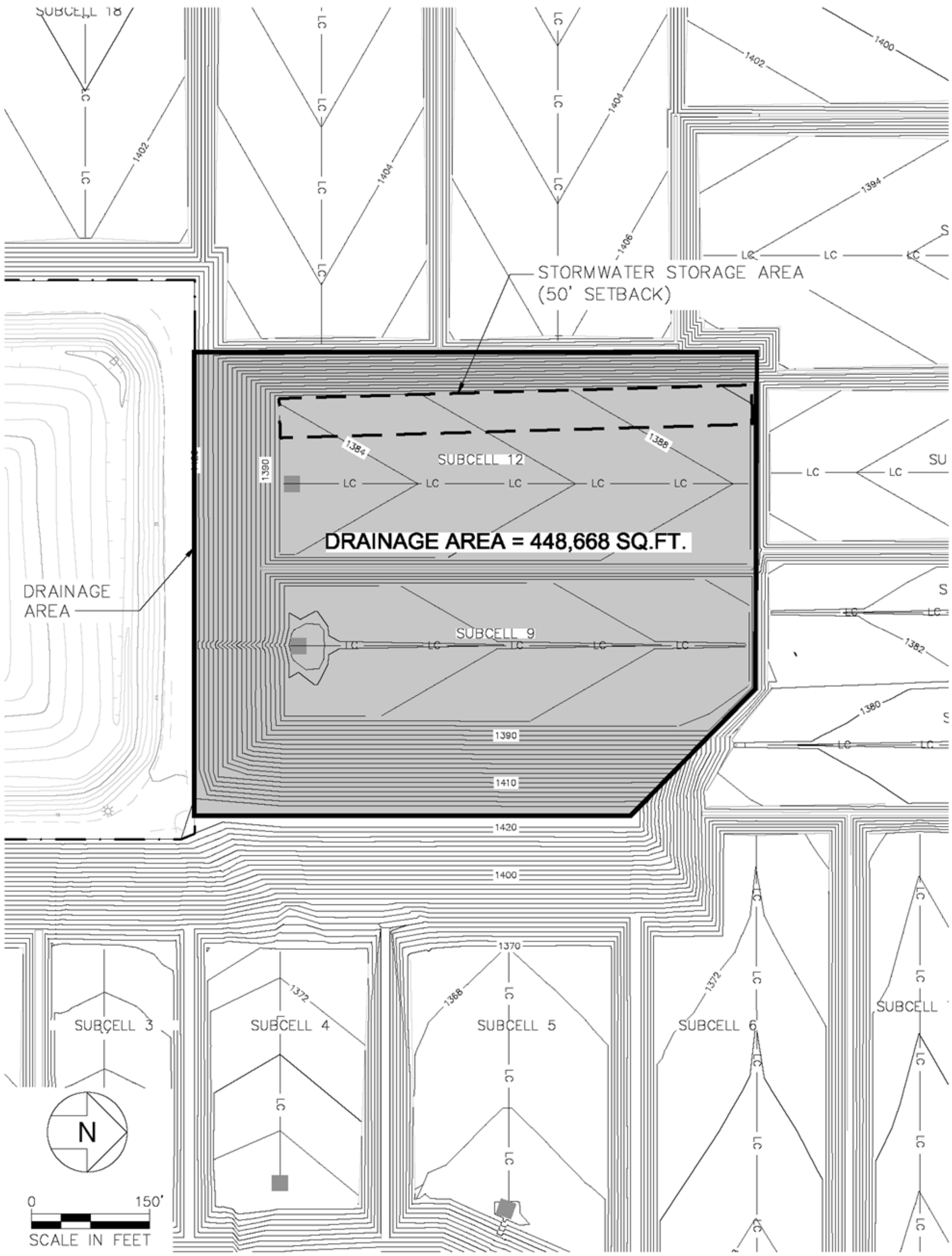


Figure C-4. Drainage Area for Subcell 12 Operational Storm Water Storage Area.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

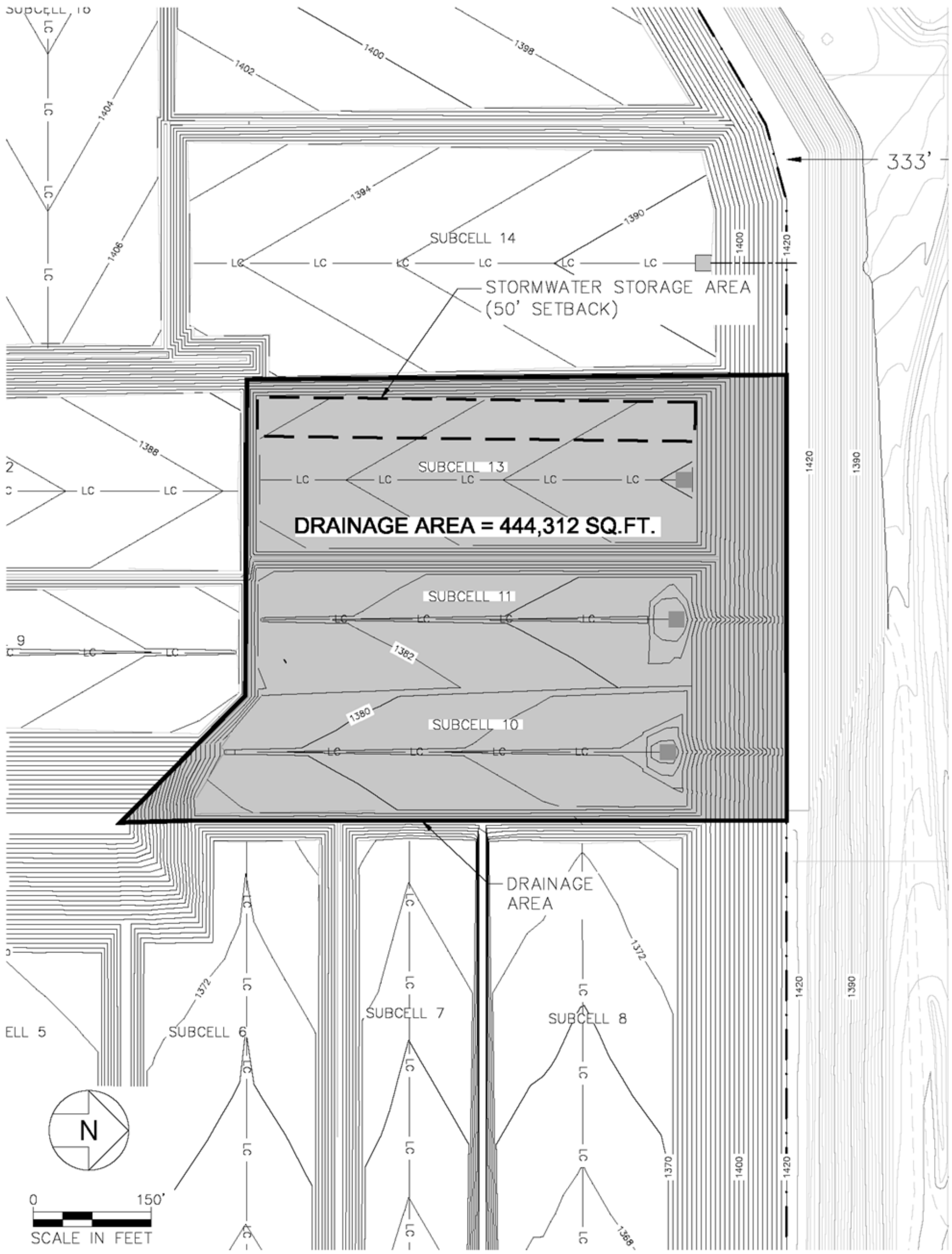


Figure C-5. Drainage Area for Subcell 13 Operational Storm Water Storage Area.

Written by: **Y. Bholat**	Date: **2/5/2014**	Reviewed by: **S. Graves**	Date: **3/4/2014**
Client: **Clean Harbors**	Project: **Lone Mountain Facility**	Project No.: **TXL0380**	Phase No.: **04**

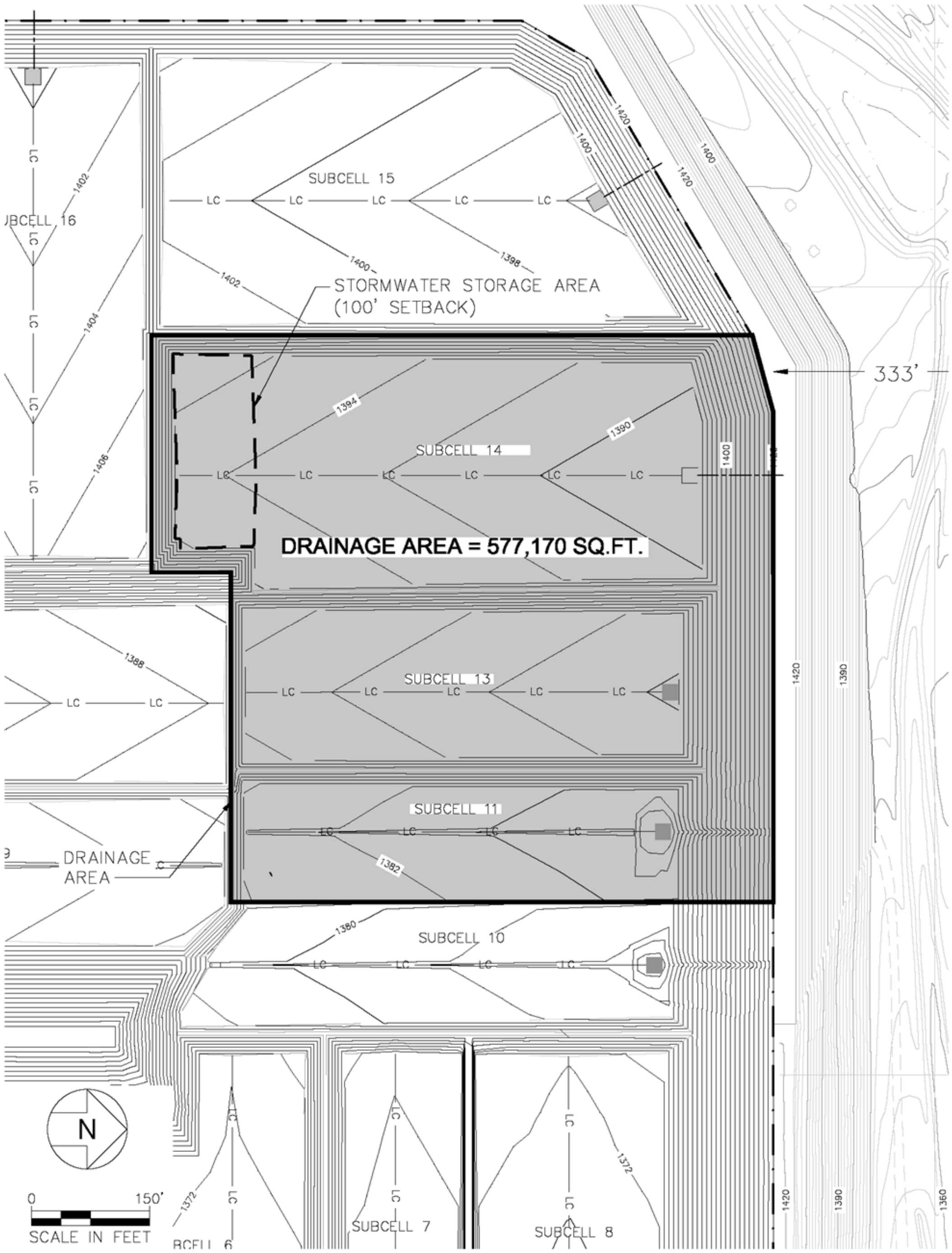


Figure C-6. Drainage Area for Subcell 14 Operational Storm Water Storage Area.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

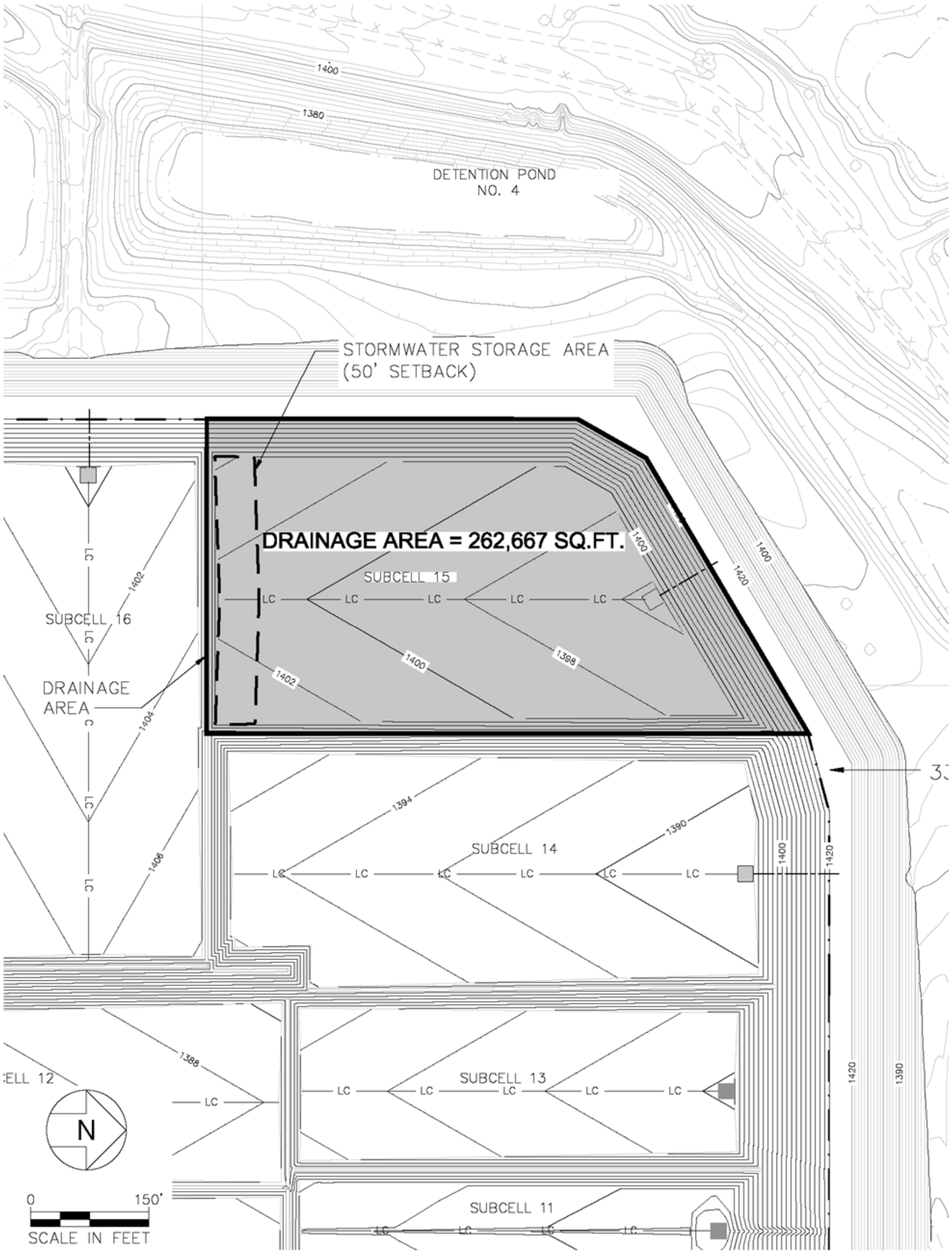


Figure C-7. Drainage Area for Subcell 15 Operational Storm Water Storage Area.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

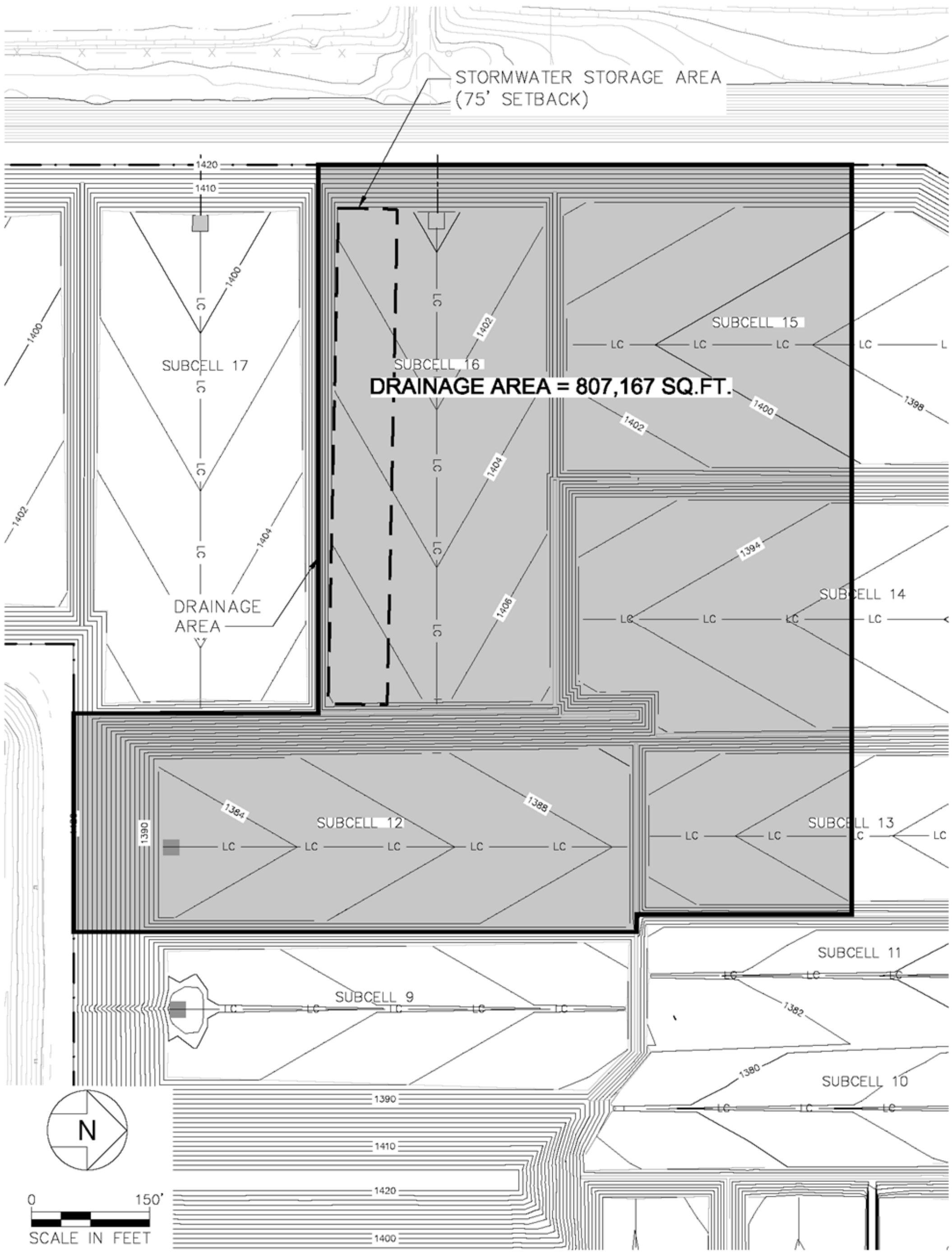


Figure C-8. Drainage Area for Subcell 16 Operational Storm Water Storage Area.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

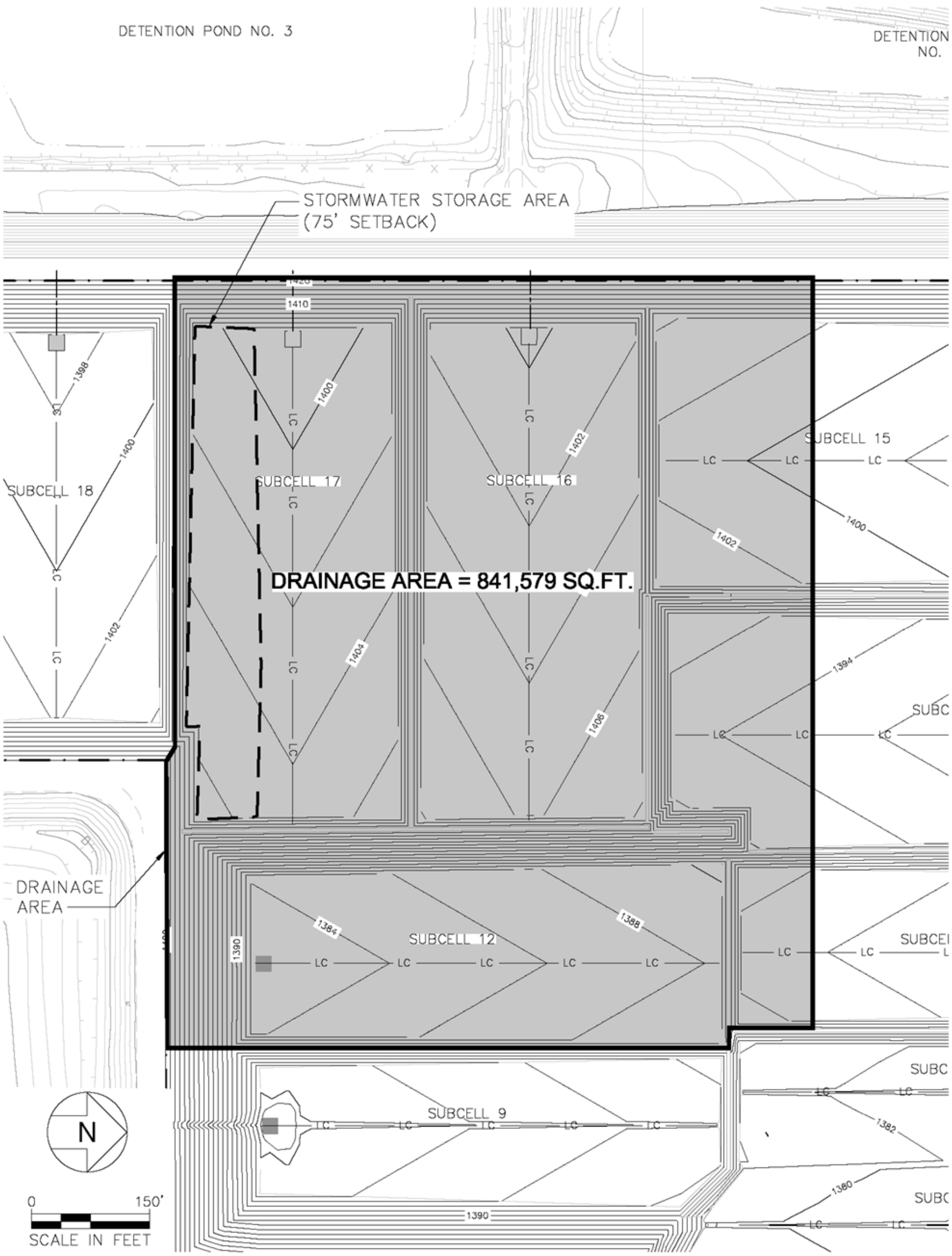


Figure C-9. Drainage Area for Subcell 17 Operational Storm Water Storage Area.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

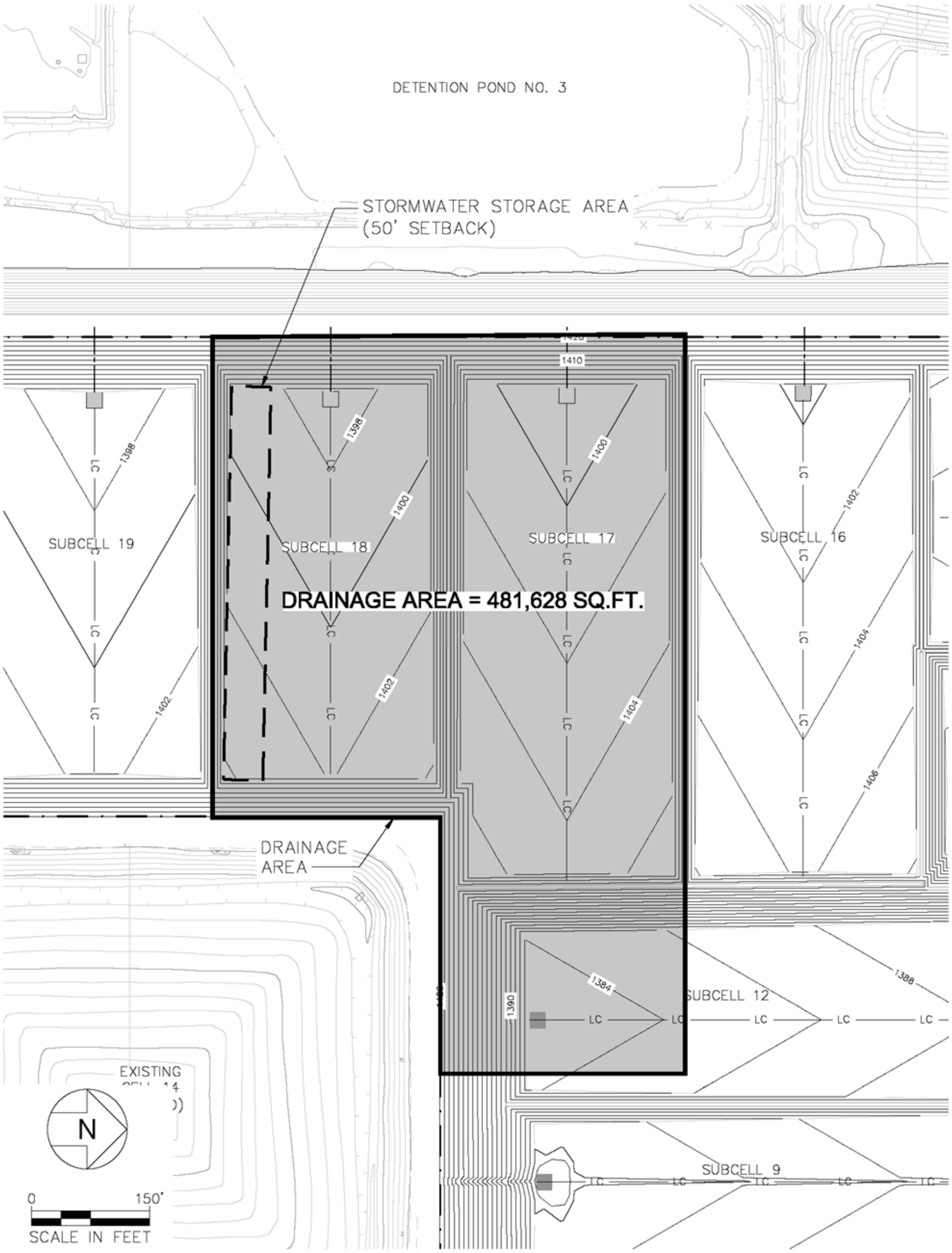


Figure C-10. Drainage Area for Subcell 18 Operational Storm Water Storage Area.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

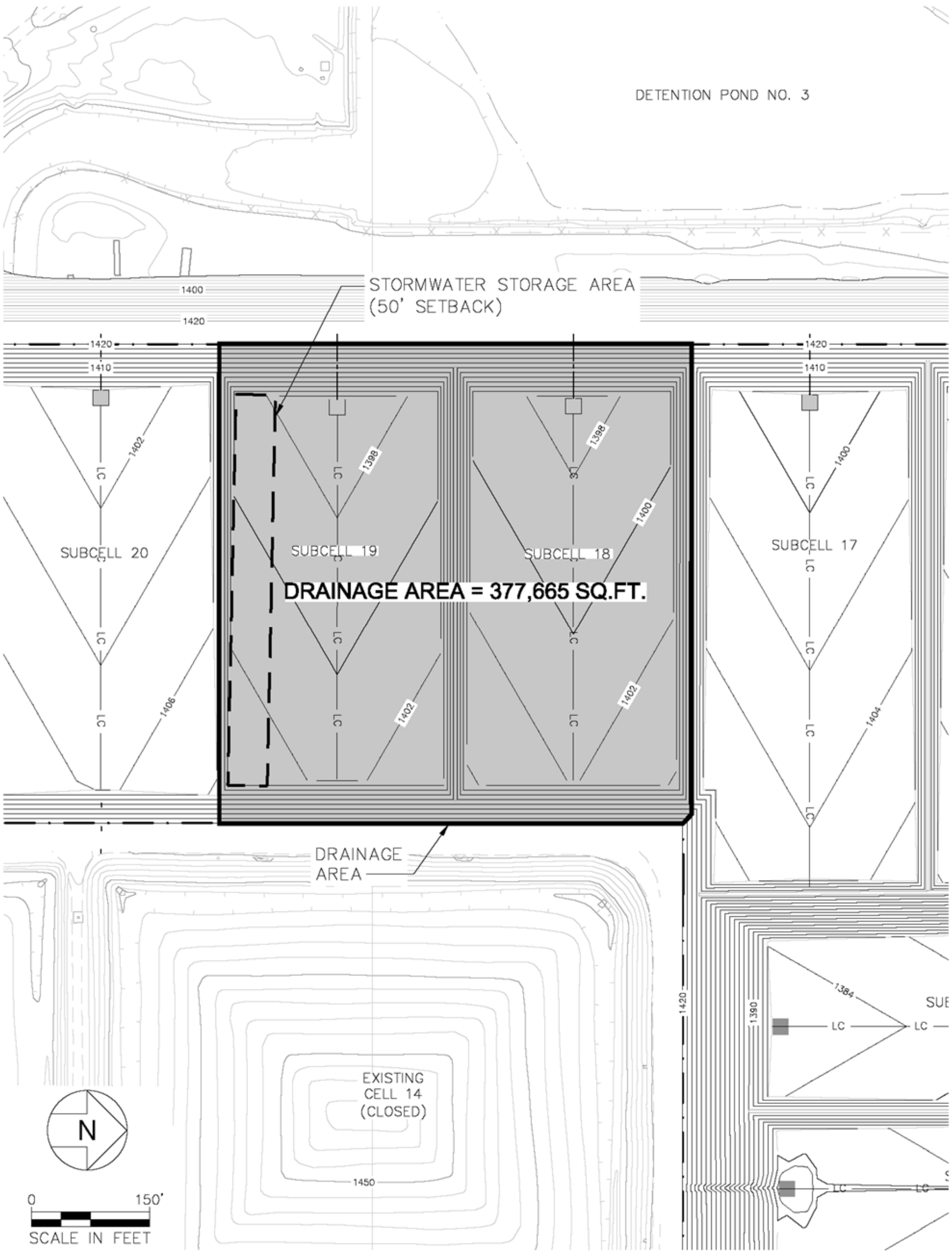


Figure C-11. Drainage Area for Subcell 19 Operational Storm Water Storage Area.

Written by: **Y. Bholat**	Date: **2/5/2014**	Reviewed by: **S. Graves**	Date: **3/4/2014**
Client: **Clean Harbors**	Project: **Lone Mountain Facility**	Project No.: **TXL0380**	Phase No.: **04**

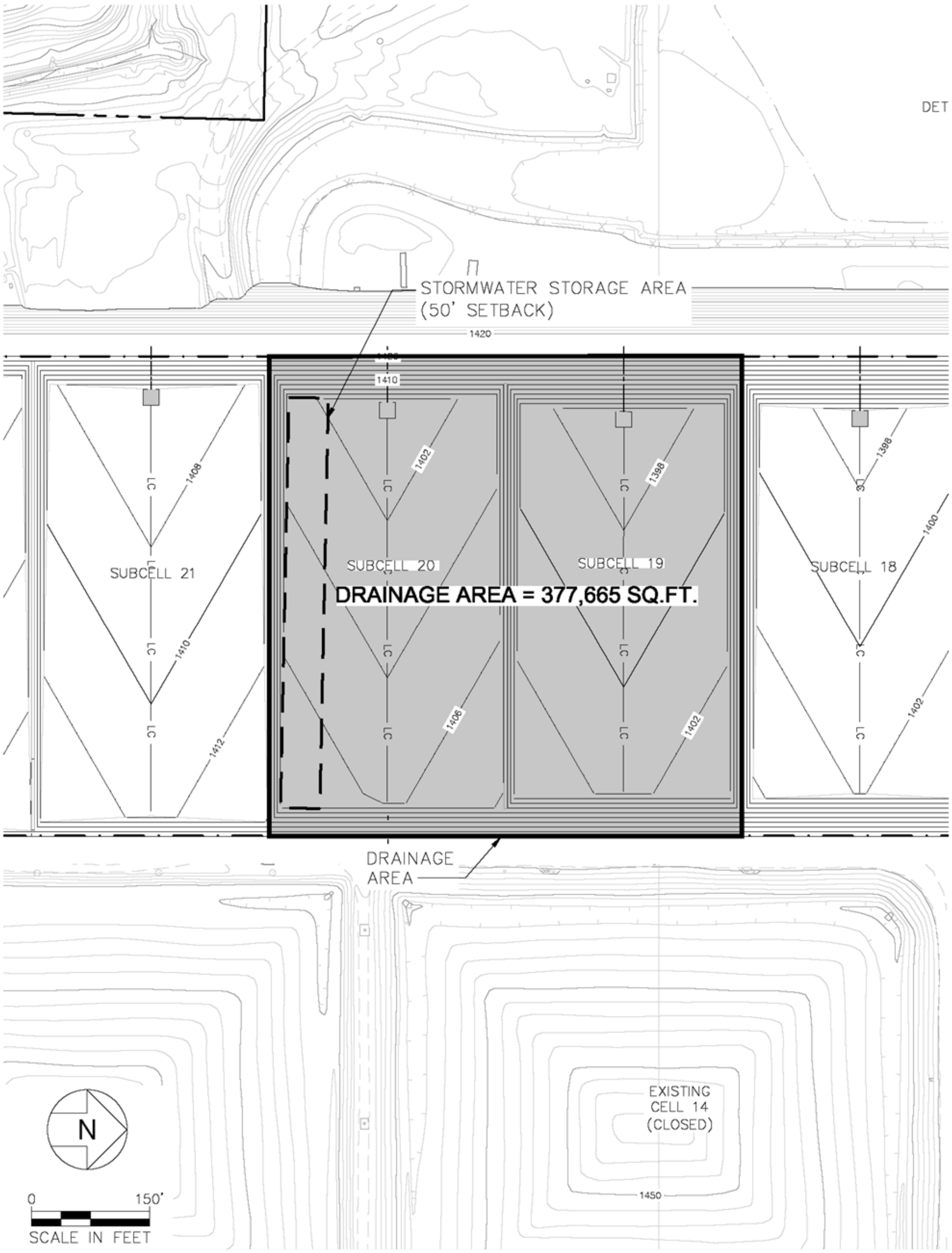


Figure C-12. Drainage Area for Subcell 20 Operational Storm Water Storage Area.

Written by: **Y. Bholat**	Date: **2/5/2014**	Reviewed by: **S. Graves**	Date: **3/4/2014**
Client: **Clean Harbors**	Project: **Lone Mountain Facility**	Project No.: **TXL0380**	Phase No.: **04**

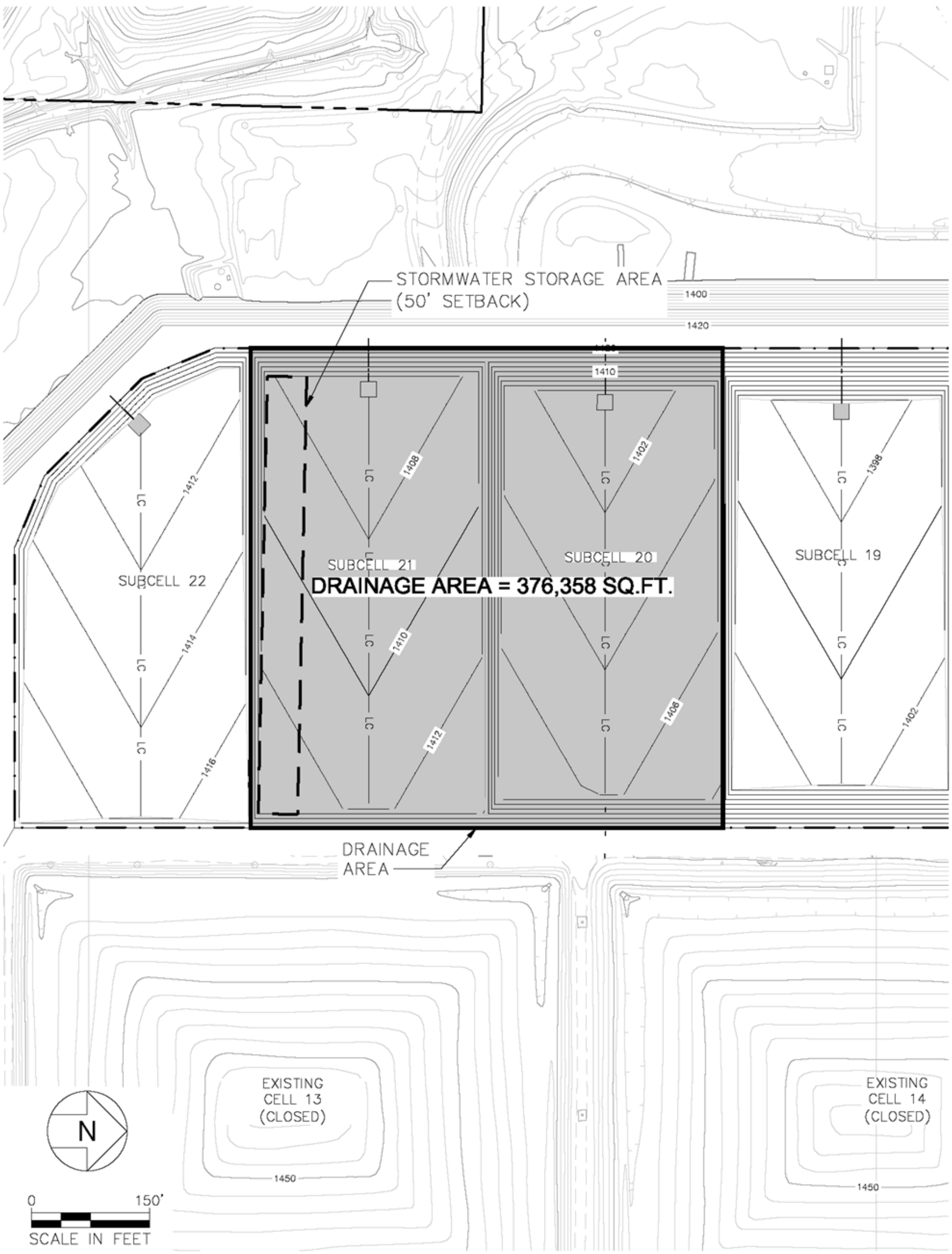


Figure C-13. Drainage Area for Subcell 21 Operational Storm Water Storage Area.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

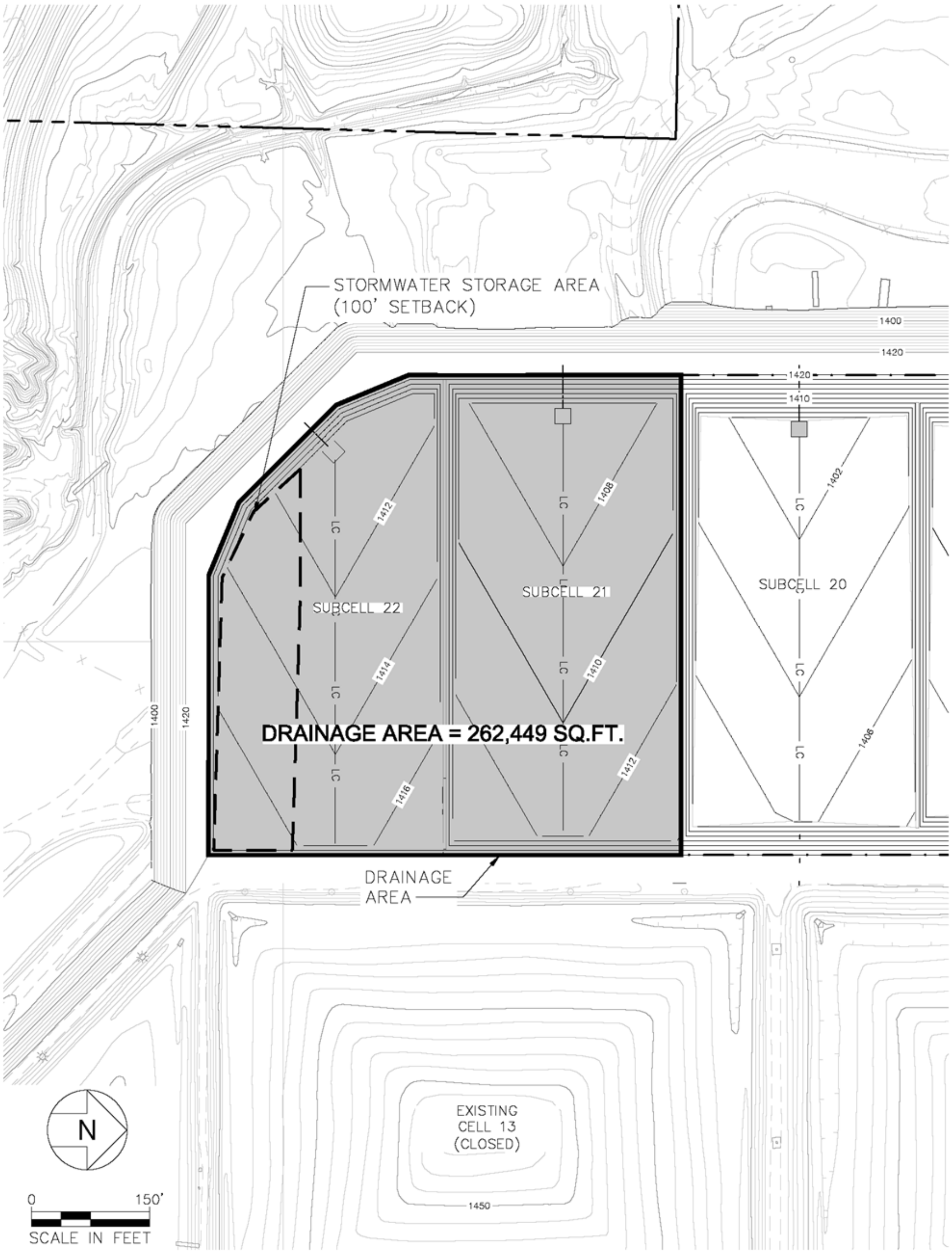


Figure C-14. Drainage Area for Subcell 22 Operational Storm Water Storage Area.

APPENDIX

- Appendix C-1. Operational Storm Water Storage Spreadsheet Calculations

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed & Revised by: **S. Graves** Date: **10/10/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Subcell 9 with Setback = 50 ft.

Case	Floor Length (ft)	Floor Width (ft)	Floor Area (sq. ft)	Water Depth (ft)	Top Area Length (ft)	Top Area Width (ft)	Top Area Area (sq. ft)	Available Storage (cu. ft)	Catchment Area (sq. ft)	Rainfall Depth (in.)	Required Storage (cu. ft)	Average Berm Height
Subcell 4 *Subcell 5* Subcell 6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	241,268	459,558	6.30	241,268	7.3 ft
Subcell 9	590	50	29500	6.32	622	75	46805					

Notes:
1. Due to sequencing, when Subcell 9 is open, Subcells 10 and 11 will also need to have an open storage area (i.e., all three subcells will be active).
2. The contributing area to Subcell 9 is assumed to be a quarter of Subcell 6, half of Subcells 4 and 5, plus all of Subcell 9 itself.
3. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
4. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
5. The average berm height includes 1 foot of freeboard.

Subcell 11 with Setback = 50 ft.

Case	Floor Length (ft)	Floor Width (ft)	Floor Area (sq. ft)	Water Depth (ft)	Top Area Length (ft)	Top Area Width (ft)	Top Area Area (sq. ft)	Available Storage (cu. ft)	Catchment Area (sq. ft)	Rainfall Depth (in.)	Required Storage (cu. ft)	Average Berm Height
Subcell 6 *Subcell 7* *Subcell 8* Subcell 10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	273,285	520,542	6.30	273,285	8.4 ft
Subcell 11	550	50	27500	7.37	587	79	46647					

Notes:
1. Due to sequencing, Subcells 10 and 11 are constructed together and will have a single open area for storm water storage.
2. Due to sequencing, when Subcells 10 and 11 are open, Subcell 9 will also need to have open area for storm water storage.
3. The contributing area to Subcell 11 is a quarter of Subcell 6, half of Subcells 7 and 8, plus all of Subcells 10 and 11.
4. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
5. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
6. The average berm height includes 1 foot of freeboard.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Subcell 12 with Setback = 50 ft.

Case	Floor Length (ft)	Floor Width (ft)	Floor Area (sq. ft)	Water Depth (ft)	Top Area Length (ft)	Top Area Width (ft)	Top Area Area (sq. ft)	Available Storage (cu. ft)	Catchment Area (sq. ft)	Rainfall Depth (in.)	Required Storage (cu. ft)	Average Berm Height
Subcell 9	N/A	N/A	N/A	N/A	N/A	N/A	N/A	235,551	448,668	6.30	235,551	7.1 ft
Subcell 12	600	50	30000	6.12	631	74	46969					

Notes:
1. Due to sequencing, when Subcell 12 is open, Subcell 11 will also need to have open area for stormwater storage.
2. The contributing area to Subcell 12 is Subcell 9 plus Subcell 12 itself.
3. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
4. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
5. The average berm height includes 1 foot of freeboard.

Subcell 13 with Setback = 50 ft.

Case	Floor Length (ft)	Floor Width (ft)	Floor Area (sq. ft)	Water Depth (ft)	Top Area Length (ft)	Top Area Width (ft)	Top Area Area (sq. ft)	Available Storage (cu. ft)	Catchment Area (sq. ft)	Rainfall Depth (in.)	Required Storage (cu. ft)	Average Berm Height
Subcell 10 *Subcell 11*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	233,264	444,312	6.30	233,264	7.4 ft
Subcell 13	560	50	28000	6.41	592	76	44782					

Notes:
1. Due to sequencing, when Subcell 13 is open, Subcell 12 will also need to have open area for stormwater storage.
2. The contributing area to Subcell 13 is Subcells 10 and 11 plus Subcell 13 itself.
3. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
4. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
5. The average berm height includes 1 foot of freeboard.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Subcell 14 with Setback = 100 ft.

Case	Floor			Water	Top Area			Available	Catchment	Rainfall	Required	Average
	Length	Width	Area	Depth	Length	Width	Area	Storage	Area	Depth	Storage	Berm
	(ft)	(ft)	(sq. ft)	(ft)	(ft)	(ft)	(sq. ft)	(cu. ft)	(sq. ft)	(in.)	(cu. ft)	Height
Subcell 11 *Subcell 13*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	303,014	577,170	6.30	303,014	9.4 ft
Subcell 14	290	100	29000	8.39	324	134	43218					

Notes:
1. Due to sequencing, when Subcell 14 is open, Subcell 12 will also need to have open area for stormwater storage.
2. The contributing area to Subcell 14 is Subcells 11 and 13 plus Subcell 14 itself.
3. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
4. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
5. The average berm height includes 1 foot of freeboard.

Subcell 15 with Setback = 50 ft.

Case	Floor			Water	Top Area			Available	Catchment	Rainfall	Required	Average
	Length	Width	Area	Depth	Length	Width	Area	Storage	Area	Depth	Storage	Berm
	(ft)	(ft)	(sq. ft)	(ft)	(ft)	(ft)	(sq. ft)	(cu. ft)	(sq. ft)	(in.)	(cu. ft)	Height
Subcell 15	340	50	17000	6.17	371	75	27696	137,900	262,667	6.30	137,900	7.2 ft

Notes:
1. Due to sequencing, when Subcell 15 is open, Subcell 14 will also need to have open area for stormwater storage.
2. The contributing area to Subcell 15 is Subcell 15 itself.
3. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
4. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
5. The average berm height includes 1 foot of freeboard.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Subcell 16 with Setback = 75 ft.

Case	Floor Length (ft)	Floor Width (ft)	Floor Area (sq. ft)	Water Depth (ft)	Top Area Length (ft)	Top Area Width (ft)	Top Area Area (sq. ft)	Available Storage (cu. ft)	Catchment Area (sq. ft)	Rainfall Depth (in.)	Required Storage (cu. ft)	Average Berm Height
Subcell 12 *Subcell 13* *Subcell 14* *Subcell 15*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	423,763	807,167	6.30	423,763	8.2 ft
Subcell 16	640	75	48000	7.18	676	104	70094					

Notes:
1. The contributing area to Subcell 16 is Subcell 12, half of Subcells 13, 14, and 15, plus Subcell 16 itself.
2. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
3. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
4. The average berm height includes 1 foot of freeboard.

Subcell 17 with Setback = 75 ft.

Case	Floor Length (ft)	Floor Width (ft)	Floor Area (sq. ft)	Water Depth (ft)	Top Area Length (ft)	Top Area Width (ft)	Top Area Area (sq. ft)	Available Storage (cu. ft)	Catchment Area (sq. ft)	Rainfall Depth (in.)	Required Storage (cu. ft)	Average Berm Height
Subcell 12 *Subcell 13* *Subcell 14* *Subcell 15* *Subcell 16*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	441,829	841,579	6.30	441,829	8.4 ft
Subcell 17	640	75	48000	7.43	677	105	70915					

Notes:
1. The contributing area to Subcell 17 is Subcell 12 and 16, a quarter of Subcells 13, 14, and 15, plus Subcell 17 itself.
2. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
3. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
4. The average berm height includes 1 foot of freeboard.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Subcell 18 with Setback = 50 ft.

Case	Floor Length (ft)	Floor Width (ft)	Floor Area (sq. ft)	Water Depth (ft)	Top Area Length (ft)	Top Area Width (ft)	Top Area Area (sq. ft)	Available Storage (cu. ft)	Catchment Area (sq. ft)	Rainfall Depth (in.)	Required Storage (cu. ft)	Average Berm Height
Subcell 12 / *Subcell 17*	N/A	N/A	N/A	N/A	N/A	N/A	N/A	252,855	481,628	6.30	252,855	8.4 ft
Subcell 18	500	50	25000	7.40	544	80	43335					

Notes:
1. The contributing area to Subcell 18 is a third of Subcell 12, all of Subcell 17, plus Subcell 18 itself.
2. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
3. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
4. The average berm height includes 1 foot of freeboard.

Subcell 19 with Setback = 50 ft.

Case	Floor Length (ft)	Floor Width (ft)	Floor Area (sq. ft)	Water Depth (ft)	Top Area Length (ft)	Top Area Width (ft)	Top Area Area (sq. ft)	Available Storage (cu. ft)	Catchment Area (sq. ft)	Rainfall Depth (in.)	Required Storage (cu. ft)	Average Berm Height
Subcell 18	N/A	N/A	N/A	N/A	N/A	N/A	N/A	198,274	377,665	6.30	198,274	7.1 ft
Subcell 19	500	50	25000	6.11	537	74	39940					

Notes:
1. The contributing area to Subcell 19 is Subcell 18 plus Subcell 19 itself
2. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
3. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
4. The average berm height includes 1 foot of freeboard.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Subcell 20 with Setback = 50 ft.

Case	Floor			Water	Top Area			Available	Catchment	Rainfall	Required	Average
	Length	Width	Area	Depth	Length	Width	Area	Storage	Area	Depth	Storage	Berm
	(ft)	(ft)	(sq. ft)	(ft)	(ft)	(ft)	(sq. ft)	(cu. ft)	(sq. ft)	(in.)	(cu. ft)	Height
Subcell 19	N/A	N/A	N/A	N/A	N/A	N/A	N/A	198,274	377,665	6.30	198,274	6.9 ft
Subcell 20	520	50	26000	5.92	556	74	40941					

Notes:
1. The contributing area to Subcell 20 is Subcell 19 plus Subcell 20 itself
2. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
3. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
4. The average berm height includes 1 foot of freeboard.

Subcell 21 with Setback = 50 ft.

Case	Floor			Water	Top Area			Available	Catchment	Rainfall	Required	Average
	Length	Width	Area	Depth	Length	Width	Area	Storage	Area	Depth	Storage	Berm
	(ft)	(ft)	(sq. ft)	(ft)	(ft)	(ft)	(sq. ft)	(cu. ft)	(sq. ft)	(in.)	(cu. ft)	Height
Subcell 20	N/A	N/A	N/A	N/A	N/A	N/A	N/A	197,588	376,358	6.30	197,588	6.6 ft
Subcell 21	560	50	28000	5.57	593	72	42902					

Notes:
1. The contributing area to Subcell 21 is Subcell 20 plus Subcell 21 itself
2. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
3. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
4. The average berm height includes 1 foot of freeboard.

Written by: **Y. Bholat** Date: **2/5/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Subcell 22 with Setback = 100 ft.

Case	Floor			Water	Top Area			Available	Catchment	Rainfall	Required	Average
	Length	Width	Area	Depth	Length	Width	Area	Storage	Area	Depth	Storage	Berm
	(ft)	(ft)	(sq. ft)	(ft)	(ft)	(ft)	(sq. ft)	(cu. ft)	(sq. ft)	(in.)	(cu. ft)	Height
Subcell 21	N/A	N/A	N/A	N/A	N/A	N/A	N/A	137,786	262,449	6.30	137,786	4. ft
Subcell 22	420	100	42000	2.98	438	115	50326					

Notes:
1. The contributing area to Subcell 22 is half of Subcell 21 plus Subcell 22 itself
2. Catchment area based on CADD-calculated areas of Subcells (or subdivisions thereof), as presented in the Cell 15 Engineering Report.
3. Setback length is defined as distance from inside edge of the divider berm to the toe of waste.
4. The average berm height includes 1 foot of freeboard.

EXHIBIT D

LINER ANCHOR TRENCH DESIGN

Written by: **A. Brown** Date: **2/26/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

ANCHOR TRENCH DESIGN AND CALCULATED TENSILE FORCES IN GEOSYNTHETICS

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

6/13/2014

Scott M. Graves, P.E.
State of Oklahoma Registration # 19710
Geosyntec Consultants
Oklahoma Certificate of Authorization No. 1996
Exp. 06/30/2014

SEALED FOR CALCULATION PAGES
D-1 THROUGH D-10

1 INTRODUCTION

1.1 Purpose

The purpose of this calculation package is to (i) evaluate the anticipated stresses in the geosynthetics components of the landfill liner system and resulting tensile forces (if any); and (ii) demonstrate that the anchor trench configuration is adequately designed in the event excessive tensile loading is experienced. The prescribed anchor trench runout length, depth, and interface friction have been evaluated to verify that the geosynthetics will pull out of the anchor trench before tension failure (rupture) of the geosynthetics occurs.

It is noted that separate liner system slope stability analyses were performed using limit equilibrium methods, and the results are presented in Exhibit B-2 of the permit application. In Geosyntec's experience, if these traditional slope stability analyses show an adequate calculated factor of safety, by definition the tensile forces are negligible. Nevertheless, this calculation package was prepared for a hypothetical case of load transfer to the geosynthetics.

1.2 Method

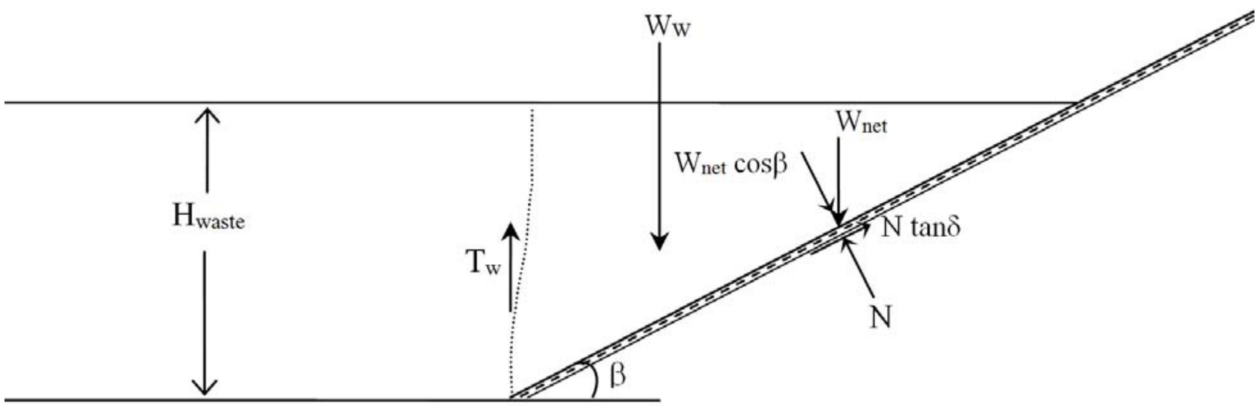
Loading of the geosynthetics materials is estimated and the stresses transmitted by friction to the underlying geosynthetic materials are predicted based on a method presented by Koerner (1998). The method utilizes a single lift of waste, assuming that there is sufficient time between lifts for readjustment of the system to occur (i.e. either equilibrium will be restored or problems will make themselves evident).

Written by: **A. Brown** Date: **2/26/2014** Reviewed by: **S. Graves** Date: **3/5/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

2 ANALYSIS PROCEDURE

2.1 Anticipated Stresses in Geosynthetics



For geosynthetic components which may carry tensile loads, the factor of safety against yielding of the geosynthetic is calculated utilizing the following steps:

1. The net weight, W_{net}, of a lift of waste acting on the slope is determined. The net weight accounts for the shear resistance, T_w, provided by the waste at the toe of the slope and is determined using equation (1).

$$W_{net} = W_w - T_w \tag{1}$$

where W_w = the weight of a single lift of waste acting on a slope.

$$\begin{aligned} T_w &= \sigma_h tan(\varphi_{waste}) H_{waste} \\ &= K_0 \sigma_{v,avg} tan(\varphi_{waste}) H_{waste} \end{aligned} \tag{2}$$

where σ_h = average horizontal stress in the waste at the toe of the slope for at rest (K_0) conditions

φ_{waste} = friction angle of waste

H_{waste} = thickness of a lift of waste

$\sigma_{v,avg}$ = average vertical stress within the waste at the toe of the slope

K_0 = coefficient of lateral earth pressure at rest

$$K_0 = 1 - \sin(\varphi_{waste}) \tag{3}$$

2. The normal force, N, acting through the cover soil to the top geosynthetic material acting perpendicular to the slope, β, is calculated using equation (4).

$$N = W_{net}cos(\beta) \tag{4}$$

3. The shear forces above and below each geosynthetic component in the system are determined using equation (5).

$$F_i = Ntan(\delta_i) \tag{5}$$

where δ_i = interface friction angle between two materials

4. If the driving force above a geosynthetic component interface is greater than the shear resistance provided by the interface below the component, the geosynthetic component in question will be required to carry a tensile load equal to the difference between the driving and resisting force.

5. If a tension load is carried by the geosynthetic material, the factor of safety, FS, against yielding is calculated using equation 6.

$$FS = \frac{\sigma_y}{\sigma_{act}} \tag{6}$$

where σ_y = maximum yield stress of the geosynthetic component
σ_{act} = actual stress imparted on the geosynthetic component

2.2 Anchor Trench Pullout

The Anchorage Ratio, AR, is evaluated for the anchor trench configuration presented in Drawing 14 of Exhibit A of the permit application using the method presented in Koerner (1990). The method assumes frictionless pulleys located at the crest of the slope and the top of the anchor trench. The anchorage ratio is defined by equation (7).

$$AR = \frac{T_{allow}}{T_{AT}} \tag{7}$$

where T_{AT} = maximum tension resistance of the anchor trench determined by analyzing a free-body diagram of the anchor trench configuration; and

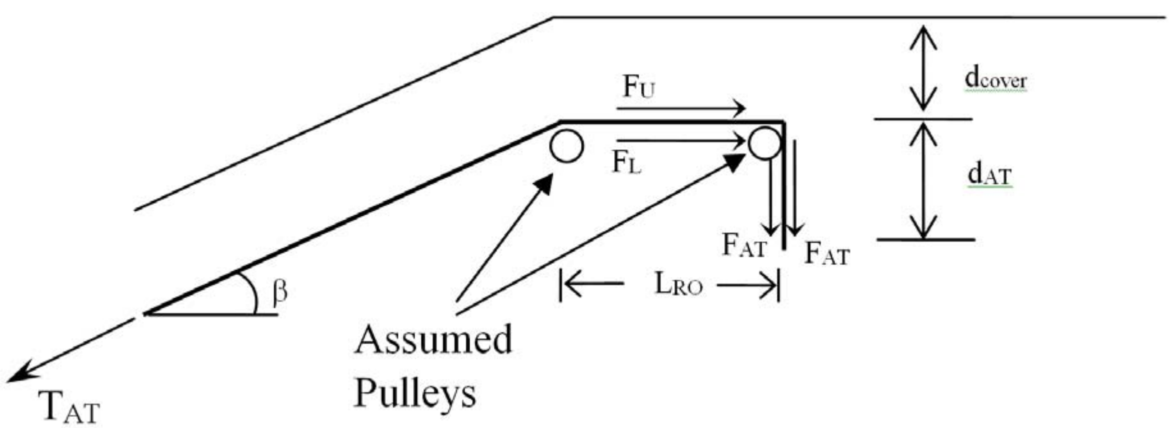
T_{allow} = allowable tension in the geosynthetic material.

$$T_{allow} = \frac{T_{ult}}{FS} \tag{8}$$

where T_{ult} = tensile yield strength of the geosynthetic material; and

FS = desired factor of safety.

If AR > 1.0, then the geosynthetic pullout mode of failure governs. If AR < 1.0, then the geosynthetic rupture (due to tension) mode of failure governs. If AR = 1.0, then the system is balanced. It is generally considered desirable to have AR > 1.0, so that if any tension develops, it will be manifested as anchor trench pullout, which can be more readily repaired.



The tensile force in the geosynthetic can be determined using equation (9).

$$T_{AT} = F_U + F_L + 2F_{AT} \tag{9}$$

where F_U = frictional resistance above the geomembrane due to load of the cover soil; assumed to be zero because any movement of the geomembrane would carry the soil with it;

F_L = frictional resistance provided by the geomembrane-subgrade interface due to the weight of the cover soil (calculated using equation 10); and

F_{AT} = frictional resistance provided by the geomembrane-soil interface due to the lateral earth pressure (assume to be at-rest K_0 conditions) of the anchor trench backfill and the subgrade materials (calculated using equation 11).

$$F_L = d_{cover}\gamma_s L_{RO} tan(\delta_{GM-S}) \tag{10}$$

where d_{cover} = depth of cover soil
γ_s = unit weight of cover soil
L_{RO} = length of run out
δ_{GM-S} = interface friction angle between the geomembrane and subgrade

$$\begin{aligned} F_{AT} &= \sigma_h d_{AT} tan(\delta_{GM-S}) \\ &= K_0 \sigma_{v,avg} d_{AT} tan(\delta_{GM-S}) \\ &= [1 - sin(\varphi_{soil})][0.5 * (d_{cover}\gamma_s + [d_{cover} + d_{AT}]\gamma_s)] d_{AT} tan(\delta_{GM-S}) \end{aligned} \tag{11}$$

where φ_{soil} = friction angle of the subgrade and trench backfill soil
d_{AT} = depth of the anchor trench
γ_s = unit weight of the cover soil

It is noted that the above method follows that presented in Koerner (1990). In a more recent edition(s) of the Koerner publication, the author suggests using active and passive earth pressures instead of at rest earth pressures for calculating F_{AT}. Geosyntec reviewed this procedure and decided that the anchor trench is unlikely to develop active and passive earth pressure along the entire depth of the anchor trench due to the flexibility of the geosynthetic material, which will cause it to pull upward and experience frictional sliding generated from the earth pressure at rest, instead of moving laterally and inducing active and passive earth pressures. Therefore, it was decided to use the original method of Koerner (1990).

3 ANCHOR TRENCH CONFIGURATION

The prescribed anchor trench design, as shown on the details in Drawing 14 of Exhibit A of the permit application, consists of the following:

- a 3:1 (horizontal to vertical) sideslope, β=18.4°;
- runout length of 2-ft;
- anchor trench depth of 2-ft; and

- liner system on the slopes consisting of the following, from top to bottom:
  - 2-ft protective cover soil;
  - geocomposite drainage layer;
  - 60-mil thick upper HDPE geomembrane liner;
  - geosynthetic clay liner (GCL);
  - geocomposite drainage layer;
  - 60-mil thick bottom HDPE geomembrane liner; and
  - 3-ft compacted clay liner.

4 MATERIAL PROPERTIES

4.1 Soil and Waste Parameters

The following parameters are used in the analyses described above and are consistent with the parameters used in Exhibit B2 (Slope Stability Analysis) of the permit application:

- The compacted clay liner and cover soil was assigned a unit weight of 120 pcf and a friction angle, φ', of 28°.
- The protective cover (sand) material was assigned a unit weight of 120 pcf and a friction angle, φ', of 28°.
- The waste material was assigned a unit weight of 120 pcf and a friction angle, φ', of 45°.
- The height of each lift of waste material, H_{waste}, was assumed to be 5 feet.

4.2 Geosynthetics Parameters

The geosynthetic material properties used in these analyses are listed below. The interface friction values are based on Table B2-3 of Exhibit B2.

Interface	Selected Friction Angle (°)
$\delta_{S\text{-}GC}$, Cover soil – Geocomposite drainage layer (value for Nonwoven Geotextile/Compacted Clay in Table B2-3 of Exhibit B2)	26
$\delta_{GC\text{-}GM}$, Geocomposite drainage layer – 60-mil textured HDPE (value for Nonwoven Geotextile/textured HDPE in Table B2-3 of Exhibit B2)	25
$\delta_{GM\text{-}GCL}$, Geomembrane- 60-mil textured HDPE – Geosynthetic clay liner (value for Textured Geomembrane/Hydrated GCL in Table B2-3 of Exhibit B2)	26
$\delta_{GM\text{-}S}$, Geomembrane- 60-mil textured HDPE – Soil (value for Textured HDPE/Compacted Clay in Table B2-3 of Exhibit B2)	21

It is noted that the above values correspond to typical interface shear strengths for these materials. Given the hypothetical nature of these calculations and the demonstration of overall slope stability presented in Exhibit B2 of the permit application, it is not appropriate to perform an elaborate back-analysis of interface shear strengths for this anchor trench and tensile force evaluation. The ultimate tensile strength ($T_{ultimate}$) of the geomembrane was assumed to be 1512 lb/ft, while the ultimate tensile strength of the geocomposite was assumed to be 540 lb/ft. It should be noted that according to the previous table, the weakest interface is expected to be the textured geomembrane-compacted clay liner interface; therefore, this is the only interface analyzed in the anchor trench calculations.

5 SUMMARY AND CONCLUSIONS

The evaluation of the anticipated stresses in the geosynthetics and the demonstration of adequate design of the anchor trench were conducted in a Microsoft EXCEL® spreadsheet presented in Appendix D-1. The calculation shows the no tensile forces are predicted in the geosynthetics liner components. This is because the available shear strength along each interface exceeds the driving shear force.

Notwithstanding the above calculation showing no expected tensile forces in the geosynthetics, the calculation of the anchor trench serves as a check to evaluate whether the anchor trench would pull out before geomembrane rupture, should higher unexpected tensile forces develop. The calculation of the anchor trench design concluded that the geosynthetic components will pull out of the trench prior to reaching the yield strength of the geosynthetic liner materials (anchorage ratio, AR = 1.58), which is the desired result and therefore acceptable.

Written by:	**A. Brown**	Date:	**2/26/2014**	Reviewed by:	**S. Graves**	Date:	**3/5/2014**
Client:	**Clean Harbors**	Project:	**Lone Mountain Facility**	Project No.:	**TXL0380**	Phase No.:	**04**

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Koerner, R.M. *Designing with Geosynthetics*. 2nd ed. Prentice Hall, 1990. Print.

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Written by:	**A. Brown**	Date:	**2/26/2014**	Reviewed by:	**S. Graves**	Date:	**3/5/2014**
Client:	**Clean Harbors**	Project:	**Lone Mountain Facility**	Project No.:	**TXL0380**	Phase No.:	**04**

APPENDIX D-1

ANCHOR TRENCH CALCULATIONS

Written by:	A. Brown	Date:	2/26/2014	Reviewed by:	S. Graves	Date:	3/5/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

Lone Mountain Cell 15

Anchor Trench Calculations

INPUTS		
Waste		
γ_{waste} =	120	pcf
Φ_{waste} =	45	°
H_{waste} =	5.0	ft
Slope		
1 V :	3.0	H
Liner and Cover Soil		
γ_{soil} =	120	pcf
Φ_{soil} =	28	°
Protective Cover		
γ_{soil} =	120	pcf
Φ_{soil} =	28	°
Anchor Trench		
Lro =	2.0	ft
d_{cover} =	2.0	ft
d_{AT} =	2.0	ft
CALCULATIONS		
β =	18.4	°
K_o =	0.29	
L =	15.0	ft
$\sigma_{v,avg}$ =	300.0	psf
σ_h =	87.9	psf
T_w =	439.3	lb/ft
W_w =	4500.0	lb/ft
W_{net} =	4060.7	lb/ft
N =	3852.3	lb/ft

γ_{waste}: unit weight of the waste, pcf;
Φ_{waste}: waste friction angle,deg.;
H_{waste}: vertical heigh of the waste, ft;
γ_{soil}: unit weight of the soil, pcf;
Φ_{soil}: soil friction angle, deg.;
L_{ro}: length of run out, ft;
d_{cover}: depth of soil cover, ft;
d_{AT}: depth of anchor trench, ft;
T_{ult}: ultimate tensile strength of the weekest geosynthetic, lb/in.;
β: slope angle, deg;
K_o: at rest lateral earth pressure;
L: length of waste placed along the slope, ft;
$\sigma_{v,avg}$: average vertical stress, psf;
σ_h: average horizontal stress, psf;
T_w: shear resistance provided by the waste at the toe of the slope, lb/ft;
W_w: weight of waste, lb/ft;
W_{net}: net weight = W_w - T_w, lb/ft;
N: normal force acting through the cover soil to the top geosynthetic material perpendicular to the slope
= $W_{net} \cos\beta$, lb/ft;
F_0: driving force on top of the top geosynthetic, lb/ft;
$F_{1..n}$: shear force developed at interface (n), lb/ft;
$\delta_{1..n}$: interface friction angle at interface (n); deg.;
T = tension in geosynthetic layer, lb/ft
T_{ult} = ultimate tensile strength, lb/ft;
FS: factor of safety on the tensile strength = T_{ult}/T;
T_{all}: allowable tensile strength of geosynthetic at weekest interface using a minimum factor of safety , lb/ft
F_u: frictional resistance above the geomembrane due to the load of the cover soil, lb/ft;
F_L: frictional resistance provided by the geomembrane-subgrade interface due to the weight of the cover soil, lb/ft;
F_{AT}: frictional resistance provided by the geomembrane-soil interface due to the lateral earth pressure of the anchor trench backfill and the subgrade materials, lb/ft
T_{AT}: tensile force in the geosynthetic, lb/ft; and,
AR: anchorage ratio.

TENSION IN GEOSYNTHETICS

			F0=	1284.1	lb/ft				
Interface						**Material**	**T(lb/ft)**	**T_{ult}(lb/ft)**	**FS**
Soil/GC	δ_1=	26	F1=	1843.5	lb/ft	Soil	0.0		∞
GC/GM	δ_2=	25	F2=	1796.3	lb/ft	GC	0.0	540	∞
GM/GCL	δ_3=	26	F3=	1878.9	lb/ft	GM	0.0	1512	∞
GCL/GM	δ_4=	26	F4=	1878.9	lb/ft	GCl	0.0		∞
GM/GC	δ_5=	25	F5=	1796.3	lb/ft	GM	0.0	1512	∞
GC/GM	δ_6=	25	F6=	1796.3	lb/ft	GC	0.0	540	∞
GM/CCL	δ_7=	21	F7=	1478.8	lb/ft	GM	0.0	1512	∞

ANCHOR TRENCH PULLOUT

T_{all} =	756	lb/ft	(geomembrane, FS_{min} = 2)
Koerner (1990) Eq.s			
F_u =	0.0	lb/ft	
F_L =	184.3	lb/ft	
F_{AT} =	146.6	lb/ft	
T_{AT} =	477.5	lb/ft	
AR =	**1.58**	**Geosynthetic pullout governs**	

EXHIBIT E

LEACHATE COLLECTION AND LEAK DETECTION SYSTEM DESIGN

Exhibit E-1

Leachate Generation Rates (*HELP* Modeling) and Head on Liner

Written by:	**Y. Bholat**	Date:	**2/6/2014**	Reviewed by:	**S. Graves**	Date:	**3/4/2014**
Client:	**Clean Harbors**	Project:	**Lone Mountain Facility**	Project No.:	**TXL0380**	Phase No.:	**04**

LEACHATE GENERATION RATES AND HEAD ON LINER (*HELP* MODELING)

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6/13/2014

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Exp. 06/30/2014

SEALED FOR CALCULATION PAGES
E1-1 THROUGH E1-66

1. INTRODUCTION

The purposes of this analysis are to:

- estimate the design leachate generation rates for various operation conditions;
- calculate the design hydraulic conductivity and transmissivity of the leachate drainage layer in the leachate collection system; and
- evaluate the maximum leachate head on the liner system for compliance with the Federal regulations, which require the maximum head of leachate to be less than 30 cm (12 in.) [40 CFR Part 264].

2. METHOD OF ANALYSIS

The leachate collection rates and maximum leachate head on the liner system were estimated using the Hydrologic Evaluation of Landfill Performance (*HELP*) computer model, Version 3.07, developed by the U.S. Environmental Protection Agency (USEPA). The *HELP* model simulates hydrologic processes for a landfill by performing daily, sequential water balance analyses using a quasi-two-dimensional, deterministic approach (Schroeder et al., 1994a, 1994b).

The hydrologic processes considered in the *HELP* model include precipitation, surface-water evaporation, runoff, infiltration, plant transpiration, soil water evaporation, soil water storage, vertical drainage (saturated and unsaturated), lateral drainage (saturated), vertical drainage (saturated) through compacted soil liners and geosynthetic clay liners (GCLs), and leakage through geomembranes.

3. ANALYSIS CASES AND SCENARIOS

The Lone Mountain Facility Landfill Cell 15 will consist of twenty-two subcells: Subcells 1 to 22. This calculation package covers Subcells 14 to 22, which are proposed subcells. Subcells 1 to 13 are not analyzed or part of the design, since they have already been designed and permitted (and were covered by previously submitted calculations that were subsequently approved). Leachate generation rates during four operational scenarios expected in the nine future subcells of the landfill were considered herein. The leachate collection rate and maximum leachate head on the floor of the liner system were calculated for the following four typical operational conditions:

- Case (I) - initial condition: 10-ft of waste overlying 2-ft of protective cover and the rest of the liner system.
- Case (INT) - intermediate condition: 50-ft of waste overlying 2-ft of protective cover and the rest of the liner system.
- Case (FNC) - final condition prior to installation of final cover: 94-ft of waste overlying 2-ft of protective cover and the rest of the liner system.
- Case (FC) - final condition after installation of final cover: final cover system on top of 94-ft of waste overlying 2-ft of protective cover and the rest of the liner system.

It should be noted that the leachate generation rates from the side slope liner system would be lower compared to the leachate generation rates for the floor liner system because of steeper side slopes. Therefore, no analysis was done for the sideslope liner system and the transmissivity for the sideslope liner system was conservatively assumed to be similar to the floor liner system.

The proposed liner system on the base of the landfill for Subcells 14 through 22 of the Lone Mountain Facility Landfill Cell 15 will consist of the following components, from top to bottom:

- 2-ft thick protective cover;
- upper geocomposite drainage layer;
- upper 60-mil thick high density polyethylene (HDPE) geomembrane liner;
- geosynthetic clay liner;
- middle 60-mil thick HDPE geomembrane liner (only on floor);
- bottom geocomposite drainage layer;
- bottom 60-mil thick HDPE geomembrane liner; and
- 3-ft thick compacted soil liner.

The Landfill Cell 15 proposed final cover system will consist of the following components, from top to bottom:

- 6-in. thick top soil;
- 1.5-ft thick protective cover soil;
- geocomposite drainage layer;
- 60-mil thick textured high density polyethylene (HDPE) geomembrane liner;
- geosynthetic clay liner (GCL); and
- 12-in. thick interim cover clay (bedding clay).

4. PARAMETERS USED IN ANALYSIS

The *HELP* model requires the input of daily weather data, vegetation data, soils data, and landfill design data. The input data are described in this section and summarized on the *HELP* model output presented in Appendix E1-1.

4.1 <u>Weather Data</u>

4.1.1 Precipitation and Temperature Data

Thirty years of synthetic weather data were generated for the Lone Mountain Facility Landfill Cell 15 using built-in climatic data for nearby Oklahoma City, Oklahoma (selected city). However, the Lone Mountain facility is about 98.4 miles from Oklahoma City. Therefore, the *HELP* data was supplemented with data from the National Climatic Data Center (NCDC, 2013) for the closest weather station to the site: Waynoka, OK, US (Station ID: USC00349404), which is about 10.5 miles from the landfill facility and is similar in elevation. The NCDC publishes 1981-2010 Normals which comprise all climate normals using the data during the thirty year period.

The *HELP* user's manual advises that site-specific normal mean monthly data should be used to adjust the synthetically generated (1) precipitation data if the site is more than a few miles from the selected city and (2) temperature data if the site is more than about 100 miles away from the selected city. Therefore, as recommended in the *HELP* user's manual, the default normal mean monthly precipitation and temperature values that are used by *HELP* to generate the synthetic weather data were modified to the normal mean monthly precipitation and temperature values reported by the NCDC for the above-referenced Waynoka, OK weather station, which are values more representative of those likely to occur at the Lone Mountain facility.

After inputting the normal mean monthly precipitation values in the *HELP* model, thirty years of synthetic weather data were generated. To further make the synthetic data more site-specific, the peak daily rainfall from the synthetically generated precipitation record (4.20 in.) was manually increased to model the impact of the 25-year, 24-hour storm event on peak hydraulic head. The 25-year, 24-hour storm intensity for the site was estimated to be 6.15 in. based on the average of values reported in a Technical Paper, TR-55 (USDA, 1986). It is noted that in Tortorelli et al. (1999), the 25-year, 24-hour storm intensity for the site was estimated to be 5.0 in. The conservative value of 6.15 in. was used in the analysis.

4.1.2 Evapotranspiration and Solar Radiation

Synthetic data was generated for the evapotranspiration and solar radiation data as well. As with the precipitation and temperature data, Oklahoma City, Oklahoma was selected in the analysis since it is the closest city to the landfill facility. The *HELP* manual advises the user to enter the site's latitude if the site is more than about 50 miles north or south of the selected city; since the Lone Mountain facility is about 67 miles north of Oklahoma City, the site-specific latitude of 36.437°N was manually input.

Vegetation was assumed only on the final cover system (Case FC). The final cover system was assumed to have good vegetation with a maximum LAI of 3.5. An evaporative zone depth of 24 in. was selected to equal the thickness of the erosion layer above the composite barrier. For initial and intermediate conditions, an evaporative zone depth of 10 in. was selected.

4.2 Materials Data

4.2.1 Top Soil for Final Cover System

The top soil of the final cover system was modeled as a vertical percolation layer with *HELP* material texture 11 (representative of low density CL cover soil).

4.2.2 Protective Cover Soil for Final Cover System

The protective cover soil of the final cover system was modeled as a vertical percolation layer with *HELP* material texture 26 (representative of moderately compacted CL soil).

4.2.3 Geosynthetic Drainage Layer for Final Cover System

The geocomposite drainage layer was modeled as a lateral drainage layer with *HELP* material texture 20 (representative of 0.2-in. thick geonet drainage layer). The design hydraulic conductivity (k) of the drainage layer was calculated from the final-condition scenario (Case FC) by varying k until the peak daily average head on the geomembrane liner on the final cover was approximately equal to the thickness of erosion layer (24 in.). This was done to allow maximum head, resulting in a conservative estimate of the amount of water penetrating into the landfill.

A special case of the final cover condition (Case FC-S) was also run to determine the hydraulic conductivity required to maintain a peak daily average head no greater than the thickness of the geocomposite drainage layer. It is noted that this case is not used for the determination of leachate generation, but rather for the calculation of the minimum required transmissivity of the geosynthetic drainage layer in the final cover system.

4.2.4 Geomembrane Barrier for Final Cover System

The geomembrane barrier of the final cover system was modeled as a flexible membrane liner with *HELP* material texture 35 (representative of HDPE geomembrane), installation condition = poor, pinhole defect frequency = 2 per acre, and installation defect frequency = 2 per acre. This hole frequency is an assumption for design purposes only and is not a reflection of the expected or allowable hole density.

4.2.5 Geosynthetic Clay Liner for Final cover system

The Geosynthetic Clay Liner (GCL) was modeled as a vertical percolation layer with *HELP* material texture 17 having a saturated hydraulic conductivity of 3×10^{-9} cm/s.

4.2.6 Clay Bedding Layer for Final Cover System

The clay bedding layer was modeled as a vertical percolation layer with *HELP* material texture 26 (representative of moderately compacted CL soil).

4.2.7 Waste

The waste to be disposed of at the Cell 15 of the Lone Mountain Facility appears to be made up of hazardous waste streams that have the appearance of construction and demolition waste and other industrial and hazardous-type soils and debris. No default *HELP* material texture is available for the type of waste to be disposed of at the Lone Mountain Facility. Furthermore, no specific properties were found for this type of waste from a thorough literature search and from a Geosyntec company wide technical data search. Instead, it was conservatively assumed that the waste properties would best be approximated as being in-between the properties of municipal solid waste (MSW) and silty sand (SM) type of material. Accordingly, the waste layer was modeled as a vertical percolation layer with the average properties of *HELP* material texture 18 (representative of municipal waste) and 7 (representative of SM type soil) having a hydraulic conductivity of 7.6×10^{-4} cm/s.

4.2.8 Protective Cover Layer for Liner System

The protective cover layer will be screened waste. For calculation purposes, this layer was modeled as a vertical percolation layer with *HELP* material texture 11 (representative of low density CL soil).

4.2.9 Geosynthetic Drainage Layers for Liner System

The leachate collection and leak detection systems consist of geocomposite drainage layers responsible for lateral drainage of percolating leachate. The geocomposite drainage layers of the liner system were modeled as a lateral drainage layer with *HELP* material texture 20 (representative of 0.2-in. thick geonet drainage layer). The design hydraulic conductivity (k) of the drainage layer was calculated for each operation case by varying k until the peak daily average head on the geomembrane liner was approximately equal to the thickness of drainage layer. However, the minimum design hydraulic conductivity used in the calculations was 0.01 cm/s. This procedure is conservative because the drainage layer thickness is much less than the regulated maximum head of 12 in. and because the peak daily average head is typically much greater than the annual average head.

4.2.10 Geomembrane Liners for Liner System

The landfill liner on the base of the landfill consists of three geomembrane liners: upper, middle, and bottom liners. The geomembrane layers were modeled as flexible membrane liners with *HELP* material texture 35 (representative of HDPE geomembrane), pinhole defect frequency = 2 per acre, and installation defect frequency = 2 per acre. This hole frequency is an assumption for design purposes only and is not a reflection of the expected or allowable hole density. The geomembrane installation condition was assumed poor for the initial condition due to lack of sufficient vertical stress to develop good contact between the geomembrane and the underlying soil liner. In the case of intermediate and final condition scenarios, the geomembrane installation condition was assumed good.

4.2.11 Geosynthetic Clay Liner for Liner system

The Geosynthetic Clay Liner (GCL) of the liner system was modeled as a vertical percolation layer with *HELP* material texture 17 having a saturated hydraulic conductivity of 3×10^{-9} cm/s.

4.2.12 Compacted Soil Liner for Liner System

The compacted soil liner was modeled as a barrier soil liner with *HELP* material texture 16 (representative of well compacted clay soil) having a hydraulic conductivity of 1×10^{-7} cm/s.

4.3 Landfill Design Data

The design data required by the *HELP* model consists of: (i) the slope and slope length of the surface of the top layer; (ii) the slope and slope length of lateral drainage layers (geosynthetic drainage component) in the final cover system and liner system; and (iii) the percentage of runoff that can be directed off of the landfill whether as clean surface water or as leachate running off the waste to a storm water storage area. It was assumed that the potential runoff is 100% for surfaces where runoff was allowed. The actual percentage runoff is calculated by the *HELP* model based on surface slope, slope length, material texture, and vegetation. The landfill design parameters used in the analysis are presented on Figure E1-1 for the four scenarios evaluated.

5. RESULTS OF ANALYSIS

The results of the *HELP* model analysis are summarized below. The output files are presented in Appendix E1-2.

5.1 Estimated Leachate Generation/Collection Rates

The estimated leachate generation rates are shown in Table E1-1. The leachate generation rates shown correspond to the lateral drainage collected from the leachate collection layer.

The maximum leachate generation rate was for the initial condition Case I that has the thinnest layer of waste (10 ft). For the initial condition (Case I), the maximum daily leachate collection rate is calculated to be 1,915 gallons per acre per day (gpad), and the average annual collection rate is calculated to be 144 gpad.

For the intermediate condition (Case INT), the calculated maximum daily and average annual leachate collection rates on the landfill floor are 1,218 gpad and 150 gpad, respectively.

The average leachate collection rate after closure of the landfill (Cases FNC and FC) is expected to decrease over time as leachate is drained from the waste. The maximum daily and average annual leachate collection rates on the landfill floor for final closure conditions are calculated to be about 1,175 gpad and 146 gpad, respectively, prior to placement of final cover, and 1.1 gpad and 0.04 gpad, respectively, after placement of final cover.

As mentioned earlier, the leachate collection rate and maximum leachate head on the side slope liner system would be lower compared to that of the floor liner system due to the steeper side slopes. Since no analysis was done for the side slope liner system, it was conservatively assumed for design purposes that the leachate collection rate and maximum leachate head on the side slope liner system would be similar to the floor liner system.

The peak daily and average annual leachate volumes for each subcell were calculated based on the tributary area for each subcell and the estimated peak daily and average annual leachate generation/collection rates for each case and are shown in Table E1-2 and Table E1-3, respectively.

5.2 Drainage Layer Design Hydraulic Conductivity and Transmissivity

The design hydraulic conductivity of the leachate drainage layer was calculated for each operation case by varying hydraulic conductivity until the peak daily average head on the geomembrane liner was approximately equal to the thickness of the geosynthetic drainage layer. However, the minimum hydraulic conductivity of the leachate drainage layer was assumed to be 0.01 cm/s. The transmissivity was calculated by multiplying drainage layer hydraulic conductivity by thickness. Results for each case are presented in Table E1-4. These represent the design transmissivity values. Refer to Exhibit E3 for an evaluation of the required in-service transmissivity and resulting drainage layer specifications.

5.3 Head of Leachate over Composite Barriers

The hydraulic heads on top of the geomembranes of the composite barrier systems calculated using the predicted *HELP* model are summarized in Table E1-5. The calculated annual average heads on the liner upper geomembrane range from zero to 0.024 in., while the annual average heads on the middle and bottom geomembranes are zero.

Considering all cases analyzed, the maximum calculated peak daily average head is 0.198 in. on the upper geomembrane and zero on the middle and bottom geomembranes. The maximum calculated peak daily average head on the geomembrane is less than the allowable hydraulic head of 30 cm (12 in.). The calculated peak daily average heads are less than or equal to the thickness of a geocomposite drainage layer (0.2 in.) on the landfill floor and sideslope. Thus, the flow is predicted to occur within the drainage layer only. Based on the above, the geosynthetic drainage layer is considered adequate in minimizing liquid head on top of the liner.

6. SUMMARY AND CONCLUSIONS

The *HELP* model was used to estimate the design leachate collection rates in the geosynthetic drainage layer, calculate the design in-plane hydraulic conductivity and transmissivity of the geosynthetic drainage layer, and calculate the maximum leachate head on the liner system. Parameters for various design and operational conditions that characterize the site over time were input into the model.

Results from the *HELP* model show that maximum peak daily leachate collection rate will be 1,915 gpad (during initial condition), while the maximum annual average leachate collection rate will be 150 gpad (during intermediate condition). For all operational cases, the calculated head of leachate on the liner is less than the regulatory maximum of 30 cm (12 in.).

7. REFERENCES

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Schroeder, P.R., Lloyd, C.M., and Zappi, P.A., "The Hydrologic Evaluation of Landfill Performance (*HELP*) Model, User's Guide for Version 3," U.S. Environmental Protection Agency, Office of Research and Development Washington, D.C., Report No. EPA/600/R-94/168a, 1994b.

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TABLES

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

TABLE E1-1. LEACHATE GENERATION RATES

Case	Average Annual		Peak Daily	
	(in./yr)	(gpad)	(in./day)	(gpad)
I	1.937	144.1	0.071	1915.5
INT	2.015	149.9	0.045	1217.9
FNC	1.967	146.3	0.043	1175.2
FC	5.1E-4	0.04	4.0E-5	1.1

Note: gpad = gallons per acre per day

TABLE E1-2. PEAK DAILY LEACHATE VOLUME

Subcell	Tributary Area	Calculated Peak Daily Leachate Volume							
		Case I		Case INT		Case FNC		Case FC	
	(acres)	(in.)	(gallons)	(in.)	(gallons)	(in.)	(gallons)	(in.)	(gallons)
14	6.05	0.071	11,588	0.045	7,368	0.043	7,110	4E-5	7
15	6.03	0.071	11,545	0.045	7,341	0.043	7,084	4E-5	7
16	4.89	0.071	9,374	0.045	5,960	0.043	5,751	4E-5	5
17	4.96	0.071	9,503	0.045	6,042	0.043	5,830	4E-5	5
18	4.33	0.071	8,294	0.045	5,274	0.043	5,089	4E-5	5
19	4.34	0.071	8,312	0.045	5,285	0.043	5,100	4E-5	5
20	4.33	0.071	8,295	0.045	5,274	0.043	5,089	4E-5	5
21	4.31	0.071	8,262	0.045	5,253	0.043	5,069	4E-5	5
22	3.87	0.071	7,417	0.045	4,716	0.043	4,551	4E-5	4

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TABLE E1-3. AVERAGE ANNUAL LEACHATE VOLUME

Subcell	Tributary Area	Calculated Annual Leachate Volume							
		Case I		Case INT		Case FNC		Case FC	
	(acres)	(in.)	(gallons)	(in.)	(gallons)	(in.)	(gallons)	(in.)	(gallons)
14	6.05	1.937	318,152	2.015	331,069	1.967	323,143	5.1E-4	84
15	6.03	1.937	316,975	2.015	329,844	1.967	321,947	5.1E-4	83
16	4.89	1.937	257,364	2.015	267,813	1.967	261,401	5.1E-4	68
17	4.96	1.937	260,897	2.015	271,490	1.967	264,990	5.1E-4	69
18	4.33	1.937	227,718	2.015	236,963	1.967	231,290	5.1E-4	60
19	4.34	1.937	228,204	2.015	237,470	1.967	231,784	5.1E-4	60
20	4.33	1.937	227,732	2.015	236,978	1.967	231,304	5.1E-4	60
21	4.31	1.937	226,822	2.015	236,031	1.967	230,380	5.1E-4	60
22	3.87	1.937	203,635	2.015	211,902	1.967	206,829	5.1E-4	54

TABLE E1-4. LIQUID COLLECTION LAYER DESIGN HYDRAULIC CONDUCTIVITY AND TRANSMISSIVITY

Case	Design Hydraulic Conductivity (cm/s)	Liquid Drainage Layer Thickness (in.)	Design Transmissivity (m^2/s)
I	0.72	0.20	3.7E-05
INT	0.46	0.20	2.3E-05
FNC	0.45	0.20	2.3E-05
FC	0.01	0.20	5.1E-07
FC-S	0.43	0.20	2.2E-05

Notes:

1. Design hydraulic conductivities and transmissivities shown here are not specifications for the leachate drainage layer. Specifications for the leachate drainage layer, after accounting for in-service effects, are presented in Exhibit E-3.
2. Design transmissivity = design hydraulic conductivity × drainage layer thickness.
3. Case I, INT, FNC, and FC values refer to design transmissivities of the leachate collection layer in the liner system.
4. Case FC-S values refer to the design transmissivity of the liquid collection layer in the final cover system.

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

TABLE E1-5. CALCULATED LEACHATE HEAD ON TOP OF GEOMEMBRANE

Case	Head on Top of Upper Geomembrane (in.)			Head on Top of Middle Geomembrane (in.)			Head on Top of Bottom Geomembrane (in.)		
	Annual Average	Peak Daily Average	Peak Daily Maximum	Annual Average	Peak Daily Average	Peak Daily Maximum	Annual Average	Peak Daily Average	Peak Daily Maximum
I[1]	0.015	0.198	0.385	0	0	0	0	0	0.004
INT[1]	0.024	0.197	0.383	0	0	0	0	0	0.008
FNC[1]	0.024	0.194	0.378	0	0	0	0	0	0.008
FC[2]	0	0.007	0.013	0	0	0	0	0	0.010

Notes:

1. Values calculated for Case I, INT, and FNC are based on a back-calculated hydraulic conductivity for the geocomposite drainage layers such that they yield a maximum peak daily average head of 0.2 in. from the *HELP* analysis.
2. Values calculated for Case FC (final cover condition) are based on a minimum geocomposite hydraulic conductivity of 0.01 cm/s.

FIGURES

Written by:	Y. Bholat	Date:	2/6/2014	Reviewed by:	S. Graves	Date:	3/4/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

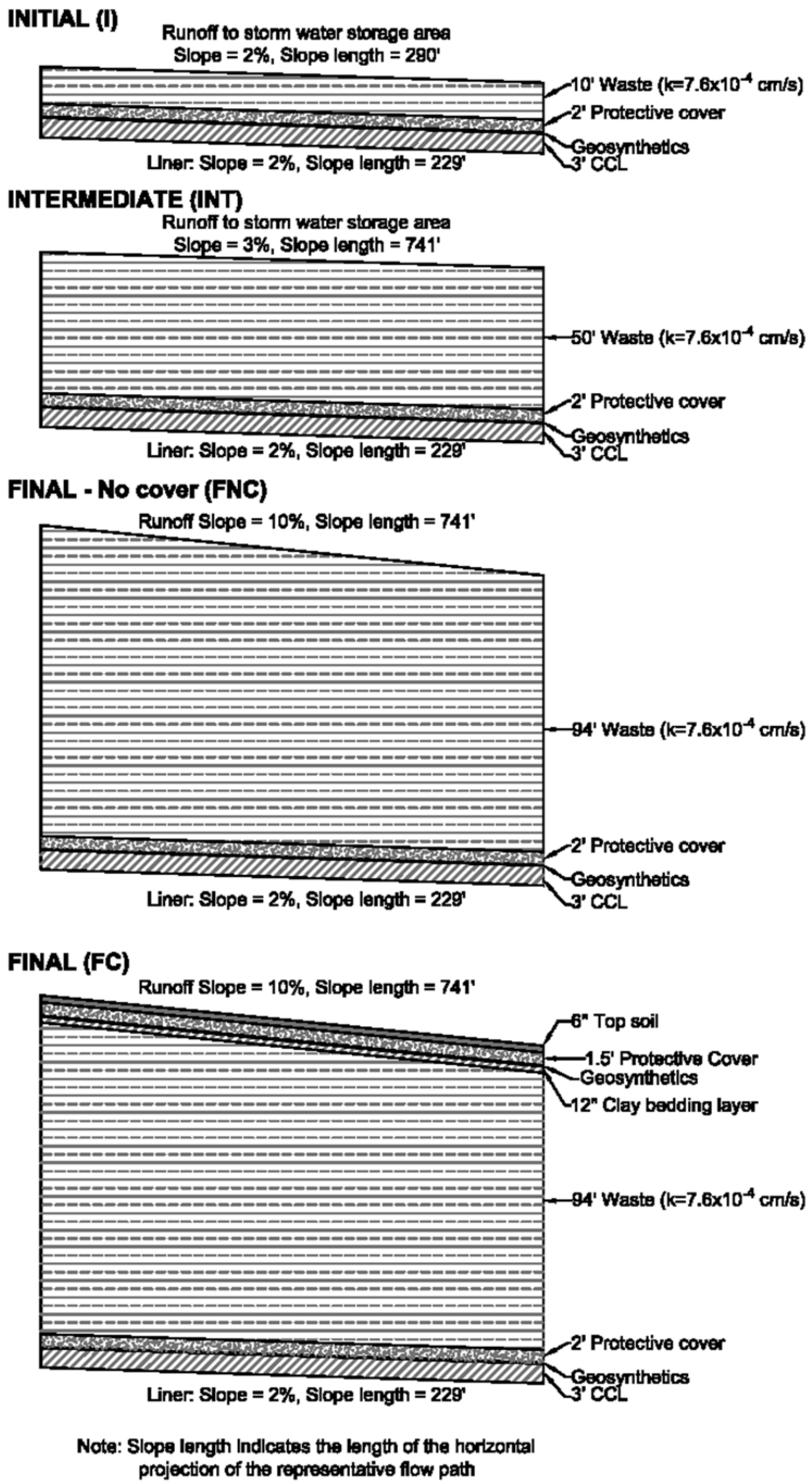

Figure E1-1. Landfill Design Parameters used in *HELP* Model Analysis.

APPENDIX E1-1

HELP MODEL COMPUTER PROGRAM INPUT FILES

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Precipitation Data

2
1
OKLAHOMA CITY OKLAHOMA
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1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.12 0.04 3
1 0.21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 4
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1 0.00 0.04 0.00 0.00 0.00 0.00 0.00 0.00 0.08 0.22 6
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4	0.00	0.00	0.00	0.00	0.00	0.49	0.00	0.00	0.00	0.00	14
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4	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	16
4	0.21	0.84	0.00	0.00	0.00	0.11	0.01	0.00	0.00	0.47	17
4	0.18	0.11	0.00	0.00	0.00	0.71	0.03	0.03	0.00	0.00	18
4	0.00	0.41	0.00	1.55	0.00	0.00	0.49	0.00	0.00	0.00	19
4	0.30	0.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21
4	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.77	1.16	0.14	22
4	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	23
4	0.10	0.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	24
4	0.00	0.00	0.00	0.00	0.00	0.00	1.81	0.00	0.00	0.59	25
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	26
4	0.00	0.00	0.00	0.17	0.00	0.00	0.00	0.00	0.00	0.00	27
4	0.00	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00	28
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29
4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30
4	0.32	0.73	0.00	0.52	0.00	0.00	0.06	0.05	0.09	0.30	31
4	0.00	0.00	0.20	0.22	0.00	0.00	0.00	0.00	0.00	0.00	32
4	0.44	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33
4	0.20	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	34
4	0.00	0.00	0.00	0.00	0.43	0.05	0.00	0.00	0.25	0.00	35
4	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36
4	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.00	37
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	2
5	0.00	0.04	0.01	0.01	0.24	0.01	0.00	0.00	0.00	0.00	3
5	0.00	0.00	0.33	0.17	0.00	0.00	0.00	0.00	0.00	0.00	4
5	0.00	0.00	0.00	0.00	0.00	0.36	0.00	0.00	0.00	0.00	5
5	0.00	0.35	0.00	0.00	0.00	0.05	0.08	0.00	0.00	0.00	6
5	0.20	0.16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	7
5	0.00	0.15	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.44	8
5	0.09	0.06	0.00	0.00	0.03	0.08	0.00	0.00	1.04	0.00	9
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	10
5	0.11	0.17	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	11
5	0.00	0.00	0.00	0.00	0.06	0.16	0.00	0.00	0.00	0.00	12
5	0.00	0.21	0.49	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13
5	0.00	0.08	0.80	0.03	0.48	0.00	0.00	0.00	0.23	0.28	14
5	0.00	0.00	0.00	0.00	0.30	0.00	0.02	0.02	0.00	0.00	15
5	0.36	0.04	0.40	0.00	0.00	0.16	0.00	0.00	0.00	0.00	16
5	0.00	0.00	0.00	0.35	0.00	0.00	0.00	0.37	0.00	0.00	17
5	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.12	1.26	0.24	18
5	0.00	0.00	0.02	0.67	0.31	0.00	0.00	0.00	0.00	0.00	19
5	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.00	20
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	21
5	0.00	0.00	0.00	0.20	0.00	0.06	0.00	0.00	0.00	0.22	22
5	0.00	0.00	0.05	0.00	0.00	0.00	0.35	0.00	0.00	0.00	23
5	0.03	0.00	0.00	0.00	0.08	0.12	0.47	0.00	0.00	0.00	24
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25
5	0.00	0.00	0.13	0.00	0.00	0.23	0.23	0.00	0.00	0.00	26
5	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.02	0.00	0.00	27
5	0.24	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29
5	0.00	0.15	0.06	0.00	0.24	0.30	0.00	0.00	0.00	0.00	30
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.00	0.00	31
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	32
5	0.00	0.00	0.00	0.00	0.00	0.00	1.31	0.00	0.00	0.00	33
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34
5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35
5	0.00	0.00	0.00	0.00	0.00	0.00	1.23	0.01	0.07	0.01	36
5	0.00	0.00	0.00	0.09	0.02	0.06	0.00	0.00	0.00	0.00	37
6	0.00	0.00	0.02	0.00	0.00	0.13	0.06	0.08	0.00	0.00	1
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2
6	0.00	0.06	0.09	0.04	0.32	0.00	0.00	0.00	0.00	0.08	3
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	4
6	0.73	0.01	0.23	0.00	0.00	0.00	0.27	0.08	0.11	0.42	5
6	0.31	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	6
6	0.00	0.02	0.01	0.00	0.00	0.00	0.00	0.08	0.93	0.18	7
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9
6	0.00	0.00	0.00	0.00	1.09	0.00	0.17	0.01	0.65	0.00	10
6	0.00	0.60	0.21	0.37	0.00	0.24	0.00	0.00	0.00	0.00	11
6	0.00	0.06	0.57	0.40	0.00	0.00	0.00	0.00	0.00	0.00	12
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.27	0.00	0.97	13
6	0.85	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.24	14
6	0.00	0.00	0.00	0.00	0.00	0.61	0.00	0.00	0.01	0.27	15
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.03	16
6	0.00	1.10	0.17	0.00	0.00	2.16	0.00	1.52	0.00	0.00	17
6	0.00	0.00	0.03	0.77	0.00	0.00	0.00	0.00	0.00	0.00	18
6	0.00	0.00	1.05	0.00	0.00	0.00	0.00	0.00	0.00	0.61	19
6	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00	0.06	20
6	0.05	0.00	0.00	0.00	0.00	0.09	0.00	0.07	0.00	0.00	21
6	0.00	0.00	0.10	0.00	0.00	0.00	0.05	0.00	0.00	2.49	22
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23
6	0.00	0.07	0.00	0.05	0.00	0.00	0.00	0.86	0.00	0.00	24
6	0.00	0.00	0.00	0.00	0.09	0.01	0.17	0.00	0.12	0.00	25
6	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	26
6	0.04	0.00	0.00	0.17	0.05	0.17	0.00	0.00	0.00	0.00	27
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.78	0.00	28
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	29
6	0.00	0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	30
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.31	32
6	1.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	33
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.19	0.00	0.00	35
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36
6	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37

7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1
7 0.00 0.06 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 3
7 0.09 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 4
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 5
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.22 6
7 0.20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 7
7 0.00 0.00 0.00 0.00 0.00 0.01 0.06 0.00 0.33 0.67 8
7 0.67 0.00 0.45 0.19 0.00 0.00 0.00 0.07 0.00 0.00 9
7 0.00 0.00 0.00 0.45 0.00 0.00 0.47 0.00 0.00 0.00 10
7 0.00 0.00 0.23 0.00 0.00 0.00 0.01 0.00 0.00 0.00 11
7 0.00 0.00 0.00 0.75 0.05 0.00 0.00 0.35 0.00 0.00 12
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.06 13
7 0.05 0.00 0.00 0.00 0.00 0.00 0.56 0.46 0.00 0.00 14
7 0.32 1.87 0.74 0.84 0.00 0.89 0.00 0.15 0.02 0.00 15
7 0.14 0.11 1.27 0.00 0.00 0.59 0.00 1.70 0.50 0.00 16
7 0.11 0.00 0.19 0.00 0.02 0.00 0.00 0.00 0.00 0.39 17
7 0.24 0.00 0.09 0.00 0.43 0.97 0.00 0.00 0.00 0.00 18
7 1.57 0.00 0.00 0.00 0.00 0.74 0.54 0.00 0.00 0.00 19
7 0.00 0.00 0.00 0.00 0.00 0.75 0.00 0.00 0.00 0.00 20
7 0.00 0.00 0.00 0.25 0.39 0.71 0.00 0.00 0.00 0.00 21
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.27 0.40 0.00 22
7 0.00 0.00 0.00 0.00 0.41 0.00 0.00 2.64 0.00 0.33 23
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 24
7 0.00 0.00 0.00 0.00 0.00 0.00 0.17 0.33 0.00 0.04 25
7 0.05 0.00 0.00 1.10 0.31 0.00 0.00 0.23 0.13 0.00 26
7 0.00 0.00 0.10 0.06 0.00 0.00 0.00 0.00 0.00 0.00 27
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 28
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 29
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 30
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 31
7 0.00 0.62 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 32
7 0.00 0.00 0.30 0.04 0.41 0.00 0.00 0.00 0.00 0.00 33
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 34
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 35
7 0.00 0.00 1.01 0.00 0.00 0.00 0.00 0.00 0.05 0.00 36
7 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 37
8 0.00 0.00 0.00 0.23 0.00 0.00 0.00 0.00 0.00 0.00 1
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 3
8 0.00 0.00 0.00 0.00 0.00 0.13 0.00 0.00 0.00 0.00 4
8 0.00 0.00 0.07 0.66 0.00 0.00 0.00 0.00 0.45 0.23 5
8 0.00 0.00 0.28 0.00 0.00 0.17 0.11 0.00 0.00 0.00 6
8 0.00 0.00 0.00 0.00 0.27 0.00 0.00 0.00 0.00 0.00 7
8 0.01 0.31 0.00 0.00 0.02 0.01 0.00 0.00 0.00 0.00 8
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.22 9
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.09 0.00 10
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 11
8 0.00 0.00 0.99 0.62 0.03 0.00 0.00 0.06 0.00 0.20 12
8 0.00 0.02 0.17 0.00 4.07 0.00 0.00 0.00 0.00 0.00 13
8 0.00 0.47 0.11 0.41 0.00 0.00 1.12 0.31 0.08 0.05 14
8 0.00 0.00 0.00 0.00 0.31 0.00 0.00 0.29 0.00 0.00 15
8 0.00 1.55 0.41 0.00 0.00 0.33 0.01 0.01 0.11 0.96 16
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 17
8 0.00 0.00 0.00 0.41 0.42 0.00 0.00 0.00 0.00 0.00 18
8 0.70 0.33 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 19
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 20
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 21
8 0.00 0.00 0.00 0.00 0.00 0.33 0.00 0.22 0.00 0.00 22
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 23
8 0.00 0.00 0.00 0.00 0.00 0.00 0.34 0.00 0.00 0.00 24
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 25
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.15 26
8 0.00 0.00 0.00 0.25 0.00 0.00 0.00 0.00 0.00 0.00 27
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 1.34 28
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 29
8 0.00 0.00 0.00 0.00 0.36 0.00 0.00 0.00 0.00 0.00 30
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 31
8 0.00 0.00 0.00 0.00 0.00 1.04 0.00 0.00 0.00 0.00 32
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.54 0.00 0.00 33
8 0.04 0.04 0.00 0.00 0.00 0.04 0.32 0.00 0.00 0.00 34
8 0.00 0.00 0.00 0.00 0.00 0.80 0.00 0.00 0.00 0.00 35
8 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 36
8 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 37
9 0.00 0.00 0.00 0.29 0.28 0.00 0.00 0.00 0.00 0.00 1
9 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
9 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 3
9 0.00 0.00 0.00 0.01 0.00 0.00 0.15 0.12 0.03 0.00 4
9 1.05 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 5
9 0.04 0.00 0.00 0.00 0.00 0.15 0.00 0.00 0.00 0.00 6
9 0.00 0.00 0.00 0.00 0.05 0.26 0.08 0.00 0.00 0.04 7
9 0.00 0.10 0.32 0.05 0.38 0.00 0.00 0.75 0.00 0.33 8
9 0.00 0.00 0.01 0.76 0.00 0.00 0.02 0.00 0.00 0.00 9
9 0.00 0.00 0.00 0.09 0.38 0.26 0.00 0.00 0.00 0.00 10
9 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.55 11
9 0.00 0.00 0.08 0.00 0.00 1.09 0.93 1.38 0.00 0.00 12
9 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 13
9 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 14
9 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 15
9 0.00 0.00 0.00 0.04 0.19 0.00 0.00 0.00 0.00 0.00 16
9 0.00 0.00 0.00 0.00 0.12 2.68 0.00 0.00 0.00 0.43 17
9 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 18
9 0.00 0.45 0.00 0.00 0.00 0.36 0.23 0.00 0.00 0.00 19
9 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 20
9 0.11 0.00 0.04 0.00 0.00 0.00 0.00 0.00 0.00 0.79 21
9 0.04 0.01 0.00 0.00 0.00 0.22 0.00 0.00 1.11 0.00 22
9 0.00 0.00 0.56 0.00 2.25 0.00 0.00 0.20 0.02 0.03 23
9 0.83 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 24
9 0.07 0.00 0.21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 25
9 0.00 0.00 0.91 0.00 0.00 0.00 0.00 0.00 0.00 0.08 26
9 0.23 0.00 0.00 0.00 0.04 0.51 0.35 0.00 0.00 0.00 27
9 0.25 0.00 0.00 0.00 0.00 0.13 0.00 0.00 0.99 0.02 28
9 0.41 0.00 0.00 0.11 0.00 0.00 0.00 0.00 0.00 0.00 29
9 0.00 0.24 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 30
9 0.00 0.00 0.32 0.27 0.00 0.00 0.00 0.00 0.00 0.00 31
9 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 32
9 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 33
9 0.00 0.00 0.06 0.53 0.17 0.43 0.07 0.00 0.00 0.00 34
9 0.07 0.00 0.00 0.00 0.00 0.20 0.00 0.00 0.00 0.00 35
9 0.00 0.00 0.00 0.00 0.00 0.00 0.12 0.00 0.01 0.00 36
9 0.28 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 37
10 0.00 0.47 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1
10 0.00 0.00 0.00 0.00 0.00 0.11 0.00 0.00 0.00 0.02 2
10 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 3

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

10 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	4
10 0.00 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.00 0.00	5
10 0.04 0.00 0.00 0.00 0.00 0.01 0.31 0.38 0.78 0.02	6
10 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	7
10 0.00 0.00 0.00 0.00 0.05 1.23 0.00 0.00 0.00 0.00	8
10 0.00 0.00 0.00 0.00 0.00 0.52 0.00 0.00 0.00 0.00	9
10 0.00 0.00 0.00 0.04 0.00 0.11 0.00 0.00 0.00 0.00	10
10 0.00 0.00 0.00 0.33 0.00 0.12 0.29 0.21 0.00 0.00	11
10 0.00 0.00 0.00 0.62 0.04 0.00 0.00 0.00 0.00 0.13	12
10 0.00 0.00 0.02 0.00 0.00 0.49 0.04 0.00 0.00 0.00	13
10 0.00 0.02 0.24 0.88 0.06 0.00 0.00 0.00 1.04 0.53	14
10 2.14 0.00 0.08 0.00 0.00 0.00 0.00 0.75 0.00 0.00	15
10 0.47 0.00 0.00 0.00 0.00 0.00 0.00 0.79 0.00 0.00	16
10 1.45 0.26 0.00 0.32 0.00 0.08 0.76 0.06 0.74 0.04	17
10 0.88 0.00 0.11 0.62 0.13 0.00 0.00 0.00 0.00 0.00	18
10 0.00 0.00 0.00 0.00 0.07 0.00 0.00 0.26 0.00 0.00	19
10 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	20
10 0.00 0.19 0.00 0.07 0.00 0.00 0.00 0.00 0.00 0.00	21
10 0.00 0.00 0.00 0.00 0.00 0.00 1.54 0.34 0.32 0.00	22
10 0.00 0.44 0.15 0.00 0.00 0.90 1.27 0.00 0.00 0.89	23
10 0.00 0.00 0.00 0.00 0.97 0.01 1.00 0.29 0.00 0.00	24
10 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	25
10 0.07 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.05	26
10 0.00 0.00 0.00 0.00 0.00 0.00 0.25 0.00 0.00 0.00	27
10 0.00 0.05 0.37 0.10 0.44 0.00 0.29 0.69 0.11 0.00	28
10 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.69 0.00	29
10 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	30
10 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	31
10 0.08 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	32
10 0.00 0.00 0.00 0.00 0.00 0.00 0.46 0.25 0.00 0.00	33
10 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00	34
10 0.00 0.00 0.00 0.00 0.01 0.00 0.00 0.18 0.00 0.00	35
10 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	36
10 0.00 0.12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	37
11 0.38 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	1
11 0.00 0.00 0.00 0.00 0.04 0.00 0.00 0.00 0.00 0.00	2
11 0.00 0.00 0.00 0.00 0.00 0.00 0.19 0.00 0.00 0.00	3
11 0.00 0.00 0.00 0.00 0.00 0.00 0.02 0.01 0.88 0.09	4
11 0.03 0.15 0.08 0.00 0.00 0.00 0.00 0.00 0.00 0.00	5
11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	6
11 0.00 0.06 0.96 0.00 0.35 0.00 0.78 0.01 0.00 0.00	7
11 0.00 0.00 0.00 0.00 0.00 0.76 0.07 0.03 0.84 0.00	8
11 0.00 0.00 0.00 0.00 0.80 0.00 0.00 0.00 0.00 0.09	9
11 0.32 0.58 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	10
11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.75 0.14 0.00	11
11 0.00 0.00 0.06 0.00 0.00 0.00 0.00 0.00 0.00 0.00	12
11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	13
11 0.51 0.38 0.01 0.00 0.13 0.03 0.00 0.01 0.00 0.00	14
11 0.00 0.17 0.06 0.27 0.00 0.00 0.00 0.00 0.17 0.01	15
11 0.00 0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00	16
11 1.34 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	17
11 0.00 0.30 0.13 0.00 0.13 0.00 0.37 0.54 0.16 0.04	18
11 0.00 0.00 0.00 0.00 0.11 0.01 0.00 0.00 0.00 0.00	19
11 0.00 0.00 0.00 0.25 0.00 0.00 0.00 0.00 0.00 0.00	20
11 0.00 1.65 0.00 0.00 0.00 0.00 0.00 0.00 0.05 0.00	21
11 0.00 0.44 0.00 0.00 0.00 0.00 0.00 0.29 0.00 0.01	22
11 0.54 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	23

11 0.00 0.00 1.14 0.00 0.00 0.57 0.12 0.00 0.00 0.00	24
11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.05 0.00	25
11 0.00 0.00 0.30 0.08 0.00 0.00 0.29 0.00 0.03 0.00	26
11 0.00 0.00 0.00 0.00 0.00 0.00 0.15 0.00 0.00 0.00	27
11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	28
11 0.00 0.00 0.00 0.00 1.07 1.88 0.00 0.00 0.00 0.00	29
11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	30
11 1.14 0.00 0.00 0.00 0.02 0.21 0.00 0.00 0.00 0.00	31
11 0.00 0.00 0.16 0.00 0.00 0.00 0.00 0.00 0.00 0.00	32
11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.11	33
11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.45 0.00	34
11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	35
11 0.00 0.00 0.00 0.00 0.00 0.00 0.21 0.04 0.00 0.00	36
11 0.00 0.00 0.00 0.00 0.00 0.08 0.00 0.00 0.00 0.00	37
12 0.00 0.00 0.00 0.00 0.17 0.00 0.00 0.00 0.00 0.00	1
12 0.00 0.00 0.00 0.00 0.00 0.00 0.19 0.00 0.29 0.08	2
12 0.00 0.00 0.00 0.00 0.00 0.05 0.14 0.00 0.01 0.06	3
12 0.21 0.03 0.05 0.06 0.00 0.00 0.00 0.00 0.00 0.02	4
12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	5
12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.06	6
12 0.01 0.00 0.00 0.00 1.25 0.24 0.00 0.18 0.00 0.00	7
12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	8
12 0.00 0.43 0.50 0.10 0.00 0.00 0.00 0.00 0.00 0.00	9
12 0.07 1.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	10
12 0.00 0.00 0.00 0.00 0.00 0.43 0.04 0.00 0.00 0.00	11
12 0.00 0.01 0.59 0.05 0.19 0.00 0.00 0.00 0.00 0.00	12
12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.68 0.00	13
12 0.00 0.41 0.65 0.00 0.17 0.00 0.00 0.00 0.00 2.03	14
12 0.12 3.26 0.00 1.33 0.32 0.25 0.93 0.23 0.36 0.02	15
12 0.24 0.00 0.00 0.17 0.10 0.00 0.00 0.00 0.00 0.00	16
12 0.00 0.00 0.00 0.00 0.00 0.33 0.72 0.02 0.18 0.12	17
12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	18
12 0.44 0.00 0.44 0.00 0.00 0.00 0.00 0.00 0.00 0.00	19
12 0.00 0.00 0.00 0.00 0.00 0.00 0.26 0.00 0.00 0.00	20
12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.27 0.00 0.00	21
12 0.00 0.00 0.00 0.00 0.00 0.29 0.00 0.00 0.00 0.00	22
12 0.00 0.00 0.21 0.44 0.00 0.16 0.00 0.00 0.00 0.00	23
12 0.09 0.61 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	24
12 0.00 0.00 0.00 0.00 0.00 0.00 0.04 0.00 0.00 0.37	25
12 0.07 0.37 0.00 0.00 0.62 0.00 0.00 0.00 0.00 1.64	26
12 0.00 0.00 0.00 0.00 0.00 0.03 0.00 0.00 0.00 0.00	27
12 0.38 0.00 0.00 0.00 0.09 0.00 0.00 0.00 0.00 0.00	28
12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	29
12 0.00 0.00 0.01 1.79 0.37 0.00 0.69 0.10 0.00 0.00	30
12 0.00 0.00 0.00 0.00 0.00 0.03 0.00 0.00 0.00 0.00	31
12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	32
12 0.00 0.06 0.00 0.00 0.04 0.00 0.00 0.00 0.00 0.44	33
12 0.00 0.04 0.15 0.00 0.00 0.01 0.00 0.00 0.00 0.00	34
12 0.39 0.01 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00	35
12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	36
12 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	37
13 0.00 0.00 0.00 0.44 0.00 0.00 0.03 0.00 0.00 0.00	1
13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	2
13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	3
13 0.00 0.00 0.02 0.00 0.00 0.00 0.00 0.00 0.00 0.00	4
13 0.00 0.00 0.05 0.00 0.15 0.00 0.02 0.33 0.01 0.00	5
13 0.00 0.00 0.45 0.00 0.00 0.00 0.00 0.00 0.01 0.01	6

13 0.01 0.00 0.00 0.00 0.58 0.00 0.00 0.00 0.13 0.00	7
13 0.00 0.00 0.25 0.01 0.23 0.00 0.00 0.00 0.00 0.00	8
13 0.00 0.00 0.75 0.01 0.00 0.00 0.00 0.00 0.00 0.00	9
13 0.23 0.00 0.00 0.33 0.00 0.00 0.00 0.00 0.01 0.17	10
13 0.00 0.00 0.00 0.00 0.00 0.00 0.45 0.34 0.08 0.00	11
13 0.02 0.34 0.00 0.00 0.00 0.00 0.00 0.12 1.35 0.87	12
13 0.11 0.11 0.00 0.10 0.47 0.00 0.00 0.00 0.00 0.00	13
13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.53 0.00	14
13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	15
13 0.00 0.31 0.04 0.00 0.00 0.00 0.01 0.02 0.00 0.00	16
13 0.00 0.00 0.00 0.06 0.02 0.00 0.00 0.00 0.00 0.00	17
13 0.00 0.00 0.00 0.00 0.00 0.27 0.00 0.00 0.00 0.00	18
13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.00	19
13 0.13 0.00 0.00 0.00 0.00 0.55 0.00 0.00 0.12 0.00	20
13 0.00 0.09 0.00 0.00 0.21 0.00 0.00 0.00 0.00 0.00	21
13 0.00 0.00 0.00 0.00 0.22 0.05 0.00 0.00 0.00 0.00	22
13 0.09 0.10 0.00 0.00 0.00 0.15 0.00 0.00 0.00 0.00	23
13 0.00 0.00 0.00 0.03 0.00 0.00 0.05 0.00 0.00 0.47	24
13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	25
13 0.00 0.00 0.05 0.00 0.00 0.00 0.00 0.00 0.00 0.00	26
13 0.00 0.00 0.00 0.20 0.00 0.00 0.00 0.00 0.00 0.00	27
13 0.00 0.00 0.00 0.18 0.00 0.00 0.41 1.12 0.00 0.00	28
13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	29
13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.02 0.00	30
13 0.10 0.00 0.01 0.00 0.25 0.36 0.01 0.00 0.00 0.00	31
13 0.09 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	32
13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.10	33
13 0.23 0.00 0.54 0.00 0.00 0.00 0.00 0.00 0.00 0.00	34
13 0.04 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	35
13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.25	36
13 0.03 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	37
14 0.76 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	1
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	2
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	3
14 0.00 0.00 0.52 0.00 0.00 0.00 0.00 0.00 0.00 0.00	4
14 0.00 0.00 0.03 0.00 0.00 0.00 0.06 0.00 0.00 0.09	5
14 0.00 0.00 0.00 0.00 0.00 0.00 0.11 0.00 0.12 0.10	6
14 0.04 0.00 0.00 0.00 0.06 0.00 0.00 0.23 0.00 0.00	7
14 0.32 0.42 0.33 0.01 0.03 1.06 0.18 0.11 0.12 0.00	8
14 0.00 0.00 0.00 0.12 0.00 0.00 0.00 0.00 0.00 0.00	9
14 0.00 0.06 0.05 0.00 0.00 0.00 0.00 0.00 0.30 0.00	10
14 0.00 0.00 0.11 0.00 0.00 0.35 0.14 0.00 0.00 0.00	11
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	12
14 0.00 1.61 0.00 0.00 0.00 0.00 0.16 0.11 0.57 0.00	13
14 0.00 0.07 0.00 0.00 0.00 0.00 1.29 0.03 0.59 0.03	14
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	15
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	16
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	17
14 1.17 0.04 0.14 0.00 0.00 0.00 0.00 0.00 0.67 0.00	18
14 0.00 0.24 0.00 0.07 0.13 0.00 0.00 0.00 0.00 0.00	19
14 0.08 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	20
14 0.00 0.35 0.00 0.00 0.00 0.00 0.00 0.11 0.00 0.00	21
14 0.11 0.46 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	22
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	23
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	24
14 0.00 0.03 0.00 0.42 0.00 0.00 0.00 0.00 0.00 0.00	25
14 0.00 0.00 0.33 0.00 0.00 0.00 0.00 0.00 0.00 0.00	26
14 0.00 0.00 0.00 0.92 0.00 0.00 0.00 0.00 0.00 0.09	27
14 0.00 0.00 0.00 0.00 0.00 0.00 0.08 1.16 0.00 0.00	28
14 0.00 0.00 0.00 0.08 0.00 0.00 0.00 0.44 0.00 0.00	29
14 0.00 0.00 0.00 2.75 0.00 0.00 0.00 0.01 0.00 0.00	30
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	31
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	32
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.06	33
14 0.00 0.25 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	34
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.00	35
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	36
14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	37
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	1
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	2
15 0.60 0.26 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.08	3
15 0.01 0.00 0.00 0.02 0.03 0.00 0.00 0.00 0.00 0.00	4
15 0.00 0.00 0.00 0.00 0.00 0.00 0.02 0.00 0.16 0.00	5
15 0.00 0.00 0.00 0.00 0.00 0.22 0.00 0.00 0.00 0.19	6
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.01 0.00	7
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.28 0.00	8
15 0.00 0.00 0.00 0.00 0.00 0.00 0.26 0.34 0.00 0.00	9
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	10
15 0.10 0.00 0.00 0.17 0.83 0.00 0.00 0.00 0.00 0.00	11
15 0.00 0.88 0.00 0.00 0.00 0.00 0.45 0.00 0.00 0.00	12
15 0.00 0.00 0.86 0.00 0.00 0.00 0.00 0.00 0.07 1.97	13
15 0.54 0.00 0.00 0.00 0.03 0.00 0.00 0.00 0.00 0.14	14
15 0.00 0.00 0.00 1.70 0.10 1.55 0.00 0.00 0.00 0.00	15
15 0.00 0.15 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00	16
15 0.00 0.00 0.00 0.00 0.00 0.82 0.00 0.92 0.00 0.00	17
15 0.00 0.00 0.00 0.00 0.00 0.09 2.02 0.00 0.00 0.27	18
15 0.00 0.38 0.00 0.00 0.00 0.00 0.17 0.00 0.00 0.00	19
15 0.00 0.00 0.00 0.00 0.00 0.52 0.00 0.00 0.00 0.00	20
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.07 0.00 0.00	21
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	22
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.12	23
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	24
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	25
15 0.00 0.00 0.00 0.00 0.00 0.00 0.64 0.00 0.00 0.00	26
15 0.00 0.00 0.00 0.00 0.00 1.95 0.00 0.00 0.00 0.00	27
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	28
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	29
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	30
15 0.00 0.00 0.00 0.00 0.00 0.09 0.00 0.00 0.00 0.00	31
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	32
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	33
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.26	34
15 0.00 0.00 0.00 0.13 0.32 0.00 0.00 0.38 0.00 0.00	35
15 0.09 0.00 0.00 0.00 0.90 0.00 0.00 0.00 0.00 0.00	36
15 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	37
16 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	1
16 0.00 0.00 0.00 0.00 0.09 0.00 0.16 0.00 0.00 0.00	2
16 0.00 0.00 0.00 0.00 0.10 0.00 0.00 0.00 0.00 0.00	3
16 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.12 0.10	4
16 0.00 0.11 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	5
16 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	6
16 0.00 0.00 0.00 0.00 0.00 0.00 1.33 0.08 0.00 0.00	7
16 0.00 0.00 0.01 0.10 0.00 0.00 0.05 0.00 0.00 0.00	8
16 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	9

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

16 0.02 0.00 0.00 0.00 0.00 0.00 0.00 0.58 0.00 0.00	10
16 0.00 0.00 0.00 0.00 0.14 0.00 0.47 1.19 0.00 0.00	11
16 0.00 0.03 0.43 0.00 0.00 0.00 0.00 0.00 0.02 0.00	12
16 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.52 0.00 0.28	13
16 0.01 0.01 0.00 0.00 0.55 0.00 0.00 0.00 0.00 0.00	14
16 0.00 0.00 0.00 0.00 0.41 0.00 0.05 0.03 0.00 0.00	15
16 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	16
16 0.00 0.00 0.16 0.00 0.00 0.00 0.00 0.00 0.00 0.00	17
16 0.00 0.00 0.00 0.00 0.16 0.00 0.00 0.00 0.00 0.00	18
16 0.00 0.00 0.00 0.00 0.00 0.00 0.07 0.22 0.00 0.00	19
16 0.92 0.00 0.08 0.33 0.00 0.00 0.00 0.00 0.00 0.00	20
16 0.00 0.09 0.00 0.00 0.00 0.00 0.00 0.00 0.27 0.00	21
16 0.00 0.00 0.30 1.63 0.00 0.00 0.00 0.29 0.00 0.48	22
16 0.00 0.00 0.00 0.00 0.00 0.00 2.23 0.00 0.26 0.22	23
16 0.00 0.00 0.08 0.35 0.00 0.00 0.00 0.00 0.00 0.00	24
16 1.13 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	25
16 0.00 0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.00	26
16 0.00 0.00 0.00 0.00 0.25 0.00 0.00 0.00 0.00 0.28	27
16 0.40 0.00 0.83 0.19 0.00 0.00 0.00 0.00 0.00 0.00	28
16 0.23 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.17 0.00	29
16 0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.00	30
16 0.00 0.00 0.00 0.55 0.06 0.11 0.00 0.00 0.00 0.00	31
16 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.06 0.00	32
16 0.05 0.00 0.00 0.00 0.00 0.00 0.60 0.00 0.00 0.00	33
16 0.00 0.00 0.00 0.00 0.00 0.00 0.09 0.00 0.00 0.00	34
16 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	35
16 0.01 0.00 0.00 0.00 0.00 0.28 0.00 0.00 0.00 0.00	36
16 0.06 0.64 0.00 0.00 0.07 0.19 0.00 0.00 0.00 0.00	37
17 0.02 0.12 0.07 0.00 0.00 0.00 0.00 0.00 0.00 0.00	1
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.02	2
17 0.00 0.00 0.00 0.23 0.31 0.00 0.00 0.00 0.00 0.00	3
17 0.00 0.00 0.00 0.00 0.04 0.16 0.00 0.00 0.18 0.04	4
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	5
17 0.04 0.00 0.00 0.00 0.00 0.00 0.00 0.28 0.25 0.00	6
17 0.31 0.03 0.08 0.12 0.00 0.00 0.55 0.41 0.00 0.00	7
17 0.00 0.00 0.00 0.19 0.00 0.00 0.00 0.00 0.28 0.38	8
17 0.00 0.09 0.21 0.00 0.00 0.00 0.00 0.02 0.00 0.00	9
17 0.00 0.53 0.00 0.06 0.00 0.00 0.00 0.00 0.00 0.00	10
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.21 0.00	11
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	12
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.67 0.04	13
17 0.00 0.01 0.00 0.15 0.00 0.00 0.00 0.00 0.00 0.00	14
17 0.40 1.17 0.10 6.15 0.00 0.00 0.00 0.00 0.00 2.76	15
17 1.04 0.00 0.00 0.75 1.49 0.00 0.02 0.00 0.00 0.00	16
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	17
17 0.00 0.00 0.00 0.00 0.02 0.00 0.00 0.00 0.00 0.00	18
17 0.00 0.63 0.00 0.00 0.00 0.00 0.00 0.04 0.00 0.00	19
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	20
17 0.00 0.03 0.00 0.00 0.37 0.00 0.00 0.38 0.00 0.00	21
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.14 0.00 1.49	22
17 0.23 0.00 0.00 1.05 0.35 0.22 0.00 0.00 0.00 0.00	23
17 0.34 0.33 0.00 0.00 0.00 0.00 1.42 0.00 0.00 0.00	24
17 0.00 0.00 0.00 0.00 0.00 0.00 0.63 0.12 0.00 0.00	25
17 0.00 0.33 0.00 0.00 0.00 0.00 0.00 0.00 0.07 0.00	26
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.10 0.00	27
17 0.01 0.00 0.03 0.03 0.12 0.00 0.10 0.00 0.00 0.00	28
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	29
17 0.00 0.00 0.04 0.00 0.00 0.00 0.00 0.00 0.00 0.00	30
17 0.09 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	31
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	32
17 0.00 0.04 0.00 0.00 0.00 0.00 0.10 0.00 0.00 0.00	33
17 0.00 0.00 0.00 0.63 0.00 0.00 0.00 0.00 0.00 0.00	34
17 1.50 0.05 0.01 0.01 0.00 0.00 0.02 0.00 0.00 0.00	35
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	36
17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	37
18 0.00 0.00 0.53 0.03 0.00 0.00 0.03 0.00 0.00 0.00	1
18 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	2
18 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	3
18 0.00 0.04 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.07	4
18 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.18	5
18 0.00 0.07 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.10	6
18 0.00 0.00 0.03 1.12 0.00 0.00 0.00 0.00 0.00 0.00	7
18 0.00 0.00 0.62 0.00 0.00 0.22 0.00 0.00 0.00 0.00	8
18 0.83 0.32 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	9
18 0.00 0.00 0.00 0.97 0.00 0.00 0.00 0.00 0.00 0.00	10
18 0.00 0.62 0.13 0.00 0.00 0.00 0.00 0.00 0.00 0.00	11
18 0.00 0.08 0.02 0.00 0.00 0.00 0.00 0.00 0.34 0.00	12
18 0.00 0.00 0.00 0.00 0.34 0.27 0.00 0.18 0.11 0.07	13
18 0.04 0.00 0.00 0.00 0.00 0.00 0.15 0.00 0.00 0.00	14
18 0.00 0.00 0.51 0.00 0.00 0.00 0.04 0.00 0.00 0.00	15
18 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	16
18 0.00 0.00 0.86 0.00 0.00 0.00 0.00 0.00 0.00 0.00	17
18 0.25 1.54 0.00 0.00 0.49 0.00 0.67 0.00 0.15 0.00	18
18 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	19
18 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	20
18 0.00 0.00 2.48 0.00 0.00 0.00 0.78 0.00 0.00 0.00	21
18 0.00 0.03 0.00 0.00 0.06 0.49 0.00 0.00 0.00 0.00	22
18 0.00 0.68 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.60	23
18 0.11 0.00 0.00 0.12 0.00 0.00 0.23 0.00 0.00 0.00	24
18 0.00 0.00 0.00 1.03 0.00 0.00 0.00 0.00 0.00 0.00	25
18 0.00 0.00 0.00 0.00 0.05 0.00 0.00 0.29 0.58 0.30	26
18 0.00 0.00 0.00 0.00 1.03 0.00 0.00 0.00 0.00 1.23	27
18 0.06 0.00 0.00 0.23 0.00 0.00 0.00 0.00 0.00 0.00	28
18 0.00 0.00 0.00 0.00 0.00 0.17 0.00 0.00 0.00 0.00	29
18 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.19 0.08 0.15	30
18 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.81 0.05 0.00	31
18 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	32
18 0.00 0.39 0.21 0.00 0.00 0.00 0.52 0.00 0.00 0.00	33
18 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	34
18 0.00 0.00 0.00 0.00 0.00 0.00 0.01 0.01 0.00 0.00	35
18 0.00 0.00 0.00 0.17 0.00 0.00 0.00 0.00 0.00 0.00	36
18 0.21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	37
19 0.00 0.00 0.00 0.02 0.27 0.00 0.00 0.00 0.00 0.00	1
19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.10 0.00	2
19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	3
19 0.00 0.00 0.12 0.25 0.06 0.06 0.00 0.00 0.00 0.00	4
19 0.00 0.00 0.13 0.22 0.00 0.64 0.00 0.05 0.00 0.00	5
19 0.00 0.00 0.02 0.00 0.00 0.00 0.00 0.00 0.00 0.00	6
19 0.10 0.01 0.00 0.00 0.00 0.00 0.24 0.00 0.00 0.31	7
19 0.00 0.00 0.00 0.01 0.32 1.04 0.00 0.00 0.00 0.07	8
19 0.03 0.07 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00	9
19 0.00 0.00 0.00 0.18 0.65 0.11 0.00 0.00 0.00 0.00	10
19 0.00 0.25 0.00 0.00 0.00 0.00 0.00 0.00 0.16 0.00	11
19 0.00 0.00 0.00 0.15 0.09 0.00 0.00 0.00 0.00 0.00	12

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

19 0.00 0.00 0.52 0.00 0.00 0.00 0.00 0.00 0.00 0.00 13
19 0.00 0.66 0.15 1.19 0.00 0.57 0.00 0.00 0.00 0.00 14
19 0.00 0.00 0.00 0.93 0.00 0.00 0.00 0.00 0.00 0.00 15
19 0.00 0.00 0.00 0.00 0.00 0.00 0.59 0.00 0.85 0.00 16
19 0.00 0.48 0.00 0.00 0.00 0.00 0.00 0.01 0.00 0.07 17
19 0.14 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 18
19 0.00 0.81 0.00 0.00 0.00 0.80 0.00 0.00 0.29 0.07 19
19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 20
19 0.00 0.00 0.74 0.53 0.08 0.00 0.00 0.00 0.01 0.64 21
19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.09 22
19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.05 0.04 23
19 0.00 0.00 0.00 0.00 0.00 0.22 0.08 0.00 0.00 0.00 24
19 0.00 0.75 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 25
19 0.09 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.02 26
19 0.03 0.00 0.00 0.14 0.00 0.00 0.00 0.00 0.00 0.00 27
19 0.00 0.00 0.00 0.00 0.00 0.26 0.00 0.00 0.00 0.00 28
19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 29
19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.10 30
19 0.87 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 31
19 0.00 0.00 0.00 0.00 0.00 0.00 0.05 0.82 0.00 0.00 32
19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 33
19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 34
19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 35
19 0.00 0.00 0.00 0.01 0.00 0.00 0.00 0.00 0.00 0.00 36
19 0.00 0.00 0.27 0.00 0.00 0.00 0.00 0.00 0.00 0.00 37
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.02 0.00 0.01 1
20 0.00 0.15 0.00 0.00 0.00 0.00 0.04 0.15 0.10 0.00 2
20 0.00 0.00 0.00 0.00 0.00 0.02 0.00 0.00 0.00 0.00 3
20 0.00 0.00 0.00 0.00 0.00 0.00 0.16 0.21 0.01 0.00 4
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 5
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 6
20 0.47 0.04 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 7
20 0.00 0.00 0.00 0.03 0.07 0.46 1.04 0.00 0.00 0.00 8
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 9
20 0.65 0.00 0.00 0.00 0.00 0.82 0.00 0.00 0.00 0.15 10
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.49 11
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 12
20 0.00 0.00 0.00 0.00 0.29 0.00 1.85 0.01 0.00 0.00 13
20 0.04 0.01 0.00 0.00 1.14 0.19 0.00 0.00 0.00 0.72 14
20 0.07 0.00 0.00 0.23 0.00 0.00 0.00 0.00 0.08 0.00 15
20 0.00 0.00 0.58 0.12 0.00 0.17 0.04 0.00 0.00 0.00 16
20 0.00 0.00 0.53 0.80 0.11 0.00 0.00 0.00 0.35 0.52 17
20 0.00 0.00 0.00 0.00 1.55 0.03 0.22 0.51 0.00 0.00 18
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.31 0.00 0.00 19
20 0.00 0.03 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 20
20 0.00 0.35 0.00 0.00 0.27 0.03 0.01 0.03 0.81 0.02 21
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 22
20 0.01 0.00 1.98 0.00 0.00 0.10 0.00 0.00 0.00 0.04 23
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 24
20 0.00 0.00 0.00 0.00 0.00 0.00 0.10 0.00 0.23 0.00 25
20 0.00 0.00 0.00 0.36 0.08 0.12 0.00 0.00 0.00 0.05 26
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.04 0.00 27
20 0.00 0.43 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 28
20 0.00 0.19 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 29
20 0.00 0.43 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 30
20 0.79 0.00 0.00 0.10 0.00 0.00 0.00 0.00 0.00 0.00 31
20 0.01 0.00 0.26 0.00 0.00 0.00 0.27 0.00 0.34 0.00 32
20 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 33
20 0.00 0.57 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 34
20 0.09 0.00 0.00 0.61 0.19 0.00 0.27 0.00 0.30 0.00 35
20 0.00 0.00 0.00 0.00 0.00 0.00 0.09 0.00 0.00 0.00 36
20 0.00 0.00 0.00 0.00 0.01 0.65 0.00 0.00 0.00 0.00 37
21 0.04 0.00 0.02 0.00 0.00 0.00 0.00 0.00 0.13 0.00 1
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 3
21 0.00 0.00 0.00 0.36 0.00 0.00 0.00 0.20 0.00 0.00 4
21 0.00 0.34 0.17 0.00 0.00 0.00 0.00 0.11 0.00 0.00 5
21 0.00 0.00 0.00 0.00 0.00 0.00 0.17 0.00 0.00 0.00 6
21 0.00 0.00 0.00 0.07 0.20 0.00 0.65 0.00 1.52 0.00 7
21 0.00 1.02 0.07 0.02 0.00 0.00 0.00 0.00 0.70 0.00 8
21 0.00 0.00 0.00 1.04 0.00 0.00 0.00 0.00 0.00 0.00 9
21 0.01 0.20 0.31 0.00 0.00 1.66 0.04 0.00 0.00 0.00 10
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.32 0.00 11
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.15 0.00 12
21 0.06 0.78 1.41 0.00 0.00 0.00 0.08 0.00 0.03 0.00 13
21 0.00 0.00 0.00 0.00 0.17 0.00 0.00 0.00 0.00 0.00 14
21 0.37 0.00 0.00 0.91 0.03 0.00 0.00 0.00 0.09 0.00 15
21 0.00 0.30 0.00 0.00 0.00 0.00 0.00 1.00 0.00 0.45 16
21 0.00 0.22 0.00 0.00 0.00 0.41 0.00 0.27 0.11 0.00 17
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.66 0.00 18
21 0.47 0.00 0.00 0.69 0.15 0.35 0.18 0.00 0.00 0.00 19
21 0.00 0.00 0.00 0.00 0.00 0.00 0.40 0.00 0.00 0.00 20
21 0.00 0.55 0.00 0.00 0.00 0.00 0.03 0.00 0.00 0.00 21
21 0.00 0.00 0.00 0.59 0.22 0.01 0.00 0.00 0.00 1.70 22
21 0.00 0.00 0.00 0.17 0.00 0.00 0.67 0.20 0.00 1.33 23
21 0.00 0.00 0.00 0.07 0.00 0.00 0.00 0.00 0.00 0.00 24
21 0.00 0.05 0.00 0.18 0.54 0.00 0.00 0.14 0.00 0.00 25
21 0.00 0.00 0.00 0.00 0.02 0.16 0.01 0.09 0.17 0.36 26
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 27
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 28
21 0.00 0.00 0.00 0.00 3.88 0.00 0.00 0.00 0.00 0.00 29
21 0.00 0.00 0.00 0.00 0.01 0.45 0.00 0.00 0.00 0.00 30
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 31
21 0.00 0.00 0.00 0.00 0.00 0.14 0.13 0.15 0.00 0.00 32
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 33
21 0.00 0.00 0.00 0.00 0.00 0.07 0.00 0.00 0.00 0.00 34
21 0.00 0.00 0.00 0.00 0.00 0.00 0.02 0.07 0.01 0.00 35
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 36
21 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 37
22 0.00 0.10 0.00 0.27 0.00 0.00 0.03 0.61 0.00 0.00 1
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 3
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.04 4
22 0.01 0.16 0.11 0.09 0.00 0.07 0.92 0.00 0.00 0.00 5
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 6
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 7
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.20 8
22 0.00 0.00 0.00 0.00 0.14 0.06 0.09 0.00 0.00 0.00 9
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 10
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 11
22 0.00 0.02 0.00 0.00 0.00 0.04 0.00 0.00 0.00 0.00 12
22 0.00 0.48 0.00 0.30 0.00 0.00 0.00 0.00 1.26 0.00 13
22 0.01 0.00 0.00 0.00 0.00 0.00 0.00 0.59 0.00 0.00 14
22 0.93 2.00 0.00 0.00 0.87 0.11 0.00 0.00 0.00 0.00 15

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.69 0.00 16
22 0.00 0.00 0.18 0.00 0.21 0.00 0.34 0.00 0.00 0.00 17
22 0.00 0.01 0.00 0.51 0.00 0.00 0.00 0.00 0.00 0.00 18
22 0.17 0.44 0.00 0.00 0.83 0.00 0.00 0.00 0.00 0.00 19
22 0.00 0.00 0.00 0.08 1.01 0.00 0.87 0.02 0.00 0.50 20
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 21
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 22
22 0.00 0.00 0.00 0.00 0.03 0.00 0.00 0.00 0.00 0.00 23
22 0.33 0.31 0.21 0.13 0.00 0.39 0.00 0.00 0.02 0.02 24
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 25
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22 0.00 0.05 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 28
22 0.00 0.00 0.00 0.18 0.00 0.00 0.00 0.00 0.00 0.00 29
22 0.00 0.00 0.00 0.00 0.00 0.12 0.00 0.00 0.96 0.00 30
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 31
22 0.00 0.00 0.00 0.00 0.10 0.40 0.00 0.00 0.00 0.00 32
22 0.00 0.00 0.00 0.00 0.00 0.02 0.18 0.00 0.00 0.00 33
22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 34
22 0.56 0.00 0.00 0.18 0.00 0.00 0.00 0.45 0.00 0.00 35
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22 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 37
23 0.00 0.08 0.00 0.00 0.00 0.00 0.00 0.50 0.00 0.00 1
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23 0.31 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 4
23 0.00 0.00 0.00 0.20 0.02 0.00 0.30 0.09 0.00 0.00 5
23 0.00 0.00 0.00 0.20 0.13 0.16 0.21 0.62 0.00 0.00 6
23 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 7
23 0.00 0.53 0.04 0.00 0.00 0.00 0.00 0.15 0.53 0.00 8
23 0.00 0.00 0.00 0.00 0.00 0.00 0.36 0.94 0.15 0.00 9
23 0.00 0.00 0.34 0.54 0.38 0.62 0.00 0.00 0.00 0.41 10
23 0.47 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.37 0.00 11
23 0.00 0.25 2.31 0.07 0.00 0.00 0.00 0.00 0.00 0.00 12
23 0.00 0.00 0.00 0.00 0.00 1.50 0.37 0.00 0.12 0.62 13
23 0.27 0.72 1.04 0.26 0.00 1.19 0.00 0.00 0.00 0.00 14
23 0.00 0.00 0.00 0.00 0.00 0.44 0.00 0.00 0.00 0.00 15
23 1.33 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 16
23 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.26 17
23 0.42 1.04 0.03 0.84 0.00 0.00 0.00 0.00 0.05 0.35 18
23 0.36 0.26 0.58 0.21 0.00 0.00 0.00 0.00 1.51 0.00 19
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23 0.07 0.00 0.73 0.33 0.00 0.00 0.00 0.01 1.49 1.51 22
23 0.48 0.12 0.57 0.00 0.00 0.00 0.00 0.01 0.00 0.00 23
23 0.06 0.00 0.00 0.00 0.00 0.88 0.24 0.00 0.00 0.00 24
23 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 25
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23 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 27
23 0.00 0.00 0.00 0.21 0.00 0.61 0.70 0.23 0.05 0.01 28
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23 0.00 0.00 0.00 0.00 0.39 0.00 0.00 0.00 0.00 0.00 34
23 0.42 0.43 0.00 0.00 0.00 0.00 0.00 0.02 0.03 0.03 35
23 0.22 0.00 0.00 0.00 0.00 0.04 0.00 0.00 0.00 0.00 36
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24 0.00 0.00 0.21 0.15 0.00 0.00 0.04 0.01 0.00 0.21 2
24 0.05 0.31 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.04 3
24 0.10 0.70 0.28 0.00 0.00 0.00 0.00 0.00 0.00 0.00 4
24 0.00 0.00 0.07 0.00 0.00 0.00 0.00 0.08 0.04 0.20 5
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24 0.17 0.00 0.00 0.36 0.00 0.00 0.00 0.00 0.08 0.00 16
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25 0.00 0.02 0.00 0.00 0.05 0.00 0.02 0.08 0.18 0.37 2
25 0.02 0.39 0.05 0.00 0.00 0.00 0.00 0.00 0.00 0.00 3
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25 0.02 0.00 0.00 0.00 0.00 0.95 0.00 0.00 0.00 0.00 15
25 0.00 0.90 0.00 0.33 0.00 0.00 0.17 2.11 0.03 0.00 16
25 0.78 0.45 0.00 0.00 0.00 0.00 0.00 0.11 0.55 0.56 17
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25 0.00 0.00 0.00 0.02 0.24 0.00 0.19 0.00 0.44 0.00 26
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25 0.00 0.66 0.00 0.02 0.02 0.47 0.00 0.29 0.04 0.00 32
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26 0.00 0.00 0.17 0.63 0.41 0.31 0.00 0.00 0.00 0.00 12
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27 0.00 0.00 0.08 0.00 0.34 0.00 0.25 0.00 0.00 0.00 4
27 0.00 0.51 0.17 0.00 0.00 0.00 0.00 0.00 0.00 0.00 5
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28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.00	0.00	22
28	0.00	0.47	0.00	0.00	0.00	0.00	0.00	0.00	1.22	0.00	23
28	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.54	24
28	0.00	0.00	0.30	0.37	0.00	0.00	0.00	0.25	0.00	0.00	25
28	0.00	0.00	0.27	0.07	0.00	0.00	0.00	0.00	0.32	0.00	26
28	0.00	0.00	0.00	0.00	0.11	0.73	0.02	0.00	0.00	0.00	27
28	0.18	0.00	0.34	0.00	0.00	1.28	0.53	0.00	0.00	0.18	28
28	0.04	0.00	0.00	0.22	0.00	0.00	0.00	0.00	0.00	0.00	29
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	30
28	1.81	0.33	0.60	0.12	0.33	0.00	0.00	0.00	0.00	0.00	31
28	0.00	0.00	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	32
28	0.00	0.42	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.00	33
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	34
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	35
28	0.00	0.00	0.00	0.01	0.14	0.00	0.09	0.00	0.00	0.00	36
28	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37
29	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1
29	0.00	0.00	0.09	0.07	0.00	0.00	0.00	0.00	0.11	0.00	2
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.00	3
29	0.00	0.00	0.00	0.00	0.04	0.29	0.00	0.00	0.00	0.05	4
29	0.00	0.08	0.31	0.99	0.13	0.00	0.00	0.08	0.05	0.01	5
29	0.35	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.16	0.13	6
29	0.28	0.71	0.00	0.00	0.54	0.05	0.02	0.00	0.00	0.00	7
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.94	0.18	0.03	8
29	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	9
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	10
29	0.00	0.00	0.00	0.00	0.00	0.00	0.12	0.00	0.02	0.02	11
29	0.19	0.47	0.00	0.50	0.00	0.00	0.00	0.00	0.10	0.00	12
29	0.11	0.00	0.00	0.00	0.65	0.66	0.05	0.00	0.00	0.04	13
29	0.00	0.01	0.00	0.00	0.00	0.00	0.24	0.84	0.00	0.00	14
29	0.00	0.00	1.24	0.00	0.00	0.00	0.00	0.58	0.04	0.84	15
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.11	0.00	16
29	0.00	0.00	0.00	0.00	0.00	0.00	0.71	0.00	0.00	0.00	17
29	0.13	1.22	0.23	0.04	0.17	1.84	0.06	0.00	0.40	0.00	18
29	0.00	0.00	0.00	0.09	0.00	0.00	0.00	0.00	0.00	0.00	19
29	0.00	0.00	1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20
29	0.00	0.00	0.00	0.00	0.00	0.00	0.65	0.00	0.00	0.20	21
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49	1.13	0.00	22
29	0.00	0.00	0.00	0.00	0.00	0.00	0.15	0.00	0.00	0.00	23
29	0.00	0.00	0.00	0.00	0.04	0.29	0.04	0.00	0.17	0.00	24
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	25
29	0.00	0.00	0.00	0.39	0.00	0.00	0.00	0.00	0.00	0.09	26
29	0.00	0.00	0.00	0.29	0.00	0.00	0.00	0.00	0.00	0.00	27
29	0.00	1.24	0.67	0.01	0.00	0.00	0.00	0.00	0.00	0.00	28
29	0.00	0.00	0.00	0.21	0.00	0.00	0.00	0.00	0.00	0.00	29
29	0.00	0.00	0.19	0.00	0.00	0.00	1.82	0.00	0.00	0.00	30
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	31
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.84	0.00	0.00	32
29	0.00	0.00	0.00	0.04	0.00	0.00	0.43	0.42	0.20	0.00	33
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.19	34
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.10	35
29	0.01	0.00	0.00	0.01	0.56	0.08	0.03	0.00	0.00	0.00	36
29	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1
30	0.00	0.00	0.00	0.25	0.00	0.00	0.00	0.00	0.00	0.00	2
30	0.00	0.00	0.00	0.00	0.03	0.07	0.00	0.00	0.00	0.22	3
30	0.00	0.32	0.00	0.04	0.13	0.00	0.04	0.08	0.01	0.00	4
30	0.00	0.03	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.27	5
30	0.02	0.38	0.00	0.30	0.05	0.01	0.25	0.00	0.00	0.00	6
30	0.05	0.45	0.59	0.15	0.00	0.00	0.00	0.00	0.00	0.09	7
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	8
30	0.00	0.14	0.32	0.05	0.03	0.04	0.07	0.00	0.00	0.00	9
30	0.00	0.00	0.00	0.00	0.12	0.00	0.00	0.00	0.43	0.00	10
30	0.00	0.00	0.00	0.11	0.00	0.00	0.20	0.00	0.01	0.00	11
30	0.00	0.00	0.56	0.00	0.03	0.00	0.00	0.00	0.00	0.00	12
30	0.16	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	13
30	0.00	0.00	0.00	0.31	0.42	0.02	0.00	0.00	0.00	0.00	14
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	15
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.00	16
30	1.07	0.00	0.00	0.00	0.00	0.77	0.00	0.00	0.64	0.00	17
30	0.00	0.59	0.63	0.21	0.24	0.00	0.19	0.16	0.00	0.00	18
30	0.14	0.30	1.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20
30	0.00	0.00	0.17	0.00	0.00	0.00	0.17	1.40	0.01	0.00	21
30	0.00	0.00	0.00	0.04	0.07	0.00	0.00	0.00	0.00	0.05	22
30	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	23
30	0.00	0.00	0.00	0.09	0.00	0.00	1.48	0.00	0.00	0.00	24
30	1.07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	25
30	0.00	0.00	0.73	0.00	0.09	0.34	0.00	0.00	0.00	0.00	26
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	27
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	28
30	0.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29
30	1.11	0.73	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.11	30
30	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.24	0.00	31
30	0.00	0.00	0.00	0.00	0.00	0.24	0.41	0.00	0.00	0.00	32
30	0.00	0.00	0.00	0.95	0.00	0.00	0.00	0.00	0.00	0.00	33
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	34
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	35
30	0.00	0.00	0.31	0.00	0.00	0.33	0.29	0.00	0.00	0.00	36
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37

Temperature Data

2
1
OKLAHOMA CITY OKLAHOMA
34.8 38.9 47.3 57.6 67.8 77.1 82.7 81.0 72.2 59.4 46.5 35.3
1 36.2 32.3 32.0 25.0 32.3 43.9 35.2 36.4 38.4 28.0 1
1 34.7 27.9 27.8 24.5 18.2 24.6 31.1 31.4 50.7 56.0 2
1 61.5 49.8 59.8 62.2 50.9 44.9 46.7 45.0 38.7 47.4 3
1 42.2 38.2 34.9 42.0 31.7 32.6 37.0 50.5 51.5 47.7 4
1 52.6 53.9 53.9 54.7 52.8 51.8 45.9 50.0 49.2 42.7 5
1 50.2 43.4 39.1 35.5 41.0 35.2 39.4 46.7 44.7 41.7 6
1 29.4 26.4 40.1 45.2 35.5 32.6 46.8 34.2 37.5 35.5 7
1 30.7 30.1 35.0 45.3 53.1 46.2 39.8 52.7 65.8 50.3 8
1 50.4 48.2 49.1 59.9 62.6 64.5 55.0 58.3 63.8 64.3 9
1 55.9 70.2 62.3 49.2 48.1 39.8 39.2 46.7 34.1 59.7 10
1 47.2 46.5 53.0 61.0 55.3 61.6 71.5 74.3 79.6 76.7 11
1 78.4 63.2 60.0 58.6 59.9 57.5 62.6 54.8 55.2 61.5 12
1 59.7 63.3 63.4 71.5 70.1 73.1 65.3 66.2 72.3 62.7 13
1 66.0 70.7 71.0 66.4 71.6 69.4 65.9 65.4 70.0 67.4 14
1 60.7 69.0 66.7 57.1 62.2 61.5 69.8 72.9 69.0 79.4 15
1 74.4 79.3 89.2 80.5 73.3 75.8 81.7 81.7 77.8 80.7 16
1 80.6 83.0 83.4 75.1 71.9 72.6 75.9 79.7 83.6 78.2 17
1 81.2 82.2 83.0 81.5 82.7 82.7 81.4 81.0 76.7 79.0 18
1 82.1 80.8 77.8 77.1 77.9 81.5 86.5 85.6 87.7 88.4 19
1 86.9 82.5 81.7 89.2 90.9 91.8 89.9 87.8 89.1 84.6 20
1 90.0 89.1 87.1 86.5 82.8 81.5 81.5 82.0 78.6 77.8 21
1 73.3 78.2 79.4 79.8 77.2 73.2 73.2 79.2 79.9 84.5 22
1 86.4 89.5 85.6 87.3 80.0 75.3 74.9 70.7 73.9 81.3 23
1 77.5 72.3 81.1 80.7 81.5 81.6 81.2 78.3 74.7 72.3 24
1 72.2 71.9 70.0 67.2 66.6 70.4 73.0 62.1 64.6 61.3 25
1 64.3 61.7 65.0 66.6 67.8 55.7 59.1 66.9 61.3 75.7 26
1 73.3 73.6 72.3 70.1 68.4 69.5 74.0 71.6 63.1 75.7 27
1 73.4 78.3 68.7 65.7 62.4 64.9 74.6 61.2 68.6 76.3 28
1 70.4 75.8 75.7 74.3 74.5 63.8 59.4 63.0 61.9 55.7 29
1 60.5 57.5 53.6 62.0 51.7 49.1 49.1 48.2 62.2 64.3 30
1 59.5 60.9 57.8 63.8 60.1 53.3 57.3 62.9 58.9 63.2 31
1 59.4 62.9 65.1 68.3 65.2 62.5 62.9 57.2 67.0 65.5 32
1 58.5 43.6 51.6 55.5 42.5 41.3 35.9 38.2 46.6 52.8 33
1 38.5 38.8 55.2 38.7 43.6 37.0 42.3 33.9 35.3 41.3 34
1 37.9 40.2 42.8 33.8 23.3 19.7 12.3 10.2 26.2 42.9 35
1 49.5 33.5 26.7 12.9 16.8 34.2 44.8 52.7 51.2 48.4 36
1 47.8 58.9 53.4 54.3 42.7 0.0 0.0 0.0 0.0 0.0 37
2 44.8 36.1 36.1 34.5 39.4 45.0 45.1 34.0 22.2 23.7 1
2 13.0 24.1 11.2 12.3 17.8 23.8 30.7 35.7 38.8 32.8 2
2 35.3 30.6 33.9 25.4 26.7 19.6 30.5 32.9 28.9 23.5 3
2 33.3 40.7 30.9 29.3 33.6 29.9 31.4 37.4 44.0 49.5 4
2 45.1 44.7 46.5 33.8 24.0 33.5 41.4 25.3 26.7 34.0 5
2 38.6 38.1 31.9 34.3 36.8 31.7 32.8 38.3 33.4 33.1 6
2 36.1 29.0 29.9 26.8 44.0 55.7 54.1 52.2 46.5 43.7 7
2 52.3 57.9 60.2 45.7 49.2 55.6 53.1 39.4 35.7 35.3 8
2 43.9 44.5 60.5 68.1 65.7 67.0 51.8 55.6 57.6 59.0 9
2 54.5 56.4 64.1 60.6 51.3 52.1 51.8 55.6 58.2 53.5 10
2 62.6 77.3 70.6 74.7 61.3 58.1 50.0 58.7 62.8 51.5 11
2 63.0 66.5 72.7 78.3 70.1 55.5 57.8 50.1 63.0 61.9 12
2 60.7 68.7 56.5 68.0 75.1 62.2 66.5 71.1 68.8 68.9 13
2 66.9 67.8 61.1 53.9 50.2 49.5 52.5 57.5 58.5 64.7 14
2 65.4 71.6 72.5 67.6 67.8 69.4 69.6 71.4 60.7 67.2 15
2 70.6 71.1 68.1 64.6 64.0 72.8 77.0 78.7 79.1 84.2 16
2 82.5 80.9 81.1 77.0 75.3 72.5 71.6 69.8 66.9 72.7 17
2 78.4 80.6 80.9 78.6 80.3 80.5 76.4 77.4 80.1 83.7 18
2 84.6 80.9 86.5 84.7 84.7 83.9 83.6 83.8 83.9 88.9 19
2 86.3 89.0 84.8 86.1 83.6 80.5 80.0 81.9 85.1 83.4 20
2 81.8 82.7 80.7 87.0 85.8 88.1 86.5 86.4 82.5 86.6 21
2 85.9 83.5 85.3 82.5 83.5 84.8 83.5 81.5 79.6 80.5 22
2 87.8 88.8 78.8 83.9 81.4 84.9 79.1 77.6 74.4 82.0 23
2 81.8 78.2 76.3 77.5 84.3 81.6 78.2 76.6 76.6 79.7 24
2 74.2 72.3 81.7 81.0 83.5 84.5 82.7 80.9 80.1 77.3 25
2 71.3 75.5 77.3 75.9 82.8 87.5 79.5 66.6 66.1 71.9 26
2 65.8 65.0 67.8 70.4 63.5 71.9 70.6 73.9 63.8 68.2 27
2 67.7 63.4 62.2 55.5 55.2 63.8 55.4 59.1 57.4 61.0 28
2 61.3 59.3 55.9 53.8 58.2 62.0 69.2 80.5 74.9 73.7 29
2 69.8 73.5 71.4 69.7 63.6 54.6 49.0 53.7 59.3 61.3 30
2 56.6 46.4 47.4 50.1 50.8 44.3 46.8 56.8 55.5 52.7 31
2 52.4 57.0 38.1 51.1 53.3 47.1 36.7 42.3 51.1 54.5 32
2 48.3 48.5 53.1 51.8 49.7 52.1 36.8 29.1 47.2 42.2 33
2 51.6 59.2 60.6 55.4 54.7 55.2 63.4 45.9 36.6 42.0 34
2 44.5 25.4 17.8 13.8 21.7 15.3 16.6 24.7 16.9 22.3 35
2 36.7 25.3 16.5 25.6 28.6 34.8 39.7 36.4 29.5 25.2 36
2 16.6 10.6 22.7 36.2 38.3 0.0 0.0 0.0 0.0 0.0 37
3 41.7 45.3 39.4 43.7 36.5 41.4 36.2 25.7 17.5 28.1 1
3 40.8 39.8 36.4 43.4 40.3 42.2 42.3 38.4 36.3 43.8 2
3 41.3 43.7 36.0 42.4 31.9 28.1 28.9 39.2 33.5 47.4 3
3 52.8 54.9 49.0 36.7 38.1 35.9 45.9 40.8 44.5 35.2 4
3 47.5 44.8 50.0 56.2 43.4 49.8 37.3 34.3 40.7 33.1 5
3 33.5 34.5 45.4 37.8 33.8 33.3 41.4 46.6 45.4 44.8 6
3 39.5 32.6 50.6 44.1 38.1 49.1 45.4 44.1 56.1 44.5 7
3 32.2 21.7 39.9 33.0 43.0 38.8 40.6 45.8 43.1 47.9 8
3 41.7 48.8 44.6 54.4 51.2 44.0 41.7 34.4 49.9 46.5 9
3 48.7 48.5 49.9 49.6 50.3 45.1 51.7 45.4 49.8 52.5 10
3 62.1 56.9 52.4 59.9 57.3 59.6 58.6 69.8 60.7 64.8 11
3 64.2 66.7 66.9 71.3 68.3 76.7 65.5 75.5 70.0 65.6 12
3 66.3 59.2 61.6 59.3 55.4 68.6 63.9 61.8 65.4 66.5 13
3 71.3 61.6 64.4 62.7 64.4 67.8 61.3 64.4 63.0 59.6 14
3 61.7 69.1 68.0 68.1 67.8 68.6 67.5 67.3 71.3 70.9 15
3 77.6 79.2 82.9 83.3 83.1 85.9 83.8 79.8 75.2 71.4 16
3 71.6 68.0 67.8 67.2 68.6 69.1 74.2 72.1 73.3 75.4 17
3 76.3 73.7 77.5 77.5 74.5 76.2 83.1 82.6 73.2 72.6 18
3 75.9 76.7 80.3 76.1 76.5 79.3 84.3 83.0 78.6 84.9 19
3 84.7 81.0 78.2 80.5 82.1 85.5 84.7 83.6 84.3 87.6 20
3 90.2 89.4 88.1 87.6 82.2 84.1 82.2 82.5 81.1 82.7 21
3 83.9 84.9 82.1 81.2 79.4 84.2 82.7 83.1 81.0 83.2 22
3 78.6 77.3 77.5 77.0 78.3 78.2 80.3 79.1 75.7 77.2 23
3 78.6 84.8 76.0 77.2 81.1 78.5 78.5 69.5 70.3 73.1 24
3 71.4 66.2 70.9 65.6 68.3 67.4 67.0 71.0 79.8 76.5 25
3 75.3 64.8 69.4 67.7 68.8 66.5 68.8 67.6 62.8 65.5 26
3 64.3 68.3 62.2 65.3 62.9 63.6 58.5 57.8 56.9 65.3 27
3 62.5 64.3 58.8 65.6 63.9 64.1 65.6 72.0 71.3 60.9 28
3 70.5 64.1 65.8 71.4 74.6 66.5 67.0 71.6 54.9 60.3 29
3 70.0 51.7 41.6 39.1 31.2 26.9 37.7 47.1 50.0 50.7 30
3 53.6 53.8 52.9 55.7 60.1 52.8 49.3 43.4 54.3 59.4 31
3 72.6 53.0 37.7 39.6 41.3 49.6 56.5 44.0 50.2 53.1 32
3 59.9 54.4 50.5 49.2 47.9 34.4 38.7 35.2 46.3 53.8 33
3 51.3 35.9 19.2 32.8 31.4 36.3 37.0 30.5 22.7 9.6 34

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

3	10.3	16.6	15.1	26.0	35.9	38.2	29.1	34.3	29.7	37.8	35
3	27.5	26.2	25.0	28.5	33.5	34.0	36.1	42.2	44.6	42.4	36
3	22.8	23.0	21.5	23.4	23.2	0.0	0.0	0.0	0.0	0.0	37
4	33.2	36.2	24.0	36.0	31.0	45.3	42.1	47.3	37.2	41.3	1
4	36.4	28.6	23.8	31.8	26.6	17.6	15.2	10.1	23.0	25.2	2
4	27.5	18.6	25.0	28.5	39.4	41.3	49.6	38.6	46.6	54.8	3
4	42.3	43.1	42.4	43.0	38.7	41.5	32.3	37.3	20.7	28.0	4
4	21.6	43.7	48.6	53.1	59.2	41.5	40.7	46.8	43.6	46.5	5
4	45.9	49.7	58.3	48.7	43.6	45.3	43.6	40.8	42.3	40.6	6
4	40.6	31.5	30.1	27.6	34.0	44.1	39.5	36.4	49.6	38.5	7
4	40.6	42.3	39.1	39.3	28.3	35.7	29.7	44.1	49.1	48.1	8
4	51.9	37.7	52.4	41.0	38.6	32.1	45.8	51.2	53.3	55.5	9
4	44.4	37.8	44.9	52.5	44.7	59.8	58.2	60.6	57.4	61.4	10
4	57.4	55.1	55.6	53.6	50.0	44.0	44.5	53.7	52.6	65.8	11
4	75.1	64.7	58.5	58.2	67.6	69.1	62.7	60.6	59.2	59.1	12
4	60.7	62.9	70.2	79.9	77.6	68.7	68.5	67.3	70.0	75.6	13
4	75.7	81.7	81.8	74.1	69.5	76.2	76.8	73.7	67.6	64.9	14
4	64.9	67.8	73.2	75.3	68.7	66.2	56.5	53.6	58.6	60.6	15
4	65.8	67.9	66.4	66.2	75.7	77.3	77.9	75.5	72.5	74.3	16
4	70.1	68.6	75.1	76.2	77.2	75.9	74.7	78.4	80.0	75.9	17
4	77.7	77.0	73.6	80.0	83.2	76.7	78.7	79.8	81.5	80.7	18
4	81.7	82.2	87.1	83.9	86.4	82.9	81.8	82.5	81.8	81.5	19
4	81.7	82.2	86.7	86.3	89.5	88.5	86.5	86.8	84.4	87.1	20
4	82.7	83.3	80.9	86.7	84.7	83.8	83.9	82.2	81.9	85.6	21
4	81.8	81.8	81.8	82.8	79.3	84.3	84.4	84.3	84.0	83.7	22
4	78.5	74.3	81.2	80.6	79.1	81.2	85.7	83.0	76.5	78.4	23
4	76.2	75.5	74.0	78.4	77.1	76.0	85.9	84.0	85.0	80.2	24
4	75.6	75.1	75.7	82.9	80.8	80.7	74.9	75.5	66.1	68.6	25
4	74.4	63.5	57.7	58.5	62.0	62.7	66.5	72.2	71.9	77.7	26
4	75.6	81.8	77.4	78.7	75.1	75.6	77.0	80.9	75.8	77.0	27
4	70.0	74.3	81.1	83.6	69.2	70.3	71.3	68.2	63.9	51.5	28
4	52.8	58.6	66.2	67.2	69.9	65.5	63.1	69.4	75.1	70.6	29
4	66.2	63.7	54.0	44.8	53.1	62.2	63.8	57.5	45.2	46.6	30
4	50.6	45.4	55.7	43.0	41.7	39.3	43.6	59.2	51.8	59.0	31
4	56.4	62.4	63.1	67.7	61.7	61.4	65.6	62.0	50.8	46.2	32
4	33.5	27.9	39.7	40.4	43.8	55.0	47.4	44.5	35.6	49.2	33
4	49.1	47.1	35.7	34.4	40.2	32.8	36.7	39.0	29.4	38.2	34
4	31.8	33.1	27.1	23.8	20.3	26.7	37.8	31.6	35.5	28.4	35
4	19.5	21.7	23.1	17.9	20.6	32.1	51.3	51.7	49.3	47.1	36
4	38.1	45.2	37.0	37.2	28.5	28.9	0.0	0.0	0.0	0.0	37
5	39.5	45.0	39.7	25.5	21.2	35.5	44.8	49.5	51.0	31.2	1
5	39.9	25.1	22.0	30.8	25.4	13.3	20.9	21.6	15.9	12.6	2
5	17.9	22.7	35.5	34.2	35.7	41.7	54.6	52.7	46.3	49.9	3
5	49.3	53.3	49.6	45.0	36.8	33.5	32.7	33.2	33.4	20.4	4
5	20.9	23.3	25.8	24.8	24.0	23.1	24.7	36.8	43.5	42.5	5
5	52.4	41.5	48.8	49.6	58.2	37.5	39.2	44.6	39.5	36.5	6
5	33.6	41.6	42.3	47.5	31.2	39.4	46.3	66.3	71.1	74.5	7
5	67.3	53.0	57.6	57.7	68.2	75.4	56.6	56.8	55.1	49.2	8
5	44.8	38.9	42.6	42.5	44.1	43.1	52.8	44.9	42.8	46.7	9
5	45.3	40.3	37.0	51.5	44.6	40.9	45.1	48.2	42.6	48.5	10
5	38.0	35.8	52.4	41.9	44.1	48.3	47.9	50.2	50.9	59.6	11
5	60.7	65.7	69.5	69.0	51.2	51.1	61.7	60.0	65.3	67.8	12
5	76.6	57.5	47.6	60.3	59.9	62.5	68.7	67.6	73.2	65.9	13
5	59.0	57.1	64.6	67.6	67.4	77.8	77.7	69.6	58.6	65.0	14
5	71.9	69.6	72.0	73.9	75.7	79.5	68.5	74.5	74.6	77.8	15
5	70.0	66.6	67.6	74.8	72.4	67.2	72.2	72.6	74.9	77.0	16
5	85.0	84.0	87.3	77.5	74.3	76.8	78.2	73.5	79.8	75.4	17
5	75.5	74.4	75.7	78.9	78.3	75.7	70.0	72.2	75.8	77.8	18
5	81.8	78.1	76.1	76.5	75.2	81.4	83.2	85.7	86.5	82.1	19
5	84.7	79.5	81.7	86.2	86.5	86.1	83.3	86.5	88.0	90.1	20
5	82.9	83.5	82.1	84.6	85.7	86.4	89.1	88.2	83.0	83.5	21
5	84.3	84.5	89.7	87.8	84.3	79.5	83.9	81.0	78.9	80.3	22
5	81.6	81.4	80.3	81.2	81.8	85.8	85.7	85.0	88.3	83.6	23
5	79.7	84.3	83.8	79.8	74.7	71.6	67.5	69.4	70.4	69.0	24
5	74.5	72.5	73.5	80.3	82.8	79.1	72.6	66.3	61.8	59.9	25
5	65.7	72.7	74.8	72.2	72.9	61.0	62.0	60.0	67.9	76.7	26
5	76.8	72.4	70.1	66.1	64.1	55.0	58.4	64.3	63.3	59.3	27
5	62.6	65.5	68.7	71.1	82.8	83.8	74.1	77.8	81.4	66.6	28
5	62.1	71.6	61.9	58.3	62.5	67.9	65.8	68.4	57.9	58.3	29
5	52.7	40.3	45.4	49.9	34.8	39.1	43.9	44.5	53.9	47.1	30
5	52.2	49.5	48.7	55.4	53.9	55.2	61.8	58.8	57.6	42.5	31
5	42.4	42.1	44.9	45.7	42.7	43.4	47.5	54.1	54.0	54.9	32
5	57.2	65.6	57.5	65.5	62.7	53.8	50.6	60.3	60.9	60.8	33
5	61.2	58.3	72.2	66.0	41.7	36.3	35.3	29.4	43.2	39.4	34
5	47.9	37.3	42.4	43.1	50.1	38.2	51.3	59.0	51.9	38.4	35
5	34.8	45.1	36.7	31.9	32.3	20.5	22.9	27.0	25.7	31.9	36
5	28.1	33.1	45.3	31.9	39.7	28.9	0.0	0.0	0.0	0.0	37
6	41.9	35.7	39.9	34.1	20.0	20.8	16.2	30.8	30.2	31.5	1
6	39.8	35.3	38.3	40.2	27.2	26.8	27.6	26.5	19.0	14.3	2
6	31.6	27.2	29.1	21.2	22.7	18.8	22.9	23.5	38.6	39.9	3
6	43.0	46.4	43.2	40.4	30.8	26.4	38.7	53.4	43.4	43.0	4
6	40.3	42.5	32.4	38.1	36.6	42.0	39.7	30.0	39.2	40.3	5
6	37.9	40.1	47.4	56.4	52.9	48.0	55.5	43.9	53.2	48.2	6
6	51.0	43.3	32.1	50.0	44.3	37.1	39.5	28.4	28.0	43.0	7
6	55.5	51.5	43.8	51.2	52.8	44.8	44.9	46.7	56.2	54.9	8
6	47.7	62.1	58.2	54.6	62.0	62.4	55.5	53.0	49.4	51.4	9
6	42.9	45.1	52.0	60.6	71.6	75.7	66.8	64.3	59.2	58.2	10
6	74.4	64.3	59.6	51.3	60.3	57.9	54.1	61.1	66.6	57.1	11
6	65.5	61.6	50.0	45.4	50.5	48.0	51.1	58.5	57.0	61.3	12
6	59.5	61.0	71.0	68.7	64.7	72.8	65.0	60.2	65.7	60.2	13
6	51.9	66.1	75.1	78.0	77.7	77.6	70.2	74.7	75.4	78.0	14
6	79.8	71.8	68.3	70.0	75.1	68.8	73.1	72.1	75.6	72.3	15
6	75.9	80.2	80.3	76.9	72.0	70.9	68.6	74.3	76.5	75.1	16
6	76.0	72.4	68.1	73.3	73.6	73.3	78.0	75.4	76.9	77.3	17
6	82.6	77.6	76.4	74.0	80.6	79.6	80.8	81.1	80.5	83.6	18
6	81.3	82.6	76.7	78.9	81.8	85.1	88.0	87.1	86.7	82.7	19
6	81.4	82.4	82.3	79.4	82.5	84.0	84.4	79.9	79.8	75.1	20
6	79.3	86.7	85.7	84.6	87.5	83.1	87.7	85.7	89.7	85.0	21
6	84.0	85.5	82.2	87.2	84.5	89.1	79.1	83.2	87.1	84.0	22
6	83.2	80.2	84.6	75.6	78.9	80.1	81.5	80.8	82.6	82.8	23
6	80.5	77.6	77.2	75.7	79.1	73.6	79.5	77.8	81.7	81.2	24
6	77.3	80.2	82.4	80.3	75.2	77.6	69.5	69.4	69.5	69.2	25
6	72.5	73.8	79.9	69.1	73.7	71.5	70.0	69.4	72.3	73.3	26
6	72.4	83.3	74.4	79.3	70.9	69.3	64.3	68.3	60.9	56.0	27
6	61.3	69.2	68.8	62.0	70.3	59.1	54.0	58.9	58.2	55.0	28
6	65.5	59.0	54.9	63.7	58.7	64.0	61.5	52.1	55.5	55.3	29
6	53.1	49.4	41.0	44.7	47.8	54.2	61.1	60.6	52.8	42.3	30
6	40.9	41.3	50.5	42.0	48.9	53.5	56.8	54.5	56.4	66.3	31
6	59.2	60.5	62.5	55.0	53.6	48.3	46.9	53.1	57.5	48.1	32
6	60.8	54.8	53.3	52.0	47.5	48.5	35.7	39.6	29.8	36.2	33
6	34.3	39.1	42.3	45.1	37.8	40.7	39.7	41.0	36.6	36.6	34
6	36.9	34.3	29.2	42.6	42.1	28.8	32.3	27.5	33.5	31.0	35
6	30.5	26.3	31.4	24.9	37.1	27.9	26.7	22.4	24.9	37.0	36
6	36.9	34.4	37.6	37.4	30.5	28.9	0.0	0.0	0.0	0.0	37

Geosyntec consultants

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

7	41.0	38.5	47.6	41.6	48.3	48.0	43.0	37.5	27.7	30.7	1
7	27.7	24.0	30.4	26.1	33.8	19.0	20.7	29.0	38.9	43.9	2
7	45.7	40.2	51.4	56.3	35.9	34.6	24.5	33.1	34.7	32.4	3
7	25.7	22.4	37.1	32.4	41.2	38.3	53.3	61.1	53.0	43.4	4
7	37.8	33.8	33.5	24.2	29.1	42.2	37.0	27.2	26.4	25.8	5
7	23.4	27.1	27.6	33.4	38.7	48.7	51.6	59.2	57.6	61.1	6
7	61.7	53.2	60.8	60.9	59.2	58.6	52.2	56.6	51.7	51.8	7
7	53.3	63.2	50.6	56.2	37.9	47.0	41.4	28.0	38.8	32.2	8
7	34.3	43.4	40.0	49.3	47.7	42.3	40.7	44.5	40.8	34.3	9
7	53.7	61.6	55.0	55.6	60.2	60.6	47.4	45.0	43.6	53.1	10
7	49.5	52.6	42.8	56.8	67.4	71.7	79.7	67.1	60.0	58.5	11
7	54.7	64.0	58.0	48.1	56.3	59.0	65.8	67.8	66.7	62.2	12
7	66.6	62.6	68.1	67.7	65.2	60.6	66.6	68.2	63.4	59.1	13
7	63.1	68.5	66.9	65.4	56.5	63.8	56.3	63.2	71.6	74.8	14
7	66.3	67.9	65.1	64.8	62.0	57.0	64.9	63.4	72.7	81.5	15
7	78.5	79.0	74.4	75.9	73.5	68.0	70.6	71.4	77.8	82.0	16
7	75.5	81.6	74.3	76.9	70.5	75.3	74.3	77.8	81.0	76.8	17
7	77.0	79.9	76.0	80.1	76.6	78.6	85.0	81.5	82.4	86.2	18
7	78.2	84.8	83.8	83.1	82.2	79.0	79.0	82.0	83.2	82.3	19
7	87.1	87.4	86.5	88.4	89.0	83.1	83.8	80.8	79.9	84.0	20
7	83.5	80.0	83.4	80.7	82.5	79.9	80.7	82.4	79.8	80.2	21
7	81.8	86.2	88.8	83.7	85.5	81.6	84.5	82.0	81.8	85.4	22
7	79.5	81.2	81.2	86.0	76.8	79.4	80.0	75.7	80.9	77.8	23
7	84.5	86.4	82.6	87.1	82.8	81.8	79.3	82.7	81.7	86.2	24
7	89.1	86.2	81.0	80.1	81.3	78.5	70.9	72.6	74.9	69.5	25
7	68.9	78.7	73.7	68.1	70.2	69.8	69.3	64.3	71.4	72.4	26
7	77.5	71.4	70.6	66.6	68.4	80.0	74.7	69.5	66.1	62.9	27
7	63.5	67.9	62.6	62.2	64.0	66.5	65.2	65.8	64.1	65.8	28
7	62.7	66.2	63.2	64.7	56.3	70.0	53.8	51.6	52.7	51.5	29
7	51.2	66.1	61.4	61.1	60.8	42.6	56.2	63.5	52.6	44.6	30
7	37.1	32.7	36.2	35.1	37.4	37.2	39.6	43.4	40.1	43.0	31
7	36.4	42.2	41.6	43.9	37.6	46.0	58.6	54.5	58.8	54.7	32
7	44.9	40.1	43.1	43.4	49.3	50.8	47.5	60.9	54.0	57.3	33
7	49.4	43.0	47.4	56.6	59.4	56.6	57.7	49.5	36.2	29.5	34
7	25.3	32.1	29.1	19.7	23.0	25.7	35.1	31.1	39.7	41.7	35
7	33.7	36.3	40.1	52.2	39.3	37.9	37.8	38.8	39.3	46.9	36
7	45.1	32.3	27.3	26.4	39.4	28.9	0.0	0.0	0.0	0.0	37
8	40.1	32.3	42.3	40.5	41.4	46.8	48.5	52.6	52.1	44.1	1
8	35.8	37.9	47.2	46.6	46.6	42.7	35.2	25.3	31.2	36.4	2
8	38.4	46.2	45.7	42.5	36.9	35.4	40.8	45.7	53.1	51.8	3
8	64.8	48.9	47.4	35.9	32.5	40.9	44.6	22.3	38.9	41.5	4
8	38.7	34.5	20.5	30.1	43.1	54.0	48.5	50.0	49.8	52.0	5
8	46.1	47.9	47.0	43.5	40.9	45.4	50.7	47.0	57.1	48.1	6
8	42.1	45.9	46.6	45.4	36.0	39.2	42.4	54.4	41.2	42.9	7
8	45.0	56.8	46.8	37.2	27.9	45.0	53.8	59.1	64.0	60.0	8
8	64.3	60.5	49.9	38.5	41.9	38.5	38.6	45.2	55.3	53.1	9
8	58.6	56.6	59.2	40.0	49.2	42.3	52.5	61.5	46.3	52.5	10
8	57.5	56.8	59.1	71.0	70.8	65.7	67.5	57.4	62.1	68.1	11
8	71.5	65.1	65.0	52.6	56.9	56.2	60.1	59.2	68.9	71.0	12
8	69.0	64.0	63.6	67.4	60.3	73.1	74.4	77.5	81.5	73.8	13
8	79.1	76.3	67.0	57.4	59.0	65.4	64.7	73.7	72.7	66.0	14
8	65.2	56.7	57.0	62.8	60.1	64.3	69.5	59.9	59.9	70.1	15
8	73.3	71.1	71.1	76.9	73.0	73.8	72.7	76.3	78.4	79.5	16
8	77.4	76.1	72.6	75.6	70.3	71.0	73.8	81.1	85.6	86.1	17
8	83.6	81.7	82.5	78.0	83.5	84.7	82.9	82.6	82.9	79.1	18
8	74.4	76.7	84.0	82.7	81.5	83.3	88.2	84.7	84.9	84.9	19
8	86.2	86.4	84.2	83.8	81.1	81.3	81.4	79.4	81.7	84.5	20
8	86.3	84.9	81.4	80.2	84.4	83.5	83.0	82.4	84.7	84.4	21
8	84.8	85.8	85.8	84.6	86.6	81.0	80.9	75.4	80.4	81.6	22
8	81.9	78.5	78.6	78.3	76.1	78.7	78.3	80.7	83.4	80.5	23
8	85.2	88.5	89.0	90.9	86.5	85.6	79.9	83.5	81.4	78.8	24
8	74.9	75.3	72.5	73.7	74.9	69.9	73.1	75.7	72.0	71.8	25
8	74.3	77.1	81.6	76.4	79.7	74.6	63.5	66.1	69.7	63.4	26
8	64.1	65.0	66.0	60.9	67.1	72.0	68.2	65.2	62.0	65.8	27
8	66.3	64.9	57.1	51.4	47.0	53.7	60.3	57.3	53.6	56.4	28
8	75.8	71.3	67.9	64.5	64.2	65.1	66.0	63.8	68.0	72.2	29
8	71.7	74.0	87.5	83.3	78.6	85.2	68.8	60.1	66.2	50.1	30
8	45.2	49.5	36.1	46.8	48.6	48.3	39.9	29.6	47.9	43.0	31
8	49.9	58.5	49.9	45.2	58.0	44.1	51.2	54.5	60.7	60.4	32
8	50.0	38.7	39.0	45.1	43.8	53.2	57.9	48.0	44.7	50.3	33
8	44.3	35.3	41.3	42.8	43.0	21.1	16.6	33.5	29.8	36.1	34
8	40.9	45.2	44.4	34.7	27.5	22.4	34.1	23.4	28.4	34.0	35
8	19.1	13.2	15.1	3.9	9.4	31.5	21.1	24.1	25.0	24.1	36
8	32.2	37.9	39.3	34.4	40.6	41.8	0.0	0.0	0.0	0.0	37
9	52.9	43.3	31.9	45.2	33.0	35.7	40.4	43.4	37.9	44.7	1
9	26.7	25.2	33.3	26.8	29.6	32.6	32.9	29.7	36.2	36.5	2
9	42.9	42.9	43.6	41.9	48.9	44.3	44.2	34.3	30.7	28.9	3
9	25.9	22.1	27.8	30.9	35.4	35.0	41.5	40.5	35.2	36.8	4
9	30.2	35.3	45.7	43.3	35.8	40.5	49.9	38.1	32.7	23.4	5
9	31.2	37.6	47.5	42.9	42.6	29.5	27.1	22.6	26.4	17.8	6
9	24.0	41.6	40.3	34.5	28.4	34.9	35.4	48.1	48.9	40.6	7
9	42.2	33.1	46.7	47.7	41.9	48.3	49.4	47.5	49.2	55.6	8
9	56.6	44.6	42.4	54.1	56.7	57.0	50.1	61.3	54.0	59.8	9
9	52.2	41.4	44.9	54.3	51.9	54.6	59.1	51.0	54.5	64.5	10
9	71.6	76.7	66.9	68.5	60.8	69.8	62.7	59.9	64.2	61.3	11
9	67.2	59.6	57.7	52.3	53.7	56.0	69.4	60.7	59.3	60.2	12
9	62.0	61.9	59.5	64.9	68.5	69.8	63.0	65.0	68.9	63.2	13
9	68.8	59.3	58.7	64.6	64.7	67.5	66.0	68.2	66.6	62.6	14
9	66.5	68.0	74.7	74.0	74.8	67.7	72.6	70.6	71.6	74.2	15
9	79.6	80.0	86.9	80.9	82.5	82.5	83.2	87.5	79.0	81.3	16
9	77.5	71.0	66.9	73.3	79.5	79.1	82.8	77.2	83.3	80.7	17
9	78.3	74.4	76.6	76.3	78.6	76.1	75.8	80.3	79.3	78.3	18
9	82.0	85.9	89.9	91.7	86.4	85.4	81.9	85.7	83.0	85.0	19
9	83.8	80.5	80.1	82.3	89.2	87.1	85.4	83.2	83.4	83.4	20
9	75.9	81.5	82.7	85.7	83.5	85.1	85.7	81.4	82.8	81.7	21
9	80.2	83.1	87.6	86.4	85.1	82.8	84.5	81.0	74.0	76.3	22
9	79.8	79.1	75.3	80.0	74.7	77.9	78.3	73.7	73.5	71.5	23
9	77.8	81.0	87.0	90.3	82.8	84.6	81.5	81.2	86.1	76.9	24
9	72.9	80.6	78.0	81.5	90.0	90.0	86.7	85.3	80.4	75.6	25
9	76.7	69.7	66.6	70.8	75.5	69.2	69.4	82.7	78.7	71.1	26
9	72.7	67.6	61.7	62.5	67.3	72.3	65.8	63.6	63.6	64.5	27
9	64.2	73.7	65.7	67.5	57.7	53.5	67.9	55.6	47.1	47.2	28
9	48.7	61.3	70.4	65.1	65.9	60.6	61.4	71.6	68.4	71.3	29
9	62.6	60.2	67.7	62.2	59.5	65.0	59.7	64.6	59.4	64.6	30
9	53.7	59.4	58.9	63.1	66.1	48.4	50.1	49.9	40.0	36.9	31
9	45.0	52.7	51.1	45.0	43.7	37.0	43.5	42.8	46.6	60.3	32
9	51.1	49.0	46.8	42.9	50.9	53.1	48.3	54.7	67.6	55.5	33
9	45.3	34.7	26.7	28.6	40.0	31.4	24.2	33.1	29.6	34.5	34
9	24.7	28.8	27.1	31.3	27.9	33.1	47.3	33.3	31.4	26.3	35
9	39.3	31.7	28.5	35.7	47.3	37.7	32.5	31.5	17.2	17.8	36
9	6.9	8.1	8.0	19.1	32.5	41.8	0.0	0.0	0.0	0.0	37
10	36.0	26.1	22.6	28.6	21.7	29.3	41.7	54.9	44.5	45.3	1
10	58.4	47.0	44.9	29.6	26.1	30.9	43.3	48.3	32.9	12.4	2
10	30.7	33.4	40.0	35.5	36.2	49.7	52.1	64.1	50.7	44.4	3

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

10	39.2	43.9	54.0	46.7	36.5	39.0	50.6	35.3	32.8	28.1	4
10	39.3	28.3	35.1	41.0	32.7	31.4	34.2	40.1	50.0	42.3	5
10	31.8	29.1	35.6	32.3	47.3	45.8	53.5	58.0	42.4	40.2	6
10	41.3	44.6	36.1	47.9	48.1	55.8	52.1	49.9	50.2	50.0	7
10	51.6	57.2	55.7	62.6	53.7	49.5	66.0	54.5	63.3	60.6	8
10	53.7	55.6	61.8	47.9	48.0	51.0	51.3	46.9	39.4	49.9	9
10	57.3	45.6	47.6	40.1	44.1	40.2	49.0	53.9	57.6	49.9	10
10	46.1	55.0	60.6	51.4	60.1	61.2	59.2	61.0	65.7	68.5	11
10	70.0	71.4	75.0	67.6	59.4	58.2	58.2	50.5	55.2	58.6	12
10	59.8	66.1	59.4	62.4	67.9	61.0	65.9	75.8	66.3	65.3	13
10	69.7	63.7	63.2	68.3	61.2	66.1	69.9	72.8	69.5	71.5	14
10	64.9	62.1	62.7	73.7	69.2	72.5	72.5	65.0	72.3	75.0	15
10	69.6	73.8	69.9	76.2	76.1	80.4	79.7	74.8	79.4	81.3	16
10	80.9	77.9	80.3	79.1	80.4	81.5	78.8	81.3	83.6	81.4	17
10	82.7	84.9	83.7	83.6	75.9	82.0	83.9	84.8	82.6	80.3	18
10	80.1	83.6	85.1	82.2	72.4	83.2	80.3	79.2	79.9	78.5	19
10	79.8	80.0	81.3	82.5	83.7	80.3	82.6	80.8	80.6	80.7	20
10	79.7	77.5	81.8	80.9	81.4	79.7	82.0	81.8	79.6	84.3	21
10	86.3	86.1	86.3	88.0	82.7	80.0	82.2	76.8	76.7	79.3	22
10	76.3	76.2	73.6	78.8	81.1	77.4	77.0	79.1	78.2	77.6	23
10	81.3	84.6	85.0	78.4	77.7	83.9	85.9	84.9	81.9	80.6	24
10	84.0	83.4	79.0	82.0	80.6	73.7	70.0	68.7	67.9	71.2	25
10	67.4	75.9	77.8	80.4	83.7	80.5	75.4	85.9	80.7	74.1	26
10	79.5	76.9	72.5	68.3	76.0	67.2	62.7	63.8	65.8	80.4	27
10	81.4	67.8	52.5	52.0	56.0	68.7	70.3	70.6	65.4	70.1	28
10	70.6	58.5	59.3	61.5	54.7	59.6	65.0	62.6	71.1	74.8	29
10	64.0	51.3	55.2	55.1	49.6	45.3	54.6	59.8	56.5	44.5	30
10	37.7	43.6	50.2	52.8	53.5	46.2	42.3	48.1	56.5	55.0	31
10	53.9	47.8	38.6	35.1	44.8	40.4	35.0	28.7	37.5	38.3	32
10	52.7	43.0	36.2	44.1	42.4	43.6	46.0	55.1	57.5	35.1	33
10	36.8	43.5	47.0	46.2	39.8	37.7	37.2	27.8	26.4	38.7	34
10	32.6	29.6	28.2	27.8	32.7	19.5	30.8	33.7	41.6	31.0	35
10	37.1	34.2	29.4	34.7	28.6	19.5	24.8	27.7	20.4	24.3	36
10	16.9	21.5	24.8	35.1	42.3	41.8	0.0	0.0	0.0	0.0	37
11	28.4	34.4	44.7	43.0	33.5	50.0	41.5	37.6	37.4	28.1	1
11	38.3	43.4	36.0	38.6	22.3	22.1	27.6	26.5	20.4	25.2	2
11	43.0	41.9	52.3	52.9	52.4	50.7	36.9	38.9	37.6	36.5	3
11	41.4	29.6	37.8	42.5	52.3	48.0	36.5	28.7	33.5	31.9	4
11	33.1	27.4	21.3	38.0	39.4	33.3	28.4	30.5	33.9	39.9	5
11	41.0	40.1	39.3	39.7	39.3	40.1	49.3	45.6	47.4	48.7	6
11	58.8	46.6	49.4	57.9	44.0	54.7	47.1	41.1	38.0	49.7	7
11	49.7	52.6	52.4	47.5	58.2	56.4	49.3	52.3	48.4	48.0	8
11	46.8	54.7	56.3	59.4	55.2	51.1	50.4	54.4	43.8	37.0	9
11	41.7	36.5	51.8	35.2	48.9	52.0	64.7	62.9	53.9	41.0	10
11	44.6	46.3	60.8	66.2	73.0	62.6	59.4	59.6	65.0	72.6	11
11	64.9	71.0	70.6	65.2	60.4	64.5	69.5	73.7	75.1	71.9	12
11	75.3	68.9	65.0	63.2	62.8	64.3	60.2	61.5	67.3	70.1	13
11	65.8	58.6	61.5	61.8	58.4	59.5	69.2	64.5	68.6	69.8	14
11	73.6	79.5	75.2	74.5	77.6	76.6	79.0	74.7	68.5	68.0	15
11	79.0	81.5	81.3	84.9	81.0	79.8	77.4	70.9	75.0	71.5	16
11	71.8	81.5	82.2	80.4	80.5	84.9	78.4	78.6	75.5	81.6	17
11	84.1	79.5	74.7	80.9	79.1	82.4	78.8	78.0	79.8	79.7	18
11	80.5	81.9	79.2	80.0	81.4	77.6	82.0	81.6	85.4	86.2	19
11	85.8	88.7	88.2	83.1	86.4	81.8	81.6	82.9	82.3	82.3	20
11	82.1	80.1	79.9	79.0	81.0	79.3	81.6	81.2	77.4	81.6	21
11	78.3	76.4	82.5	83.3	84.4	86.6	82.4	83.5	84.6	84.4	22
11	85.2	86.0	83.7	89.1	84.8	85.6	84.7	82.4	83.3	79.4	23
11	84.4	85.0	79.9	83.2	80.2	78.2	76.1	75.8	77.5	72.9	24
11	69.9	72.8	73.1	69.1	74.5	70.1	71.6	72.6	63.5	66.1	25
11	70.6	71.3	76.0	74.3	78.6	80.9	70.4	69.6	63.9	64.7	26
11	68.6	67.7	68.9	64.9	68.8	64.7	62.7	76.0	69.6	65.6	27
11	64.8	56.3	61.9	57.3	61.4	49.3	53.6	44.5	47.0	53.1	28
11	50.2	58.8	53.5	49.2	57.4	54.3	59.9	56.9	60.8	59.2	29
11	50.6	51.8	53.1	58.7	53.2	51.9	60.5	65.3	70.2	70.0	30
11	53.9	49.4	44.4	46.4	48.7	59.2	54.5	62.7	65.7	66.9	31
11	42.5	58.9	51.5	55.4	51.9	59.7	58.9	46.6	47.8	48.9	32
11	45.3	49.8	53.8	50.8	53.0	45.9	53.9	48.2	52.3	43.6	33
11	56.8	43.4	39.7	39.7	33.7	24.6	21.0	26.6	27.6	46.9	34
11	49.7	50.5	47.7	35.3	32.3	37.8	34.4	38.6	33.7	31.1	35
11	34.8	28.3	18.6	24.2	36.8	37.2	28.9	25.5	30.7	29.3	36
11	30.0	27.0	24.4	23.4	29.7	41.8	0.0	0.0	0.0	0.0	37
12	28.2	20.6	17.5	25.0	22.5	45.7	54.3	38.4	32.5	26.0	1
12	26.6	31.6	23.9	35.7	36.9	37.5	27.4	24.3	16.6	20.9	2
12	26.9	27.9	23.6	26.4	34.8	33.0	15.0	18.0	27.7	27.5	3
12	31.5	37.2	23.5	24.3	25.3	34.9	38.2	31.9	15.6	22.9	4
12	23.6	15.1	29.1	22.1	35.5	23.7	19.6	21.2	29.9	34.0	5
12	33.1	35.2	45.9	53.3	49.3	42.4	41.4	50.5	54.3	41.1	6
12	48.7	45.6	36.8	37.9	37.6	39.7	43.2	44.6	48.9	45.5	7
12	46.1	44.2	46.9	44.1	51.2	49.0	53.0	43.5	38.6	50.5	8
12	55.8	49.6	35.2	37.3	47.0	46.2	46.1	50.9	61.9	66.1	9
12	53.1	53.6	68.5	64.5	54.5	48.9	56.0	62.5	59.4	52.7	10
12	47.1	47.2	57.5	56.4	58.5	56.7	64.5	68.9	58.9	53.1	11
12	62.1	53.7	49.8	49.5	50.3	54.3	65.8	69.1	79.7	76.4	12
12	85.1	73.5	63.7	64.4	68.4	59.4	62.9	68.9	63.9	66.3	13
12	68.1	63.8	67.6	74.4	65.5	67.6	58.8	68.2	67.8	69.7	14
12	73.8	73.7	65.1	63.2	68.7	65.2	63.0	66.4	69.9	71.0	15
12	62.3	66.2	72.3	67.7	71.2	77.0	75.2	75.2	77.2	73.7	16
12	74.1	78.8	78.7	78.2	76.0	71.1	77.0	76.9	81.0	81.5	17
12	86.8	86.2	85.6	85.4	76.3	81.6	85.6	83.7	84.8	86.6	18
12	87.1	92.0	92.3	92.2	87.6	84.3	85.1	85.6	85.6	79.9	19
12	82.2	82.8	84.8	83.3	85.4	85.5	83.2	84.3	82.2	85.0	20
12	84.7	80.2	83.5	83.5	81.9	81.6	85.0	80.6	83.0	82.6	21
12	80.8	83.1	86.7	89.9	87.4	84.5	90.0	86.9	81.7	85.1	22
12	81.3	81.2	82.9	83.5	86.3	81.9	86.4	86.3	87.5	84.3	23
12	78.0	76.4	75.0	77.5	79.2	80.6	81.5	79.1	76.3	71.2	24
12	74.9	71.9	64.0	72.3	71.0	69.6	75.5	75.7	75.5	76.2	25
12	74.7	72.7	69.9	71.6	70.6	79.6	76.6	77.2	68.8	65.0	26
12	71.7	69.0	65.7	58.3	63.2	59.8	64.6	63.0	62.1	65.3	27
12	65.5	68.1	65.8	57.1	55.0	51.8	48.7	42.0	47.2	48.4	28
12	42.3	54.0	48.9	43.1	39.9	48.6	46.8	45.7	45.8	50.3	29
12	60.9	65.2	51.3	61.9	53.9	55.1	65.9	52.3	46.4	40.9	30
12	41.8	40.1	46.9	50.2	45.8	45.7	53.4	56.2	52.1	56.4	31
12	68.6	73.5	74.9	66.7	58.9	62.3	65.0	59.5	55.1	62.2	32
12	42.9	49.1	47.2	43.0	53.1	49.5	55.2	52.3	48.0	46.9	33
12	43.1	41.9	36.6	58.2	53.9	49.1	38.7	34.1	31.9	40.1	34
12	29.4	44.9	49.2	42.1	39.0	45.0	37.8	38.7	43.6	29.4	35
12	31.3	33.9	26.4	46.7	54.2	36.1	39.4	37.0	29.7	23.7	36
12	28.5	32.3	23.4	21.6	27.9	25.0	0.0	0.0	0.0	0.0	37
13	32.1	41.2	37.9	40.6	38.3	42.0	34.9	37.6	35.4	38.9	1
13	40.3	37.4	47.3	52.6	43.2	33.5	42.4	36.1	34.5	25.7	2
13	23.0	14.8	30.8	28.4	34.8	33.9	43.5	26.7	18.7	27.8	3
13	36.8	36.0	26.0	36.6	33.4	24.0	23.7	26.7	22.8	21.1	4
13	28.6	23.7	27.9	35.7	34.2	47.7	44.9	40.8	35.6	34.8	5
13	26.0	25.5	26.7	27.5	34.0	43.2	44.1	41.7	41.3	54.8	6

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

13	59.1	54.9	48.6	42.7	33.1	52.3	49.1	45.1	43.6	36.3	7
13	46.9	52.6	51.7	46.8	52.2	64.5	68.9	77.5	68.8	57.5	8
13	46.3	44.9	49.9	52.1	57.0	56.4	61.1	62.9	65.7	54.6	9
13	54.6	61.9	65.8	57.1	52.7	50.1	44.5	51.6	50.0	52.3	10
13	45.8	62.0	72.6	75.4	73.4	63.8	62.5	62.9	53.7	62.0	11
13	55.5	55.4	64.4	70.3	78.2	78.7	65.2	56.5	63.0	58.2	12
13	68.2	66.7	63.6	59.1	63.7	61.7	57.8	55.4	54.7	58.4	13
13	65.0	61.3	62.9	65.2	69.8	68.8	79.6	79.7	77.3	77.0	14
13	78.2	73.4	75.5	72.5	74.2	75.8	70.1	68.9	67.1	74.3	15
13	70.4	71.6	76.2	77.5	76.9	76.0	73.2	74.1	80.3	82.1	16
13	78.4	76.4	78.3	78.2	72.6	79.5	82.9	78.0	75.0	73.2	17
13	69.2	69.8	77.3	72.1	75.9	71.3	75.5	80.1	83.2	82.6	18
13	79.7	83.6	87.2	86.6	84.1	80.2	83.6	78.4	86.6	81.8	19
13	79.2	86.5	88.4	88.9	87.4	81.4	84.0	84.7	84.9	86.2	20
13	82.6	79.3	83.7	84.1	80.7	84.8	84.9	85.6	85.2	83.3	21
13	83.1	82.5	83.0	83.1	79.1	79.1	77.8	79.9	81.2	84.8	22
13	84.2	81.7	81.3	85.4	86.7	86.8	88.2	85.9	90.0	87.2	23
13	79.4	70.7	75.0	75.5	78.1	77.6	72.7	77.6	76.5	77.9	24
13	78.2	78.1	73.3	73.1	70.5	70.6	74.7	73.6	77.3	80.0	25
13	76.4	76.1	74.9	75.1	77.1	79.6	73.6	76.4	80.2	85.7	26
13	78.2	71.6	76.4	75.9	83.0	78.0	70.8	78.9	78.3	75.3	27
13	70.7	63.8	67.9	68.7	66.2	65.6	65.1	70.9	68.6	70.8	28
13	69.9	62.2	61.7	62.9	61.1	57.1	66.3	61.3	61.3	53.2	29
13	40.4	41.1	52.6	50.0	54.6	52.2	52.0	61.2	52.6	52.9	30
13	60.3	63.7	57.0	61.4	51.2	52.7	54.9	56.4	54.3	55.7	31
13	46.9	43.9	45.2	45.7	47.9	52.4	64.9	63.1	41.5	40.9	32
13	39.9	36.4	39.8	41.5	49.9	43.4	43.7	29.1	28.0	28.4	33
13	23.5	15.3	22.9	35.6	50.0	49.6	44.0	46.6	49.5	55.9	34
13	38.5	50.1	52.9	42.1	33.2	41.3	40.9	27.3	25.8	29.6	35
13	25.0	33.7	29.1	27.2	28.9	22.7	32.1	28.7	23.3	27.8	36
13	37.4	34.4	43.5	44.8	38.5	25.0	0.0	0.0	0.0	0.0	37
14	43.2	39.0	39.1	35.0	31.3	29.9	32.7	29.2	24.9	38.5	1
14	29.9	30.3	26.2	30.4	24.5	28.0	36.1	32.2	27.6	24.9	2
14	22.7	22.9	22.5	17.2	33.4	24.0	23.8	19.7	17.2	19.9	3
14	32.6	42.9	32.9	32.7	33.6	39.7	41.4	35.1	47.1	58.8	4
14	60.8	69.0	52.5	39.8	42.1	42.3	32.4	36.4	41.8	31.2	5
14	31.9	29.7	33.3	52.1	51.2	41.0	44.2	44.7	42.8	42.0	6
14	35.7	45.6	44.0	37.2	48.6	51.3	63.0	47.5	50.3	43.6	7
14	48.3	55.8	60.3	55.5	48.6	43.0	42.9	52.4	54.1	59.4	8
14	56.2	48.2	34.8	35.8	51.0	50.7	35.3	48.3	37.8	46.4	9
14	54.5	44.4	49.8	60.0	56.5	65.0	58.6	57.7	44.7	48.2	10
14	65.5	70.8	76.2	71.8	65.4	58.8	66.0	65.2	74.2	64.8	11
14	62.5	68.3	69.0	64.7	54.7	53.3	65.7	61.4	63.1	67.7	12
14	66.5	59.1	65.8	69.1	74.6	67.5	61.7	65.5	63.5	57.9	13
14	60.1	51.5	62.8	61.7	56.9	62.1	61.4	69.6	74.2	75.9	14
14	85.9	77.0	73.2	73.0	68.9	73.6	72.3	75.7	67.6	73.3	15
14	75.7	66.7	76.6	77.5	75.7	78.3	81.9	83.3	86.7	78.2	16
14	75.0	72.1	73.8	73.8	75.6	76.3	75.3	70.6	64.7	66.3	17
14	66.5	63.5	69.2	70.3	70.7	69.9	73.1	76.8	74.9	80.0	18
14	79.3	79.2	83.2	77.5	78.4	85.4	80.1	81.6	81.8	81.4	19
14	77.0	82.2	85.1	87.8	85.5	84.8	85.3	84.2	85.6	85.1	20
14	85.8	83.0	86.0	86.3	85.8	82.7	78.2	72.0	75.5	75.5	21
14	76.9	79.2	82.8	85.2	84.7	86.1	86.0	87.2	90.2	84.2	22
14	82.7	82.1	82.3	83.5	79.2	79.6	79.5	76.0	78.0	80.2	23
14	81.8	79.8	79.6	83.5	79.4	74.7	82.6	85.2	79.3	80.0	24
14	79.0	73.0	74.7	69.9	79.7	80.5	78.2	77.0	79.3	73.6	25
14	77.3	71.1	69.4	67.2	61.1	62.6	67.8	64.9	70.5	78.1	26
14	73.7	71.5	63.8	60.2	68.8	83.3	81.0	75.1	74.2	66.0	27
14	67.6	69.8	66.3	63.7	68.8	64.6	58.7	67.7	62.3	54.8	28
14	51.5	50.3	46.0	47.8	54.8	59.4	65.1	60.3	68.3	73.4	29
14	63.9	63.0	58.5	49.4	45.3	49.0	58.1	62.8	57.3	56.2	30
14	56.2	53.8	44.2	48.4	51.8	47.7	44.6	44.3	38.2	31.0	31
14	45.5	53.3	43.2	48.3	42.1	35.5	39.4	38.6	45.7	36.6	32
14	30.4	28.5	35.5	36.6	22.6	20.8	31.3	50.6	54.1	52.0	33
14	50.8	46.2	61.2	60.6	59.2	43.1	38.4	38.8	37.5	45.6	34
14	44.1	45.8	44.9	39.1	40.9	47.4	39.5	37.0	35.4	33.5	35
14	31.0	35.7	24.4	26.3	28.9	27.6	26.5	34.1	36.0	39.7	36
14	40.3	36.3	26.9	17.8	21.5	25.0	0.0	0.0	0.0	0.0	37
15	28.9	25.4	35.1	34.4	39.2	30.3	44.9	35.0	26.7	26.6	1
15	19.2	22.6	16.1	21.5	25.0	26.3	26.2	36.8	40.8	34.1	2
15	44.3	34.5	33.8	32.1	41.2	45.4	35.2	43.5	33.1	34.7	3
15	44.2	47.0	37.3	35.0	33.0	33.7	37.9	26.9	27.4	33.2	4
15	36.3	34.5	26.5	26.9	27.7	38.4	31.7	38.2	25.1	27.9	5
15	47.4	39.8	45.2	51.9	41.4	28.5	42.6	40.3	38.2	52.3	6
15	45.2	54.3	47.8	42.0	36.7	37.8	31.2	45.1	41.0	38.5	7
15	31.8	40.3	52.6	48.5	49.6	56.0	53.1	42.4	41.6	49.3	8
15	49.1	54.0	58.7	64.5	61.0	59.6	63.0	69.0	68.6	64.1	9
15	62.6	63.6	62.5	61.7	59.8	54.9	69.8	59.9	62.9	60.2	10
15	54.3	59.8	61.6	62.3	64.5	69.1	64.2	66.0	54.3	58.2	11
15	61.8	57.9	57.4	58.8	50.2	51.8	54.8	66.1	67.1	61.1	12
15	63.1	69.9	64.9	80.9	82.4	69.8	66.8	77.0	69.8	64.7	13
15	72.0	69.7	74.8	76.1	73.0	65.1	69.2	67.8	71.5	61.7	14
15	68.3	67.9	80.1	74.8	65.3	65.7	78.6	77.8	70.0	67.3	15
15	71.6	76.7	78.2	81.0	75.2	82.5	80.1	77.6	74.3	78.6	16
15	78.4	79.6	79.0	80.5	80.1	82.6	81.4	77.6	83.5	79.6	17
15	80.2	79.1	82.2	80.4	79.1	76.2	79.5	81.2	81.9	76.7	18
15	82.0	83.7	83.8	85.6	84.7	83.1	78.2	84.8	87.9	88.1	19
15	85.1	82.4	82.7	80.6	81.9	80.7	86.4	84.8	90.2	90.8	20
15	89.1	87.8	83.8	87.8	88.9	86.2	84.1	77.7	85.9	82.8	21
15	84.2	87.3	87.5	85.8	90.1	91.4	93.4	92.2	87.8	84.8	22
15	87.9	85.6	86.6	83.2	79.4	80.2	78.5	82.9	83.8	80.3	23
15	75.6	79.9	87.8	83.5	84.0	78.7	72.0	79.7	85.1	80.6	24
15	78.4	74.4	75.5	78.1	75.1	74.2	78.6	72.9	70.8	76.7	25
15	80.3	78.3	84.6	88.0	82.6	76.8	73.6	71.8	75.6	69.1	26
15	73.1	64.3	66.0	62.2	67.8	67.5	73.1	81.8	74.5	63.3	27
15	61.1	53.4	56.0	69.7	72.9	70.7	67.1	75.9	73.9	65.1	28
15	61.6	61.8	57.3	63.2	54.4	57.6	59.6	50.8	49.3	46.5	29
15	40.7	38.0	52.8	52.0	46.3	45.6	49.4	41.5	44.1	54.1	30
15	57.3	60.4	71.3	61.9	47.2	42.5	52.2	62.4	54.6	39.0	31
15	57.2	54.2	54.2	41.9	45.3	59.0	57.4	61.0	51.4	37.0	32
15	25.7	33.4	33.5	45.4	52.7	49.4	46.4	46.7	52.6	54.6	33
15	43.5	43.8	43.5	46.8	37.8	46.4	32.3	41.9	45.4	32.5	34
15	38.1	24.8	20.7	35.0	32.0	43.4	36.1	44.9	50.1	44.3	35
15	36.0	25.1	32.1	43.9	42.3	45.8	36.3	26.8	29.3	28.6	36
15	22.4	28.1	32.3	41.7	41.6	25.0	0.0	0.0	0.0	0.0	37
16	39.7	38.8	35.6	39.0	42.3	32.0	26.5	35.7	39.3	36.8	1
16	42.5	37.0	41.0	40.1	30.0	45.5	38.3	40.3	43.0	47.6	2
16	40.8	42.2	31.4	14.2	13.6	24.8	21.2	27.5	44.7	34.8	3
16	30.9	27.8	44.7	45.9	49.2	41.9	22.7	29.0	26.9	22.7	4
16	35.5	29.6	35.5	21.6	20.2	25.4	32.0	31.1	38.1	48.0	5
16	51.4	36.9	34.8	32.2	31.5	42.0	47.9	35.9	43.3	49.7	6
16	45.7	57.5	53.6	52.5	59.2	47.1	52.2	43.2	47.9	47.6	7
16	56.2	61.5	46.9	41.8	40.5	36.9	41.4	39.8	48.6	48.2	8
16	61.3	49.5	51.9	67.8	54.5	59.5	45.7	43.5	43.0	50.9	9

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

16 45.9 52.7 63.1 80.3 65.5 68.5 57.1 57.8 63.8 73.3 10
16 65.5 69.2 56.6 52.9 50.3 56.3 45.4 48.7 54.2 59.1 11
16 65.4 68.8 72.2 64.1 78.5 77.1 63.6 60.6 58.9 63.0 12
16 60.8 65.2 60.6 57.8 61.7 74.1 62.7 67.8 66.1 57.4 13
16 64.5 63.7 68.6 72.0 65.7 73.9 71.4 64.7 64.7 63.8 14
16 69.3 68.8 68.9 71.9 63.2 64.8 67.4 76.6 79.0 77.4 15
16 74.4 69.4 76.2 77.6 74.8 74.3 76.8 84.3 79.2 83.1 16
16 80.5 84.8 78.4 84.1 80.7 76.7 69.2 76.6 75.1 77.8 17
16 78.4 76.4 72.2 75.1 69.0 74.8 78.4 78.8 78.8 79.0 18
16 80.9 84.6 88.5 86.8 87.5 83.7 81.6 79.5 86.6 84.3 19
16 79.6 80.0 79.9 79.9 82.6 83.9 81.9 86.1 86.0 87.7 20
16 86.3 85.0 84.2 81.4 81.0 84.3 84.5 81.8 79.7 86.3 21
16 86.9 86.0 82.2 79.7 83.6 83.4 83.3 77.3 78.0 77.3 22
16 77.5 77.9 72.9 74.3 76.8 76.3 73.7 80.3 79.0 73.4 23
16 76.1 73.6 75.8 78.9 79.7 79.2 82.4 79.6 87.7 81.4 24
16 71.2 70.8 75.6 75.6 74.6 72.3 72.8 74.4 74.2 76.5 25
16 75.0 77.4 67.9 70.0 70.5 72.5 71.2 71.5 77.9 77.0 26
16 66.8 63.4 68.3 72.6 63.1 67.5 71.2 67.8 78.3 75.4 27
16 67.8 75.9 66.1 56.7 55.1 55.9 57.9 59.9 57.9 45.2 28
16 50.9 53.6 61.8 70.4 62.0 52.9 51.2 56.8 53.2 59.9 29
16 58.9 45.9 56.8 67.8 64.0 56.7 62.9 62.5 47.0 58.8 30
16 71.4 64.6 62.5 50.7 44.0 54.1 48.6 41.0 35.9 36.8 31
16 30.0 35.3 35.1 42.9 41.9 39.4 45.6 61.3 61.4 68.1 32
16 73.3 75.2 64.9 51.2 43.8 46.9 31.6 35.4 34.5 33.9 33
16 30.4 34.3 37.0 52.2 47.5 55.9 44.8 40.0 52.4 51.6 34
16 59.9 53.8 51.8 28.9 28.9 24.7 28.6 26.2 35.5 41.5 35
16 36.4 23.5 31.9 26.5 28.3 21.9 26.3 23.7 32.6 31.3 36
16 33.7 42.7 55.9 37.6 26.4 33.1 0.0 0.0 0.0 0.0 37
17 41.5 46.9 36.3 43.0 40.5 29.5 29.4 41.7 53.6 47.5 1
17 36.4 24.1 34.2 28.1 35.2 31.1 22.5 24.0 27.0 34.8 2
17 31.5 26.8 35.7 21.5 23.0 20.4 35.0 21.6 28.1 38.9 3
17 31.5 30.1 28.4 42.5 31.1 37.0 47.5 43.8 49.1 41.5 4
17 53.5 47.4 39.0 44.9 44.7 32.2 40.1 35.9 33.9 36.5 5
17 25.3 34.7 35.5 23.3 25.0 42.0 48.1 45.1 37.5 38.9 6
17 38.8 34.5 41.4 41.8 53.8 53.9 51.3 61.2 55.2 42.8 7
17 47.6 53.7 48.7 43.7 47.4 51.3 57.0 56.8 56.8 52.0 8
17 63.3 59.7 62.0 69.3 75.5 73.6 73.4 64.7 65.2 59.8 9
17 57.8 62.4 66.9 62.2 64.4 48.0 67.2 52.2 51.2 56.7 10
17 61.5 52.3 47.3 56.6 50.5 55.9 62.6 53.2 54.6 50.7 11
17 52.2 51.2 61.1 61.4 61.1 72.1 59.5 55.5 74.3 68.0 12
17 63.8 62.5 71.7 62.4 55.8 57.6 52.5 60.3 61.4 62.1 13
17 68.3 65.6 70.6 75.6 73.5 75.3 75.0 75.4 76.0 71.4 14
17 64.1 71.8 65.4 65.5 66.4 65.0 72.8 78.3 82.6 79.8 15
17 78.7 86.3 84.0 74.6 76.1 83.9 77.6 78.4 71.8 68.5 16
17 72.7 67.3 64.7 63.0 66.5 74.1 81.3 83.5 83.6 82.7 17
17 85.4 87.5 85.7 83.3 82.3 78.2 76.0 78.2 75.6 78.9 18
17 83.6 84.4 89.0 86.6 85.0 85.5 79.7 75.7 83.2 81.2 19
17 80.9 79.3 81.5 82.3 83.5 80.7 84.0 84.7 85.2 86.7 20
17 84.8 82.4 83.1 82.5 79.5 82.5 79.4 77.4 77.7 78.3 21
17 82.1 82.9 83.6 82.6 83.3 87.5 88.1 84.1 88.1 83.8 22
17 85.5 87.1 87.0 84.4 83.2 79.7 83.2 80.0 82.5 81.4 23
17 73.2 73.8 78.8 77.2 79.3 82.0 84.4 83.3 79.5 80.1 24
17 77.4 78.2 81.7 79.5 79.6 76.6 78.7 83.7 82.1 86.6 25
17 82.3 73.0 79.9 77.4 79.5 74.1 74.3 72.6 67.0 64.0 26
17 63.8 66.0 60.5 63.6 67.5 65.2 73.3 74.2 63.4 73.1 27
17 71.9 75.1 67.2 64.9 68.7 66.2 66.9 71.4 70.3 65.0 28
17 68.2 76.6 67.6 72.7 69.0 66.0 55.0 64.8 68.5 64.5 29
17 74.6 73.4 72.5 56.2 60.8 65.2 56.1 41.4 61.6 44.0 30
17 36.9 47.5 56.0 48.2 51.5 46.1 46.3 62.2 69.8 57.2 31
17 56.5 49.8 44.6 51.7 38.4 35.1 37.4 38.3 40.2 31.2 32
17 35.4 42.2 37.2 35.1 34.7 28.4 17.4 32.4 47.9 45.6 33
17 42.5 41.9 37.6 33.3 32.6 40.6 37.5 37.7 35.9 30.5 34
17 33.7 45.9 36.0 40.2 39.3 32.7 37.3 36.1 40.7 44.4 35
17 47.5 37.9 32.3 24.6 36.2 42.4 35.0 26.6 36.2 26.3 36
17 26.0 19.7 33.3 34.9 34.3 33.1 0.0 0.0 0.0 0.0 37
18 52.9 47.3 39.5 43.7 33.6 31.2 22.1 18.2 27.9 32.7 1
18 35.7 39.8 34.2 29.1 34.4 37.3 43.8 56.9 45.6 41.5 2
18 30.8 37.4 44.3 45.9 43.0 39.7 44.9 47.4 33.4 32.5 3
18 34.0 17.2 16.5 21.7 33.0 31.3 19.0 22.0 17.1 19.2 4
18 28.3 29.3 25.5 20.1 25.6 37.0 40.3 39.6 34.9 37.9 5
18 28.9 27.4 34.1 36.6 23.4 14.5 13.3 25.2 34.2 37.7 6
18 40.2 41.7 47.9 52.5 49.6 53.8 46.7 33.6 41.8 41.1 7
18 50.3 47.4 45.8 56.4 39.3 40.9 46.4 46.1 48.7 41.2 8
18 44.9 42.9 55.5 41.4 45.8 57.1 67.6 65.2 72.1 75.7 9
18 76.2 72.5 67.5 54.3 59.1 61.3 56.3 51.7 56.1 47.8 10
18 45.6 37.9 42.0 47.7 45.4 56.8 51.9 53.3 60.8 47.9 11
18 52.6 51.6 62.6 54.0 46.6 51.2 61.1 58.8 52.7 59.1 12
18 52.4 60.2 58.3 66.9 60.0 60.5 55.4 60.4 62.8 63.2 13
18 57.7 62.3 61.5 54.5 57.1 67.7 68.4 73.5 70.6 61.6 14
18 65.6 66.4 61.2 72.1 76.2 87.0 78.6 83.4 86.1 86.3 15
18 81.6 76.4 73.9 76.8 71.3 72.5 74.4 80.6 78.5 80.7 16
18 74.2 77.0 69.5 66.5 72.5 78.9 77.2 76.3 78.4 80.4 17
18 78.9 78.1 80.5 83.5 78.7 83.1 76.7 76.8 76.5 79.6 18
18 82.6 84.1 84.0 88.2 84.9 81.5 83.7 88.8 83.5 82.9 19
18 84.4 81.2 79.6 82.2 83.5 84.1 85.9 82.2 84.3 82.4 20
18 84.5 85.1 79.8 81.3 76.2 80.2 74.2 75.0 76.6 73.3 21
18 81.3 83.1 85.1 83.7 77.9 84.5 84.3 89.4 89.6 90.4 22
18 87.7 81.9 80.8 82.4 83.2 86.1 78.9 80.9 77.4 70.0 23
18 73.9 76.9 78.7 78.4 83.4 80.2 75.5 79.3 82.3 74.2 24
18 74.4 74.8 74.8 67.6 72.9 78.9 74.8 77.0 81.6 75.4 25
18 83.5 86.7 84.4 73.0 78.2 81.2 84.0 65.0 68.6 66.7 26
18 72.1 66.7 65.0 69.6 67.2 75.4 72.2 79.4 81.5 77.8 27
18 79.6 81.7 80.5 80.6 78.6 64.8 61.8 62.8 61.4 62.6 28
18 68.9 75.2 71.8 72.5 58.1 61.9 71.0 81.0 76.4 70.1 29
18 68.7 72.8 78.1 61.1 47.3 46.0 47.8 35.6 29.2 34.9 30
18 49.9 58.4 54.1 58.2 55.1 58.5 58.2 54.8 52.8 53.0 31
18 60.8 53.2 49.9 53.0 55.7 62.5 61.6 60.2 56.8 50.3 32
18 39.5 37.8 49.6 57.3 64.9 55.1 45.8 60.4 50.1 52.2 33
18 51.9 57.0 49.6 42.1 28.9 22.1 23.0 26.3 24.9 35.6 34
18 40.5 42.3 38.5 25.5 32.5 35.2 25.6 13.2 26.9 24.2 35
18 27.8 24.1 25.0 34.3 34.2 37.2 46.7 50.3 47.7 35.0 36
18 39.1 37.7 35.6 39.9 27.9 33.1 0.0 0.0 0.0 0.0 37
19 33.6 38.2 44.6 35.1 38.3 36.7 50.8 53.4 44.1 44.4 1
19 28.5 26.0 18.4 14.6 28.5 32.7 32.1 34.5 29.3 32.6 2
19 30.2 29.7 18.1 29.1 38.6 38.4 51.1 37.9 43.8 45.1 3
19 51.5 51.3 48.7 52.0 54.3 42.9 43.9 49.6 46.7 31.4 4
19 20.1 26.0 20.8 34.1 29.7 16.9 22.4 20.0 28.9 36.9 5
19 45.1 39.3 35.1 36.4 39.9 32.1 32.0 37.5 35.4 42.3 6
19 41.1 43.9 45.2 35.2 43.9 44.7 33.0 41.5 41.1 38.7 7
19 41.2 44.8 58.0 56.3 58.4 58.1 48.7 55.3 51.5 58.6 8
19 53.0 51.7 58.2 41.7 46.8 50.3 53.0 47.3 43.9 48.2 9
19 47.6 41.3 48.4 43.2 44.7 45.3 58.2 44.7 47.0 55.4 10
19 56.7 47.5 62.2 63.8 67.1 74.7 66.4 62.1 63.6 67.2 11
19 60.1 59.8 66.3 65.6 57.8 66.0 72.2 76.8 66.9 68.0 12

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

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19	51.6	57.8	48.8	58.6	64.8	64.7	59.6	64.9	58.0	54.7	13
19	63.0	55.2	66.6	64.0	73.5	62.9	66.8	69.5	73.6	66.3	14
19	65.6	64.4	64.2	56.5	71.8	68.3	69.7	70.7	75.3	74.7	15
19	71.0	72.2	71.8	68.6	71.4	72.0	67.6	68.0	65.6	71.1	16
19	78.2	76.2	82.4	81.8	78.9	77.6	79.9	75.8	82.2	76.4	17
19	76.6	83.7	77.9	75.7	75.4	78.3	79.1	78.6	76.5	75.0	18
19	78.4	78.0	82.3	80.1	81.0	83.8	85.4	84.5	81.3	80.6	19
19	84.0	87.8	82.7	81.8	82.0	84.0	83.8	84.5	85.2	84.1	20
19	86.0	85.3	80.8	80.6	79.9	80.7	80.0	78.3	73.4	79.1	21
19	78.4	80.1	77.9	79.3	81.8	86.1	88.6	85.7	87.0	80.3	22
19	80.3	83.0	82.2	82.2	82.5	80.6	86.3	82.2	76.9	78.6	23
19	82.7	82.5	80.4	83.9	87.4	85.4	76.3	75.1	69.0	71.2	24
19	72.4	69.2	71.4	72.7	76.2	84.9	83.6	91.4	88.7	75.6	25
19	69.9	74.4	74.3	66.4	69.0	74.1	74.4	61.7	66.5	66.0	26
19	69.9	77.6	74.8	56.7	62.2	66.7	63.0	61.8	64.0	56.5	27
19	65.1	63.3	62.1	58.2	64.2	63.1	53.5	51.2	54.9	61.8	28
19	65.6	68.6	65.5	66.3	66.9	64.0	69.6	63.1	53.0	55.8	29
19	52.0	42.5	40.9	36.0	43.4	41.4	53.9	54.2	52.1	53.2	30
19	53.4	49.6	52.1	45.2	52.2	55.9	57.5	62.6	51.8	55.7	31
19	55.2	55.2	46.7	48.7	37.3	43.6	41.6	42.9	47.1	43.5	32
19	37.7	39.3	42.9	47.7	36.1	42.9	30.6	35.2	40.5	37.6	33
19	32.3	44.0	59.7	53.5	51.9	50.4	41.9	39.0	31.8	23.1	34
19	16.1	15.9	30.8	38.7	28.8	33.5	38.8	36.7	37.2	22.9	35
19	28.8	27.0	27.7	25.2	19.1	39.3	40.3	45.1	39.2	40.8	36
19	41.6	34.1	30.1	25.7	18.6	33.1	0.0	0.0	0.0	0.0	37
20	17.6	13.7	31.4	26.3	36.3	34.4	25.7	16.7	32.8	28.7	1
20	42.6	45.5	37.7	39.1	40.3	39.8	31.0	31.1	39.8	46.8	2
20	39.3	48.3	36.0	44.1	37.2	31.1	31.2	30.9	42.9	41.9	3
20	38.8	41.4	39.5	38.6	36.7	29.2	41.0	42.0	38.6	41.5	4
20	45.6	38.0	40.7	33.5	29.2	29.8	34.2	27.6	36.4	37.2	5
20	46.8	50.2	48.9	49.8	46.0	36.0	38.9	28.5	30.7	33.0	6
20	32.8	35.3	38.7	30.3	38.9	32.1	35.5	34.1	26.1	29.6	7
20	36.1	46.8	52.6	55.1	57.5	53.6	40.7	45.5	53.9	56.9	8
20	48.7	35.4	36.7	35.5	40.0	40.5	49.5	41.9	55.6	57.9	9
20	48.7	44.9	51.3	43.6	44.2	38.6	50.7	54.4	62.3	66.2	10
20	64.0	75.0	68.6	85.8	90.8	76.8	68.2	54.0	52.9	57.4	11
20	62.9	63.0	62.7	61.4	61.6	79.0	68.9	76.1	76.6	72.4	12
20	70.7	78.9	79.1	72.3	67.9	71.6	65.3	61.8	70.8	71.4	13
20	66.0	59.7	63.9	67.5	62.4	60.9	70.2	75.8	71.8	69.2	14
20	68.4	70.4	68.5	65.8	76.0	70.2	67.0	72.3	72.6	72.9	15
20	76.2	65.2	61.0	63.1	70.0	68.9	71.5	79.6	72.6	76.3	16
20	72.0	74.8	69.8	76.9	75.7	81.4	77.5	80.3	81.1	81.6	17
20	77.9	85.1	90.1	86.6	74.1	76.1	73.7	76.1	81.6	82.9	18
20	83.9	84.5	85.0	85.8	85.0	83.2	82.0	81.6	86.0	82.6	19
20	83.6	80.3	83.7	82.0	82.5	84.6	82.7	85.2	83.8	85.1	20
20	84.4	81.3	81.2	80.2	73.2	77.3	75.1	75.8	77.8	75.0	21
20	79.6	79.9	81.3	80.0	84.5	85.7	85.6	82.6	81.6	80.3	22
20	81.9	84.0	77.0	80.0	76.2	78.1	78.2	83.5	86.2	88.0	23
20	88.7	87.9	86.6	84.7	84.8	85.2	79.7	76.8	79.1	79.0	24
20	75.4	75.8	72.1	74.6	65.2	67.6	73.2	77.7	78.8	82.9	25
20	78.2	77.6	78.0	72.9	72.3	73.8	76.8	75.2	77.0	67.8	26
20	75.2	74.0	71.9	79.3	77.3	71.5	75.3	79.0	76.2	87.7	27
20	76.1	73.9	70.0	62.3	56.9	55.0	60.3	59.5	57.5	57.5	28
20	65.1	58.5	64.7	78.4	73.3	66.5	66.5	64.4	55.5	53.0	29
20	60.3	51.6	55.3	49.0	53.5	62.6	59.0	69.5	69.4	67.4	30
20	71.7	72.8	72.5	68.6	73.0	56.7	42.3	43.7	38.9	37.3	31
20	41.1	37.4	32.0	35.7	33.3	30.4	33.8	27.5	28.5	41.1	32
20	58.2	52.8	53.4	60.0	54.3	64.4	61.3	55.4	55.0	39.2	33
20	36.2	38.6	44.1	36.6	42.1	48.4	48.0	40.1	37.8	47.9	34
20	44.1	44.8	38.6	31.9	36.4	37.3	41.3	52.4	42.3	45.6	35
20	34.1	39.8	29.9	45.5	43.9	44.0	40.4	38.5	32.0	40.3	36
20	26.6	25.3	25.1	45.4	49.2	46.2	0.0	0.0	0.0	0.0	37
21	52.1	53.9	42.8	42.2	38.9	39.9	43.4	43.2	34.0	37.2	1
21	41.8	36.8	36.8	34.2	48.6	45.6	47.1	40.7	42.8	35.0	2
21	33.3	30.9	26.0	28.1	29.6	38.7	32.6	35.0	34.6	32.7	3
21	26.3	25.9	24.2	28.0	34.7	31.4	42.7	27.6	33.0	41.8	4
21	44.0	31.8	36.7	48.6	39.3	47.3	34.2	22.2	26.0	25.3	5
21	22.5	31.5	39.5	36.5	37.3	39.9	53.6	51.5	43.9	46.6	6
21	48.9	45.1	44.1	54.4	45.3	45.7	49.6	42.7	38.1	44.3	7
21	43.1	40.1	34.5	42.7	63.8	71.8	60.2	60.8	65.7	60.0	8
21	53.7	58.1	55.3	55.4	60.9	64.8	48.6	45.2	47.4	60.1	9
21	54.4	62.5	56.9	59.2	53.3	65.2	52.6	47.1	44.0	46.8	10
21	44.9	39.1	39.8	34.7	42.9	52.0	65.0	68.5	68.4	63.3	11
21	62.3	54.6	64.9	62.9	60.0	61.0	62.0	55.9	50.5	45.4	12
21	55.5	66.7	64.3	68.3	67.5	63.4	55.0	62.9	56.3	64.4	13
21	63.5	64.3	62.6	64.3	57.3	61.1	59.8	69.4	71.6	69.9	14
21	64.1	78.7	79.6	80.4	80.4	77.9	74.1	77.0	67.8	72.8	15
21	75.2	71.6	73.6	73.2	71.1	77.7	77.6	73.7	78.8	73.0	16
21	78.8	75.2	77.4	77.6	78.7	73.8	82.5	71.5	72.5	73.7	17
21	78.7	75.6	76.7	80.6	78.6	78.5	77.5	83.6	77.2	76.4	18
21	79.3	81.7	76.8	79.7	78.8	79.3	79.3	86.0	86.6	84.3	19
21	82.6	81.8	83.9	80.0	83.8	84.6	85.1	80.9	83.5	84.7	20
21	84.9	80.2	86.3	82.7	82.1	82.1	81.1	88.1	89.2	86.1	21
21	82.2	83.4	83.3	77.2	77.1	79.9	83.0	80.8	84.1	83.7	22
21	85.9	84.1	84.2	79.8	80.3	81.9	84.1	80.3	82.9	87.5	23
21	90.6	87.7	87.9	80.9	85.1	87.2	83.1	78.8	74.1	80.5	24
21	74.2	71.8	74.5	75.4	74.7	73.7	83.7	76.4	76.2	74.6	25
21	71.5	68.1	70.6	82.7	70.3	69.0	74.4	75.1	73.9	69.4	26
21	70.6	67.0	67.2	70.0	78.7	74.2	74.8	72.4	78.9	74.1	27
21	67.9	73.7	68.7	67.7	67.3	64.6	57.6	65.1	61.6	67.7	28
21	64.8	62.0	64.2	71.3	71.1	75.5	66.8	66.7	64.0	60.0	29
21	63.0	68.8	56.1	59.8	66.0	64.1	64.4	67.5	67.9	63.1	30
21	66.0	65.0	57.3	65.2	57.3	56.5	62.7	52.3	48.7	46.8	31
21	50.3	54.2	49.4	42.5	47.3	42.4	45.5	56.3	56.6	51.1	32
21	58.5	59.1	47.9	42.8	46.3	52.1	53.9	57.1	55.1	53.6	33
21	54.2	52.1	42.6	35.6	26.2	30.2	34.7	28.5	32.8	22.8	34
21	30.7	42.1	43.3	42.0	29.8	43.2	33.4	29.7	20.2	28.9	35
21	31.8	43.2	32.9	26.2	31.2	32.3	40.2	40.8	37.9	32.1	36
21	34.1	43.0	46.5	37.9	40.9	46.2	0.0	0.0	0.0	0.0	37
22	42.4	37.4	33.7	27.3	38.3	34.9	22.9	29.3	38.6	37.0	1
22	53.8	44.2	40.0	35.6	39.3	46.6	47.8	44.3	32.5	42.9	2
22	24.7	28.8	35.2	49.1	38.8	43.1	36.6	34.8	26.6	30.9	3
22	24.4	31.9	26.5	36.5	30.4	28.6	19.9	26.8	34.8	36.8	4
22	43.6	51.2	33.4	31.7	39.1	32.7	40.2	47.2	28.2	31.8	5
22	33.1	32.8	45.1	35.9	46.6	51.8	45.1	47.6	52.7	44.2	6
22	41.2	44.7	50.0	52.8	45.1	45.0	50.2	49.9	56.5	67.8	7
22	62.2	52.7	48.7	44.2	46.0	36.7	38.6	40.4	45.1	41.0	8
22	55.8	63.7	54.6	52.6	49.3	48.4	48.8	53.6	52.1	53.5	9
22	51.6	58.7	52.2	55.3	41.6	56.0	48.0	57.9	59.5	51.4	10
22	55.9	55.5	63.0	65.1	66.1	75.2	70.0	60.9	59.9	63.3	11
22	56.0	52.0	61.4	63.1	57.6	61.6	69.8	61.5	53.8	63.9	12
22	62.1	54.9	58.4	60.5	52.3	67.0	67.6	76.8	68.7	71.5	13
22	70.1	61.3	61.0	66.5	60.1	56.5	60.5	62.3	71.8	66.9	14
22	67.2	63.7	65.0	68.4	62.5	61.0	69.8	71.9	71.7	66.1	15

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

22	67.7	64.3	71.0	74.7	74.0	73.6	72.2	79.8	78.8	77.2	16
22	80.5	83.3	75.8	76.4	77.4	81.7	72.4	76.0	77.8	79.9	17
22	78.6	73.0	76.7	71.2	75.0	74.5	75.5	75.6	78.0	81.1	18
22	76.9	83.0	86.9	91.1	89.2	86.9	88.8	86.0	83.2	82.2	19
22	82.4	79.0	77.2	76.3	80.7	86.3	81.3	80.4	82.7	79.3	20
22	84.2	81.1	82.5	81.3	78.0	81.8	83.3	82.2	82.5	82.4	21
22	82.0	83.6	85.4	84.7	84.3	84.3	83.1	86.8	83.5	85.0	22
22	87.2	87.3	86.0	88.7	83.7	86.1	86.8	86.3	79.9	80.6	23
22	78.8	74.9	73.5	73.0	78.1	73.6	77.4	75.7	74.0	73.1	24
22	73.8	75.6	77.8	80.3	80.8	78.6	75.8	81.2	79.7	79.8	25
22	77.3	76.8	77.6	76.4	76.1	74.2	78.9	72.7	75.6	82.5	26
22	77.2	67.9	61.9	68.7	66.4	72.7	71.2	68.2	58.8	71.7	27
22	66.5	67.5	69.5	71.6	72.3	69.8	54.9	62.1	59.9	56.2	28
22	68.3	62.3	53.7	56.7	63.7	61.2	66.4	66.0	70.9	64.2	29
22	73.6	61.4	56.5	53.4	50.0	47.4	53.5	59.8	51.3	56.1	30
22	56.3	61.7	54.7	68.5	51.0	55.6	49.8	50.2	49.7	40.0	31
22	40.2	35.2	40.6	47.9	56.4	47.3	55.0	45.9	50.7	51.8	32
22	56.1	58.9	54.0	47.9	50.3	44.6	48.9	45.8	45.7	49.0	33
22	43.9	48.7	41.3	31.0	28.1	17.9	36.7	39.4	38.5	28.6	34
22	27.0	35.9	36.9	26.3	31.2	35.5	32.6	31.9	42.8	36.0	35
22	44.1	40.9	31.0	25.5	27.9	22.9	30.7	30.8	33.1	21.5	36
22	30.1	36.4	25.7	14.7	31.8	46.2	0.0	0.0	0.0	0.0	37
23	24.0	17.1	22.8	42.4	39.6	31.8	28.8	35.4	36.2	28.5	1
23	31.6	41.8	33.5	41.1	41.4	35.1	34.7	38.2	38.5	41.2	2
23	42.6	42.7	34.8	25.6	30.0	44.5	40.3	31.8	33.2	41.6	3
23	42.9	45.6	47.5	64.0	53.0	43.3	54.5	39.7	44.1	47.1	4
23	43.9	46.1	42.2	31.0	33.0	38.9	36.3	35.6	46.0	42.2	5
23	43.5	45.1	43.8	37.9	29.3	39.6	42.6	51.1	52.9	61.8	6
23	60.2	61.6	59.1	56.0	45.4	41.6	35.0	39.9	42.8	55.4	7
23	58.0	43.6	40.7	49.9	46.4	45.6	40.8	42.6	39.7	47.8	8
23	47.0	53.5	53.0	57.4	58.6	49.3	51.8	46.6	54.0	42.8	9
23	44.9	42.7	41.2	42.1	41.2	47.6	48.4	52.0	47.0	41.3	10
23	41.1	58.9	57.7	59.0	65.2	49.0	53.6	52.9	47.1	40.3	11
23	51.3	49.9	49.4	54.3	66.9	66.0	52.4	48.7	56.0	65.5	12
23	62.9	58.9	63.3	57.7	60.0	74.1	70.5	75.6	59.6	63.0	13
23	73.7	64.3	63.5	63.1	73.6	80.9	76.3	82.3	78.5	76.9	14
23	69.8	67.9	67.5	74.2	64.4	58.5	61.9	63.3	69.0	74.4	15
23	73.0	78.3	72.8	74.3	68.6	75.2	71.3	70.3	72.6	69.0	16
23	74.7	71.8	71.4	72.1	73.5	71.2	73.9	77.8	82.4	78.5	17
23	76.7	77.5	81.8	80.4	79.6	78.8	80.3	77.9	80.0	81.4	18
23	79.8	85.7	80.0	77.8	83.3	82.9	83.3	83.6	83.1	86.4	19
23	86.6	88.3	86.2	87.7	86.0	84.4	80.9	82.4	80.2	81.5	20
23	82.9	79.9	81.0	84.8	83.7	81.1	85.1	78.6	83.9	80.0	21
23	76.7	76.0	75.7	78.4	83.8	78.6	77.9	74.4	75.3	77.3	22
23	74.8	76.9	73.4	82.6	83.8	86.2	80.9	82.5	82.0	85.7	23
23	80.1	81.0	87.3	80.2	80.1	84.6	83.3	79.8	81.9	75.5	24
23	76.7	75.2	73.6	77.0	77.0	79.1	83.4	78.7	79.3	80.2	25
23	80.5	75.5	80.7	79.1	75.8	79.6	82.3	84.9	80.4	74.0	26
23	73.9	68.3	66.7	64.0	63.7	54.7	56.1	60.1	63.5	70.4	27
23	67.0	66.1	73.1	59.1	59.9	66.2	60.7	57.7	61.4	70.0	28
23	68.0	62.0	63.1	64.4	55.1	57.1	61.4	64.9	65.4	64.0	29
23	60.8	61.9	58.7	55.0	52.3	56.7	54.1	49.5	58.5	55.0	30
23	70.5	56.1	59.1	57.7	60.3	59.4	56.2	50.1	44.0	49.0	31
23	48.3	53.6	54.3	44.7	46.1	37.8	36.4	48.6	54.1	48.8	32
23	52.2	39.7	43.0	55.3	45.6	44.4	58.6	61.4	57.0	62.9	33
23	53.6	46.8	44.8	38.8	32.6	40.8	41.3	41.4	31.2	41.4	34
23	33.8	35.1	45.3	54.1	45.9	49.7	43.7	43.7	39.9	41.4	35

23	33.4	42.2	41.0	27.7	30.4	20.8	35.4	45.5	40.1	43.2	36
23	45.3	37.4	33.7	32.2	36.3	46.2	0.0	0.0	0.0	0.0	37
24	30.0	30.2	32.6	29.6	34.7	37.1	45.0	42.8	34.8	39.1	1
24	38.2	31.4	25.0	20.1	26.2	28.5	26.1	28.6	22.5	34.2	2
24	25.3	29.9	29.8	29.8	31.4	32.5	34.2	32.5	32.4	22.5	3
24	17.1	30.1	34.2	48.1	47.5	49.2	29.1	30.0	29.8	37.6	4
24	33.8	27.9	24.6	16.1	32.8	37.2	39.9	43.4	40.4	32.1	5
24	27.7	36.1	24.4	34.9	44.8	40.2	42.7	47.5	50.4	43.1	6
24	48.0	52.4	57.2	41.1	40.3	45.4	47.3	48.0	38.1	34.7	7
24	38.0	40.8	47.9	50.8	46.4	47.4	39.7	46.4	51.1	47.7	8
24	43.3	40.8	41.1	45.4	53.2	51.1	51.2	53.1	50.7	51.9	9
24	54.4	31.9	28.4	32.8	36.1	38.9	42.0	43.9	50.6	52.8	10
24	54.6	57.8	53.7	50.0	51.4	63.0	58.6	54.2	55.5	52.6	11
24	58.0	58.7	63.1	58.5	52.4	52.8	53.6	65.4	70.8	63.1	12
24	50.8	55.2	59.0	58.6	52.8	67.1	68.4	69.1	70.2	69.7	13
24	66.2	73.8	63.6	60.2	67.5	61.5	63.1	66.7	64.0	64.9	14
24	69.2	69.8	65.5	62.5	61.4	66.1	64.5	68.0	76.6	77.1	15
24	79.8	82.2	85.9	83.7	80.2	77.5	70.6	72.2	73.3	80.5	16
24	84.3	83.0	82.7	82.8	82.4	79.5	79.5	81.7	82.0	78.5	17
24	79.2	83.2	86.1	82.6	83.5	86.4	86.1	84.1	79.7	76.1	18
24	79.7	80.9	80.5	81.4	80.9	77.6	83.7	89.3	86.7	84.6	19
24	83.0	82.3	82.0	80.8	80.2	81.1	80.6	81.1	82.7	79.4	20
24	79.1	82.4	82.6	81.9	78.2	83.1	84.5	83.9	83.4	85.4	21
24	85.4	83.7	85.5	88.9	87.6	87.8	86.7	85.0	83.8	81.1	22
24	82.5	80.2	79.8	82.6	81.4	78.8	75.9	81.4	79.0	83.0	23
24	79.1	80.7	89.2	87.3	87.7	90.6	89.3	85.6	79.8	78.8	24
24	76.7	78.8	83.2	86.6	88.3	80.7	79.8	77.8	80.0	82.7	25
24	76.1	77.9	80.1	73.9	76.5	73.9	67.7	70.9	80.4	75.2	26
24	73.3	69.8	69.3	65.0	63.1	62.3	64.2	68.6	73.0	64.0	27
24	65.0	57.8	62.6	65.7	68.0	58.7	58.9	60.3	53.2	49.1	28
24	53.1	60.9	55.9	51.6	47.4	48.7	62.3	72.3	66.0	66.5	29
24	54.4	50.7	60.6	51.3	55.0	65.4	60.9	54.8	37.8	46.7	30
24	46.6	61.7	55.1	54.1	50.4	36.9	43.6	41.1	47.1	43.0	31
24	42.7	43.5	43.5	52.5	56.5	54.3	52.0	53.5	44.1	37.0	32
24	24.5	38.4	45.6	48.2	61.5	51.0	49.9	54.2	50.2	43.3	33
24	44.9	29.0	40.7	39.1	39.8	30.0	42.2	45.9	50.9	38.8	34
24	33.0	27.6	25.5	25.4	19.4	24.4	16.5	19.1	33.6	39.7	35
24	29.3	32.5	30.0	45.3	34.2	25.8	29.4	22.9	31.8	34.1	36
24	46.2	54.6	51.2	42.7	42.0	42.8	0.0	0.0	0.0	0.0	37
25	39.4	44.0	51.0	37.7	43.1	38.2	29.8	29.1	31.6	23.3	1
25	28.9	28.2	27.7	33.4	28.1	44.2	30.5	34.8	38.8	50.1	2
25	44.9	47.2	31.4	38.4	32.1	33.0	33.4	40.8	37.0	34.1	3
25	33.3	43.5	32.0	29.9	23.4	32.7	42.8	45.5	47.4	31.4	4
25	29.1	26.8	24.0	28.7	29.4	30.6	41.8	34.3	26.2	29.3	5
25	27.7	31.9	32.4	27.3	39.3	53.9	56.3	71.1	57.6	51.0	6
25	49.4	49.1	48.3	45.7	48.0	54.7	55.3	53.9	44.9	43.0	7
25	46.4	42.3	40.8	32.9	36.6	40.0	46.8	54.8	40.0	43.7	8
25	47.3	50.9	58.8	60.1	50.7	53.5	43.6	54.3	47.0	48.5	9
25	42.4	51.1	38.5	51.4	46.4	36.8	42.1	59.2	46.5	51.6	10
25	46.4	49.2	50.4	41.0	50.1	47.9	42.5	58.1	57.6	70.9	11
25	71.3	68.2	71.4	77.2	72.2	72.8	82.0	82.9	71.4	69.5	12
25	69.3	63.5	68.8	69.5	58.6	61.7	62.0	67.0	59.8	62.8	13
25	51.7	54.2	59.1	57.4	65.3	63.8	73.5	68.9	68.7	62.8	14
25	58.8	70.4	65.5	69.8	66.5	60.0	63.1	62.2	56.2	58.5	15
25	64.8	67.5	73.8	75.9	76.2	82.1	78.2	74.6	72.0	73.8	16
25	70.4	72.8	74.0	72.7	73.0	76.3	72.0	75.3	77.6	78.5	17
25	88.0	83.6	84.5	84.9	81.0	79.4	80.5	78.8	80.0	77.3	18

25	78.6	83.1	82.1	78.0	76.8	86.1	88.4	89.9	85.1	84.5	19
25	85.7	81.1	82.3	82.6	84.7	88.5	85.2	83.2	86.1	85.8	20
25	83.4	83.8	86.0	84.5	80.1	78.3	82.1	84.6	84.4	84.0	21
25	92.0	88.5	84.3	86.2	84.5	84.8	84.4	88.1	85.8	88.2	22
25	84.3	77.2	81.6	83.3	81.1	79.2	78.9	81.1	82.0	81.5	23
25	76.3	78.6	76.5	74.2	68.0	73.2	81.3	76.2	75.3	77.6	24
25	83.5	89.4	88.5	78.4	81.7	76.4	72.4	76.1	76.4	74.8	25
25	73.6	70.8	64.1	75.7	71.4	72.5	74.6	82.0	75.6	74.7	26
25	84.0	79.9	90.5	87.5	85.2	79.8	80.8	82.4	69.9	67.0	27
25	64.7	63.4	64.4	61.9	53.8	67.0	60.5	60.0	62.0	59.0	28
25	57.8	71.5	60.2	51.4	57.4	55.1	50.7	51.6	54.7	50.7	29
25	47.3	48.6	50.7	49.6	62.5	51.4	51.3	40.7	33.6	42.2	30
25	39.0	48.4	54.8	57.5	57.2	56.0	59.4	57.8	51.0	56.0	31
25	56.9	42.8	45.5	35.7	34.8	41.9	56.2	57.6	62.7	43.3	32
25	37.1	33.7	41.8	44.9	55.3	56.5	58.5	67.9	62.7	42.6	33
25	39.7	37.2	27.5	34.3	32.1	30.7	38.0	41.5	32.5	25.1	34
25	41.3	38.9	43.7	40.8	30.8	26.0	21.1	22.9	29.0	29.1	35
25	28.2	24.4	13.4	22.2	31.0	24.7	17.7	14.4	6.3	22.8	36
25	36.3	34.1	32.1	33.0	42.8	42.8	0.0	0.0	0.0	0.0	37
26	42.4	30.8	29.7	32.5	32.9	43.6	31.8	22.8	25.7	40.8	1
26	39.3	37.6	36.2	33.1	20.0	25.3	20.8	22.7	24.2	25.3	2
26	22.5	21.4	26.9	25.9	31.4	17.9	28.9	45.3	44.8	38.8	3
26	28.5	32.6	31.9	39.7	40.4	46.7	46.4	44.6	41.0	38.3	4
26	41.3	52.0	53.9	46.0	56.6	50.0	49.0	41.1	43.7	49.2	5
26	51.8	42.3	43.3	48.9	55.2	50.0	36.0	42.5	43.0	47.6	6
26	39.7	45.9	45.9	39.5	44.5	46.6	40.4	40.1	50.4	42.5	7
26	48.3	45.3	43.3	41.3	52.6	46.7	44.2	31.3	39.3	31.4	8
26	37.1	49.2	39.0	45.7	42.3	54.3	71.2	78.3	77.4	65.3	9
26	72.0	68.6	74.6	48.2	55.2	52.0	52.8	54.4	49.5	53.6	10
26	42.6	45.0	43.2	52.4	52.9	56.9	58.5	52.8	56.8	69.4	11
26	75.8	79.6	60.7	70.4	62.2	62.4	69.8	65.1	61.4	74.7	12
26	68.2	63.7	64.8	55.3	52.5	61.4	68.4	69.5	70.3	65.3	13
26	62.9	64.3	61.1	66.9	72.8	70.0	62.6	58.9	53.5	59.2	14
26	67.8	80.3	82.3	88.7	85.1	73.7	71.0	69.8	67.7	76.8	15
26	78.4	79.6	80.3	77.4	78.1	82.5	80.2	78.7	78.7	80.6	16
26	82.3	81.1	80.8	86.2	84.2	85.5	85.7	84.1	83.6	77.6	17
26	79.7	76.0	84.0	80.8	81.0	79.6	81.2	80.9	80.0	79.3	18
26	81.7	89.0	88.0	86.6	79.8	78.6	83.8	87.8	89.7	88.5	19
26	81.1	84.2	83.1	83.7	82.4	81.4	82.6	86.0	80.0	83.7	20
26	86.3	83.0	82.9	82.5	86.1	80.1	83.5	88.1	89.3	88.5	21
26	85.3	81.3	82.6	89.3	78.9	77.6	80.8	81.9	85.5	83.6	22
26	81.2	86.1	83.9	83.2	82.2	79.0	83.1	81.6	79.0	82.7	23
26	81.2	76.2	76.4	79.1	71.2	76.7	75.5	71.6	69.1	76.0	24
26	80.7	70.3	68.3	67.2	71.3	71.7	73.3	77.4	75.7	86.8	25
26	85.2	82.2	82.5	81.6	84.2	78.3	70.7	67.7	70.3	65.8	26
26	69.3	73.2	65.2	60.0	61.4	63.7	65.8	64.0	61.4	68.2	27
26	71.1	72.7	76.0	59.3	66.0	63.2	62.4	59.5	69.8	77.5	28
26	74.8	62.9	62.2	63.8	57.7	63.3	57.8	55.9	62.2	71.8	29
26	64.8	51.4	44.3	42.3	49.7	66.8	66.6	65.4	50.9	59.7	30
26	43.6	53.4	51.8	57.4	61.5	62.9	58.7	42.1	46.7	49.0	31
26	55.3	62.9	61.9	61.1	49.8	34.8	43.2	42.4	36.5	40.1	32
26	49.9	56.3	49.6	48.5	51.2	49.3	51.3	42.8	51.5	58.5	33
26	54.9	59.6	52.2	48.9	52.2	45.6	35.7	37.7	44.4	36.4	34
26	42.7	32.8	24.2	28.4	26.4	27.0	34.5	46.4	49.4	56.9	35
26	42.7	27.4	16.5	16.6	22.0	24.4	33.2	40.8	39.6	28.0	36
26	42.9	25.6	37.9	46.0	56.0	42.8	0.0	0.0	0.0	0.0	37
27	54.8	53.7	37.6	47.0	44.0	47.7	37.3	31.9	47.1	54.9	1
27	52.9	43.0	45.7	44.7	43.3	36.7	48.7	41.8	45.9	38.4	2
27	47.0	50.3	51.3	42.3	37.8	40.7	43.0	37.4	28.9	27.3	3
27	24.9	20.9	31.2	16.8	6.3	15.4	19.9	19.8	30.5	29.3	4
27	39.9	44.6	51.4	45.9	32.4	33.9	31.4	31.5	29.7	35.0	5
27	43.7	43.0	36.2	41.2	38.5	45.8	34.4	32.3	43.3	48.4	6
27	48.5	44.8	42.6	37.9	49.2	47.8	43.7	34.3	32.0	38.4	7
27	22.9	11.3	23.4	30.2	37.9	49.4	54.4	49.2	46.3	37.1	8
27	27.2	37.8	55.6	56.9	51.3	52.7	47.2	44.1	52.4	56.7	9
27	58.4	63.5	67.3	67.3	65.7	69.0	67.1	57.9	71.9	71.0	10
27	68.7	62.5	62.6	56.9	62.4	46.4	51.0	55.7	60.6	70.0	11
27	69.2	62.8	65.6	65.1	65.7	50.9	53.8	56.4	65.6	64.9	12
27	61.4	55.4	59.6	59.8	61.7	59.9	55.0	69.1	67.0	71.9	13
27	74.4	71.4	74.4	69.0	61.2	68.6	68.2	67.8	77.1	70.5	14
27	68.7	66.4	66.4	70.7	67.3	72.5	72.7	76.7	77.1	75.3	15
27	79.0	71.5	78.8	81.7	82.7	75.4	69.6	75.2	69.9	78.5	16
27	76.5	75.6	78.2	81.7	83.1	82.9	80.5	73.9	72.3	74.7	17
27	78.2	83.2	86.4	82.9	81.0	82.6	83.2	85.6	76.2	82.9	18
27	80.4	80.4	82.5	84.3	88.3	84.3	75.8	80.8	78.5	79.4	19
27	82.4	87.4	86.7	88.2	90.1	84.2	86.1	80.6	80.4	84.6	20
27	84.0	87.2	84.2	86.5	81.8	83.7	84.6	85.3	84.6	81.6	21
27	77.2	85.7	84.5	81.0	86.5	81.1	81.9	77.5	77.9	75.8	22
27	75.0	76.7	80.4	82.2	80.3	77.1	83.4	84.2	80.0	79.1	23
27	78.6	82.3	82.2	77.1	76.9	77.7	81.9	76.7	83.5	80.9	24
27	83.2	80.8	77.9	76.2	78.6	78.9	78.5	78.7	82.5	76.9	25
27	77.1	79.3	78.6	71.1	67.8	71.3	75.5	75.1	74.3	79.3	26
27	78.6	74.4	69.6	64.1	64.9	61.3	54.4	62.2	58.3	65.1	27
27	67.0	77.3	70.9	58.1	48.4	50.6	59.0	54.3	57.8	52.1	28
27	57.4	64.7	71.4	57.2	53.8	61.0	47.8	38.9	49.5	56.0	29
27	56.9	53.0	51.0	54.2	61.0	56.0	43.7	50.6	58.7	64.7	30
27	65.3	68.2	67.2	78.1	70.1	65.6	59.0	54.5	53.8	46.3	31
27	49.2	33.7	31.8	28.3	30.8	34.9	41.9	58.5	47.9	45.4	32
27	45.3	48.2	55.7	57.8	50.1	47.9	48.8	60.3	56.6	54.1	33
27	46.4	40.5	39.8	45.0	55.2	58.6	60.3	65.4	70.3	59.2	34
27	52.4	49.0	32.5	37.5	35.3	45.3	44.8	45.4	52.5	42.1	35
27	38.1	39.0	43.4	45.5	56.1	48.6	42.0	31.5	46.4	39.8	36
27	45.4	39.5	29.7	34.2	40.0	42.8	0.0	0.0	0.0	0.0	37
28	36.5	36.9	33.5	36.8	41.1	38.2	47.2	39.4	38.3	39.8	1
28	30.2	22.8	19.3	32.4	25.0	21.1	24.7	18.8	16.1	26.5	2
28	30.2	32.1	47.5	49.5	45.6	46.4	35.4	33.8	37.3	32.3	3
28	33.7	33.7	41.7	44.0	37.1	28.2	23.6	19.6	35.4	42.7	4
28	42.6	40.9	45.8	37.0	29.5	44.1	49.7	52.7	52.6	55.7	5
28	51.4	41.6	52.5	40.3	40.5	49.2	54.2	45.1	43.6	43.4	6
28	40.8	35.3	30.3	42.1	40.3	29.6	25.6	21.9	19.5	30.2	7
28	37.0	43.0	46.3	44.5	36.9	36.7	30.5	33.9	34.1	28.6	8
28	26.9	33.9	51.1	46.0	34.8	44.7	36.1	36.1	44.7	52.9	9
28	51.7	46.4	46.9	47.5	44.9	39.2	54.4	55.5	54.6	44.4	10
28	64.7	53.6	61.2	65.9	61.7	50.4	54.9	53.2	41.7	43.7	11
28	53.5	50.8	57.9	54.3	52.7	55.7	51.8	56.6	56.7	57.8	12
28	56.2	67.3	73.6	59.2	58.6	55.8	64.7	55.2	56.2	56.1	13
28	61.2	60.0	62.5	56.8	68.5	67.9	60.7	61.0	61.3	62.7	14
28	66.2	68.4	64.8	66.1	66.8	64.6	63.7	73.0	79.3	82.6	15
28	79.3	82.7	83.5	71.6	78.1	75.1	76.9	71.5	72.6	72.4	16
28	75.9	77.6	79.2	73.3	74.6	69.3	67.8	67.3	74.6	85.0	17
28	84.1	83.8	86.1	84.2	82.5	82.2	82.0	81.1	78.0	76.0	18
28	78.1	81.6	87.3	88.2	83.6	82.3	78.1	80.4	75.9	75.7	19
28	74.1	79.8	82.2	81.9	81.0	83.1	81.2	78.0	80.1	81.8	20
28	84.3	86.0	82.9	84.0	84.4	84.0	84.1	84.8	89.2	85.4	21

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

28	84.7	88.4	90.2	91.6	91.9	86.5	86.8	82.7	81.5	83.5	22
28	79.0	80.5	78.4	80.4	80.6	77.6	76.5	77.2	75.2	74.0	23
28	73.2	73.4	73.4	75.9	76.5	74.9	73.3	76.7	76.8	73.3	24
28	76.3	80.0	71.1	70.0	77.9	75.3	84.1	78.1	75.7	80.4	25
28	75.1	67.9	70.4	70.4	74.5	69.3	73.1	71.1	76.9	76.0	26
28	77.1	78.7	77.4	76.5	71.3	65.0	64.8	64.5	64.0	65.9	27
28	63.1	55.4	59.9	59.8	58.8	55.6	55.5	56.3	52.4	50.6	28
28	51.9	48.8	46.5	37.4	42.6	36.1	42.4	48.9	48.0	48.8	29
28	60.8	62.4	58.7	60.2	54.3	58.2	66.6	61.7	62.1	55.9	30
28	58.7	55.5	57.6	51.6	45.0	45.4	45.5	37.6	48.1	48.7	31
28	41.7	45.9	27.2	32.9	46.9	45.3	37.2	32.9	41.0	38.5	32
28	43.0	50.1	49.3	38.2	41.4	40.5	45.7	43.2	52.1	46.0	33
28	57.1	63.1	55.8	50.5	46.0	45.5	34.4	25.2	14.8	19.0	34
28	32.5	33.8	36.4	31.4	27.3	30.6	29.3	21.4	20.9	23.5	35
28	23.1	20.5	19.8	34.0	40.2	36.1	31.6	31.8	30.0	27.1	36
28	42.8	45.0	35.7	34.5	24.1	36.2	0.0	0.0	0.0	0.0	37
29	44.4	41.3	35.9	36.9	29.7	33.0	33.0	25.6	28.5	45.9	1
29	38.6	52.0	46.0	52.8	44.6	31.2	31.9	34.5	22.6	29.3	2
29	31.6	30.3	41.1	38.6	31.4	18.6	19.5	12.9	8.5	9.6	3
29	10.7	35.1	27.4	36.5	39.5	41.5	50.9	45.5	38.2	21.7	4
29	29.1	28.1	27.3	39.7	50.0	45.7	51.8	39.7	47.2	39.3	5
29	31.3	32.3	37.3	40.3	22.3	32.2	39.1	53.2	54.8	40.6	6
29	41.2	41.1	44.7	44.1	40.7	42.5	46.5	48.9	48.8	48.8	7
29	58.7	64.1	65.5	55.3	52.3	55.7	64.0	52.4	61.2	66.2	8
29	61.9	50.1	50.1	47.5	52.1	52.1	51.2	57.2	54.2	45.6	9
29	48.7	53.9	50.1	65.1	54.8	48.8	47.8	43.1	52.5	54.9	10
29	59.1	62.3	66.5	68.1	58.0	68.5	65.9	67.7	59.4	72.1	11
29	63.5	54.5	55.7	52.7	61.9	54.5	55.8	47.3	39.8	63.2	12
29	60.4	56.1	57.7	64.0	52.7	52.4	51.4	60.5	63.2	60.7	13
29	66.7	63.9	64.0	65.6	74.8	72.6	62.7	69.9	71.0	70.8	14
29	70.1	62.7	67.3	78.6	74.0	78.5	78.0	69.2	72.9	80.6	15
29	84.8	86.2	81.9	75.0	78.5	82.0	84.3	79.8	79.3	74.9	16
29	78.7	82.8	79.5	79.7	78.9	76.8	76.1	76.5	80.4	84.0	17
29	82.8	80.1	78.1	77.1	76.8	83.4	83.8	85.2	82.0	83.1	18
29	81.7	83.5	84.1	84.7	86.2	87.3	87.3	84.5	86.3	84.3	19
29	83.8	82.1	83.1	89.7	89.1	87.0	82.6	81.6	85.4	84.1	20
29	80.7	80.2	79.7	79.9	82.6	82.0	82.2	90.9	93.5	87.4	21
29	90.3	88.1	90.0	84.2	87.8	87.2	86.8	81.3	82.0	87.2	22
29	86.1	80.8	83.7	86.1	83.1	82.6	76.9	79.6	77.9	79.8	23
29	80.6	82.1	79.4	83.7	78.8	80.7	80.8	74.5	74.9	79.5	24
29	84.2	86.4	85.7	75.9	77.1	76.5	66.3	73.3	75.4	79.0	25
29	74.2	77.0	79.0	76.9	73.9	74.5	71.9	69.8	64.9	70.5	26
29	72.1	77.7	75.4	76.0	70.6	78.3	76.2	72.6	80.8	88.0	27
29	82.7	78.3	72.5	68.8	69.0	63.5	65.2	61.2	67.3	65.7	28
29	56.3	55.0	62.8	62.3	59.3	54.1	59.5	56.6	45.9	57.8	29
29	62.4	69.1	51.9	56.0	56.6	50.9	59.3	56.0	57.7	60.0	30
29	62.2	55.9	52.5	42.0	35.5	34.8	43.2	49.4	46.6	42.9	31
29	42.1	31.1	26.0	38.1	39.8	45.4	51.1	48.1	41.2	37.1	32
29	39.1	31.1	45.9	36.9	38.2	40.1	42.9	40.2	40.6	40.9	33
29	30.3	49.7	48.6	45.1	42.0	42.5	38.5	30.5	32.5	31.2	34
29	29.0	36.6	38.7	38.5	50.1	41.0	23.6	27.3	14.6	21.6	35
29	28.4	35.2	25.6	22.8	33.6	31.2	19.8	35.0	37.6	41.7	36
29	31.9	26.5	31.2	24.3	33.1	36.2	0.0	0.0	0.0	0.0	37
30	38.4	35.7	37.0	36.3	35.1	24.6	29.1	34.5	32.8	28.1	1
30	18.8	28.3	29.0	32.1	43.7	34.8	27.8	33.0	21.2	17.6	2
30	20.4	38.7	45.6	43.4	32.1	40.6	46.2	47.9	41.1	31.4	3
30	34.5	32.3	23.6	36.2	37.2	32.0	30.7	30.1	19.0	25.7	4
30	33.0	31.7	28.2	29.7	41.3	34.2	37.8	27.8	30.7	37.8	5
30	38.7	22.3	37.1	48.4	54.4	45.0	29.2	38.0	49.0	58.0	6
30	39.6	47.7	47.8	45.0	49.7	45.0	48.4	48.9	46.1	46.7	7
30	58.9	39.7	39.6	54.4	48.9	41.5	47.9	49.2	47.8	41.1	8
30	52.9	47.5	53.0	52.5	53.3	64.5	49.3	60.3	63.0	47.1	9
30	63.3	61.2	61.6	55.3	60.3	67.6	65.9	54.5	58.2	51.0	10
30	45.5	41.3	44.1	36.2	53.2	58.8	55.0	58.6	57.8	67.8	11
30	70.7	66.1	54.7	61.2	57.5	69.7	72.9	80.4	62.4	69.7	12
30	63.0	69.1	70.5	72.2	76.5	69.6	59.4	69.9	64.5	59.1	13
30	57.9	56.8	65.7	75.4	77.7	70.0	65.8	62.9	66.9	64.3	14
30	67.0	72.9	70.9	72.6	72.2	75.7	72.9	75.4	69.7	69.4	15
30	71.1	73.0	73.5	73.9	75.7	77.2	75.1	76.3	68.6	73.5	16
30	68.7	72.4	72.0	77.7	86.7	80.3	85.1	84.1	81.8	85.1	17
30	81.4	75.8	73.9	73.0	73.6	77.0	73.9	74.3	77.5	75.9	18
30	75.6	79.3	77.8	82.1	83.2	79.1	76.3	77.1	77.4	78.3	19
30	78.9	80.6	82.5	84.0	83.7	80.5	85.5	80.1	83.3	82.6	20
30	83.7	83.8	83.6	84.2	89.3	85.1	79.1	81.6	82.2	86.4	21
30	86.2	85.2	83.1	79.1	79.4	78.0	83.1	79.1	76.4	76.8	22
30	75.9	75.5	79.7	82.1	83.1	83.0	78.6	76.8	77.6	75.6	23
30	74.7	69.4	77.4	76.7	79.7	79.1	78.2	81.8	75.5	75.3	24
30	70.5	78.3	75.3	70.2	66.1	68.5	70.1	79.9	74.6	64.7	25
30	64.7	73.6	73.5	73.4	78.6	79.0	84.7	87.1	83.2	78.6	26
30	74.3	67.7	75.9	74.2	63.4	67.0	60.4	56.0	57.9	69.9	27
30	60.2	57.5	63.8	62.4	63.8	69.6	70.2	68.4	70.0	67.2	28
30	53.9	57.6	57.7	49.9	52.9	57.4	54.7	65.4	67.1	62.5	29
30	62.8	68.3	63.7	48.9	56.1	57.4	53.6	51.3	54.3	53.1	30
30	54.9	61.2	60.9	51.8	46.6	57.7	59.1	52.0	46.6	47.6	31
30	40.7	45.3	48.3	50.8	44.6	45.0	38.5	38.9	50.7	51.0	32
30	42.8	38.5	32.3	26.7	44.9	46.7	45.8	46.1	34.2	46.8	33
30	50.8	53.5	48.4	29.1	27.8	25.5	41.1	45.4	48.5	28.4	34
30	35.3	47.6	32.0	33.1	28.7	32.4	38.4	42.5	39.4	55.9	35
30	52.8	51.5	42.3	57.1	49.5	43.1	44.0	42.9	38.4	42.5	36
30	43.4	36.4	29.1	33.6	30.5	36.2	0.0	0.0	0.0	0.0	37

Solar Radiation Data

2
1
OKLAHOMA CITY OKLAHOMA
36.44
1 250.9 260.4 305.7 151.0 215.4 208.7 264.7 236.6 282.2 198.2 1
1 204.0 218.0 99.6 276.3 264.9 196.3 135.5 66.6 207.1 306.3 2
1 287.5 214.6 260.4 193.2 312.1 307.5 357.7 360.8 144.6 73.4 3
1 74.1 252.1 288.1 271.4 217.3 267.4 340.5 394.9 294.3 209.9 4
1 133.9 410.1 375.0 129.6 391.7 360.6 86.0 290.1 318.4 364.9 5
1 218.9 261.7 227.7 292.3 163.5 229.3 291.3 362.4 96.3 153.4 6
1 177.1 439.8 99.9 481.1 101.7 107.0 356.6 260.3 250.6 371.0 7
1 107.1 167.6 323.2 424.4 356.4 112.2 296.5 506.7 319.9 115.2 8
1 496.6 584.6 550.0 410.8 448.5 277.1 444.0 550.9 477.6 421.8 9
1 340.0 373.7 241.1 520.0 549.5 299.0 163.3 246.5 169.4 475.5 10
1 575.4 458.2 557.1 371.0 385.7 492.3 576.5 374.7 497.1 601.3 11
1 599.8 520.4 465.5 627.5 464.6 656.0 630.6 621.5 712.9 430.9 12
1 321.4 437.0 467.2 564.6 440.5 638.5 577.9 563.1 716.2 692.4 13
1 515.0 690.6 733.2 565.0 537.1 597.9 555.8 273.3 752.5 541.3 14
1 622.4 742.2 709.0 425.4 515.9 500.7 596.5 514.3 383.9 780.2 15
1 349.1 673.9 657.6 609.8 539.3 486.7 546.6 393.6 443.8 550.9 16
1 440.1 448.9 597.0 746.4 635.2 713.3 580.3 436.7 317.3 565.8 17
1 497.6 763.8 790.0 639.7 789.5 712.9 572.9 724.5 693.2 349.7 18
1 756.1 733.7 562.3 341.0 427.8 239.2 738.4 636.2 529.0 591.8 19
1 657.8 598.1 653.2 699.4 707.0 664.2 770.3 660.8 426.6 328.4 20
1 609.4 477.7 492.0 366.8 400.9 601.6 455.1 462.8 525.6 672.3 21
1 370.2 707.1 702.4 619.8 627.9 409.6 321.3 441.1 293.6 521.2 22
1 436.9 412.8 412.4 444.3 428.5 433.3 624.2 564.5 696.8 693.7 23
1 590.6 454.9 591.1 520.9 652.4 527.8 395.5 644.0 435.7 237.7 24
1 614.8 650.7 565.1 495.8 409.2 540.7 426.2 428.5 542.8 347.1 25
1 382.0 239.4 494.3 450.4 469.8 361.0 146.1 588.6 280.2 250.7 26
1 457.5 470.1 397.3 345.7 358.5 465.9 412.0 545.4 524.3 536.6 27
1 451.8 505.4 209.3 103.8 130.5 258.5 372.6 167.6 274.3 458.8 28
1 488.2 405.1 230.9 182.0 300.0 366.4 412.1 428.2 90.8 276.3 29
1 364.7 271.9 428.8 417.0 399.0 327.0 340.0 161.0 132.9 208.4 30
1 286.4 171.7 304.0 227.1 131.4 122.6 275.5 192.2 332.8 373.6 31
1 370.3 367.0 235.8 360.8 108.4 168.8 351.8 349.0 299.1 342.8 32
1 210.3 128.4 67.2 279.2 209.6 328.7 326.5 235.0 121.1 168.5 33
1 63.7 86.9 99.0 62.6 63.3 224.4 156.6 307.2 303.8 60.9 34
1 180.8 302.6 137.8 300.8 300.0 293.0 250.7 202.3 59.5 285.0 35
1 214.8 212.8 278.9 296.8 296.8 245.2 186.5 277.5 296.6 298.4 36
1 282.8 299.7 300.4 301.2 242.6 0.0 0.0 0.0 0.0 0.0 37
2 93.4 188.3 191.0 307.0 164.9 125.6 204.7 198.6 302.6 316.3 1
2 312.3 252.6 322.0 237.4 326.2 215.8 279.0 264.4 310.7 303.7 2
2 115.5 313.0 285.1 348.9 155.0 292.1 177.8 72.2 363.9 73.4 3
2 223.7 263.2 75.4 272.2 192.5 115.4 83.0 181.7 398.7 153.0 4
2 81.3 119.7 256.1 402.5 92.6 154.1 383.9 220.3 120.4 149.1 5
2 310.1 426.4 443.4 301.5 155.0 147.7 396.9 194.6 252.5 486.1 6
2 346.6 260.6 387.9 376.6 367.6 466.5 313.7 290.4 207.8 471.5 7
2 226.4 242.3 307.3 312.8 110.7 116.9 481.8 230.7 503.2 428.6 8
2 555.8 343.4 220.5 345.0 458.8 509.0 267.9 149.8 383.4 298.6 9
2 124.6 370.6 631.0 602.5 538.9 613.0 389.1 347.0 529.4 580.3 10
2 356.3 641.7 574.3 461.1 379.3 679.9 475.1 423.7 538.4 590.8 11
2 587.6 678.0 535.5 532.5 352.5 415.6 579.3 691.3 285.5 302.0 12
2 495.6 512.5 728.3 467.3 559.8 524.6 580.2 700.5 305.9 532.0 13
2 367.3 490.4 449.7 398.9 151.6 365.3 630.4 667.5 715.4 548.3 14
2 503.9 449.0 519.2 629.4 638.3 669.2 652.1 648.4 623.1 566.0 15
2 460.5 587.2 608.2 631.6 700.4 566.3 719.4 607.3 638.4 788.0 16
2 687.1 547.0 681.9 655.5 530.2 771.9 658.1 503.4 431.7 454.6 17
2 595.2 564.5 376.4 593.5 262.6 544.1 479.4 460.4 617.6 742.9 18
2 278.5 354.6 785.5 727.0 717.6 781.1 601.1 382.1 302.8 600.9 19
2 407.4 644.0 309.7 411.7 530.3 378.8 396.2 763.6 613.0 659.1 20
2 654.2 762.3 674.6 708.9 627.0 625.2 591.4 751.1 644.5 606.9 21
2 648.4 528.6 610.9 737.9 605.2 610.0 730.6 728.1 546.1 531.1 22
2 585.5 551.0 179.0 439.9 397.4 645.2 615.1 427.2 456.9 350.1 23
2 441.3 192.3 539.0 405.1 512.3 632.2 589.7 629.0 526.0 659.7 24
2 234.7 438.7 648.7 517.7 375.3 484.5 633.4 629.5 606.2 379.8 25
2 395.6 513.6 337.0 484.4 526.8 461.1 592.9 142.0 131.1 309.8 26
2 289.8 293.7 500.8 483.3 446.1 416.6 412.3 464.5 388.4 401.4 27
2 358.9 527.8 512.4 162.0 276.2 215.9 458.9 501.4 475.9 417.1 28
2 261.0 388.9 139.2 390.3 461.7 198.4 243.5 454.3 343.5 351.5 29
2 441.9 420.1 298.0 290.0 196.1 185.6 153.1 353.9 333.8 232.8 30
2 281.6 245.7 346.5 261.8 348.4 302.5 264.7 372.1 219.1 74.7 31
2 367.6 362.5 202.0 216.0 309.4 289.8 333.3 72.9 262.2 158.3 32
2 293.4 338.3 299.3 333.3 317.2 204.5 143.9 218.5 295.4 284.5 33
2 274.1 316.5 268.1 313.1 137.1 90.6 195.6 167.9 305.9 193.1 34
2 257.9 131.4 252.5 97.5 209.9 299.3 298.7 186.4 59.5 59.5 35
2 157.0 259.9 289.9 222.5 296.8 264.7 297.2 230.3 87.9 269.1 36
2 278.2 293.9 241.9 78.6 80.7 0.0 0.0 0.0 0.0 0.0 37
3 105.9 60.9 63.1 292.3 194.0 273.1 138.2 62.6 62.9 272.1 1
3 247.5 216.6 117.9 194.6 179.9 230.6 201.5 234.8 311.4 110.0 2
3 203.4 343.4 204.2 348.9 263.4 284.7 357.7 360.8 208.1 350.5 3
3 269.9 302.3 269.7 76.1 78.3 235.4 209.2 311.3 310.8 287.7 4
3 264.5 215.6 269.2 381.5 256.4 240.0 222.3 434.3 438.4 403.0 5
3 399.6 185.5 455.4 422.9 464.1 428.9 348.5 330.8 171.3 274.5 6
3 455.3 390.5 410.5 504.0 500.4 479.4 517.5 357.9 295.1 218.1 7
3 190.1 403.5 356.1 292.9 518.7 421.8 119.5 391.4 379.9 442.1 8
3 483.9 403.6 542.9 365.7 466.9 518.5 606.1 442.7 358.6 346.0 9
3 348.2 125.4 433.3 497.0 510.5 451.8 549.4 515.2 285.1 337.5 10
3 522.3 589.5 467.3 538.7 385.8 569.7 300.1 582.9 349.7 444.0 11
3 558.5 384.2 451.7 629.8 709.1 451.2 595.0 600.8 680.1 525.4 12
3 726.1 681.4 657.3 605.2 652.3 546.0 475.3 505.3 549.7 687.8 13
3 577.9 504.1 416.9 276.4 383.1 760.0 478.2 609.7 658.8 722.1 14
3 631.2 718.1 439.1 623.2 575.5 775.6 489.5 376.2 652.6 384.3 15
3 720.7 481.9 733.3 747.2 736.5 711.1 644.3 744.2 643.2 548.9 16
3 651.7 632.4 644.7 644.7 771.7 673.8 432.9 343.6 775.4 646.9 17
3 654.3 378.9 572.7 523.5 428.3 554.3 773.2 626.8 278.3 378.5 18
3 475.1 567.8 416.3 621.5 652.2 622.6 575.8 633.7 437.6 322.9 19
3 488.6 698.0 775.7 774.4 773.1 771.7 698.6 637.5 711.9 722.5 20
3 688.7 623.7 750.0 618.5 685.5 665.5 753.1 585.7 712.8 509.4 21
3 417.5 553.8 702.1 585.2 634.8 566.1 451.6 597.8 615.7 722.9 22
3 321.5 549.2 645.6 709.4 557.6 518.3 505.1 384.4 564.8 544.6 23
3 615.9 645.4 619.7 680.7 567.2 673.9 655.1 502.6 347.3 659.7 24
3 597.0 460.3 602.8 535.3 382.2 343.1 509.9 460.9 486.4 444.1 25
3 584.9 122.7 373.0 605.3 449.0 459.8 373.0 500.1 442.8 264.7 26
3 482.5 439.7 289.6 458.4 262.6 299.8 364.4 432.6 395.2 467.7 27
3 522.0 399.3 104.7 367.9 514.6 464.6 505.8 420.2 468.6 377.0 28
3 433.3 473.6 445.8 394.0 328.9 239.0 169.7 299.5 272.6 180.5 29
3 297.7 230.1 213.4 433.1 429.0 425.0 308.5 321.2 125.7 295.8 30
3 286.6 329.0 398.1 250.5 381.3 387.3 296.1 321.8 313.0 234.7 31
3 215.7 227.1 138.8 310.2 144.7 123.6 343.7 332.3 255.9 343.5 32
3 131.5 338.3 316.4 290.2 328.6 219.9 144.9 304.8 252.3 320.3 33
3 267.3 233.3 93.8 62.6 178.2 292.1 238.8 307.2 150.5 149.1 34

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

3 303.6 244.7 245.5 87.4 220.8 261.2 210.1 197.5 206.2 240.2 35
3 212.6 296.9 245.7 296.8 173.7 170.5 233.0 297.5 214.6 96.2 36
3 246.1 299.7 252.3 301.2 302.1 0.0 0.0 0.0 0.0 0.0 37
4 129.0 221.2 99.5 234.1 253.4 261.3 311.3 245.1 314.5 316.3 1
4 208.3 320.0 322.0 193.5 232.7 144.9 124.8 84.3 287.4 248.7 2
4 340.7 343.4 346.1 134.3 251.1 137.3 142.9 97.3 139.7 164.5 3
4 283.2 164.6 330.5 308.0 319.4 134.2 391.3 394.9 398.7 402.4 4
4 156.6 322.1 199.2 335.9 335.5 232.6 86.0 122.0 212.4 105.4 5
4 317.3 272.0 277.4 138.0 455.1 377.9 263.3 95.4 323.0 380.3 6
4 480.5 403.9 499.5 432.8 102.5 339.3 361.1 192.1 381.4 377.3 7
4 535.6 248.9 441.6 289.5 233.4 423.3 369.4 209.6 114.3 124.3 8
4 442.1 339.4 189.2 159.1 412.1 393.1 472.6 467.5 287.1 250.6 9
4 283.6 392.7 365.3 565.9 348.7 457.7 272.1 442.2 324.6 615.6 10
4 558.7 525.8 657.5 654.3 670.9 481.0 482.7 394.2 580.0 536.3 11
4 536.2 607.9 551.6 579.6 529.7 450.1 477.4 713.3 720.7 575.8 12
4 233.5 725.6 581.5 710.8 705.7 591.0 533.9 620.5 696.9 582.8 13
4 593.7 657.9 651.1 744.9 740.9 489.9 566.4 635.7 755.0 748.3 14
4 577.9 626.9 653.3 759.6 691.6 775.6 718.1 375.1 442.5 673.9 15
4 673.8 638.9 488.4 567.4 487.8 660.8 658.9 668.0 777.3 543.6 16
4 157.7 422.8 690.2 674.0 644.0 426.4 410.8 705.7 723.7 482.5 17
4 573.2 332.0 755.3 607.3 675.6 304.3 487.1 510.9 490.0 633.3 18
4 786.8 499.6 618.4 379.4 700.8 732.8 548.2 622.6 710.1 779.2 19
4 413.7 652.2 667.0 475.5 575.1 639.2 547.4 684.2 650.3 576.2 20
4 545.6 644.2 709.3 670.3 551.5 552.7 726.3 613.2 695.8 636.9 21
4 383.7 658.3 681.0 737.9 632.8 518.4 483.4 499.3 417.2 315.9 22
4 578.6 284.1 612.1 683.8 682.8 662.1 593.6 655.8 513.6 547.1 23
4 243.5 520.9 599.4 511.4 472.0 362.6 498.0 571.0 663.3 575.6 24
4 557.8 403.6 320.2 438.4 517.6 586.7 126.7 403.8 455.6 289.6 25
4 517.9 514.4 605.8 405.8 472.7 580.4 508.7 509.8 537.7 377.8 26
4 575.9 452.1 364.8 112.6 275.4 385.4 280.1 428.4 244.1 487.9 27
4 377.1 409.1 320.6 103.8 281.2 343.8 185.1 349.9 325.1 290.2 28
4 294.7 241.0 333.0 427.9 454.5 466.5 462.3 458.0 453.8 293.4 29
4 445.3 434.7 233.0 266.4 319.2 348.7 334.2 315.2 237.8 405.3 30
4 164.4 80.4 293.0 78.9 390.8 288.9 76.8 76.1 75.4 174.6 31
4 343.7 304.7 117.3 72.2 141.6 354.7 318.1 347.6 346.2 182.8 32
4 76.8 67.7 242.5 333.3 248.2 219.4 277.0 201.5 241.3 320.3 33
4 133.1 316.5 314.8 159.3 103.0 310.0 296.4 178.9 255.1 269.3 34
4 215.2 302.6 301.7 300.8 138.0 89.9 249.1 298.2 71.7 273.6 35
4 66.3 272.8 201.9 198.5 205.1 297.0 293.7 297.5 297.9 194.6 36
4 155.0 155.0 274.2 301.2 162.4 94.0 0.0 0.0 0.0 0.0 37
5 150.0 91.4 210.9 97.8 156.7 223.2 311.3 312.9 284.2 221.1 1
5 216.0 248.1 322.0 272.3 326.2 310.2 269.3 333.0 117.6 177.0 2
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5 179.2 235.4 300.8 299.8 136.5 120.4 462.7 332.5 486.7 477.1 9
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5 417.1 450.2 404.9 509.1 394.8 705.2 464.7 699.9 489.1 615.6 23
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5 281.9 296.9 296.8 287.3 204.1 183.0 59.4 66.3 110.0 91.9 36
5 262.6 242.0 125.2 60.2 60.4 94.0 0.0 0.0 0.0 0.0 37
6 252.0 215.5 61.1 296.1 205.4 87.1 62.3 158.3 264.4 316.3 1
6 279.1 230.3 228.0 198.0 268.4 65.7 230.1 171.6 206.5 292.0 2
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6 152.9 166.1 217.4 202.2 151.0 255.3 176.7 150.2 234.3 88.5 5
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6 588.0 418.6 749.5 611.3 624.5 570.7 761.3 617.1 560.0 503.4 15
6 581.7 546.4 729.7 630.9 613.3 579.2 443.8 669.3 323.8 479.5 16
6 614.7 528.0 396.5 471.0 650.1 397.3 578.4 388.9 506.4 767.3 17
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6 124.7 171.3 335.8 190.2 331.0 328.7 326.5 213.8 322.3 261.9 33
6 318.4 316.5 249.5 313.1 302.3 310.0 308.6 262.0 204.5 259.1 34
6 75.3 71.6 117.5 182.8 213.7 60.6 132.6 59.6 200.9 287.3 35
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7 239.9 78.3 281.8 218.9 239.6 288.9 311.3 146.3 314.5 316.3 1
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7 499.5 306.0 337.3 546.4 141.8 398.8 678.1 684.2 643.0 654.6 23
7 538.2 618.5 650.2 596.6 508.2 418.0 621.2 569.3 464.7 528.7 24
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7 332.9 290.4 67.2 66.7 136.5 328.7 326.5 307.1 189.8 148.8 33
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8 261.1 304.5 224.4 61.4 176.0 247.7 193.1 248.8 235.4 220.4 1
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8 311.8 111.5 145.1 259.5 182.2 251.9 189.9 230.1 254.9 310.5 3
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10 622.3 386.1 390.6 390.4 542.0 317.3 314.4 432.6 399.9 401.9 25
10 149.4 574.5 549.9 550.1 521.2 396.0 386.8 580.4 425.9 395.5 26
10 360.3 289.3 247.5 398.1 526.0 477.3 284.1 540.6 541.0 360.4 27
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10 240.4 231.2 328.9 348.8 332.1 258.9 238.1 174.7 181.3 252.9 31
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10 337.6 304.6 234.1 257.0 304.4 267.9 113.8 155.4 202.6 255.6 33
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15 189.6 227.8 252.0 307.0 185.4 309.8 311.3 183.1 220.9 316.3 1
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15 399.4 363.0 398.1 394.4 390.8 172.0 383.8 380.3 376.9 353.8 31
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16 225.6 274.6 305.7 232.8 308.3 218.2 295.8 312.9 314.5 316.3 1
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16 579.6 492.0 383.7 429.6 561.0 584.0 468.7 312.9 369.1 468.3 9

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

16 356.9 567.3 611.2 553.2 555.2 472.3 241.9 251.3 424.9 524.8 10
16 644.8 665.6 548.8 651.3 307.6 587.6 415.6 453.7 654.1 653.9 11
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23 276.3 202.1 289.9 187.9 163.1 224.2 323.7 313.2 67.1 338.1 2
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29 340.7 210.0 346.1 301.0 198.2 349.9 303.0 360.8 192.4 367.1    3
29 370.4 144.3 377.1 236.9 167.1 363.7 329.7 394.9 398.7 308.9    4
29 284.3 101.7 256.0  83.6 104.9 310.3 339.7 222.0  87.7  98.0    5
29 205.3 150.0 357.9 459.7 438.5 192.1 181.9  95.4 108.3  97.2    6
29 238.1 258.3 297.4 367.2 254.4 305.7 218.5 503.2 509.6 390.7    7
29 506.1 330.8 326.2 427.2 475.8 474.3 364.0 113.4 297.7 285.4    8
29 414.1 462.2 161.0 370.8 460.9 547.5 459.8 466.4 532.8 532.1    9
29 399.0 326.0 394.0 315.4 576.7 364.7 458.1 623.4 533.4 461.9   10
29 582.8 389.1 468.4 411.5 605.4 572.1 277.3 549.0 156.5 402.1   11
29 257.0 187.7 543.2 243.1 328.0 453.0 491.5 363.9 234.2 723.4   12
29 504.4 638.4 731.4 639.4 531.9 518.6 369.7 640.9 745.8 394.3   13
29 746.1 369.2 629.4 678.6 578.6 553.4 440.3 230.2 447.9 621.6   14
29 575.7 498.0 628.3 772.9 774.3 775.6 714.3 436.1 543.8 352.3   15
29 603.6 656.3 522.2 487.8 582.8 554.4 648.1 436.2 680.3 788.0   16
29 750.3 467.6 543.5 789.6 571.7 701.8 528.2 624.4 636.9 729.0   17
29 192.3 325.7 418.0 605.6 389.3 361.4 517.6 788.4 633.6 740.2   18
29 704.0 666.1 624.8 492.2 594.6 730.1 696.0 579.9 680.3 486.1   19
29 506.3 733.7 269.9 394.9 517.1 528.1 582.1 543.3 474.3 489.3   20
29 517.0 623.6 560.2 525.4 562.0 590.0 429.6 677.6 648.6 563.9   21
29 729.8 636.3 621.1 631.6 603.9 621.5 549.4 497.6 517.7 550.4   22
29 627.8 420.7 385.3 522.2 572.6 536.0 430.0 691.9 576.0 604.4   23
29 400.6 510.9 502.3 392.1 325.9 495.0 369.9 522.2 322.0 562.3   24
29 548.6 515.7 413.7 550.9 266.6 480.1 347.9 400.5 535.4 378.4   25
29 367.6 534.8 578.2 411.9 597.1 471.9 497.5 588.6 487.0 455.8   26
29 407.4 458.6 410.2 112.6 558.6 463.3 373.6 497.0 489.7 426.1   27
29 406.0 296.2 392.7 103.8 453.6 510.0 325.4 269.7 302.5 262.8   28
29 229.7 436.0 332.0 252.5 470.8 466.5 252.6 290.1 420.5 449.6   29
29 347.2 351.4 160.5 256.9 259.8 394.9 135.2 405.2 245.0 360.0   30
29 324.3 328.0 301.1 394.4 280.8 164.7 382.5 292.8 201.8 190.5   31
29 240.1 312.4 363.9 298.7 309.9 217.0 312.9  69.8 233.8 178.8   32
29 121.6 306.4 278.6 118.2 297.0 310.1 135.2  64.9 145.9 227.7   33
29 196.9 316.5 246.4 313.1 269.1 213.1 258.1 231.3 235.6 132.3   34
29 303.6 214.0 301.7 176.6 223.2 195.9 187.3 228.5  59.5  72.4   35
29  98.7 176.2 296.8 158.3 181.5 103.9  72.4 297.5 282.7 298.4   36
29 129.3 263.2 183.1 242.7 302.1 190.1   0.0   0.0   0.0   0.0   37
30 275.5 297.2 305.7 307.0 290.3 161.4 152.5 291.4 269.0 309.6    1
30 239.8 309.1 311.3 110.1 324.3 285.9 231.1 299.8 331.2 224.8    2
30 340.7 343.4 346.1 266.3 177.9 126.2 325.5 204.3 266.1  83.0    3
30 220.9  74.7 377.1 318.9 157.1 354.8 219.0 271.1 185.6 402.4    4
30 406.3 242.0 414.0  83.6 341.9 383.8 157.0 407.5 438.4 130.2    5
30 267.7 179.8 422.7 208.2  92.8  93.7  94.6 198.1 481.7 434.7    6
30 143.5 264.0 347.2 100.8 390.2 206.9 409.6 522.1 434.0 106.2    7
30 352.6 525.8 518.8 402.6 383.9 335.5 482.3 475.5 571.4 418.2    8
30 526.2 494.7 431.8 134.3 170.4 469.1 408.2 610.3 614.1 406.0    9
30 622.8 626.9 570.5 542.4 505.6 642.9 530.4 444.6 130.9 658.2   10
30 561.7 664.2 669.3 288.8 481.8 416.7 440.4 617.1 411.2 599.0   11
30 548.3 506.4 320.4 628.0 378.8 606.9 505.0 471.4 662.6 562.8   12
30 225.9 388.0 477.3 548.9 651.5 494.1 483.9 634.1 546.4 630.1   13
30 683.9 654.8 511.3 151.2 173.4 152.0 465.4 736.3 445.1 545.6   14
30 714.1 665.4 659.6 727.8 409.0 683.3 631.0 565.9 779.1 668.2   15
30 709.4 770.3 629.8 734.4 631.7 554.0 681.9 786.9 684.9 650.4   16
30 305.9 470.5 446.5 362.1 703.3 341.7 590.4 576.8 628.2 671.7   17
30 594.8 473.8 546.7 638.2 388.3 526.4 480.4 353.6 482.0 571.7   18
30 334.5 157.2 242.3 544.0 696.7 609.1 620.1 559.8 644.4 582.7   19
30 500.7 721.1 687.5 566.6 613.3 585.5 662.0 530.1 509.2 619.9   20
30 764.0 762.3 431.3 550.7 612.4 463.4 232.9 228.3 352.2 630.2   21
30 672.0 540.8 522.8 529.6 574.1 503.9 384.3 451.7 713.8 313.2   22
30 658.5 306.2 462.9 711.8 708.9 699.4 604.1 461.5 550.2 492.0   23
30 645.3 467.9 433.4 163.2 458.4 623.7 265.8 666.9 663.3 613.1   24
30 308.1 482.2 520.9 644.9 641.1 629.4 511.7 550.8 560.7 554.7   25
30 365.7 466.0 428.0 492.3 272.1 285.2 316.2 389.4 343.8 579.3   26
30 575.9 524.3 434.4 454.6 349.4 543.4 371.5 208.1 354.8 428.8   27
30 359.8 132.7 523.4 519.0 503.1 386.7 429.0 323.7 460.0 376.9   28
30 141.9 279.3 299.1 277.7 230.2 466.5 462.3 340.4 228.5 234.6   29
30  89.1 247.7 403.4 202.1 205.6 270.4 208.0 417.1 361.3 156.5   30
30 235.7 351.6 300.4 394.4 390.8 387.3 250.5 254.1  75.4 227.0   31
30 123.0 147.7 210.1 196.3 172.6  70.9 140.9 201.4 346.2 265.7   32
30 286.4 338.3 335.8 165.8 313.8 302.1 238.3 210.3 185.7 172.6   33
30 276.0 285.6 314.8 230.7 232.7 306.4 307.1 307.2 305.9 286.8   34
30 209.6 302.6 301.7 300.8 300.0 299.3 298.7 298.2 297.7 213.6   35
30 189.8 195.2  59.4 296.8 282.4  59.4  59.4 272.4 190.7 298.4   36
30 299.0 299.7 267.3 183.2 182.8 190.1   0.0   0.0   0.0   0.0   37
```

APPENDIX E1-2

HELP MODEL COMPUTER PROGRAM OUTPUT FILES

Case I: Initial Condition

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:\data\PRCP.D4
TEMPERATURE DATA FILE:       C:\data\TEMP.D7
SOLAR RADIATION DATA FILE:   c:\data\SOLR.D13
EVAPOTRANSPIRATION DATA:     C:\data\NFCEVAP.D11
SOIL AND DESIGN DATA FILE:   C:\data\ISOIL.D10
OUTPUT DATA FILE:            C:\data\IOUT.OUT


TIME:  13:11     DATE:  11/27/2013


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

     TITLE:  LONE MOUNTAIN CELL 15 WESTWARD EXPANSION

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


     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  52
        THICKNESS                   =   120.00   INCHES
        POROSITY                    =     0.5720 VOL/VOL
        FIELD CAPACITY              =     0.2570 VOL/VOL
        WILTING POINT               =     0.0910 VOL/VOL
        INITIAL SOIL WATER CONTENT  =     0.2472 VOL/VOL
        EFFECTIVE SAT. HYD. COND.   =  0.760000024000E-03 CM/SEC


                                  LAYER  2
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  11
        THICKNESS                   =    24.00   INCHES
        POROSITY                    =     0.4640 VOL/VOL
        FIELD CAPACITY              =     0.3100 VOL/VOL
        WILTING POINT               =     0.1870 VOL/VOL
        INITIAL SOIL WATER CONTENT  =     0.3177 VOL/VOL
        EFFECTIVE SAT. HYD. COND.   =  0.639999998000E-04 CM/SEC


                                  LAYER  3
                                  --------

                      TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER   0
        THICKNESS                   =     0.20   INCHES
        POROSITY                    =     0.8500 VOL/VOL
        FIELD CAPACITY              =     0.0100 VOL/VOL
        WILTING POINT               =     0.0050 VOL/VOL
        INITIAL SOIL WATER CONTENT  =     0.0101 VOL/VOL
        EFFECTIVE SAT. HYD. COND.   =  0.720000029000     CM/SEC
        SLOPE                       =     2.00   PERCENT
        DRAINAGE LENGTH             =   229.0    FEET


                                  LAYER  4
                                  --------

                      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         =     2.00   HOLES/ACRE
        FML INSTALLATION DEFECTS    =     2.00   HOLES/ACRE
        FML PLACEMENT QUALITY       =  4 - POOR


                                  LAYER  5
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  17
        THICKNESS                   =     0.20   INCHES
        POROSITY                    =     0.7500 VOL/VOL
        FIELD CAPACITY              =     0.7470 VOL/VOL
        WILTING POINT               =     0.4000 VOL/VOL
        INITIAL SOIL WATER CONTENT  =     0.7470 VOL/VOL
        EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC


                                  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         =     2.00   HOLES/ACRE
        FML INSTALLATION DEFECTS    =     2.00   HOLES/ACRE
        FML PLACEMENT QUALITY       =  4 - POOR


                                  LAYER  7
                                  --------

                      TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER   0
        THICKNESS                   =     0.20   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.   =  0.720000029000     CM/SEC
        SLOPE                       =     2.00   PERCENT
        DRAINAGE LENGTH             =   229.0    FEET


                                  LAYER  8
                                  --------

                      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         =     2.00   HOLES/ACRE
        FML INSTALLATION DEFECTS    =     2.00   HOLES/ACRE
        FML PLACEMENT QUALITY       =  4 - POOR


                                  LAYER  9
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  16
        THICKNESS                   =    36.00   INCHES
        POROSITY                    =     0.4270 VOL/VOL
        FIELD CAPACITY              =     0.4180 VOL/VOL
        WILTING POINT               =     0.3670 VOL/VOL
        INITIAL SOIL WATER CONTENT  =     0.4179 VOL/VOL
        EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


                  GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                  ----------------------------------------

      NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
               SOIL DATA BASE USING SOIL TEXTURE # 7 WITH BARE
               GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
               A SLOPE LENGTH OF  290. FEET.
```

SCS RUNOFF CURVE NUMBER = 88.30
FRACTION OF AREA ALLOWING RUNOFF = 100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 1.000 ACRES
EVAPORATIVE ZONE DEPTH = 10.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 1.391 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 5.720 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 0.910 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 52.484 INCHES
TOTAL INITIAL WATER = 52.484 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM WAYNOKA OKLAHOMA

STATION LATITUDE = 36.44 DEGREES
MAXIMUM LEAF AREA INDEX = 0.00
START OF GROWING SEASON (JULIAN DATE) = 86
END OF GROWING SEASON (JULIAN DATE) = 310
EVAPORATIVE ZONE DEPTH = 10.0 INCHES
AVERAGE ANNUAL WIND SPEED = 12.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 66.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 63.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 66.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.75	1.01	2.16	2.17	4.31	4.28
2.69	3.13	2.28	2.50	1.38	1.08

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
34.80	38.90	47.30	57.60	67.80	77.10
82.70	81.00	72.20	59.40	46.50	35.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA AND STATION LATITUDE = 36.44 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	0.78	1.19	2.57	2.32	4.38	3.97
	2.34	3.06	1.68	2.18	1.26	0.89
STD. DEVIATIONS	0.45	0.78	1.15	1.41	3.03	1.96
	1.51	2.08	1.00	1.34	0.95	0.69
RUNOFF						
TOTALS	0.013	0.064	0.073	0.083	0.514	0.236
	0.107	0.219	0.052	0.195	0.047	0.009
STD. DEVIATIONS	0.036	0.185	0.100	0.146	1.008	0.256
	0.206	0.268	0.096	0.334	0.137	0.037
EVAPOTRANSPIRATION						
TOTALS	0.808	0.896	2.284	2.181	3.160	3.437
	2.487	2.479	1.512	1.820	1.179	0.832
STD. DEVIATIONS	0.479	0.523	0.973	1.042	1.435	1.613
	1.454	1.683	0.933	0.836	0.744	0.455
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.1290	0.0734	0.0413	0.0448	0.1311	0.1567
	0.3756	0.3440	0.1876	0.1780	0.1218	0.1534
STD. DEVIATIONS	0.1479	0.1116	0.1172	0.0570	0.1612	0.1572
	0.4361	0.4001	0.2158	0.2625	0.1424	0.1816
PERCOLATION/LEAKAGE THROUGH LAYER 4						
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
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
LATERAL DRAINAGE COLLECTED FROM 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
PERCOLATION/LEAKAGE THROUGH LAYER 8						
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
PERCOLATION/LEAKAGE THROUGH LAYER 9						
TOTALS	0.0008	0.0006	0.0004	0.0007	0.0005	0.0007
	0.0006	0.0006	0.0005	0.0002	0.0007	0.0006
STD. DEVIATIONS	0.0018	0.0021	0.0008	0.0019	0.0011	0.0011
	0.0013	0.0013	0.0010	0.0004	0.0012	0.0013

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4						
AVERAGES	0.0117	0.0073	0.0037	0.0042	0.0119	0.0147
	0.0340	0.0311	0.0175	0.0161	0.0114	0.0139
STD. DEVIATIONS	0.0134	0.0112	0.0106	0.0053	0.0146	0.0147
	0.0395	0.0362	0.0202	0.0238	0.0133	0.0164
DAILY AVERAGE HEAD ON TOP OF LAYER 6						
AVERAGES	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
DAILY AVERAGE HEAD ON TOP OF LAYER 8						
AVERAGES	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

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	26.63 (5.302)	96662.1	100.00
RUNOFF	1.613 (1.1157)	5854.51	6.057
EVAPOTRANSPIRATION	23.076 (4.1655)	83766.00	86.659
LATERAL DRAINAGE COLLECTED FROM LAYER 3	1.93667 (1.29695)	7030.111	7.27287
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00001 (0.00000)	0.030	0.00003
AVERAGE HEAD ON TOP OF LAYER 4	0.015 (0.010)		
PERCOLATION/LEAKAGE THROUGH	0.00001 (0.00000)	0.030	0.00003

```
   LAYER  6

 AVERAGE HEAD ON TOP           0.000 (    0.000)
   OF LAYER  6

 LATERAL DRAINAGE COLLECTED    0.00001 (  0.00000)        0.022     0.00002
   FROM LAYER  7

 PERCOLATION/LEAKAGE THROUGH   0.00000 (  0.00000)        0.008      0.00001
   LAYER  8

 AVERAGE HEAD ON TOP           0.000 (    0.000)
   OF LAYER  8

 PERCOLATION/LEAKAGE THROUGH   0.00693 (  0.00430)       25.169      0.02604
   LAYER  9

 CHANGE IN WATER STORAGE      -0.004   (  0.8400)       -13.75     -0.014
*******************************************************************************


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

            PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
  ------------------------------------------------------------------------
                                                (INCHES)      (CU. FT.)
                                               ----------    -------------
    PRECIPITATION                                 6.15         22324.500

    RUNOFF                                        3.893        14132.1416

    DRAINAGE COLLECTED FROM LAYER  3              0.07054        256.07175

    PERCOLATION/LEAKAGE THROUGH LAYER  4          0.000000         0.00078

    AVERAGE HEAD ON TOP OF LAYER  4               0.198

    MAXIMUM HEAD ON TOP OF LAYER  4               0.385

    LOCATION OF MAXIMUM HEAD IN LAYER  3
          (DISTANCE FROM DRAIN)                   6.4 FEET

    PERCOLATION/LEAKAGE THROUGH LAYER  6          0.000000         0.00073

    AVERAGE HEAD ON TOP OF LAYER  6               0.000

    DRAINAGE COLLECTED FROM LAYER  7              0.00000          0.00070

    PERCOLATION/LEAKAGE THROUGH LAYER  8          0.000000         0.00002

    AVERAGE HEAD ON TOP OF LAYER  8               0.000

    MAXIMUM HEAD ON TOP OF LAYER  8               0.004

    LOCATION OF MAXIMUM HEAD IN LAYER  7
          (DISTANCE FROM DRAIN)                   0.0 FEET

    PERCOLATION/LEAKAGE THROUGH LAYER  9          0.001371         4.97720

    SNOW WATER                                    1.23          4466.0435


    MAXIMUM VEG. SOIL WATER (VOL/VOL)                     0.4248

    MINIMUM VEG. SOIL WATER (VOL/VOL)                     0.0910

     ***  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           29.5910         0.2466

                       2            7.7605         0.3234

                       3            0.0291         0.1457

                       4            0.0000         0.0000

                       5            0.1494         0.7470

                       6            0.0000         0.0000

                       7            0.0020         0.0100

                       8            0.0000         0.0000

                       9           14.8380         0.4122

                   SNOW WATER       0.000

******************************************************************************
******************************************************************************
```

Case INT: Intermediate Condition

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:\data\PRCP.D4
TEMPERATURE DATA FILE:      C:\data\TEMP.D7
SOLAR RADIATION DATA FILE:  c:\data\SOLR.D13
EVAPOTRANSPIRATION DATA:    C:\data\NFCEVAP.D11
SOIL AND DESIGN DATA FILE:  C:\data\INTSOIL.D10
OUTPUT DATA FILE:           C:\data\INTOUT.OUT


TIME:  13:32     DATE:  11/27/2013


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

     TITLE:  LONE MOUNTAIN CELL 15 WESTWARD EXPANSION

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     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  52
           THICKNESS                    =   600.00   INCHES
           POROSITY                     =     0.5720 VOL/VOL
           FIELD CAPACITY               =     0.2570 VOL/VOL
           WILTING POINT                =     0.0910 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.2550 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.760000024000E-03 CM/SEC


                                  LAYER  2
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  11
           THICKNESS                    =    24.00   INCHES
           POROSITY                     =     0.4640 VOL/VOL
           FIELD CAPACITY               =     0.3100 VOL/VOL
           WILTING POINT                =     0.1870 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.3203 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.639999998000E-04 CM/SEC


                                  LAYER  3
                                  --------

                      TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =     0.20   INCHES
           POROSITY                     =     0.8500 VOL/VOL
           FIELD CAPACITY               =     0.0100 VOL/VOL
           WILTING POINT                =     0.0050 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.0105 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.460000008000     CM/SEC
           SLOPE                        =     2.00   PERCENT
           DRAINAGE LENGTH              =   229.0    FEET


                                  LAYER  4
                                  --------

                      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          =     2.00   HOLES/ACRE
           FML INSTALLATION DEFECTS     =     2.00   HOLES/ACRE
           FML PLACEMENT QUALITY        =  2 - EXCELLENT


                                  LAYER  5
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  17
           THICKNESS                    =     0.20   INCHES
           POROSITY                     =     0.7500 VOL/VOL
           FIELD CAPACITY               =     0.7470 VOL/VOL
           WILTING POINT                =     0.4000 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.7470 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.300000003000E-08 CM/SEC


                                  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          =     2.00   HOLES/ACRE
           FML INSTALLATION DEFECTS     =     2.00   HOLES/ACRE
           FML PLACEMENT QUALITY        =  2 - EXCELLENT


                                  LAYER  7
                                  --------

                      TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =     0.20   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.    =  0.460000008000     CM/SEC
           SLOPE                        =     2.00   PERCENT
           DRAINAGE LENGTH              =   229.0    FEET


                                  LAYER  8
                                  --------

                      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          =     2.00   HOLES/ACRE
           FML INSTALLATION DEFECTS     =     2.00   HOLES/ACRE
           FML PLACEMENT QUALITY        =  2 - EXCELLENT


                                  LAYER  9
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  16
           THICKNESS                    =    36.00   INCHES
           POROSITY                     =     0.4270 VOL/VOL
           FIELD CAPACITY               =     0.4180 VOL/VOL
           WILTING POINT                =     0.3670 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.4179 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC


                 GENERAL DESIGN AND EVAPORATIVE ZONE DATA
                 ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 7 WITH BARE
       GROUND CONDITIONS, A SURFACE SLOPE OF  3.% AND
       A SLOPE LENGTH OF  741. FEET.
```

SCS RUNOFF CURVE NUMBER	=	87.80	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.391	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	5.720	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.910	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	175.908	INCHES
TOTAL INITIAL WATER	=	175.908	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
WAYNOKA OKLAHOMA

STATION LATITUDE	=	36.44 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	10.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	12.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	63.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	66.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.75	1.01	2.16	2.17	4.31	4.28
2.69	3.13	2.28	2.50	1.38	1.08

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
34.80	38.90	47.30	57.60	67.80	77.10
82.70	81.00	72.20	59.40	46.50	35.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA
AND STATION LATITUDE = 36.44 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	0.78	1.19	2.57	2.32	4.38	3.97
	2.34	3.06	1.68	2.18	1.26	0.89
STD. DEVIATIONS	0.45	0.78	1.15	1.41	3.03	1.96
	1.51	2.08	1.00	1.34	0.95	0.69
RUNOFF						
TOTALS	0.013	0.064	0.063	0.074	0.481	0.214
	0.096	0.198	0.046	0.178	0.043	0.008
STD. DEVIATIONS	0.036	0.185	0.091	0.134	0.975	0.237
	0.195	0.248	0.088	0.318	0.128	0.033
EVAPOTRANSPIRATION						
TOTALS	0.779	0.920	2.267	2.193	3.144	3.457
	2.480	2.496	1.573	1.802	1.163	0.856
STD. DEVIATIONS	0.483	0.526	0.942	1.052	1.456	1.603
	1.426	1.713	0.936	0.861	0.739	0.461
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.1563	0.0855	0.0547	0.0421	0.1047	0.1422
	0.2025	0.3763	0.2410	0.2418	0.1831	0.1852
STD. DEVIATIONS	0.1701	0.1078	0.1559	0.0697	0.1202	0.1844
	0.2034	0.3718	0.2512	0.3259	0.2606	0.2269
PERCOLATION/LEAKAGE THROUGH LAYER 4						
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
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
LATERAL DRAINAGE COLLECTED FROM 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
PERCOLATION/LEAKAGE THROUGH LAYER 8						
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
PERCOLATION/LEAKAGE THROUGH LAYER 9						
TOTALS	0.0004	0.0006	0.0004	0.0012	0.0005	0.0007
	0.0002	0.0005	0.0006	0.0004	0.0010	0.0003
STD. DEVIATIONS	0.0005	0.0019	0.0008	0.0026	0.0015	0.0013
	0.0006	0.0006	0.0014	0.0009	0.0015	0.0007

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4						
AVERAGES	0.0221	0.0133	0.0077	0.0062	0.0148	0.0208
	0.0287	0.0533	0.0353	0.0343	0.0268	0.0262
STD. DEVIATIONS	0.0241	0.0169	0.0221	0.0102	0.0170	0.0270
	0.0288	0.0527	0.0368	0.0462	0.0382	0.0321
DAILY AVERAGE HEAD ON TOP OF LAYER 6						
AVERAGES	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	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
DAILY AVERAGE HEAD ON TOP OF LAYER 8						
AVERAGES	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

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	26.63 (5.302)	96662.1	100.00
RUNOFF	1.477 (1.0695)	5362.68	5.548
EVAPOTRANSPIRATION	23.130 (4.1469)	83963.23	86.863
LATERAL DRAINAGE COLLECTED FROM LAYER 3	2.01531 (1.31358)	7315.577	7.56820
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00000 (0.00000)	0.010	0.00001
AVERAGE HEAD ON TOP OF LAYER 4	0.024 (0.016)		
PERCOLATION/LEAKAGE THROUGH	0.00000 (0.00000)	0.010	0.00001

```
  LAYER  6

AVERAGE HEAD ON TOP           0.000 (    0.000)
  OF LAYER  6

LATERAL DRAINAGE COLLECTED    0.00000 (  0.00000)        0.001    0.00000
  FROM LAYER  7

PERCOLATION/LEAKAGE THROUGH   0.00000 (  0.00000)        0.009     0.00001
  LAYER  8

AVERAGE HEAD ON TOP           0.000 (    0.000)
  OF LAYER  8

PERCOLATION/LEAKAGE THROUGH   0.00670 (  0.00475)       24.339     0.02518
  LAYER  9

CHANGE IN WATER STORAGE      -0.001   (  0.8068)        -3.77     -0.004
******************************************************************************


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            PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
  ------------------------------------------------------------------------
                                             (INCHES)      (CU. FT.)
                                            ----------    -------------
     PRECIPITATION                            6.15         22324.500

     RUNOFF                                   3.811        13834.8232

     DRAINAGE COLLECTED FROM LAYER  3         0.04485        162.81241

     PERCOLATION/LEAKAGE THROUGH LAYER  4     0.000000         0.00009

     AVERAGE HEAD ON TOP OF LAYER  4          0.197

     MAXIMUM HEAD ON TOP OF LAYER  4          0.383

     LOCATION OF MAXIMUM HEAD IN LAYER  3
           (DISTANCE FROM DRAIN)              6.4 FEET

     PERCOLATION/LEAKAGE THROUGH LAYER  6     0.000000         0.00003

     AVERAGE HEAD ON TOP OF LAYER  6          0.000

     DRAINAGE COLLECTED FROM LAYER  7         0.00000          0.00001

     PERCOLATION/LEAKAGE THROUGH LAYER  8     0.000000         0.00002

     AVERAGE HEAD ON TOP OF LAYER  8          0.000

     MAXIMUM HEAD ON TOP OF LAYER  8          0.008

     LOCATION OF MAXIMUM HEAD IN LAYER  7
           (DISTANCE FROM DRAIN)              0.0 FEET

     PERCOLATION/LEAKAGE THROUGH LAYER  9     0.001374         4.98647

     SNOW WATER                               1.23          4466.0435


     MAXIMUM VEG. SOIL WATER (VOL/VOL)               0.4307

     MINIMUM VEG. SOIL WATER (VOL/VOL)               0.0910

      ***  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          153.4383       0.2557

                    2            7.4400       0.3100

                    3            0.0020       0.0100

                    4            0.0000       0.0000

                    5            0.1494       0.7470

                    6            0.0000       0.0000

                    7            0.0020       0.0100

                    8            0.0000       0.0000

                    9           14.8449       0.4124

              SNOW WATER         0.000

******************************************************************************
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```

Case FNC: Final Waste Condition – No Final Cover

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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:\data\PRCP.D4
TEMPERATURE DATA FILE:       C:\data\TEMP.D7
SOLAR RADIATION DATA FILE:   c:\data\SOLR.D13
EVAPOTRANSPIRATION DATA:     C:\data\NFCEVAP.D11
SOIL AND DESIGN DATA FILE:   C:\data\FNCSOIL.D10
OUTPUT DATA FILE:            C:\data\FNCOUT.OUT


TIME:  14:11     DATE:  11/27/2013


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

     TITLE:  LONE MOUNTAIN CELL 15 WESTWARD EXPANSION

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


     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  52
        THICKNESS                  =  1128.00   INCHES
        POROSITY                   =     0.5720 VOL/VOL
        FIELD CAPACITY             =     0.2570 VOL/VOL
        WILTING POINT              =     0.0910 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.2560 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  = 0.760000024000E-03 CM/SEC


                                 LAYER  2
                                 --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  11
        THICKNESS                  =    24.00   INCHES
        POROSITY                   =     0.4640 VOL/VOL
        FIELD CAPACITY             =     0.3100 VOL/VOL
        WILTING POINT              =     0.1870 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.3174 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  = 0.639999998000E-04 CM/SEC


                                 LAYER  3
                                 --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER   0
        THICKNESS                  =     0.20   INCHES
        POROSITY                   =     0.8500 VOL/VOL
        FIELD CAPACITY             =     0.0100 VOL/VOL
        WILTING POINT              =     0.0050 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.0107 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  = 0.449999988000     CM/SEC
        SLOPE                      =     2.00   PERCENT
        DRAINAGE LENGTH            =    229.0    FEET


                                 LAYER  4
                                 --------

                    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        =     2.00   HOLES/ACRE
        FML INSTALLATION DEFECTS   =     2.00   HOLES/ACRE
        FML PLACEMENT QUALITY      =  2 - EXCELLENT


                                 LAYER  5
                                 --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  17
        THICKNESS                  =     0.20   INCHES
        POROSITY                   =     0.7500 VOL/VOL
        FIELD CAPACITY             =     0.7470 VOL/VOL
        WILTING POINT              =     0.4000 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.7470 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  = 0.300000003000E-08 CM/SEC


                                 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        =     2.00   HOLES/ACRE
        FML INSTALLATION DEFECTS   =     2.00   HOLES/ACRE
        FML PLACEMENT QUALITY      =  2 - EXCELLENT


                                 LAYER  7
                                 --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER   0
        THICKNESS                  =     0.20   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.  = 0.449999988000     CM/SEC
        SLOPE                      =     2.00   PERCENT
        DRAINAGE LENGTH            =    229.0    FEET


                                 LAYER  8
                                 --------

                    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        =     2.00   HOLES/ACRE
        FML INSTALLATION DEFECTS   =     2.00   HOLES/ACRE
        FML PLACEMENT QUALITY      =  2 - EXCELLENT


                                 LAYER  9
                                 --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                       MATERIAL TEXTURE NUMBER  16
        THICKNESS                  =    36.00   INCHES
        POROSITY                   =     0.4270 VOL/VOL
        FIELD CAPACITY             =     0.4180 VOL/VOL
        WILTING POINT              =     0.3670 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.4179 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  = 0.100000001000E-06 CM/SEC


           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE # 7 WITH BARE
       GROUND CONDITIONS, A SURFACE SLOPE OF 10.% AND
       A SLOPE LENGTH OF  741. FEET.
```

SCS RUNOFF CURVE NUMBER	=	88.20	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.391	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	5.720	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.910	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	311.534	INCHES
TOTAL INITIAL WATER	=	311.534	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM WAYNOKA OKLAHOMA

STATION LATITUDE	=	36.44 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	10.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	12.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	63.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	66.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.75	1.01	2.16	2.17	4.31	4.28
2.69	3.13	2.28	2.50	1.38	1.08

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
34.80	38.90	47.30	57.60	67.80	77.10
82.70	81.00	72.20	59.40	46.50	35.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA AND STATION LATITUDE = 36.44 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	0.78	1.19	2.57	2.32	4.38	3.97
	2.34	3.06	1.68	2.18	1.26	0.89
STD. DEVIATIONS	0.45	0.78	1.15	1.41	3.03	1.96
	1.51	2.08	1.00	1.34	0.95	0.69
RUNOFF						
TOTALS	0.013	0.064	0.071	0.081	0.509	0.231
	0.104	0.214	0.051	0.191	0.046	0.009
STD. DEVIATIONS	0.036	0.185	0.098	0.143	1.002	0.252
	0.203	0.264	0.094	0.331	0.136	0.036
EVAPOTRANSPIRATION						
TOTALS	0.802	0.893	2.287	2.191	3.151	3.416
	2.479	2.503	1.525	1.795	1.190	0.839
STD. DEVIATIONS	0.477	0.525	0.968	1.045	1.445	1.608
	1.442	1.693	0.932	0.853	0.742	0.459
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.1600	0.0835	0.0548	0.0439	0.1051	0.1384
	0.1914	0.3523	0.2352	0.2341	0.1816	0.1867
STD. DEVIATIONS	0.1817	0.1064	0.1540	0.0691	0.1136	0.1766
	0.1915	0.3452	0.2403	0.3142	0.2528	0.2278
PERCOLATION/LEAKAGE THROUGH LAYER 4						
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
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
LATERAL DRAINAGE COLLECTED FROM 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
PERCOLATION/LEAKAGE THROUGH LAYER 8						
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
PERCOLATION/LEAKAGE THROUGH LAYER 9						
TOTALS	0.0004	0.0008	0.0008	0.0006	0.0003	0.0007
	0.0004	0.0005	0.0007	0.0003	0.0009	0.0002
STD. DEVIATIONS	0.0006	0.0024	0.0017	0.0010	0.0010	0.0016
	0.0007	0.0008	0.0015	0.0006	0.0020	0.0004

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4						
AVERAGES	0.0232	0.0133	0.0079	0.0066	0.0152	0.0207
	0.0277	0.0510	0.0352	0.0339	0.0272	0.0270
STD. DEVIATIONS	0.0263	0.0170	0.0223	0.0103	0.0164	0.0264
	0.0277	0.0500	0.0360	0.0455	0.0378	0.0330
DAILY AVERAGE HEAD ON TOP OF LAYER 6						
AVERAGES	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	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0001	0.0001	0.0001
DAILY AVERAGE HEAD ON TOP OF LAYER 8						
AVERAGES	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

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	26.63 (5.302)	96662.1	100.00
RUNOFF	1.586 (1.1075)	5755.68	5.954
EVAPOTRANSPIRATION	23.071 (4.1605)	83747.58	86.640
LATERAL DRAINAGE COLLECTED FROM LAYER 3	1.96706 (1.23186)	7140.432	7.38700
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00000 (0.00000)	0.010	0.00001
AVERAGE HEAD ON TOP OF LAYER 4	0.024 (0.015)		
PERCOLATION/LEAKAGE THROUGH	0.00000 (0.00000)	0.010	0.00001

```
  LAYER  6

AVERAGE HEAD ON TOP           0.000 (    0.000)
  OF LAYER  6

LATERAL DRAINAGE COLLECTED    0.00000 (  0.00000)       0.001    0.00000
  FROM LAYER  7

PERCOLATION/LEAKAGE THROUGH   0.00000 (  0.00000)       0.009     0.00001
  LAYER  8

AVERAGE HEAD ON TOP           0.000 (    0.000)
  OF LAYER  8

PERCOLATION/LEAKAGE THROUGH   0.00671 (  0.00544)      24.375     0.02522
  LAYER  9

CHANGE IN WATER STORAGE      -0.002   (  0.8060)       -5.99     -0.006
******************************************************************************


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

          PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
  ------------------------------------------------------------------------
                                            (INCHES)      (CU. FT.)
                                           ----------    -------------
     PRECIPITATION                           6.15          22324.500

     RUNOFF                                  3.878         14076.3516

     DRAINAGE COLLECTED FROM LAYER  3        0.04328         157.11707

     PERCOLATION/LEAKAGE THROUGH LAYER  4    0.000000          0.00009

     AVERAGE HEAD ON TOP OF LAYER  4         0.194

     MAXIMUM HEAD ON TOP OF LAYER  4         0.378

     LOCATION OF MAXIMUM HEAD IN LAYER  3
           (DISTANCE FROM DRAIN)             6.3 FEET

     PERCOLATION/LEAKAGE THROUGH LAYER  6    0.000000          0.00003

     AVERAGE HEAD ON TOP OF LAYER  6         0.000

     DRAINAGE COLLECTED FROM LAYER  7        0.00000           0.00001

     PERCOLATION/LEAKAGE THROUGH LAYER  8    0.000000          0.00002

     AVERAGE HEAD ON TOP OF LAYER  8         0.000

     MAXIMUM HEAD ON TOP OF LAYER  8         0.008

     LOCATION OF MAXIMUM HEAD IN LAYER  7
           (DISTANCE FROM DRAIN)             0.0 FEET

     PERCOLATION/LEAKAGE THROUGH LAYER  9    0.001374          4.98647

     SNOW WATER                              1.23           4466.0435


     MAXIMUM VEG. SOIL WATER (VOL/VOL)               0.4260

     MINIMUM VEG. SOIL WATER (VOL/VOL)               0.0910

      ***  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.

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


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

              FINAL WATER STORAGE AT END OF YEAR   30
   ----------------------------------------------------------------------
               LAYER        (INCHES)       (VOL/VOL)
               -----        --------       ---------
                 1          288.6470        0.2559

                 2            7.7925        0.3247

                 3            0.0491        0.2454

                 4            0.0000        0.0000

                 5            0.1494        0.7470

                 6            0.0000        0.0000

                 7            0.0020        0.0100

                 8            0.0000        0.0000

                 9           14.8445        0.4123

            SNOW WATER        0.000

******************************************************************************
******************************************************************************
```

Case FC: Final Cover Condition

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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:\data\PRCP.D4
TEMPERATURE DATA FILE:      C:\data\TEMP.D7
SOLAR RADIATION DATA FILE:  c:\data\SOLR.D13
EVAPOTRANSPIRATION DATA:    C:\data\FCEVAP.D11
SOIL AND DESIGN DATA FILE:  C:\data\FCSOIL.D10
OUTPUT DATA FILE:           C:\data\FCOUT.OUT


TIME:  14:28     DATE:  12/ 3/2013


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

     TITLE:  LONE MOUNTAIN CELL 15 WESTWARD EXPANSION

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


     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  11
           THICKNESS                  =     6.00    INCHES
           POROSITY                   =     0.4640 VOL/VOL
           FIELD CAPACITY             =     0.3100 VOL/VOL
           WILTING POINT              =     0.1870 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.2544 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.639999998000E-04 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
                  FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                               LAYER  2
                               --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  26
           THICKNESS                  =    18.00    INCHES
           POROSITY                   =     0.4450 VOL/VOL
           FIELD CAPACITY             =     0.3930 VOL/VOL
           WILTING POINT              =     0.2770 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.3543 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.190000003000E-05 CM/SEC


                               LAYER  3
                               --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     0.20    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.  = 0.349999994000      CM/SEC
           SLOPE                      =    10.00    PERCENT
           DRAINAGE LENGTH            =   741.0     FEET


                               LAYER  4
                               --------

                   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        =     2.00    HOLES/ACRE
           FML INSTALLATION DEFECTS   =     2.00    HOLES/ACRE
           FML PLACEMENT QUALITY      = 4 - POOR


                               LAYER  5
                               --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  17
           THICKNESS                  =     0.20    INCHES
           POROSITY                   =     0.7500 VOL/VOL
           FIELD CAPACITY             =     0.7470 VOL/VOL
           WILTING POINT              =     0.4000 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.6482 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.300000003000E-08 CM/SEC


                               LAYER  6
                               --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  26
           THICKNESS                  =    12.00    INCHES
           POROSITY                   =     0.4450 VOL/VOL
           FIELD CAPACITY             =     0.3930 VOL/VOL
           WILTING POINT              =     0.2770 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.3930 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.190000003000E-05 CM/SEC


                               LAYER  7
                               --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  52
           THICKNESS                  =  1128.00    INCHES
           POROSITY                   =     0.5720 VOL/VOL
           FIELD CAPACITY             =     0.2570 VOL/VOL
           WILTING POINT              =     0.0910 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.2570 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.760000024000E-03 CM/SEC


                               LAYER  8
                               --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER  11
           THICKNESS                  =    24.00    INCHES
           POROSITY                   =     0.4640 VOL/VOL
           FIELD CAPACITY             =     0.3100 VOL/VOL
           WILTING POINT              =     0.1870 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.3100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.639999998000E-04 CM/SEC


                               LAYER  9
                               --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     0.20    INCHES
           POROSITY                   =     0.8500 VOL/VOL
           FIELD CAPACITY             =     0.0100 VOL/VOL
           WILTING POINT              =     0.0050 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.0399 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.999999978000E-02 CM/SEC
           SLOPE                      =     2.00    PERCENT
           DRAINAGE LENGTH            =   229.0     FEET


                               LAYER 10
                               --------

                   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        =     2.00    HOLES/ACRE
           FML INSTALLATION DEFECTS   =     2.00    HOLES/ACRE
```

```
FML PLACEMENT QUALITY       =  2 - EXCELLENT


                LAYER 11
                --------

         TYPE 1 - VERTICAL PERCOLATION LAYER
            MATERIAL TEXTURE NUMBER  17
THICKNESS                   =     0.20   INCHES
POROSITY                    =     0.7500 VOL/VOL
FIELD CAPACITY              =     0.7470 VOL/VOL
WILTING POINT               =     0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.7470 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.300000003000E-08 CM/SEC


                LAYER 12
                --------

         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         =     2.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =     2.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  2 - EXCELLENT


                LAYER 13
                --------

         TYPE 2 - LATERAL DRAINAGE LAYER
            MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     0.20   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.   =  0.999999978000E-02 CM/SEC
SLOPE                       =     2.00   PERCENT
DRAINAGE LENGTH             =   229.0    FEET


                LAYER 14
                --------

         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         =     2.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =     2.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  2 - EXCELLENT


                LAYER 15
                --------

         TYPE 1 - VERTICAL PERCOLATION LAYER
            MATERIAL TEXTURE NUMBER  16
THICKNESS                   =    36.00   INCHES
POROSITY                    =     0.4270 VOL/VOL
FIELD CAPACITY              =     0.4180 VOL/VOL
WILTING POINT               =     0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.4179 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


       GENERAL DESIGN AND EVAPORATIVE ZONE DATA
       ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE #11 WITH A
       GOOD STAND OF GRASS, A SURFACE SLOPE OF 10.%
       AND A SLOPE LENGTH OF  741. FEET.

SCS RUNOFF CURVE NUMBER            =     81.70
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
EVAPORATIVE ZONE DEPTH             =     24.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      7.905  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     10.794  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      6.108  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    325.291  INCHES
TOTAL INITIAL WATER                =    325.291  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR


           EVAPOTRANSPIRATION AND WEATHER DATA
           -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         WAYNOKA              OKLAHOMA

     STATION LATITUDE                         = 36.44 DEGREES
     MAXIMUM LEAF AREA INDEX                  =  3.50
     START OF GROWING SEASON (JULIAN DATE)    =   86
     END OF GROWING SEASON (JULIAN DATE)      =  310
     EVAPORATIVE ZONE DEPTH                   = 24.0  INCHES
     AVERAGE ANNUAL WIND SPEED                = 12.50 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY    = 64.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY    = 66.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY    = 63.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY    = 66.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    OKLAHOMA CITY       OKLAHOMA

         NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
-------     -------     -------     -------     -------     -------
  0.75        1.01        2.16        2.17        4.31        4.28
  2.69        3.13        2.28        2.50        1.38        1.08


NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    OKLAHOMA CITY       OKLAHOMA

    NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
-------     -------     -------     -------     -------     -------
 34.80       38.90       47.30       57.60       67.80       77.10
 82.70       81.00       72.20       59.40       46.50       35.30


NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
         COEFFICIENTS FOR    OKLAHOMA CITY       OKLAHOMA
           AND STATION LATITUDE  =  36.44 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                   0.78     1.19     2.57     2.32     4.38     3.97
                           2.34     3.06     1.68     2.18     1.26     0.89

  STD. DEVIATIONS          0.45     0.78     1.15     1.41     3.03     1.96
                           1.51     2.08     1.00     1.34     0.95     0.69

RUNOFF
------
  TOTALS                  0.018    0.068    0.058    0.191    0.663    0.168
                          0.060    0.087    0.012    0.194    0.060    0.003

  STD. DEVIATIONS         0.048    0.201    0.157    0.464    1.476    0.335
                          0.264    0.187    0.046    0.416    0.240    0.011

EVAPOTRANSPIRATION
------------------
  TOTALS                  0.766    1.051    2.032    2.437    4.858    3.855
                          2.738    2.773    1.591    0.976    0.768    0.638

  STD. DEVIATIONS         0.326    0.361    0.593    0.715    1.361    1.686
                          1.476    1.824    0.842    0.466    0.272    0.238

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                 0.0884   0.0469   0.0854   0.1977   0.0448   0.0050
                         0.0004   0.0001   0.0002   0.0000   0.0034   0.0753

  STD. DEVIATIONS        0.2313   0.0963   0.1792   0.3974   0.1397   0.0142
                         0.0009   0.0003   0.0007   0.0001   0.0184   0.2688
```

PERCOLATION/LEAKAGE THROUGH LAYER 4

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	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002

LATERAL DRAINAGE COLLECTED FROM LAYER 9

TOTALS	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

PERCOLATION/LEAKAGE THROUGH LAYER 10

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

PERCOLATION/LEAKAGE THROUGH LAYER 12

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

LATERAL DRAINAGE COLLECTED FROM LAYER 13

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

PERCOLATION/LEAKAGE THROUGH LAYER 14

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

PERCOLATION/LEAKAGE THROUGH LAYER 15

TOTALS	0.0001	0.0003	0.0006	0.0007	0.0005	0.0006
	0.0006	0.0006	0.0004	0.0006	0.0002	0.0002
STD. DEVIATIONS	0.0003	0.0006	0.0014	0.0024	0.0008	0.0013
	0.0015	0.0022	0.0007	0.0013	0.0004	0.0005

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.1192	0.0063	0.0171	0.0655	0.0054	0.0006
	0.0000	0.0000	0.0000	0.0000	0.0004	0.3409
STD. DEVIATIONS	0.6154	0.0128	0.0502	0.2519	0.0170	0.0018
	0.0001	0.0000	0.0001	0.0000	0.0023	1.8466

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003
	0.0003	0.0003	0.0002	0.0002	0.0002	0.0002
STD. DEVIATIONS	0.0014	0.0013	0.0012	0.0011	0.0011	0.0010
	0.0010	0.0009	0.0008	0.0008	0.0007	0.0007

DAILY AVERAGE HEAD ON TOP OF LAYER 12

AVERAGES	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

DAILY AVERAGE HEAD ON TOP OF LAYER 14

AVERAGES	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

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	26.63 (5.302)	96662.1	100.00
RUNOFF	1.582 (1.7677)	5742.41	5.941
EVAPOTRANSPIRATION	24.482 (3.9498)	88870.85	91.940
LATERAL DRAINAGE COLLECTED FROM LAYER 3	0.54754 (0.77678)	1987.565	2.05620
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00006 (0.00025)	0.231	0.00024
AVERAGE HEAD ON TOP OF LAYER 4	0.046 (0.161)		
LATERAL DRAINAGE COLLECTED FROM LAYER 9	0.00051 (0.00177)	1.860	0.00192
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.00000 (0.00000)	0.007	0.00001
AVERAGE HEAD ON TOP OF LAYER 10	0.000 (0.001)		
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00000 (0.00000)	0.007	0.00001
AVERAGE HEAD ON TOP OF LAYER 12	0.000 (0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 13	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.00000 (0.00000)	0.007	0.00001
AVERAGE HEAD ON TOP OF LAYER 14	0.000 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 15	0.00563 (0.00466)	20.427	0.02113
CHANGE IN WATER STORAGE	0.011 (1.3053)	38.95	0.040

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	6.15	22324.500
RUNOFF	5.056	18353.8789
DRAINAGE COLLECTED FROM LAYER 3	0.05428	197.04381
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000102	0.37043
AVERAGE HEAD ON TOP OF LAYER 4	23.919	
MAXIMUM HEAD ON TOP OF LAYER 4	42.360	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	78.3 FEET	
DRAINAGE COLLECTED FROM LAYER 9	0.00004	0.12760
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 10	0.007	
MAXIMUM HEAD ON TOP OF LAYER 10	0.013	
LOCATION OF MAXIMUM HEAD IN LAYER 9 (DISTANCE FROM DRAIN)	24.7 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 12	0.000	
DRAINAGE COLLECTED FROM LAYER 13	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 14	0.000	
MAXIMUM HEAD ON TOP OF LAYER 14	0.010	
LOCATION OF MAXIMUM HEAD IN LAYER 13 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 15	0.001362	4.94512

```
    SNOW WATER                              1.23         4466.0435

    MAXIMUM VEG. SOIL WATER (VOL/VOL)               0.4494

    MINIMUM VEG. SOIL WATER (VOL/VOL)               0.2545

     ***  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           1.7109         0.2851

                 2           6.6979         0.3721

                 3           0.0020         0.0100

                 4           0.0000         0.0000

                 5           0.1217         0.6086

                 6           4.7160         0.3930

                 7         289.8960         0.2570

                 8           7.4400         0.3100

                 9           0.0024         0.0118

                10           0.0000         0.0000

                11           0.1494         0.7470

                12           0.0000         0.0000

                13           0.0020         0.0100

                14           0.0000         0.0000

                15          14.8744         0.4132

             SNOW WATER      0.000

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Special Case FC-S: Final Cover Condition

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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:\data\PRCP.D4
TEMPERATURE DATA FILE:     C:\data\TEMP.D7
SOLAR RADIATION DATA FILE: c:\data\SOLR.D13
EVAPOTRANSPIRATION DATA:   C:\data\FCEVAP.D11
SOIL AND DESIGN DATA FILE: C:\data\FCSOIL.D10
OUTPUT DATA FILE:          C:\data\FCSOUT.OUT


TIME: 14:51    DATE: 11/27/2013


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

     TITLE:  LONE MOUNTAIN CELL 15 WESTWARD EXPANSION

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


     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  11
           THICKNESS                  =     6.00   INCHES
           POROSITY                   =     0.4640 VOL/VOL
           FIELD CAPACITY             =     0.3100 VOL/VOL
           WILTING POINT              =     0.1870 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.2544 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.639999998000E-04 CM/SEC
         NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.63
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
           THICKNESS                  =    18.00   INCHES
           POROSITY                   =     0.4450 VOL/VOL
           FIELD CAPACITY             =     0.3930 VOL/VOL
           WILTING POINT              =     0.2770 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.3543 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.190000003000E-05 CM/SEC


                                   LAYER  3
                                   --------

                       TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     0.20   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.  = 0.430000007000      CM/SEC
           SLOPE                      =    10.00   PERCENT
           DRAINAGE LENGTH            =   741.0    FEET


                                   LAYER  4
                                   --------

                       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        =     2.00   HOLES/ACRE
           FML INSTALLATION DEFECTS   =     2.00   HOLES/ACRE
           FML PLACEMENT QUALITY      = 4 - POOR


                                   LAYER  5
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  17
           THICKNESS                  =     0.20   INCHES
           POROSITY                   =     0.7500 VOL/VOL
           FIELD CAPACITY             =     0.7470 VOL/VOL
           WILTING POINT              =     0.4000 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.6482 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.300000003000E-08 CM/SEC


                                   LAYER  6
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  26
           THICKNESS                  =    12.00   INCHES
           POROSITY                   =     0.4450 VOL/VOL
           FIELD CAPACITY             =     0.3930 VOL/VOL
           WILTING POINT              =     0.2770 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.3930 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.190000003000E-05 CM/SEC


                                   LAYER  7
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  52
           THICKNESS                  =  1128.00   INCHES
           POROSITY                   =     0.5720 VOL/VOL
           FIELD CAPACITY             =     0.2570 VOL/VOL
           WILTING POINT              =     0.0910 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.2570 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.760000024000E-03 CM/SEC


                                   LAYER  8
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  11
           THICKNESS                  =    24.00   INCHES
           POROSITY                   =     0.4640 VOL/VOL
           FIELD CAPACITY             =     0.3100 VOL/VOL
           WILTING POINT              =     0.1870 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.3100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.639999998000E-04 CM/SEC


                                   LAYER  9
                                   --------

                       TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     0.20   INCHES
           POROSITY                   =     0.8500 VOL/VOL
           FIELD CAPACITY             =     0.0100 VOL/VOL
           WILTING POINT              =     0.0050 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.0105 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  = 0.430000007000      CM/SEC
           SLOPE                      =     2.00   PERCENT
           DRAINAGE LENGTH            =   229.0    FEET


                                   LAYER 10
                                   --------

                       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        =     2.00   HOLES/ACRE
           FML INSTALLATION DEFECTS   =     2.00   HOLES/ACRE
```

```
FML PLACEMENT QUALITY       = 2 - EXCELLENT


                  LAYER 11
                  --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  17
THICKNESS                  =      0.20   INCHES
POROSITY                   =      0.7500 VOL/VOL
FIELD CAPACITY             =      0.7470 VOL/VOL
WILTING POINT              =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.7470 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.300000003000E-08 CM/SEC


                  LAYER 12
                  --------

             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        =      2.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =      2.00   HOLES/ACRE
FML PLACEMENT QUALITY      = 2 - EXCELLENT


                  LAYER 13
                  --------

             TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                  =      0.20   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.  = 0.430000007000      CM/SEC
SLOPE                      =      2.00   PERCENT
DRAINAGE LENGTH            =    229.0    FEET


                  LAYER 14
                  --------

             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        =      2.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =      2.00   HOLES/ACRE
FML PLACEMENT QUALITY      = 2 - EXCELLENT


                  LAYER 15
                  --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                  =     36.00   INCHES
POROSITY                   =      0.4270 VOL/VOL
FIELD CAPACITY             =      0.4180 VOL/VOL
WILTING POINT              =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.4179 VOL/VOL
EFFECTIVE SAT. HYD. COND.  = 0.100000001000E-06 CM/SEC


        GENERAL DESIGN AND EVAPORATIVE ZONE DATA
        ----------------------------------------

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
        SOIL DATA BASE USING SOIL TEXTURE #11 WITH A
        GOOD STAND OF GRASS, A SURFACE SLOPE OF 10.%
        AND A SLOPE LENGTH OF  741. FEET.

SCS RUNOFF CURVE NUMBER            =     81.70
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      1.000  ACRES
EVAPORATIVE ZONE DEPTH             =     24.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      7.905  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     10.794  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      6.108  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    325.285  INCHES
TOTAL INITIAL WATER                =    325.285  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR


          EVAPOTRANSPIRATION AND WEATHER DATA
          ----------------------------------

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          WAYNOKA              OKLAHOMA

     STATION LATITUDE                        = 36.44 DEGREES
     MAXIMUM LEAF AREA INDEX                 =  3.50
     START OF GROWING SEASON (JULIAN DATE)   =   86
     END OF GROWING SEASON (JULIAN DATE)     =  310
     EVAPORATIVE ZONE DEPTH                  = 24.0  INCHES
     AVERAGE ANNUAL WIND SPEED               = 12.50 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   = 64.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   = 66.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   = 63.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   = 66.00 %


 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    OKLAHOMA CITY       OKLAHOMA

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
-------    -------    -------    -------    -------    -------
  0.75       1.01       2.16       2.17       4.31       4.28
  2.69       3.13       2.28       2.50       1.38       1.08


 NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    OKLAHOMA CITY       OKLAHOMA

     NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
-------    -------    -------    -------    -------    -------
 34.80      38.90      47.30      57.60      67.80      77.10
 82.70      81.00      72.20      59.40      46.50      35.30


 NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    OKLAHOMA CITY       OKLAHOMA
            AND STATION LATITUDE  =  36.44 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                   0.78     1.19     2.57     2.32     4.38     3.97
                           2.34     3.06     1.68     2.18     1.26     0.89

  STD. DEVIATIONS          0.45     0.78     1.15     1.41     3.03     1.96
                           1.51     2.08     1.00     1.34     0.95     0.69

RUNOFF
------
  TOTALS                  0.018    0.068    0.058    0.189    0.663    0.168
                          0.060    0.087    0.012    0.194    0.060    0.002

  STD. DEVIATIONS         0.048    0.201    0.157    0.463    1.476    0.335
                          0.264    0.186    0.046    0.416    0.240    0.007

EVAPOTRANSPIRATION
------------------
  TOTALS                  0.766    1.051    2.032    2.437    4.860    3.856
                          2.738    2.773    1.591    0.976    0.768    0.638

  STD. DEVIATIONS         0.326    0.361    0.593    0.715    1.361    1.686
                          1.476    1.824    0.842    0.466    0.272    0.238

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                 0.0864   0.0451   0.0868   0.1976   0.0420   0.0034
                         0.0005   0.0002   0.0001   0.0000   0.0035   0.0811

  STD. DEVIATIONS        0.2231   0.0934   0.1813   0.3983   0.1370   0.0114
                         0.0009   0.0003   0.0001   0.0001   0.0188   0.2968
```

PERCOLATION/LEAKAGE THROUGH LAYER 4

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

LATERAL DRAINAGE COLLECTED FROM LAYER 9

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	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

PERCOLATION/LEAKAGE THROUGH LAYER 10

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

PERCOLATION/LEAKAGE THROUGH LAYER 12

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

LATERAL DRAINAGE COLLECTED FROM LAYER 13

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

PERCOLATION/LEAKAGE THROUGH LAYER 14

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

PERCOLATION/LEAKAGE THROUGH LAYER 15

TOTALS	0.0004	0.0001	0.0004	0.0003	0.0003	0.0004
	0.0002	0.0002	0.0003	0.0002	0.0002	0.0002
STD. DEVIATIONS	0.0009	0.0003	0.0009	0.0006	0.0006	0.0010
	0.0004	0.0005	0.0006	0.0005	0.0005	0.0003

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0086	0.0049	0.0086	0.0202	0.0042	0.0003
	0.0000	0.0000	0.0000	0.0000	0.0004	0.0080
STD. DEVIATIONS	0.0221	0.0101	0.0180	0.0408	0.0136	0.0012
	0.0001	0.0000	0.0000	0.0000	0.0019	0.0294

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	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

DAILY AVERAGE HEAD ON TOP OF LAYER 12

AVERAGES	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

DAILY AVERAGE HEAD ON TOP OF LAYER 14

AVERAGES	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

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	26.63 (5.302)	96662.1	100.00
RUNOFF	1.580 (1.7676)	5733.70	5.932
EVAPOTRANSPIRATION	24.486 (3.9495)	88883.30	91.953
LATERAL DRAINAGE COLLECTED FROM LAYER 3	0.54652 (0.77892)	1983.876	2.05238
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00000 (0.00000)	0.011	0.00001
AVERAGE HEAD ON TOP OF LAYER 4	0.005 (0.007)		
LATERAL DRAINAGE COLLECTED FROM LAYER 9	0.00027 (0.00112)	0.975	0.00101
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.00000 (0.00000)	0.005	0.00001
AVERAGE HEAD ON TOP OF LAYER 10	0.000 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00000 (0.00000)	0.005	0.00001
AVERAGE HEAD ON TOP OF LAYER 12	0.000 (0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 13	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.00000 (0.00000)	0.005	0.00001
AVERAGE HEAD ON TOP OF LAYER 14	0.000 (0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 15	0.00304 (0.00198)	11.048	0.01143
CHANGE IN WATER STORAGE	0.014 (1.2877)	49.18	0.051

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	6.15	22324.500
RUNOFF	5.056	18353.8496
DRAINAGE COLLECTED FROM LAYER 3	0.06447	234.03278
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.00078
AVERAGE HEAD ON TOP OF LAYER 4	0.198	
MAXIMUM HEAD ON TOP OF LAYER 4	0.397	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 9	0.00002	0.08325
PERCOLATION/LEAKAGE THROUGH LAYER 10	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 10	0.000	
MAXIMUM HEAD ON TOP OF LAYER 10	0.006	
LOCATION OF MAXIMUM HEAD IN LAYER 9 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 12	0.000	
DRAINAGE COLLECTED FROM LAYER 13	0.00000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 14	0.000	
MAXIMUM HEAD ON TOP OF LAYER 14	0.003	
LOCATION OF MAXIMUM HEAD IN LAYER 13 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 15	0.001362	4.94512

```
    SNOW WATER                              1.23          4466.0435

    MAXIMUM VEG. SOIL WATER (VOL/VOL)               0.4478

    MINIMUM VEG. SOIL WATER (VOL/VOL)               0.2545

     ***  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            1.7106         0.2851

                    2            6.6997         0.3722

                    3            0.0020         0.0100

                    4            0.0000         0.0000

                    5            0.1217         0.6086

                    6            4.7160         0.3930

                    7          289.8960         0.2570

                    8            7.4400         0.3100

                    9            0.0020         0.0100

                   10            0.0000         0.0000

                   11            0.1494         0.7470

                   12            0.0000         0.0000

                   13            0.0020         0.0100

                   14            0.0000         0.0000

                   15           14.9519         0.4153

                 SNOW WATER      0.000

******************************************************************************
******************************************************************************
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Exhibit E-2

Geotextile Filter Design

Written by: Y. Bholat	Date: 2/6/2014	Reviewed by: S. Graves	Date: 3/4/2014
Client: Clean Harbors	Project: Lone Mountain Facility	Project No.: TXL0380	Phase No.: 04

GEOTEXTILE FILTER DESIGN

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6/13/2014

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Exp. 06/30/2014

SEALED FOR CALCULATION PAGES
E2-1 THROUGH E2-9

1. PURPOSE

The purpose of this calculation package is to present the design for minimum specified properties of the geotextile component of the geosynthetic drainage layer of the liner system for the Lone Mountain Facility Landfill Cell 15. As shown on the proposed liner system details in Exhibit A of the Engineering Report, a geocomposite drainage layer is proposed to serve as the leachate collection layer, and another geocomposite drainage layer is proposed to serve as the leak detection layer. The geocomposite will be composed of non-woven geotextiles bonded to the top and bottom of a geonet drainage core.

The items evaluated in this design evaluation include: (i) filtration capability and specifications for the geotextile component of the geocomposite drainage layer; and (ii) survivability specifications for the geotextiles. It is noted that the drainage layer design (hydraulic capacity) is presented in Exhibit E3.

2. METHODS OF ANALYSIS

2.1 Geotextile Filtration

The filtration characteristics of the geotextile component of the geocomposite layer will be evaluated using a retention criterion, a permeability criterion, and an anti-clogging criterion, based on methods presented in the following technical literature: Christopher and Holtz (1984), Giroud (1982), Koerner et al. (1994), USEPA (1987).

2.2 Geotextile Survivability

Survivability requirements (grab, tear, and puncture strengths) will also be considered so that the geotextile component of the geocomposite will have adequate resistance to stresses applied on the geotextile during construction (i.e., when concentrated stresses should be the highest), using the method presented in GRI-GT13 (2004).

As each criterion is evaluated and minimum specifications are derived, characteristics of geotextile products on the current market are checked to ensure the specification is reasonable and that products are available that can meet the specification. Also, this calculation package presents minimum required properties. The Landfill Cell 15 CQA Plan presents the required properties that shall be met for these components, which must at least meet the minimum values specified herein; but may in some cases be more stringent.

3. FILTRATION EVALUATION RESULTS

The filtration criteria used for the drainage layer design are presented below in Table E2-1, followed by a description justifying selection of the required design values.

Table E2-1. Filtration Criteria for Geotextile Components (adapted from Christopher and Holtz, 1984; Giroud, 1982; Koerner et al., 1994; and USEPA, 1987)

1. Retention Criterion

1.1. Soils with less than 50% particles < 0.075 mm (US Sieve No. 200)

Density index of the soil (Relative density)		Linear coefficient of uniformity of the soil	
		$1 < C'_u < 3$	$C'_u > 3$
loose soil	$I_D < 35\%$	$O_{95} < C'_u\, d_{50}$	$O_{95} < \frac{9}{C'_u} d_{50}$
medium dense soil	$35\% < I_D < 65\%$	$\boxed{O_{95} < 1.5\, C'_u\, d_{50}}$	$O_{95} < \frac{13.5}{C'_u} d_{50}$
dense soil	$I_D > 65\%$	$O_{95} < 2\, C'_u\, d_{50}$	$O_{95} < \frac{18}{C'_u} d_{50}$

1.2. Soils with more than 50% particles < 0.075 mm (US Sieve No. 200)
$O_{95} \leq 210$ µm (US Sieve No. 70)

Written by: Y. Bholat	Date: 2/6/2014	Reviewed by: S. Graves	Date: 3/4/2014
Client: Clean Harbors	Project: Lone Mountain Facility	Project No.: TXL0380	Phase No.: 04

2. Permeability Criterion

2.1. Critical and/or Severe Applications
$k_{geotextile} > 10\ k_{soil}$

2.2. Noncritical and Nonsevere Applications
$k_{geotextile} > k_{soil}$

3. Anti-Clogging Criterion

Nonwoven geotextiles: porosity, $n_g > 30\%$

Notes:
- O_{95} is the apparent opening size (AOS) of the geotextile
- C'_u = linear coefficient of uniformity = $\sqrt{d'_{100}/d'_0}$
  where d'_{100} and d'_0 are the top and bottom extremities, respectively, of a line drawn through the soil particle-size distribution curve and tangent at d_{50}.
- d_{50} and d_{85} are soil particle sizes for which 50% and 85%, respectively, of particles are finer by weight
- I_D = relative density or density index = $(e - e_{min})/(e_{max} - e_{min})$, where e = soil void ratio; e_{min} = soil minimum void ratio, and e_{max} = soil maximum void ratio
- $k_{geotextile}$ = geotextile hydraulic conductivity; k_{soil} = soil hydraulic conductivity
- porosity, n_g (dimensionless) is calculated as follows: $n_g = 1 - \mu_g/(\rho_g\ t_g)$, where: μ_g = geotextile mass per unit area, ρ_g = polymer density, and t_g = geotextile thickness.

3.1 Geotextile Retention

The geotextile must have openings that are small enough to retain fine-grained soil particles to avoid clogging or flow capacity reduction of the drainage material that it filters. Therefore, the apparent opening size (AOS, hereafter referred to as O_{95}) of the geotextile must be less than a required maximum value. The retention criterion is given in Table E2-1.

The geocomposite drainage layer in the leachate collection system will be overlain by a protective cover that is screened waste and generally exhibits particle size similar to a sandy clay. It is assumed that this material will have more than 50% particles finer than 0.075 mm (U.S. Sieve No. 200). As shown in Table E2-1, for soils classified as clays, the geotextile retention criterion is as follows:

$$O_{95} \leq 210\ \mu m \text{ (U.S. Sieve No. 70)}$$

The range of geotextile mass per unit areas anticipated for use as a filtration layer or drainage layer component are 6 to 16 oz/yd^2 (200 to 540 g/m^2). Typical O_{95} values for 6 to 16 oz/yd^2 geotextiles on the current market range from 90 to 210 μm (IFAI, 2008); thus, products are available that can meet this specification.

3.2 Geotextile Permeability

The geotextile must have openings that are large enough to allow liquid to pass through the retained soil/geotextile interface without significant flow impedance. Thus, the hydraulic conductivity or permeability of the geotextile must be greater than a minimum required value. The permeability criterion is given in Table E2-1. For severe or critical applications, the hydraulic conductivity of the geotextile, $k_{geotextile}$, should be more than ten times greater than the hydraulic conductivity of the retained soil, k_{soil}.

The material retained by the geotextile component of the geocomposite drainage layer on the floor and the side slope is screened waste. Given the importance of long-term function of the drainage layers, the geotextile components are designed so that:

$$(k_{geotextile} > 100\ k_{waste}).$$

The hydraulic conductivity was assumed to be 6.4×10^{-5} for the screened waste (consistent with loosely compacted CL material for calculation purposes). Therefore, the geotextile permeability criterion is as follows:

$$k_{geotextile} > 100 \text{ x } (6.4 \text{ x } 10^{-5} \text{ cm/s}) = 6.4 \text{ x } 10^{-3} \text{ cm/s}$$

Note that some manufacturers report the permeability property as "permittivity" (Ψ), which is defined as Ψ=k/t. Based on the range of geotextile mass per unit areas and thicknesses anticipated for the project (6 to 16 oz/yd^2 (200 to 540 g/m^2) and 1.3 to 5.7 mm, respectively), typical $k_{geotextile}$ values (calculated from typical permittivities and thicknesses) for needle punched non-woven geotextiles are 0.2 to 0.4 cm/sec. Therefore, needle punched non-woven geotextiles within the anticipated range for this project are well above the minimum required permeability value recommended to prevent excessive flow impedance or pore-water pressure development for both types of retained materials.

3.3 Geotextile Anti-Clogging

The geotextile filter must have enough openings so that blocking some of them will not significantly clog the geotextile and inhibit flow into the geonet. Thus, the porosity of the geotextile must be greater than a required minimum value. The clogging criterion is given in Table E2-1. As shown in Table E2-1, for non-woven geotextiles, the geotextile porosity n_g is required to be:

$$n_g > 30\%$$

The clogging criterion requirements apply for the geotextile component of the geocomposite drainage layer. Geotextile porosity is not a property that is directly measured or reported by manufacturers, however it can be calculated as indicated in Table E2-1 (i.e., $n_g = 1 - \mu_g/(\rho_g\ t_g)$).

Typical resulting n_g values for non-woven geotextiles are 50 to 95%. Based on the geotextile density of polypropylene or polyethylene and the range of mass per unit areas and thicknesses anticipated for the project (6 to 16 oz/yd^2 (200 to 540 g/m^2) and 1.3 to 5.7 mm, respectively), the calculated n_g values range from approximately 80% to 90%, which is well in excess of the minimum required porosity required to prevent clogging.

4. SURVIVABILITY EVALUATION RESULTS

Survivability refers to the ability of the geotextile to withstand the stresses during installation and handling in the field. The survivability criteria used for the drainage layer design are presented below in Tables E2-2 and 3 using a two-step method outlined by GRI-GT13 (2004), followed by a discussion on the assumptions used to select the required design values.

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Table E2-2. Required Degree of Survivability as a Function of Subgrade Conditions and Construction Equipment (GRI-GT13)*

Subgrade Conditions	Low ground-pressure equipment (≤ 25 kPa)	Medium ground-pressure equipment (> 25 kPa, ≤ 50 kPa)	High ground-pressure equipment (> 50 kPa)
Subgrade has been cleared of all obstacles except grass, leaves, and fine wood debris. Surface is smooth and level so that any shallow depressions and humps do not exceed 450 mm in depth or height. All larger depressions are filled. Alternatively, a smooth working table may be placed.	Low	Moderate	High
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 450 mm in depth or height. Larger depressions should be filled.	Moderate	High	Very High
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than ± 150 mm above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.	High	Very High	Not Recommended

* Recommendations are for 150 to 300 mm initial lift thickness. For other initial lift thicknesses:
  - 300 to 450 mm: reduce survivability requirement one level;
  - 450 to 600 mm: reduce survivability requirement two levels;
  - > 600 mm: reduce survivability requirement three levels

For special construction techniques such as prerutting, increase the fabric survivability requirement one level. Placement of excessive initial cover material thickness may cause bearing failure of the soft subgrade.

As shown above, the degree of survivability is first evaluated using Table E2-2 with the anticipated installation conditions. The following conditions are conservatively assumed to apply: (i) smooth and level subgrade condition; (ii) initial lift thickness of protective cover placed above geotextile is 24 in.; and (iii) maximum equipment ground pressure of 5 psi (35 kPa) (i.e., medium ground-pressure equipment is used). Using Table E2-2, a "moderate" degree of survivability is used.

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Client: Clean Harbors Project: Lone Mountain Facility Project No.: TXL0380 Phase No.: 04

Table E2-3. GRI-GT13 Geotextile Strength Property Requirements

			Geotextile Classification [1]					
			Class 1 (high)		Class 2 (moderate)		Class 3 (low)	
Tests	Test Methods	Units	Elongation < 50%	Elongation ≥ 50%	Elongation < 50%	Elongation ≥ 50%	Elongation < 50%	Elongation ≥ 50%
Grab strength	ASTM D 4632	N	1400	900	1100	700	800	500
Trapezoid Tear strength	ASTM D 4533	N	500	350	400	250	300	180
CBR Puncture strength	ASTM D 6241	N	2800	2000	2250	1400	1700	1000
Permittivity	ASTM D 4491	s^{-1}	0.02	0.02	0.02	0.02	0.02	0.02
Apparent opening size	ASTM D 4751	mm	0.6	0.6	0.6	0.6	0.6	0.6
Ultraviolet stability [2]	ASTM D 4355	% Ret. @ 500 hrs	50	50	50	50	50	50

Notes: (1) All values are MARV except UV stability (which is a minimum value) and AOS which is a maximum value).

(2) Evaluation to be on 50 mm strip tensile specimens after 500 hours exposure.

In the second step, the minimum required values for the mechanical properties of the geotextile are established from Table E2-3 based on the "moderate" or "Class 2" survivability requirement. The chart provides minimum required values for two ranges of geotextile extensibility. Values were selected for the more extensible range because this range is applicable to non-woven materials that are required for the geotextile. These survivability requirements apply for the geotextile component of the geocomposite drainage layer.

5. CONCLUSIONS

Based on the evaluations herein, the following specifications are recommended for the geotextile component of the geosynthetic drainage layer and the geotextile filter fabric.

- Retention and Filtration of Geotextile Components:
  - Apparent Opening Size, $0_{95} \leq 210$ µm (U.S. Sieve No. 70)
  - Geotextile Water Permeability, $k_{geotextile} \geq 6.4 \times 10^{-3}$ cm/s for geotextile components of the geocomposite overlain by the screened waste protective cover
- Survivability (Mechanical) Properties of Geotextile Components:
  - Grab Strength = 700 N (157 lbs)
  - Trapezoid Tear Strength = 250 N (56 lbs)
  - CBR Puncture Strength = 1400 N (315 lbs)

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Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

6. REFERENCES

Christopher, B.R., and Holtz, R.D., "*Geotextile Engineering Manual*", FHWA-DTFH61-80-C-00094, 1984.

Geosynthetic Research Institute (GRI), "Standard Specification for Test Methods and Properties for Geotextiles Used as Separation Between Subgrade Soil and Aggregate", *"GRI Standard GT-13"*, 2004.

Giroud, J.P., "Filter Criteria for Geotextiles", *Proceedings, Second International Conference on Geotextiles,* Vol. 1, Las Vegas, NV, August 1982, pp. 37-42.

Industrial Fabrics Association International (IFAI), *Geosynthetics Specifier's Guide 2008*, Roseville, MN, January 2008.

Koerner, G.R., Koerner, R.M., and Martin, J.P., "Design of Landfill Leachate-Collection Filters", *ASCE Journal of Geotechnical Engineering*, Vol. 120, No.10, October 1994, pp. 1792-1803.

USEPA, "*Background Document: Proposed Liner and Leak Detection Rule*", EPA\530-SW-87-015, Prepared by GeoServices Inc., May 1987, 526 p.

Exhibit E-3

LCS and LDS Drainage Layer Design

Written by:	Y. Bholat	Date:	2/6/2014	Reviewed by:	S. Graves	Date:	3/4/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

LEACHATE COLLECTION SYSTEM (LCS) AND LEAK DETECTION SYSTEM (LDS) DRAINAGE LAYER DESIGN

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6/13/2014

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Exp. 06/30/2014

SEALED FOR CALCULATION PAGES
E3-1 THROUGH E3-8

1. PURPOSE

The purpose of this calculation package is to present the design of the geosynthetic drainage layer of the leachate collection system (LCS) and leak detection system (LDS) for the Lone Mountain Facility Landfill Cell 15. As shown on the engineering details presented on the permit drawings in Exhibit A of the Engineering Report, the geocomposite drainage layer will be composed of an HDPE geonet core with a needle punched non-woven geotextile bonded to its top and bottom surfaces (i.e., a double-sided geocomposite). It is important to note that this calculation package does not limit the type of geocomposite to single-sided or double-sided; instead a required index transmissivity will be calculated herein for each design case, irrespective of the type of geocomposite drainage product. Refer to the permit drawings in Exhibit A of the Engineering Report, and the CQA Plan, for the material specifications.

The items evaluated in this design evaluation include: hydraulic capacities of the geosynthetic drainage layers and testing conditions for verifying that the required capacities are achieved.

2. METHODS OF ANALYSIS

The drainage layer hydraulic capacity design evaluation is performed using the design-by-function concept presented by Koerner (2005) and based on Darcy's equation (flow rate = hydraulic conductivity × hydraulic gradient × cross-sectional area of flow) for hydraulic flow in porous, saturated media. The approach herein then follows the design methodologies presented in Giroud et al. (2000) and GRI-GC8 (2001).

Written by: Y. Bholat Date: 2/6/2014 Reviewed by: S. Graves Date: 3/4/2014

Client: Clean Harbors Project: Lone Mountain Facility Project No.: TXL0380 Phase No.: 04

The design method involves the following steps:

Step 1) Calculate the required (design) transmissivity (θ_{req}) based on results of leachate generation calculations using the USEPA Hydrologic Evaluation of Landfill Performance (*HELP*) model.

Step 2) Apply a global factor of safety (FS) to find the allowable flow rate and corresponding "Long-Term In-Soil" (LTIS) transmissivity (θ_{LTIS}).

Step 3) Apply partial reduction factors (RFs) for creep, chemical clogging, and biological clogging to account for the long-term decrease in flow capacity behavior, and calculate the baseline flow rate and corresponding baseline transmissivity (θ_{100}).

Step 4) Determine the critical operational case for θ_{100} by comparing required θ_{100} to typical θ_{100} for biplanar geocomposites at various loading conditions.

Step 5) Identify GRI-GC8 test conditions to measure θ_{100}. The resulting θ_{100} from Step 4 is a product specification for the baseline laboratory test transmissivity that should be achieved if tested in accordance with GRI-GC8, Part 6 (2001). Therefore, it is necessary to identify test conditions which simulate site-specific loading conditions and boundary conditions.

Step 6) Calculate the index transmissivity that corresponds to the baseline transmissivity from previous steps. Geocomposite manufacturers typically provide product index transmissivities based on laboratory tests in which the drainage layer is sandwiched between two steel plates as opposed to site specific boundary conditions. The index transmissivity is determined by applying a reduction factor to θ_{100} to account for geotextile/soil intrusion.

3. HYDRAULIC CAPACITY EVALUATION

Step 1) Calculate Required (Design) Transmissivity, θ_{req}

As presented in Exhibit E1, the *HELP* model was used to calculate the required (design) in-plane hydraulic conductivity and equivalent transmissivity of the leachate drainage layer. The required transmissivity is based on maintaining the peak daily average head on the liner less than or equal to the approximate thickness of the drainage layer. The required (design) transmissivity, θ_{req}, was calculated for each operational condition, and the results are repeated below.

Case Designation	Operational Condition	Waste + Protective Cover Thickness (ft)	Soil Cover Thickness (ft)	Design Transmissivity θ_{req} (m^2/s)
I	Initial	12	0	3.7E-05
INT	Intermediate	52	0	2.3E-05
FNC	Final Waste - No Cover	96	0	2.3E-05
FC	Final	96	3	5.1E-07

Step 2) Calculate Allowable "Long Term In Soil" Transmissivity, θ_{LTIS}

The allowable "Long Term In Soil" transmissivity, θ_{LTIS} is calculated by applying a factor of safety to increase the minimum required transmissivity. For leachate drainage layers, a factor of safety (FS) of 2 was assumed in the analysis.

$$\theta_{LTIS} = \theta_{req} * FS \qquad \text{(Eqn. 1)}$$

The θ_{LTIS} was calculated for each operational condition, as shown below.

Case	θ_{req} (m^2/s)	θ_{LTIS} (m^2/s)
I	3.7E-05	7.3E-05
INT	2.3E-05	4.7E-05
FNC	2.3E-05	4.6E-05
FC	5.1E-07	1.0E-06

Step 3) Calculate Baseline Geocomposite Transmissivity, θ_{100}

Factors which account for additional long-term transmissivity reduction due to intrusion, creep, chemical clogging, and biological clogging were applied to determine the minimum baseline product transmissivity, θ_{100}, for laboratory testing results as shown in Eqns. 2 and 3.

$$\theta_{LTIS} = \frac{\theta_{100}}{RF_{CR} RF_{CC} RF_{BC}} \qquad \text{(Eqn. 2)}$$

Where RF_{CR} = reduction factor for creep, RF_{CC} = reduction factor for chemical clogging and/or precipitation of chemicals, and RF_{BC} = reduction factor for biological clogging.

Creep is the long-term reduction in thickness of the drainage layer under a sustained compressive stress. For leachate collection systems, Koerner (2005) recommends that reduction factors for creep range from 1.4 to 2.0. For the final cover condition (Cases FNC and FC), the reduction factor for creep is assumed to be 1.75. The reduction factor for creep for initial case (Case I) is assumed to be 1, and then increased to 1.5 for the intermediate case (Case INT).

GRI (2001) provides guidance for clogging reduction factors for leachate collection systems. Chemical and biological clogging is expected to increase over time as leachate passes through the geocomposite. Thus, the reduction factors for clogging are assumed to increase from initial operational conditions through final cover conditions. GRI (2001) recommends a chemical clogging reduction factor between 1.5 and 2.0 and a biological clogging reduction factor between 1.1 and 1.3 at final conditions. Based on recommendations by GRI, the chemical clogging reduction factors are assumed to increase from 1.0 to 2.0 from initial through final cover conditions. For biological clogging, the assumed reduction factors increase from 1 to 1.2 from initial through final cover conditions.

Rearranging Eqn. 2 and substituting θ_{LTIS} and the reduction factors above, we obtain the following equation:

$$\theta_{100} = \theta_{LTIS}\, RF_{CR}\, RF_{CC}\, RF_{BC} \qquad \text{(Eqn. 3)}$$

The θ_{100} was calculated for each operational condition, as shown below.

Cases	θ_{LTIS} (m^2/s)	RF_{CR}	RF_{CC}	RF_{BC}	RF_{total}	θ_{100} (m^2/s)
I	7.3E-05	1.0	1.0	1.0	1.0	7.3E-05
INT	4.7E-05	1.5	1.7	1.1	2.8	1.3E-04
FNC	4.6E-05	1.75	2.0	1.2	4.2	1.9E-04
FC	1.0E-06	1.75	2.0	1.2	4.2	4.3E-06

Step 4) Calculate the Critical Operational Case for θ_{100}

Geosyntec contacted SKAPS Industries to obtain θ_{100} data for a common biplanar geocomposite on the market. The data correspond to the product, TN 270-2-8, a geocomposite with non-woven geotextile on both sides of the geonet. This does not constitute specification or endorsement of this product; it is merely intended to compare the required transmissivities to a commercially available product to check reasonableness of the design and availability of products. The TN 270-2-8 geocomposite transmissivity was measured at a gradient of 0.1 while sandwiched between sand and a geomembrane for a seating time of 100 hours under four different normal stresses.

To compare the required θ_{100} to the typical θ_{100} on the market, the normal stress expected for each operational condition must be calculated. The stress can be determined from the thickness of fill to be placed above the drainage layer as follows:

$$p = \gamma_{waste} h_{waste} + \gamma_{cover} h_{cover} \qquad \text{(Eqn. 4)}$$

where: p represents the normal stress, γ represents the density of the waste or the protective cover soil, and h represents the thickness of the waste or protective cover soil. The stress was calculated for each operational condition, as shown below.

Cases	h_{waste} (ft)	Average γ_{waste} (pcf)	h_{cover} (ft)	γ_{cover} (pcf)	Stress (psf)	θ_{100} (m^2/s)
I	12	120	0	120	1,440	7.3E-05
INT	52	120	0	120	6,240	1.3E-04
FNC	96	120	0	120	11,520	1.9E-04
FC	96	120	3	120	11,880	4.3E-06

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The required (minimum) θ_{100} is plotted versus the calculated stress in Figure E3-1. The expected θ_{100} data for a typical biplanar geocomposite is shown for reference. As shown in Figure E3-1, the required θ_{100} for all operational cases are less than θ_{100} for a typical biplanar geocomposite at corresponding stress conditions. Therefore, the geocomposite should provide adequate hydraulic capacity for operational conditions. By inspection of Figure E3-1, the most critical operational condition for the geocomposite drainage layer is the final waste condition with no cover (FNC). The critical condition occurs where the difference between required θ_{100} and measured θ_{100} is the least. The required θ_{100} is 1.9 x 10^{-4} m^2/s and the applied stress is approximately 11,500 psf.

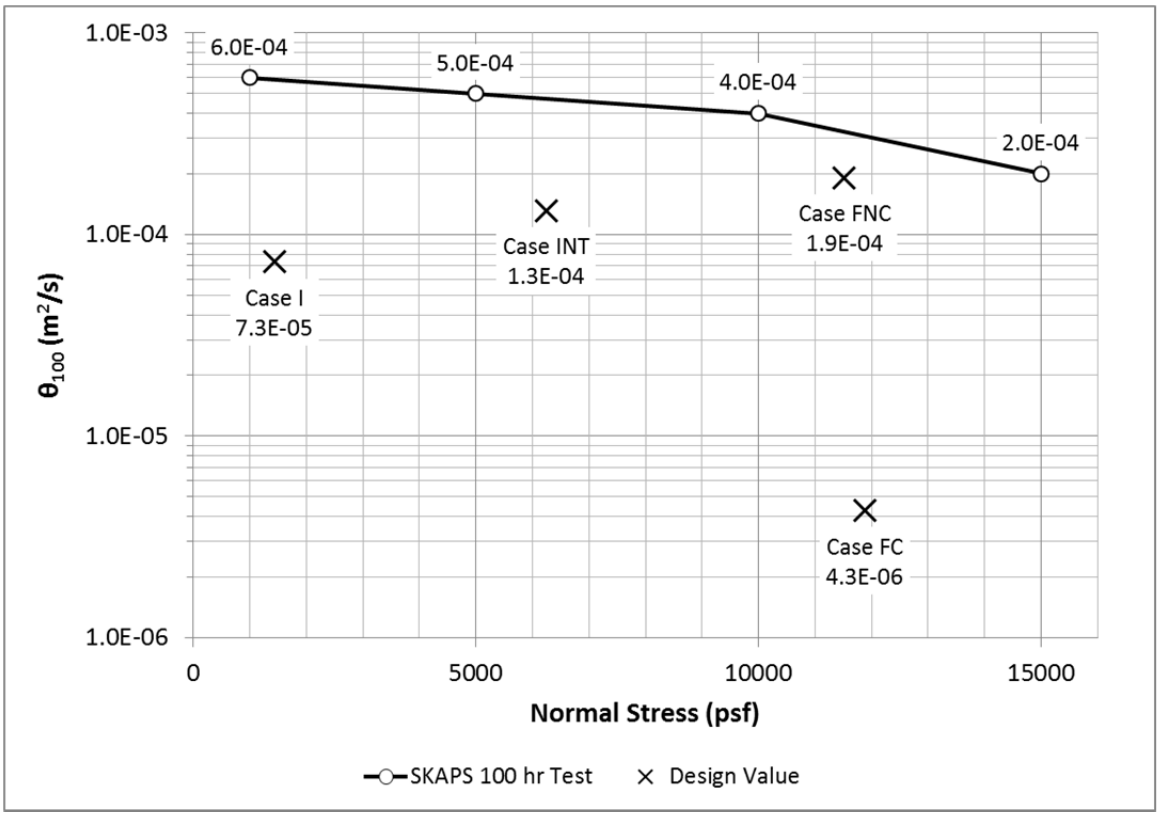

Figure E3-1. Comparison of Required θ_{100} to Typical θ_{100} Test Results at Various Normal Stresses. Note: The typical product information shown does not constitute an endorsement of these products, nor does this require the use of any specific manufacturer or product. This information is presented for comparison purposes only.

Step 5) Identify Site-Specific Conditions for Evaluating θ_{100}

The testing conditions to be used in evaluating θ_{100} using GRI Standard GC8, Part 6 are: (i) the testing configuration (i.e., stratum configuration); (ii) the applied stress; and (iii) the hydraulic gradient. These conditions are specified below.

- The recommended testing configuration for transmissivity testing of the leachate drainage layer should consist of a 60-mil HDPE geomembrane on one side of the geocomposite specimen (to simulate site-specific liner design) and a clay type of soil on the other side of the geocomposite specimen (to simulate the protective cover of screened waste).
- The stress to be applied in testing the leachate drainage layer should be equivalent to the stress at the most critical condition found in Step 4. As noted in Step 4, the most critical operational condition for the geocomposite occurs at final condition with no cover, Case FNC. Therefore, the stress on the leachate drainage layer geocomposite material to be used in determining θ_{100} is 11,500 psf.
- The geocomposite drainage layer slopes at about 2% on the cell floor towards the leachate corridor. Therefore, the hydraulic gradient to be used in determining θ_{100} for the geocomposite is 0.02.

Step 6) Determine Index Transmissivity, θ_{INDEX}, Based on θ_{100}

While the θ_{100} given above is suitable for use as a specification if desired, it is usually more convenient to report the transmissivity between two steel plates for a short duration test since manufacturers of geocomposite drainage materials often present the hydraulic capacities of their product in this manner. These transmissivities are usually higher than those that would be obtained using the site specific boundary conditions of soil on one side and a geomembrane on the other side. This is because the short duration test does not completely account for the time-delayed intrusion of the geotextile into the transmissive core resulting from the deformation of the geotextile under sustained loading. Additionally, the steel plate boundary condition of the short duration test will not account for a reduction in transmissivity due to particle migration into the transmissive core.

To compare the specified θ_{100} of the leachate drainage layer with index values reported by the manufacturer, factors can be applied to account for the reduction of the transmissivity that may be experienced due to intrusion and particulate clogging when testing the drainage layer with boundary materials other than steel plates. The index transmissivity, θ_{INDEX}, which accounts for intrusion and particulate clogging, can be determined as shown in Eqn. 5:

$$\theta_{INDEX} = \theta_{100} * RF_{INT}\, RF_{PC} \qquad \text{(Eqn. 5)}$$

Koerner (2005) recommends using an intrusion reduction factor (RF_{INT}) between 1.5 and 2.0. The intrusion factor of 1.5 was assumed for initial conditions and 2.0 for final conditions. The geotextile is expected to adequately retain particulates to avoid potential clogging of the transmissive core, as discussed in Exhibit E-2; however, a particulate clogging reduction factor

(RF_{PC}) of 1.1 is applied. The index transmissivity, θ_{INDEX}, for the geocomposite at the critical condition specified in step 4 (final waste condition FNC) is found to be:

$$\theta_{INDEX} = 1.9\times10^{-4}\ (m^2/s) \times 2.0 \times 1.1$$
$$\theta_{INDEX} = 4.2\times10^{-4}\ m^2/s$$

Comparison of Calculated Index Transmissivity to Minimum Regulatory Requirements

According to 40 CFR §264.301, the minimum transmissivity for a geosynthetic material used as a drainage layer in the liner system of a landfill disposing hazardous waste is 3×10^{-5} m^2/s. The calculated index transmissivity as presented in the above analysis is greater than that required by regulation. Therefore, the calculated transmissivity is more stringent and governs as a minimum requirement.

4. CONCLUSIONS

Based on the evaluations herein, the following specification is recommended for the leachate collection system and leak detection system drainage layer geocomposite.

- $\theta_{INDEX} = 4.2\times10^{-4}$ m^2/s (when tested between two steel plates with an applied stress of 11,500 psf at a gradient of 0.02) based on the site-specific design calculations.
- An index transmissivity equal to or greater than this value should be specified in the Landfill Cell 15 CQA Plan.

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Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

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Exhibit E-4

LCS and LDS Pipe Design

Written by: Y. Bholat Date: 2/6/2014 Reviewed by: S. Graves Date: 3/4/2014

Client: Clean Harbors Project: Lone Mountain Facility Project No.: TXL0380 Phase No.: 04

LCS AND LDS PIPES DESIGN

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SEALED FOR CALCULATION PAGES
E4-1 THROUGH E4-22

1. INTRODUCTION

The purpose of this analysis is to evaluate the hydraulic capacity of the leachate collection system (LCS) and leak detection system (LDS) pipes and the sump riser pipes and to evaluate the ability of the pipes to resist the estimated applied loads with adequate factors of safety at the Lone Mountain Facility Landfill Cell 15. The leachate collection and leak detection pipes within the landfill subcells will be 6" and 4" diameter standard dimension ratio (SDR)-11 (maximum) perforated high-density polyethylene (HDPE), respectively. The riser pipes at the sumps within the subcells will be a minimum 18" diameter SDR-17 (maximum) HDPE.

The function of leachate collection pipes is to convey leachate collected by the leachate drainage layer to the leachate sump. Similarly, leak detection pipes will convey liquid from the leak detection layer to the leak detection sump. The collection pipes must have adequate hydraulic capacity to carry leachate collected by the leachate drainage layer to the sump and should have adequate structural resistance to withstand the estimated applied loads.

The riser pipes will extend from the sumps to the top of the perimeter sideslope. A pump will be placed inside the riser pipe in each sump to transfer the liquid from the sump to the leachate transmission system (LTS). The riser pipes must have adequate structural resistance to withstand the estimated applied loads.

2. METHODS OF ANALYSES

2.1 Pipe Hydraulic Capacity Evaluation

The LCS pipe flow capacities should be greater than the leachate flow entering the pipe. The pipe flow capacity is calculated using Manning's equation for a fully flowing pipe as follows:

$$Q_p = \frac{1.486 {R_h}^{2/3} {i_p}^{0.5} A_p}{n} \quad \text{(Eqn. 1)}$$

where:

- Q_p = pipe flow capacity, cfs;
- R_h = hydraulic radius, ft (i.e., ratio of the flow area to the perimeter of the wetted area, $\frac{B_i}{4}$, where B_i is pipe inner diameter, ft);
- i_p = hydraulic gradient (i.e., slope of the pipe);
- A_p = cross-sectional area of the pipe, ft^2; and
- n = Manning's roughness coefficient.

For a pipe with a circular cross section that is flowing full, Manning's equation assumes steady, uniform, and fully-turbulent conditions. A design n value of 0.009 for HDPE pipe was chosen from Table E4-1 (CPChem, 2003).

The maximum flow rate of leachate entering the leachate collection corridor was calculated using impingement rates provided in Table E1-1 of Exhibit E-1. The peak daily impingement rates for the most critical condition, initial condition Case I, was 1,916 gallons per acre per day (gpad). The leachate collection corridor of Subcell 14, serving an area of 6.05 acres, was calculated to be the most critical with a peak daily flow rate of 11,588 gallons per day (gpd). The maximum flow rate expected from Subcell 14 is compared to the capacity of the leachate corridor collector pipe to ensure that the calculated collector pipe flow capacity is greater than the calculated maximum expected flow rates for all subcells.

Since substantially less flow will be experienced by the LDS pipe compared to the LCS pipe, a detailed evaluation of LDS capacity was not necessary, and it can be concluded by inspection that the LDS pipe capacity will be adequate for the almost negligible flows expected.

2.2 Pipe Strength Evaluation

Four potential strength failure mechanisms for plastic pipes are: (i) wall crushing; (ii) wall buckling; (iii) excessive ring deflection; and (iv) excessive bending strain. These mechanisms are evaluated below using methods presented in the technical literature for flexible plastic pipes [Uni-Bell PVC Pipe Association (Unibell), 1991; Chevron Phillips Chemical Company (CPChem), 2003]. The design methods for flexible plastic pipe are applicable for both PVC and HDPE pipes (U.S. Army Corps of Engineers, 1997).

Stress on Leachate Collection, Leak Detection, and Riser Pipes

Stresses applied to the pipes are estimated for the post-closure condition since loads during construction are expected to be significantly lower than the post-closure stresses. During the post-closure condition, the stress applied to the pipe is due to the overburden materials above the pipe (i.e., waste material and daily, intermediate, and final cover soils). This stress is calculated as follows:

$$\sigma_{max} = \gamma_p D_p \qquad \text{(Eqn. 2)}$$

where:

σ_{max} = stress on the pipe, psf;
γ_p = average unit weight of the overburden materials, pcf; and
D_p = thickness of the overburden materials, ft.

The influence of holes on the pipe stress is not normally accounted for in the design process (Bonaparte et al., 2002) and is not done so here. Instead, perforation locations that have been demonstrated to be less critical in terms of stress concentrations (Brachman and Krushelnitzky, 2002) have been specified (i.e., perforations are located at the pipe shoulders and haunches).

The structural resistance of the 4" and 6" diameter leak detection and leachate collection pipes is evaluated under loading from 124 ft of overburden material (the greatest waste thickness plus the overlying liner system component and final cover system materials).

The structural resistance of the 18" diameter riser pipe is evaluated under loading from 81 ft of overburden material (the greatest waste thickness at the sump plus the overlying liner system component and final cover system materials).

Wall Crushing

Wall crushing can occur when the stress in the pipe wall, due to external vertical pressure, exceeds the compressive strength of the pipe material. The factor of safety against pipe wall crushing may be calculated using the following equation:

$$FS_{wc} = \frac{2\sigma_y}{(SDR-1)\sigma_{max}} \qquad \text{(Eqn. 3)}$$

where:

FS_{wc} = factor of safety against pipe wall crushing;
σ_y = compressive yield strength of the pipe, psf;
SDR = standard dimension ratio of the pipe, i.e., the outer diameter of the pipe divided by the wall thickness of the pipe; and
σ_{max} = maximum stress applied to the pipe, psf.

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Wall Buckling

Wall buckling (a longitudinal wrinkling in the pipe wall) can occur when the external vertical pressure exceeds the critical buckling pressure of the pipe/bedding aggregate system. The factor of safety against pipe wall buckling may be calculated using the following equation:

$$FS_{wb} = \frac{1.2}{\sigma_{max}} \left[\frac{E'E}{(SDR)^3} \right]^{1/2} \qquad \text{(Eqn. 4)}$$

where:

- FS_{wb} = factor of safety against pipe wall buckling;
- σ_{max} = maximum stress applied to the pipe, psi;
- E' = f (E_s, ν, k) = modulus of soil reaction for pipe bedding material, psi;
- E = modulus of elasticity of the pipe material, psi; and
- SDR = standard dimension ratio of the pipe.

The modulus of soil reaction, E′, for pipe bedding is a representative parameter of soil stiffness, which is related to the overburden stress. The modulus of soil reaction is calculated using the Young's modulus of the pipe bedding material (E_s), Poisson's ratio of the pipe bedding material (ν), and an empirical factor (k) based on test data.

The following equation was used to calculate the constrained modulus of the bedding material:

$$M_s = \frac{E_s(1-\nu)}{(1+\nu)(1-2\nu)} \qquad \text{(Eqn. 5)}$$

where:

- M_s = constrained modulus of bedding material, psi;
- E_s = Young's modulus of bedding material, psi; and
- ν = Poisson's ratio of bedding material.

The Young's modulus and Poisson's ratio were taken from data presented by Selig (1990) for soils at various overburden stress levels. For the leachate collection and leak detection pipe analysis, the Young's modulus and Poisson's ratio values are based on a gravel bedding material (i.e., having a classification of GW or GP as defined by the Unified Soil Classification System (USCS)) compacted to 85 percent ASTM D698 at a stress level of 60 psi, the highest stress considered in the Selig (1990) table (Table E4-2). It is assumed that this material will be an AASHTO No. 57 stone or similar material. The calculations for the riser pipes assume two options for the bedding material: (1) a well-graded sand or gravel (having a USCS classification of SP, SW, GP, or GW) compacted to 85 percent ASTM D698 at a stress level of 60 psi; or (2) a clayey soil (having a USCS classification of CL) compacted to 85 percent ASTM D698 at a stress level of 60 psi. It is noted that the maximum applied stress on the pipes are higher than 60 psi, as shown in the calculations below. It is therefore anticipated that the constrained modulus will be even higher than the values calculated for a stress level of 60 psi.

The modulus of soil reaction can then be calculated based on the constrained modulus of the bedding material (M_s) and an empirically derived factor (k).

$$E' = k * M_s \qquad \text{(Eqn. 6)}$$

where:

- E' = modulus of soil reaction for pipe bedding material, psi;
- k = empirically derived factor; and
- M_s = constrained modulus of bedding material, psi.

The value of k may vary form 0.7 to 2.3 (Selig, 1990). For the analysis herein, an average value of k = 1.5 is used.

Ring Deflection

Excessive ring deflection is a horizontal over-deflection of the pipe causing a reversal of curvature of the pipe wall. This can occur if large external vertical pressures are applied to the pipe/bedding aggregate system. Excessive ring deflection can also lead to substantial loss in flow capacity. Ring deflection is calculated using the Modified Iowa Equation (Mosher, 1990):

$$\Delta X = \frac{D_L K W_c}{(EI/r^3)+(0.061E')} \qquad \text{(Eqn. 7)}$$

where:

- ΔX = horizontal deflection or change in diameter, in.;
- D_L = deflection lag factor;
- K = bedding constant;
- W_c = Marston's prism load per unit length of pipe, psi;
- E = short-term modulus of elasticity of the pipe, psi;
- E' = modulus of soil reaction for bedding material, psi;
- I = moment of inertia of the pipe wall per unit length, in.^{4}/in.; and
- r = mean radius of the pipe $\left[\frac{D_{od}-t}{2}\right]$, in.

For PVC pipe, Uni-Bell (1997) recommends a value of 7.5 percent as the allowable ring deflection. For non-pressure heavy wall HDPE pipe, CPChem (2003) does not recommend a specific “allowable deflection”, but instead recommends the bending strain at the predicted deflection be calculated and compared to the allowable strain.

Bending Strain

When a pipe deflects under load, bending strains are induced in the pipe wall. Bending strain occurs in the pipe wall as external pressures are applied to the pipe/bedding aggregate system. Bending strain is calculated using the following equation (Mosher, 1990):

$$\varepsilon_b = f_d \frac{t\Delta y}{D^2} \qquad \text{(Eqn. 8)}$$

where:

- ε_b = bending strain, percent;
- f_d = deformation shape factor (CPChem (2003) recommends a value of 4.28 for elliptical deformation, or 6.0 to account for imperfect deformation. The conservative value of 6.0 was used in the analysis);
- t = minimum wall thickness, in.;
- Δy = vertical deflection, in.; and
- D = mean pipe diameter, in.

The following are recommendations for allowable bending strain from the literature and manufacturers:

- an allowable bending strain of 5 percent is recommended in Wilson-Fahmy and Koerner (1994), based on ASSHTO guidelines for long term use of smooth polyethylene pipes;
- an allowable bending strain of 4.2 percent is recommended as conservative in CPChem (2003) [it is noted that strains up to 8 percent are reported in literature as acceptable for a design period of 50 years]; and
- an allowable bending strain of 3.5 percent is recommended for PVC pipe in US Army Corps of Engineers (1997).

Based on the above information, an allowable strain of 5 percent is selected for HDPE pipe.

3. CALCULATIONS

3.1 Pipe Hydraulic Capacity Calculations

The proposed collector pipe for the leachate collection system is a perforated 6 in. diameter HDPE SDR-11 pipe.

n = Manning's roughness coefficient = 0.009 (CPChem 2003)
i_p = hydraulic gradient = 1 ft/100 ft (1.0 percent slope along drainage corridor)
B_i = 5.42 in / 12 in/ft = 0.4517 ft
R_h = hydraulic radius $= \frac{B_i}{4} = \frac{0.4517\,ft}{4}$ = 0.113 ft
A_p = cross-sectional area of the pipe $= \frac{\pi {B_i}^2}{4} = \frac{\pi (0.4517\,ft)^2}{4}$ = 0.16 ft^2

Based on the parameters above, the flow capacity of the 6 in. diameter pipe is calculated as follows:

$$Q_p = \frac{1.486 {R_h}^{2/3} {i_p}^{0.5} A_p}{n}$$

$$Q_p = (1.486\ ft^{0.33}/s)(0.113\ ft)^{2/3}(0.01)^{0.5}(0.16\ ft^2) / 0.009$$

$$Q_p = 0.618\ ft^3/s = 399{,}441\ gpd$$

Given that the largest peak daily flow rate of leachate into the leachate collection corridor is calculated to be 11,588 gpd (i.e., peak flow for the largest subcell), the calculated pipe flow capacity of 399,441 gpd is predicted to have adequate capacity to convey leachate through the Landfill Cell 15 leachate collection corridors with a wide margin of safety.

3.2 Pipe Strength Calculations

Pipe strength calculations were carried out for the 6" leachate collection pipe; 4" leak detection pipe; and the 18" riser pipes under expected maximum loads (at landfill final grades). In addition, the maximum height of waste that the LCS, LDS, and riser pipes can accommodate with adequate factors of safety and allowable strains were calculated. The input parameters, and calculated and allowable factors of safety, deflections, and strains are presented in Appendix E4-1.

4. SUMMARY AND CONCLUSIONS

4.1 Pipe Hydraulic Capacity Evaluation

The highest peak daily leachate collection rate by a single leachate collection corridor of Landfill Cell 15 is 11,588 gpd. This peak daily leachate flow rate can be conveyed to the sump by a 6-in.

diameter collection pipe that has a calculated flow capacity of 399,441 gpd. Therefore it can be concluded that the LCS pipe has adequate hydraulic capacity, with substantial factor of safety. As noted, the 4-in. diameter LDS pipe will experience an almost negligible quantity of liquid in comparison to that of the 6-in diameter LCS pipe and therefore, by inspection will have adequate hydraulic capacity.

4.2 Pipe Strength Evaluation

4" and 6" ϕ SDR-11 HDPE Leak Detection and Leachate Collection Pipes

Under the expected working stresses resulting from a total waste height of 124 ft on top of the leachate collection and leak detection corridor, the pipe strength evaluation is summarized as follows:

- Factor of safety against pipe wall crushing, FS_{wc} = 2.9 (OK)
- Factor of safety against pipe wall buckling, FS_{wb} = 4.1 (OK)
- Ring deflection = 1.74 % (OK)
- Bending strain = 1.15 % (OK)

Also, for reference, as a back-calculation the maximum height of waste over the corridor that would result in acceptable factors of safety (i.e. FS $\geq$ 1.5) and allowable strains is 220 ft.

18" ϕ SDR-17 HDPE Riser Pipes (granular bedding)

Under the expected working stresses resulting from a total waste height of 81 ft on top of the riser pipes, the pipe strength evaluation is summarized as follows:

- Factor of safety against pipe wall crushing, FSwc = 2.8 (OK)
- Factor of safety against pipe wall buckling, FSwb = 3.2 (OK)
- Ring deflection = 1.24 % (OK)
- Bending strain = 0.49 % (OK)

Also, for reference, as a back-calculation the maximum height of waste over the riser pipes that would result in acceptable factors of safety (i.e. FS $\geq$ 1.5) and allowable strains is 130 ft.

Based on the above results, the specified pipes are anticipated to perform as designed.

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TABLES

Table E4-1. Values of n for use with Manning's Equation (from CPChem, 2003)

Surface	*n, range*	*n, typical design*
Polyethylene pipe	0.008 – 0.011	0.009
Uncoated cast or ductile iron pipe	0.012 – 0.015	0.013
Corrugated steel pipe	0.021 – 0.030	0.024
Concrete pipe	0.012 – 0.016	0.015
Vitrified clay pipe	0.011 – 0.017	0.013
Brick and cement mortar sewers	0.012 – 0.017	0.015
Wood stave	0.010 – 0.013	0.011
Rubble masonry	0.017 – 0.030	0.021

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Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Table E4-2. Modulus of Soil Reaction for Pipe Bedding Material (from Selig, 1990)

Soil Type: SW, SP, GW, GP

Stress level	95% D698			85% D698		
psi (kPa)	E_s	B	v_s	E_s	B	v_s
1 (7)	1600 (11)	2800 (19)	0.40	1300 (9)	900 (6)	0.26
5 (34)	4100 (28)	3300 (23)	0.29	2100 (14)	1200 (8)	0.21
10 (70)	6000 (41)	3900 (27)	0.24	2600 (18)	1400 (10)	0.19
20 (140)	8600 (59)	5300 (37)	0.23	3300 (23)	1800 (12)	0.19
40 (280)	13000 (90)	8700 (60)	0.25	4100 (28)	2500 (17)	0.23
60 (410)	16000 (110)	13000 (90)	0.29	4700 (32)	3500 (24)	0.28

Soil Type: GM, SM, ML, and GC, SC with < 20% fines

Stress level	95% D698			85% D698		
psi (kPa)	E_s	B	v_s	E_s	B	v_s
1 (7)	1800 (12)	1900 (13)	0.34	600 (4)	400 (3)	0.25
5 (34)	2500 (17)	2000 (14)	0.29	700 (5)	450 (3)	0.24
10 (70)	2900 (20)	2100 (14)	0.27	800 (6)	500 (3)	0 23
20 (140)	3200 (22)	2500 (17)	0.29	850 (6)	700 (5)	0.30
40 (280)	3700 (25)	3400 (23)	0.32	900 (6)	1200 (8)	0.38
60 (410)	4100 (28)	4500 (31)	0.35	1000 (7)	1800 (12)	0.41

Soil Type: CL, MH, GC, SC

Stress level	95% D698			85% D698		
psi (kPa)	E_s	B	v_s	E_s	B	v_s
1 (7)	400 (3)	800 (6)	0.42	100 (1)	100 (1)	0.33
5 (34)	800 (6)	900 (6)	0.35	250 (2)	200 (1)	0.29
10 (70)	1100 (8)	1000 (7)	0.32	400 (3)	300 (2)	0.28
20 (140)	1300 (9)	1100 (8)	0.30	600 (4)	400 (3)	0.25
40 (280)	1400 (10)	1600 (11)	0.35	700 (5)	800 (6)	0.35
60 (410)	1500 (10)	2100 (14)	0.38	800 (6)	1300 (9)	0.40

Note: Units of E_s and B are psi (MPa).

FIGURES

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Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

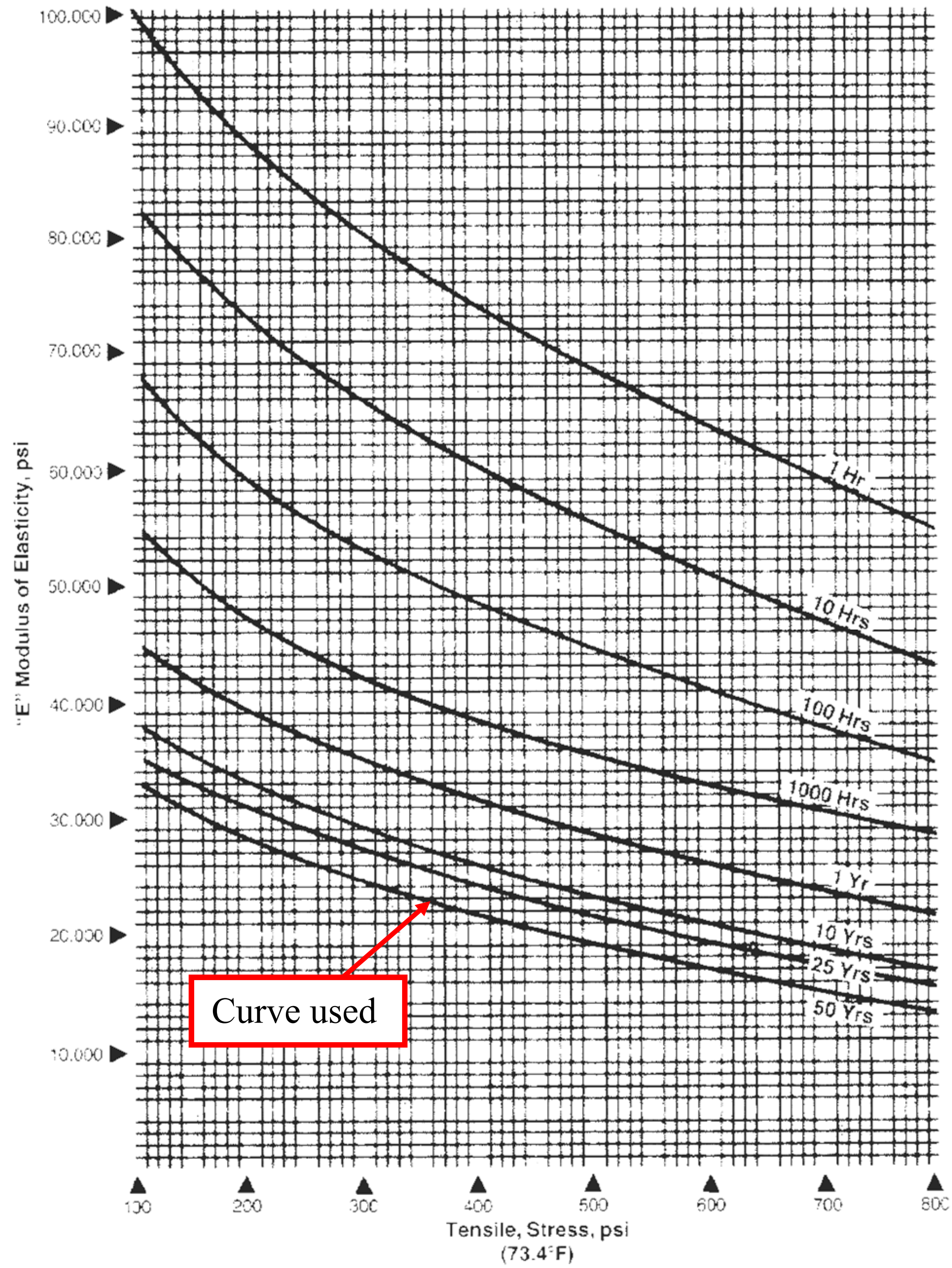

Figure E4-1. Time Dependent Modulus of Elasticity for Polyethylene Pipe (from Phillips 66, 1991)

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Values of Bedding Constant

Bedding Angle (degrees)	K
0	0.110
30	0.108
45	0.105
60	0.102
90	0.096
120	0.090
180	0.083

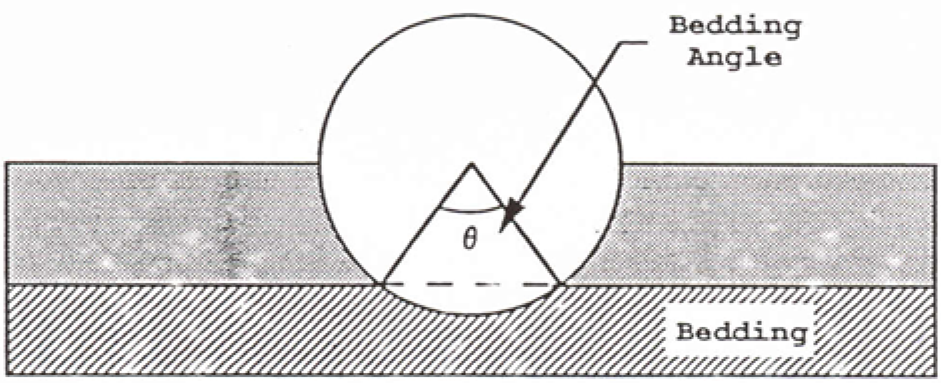

Figure E4-2. Bedding Constant (from Wilson-Fahmy and Koerner, 1994)

APPENDIX E4-1

PIPE STRENGTH CALCULATIONS

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

6”ϕ SDR-11 HDPE Leachate Collection Pipe (working stress)

Lone Mountain Facility - Pipe Strength Design

Performed by: Y. Bholat

Input Parameters

Waste

d_c =	124	ft
γ_{avg} =	120	pcf

Pipe

SDR =	11	
D_{od} =	6.625	in.
t_{min} =	0.602	in.
E =	18,331	psi
σ_y =	1500	psi
D_L =	1.25	
K =	0.083	
k =	1.5	

Bedding Soil

E_s =	4700	psi
ν =	0.28	

Calculated Parameters

σ_{max} =	103.3	psi
M_s =	6009	psi
E' =	9013	psi
W_c =	685	lb/in.
I =	0.01821	in.^{4}/in.
r_{mean} =	3.01	in.
S_A =	516.7	psi

Strength Checks

Wall Crushing

$$\boxed{FS_{WC} = \frac{2\sigma_y}{(SDR-1)\sigma_{max}}}$$

FS_{WC} = 2.9 ≥ 1.5

Wall Buckling

$$\boxed{FS_{wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'E}{SDR^3}\right]^{1/2}}$$

FS_{wb} = 4.1 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$\boxed{\Delta X = \frac{D_L K W_c}{(EI/r^3)+(0.061\,E')}}$$

Change in diameter, ΔX = 0.12 in.

Ring deflection, ΔX% = 1.74 %

Pipe wall bending strain, ε_b.

$$\boxed{\varepsilon_b = 6\cdot\frac{t_{min}\cdot\Delta y}{D^2}}$$

Δy = 0.115 in.

D = 6.02 in.

Bending strain, ε_b = 1.15 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

Varaiable Definition

d_c = maximum thickness of overlying materials, ft;
γ_{avg} = average unit weight of overlying materials (waste, liner and cover), pcf;
SDR = standard dimension ratio of the pipe;
D_{od} = outer diameter of pipe, in [CPChem, 2003];
t_{min} = minimum thickness of the pipe, in. [CPChem, 2003]
E = modulus of elasticity of the pipe material, long-term from Figure 1[based on S_A, Phillips 66, 1991], psi; short-term = 100,000 psi [CPChem, 2003];
σ_y = compressive yield strength of the pipe;
D_L = deflection lag factor (assume 1.25) [Wilson-Fahmy and Koerner, 1994];
K = bedding constant (180º => 0.083) [Wilson-Fahmy and Koerner, 1994; Figure 2];
k = an empirically derived factor for calculating E' (ranges between 0.7 and 2.3, Selig, 1990);
E_s = Young's modulus of the bedding material, psi;
ν = Poisson's ratio of the bedding material;
σ_{max} = maximum stress applied to the pipe, psi;
M_s = constrained modulus of the bedding material;
E' = the modulus of soil reaction for pipe bedding material [Selig, 1990; Table 2], psi;
W_c = Marston's prism load per unit length of pipe, lb/in. [Wilson -Fahmy and Koerner, 1994] = $(\gamma_{avg})(d_c)(D_{od})$;
I = the moment of inertia of the pipe wall per unit length ($t_{min}^3/12$), in.^{4}/in.;
r_{mean} = mean radius = $(D_{od} - t_{min})/2$, in.
$S_A = (SDR-1)\sigma_{max}/2$
FS_{WC} = factor of safety against wall crushing
FS_{wb} = factor of safety against wall buckling
ΔX = maximum horizontal deflection or change in diameter, in;
ΔX% = the ring deflection, %. = $100(\Delta X/D_{od})$
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter $(D_{od}-t_{min})$, in.;

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Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

6”ϕ SDR-11 HDPE Leachate Collection Pipe (back-calculated maximum stress)

Lone Mountain Facility - Pipe Strength Design

Performed by: Y. Bholat

Input Parameters

Waste

d_c =	220	ft
γ_{avg} =	120	pcf

Pipe

SDR =	11	
D_{od} =	6.625	in.
t_{min} =	0.602	in.
E =	7,887	psi
σ_y =	1500	psi
D_L =	1.25	
K =	0.083	
k =	1.5	

Bedding Soil

E_s =	4700	psi
ν =	0.28	

Calculated Parameters

σ_{max} =	183.3	psi
M_s =	6009	psi
E' =	9013	psi
W_c =	1,215	lb/in.
I =	0.01821	$in.^4/in.$
r_{mean} =	3.01	in.
S_A =	916.7	psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR-1)\sigma_{max}}$$

FS_{WC} = 1.6 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'E}{SDR^3}\right]^{1/2}$$

FS_{wb} = 1.5 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$\Delta X = \frac{D_L K W_c}{(EI/r^3) + (0.061\,E')}$$

Change in diameter, ΔX = 0.20 in.

Ring deflection, ΔX% = 3.09 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \cdot \frac{t_{min} \cdot \Delta y}{D^2}$$

Δy = 0.204 in.
D = 6.02 in.

Bending strain, ε_b = 2.04 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

Varaiable Definition

d_c = maximum thickness of overlying materials, ft;
γ_{avg} = average unit weight of overlying materials (waste, liner and cover), pcf;
SDR = standard dimension ratio of the pipe;
D_{od} = outer diameter of pipe, in [CPChem, 2003];
t_{min} = minimum thickness of the pipe, in. [CPChem, 2003]
E = modulus of elasticity of the pipe material, long-term from Figure 1[based on S_A, Phillips 66, 1991], psi; short-term = 100,000 psi [CPChem, 2003];
σ_y = compressive yield strength of the pipe;
D_L = deflection lag factor (assume 1.25) [Wilson-Fahmy and Koerner, 1994];
K = bedding constant (180º => 0.083) [Wilson-Fahmy and Koerner, 1994; Figure 2];
k = an empirically derived factor for calculating E' (ranges between 0.7 and 2.3, Selig, 1990);
E_s = Young's modulus of the bedding material, psi;
ν = Poisson's ratio of the bedding material;
σ_{max} = maximum stress applied to the pipe, psi;
M_s = constrained modulus of the bedding material;
E' = the modulus of soil reaction for pipe bedding material [Selig, 1990; Table 2], psi;
W_c = Marston's prism load per unit length of pipe, lb/in. [Wilson -Fahmy and Koerner, 1994] = (γ_{avg}) (d_c) (D_{od});
I = the moment of inertia of the pipe wall per unit length ($t_{min}^3/12$), $in.^4/in.$;
r_{mean} = mean radius = (D_{od} - t_{min})/2 , in.
S_A = (SDR-1)σ_{max} /2
FS_{WC} = factor of safety against wall crushing
FS_{wb} = factor of safety against wall buckling
ΔX = maximum horizontal deflection or change in diameter, in;
ΔX% = the ring deflection, %. = 100(ΔX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}), in.;

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4”ϕ SDR-11 HDPE Leak Detection Pipe (working stress)

Lone Mountain Facility - Pipe Strength Design

Performed by: Y. Bholat

Input Parameters

Waste

d_c = 124 ft

γ_{avg} = 120 pcf

Pipe

SDR = 11

D_{od} = 4.500 in.

t_{min} = 0.409 in.

E = 18,331 psi

σ_y = 1500 psi

D_L = 1.25

K = 0.083

k = 1.5

Bedding Soil

E_s = 4700 psi

ν = 0.28

Calculated Parameters

σ_{max} = 103.3 psi

M_s = 6009 psi

E' = 9013 psi

W_c = 465 lb/in.

I = 0.00571 $in.^4/in.$

r_{mean} = 2.05 in.

S_A = 516.7 psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR-1)\sigma_{max}}$$

FS_{WC} = 2.9 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'E}{SDR^3}\right]^{1/2}$$

FS_{wb} = 4.1 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$\Delta X = \frac{D_L K W_c}{(EI/r^3) + (0.061E')}$$

Change in diameter, ΔX = 0.08 in.

Ring deflection, ΔX% = 1.74 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \cdot \frac{t_{min} \cdot \Delta y}{D^2}$$

Δy = 0.078 in.

D = 4.09 in.

Bending strain, ε_b = 1.15 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

Varaiable Definition

d_c = maximum thickness of overlying materials, ft;
γ_{avg} = average unit weight of overlying materials (waste, liner and cover), pcf;
SDR = standard dimension ratio of the pipe;
D_{od} = outer diameter of pipe, in [CPChem, 2003];
t_{min} = minimum thickness of the pipe, in. [CPChem, 2003]
E = modulus of elasticity of the pipe material, long-term from Figure 1[based on S_A, Phillips 66, 1991], psi; short-term = 100,000 psi [CPChem, 2003];
σ_y = compressive yield strength of the pipe;
D_L = deflection lag factor (assume 1.25) [Wilson-Fahmy and Koerner, 1994];
K = bedding constant (180º => 0.083) [Wilson-Fahmy and Koerner, 1994; Figure 2];
k = an empirically derived factor for calculating E' (ranges between 0.7 and 2.3, Selig, 1990);
E_s = Young's modulus of the bedding material, psi;
ν = Poisson's ratio of the bedding material;
σ_{max} = maximum stress applied to the pipe, psi;
M_s = constrained modulus of the bedding material;
E' = the modulus of soil reaction for pipe bedding material [Selig, 1990; Table 2], psi;
W_c = Marston's prism load per unit length of pipe, lb/in. [Wilson -Fahmy and Koerner, 1994] = $(\gamma_{avg})(d_c)(D_{od})$;
I = the moment of inertia of the pipe wall per unit length $(t_{min}^3/12)$, $in.^4/in.$;
r_{mean} = mean radius = $(D_{od} - t_{min})/2$, in.
S_A = $(SDR-1)\sigma_{max}/2$
FS_{WC} = factor of safety against wall crushing
FS_{wb} = factor of safety against wall buckling
ΔX = maximum horizontal deflection or change in diameter, in;
ΔX% = the ring deflection, %. = $100(\Delta X/D_{od})$
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter $(D_{od}-t_{min})$, in.;

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4"ϕ SDR-11 HDPE Leak Detection Pipe (back-calculated maximum stress)

Lone Mountain Facility - Pipe Strength Design

Performed by: Y. Bholat

Input Parameters

Waste

d_c = 220 ft

γ_{avg} = 120 pcf

Pipe

SDR = 11

D_{od} = 4.500 in.

t_{min} = 0.409 in.

E = 7,887 psi

σ_y = 1500 psi

D_L = 1.25

K = 0.083

k = 1.5

Bedding Soil

E_s = 4700 psi

ν = 0.28

Calculated Parameters

σ_{max} = 183.3 psi

M_s = 6009 psi

E' = 9013 psi

W_c = 825 lb/in.

I = 0.00571 $in.^4/in.$

r_{mean} = 2.05 in.

S_A = 916.7 psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR-1)\sigma_{max}}$$

FS_{WC} = 1.6 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'E}{SDR^3}\right]^{1/2}$$

FS_{wb} = 1.5 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$\Delta X = \frac{D_L K W_c}{(EI/r^3) + (0.061\,E')}$$

Change in diameter, ΔX = 0.14 in.

Ring deflection, ΔX% = 3.09 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \cdot \frac{t_{min} \cdot \Delta y}{D^2}$$

Δy = 0.139 in.

D = 4.09 in.

Bending strain, ε_b = 2.04 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

Varaiable Definition

d_c = maximum thickness of overlying materials, ft;
γ_{avg} = average unit weight of overlying materials (waste, liner and cover), pcf;
SDR = standard dimension ratio of the pipe;
D_{od} = outer diameter of pipe, in [CPChem, 2003];
t_{min} = minimum thickness of the pipe, in. [CPChem, 2003]
E = modulus of elasticity of the pipe material, long-term from Figure 1[based on S_A, Phillips 66, 1991], psi; short-term = 100,000 psi [CPChem, 2003];
σ_y = compressive yield strength of the pipe;
D_L = deflection lag factor (assume 1.25) [Wilson-Fahmy and Koerner, 1994];
K = bedding constant (180º => 0.083) [Wilson-Fahmy and Koerner, 1994; Figure 2];
k = an empirically derived factor for calculating E' (ranges between 0.7 and 2.3, Selig, 1990);
E_s = Young's modulus of the bedding material, psi;
ν = Poisson's ratio of the bedding material;
σ_{max} = maximum stress applied to the pipe, psi;
M_s = constrained modulus of the bedding material;
E' = the modulus of soil reaction for pipe bedding material [Selig, 1990; Table 2], psi;
W_c = Marston's prism load per unit length of pipe, lb/in. [Wilson -Fahmy and Koerner, 1994] = $(\gamma_{avg})(d_c)(D_{od})$;
I = the moment of inertia of the pipe wall per unit length ($t_{min}^3/12$), $in.^4/in.$;
r_{mean} = mean radius = $(D_{od} - t_{min})/2$, in.
$S_A = (SDR-1)\sigma_{max}/2$
FS_{WC} = factor of safety against wall crushing
FS_{wb} = factor of safety against wall buckling
ΔX = maximum horizontal deflection or change in diameter, in;
ΔX% = the ring deflection, %. = 100(ΔX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}), in.;

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18”ϕ SDR-17 HDPE Riser Pipe (working stress)

Lone Mountain Facility - Pipe Strength Design

Performed by: Y. Bholat

Input Parameters

Waste

d_c =	81	ft
γ_{avg} =	120	pcf

Pipe

SDR =	17	
D_{od} =	18.000	in.
t_{min} =	1.059	in.
E =	17,806	psi
σ_y =	1500	psi
D_L =	1.25	
K =	0.083	
k =	1.5	

Bedding Soil

E_s =	4700	psi
ν =	0.28	

Calculated Parameters

σ_{max} =	67.5	psi
M_s =	6009	psi
E' =	9013	psi
W_c =	1,215	lb/in.
I =	0.09892	$in.^4/in.$
r_{mean} =	8.47	in.
S_A =	540.0	psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR - 1)\sigma_{max}}$$

FS_{WC} = 2.8 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'E}{SDR^3}\right]^{1/2}$$

FS_{wb} = 3.2 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$\Delta X = \frac{D_L K W_c}{(EI / r^3) + (0.061\,E')}$$

Change in diameter, ΔX = 0.22 in.

Ring deflection, ΔX% = 1.24 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \cdot \frac{t_{min} \cdot \Delta y}{D^2}$$

Δy = 0.223 in.
D = 16.94 in.

Bending strain, ε_b = 0.49 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

Varaiable Definition

d_c = maximum thickness of overlying materials, ft;
γ_{avg} = average unit weight of overlying materials (waste, liner and cover), pcf;
SDR = standard dimension ratio of the pipe;
D_{od} = outer diameter of pipe, in [CPChem, 2003];
t_{min} = minimum thickness of the pipe, in. [CPChem, 2003]
E = modulus of elasticity of the pipe material, long-term from Figure 1[based on S_A, Phillips 66, 1991], psi; short-term = 100,000 psi [CPChem, 2003];
σ_y = compressive yield strength of the pipe;
D_L = deflection lag factor (assume 1.25) [Wilson-Fahmy and Koerner, 1994];
K = bedding constant (180º => 0.083) [Wilson-Fahmy and Koerner, 1994; Figure 2];
k = an empirically derived factor for calculating E' (ranges between 0.7 and 2.3, Selig, 1990);
E_s = Young's modulus of the bedding material, psi;
ν = Poisson's ratio of the bedding material;
σ_{max} = maximum stress applied to the pipe, psi;
M_s = constrained modulus of the bedding material;
E' = the modulus of soil reaction for pipe bedding material [Selig, 1990; Table 2], psi;
W_c = Marston's prism load per unit length of pipe, lb/in. [Wilson -Fahmy and Koerner, 1994] = (γ_{avg}) (d_c) (D_{od});
I = the moment of inertia of the pipe wall per unit length ($t_{min}^3/12$), $in.^4/in.$;
r_{mean} = mean radius = (D_{od} - t_{min})/2 , in.
S_A = (SDR-1)σ_{max} /2
FS_{WC} = factor of safety against wall crushing
FS_{wb} = factor of safety against wall buckling
ΔX = maximum horizontal deflection or change in diameter, in;
ΔX% = the ring deflection, %. = 100(ΔX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}), in.;

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18”ϕ SDR-17 HDPE Riser Pipe (back-calculated maximum stress)

Lone Mountain Facility - Pipe Strength Design

Performed by: Y. Bholat

Input Parameters

Waste

d_c =	130	ft
γ_{avg} =	120	pcf

Pipe

SDR =	17	
D_{od} =	18.000	in.
t_{min} =	1.059	in.
E =	9,645	psi
σ_y =	1500	psi
D_L =	1.25	
K =	0.083	
k =	1.5	

Bedding Soil

E_s =	4700	psi
ν =	0.28	

Calculated Parameters

σ_{max} =	108.3	psi
M_s =	6009	psi
E' =	9013	psi
W_c =	1,950	lb/in.
I =	0.09892	$in.^4/in.$
r_{mean} =	8.47	in.
S_A =	866.7	psi

Strength Checks

Wall Crushing

$$FS_{WC} = \frac{2\sigma_y}{(SDR-1)\sigma_{max}}$$

FS_{WC} = 1.7 ≥ 1.5

Wall Buckling

$$FS_{wb} = \frac{1.2}{\sigma_{max}}\left[\frac{E'E}{SDR^3}\right]^{1/2}$$

FS_{wb} = 1.5 ≥ 1.5

Ring deflection (Modified Iowa Equation):

$$\Delta X = \frac{D_L K W_c}{(EI/r^3) + (0.061\,E')}$$

Change in diameter, ΔX = 0.36 in.

Ring deflection, ΔX% = 1.99 %

Pipe wall bending strain, ε_b.

$$\varepsilon_b = 6 \cdot \frac{t_{min} \cdot \Delta y}{D^2}$$

Δy = 0.357 in.

D = 16.94 in.

Bending strain, ε_b = 0.79 %

Allowable wall ring bending strain: from 4.2 to 8% (8% for 50 year design life) - [CPChem, 2003]

Varaiable Definition

d_c = maximum thickness of overlying materials, ft;
γ_{avg} = average unit weight of overlying materials (waste, liner and cover), pcf;
SDR = standard dimension ratio of the pipe;
D_{od} = outer diameter of pipe, in [CPChem, 2003];
t_{min} = minimum thickness of the pipe, in. [CPChem, 2003]
E = modulus of elasticity of the pipe material, long-term from Figure 1[based on S_A, Phillips 66, 1991], psi; short-term = 100,000 psi [CPChem, 2003];
σ_y = compressive yield strength of the pipe;
D_L = deflection lag factor (assume 1.25) [Wilson-Fahmy and Koerner, 1994];
K = bedding constant (180º => 0.083) [Wilson-Fahmy and Koerner, 1994; Figure 2];
k = an empirically derived factor for calculating E' (ranges between 0.7 and 2.3, Selig, 1990);
E_s = Young's modulus of the bedding material, psi;
ν = Poisson's ratio of the bedding material;
σ_{max} = maximum stress applied to the pipe, psi;
M_s = constrained modulus of the bedding material;
E' = the modulus of soil reaction for pipe bedding material [Selig, 1990; Table 2], psi;
W_c = Marston's prism load per unit length of pipe, lb/in. [Wilson -Fahmy and Koerner, 1994] = (γ_{avg}) (d_c) (D_{od});
I = the moment of inertia of the pipe wall per unit length ($t_{min}^3/12$), $in.^4/in.$;
r_{mean} = mean radius = (D_{od} - t_{min})/2 , in.
S_A = (SDR-1)σ_{max} /2
FS_{WC} = factor of safety against wall crushing
FS_{wb} = factor of safety against wall buckling
ΔX = maximum horizontal deflection or change in diameter, in;
ΔX% = the ring deflection, %. = 100(ΔX/D_{od})
ε_b = Bending strain, %;
Δy = Vertical deflection, in. = ΔX;
D = diameter = Mean diameter (D_{od}-t_{min}), in.;

Exhibit E-5

LCS Sump Capacity Calculations

Geosyntec consultants

Written by: Y. Bholat	Date: 2/6/2014	Reviewed & Revised by:	S. Graves	Date:	10/10/2014
Client: Clean Harbors	Project: Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

LEACHATE COLLECTION SYSTEM (LCS) SUMP CAPACITY CALCULATIONS

10/20/2014

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SEALED FOR CALCULATION PAGES
E5-1 THROUGH E5-6

1. INTRODUCTION

The purpose of this calculation package is to provide design calculations for the future leachate collection sumps that will be located at the low point of each new subcell of the Lone Mountain Facility Landfill Cell 15. Accordingly, this evaluation applies to Subcells 14 through 22 of Landfill Cell 15 (i.e., those subcells associated with the proposed expansion covered by this permit modification, which will each be configured according to the geometry described herein and on the drawings in Exhibit A of the Landfill Cell 15 Engineering Report). Note that the sump designs for Subcells 1 through 13 have already been approved as part of previous permit applications, and accordingly, are not part of this calculation package.

Leachate will flow into each subcell sump from a leachate collection corridor, and the floor and sideslope drainage layers immediately adjacent to the sump. Leachate will be removed from the sumps and pumped into the leachate transmission system (LTS). Specifically, in this calculation package, analyses are performed to demonstrate that the leachate sumps provide adequate leachate storage capacity so that a typically-sized submersible pump would not cycle on and off too frequently. The sump also effectively serves as a flow equalization element in the leachate collection system that stabilizes leachate flows from the subcell.

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

2. METHOD OF ANALYSIS

The proposed sumps for Subcells 14 through 22 have the same geometry and are the shape of an inverted truncated pyramid with a square base. The formula for the volume of a truncated pyramid is:

$$V = \frac{1}{3}(a^2 + ab + b^2)H \qquad \text{(Eqn. 1)}$$

where:

V = volume of truncated pyramid (i.e. sump);
a = the side length of the square top;
b = the side length of the square bottom; and
H = height of truncated pyramid.

The volume of the solid particles of the granular drainage material reduces the volume available for leachate storage. The effective volume of leachate storage in the sump is:

$$V_s = V * n \qquad \text{(Eqn. 2)}$$

where:

V_s = effective volume of sump; and
n = effective porosity of granular drainage material.

The pump-on duration is equal to the amount of time it takes to pump down the leachate level from the pump turn on level to the pump turn off level. The pump-on duration is:

$$t_1 = \frac{V_s}{Q_{pump} - Q_{in}} \qquad \text{(Eqn. 3)}$$

where:

t_1 = pump-on duration;
Q_{pump} = pump flow rate; and
Q_{in} = flow rate of leachate into the sump.

The pump-off duration is equal to the amount of time it takes for the sump to fill up from the pump-off level to the pump-on level. The pump-off duration is:

$$t_2 = \frac{V_s}{Q_{in}} \qquad \text{(Eqn. 4)}$$

where:

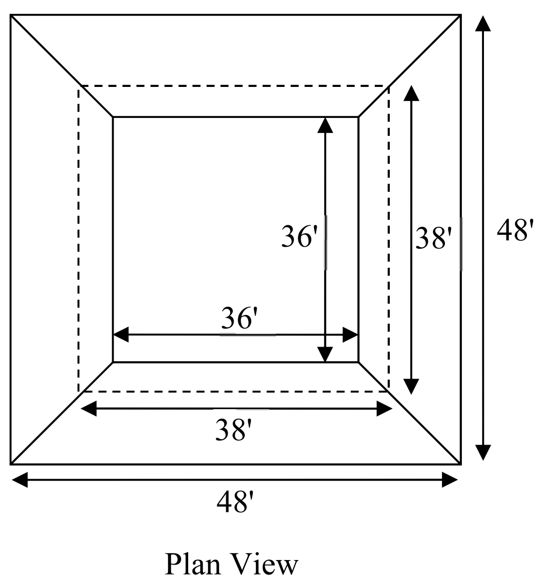
t_2 = pump-off duration.

Written by:	Y. Bholat	Date:	2/6/2014	Reviewed & Revised by:	S. Graves	Date:	10/10/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

3. CALCULATIONS

3.1 Total Volume of Sump

The proposed leachate collection sump will be 2 ft deep and will have a 36 ft x 36 ft square base (based on 48 ft x 48 ft top dimensions) with a sideslope of 3 horizontal to 1 vertical (3H:1V) to meet the landfill floor, as shown in Figure E5-1 below. The submersible pump "turn off" level for pumps with the needed discharge rate is typically four inches above the base of the sump, so the assumed operating depth of the sump is 1⅔ ft. The lower four inches of the sump will remain saturated and will therefore not contribute to the operating storage volume of the sump.



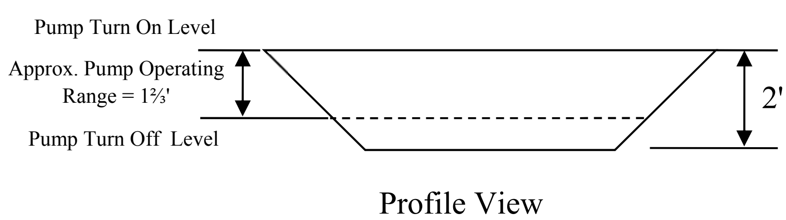


Figure E5-1. Proposed Leachate Collection Sump Configuration.

From the figure above, the operating parameters are:

$$a = 48'; b = 38'; H = 1⅔'$$

Therefore, the total operating volume of the sump is:

$$V = \frac{1}{3}(a^2 + ab + b^2)H$$

$$V = \frac{1}{3}(48^2 + 48 * 38 + 38^2) * 1⅔\ ft$$

$$V = 3{,}096\ ft^3$$

3.2 Effective Volume of Sump

The sump will be filled with granular drainage media with an approximate effective porosity of 0.32. Therefore, the effective volume of the sump is:

$$V_s = V * n$$

$$V_s = 3{,}096\ ft^3 * 0.32$$

$$V_s = 991\ ft^3 = 7410\ gallons$$

3.3 Pump-on/Pump-off Duration

The peak daily flow rate of leachate into the sump (Q_{in}) was calculated using impingement rates provided in Table E1-1 of Exhibit E-1. The peak daily impingement rate for the most critical condition, initial condition Case I, was 1916 gallons per acre per day (gpad). Since Subcell 14 has the largest area of those proposed to be built in Landfill Cell 15, serving an area of 6.05 acres, it would be expected to be the most critical in terms of the largest potential leachate generation quantities received by the sump. Based on the impingement rate multiplied by the subcell area, the peak daily flow rate is calculated to be 11,588 gallons per day (gpd) (or 8.05 gallons per minute (gpm)).

For comparison purposes, the calculated maximum average daily flow rate of leachate into the sump (Q_{in}) was calculated for Subcell 14. The maximum average daily impingement rate for the most critical condition, intermediate condition Case INT, was 150 gpad. The calculated maximum average daily leachate flow rate into the sump of Subcell 14 was 1,154 gpd (0.80 gpm).

To evaluate whether the sump storage capacity, leachate generation rate, and pump cycling is reasonable, a submersible leachate sump pump with an operating capability (Q_{pump}) of approximately 20 gpm was assumed. This is not a specification for a required pump size, but is merely a check on whether typical pump equipment would be expected to be suitable for Landfill Cell 15. For this assumed pump, for the peak daily case, the pump-on duration is:

$$t_1 = \frac{V_s}{Q_{pump} - Q_{in}}$$

$$t_1 = \frac{7{,}410\ gallons}{20\ gpm - 8.05\ gpm}$$

$$t_1 = 620\ min = 10.3\ hrs$$

and the pump-off duration is:

$$t_2 = \frac{V_s}{Q_{in}}$$

$$t_2 = \frac{7{,}410\ gallons}{8.05\ gpm}$$

$$t_2 = 920\ min = 15.3\ hrs$$

With a pump-on duration of 10.3 hrs and a pump-off duration of 15.3 hrs, a full on and off pump cycle is 25.6 hrs. Most pump manufacturers recommend that the sump pump cycle time be more than 15 min, so a cycle time of 25.2 hrs is an acceptable cycle time for the peak daily condition.

For the average daily case, the pump-on duration is:

$$t_1 = \frac{V_s}{Q_{pump} - Q_{in}}$$

$$t_1 = \frac{7{,}410\ gallons}{20\ gpm - 0.80\ gpm}$$

$$t_1 = 386\ min = 6.4\ hrs$$

and the pump-off duration is:

$$t_2 = \frac{V_s}{Q_{in}}$$

$$t_2 = \frac{7{,}410\ gallons}{0.80\ gpm}$$

$$t_2 = 9{,}263\ min = 154.4\ hrs$$

With a pump-on duration of 6.4 hrs and a pump-off duration of 154.4 hrs, a full on and off pump cycle is 160.8 hrs (6.7 days). Since most pump manufacturers recommend that sump pump cycle times be more than 15 min, a cycle time of 160.8 hrs is an acceptable cycle time for the average daily condition.

Written by:	**Y. Bholat**	Date:	**2/6/2014**	Reviewed by:	**S. Graves**	Date:	**3/4/2014**
Client:	**Clean Harbors**	Project:	**Lone Mountain Facility**	Project No.:	**TXL0380**	Phase No.:	**04**

4. CONCLUSIONS

The storage capacity of each sump for Landfill Cell 15, Subcells 14 through 22 is calculated to be 8,503 gallons. Based on the assumption that the bottom 4-inches in the sump will be "stagnant" due to pump capabilities, the "pumpable" storage capacity of the sumps is 7,410 gallons.

Using the estimated leachate generation rates presented separately in Exhibit E-1 of the Landfill Cell 15 Engineering Report, the calculations presented herein indicate that, for a given (assumed) submersible sump pump of 20 gpm, the proposed leachate sump has adequate storage capacity to provide acceptable pump cycle times considering peak and average daily operation rates.

This calculation does not require a specific size or capacity of the sump pump. It merely demonstrates the suitability of a typical size based on the anticipated flow rates and good practice for pump operation. Other pump capacities can result in adequate performance and may be selected by facility operations based on actual leachate generation rates and concepts consistent with those presented in this calculation package.

Exhibit E-6

LDS Sump Capacity Calculations

Written by:	Y. Bholat	Date:	2/6/2014	Reviewed by:	S. Graves	Date:	3/4/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

LEAK DETECTION SYSTEM (LDS) SUMP CAPACITY CALCULATIONS

REGISTERED PROFESSIONAL ENGINEER
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6/13/2014

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SEALED FOR CALCULATION PAGES
E6-1 THROUGH E6-8

1. INTRODUCTION

The purpose of this calculation package is to provide design calculations for the future leak detection sumps that will be located at the low point of each new subcell of the Lone Mountain Facility Landfill Cell 15. Accordingly, this evaluation applies to Subcells 14 through 22 of Landfill Cell 15 (i.e., those subcells proposed as the expansion area for this permit modification, which will each be configured according to the geometry described herein and on the drawings in Exhibit A of the Landfill Cell 15 Engineering Report).

As previously established for Cell 15 as approved by ODEQ, the maximum head may be greater than 12 inches but less than or equal to 16 inches in the leak detection sumps. A two-tiered action leakage rate (ALR) for the leak detection sumps is to be implemented: Tier 1 would be triggered when a leak detection sump exceeds 100 gallons per acre per day (gpad) of liquid collected and removed. Tier 2 would be triggered when a leak detection sump exceeds 345 gpad of liquid collected and removed. These rates are based on pumping occurring on a daily basis. It is beyond the scope of this calculation to fully describe the rationale for the calculated ALR or the tiered notification rates, but this information is noted here for context. Instead, this calculation package utilizes the two-tiered rates (100 gpad and 345 gpad), to evaluate whether the leak detection sumps are designed to provide adequate liquid storage capacity by limiting the liquid head in the sump to less than 16 inches between daily pumping events.

2. METHOD OF ANALYSIS

The proposed sumps for Subcells 14 through 22 of Landfill Cell 15 have the same geometry and are the shape of an inverted truncated pyramid with a square base. The formula for the volume of a truncated pyramid is:

$$V = \frac{1}{3}(a^2 + ab + b^2)H \quad \text{(Eqn. 1)}$$

where:

V	= volume of truncated pyramid (i.e. sump);
a	= the side length of the square top;
b	= the side length of the square bottom; and
H	= height of truncated pyramid.

The volume of the solid particles of the granular drainage material reduces the volume available for liquid storage. The effective volume of liquid storage in the sump is:

$$V_s = V * n \quad \text{(Eqn. 2)}$$

where:

V_s	= effective volume of sump; and
n	= effective porosity of granular drainage material.

3. CALCULATIONS

3.1 Stage Discharge Relationship for the Sump

The proposed leak detection sump will be 1.5 ft deep and will have a 27 ft x 27 ft square base with a sideslope of 3 horizontal to 1 vertical (3H:1V), as shown in Figure E6-1. The submersible pump "turn off" level for pumps with the needed discharge rate is typically four inches above the base of the sump; therefore, the lower four inches of the sump will remain saturated and will not contribute to the operating storage volume of the sump.

A stage discharge relationship (depth vs. net liquid volume) for the proposed sump was established using Eqns. (1) and (2) and varying the depth of liquid in the sump (Figure E6-2). The stage discharge relationship was used to calculate the maximum head in each subcell sump as described below.

3.2 Maximum Head in Each Subcell Sump

It should be noted that the size of each subcell sump (Subcells 14 through 22) will be the same; however, the tributary (contributory) area for each subcell is different (Tables E6-1 and E6-2). Using the relationship of depth and net liquid volume as presented in Figure E6-2, the maximum head that would develop between the daily pumping events in each subcell sump are presented in Tables E6-1 and E6-2, respectively for the two-tier liquid collection rates of 100 and 345 gpad.

Table E6-1 shows that the calculated maximum head on the sump at a 100 gpad inflow rate is less than 8 inches in every case, which is much less than the maximum allowable 16 inches of head in the sumps. Thus, no further action (e.g., change to pumping frequency) would be warranted should flows of 100 gpad be measured in the leak detection sump for the proposed sump size.

Inspection of Table E6-2 reveals that the calculated maximum head on the sump at a 345 gpad inflow rate is less than 15 inches in every case. This indicates that the pumping frequency of once per day would continue to be adequate for all subcells at an inflow rate of 345 gpad.

4. CONCLUSIONS

Calculations presented herein indicate that the proposed leak detection sump has adequate storage capacity and that the calculated liquid head in the sump did not exceed 16 inches between the daily pumping events considering the two-tier liquid inflow rates of 100 and 345 gpad.

TABLES

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

Table E6-1. Calculated Head on Sumps at Daily Inflow of 100 gpad.

Subcell	Total Sump Capacity	Tributary Area	Daily Inflow at 100 gpad	Stagnant Volume of Liquid[1]	Total Volume of Liquid	% of Sump Capacity Used	Max Head on Sump	
	gallons	acres	gallons/day	gallons	gallons	%	feet	inches
14	3587	6.05	605	626	1231	34.3%	0.62	7.4
15	3587	6.03	603	626	1229	34.3%	0.62	7.4
16	3587	4.89	489	626	1115	31.1%	0.56	6.8
17	3587	4.96	496	626	1122	31.3%	0.57	6.8
18	3587	4.33	433	626	1059	29.5%	0.54	6.5
19	3587	4.34	434	626	1060	29.5%	0.54	6.5
20	3587	4.33	433	626	1059	29.5%	0.54	6.5
21	3587	4.31	431	626	1057	29.5%	0.54	6.5
22	3587	3.87	387	626	1013	28.2%	0.52	6.2

[1] Due to four inches of stagnant liquid at the sump bottom

Table E6-2. Calculated head on sumps at daily inflow of 345 gpad.

Subcell	Total Sump Capacity	Tributary Area	Daily Inflow at 345 gpad	Stagnant Volume of Liquid[1]	Total Volume of Liquid	% of Sump Capacity Used	Max Head on Sump	
	gallons	acres	gallons/day	gallons	gallons	%	feet	inches
14	3587	6.05	2087	626	2713	75.6%	1.20	14.4
15	3587	6.03	2079	626	2705	75.4%	1.20	14.4
16	3587	4.89	1688	626	2314	64.5%	1.06	12.7
17	3587	4.96	1712	626	2337	65.2%	1.07	12.8
18	3587	4.33	1494	626	2120	59.1%	0.98	11.8
19	3587	4.34	1497	626	2123	59.2%	0.98	11.8
20	3587	4.33	1494	626	2120	59.1%	0.98	11.8
21	3587	4.31	1488	626	2114	58.9%	0.98	11.8
22	3587	3.87	1336	626	1962	54.7%	0.92	11.1

[1] Due to four inches of stagnant liquid at the sump bottom

FIGURES

Written by: **Y. Bholat**	Date: **2/6/2014**	Reviewed by: **S. Graves**	Date: **3/4/2014**
Client: **Clean Harbors**	Project: **Lone Mountain Facility**	Project No.: **TXL0380**	Phase No.: **04**

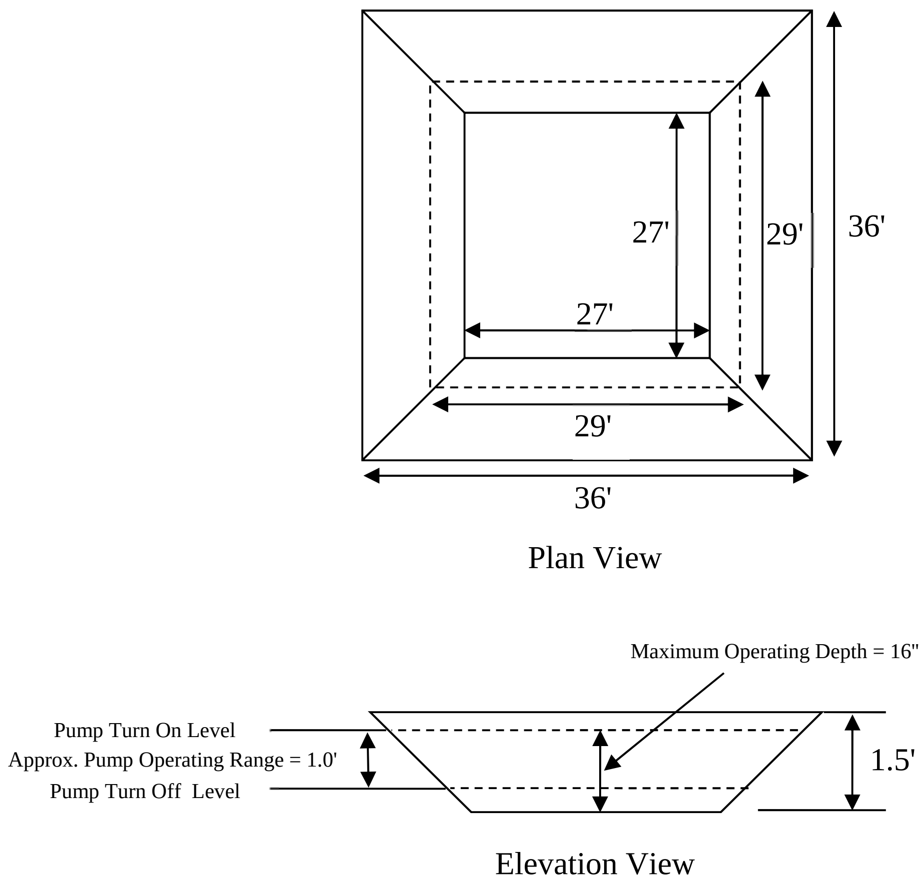

Figure E6-1. Proposed Leak Detection Sump Configuration.

Written by:	**Y. Bholat**	Date:	**2/6/2014**	Reviewed by:	**S. Graves**	Date:	**3/4/2014**
Client:	**Clean Harbors**	Project:	**Lone Mountain Facility**	Project No.:	**TXL0380**	Phase No.:	**04**

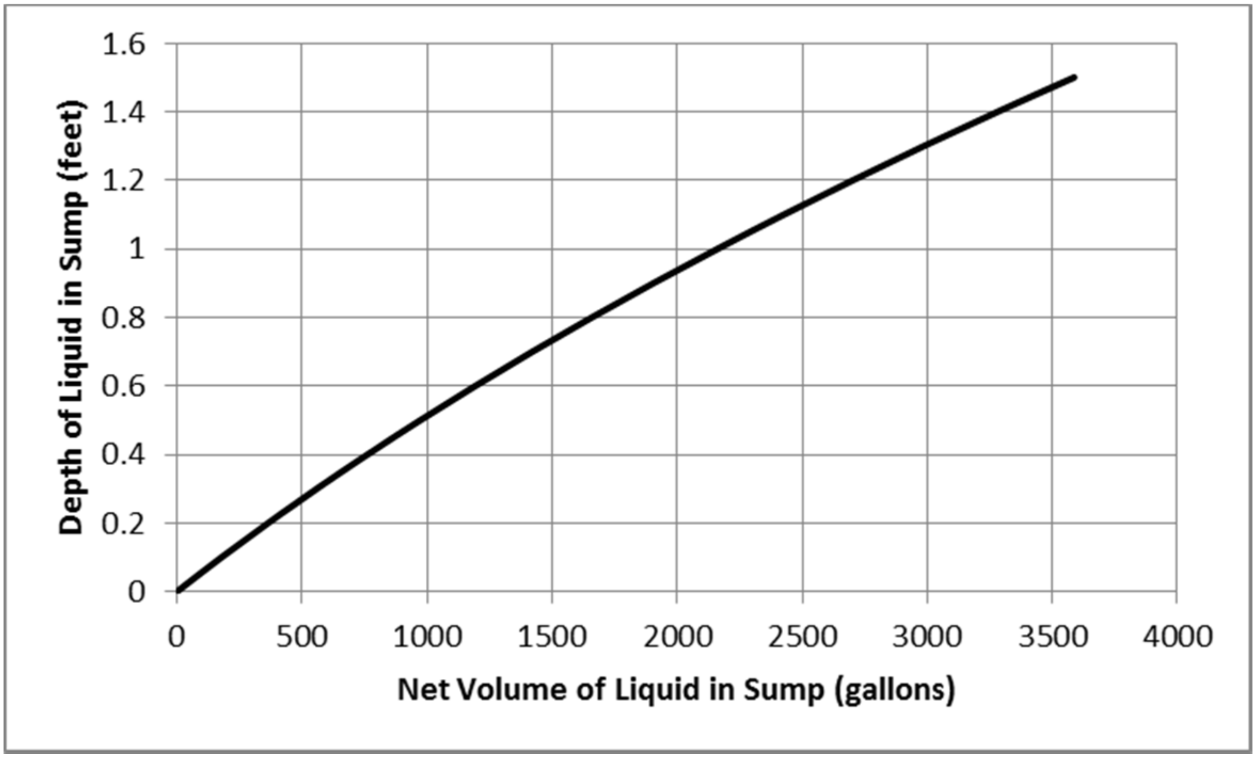

Figure E6-2. Relationship between Depth and Net Liquid Volume for the Proposed Sump.

Exhibit E-7

Comparison of Actual vs. Predicted Leachate Generation for Closed Cells 8 and 12

Written by: M. Zahirul Islam Date: 11 /12 /10 (MM DD YY) Reviewed by: Scott M. Graves Date: 11 /14 /10 (MM DD YY)

Client: Clean Harbors Project: Lone Mountain Facility Project/Proposal No.: TXL0095 Task No: 04

LEACHATE GENERATION RATES FOR CLOSED LANDFILL CELLS 8 AND 12 (HELP MODELING)

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11/17/2010

SEALED FOR CALCULATION PAGES 1 THROUGH 18

INTRODUCTION

The purpose of this analysis is to estimate the annual leachate generation rates for Lone Mountain Facility Landfill Cells 8 and 12 under final closed conditions, and compare the estimated leachate generation with the actual collected leachate from those two cells.

This analysis was performed using the Hydrologic Evaluation of Landfill Performance (*HELP*) computer model and with the same basic approach, assumptions, and methodology as were used to calculate the leachate generation rates for the closed conditions of Landfill Cell 15 in Exhibit E-1 of Geosyntec Consultant's (Geosyntec's) July 2010 Engineering Design Report (submitted to ODEQ with the Class 3 Permit Modification Application Package on 2 August 2010).

This analysis was requested by Oklahoma Department of Environmental Quality (ODEQ) in their 12 October 2010 Notice of Deficiency (NOD) letter. It is important to note that the *HELP* model is a design tool and is not intended to be an accurate predictor of actual leachate generation, as indicated in Chapter 8 of the USEPA publication, "Design and Construction of RCRA/CERCLA Final Covers" [EPA/625/4-91/025], which states *"...the accuracy and precision of the model is limited by uncertainty and variability in the properties of material existing in landfills. As such, simulation results would be expected to be best used to rate relative merits of designs rather than to accurately predict the water budget components."*

METHOD OF ANALYSIS

The leachate generation rates were estimated using the *HELP* computer model, Version 3.07, developed by the U.S. Environmental Protection Agency (USEPA). *HELP* model simulates hydrologic processes for a landfill by performing daily, sequential water balance analyses using a quasi-two-dimensional, deterministic approach (Schroeder et al., 1994a, 1994b).

The hydrologic processes considered in the *HELP* model include precipitation, surface-water evaporation, runoff, infiltration, plant transpiration, soil water evaporation, soil water storage, vertical drainage (saturated and unsaturated), lateral drainage (saturated), vertical drainage (saturated) through compacted soil liners and geosynthetic clay liners (GCLs), and leakage through geomembranes.

ANALYSIS CASES AND SCENARIOS

The Lone Mountain Facility Landfill Cells 8 and 12 had final cover systems installed and were closed in 1990 and 1999, respectively. The analysis contained in this package is to model the final closed condition of Landfill Cells 8 and 12.

According to copies of engineering drawings provided to Geosyntec by CHES personnel, the liner system on the base of the Landfill Cell 8 of the Lone Mountain Facility is composed of the following components, from top to bottom:

- 8-in. thick compacted soil cover;
- engineering fabric separator;
- 8-in. thick sand layer;
- 100-mil thick high density polyethylene (HDPE) geomembrane liner;
- 8-in. thick sand layer;
- 100-mil thick HDPE geomembrane liner; and
- 2-ft thick compacted soil liner.

The liner system on the base of the Landfill Cell 12 is composed of the following components, from top to bottom:

- 2-ft thick soil cover;
- geotextile;
- tertiary drainage net;
- 80-mil thick tertiary HDPE geomembrane liner;
- 2-ft thick protective cover soil;
- geotextile;
- primary drainage net;
- 60-mil thick primary HDPE geomembrane liner;
- secondary drainage net;
- 60-mil thick secondary HDPE geomembrane liner; and
- 3.1-ft thick compacted soil liner.

The final cover system of the Landfill Cell 8 is composed of the following components, from top to bottom:

- 4-in. thick gravel layer;
- 2-ft thick unclassified cover soil;
- geotextile;
- drainage net;
- 60-mil thick HDPE geomembrane liner; and
- 2-ft thick compacted clay.

The final cover system of the Landfill Cell 12 is composed of the following components, from top to bottom:

- 6-in. thick riprap protective cover layer;
- 4-in. thick riprap bedding material;
- 2-ft thick cover soil;
- geotextile;
- drainage net;
- 60-mil thick HDPE geomembrane liner; and
- 2-ft thick compacted clay.

PARAMETERS USED IN ANALYSIS

The *HELP* model requires the input of daily weather data, vegetation data, soils data, and landfill design data. The input data are described in this section and summarized on the *HELP* model output presented in Appendix A.

Weather Data

Thirty years of synthetic weather data were generated for the Lone Mountain Facility Landfill Cells 8 and 12 using climatic data for nearby Oklahoma City, Oklahoma. However, the peak daily rainfall from the synthetically generated precipitation record (5.36 in.) was manually increased to model the impact of the 25-year, 24-hour storm event on peak hydraulic head. The 25-year, 24-hour storm intensity for the site was estimated to be 6.15 in. based on the average of values reported in a Technical Paper, TR-55 (USDA, 1986).

Evapotranspiration Data

The final cover system for Landfill Cells 8 and 12 was assumed to have bare ground with an LAI of zero because the top of these cells was covered with a gravel layer. The *HELP* model default evaporative zone depth for bare ground (i.e., 10 in.) was selected for the purpose of accounting for the effects of evaporation.

Materials Data

All, but the sand layer for Landfill Cell 8 and gravel layer for both Landfill Cells 8 and 12, the material properties of the liner and final cover systems for Landfill Cells 8 and 12 were similar to the properties used for the Lone Mountain Facility Landfill Cell 15 (prepared by Geosyntec and submitted to ODEQ with the Class 3 Permit Modification Application Package on 2 August 2010) and are not repeated in this calculation package. The sand layer of Landfill Cell 8 was modeled as a vertical percolation layer with *HELP* material texture 2 having a saturated hydraulic conductivity of 5.8×10^{-3} cm/s. The gravel layer of both Landfill Cells 8 and 12 was modeled as a vertical percolation layer with *HELP* material texture 21 having a saturated hydraulic conductivity of 3.0×10^{-1} cm/s.

Landfill Design Data

The design data required by the *HELP* model consists of: (i) the slope and slope length of the surface of the top layer; (ii) the slope and slope length of lateral drainage layers (geosynthetic drainage component) in the final cover system and liner system; and (iii) the percentage of runoff that can be directed off of the landfill whether as clean surface water or as leachate running off the waste to a storm water storage area. It was assumed that the potential runoff is 100% for surfaces where runoff was allowed. The actual percentage runoff is calculated by the *HELP* model based on surface slope, slope length, material texture, and vegetation. The landfill design parameters used in the analysis are presented on Figure 1 for the two cells evaluated.

RESULTS OF ANALYSIS

The results of the *HELP* model analysis are summarized in this section, and the output files are presented in Appendix A. The average annual leachate volumes for each landfill cell was calculated based on the tributary area for each cell and the estimated average annual leachate generation/collection rates for each cell. Table 1, and Figures 2 and 3, show the estimated annual leachate generation from the *HELP* model, along with the actual leachate collected in recent years from Landfill Cells 8 and 12, respectively. Also for comparison, the estimated leachate generation from Landfill Cell 15 is also presented in Table 1 and plotted on Figures 2 and 3.

Written by: M. Zahirul Islam Date: 11 /12 /10 (MM DD YY) Reviewed by: Scott M. Graves Date: 11 /14 /10 (MM DD YY)

Client: Clean Harbors Project: Lone Mountain Facility Project/Proposal No.: TXL0095 Task No: 04

Table 1. Comparison of Actual and Predicted Leachate Generation

Year	Actual Leachate Generation (gallons/acre/yr)		Predicted Leachate Generation using HELP Model (gallons/acre/yr)		
	Cell 8	Cell 12	Cell 8	Cell 12	Cell 15
1998	1	41087	49	246	11
1999	0	11872	49	246	11
2000	0	6994	49	246	11
2001	733	3940	49	246	11
2002	0	3220	49	246	11
2003	0	5232	49	246	11
2004	0	2640	49	246	11
2005	0	1522	49	246	11
2006	0	277	49	246	11
2007	0	218	49	246	11
2008	0	109	49	246	11
2009	0	3	49	246	11
2010	0	210	49	246	11

For Landfill Cell 8, inspection of Table 1 and Figure 2 reveals the following:

- In most years, no leachate was collected from Landfill Cell 8.
- There were two years that were exceptions: 1998 and 2001, when approximately 1 and 733 gallons per acre of leachate were collected, respectively. Since 2001, Landfill Cell 8 has produced zero leachate.
- In comparison, using the *HELP* model, the estimated annual average leachate generation from Landfill Cell 8 for final closed conditions is calculated to be 49 gallons per acre.

For Landfill Cell 12, inspection of Table 1 and Figure 3 reveals the following:

- The actual leachate collected from Landfill Cell 12 gradually decreased from approximately 41,100 gallons per acre (in 1998, when the cell was still open) to on the order of 100 to 200 gallons per acre during the last few years).

- Experience shows that upon installation of a final cover system, over a period of time leachate generation gradually decreases, and eventually reaches a long-term closed condition that would be expected to be small and relatively consistent. The trend of actual leachate generation observed for Landfill Cell 12 follows the gradual decrease that one would expect over time after the start of closure.

- In comparison, using the *HELP* model, the estimated annual average leachate generation from Landfill Cell 12 is calculated to be 246 gallons per acre. This value is on the same order of magnitude as the actual leachate generation from 2006 to 2010.

SUMMARY AND CONCLUSIONS

The *HELP* model was used to estimate the annual leachate generation rates for closed Lone Mountain Facility Landfill Cells 8 and 12. The estimated annual leachate generation was compared with the actual leachate generation from these two cells from 1998 through 2010. The estimated leachate generation compares well with the actual leachate generation.

While the *HELP* model is a design tool only and not intended to be an accurate predictor of actual leachate generation, nevertheless it is concluded that for these evaluations the *HELP* model is a good estimator of leachate generation for the closed conditions modeled at the Lone Mountain Facility. This provides additional confidence that the *HELP* modeling performed for the design of Landfill Cell 15 is reasonable.

REFERENCES

Schroeder, P.R., Dozier, T.S., Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L., "*The Hydrologic Evaluation of Landfill Performance (HELP) Model Engineering Documentation for Version 3*," U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168b, 1994b, 116 p.

Schroeder, P.R., Lloyd, C.M., and Zappi, P.A., "*The Hydrologic Evaluation of Landfill Performance (HELP) Model, User's Guide for Version 3*," U.S. Environmental Protection Agency, Office of Research and Development Washington, D.C., Report No. EPA/600/R094/168a, 1994a.

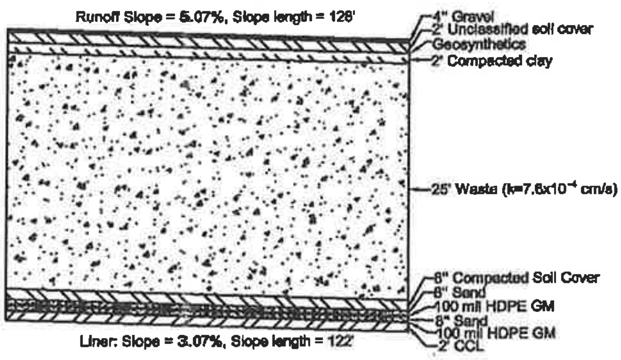
Schroeder, P.R., Dozier, T.S., Zappi, P.A., McEnroe, B.M., Sjostrom, J.W., and Peyton, R.L., "*The Hydrologic Evaluation of Landfill Performance (HELP) Model Engineering Documentation for Version*

3," U.S. Environmental Protection Agency, Office of Research and Development, Washington, D.C., Report No. EPA/600/R-94/168b, 1994b, 116 p.

USDA, "TR-55: Urban Hydrology for Small Watersheds", USDA Natural Resources conservation Services, Report No. 210-VI-TR-55, Second Ed, 1986, 164p.

Written by:	M. Zahirul Islam	Date:	11 /12 /10 (MM DD YY)	Reviewed by:	Scott M. Graves	Date:	11 /14 /10 (MM DD YY)
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project/Proposal No.:	TXL0095	Task No:	04

Cell 8 (Final Condition)



Cell 12 (Final Condition)

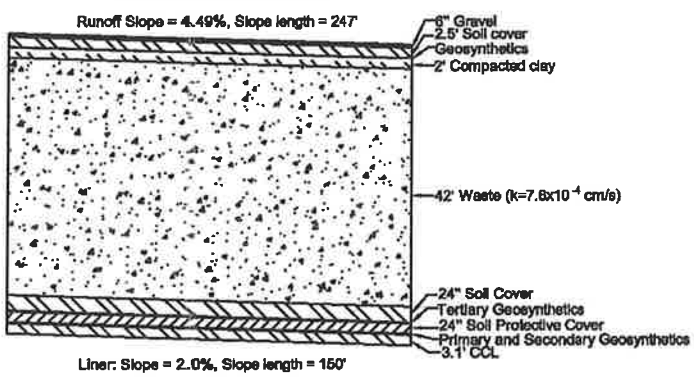


Figure1. Landfill Design Parameters used in *HELP* Model Analysis.

Written by:	M. Zahirul Islam	Date:	11 /12 /10 (MM DD YY)	Reviewed by:	Scott M. Graves	Date:	11 /14 /10 (MM DD YY)
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project/Proposal No.:	TXL0095	Task No:	04

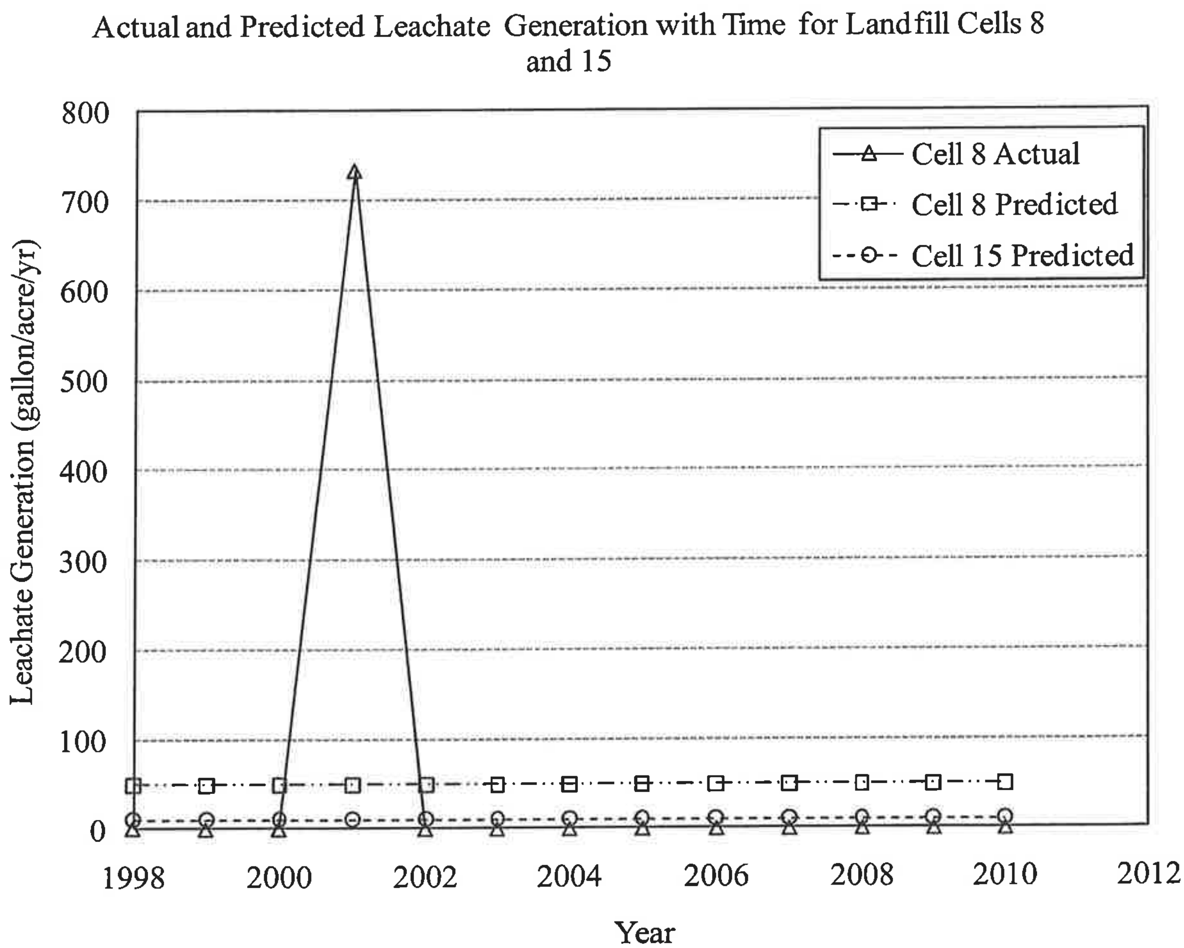


Figure 2. Actual and Predicted Leachate Generation with Time for Landfill Cells 8 and 15.

Written by: M. Zahirul Islam Date: 11 /12 /10 (MM DD YY) Reviewed by: Scott M. Graves Date: 11 /14 /10 (MM DD YY)

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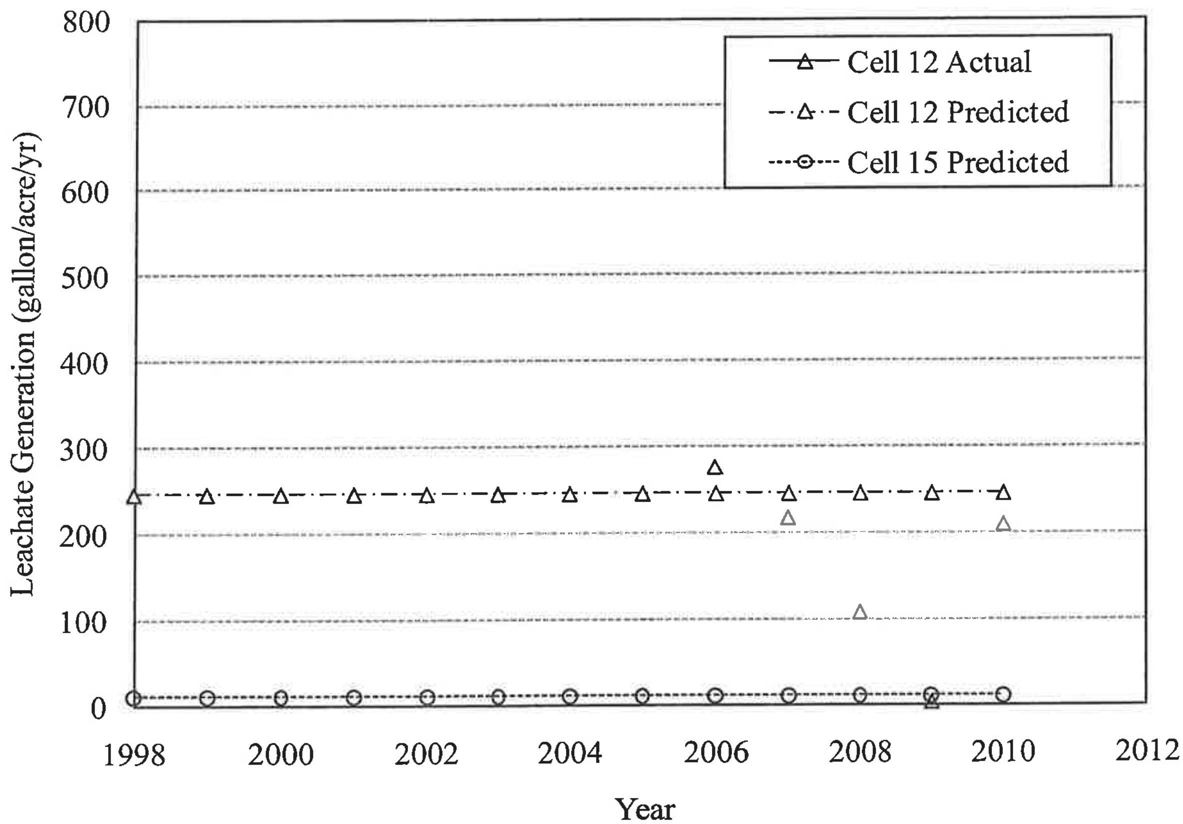

Figure 3. Actual and Predicted Leachate Generation with Time for Landfill Cells 12 and 15.

[Note: Leachate production for Cell 12 prior to 2006 was higher than the scale of this chart. This is as expected since Cell 12 was closed in 1999 and leachate generation steadily decreases over time after closure until a long-term relatively steady-state condition is reached. The scale of this chart was selected to allow the small values from years 2006 to 2010 to be legible.]

APPENDIX A

HELP MODEL COMPUTER PROGRAM OUTPUT FILES

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**            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:\DOCUME~1\ZISLAM\DESKTOP\HELP\Fc8\PREC.D4
TEMPERATURE DATA FILE:       C:\DOCUME~1\ZISLAM\DESKTOP\HELP\Fc8\TEMP.D7
SOLAR RADIATION DATA FILE:   C:\DOCUME~1\ZISLAM\DESKTOP\HELP\FC8\SR.D13
EVAPOTRANSPIRATION DATA:     C:\DOCUME~1\ZISLAM\DESKTOP\HELP\FC8\EVAP.D11
SOIL AND DESIGN DATA FILE:   C:\DOCUME~1\ZISLAM\DESKTOP\HELP\FC8\SOIL8.D10
OUTPUT DATA FILE:            C:\DOCUME~1\ZISLAM\DESKTOP\HELP\Fc8\FCOUT8.OUT

TIME:   9:19     DATE:  11/13/2010

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

     TITLE:  Lone Mountain Facility, Case # FC Cell 8

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

     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  21
     THICKNESS                      =     4.00    INCHES
     POROSITY                       =     0.3970 VOL/VOL
     FIELD CAPACITY                 =     0.0320 VOL/VOL
     WILTING POINT                  =     0.0130 VOL/VOL
     INITIAL SOIL WATER CONTENT     =     0.0394 VOL/VOL
     EFFECTIVE SAT. HYD. COND.      =  0.300000012000      CM/SEC

                                LAYER  2
                                --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER  26
     THICKNESS                      =    24.00    INCHES
     POROSITY                       =     0.4450 VOL/VOL
     FIELD CAPACITY                 =     0.3930 VOL/VOL
     WILTING POINT                  =     0.2770 VOL/VOL
     INITIAL SOIL WATER CONTENT     =     0.3733 VOL/VOL
     EFFECTIVE SAT. HYD. COND.      =  0.190000003000E-05 CM/SEC

                                LAYER  3
                                --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER   0
     THICKNESS                      =     0.20    INCHES
     POROSITY                       =     0.8500 VOL/VOL
     FIELD CAPACITY                 =     0.0100 VOL/VOL
     WILTING POINT                  =     0.0050 VOL/VOL
     INITIAL SOIL WATER CONTENT     =     0.8500 VOL/VOL
     EFFECTIVE SAT. HYD. COND.      =  0.999999978000E-02 CM/SEC
     SLOPE                          =     5.07    PERCENT
     DRAINAGE LENGTH                =   128.0     FEET

                                LAYER  4
                                --------

                    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            =     2.00    HOLES/ACRE
     FML INSTALLATION DEFECTS       =     2.00    HOLES/ACRE
     FML PLACEMENT QUALITY          =  4 - POOR

                                LAYER  5
                                --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER  16
     THICKNESS                      =    24.00    INCHES
     POROSITY                       =     0.4270 VOL/VOL
     FIELD CAPACITY                 =     0.4180 VOL/VOL
     WILTING POINT                  =     0.3670 VOL/VOL
     INITIAL SOIL WATER CONTENT     =     0.4094 VOL/VOL
     EFFECTIVE SAT. HYD. COND.      =  0.100000001000E-06 CM/SEC

                                LAYER  6
                                --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   0
     THICKNESS                      =   300.00    INCHES
     POROSITY                       =     0.5720 VOL/VOL
     FIELD CAPACITY                 =     0.2570 VOL/VOL
     WILTING POINT                  =     0.0910 VOL/VOL
     INITIAL SOIL WATER CONTENT     =     0.2570 VOL/VOL
     EFFECTIVE SAT. HYD. COND.      =  0.760000024000E-03 CM/SEC

                                LAYER  7
                                --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER  11
     THICKNESS                      =     8.00    INCHES
     POROSITY                       =     0.4640 VOL/VOL
     FIELD CAPACITY                 =     0.3100 VOL/VOL
     WILTING POINT                  =     0.1870 VOL/VOL
     INITIAL SOIL WATER CONTENT     =     0.3100 VOL/VOL
     EFFECTIVE SAT. HYD. COND.      =  0.639999998000E-04 CM/SEC

                                LAYER  8
                                --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER   2
     THICKNESS                      =     8.00    INCHES
     POROSITY                       =     0.4370 VOL/VOL
     FIELD CAPACITY                 =     0.0620 VOL/VOL
     WILTING POINT                  =     0.0240 VOL/VOL
     INITIAL SOIL WATER CONTENT     =     0.0626 VOL/VOL
     EFFECTIVE SAT. HYD. COND.      =  0.579999993000E-02 CM/SEC
     SLOPE                          =     3.07    PERCENT
     DRAINAGE LENGTH                =   122.0     FEET

                                LAYER  9
                                --------

                    TYPE 4 - FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  35
     THICKNESS                      =     0.10    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            =     2.00    HOLES/ACRE
     FML INSTALLATION DEFECTS       =     2.00    HOLES/ACRE
     FML PLACEMENT QUALITY          =  2 - EXCELLENT

                                LAYER 10
                                --------

                    TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER   2
     THICKNESS                      =     8.00    INCHES
     POROSITY                       =     0.4370 VOL/VOL
     FIELD CAPACITY                 =     0.0620 VOL/VOL
     WILTING POINT                  =     0.0240 VOL/VOL
     INITIAL SOIL WATER CONTENT     =     0.0628 VOL/VOL
     EFFECTIVE SAT. HYD. COND.      =  0.579999993000E-02 CM/SEC
     SLOPE                          =     3.07    PERCENT
     DRAINAGE LENGTH                =   122.0     FEET

                                LAYER 11
```

Written by: M. Zahirul Islam Date: 11 /12 /10 (MM DD YY) Reviewed by: Scott M. Graves Date: 11 /14 /10 (MM DD YY)

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TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.10 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	=	2.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	2.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	2 - EXCELLENT

LAYER 12

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4270 VOL/VOL
FIELD CAPACITY	=	0.4180 VOL/VOL
WILTING POINT	=	0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4180 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999994000E-08 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #26 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 128. FEET.

SCS RUNOFF CURVE NUMBER	=	97.00
FRACTION OF AREA ALLOWING RUNOFF	=	100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000 ACRES
EVAPORATIVE ZONE DEPTH	=	10.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	1.912 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.258 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.714 INCHES
INITIAL SNOW WATER	=	0.000 INCHES
INITIAL WATER IN LAYER MATERIALS	=	109.726 INCHES
TOTAL INITIAL WATER	=	109.726 INCHES
TOTAL SUBSURFACE INFLOW	=	0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM OKLAHOMA CITY OKLAHOMA

STATION LATITUDE	=	35.40 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	10.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	12.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	63.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	66.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.96	1.29	2.07	2.91	5.50	3.87
3.04	2.40	3.41	2.71	1.53	1.20

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
35.90	40.80	49.10	60.20	68.40	77.00
82.10	81.10	73.30	62.30	48.80	39.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR OKLAHOMA CITY OKLAHOMA AND STATION LATITUDE = 35.40 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	0.99	1.52	2.48	3.10	5.52	3.62
	2.62	2.36	2.46	2.38	1.40	0.99
STD. DEVIATIONS	0.58	1.00	1.12	1.89	3.72	1.81
	1.70	1.61	1.42	1.44	1.05	0.76
RUNOFF						
TOTALS	0.149	0.316	0.731	1.269	2.876	1.352
	1.021	0.814	0.940	1.083	0.421	0.231
STD. DEVIATIONS	0.185	0.343	0.535	1.043	2.698	0.921
	0.955	0.762	0.867	0.957	0.573	0.329
EVAPOTRANSPIRATION						
TOTALS	0.740	1.065	1.701	1.738	2.393	2.081
	1.615	1.453	1.405	1.310	0.871	0.803
STD. DEVIATIONS	0.403	0.647	0.675	0.768	0.910	0.964
	0.907	0.850	0.669	0.544	0.541	0.466
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.0954	0.0730	0.0719	0.0724	0.0731	0.0788
	0.0968	0.1030	0.1026	0.1036	0.1086	0.1013
STD. DEVIATIONS	0.0421	0.0401	0.0479	0.0476	0.0493	0.0440
	0.0381	0.0372	0.0331	0.0324	0.0288	0.0366
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0003	0.0002	0.0004	0.0003	0.0002	0.0003
	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003
STD. DEVIATIONS	0.0004	0.0005	0.0007	0.0007	0.0005	0.0005
	0.0005	0.0005	0.0005	0.0006	0.0005	0.0003
LATERAL DRAINAGE COLLECTED FROM LAYER 8						
TOTALS	0.0002	0.0001	0.0001	0.0002	0.0001	0.0001
	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001
STD. DEVIATIONS	0.0004	0.0002	0.0003	0.0003	0.0003	0.0002
	0.0002	0.0002	0.0002	0.0003	0.0003	0.0002
PERCOLATION/LEAKAGE THROUGH LAYER 9						
TOTALS	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001
	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
STD. DEVIATIONS	0.0003	0.0002	0.0003	0.0003	0.0003	0.0002
	0.0002	0.0003	0.0002	0.0003	0.0003	0.0002
LATERAL DRAINAGE COLLECTED FROM LAYER 10						
TOTALS	0.0003	0.0002	0.0002	0.0002	0.0002	0.0002
	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
STD. DEVIATIONS	0.0006	0.0004	0.0003	0.0002	0.0003	0.0002
	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
PERCOLATION/LEAKAGE THROUGH LAYER 11						
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
PERCOLATION/LEAKAGE THROUGH LAYER 12						
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	1.1740	0.9012	1.3073	1.1496	0.7963	1.0901
	1.3619	1.3530	1.3532	1.4721	1.1842	0.8398

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STD. DEVIATIONS	1.5632	2.0004	2.7779	2.5428	1.8616	1.7503
	1.8460	1.8883	1.9882	2.3944	1.7125	1.1435

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0007	0.0006	0.0005	0.0006	0.0005	0.0004
	0.0006	0.0007	0.0007	0.0007	0.0007	0.0005
STD. DEVIATIONS	0.0015	0.0009	0.0010	0.0013	0.0012	0.0009
	0.0009	0.0009	0.0009	0.0011	0.0011	0.0008

DAILY AVERAGE HEAD ON TOP OF LAYER 11

AVERAGES	0.0012	0.0010	0.0009	0.0008	0.0007	0.0006
	0.0007	0.0007	0.0006	0.0008	0.0009	0.0008
STD. DEVIATIONS	0.0025	0.0017	0.0011	0.0010	0.0010	0.0010
	0.0009	0.0008	0.0009	0.0009	0.0010	0.0009

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	29.46	(5.730)	106953.1	100.00
RUNOFF	11.205	(3.4685)	40674.10	38.030
EVAPOTRANSPIRATION	17.175	(2.7684)	62346.61	58.293
LATERAL DRAINAGE COLLECTED FROM LAYER 3	1.08053	(0.26987)	3922.306	3.66731
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00397	(0.00402)	14.422	0.01348
AVERAGE HEAD ON TOP OF LAYER 4	1.165	(1.251)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.00182	(0.00195)	6.621	0.00619
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00230	(0.00200)	8.367	0.00782
AVERAGE HEAD ON TOP OF LAYER 9	0.001	(0.001)		
LATERAL DRAINAGE COLLECTED FROM LAYER 10	0.00250	(0.00228)	9.087	0.00850
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 11	0.001	(0.001)		
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00000	(0.00001)	0.006	0.00001
CHANGE IN WATER STORAGE	-0.002	(0.4388)	-5.60	-0.005

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	6.15	22324.500
RUNOFF	5.555	20164.1719
DRAINAGE COLLECTED FROM LAYER 3	0.00454	16.49799
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000132	0.48041
AVERAGE HEAD ON TOP OF LAYER 4	15.555	
MAXIMUM HEAD ON TOP OF LAYER 4	21.024	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	41.3 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.00010	0.37990
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000078	0.28374
AVERAGE HEAD ON TOP OF LAYER 9	0.013	
MAXIMUM HEAD ON TOP OF LAYER 9	0.025	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	1.4 FEET	
DRAINAGE COLLECTED FROM LAYER 10	0.00014	0.49187
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.000000	0.00003
AVERAGE HEAD ON TOP OF LAYER 11	0.016	
MAXIMUM HEAD ON TOP OF LAYER 11	0.033	
LOCATION OF MAXIMUM HEAD IN LAYER 10 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.000047	0.16915
SNOW WATER	1.36	4939.7363
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3439	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1714	

*** 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.

FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	0.1576	0.0394
2	8.9264	0.3719
3	0.1660	0.8301
4	0.0000	0.0000
5	9.8250	0.4094
6	77.1000	0.2570
7	2.4800	0.3100
8	0.4961	0.0620
9	0.0000	0.0000
10	0.4961	0.0620
11	0.0000	0.0000
12	10.0320	0.4180
SNOW WATER	0.000	

Written by: M. Zahirul Islam Date: 11 /12 /10 (MM DD YY) Reviewed by: Scott M. Graves Date: 11 /14 /10 (MM DD YY)

Client: Clean Harbors Project: Lone Mountain Facility Project/Proposal No.: TXL0095 Task No: 04

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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:\DOCUME~1\ZISLAM\DESKTOP\HELP\Fc12\PREC.D4
TEMPERATURE DATA FILE:       C:\DOCUME~1\ZISLAM\DESKTOP\HELP\Fc12\TEMP.D7
SOLAR RADIATION DATA FILE:   C:\DOCUME~1\ZISLAM\DESKTOP\HELP\FC12\SR.D13
EVAPOTRANSPIRATION DATA:     C:\DOCUME~1\ZISLAM\DESKTOP\HELP\FC12\EVAP.D11
SOIL AND DESIGN DATA FILE:   C:\DOCUME~1\ZISLAM\DESKTOP\HELP\FC12\SOIL12.D10
OUTPUT DATA FILE:            C:\DOCUME~1\ZISLAM\DESKTOP\HELP\Fc12\FCOUT12.OUT


TIME:   9:46     DATE:  11/13/2010


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

     TITLE:  Lone Mountain Facility, Case # FC Cell 12

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


     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  21
          THICKNESS                  =     6.00    INCHES
          POROSITY                   =     0.3970 VOL/VOL
          FIELD CAPACITY             =     0.0320 VOL/VOL
          WILTING POINT              =     0.0130 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.0306 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.300000012000      CM/SEC


                              LAYER  2
                              --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  26
          THICKNESS                  =    30.00    INCHES
          POROSITY                   =     0.4450 VOL/VOL
          FIELD CAPACITY             =     0.3930 VOL/VOL
          WILTING POINT              =     0.2770 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.3823 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.190000003000E-05 CM/SEC


                              LAYER  3
                              --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  0
          THICKNESS                  =     0.20    INCHES
          POROSITY                   =     0.8500 VOL/VOL
          FIELD CAPACITY             =     0.0100 VOL/VOL
          WILTING POINT              =     0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.7135 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.500000007000E-01 CM/SEC
          SLOPE                      =     4.49    PERCENT
          DRAINAGE LENGTH            =   347.0     FEET


                              LAYER  4
                              --------

                   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        =     2.00    HOLES/ACRE
          FML INSTALLATION DEFECTS   =     2.00    HOLES/ACRE
          FML PLACEMENT QUALITY      =  4 - POOR


                              LAYER  5
                              --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  16
          THICKNESS                  =    24.00    INCHES
          POROSITY                   =     0.4270 VOL/VOL
          FIELD CAPACITY             =     0.4180 VOL/VOL
          WILTING POINT              =     0.3670 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.4094 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC


                              LAYER  6
                              --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  0
          THICKNESS                  =   504.00    INCHES
          POROSITY                   =     0.5720 VOL/VOL
          FIELD CAPACITY             =     0.2570 VOL/VOL
          WILTING POINT              =     0.0910 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.2570 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.760000024000E-03 CM/SEC


                              LAYER  7
                              --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  26
          THICKNESS                  =    24.00    INCHES
          POROSITY                   =     0.4450 VOL/VOL
          FIELD CAPACITY             =     0.3930 VOL/VOL
          WILTING POINT              =     0.2770 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.3930 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.190000003000E-05 CM/SEC


                              LAYER  8
                              --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER  0
          THICKNESS                  =     0.20    INCHES
          POROSITY                   =     0.8500 VOL/VOL
          FIELD CAPACITY             =     0.0100 VOL/VOL
          WILTING POINT              =     0.0050 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.2085 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.999999978000E-02 CM/SEC
          SLOPE                      =     2.00    PERCENT
          DRAINAGE LENGTH            =   150.0     FEET


                              LAYER  9
                              --------

                   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        =     2.00    HOLES/ACRE
          FML INSTALLATION DEFECTS   =     2.00    HOLES/ACRE
          FML PLACEMENT QUALITY      =  2 - EXCELLENT


                              LAYER 10
                              --------

                   TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER  26
          THICKNESS                  =    24.00    INCHES
          POROSITY                   =     0.4450 VOL/VOL
          FIELD CAPACITY             =     0.3930 VOL/VOL
          WILTING POINT              =     0.2770 VOL/VOL
          INITIAL SOIL WATER CONTENT =     0.3930 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.190000003000E-05 CM/SEC
```

Written by: M. Zahirul Islam Date: 11 /12 /10 (MM DD YY) Reviewed by: Scott M. Graves Date: 11 /14 /10 (MM DD YY)

Client: Clean Harbors Project: Lone Mountain Facility Project/Proposal No.: TXL0095 Task No: 04

```
                    LAYER 11
                    --------

         TYPE 2 - LATERAL DRAINAGE LAYER
           MATERIAL TEXTURE NUMBER   0
THICKNESS                 =      0.20    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.  =  0.999999978000E-02 CM/SEC
SLOPE                     =      2.00    PERCENT
DRAINAGE LENGTH           =    150.0     FEET


                    LAYER 12
                    --------

         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       =      2.00    HOLES/ACRE
FML INSTALLATION DEFECTS  =      2.00    HOLES/ACRE
FML PLACEMENT QUALITY     =   2 - EXCELLENT


                    LAYER 13
                    --------

         TYPE 2 - LATERAL DRAINAGE LAYER
           MATERIAL TEXTURE NUMBER   0
THICKNESS                 =      0.20    INCHES
POROSITY                  =      0.8500 VOL/VOL
FIELD CAPACITY            =      0.0100 VOL/VOL
WILTING POINT             =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT =     0.0101 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.999999978000E-02 CM/SEC
SLOPE                     =      2.00    PERCENT
DRAINAGE LENGTH           =    150.0     FEET


                    LAYER 14
                    --------

         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       =      2.00    HOLES/ACRE
FML INSTALLATION DEFECTS  =      2.00    HOLES/ACRE
FML PLACEMENT QUALITY     =   2 - EXCELLENT


                    LAYER 15
                    --------

         TYPE 1 - VERTICAL PERCOLATION LAYER
           MATERIAL TEXTURE NUMBER  16
THICKNESS                 =     37.00    INCHES
POROSITY                  =      0.4270 VOL/VOL
FIELD CAPACITY            =      0.4180 VOL/VOL
WILTING POINT             =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT =     0.4180 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC


         GENERAL DESIGN AND EVAPORATIVE ZONE DATA
         ----------------------------------------

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
       SOIL DATA BASE USING SOIL TEXTURE #26 WITH BARE
       GROUND CONDITIONS, A SURFACE SLOPE OF  4.% AND
       A SLOPE LENGTH OF  347. FEET.

SCS RUNOFF CURVE NUMBER            =    96.80
FRACTION OF AREA ALLOWING RUNOFF   =   100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =     1.000  ACRES
EVAPORATIVE ZONE DEPTH             =    10.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =     1.186  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     4.162  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =     1.186  INCHES
INITIAL SNOW WATER                 =     0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =   185.525  INCHES
TOTAL INITIAL WATER                =   185.525  INCHES
TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR


         EVAPOTRANSPIRATION AND WEATHER DATA
         -----------------------------------

NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          OKLAHOMA CITY          OKLAHOMA

     STATION LATITUDE                           =  35.40 DEGREES
     MAXIMUM LEAF AREA INDEX                    =   0.00
     START OF GROWING SEASON (JULIAN DATE)      =   86
     END OF GROWING SEASON (JULIAN DATE)        =   310
     EVAPORATIVE ZONE DEPTH                     =  10.0  INCHES
     AVERAGE ANNUAL WIND SPEED                  =  12.50 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY      =  64.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY      =  66.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY      =  63.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY      =  66.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR   OKLAHOMA CITY        OKLAHOMA

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

  JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
  -------    -------    -------    -------    -------    -------
   0.96       1.29       2.07       2.91       5.50       3.87
   3.04       2.40       3.41       2.71       1.53       1.20


NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR   OKLAHOMA CITY        OKLAHOMA

     NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

  JAN/JUL    FEB/AUG    MAR/SEP    APR/OCT    MAY/NOV    JUN/DEC
  -------    -------    -------    -------    -------    -------
   35.90      40.80      49.10      60.20      68.40      77.00
   82.10      81.10      73.30      62.30      48.80      39.90


NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR   OKLAHOMA CITY        OKLAHOMA
            AND STATION LATITUDE  =  35.40 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                  0.99     1.52     2.48     3.10     5.52     3.62
                          2.62     2.36     2.46     2.38     1.40     0.99

  STD. DEVIATIONS         0.58     1.00     1.12     1.89     3.72     1.81
                          1.70     1.61     1.42     1.44     1.05     0.76

RUNOFF
------
  TOTALS                 0.133    0.288    0.670    1.179    2.703    1.244
                         0.939    0.738    0.869    1.013    0.389    0.210

  STD. DEVIATIONS        0.166    0.317    0.500    0.972    2.580    0.861
                         0.902    0.698    0.831    0.921    0.551    0.311

EVAPOTRANSPIRATION
------------------
  TOTALS                 0.659    1.056    1.698    1.710    2.473    2.144
                         1.662    1.493    1.421    1.316    0.867    0.751

  STD. DEVIATIONS        0.424    0.634    0.694    0.799    0.926    1.013
                         0.921    0.992    0.670    0.579    0.572    0.446

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                0.1428   0.1200   0.1223   0.1419   0.1439   0.1545
                        0.1761   0.1822   0.1700   0.1617   0.1643   0.1455

  STD. DEVIATIONS       0.0806   0.0675   0.0712   0.0644   0.0722   0.0568
                        0.0585   0.0645   0.0575   0.0614   0.0544   0.0618

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                0.0005   0.0004   0.0005   0.0005   0.0005   0.0007
                        0.0011   0.0010   0.0008   0.0007   0.0006   0.0005
```

Written by: M. Zahirul Islam Date: 11 /12 /10 (MM DD YY) Reviewed by: Scott M. Graves Date: 11 /14 /10 (MM DD YY)

Client: Clean Harbors Project: Lone Mountain Facility Project/Proposal No.: TXL0095 Task No: 04

STD. DEVIATIONS	0.0007	0.0009	0.0011	0.0010	0.0009	0.0011
	0.0014	0.0014	0.0011	0.0011	0.0008	0.0008

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	0.0010	0.0008	0.0008	0.0007	0.0007	0.0006
	0.0007	0.0008	0.0008	0.0008	0.0007	0.0007
STD. DEVIATIONS	0.0018	0.0013	0.0012	0.0010	0.0009	0.0008
	0.0008	0.0008	0.0009	0.0009	0.0009	0.0009

PERCOLATION/LEAKAGE THROUGH LAYER 9

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

LATERAL DRAINAGE COLLECTED FROM LAYER 11

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

PERCOLATION/LEAKAGE THROUGH LAYER 12

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

LATERAL DRAINAGE COLLECTED FROM LAYER 13

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

PERCOLATION/LEAKAGE THROUGH LAYER 14

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

PERCOLATION/LEAKAGE THROUGH LAYER 15

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	1.8549	1.6235	1.6736	2.0151	1.9549	2.7139
	3.9013	3.7835	3.1672	2.4126	2.0504	1.6295
STD. DEVIATIONS	2.5926	3.6205	4.0231	3.8321	3.3739	4.1754
	5.1342	5.1718	4.4282	3.9717	3.2860	3.0675

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.0041	0.0036	0.0032	0.0030	0.0028	0.0028
	0.0030	0.0034	0.0036	0.0035	0.0033	0.0030
STD. DEVIATIONS	0.0079	0.0063	0.0052	0.0044	0.0039	0.0035
	0.0033	0.0036	0.0038	0.0039	0.0038	0.0036

DAILY AVERAGE HEAD ON TOP OF LAYER 12

AVERAGES	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

DAILY AVERAGE HEAD ON TOP OF LAYER 14

AVERAGES	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

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	29.46	(5.730)	106953.1	100.00
RUNOFF	10.375	(3.2619)	37662.79	35.214
EVAPOTRANSPIRATION	17.251	(2.8649)	62619.87	58.549
LATERAL DRAINAGE COLLECTED FROM LAYER 3	1.82513	(0.42711)	6625.212	6.19450
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00779	(0.00888)	28.289	0.02645
AVERAGE HEAD ON TOP OF LAYER 4	2.398	(2.837)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	0.00904	(0.00969)	32.822	0.03069
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00001	(0.00000)	0.024	0.00002
AVERAGE HEAD ON TOP OF LAYER 9	0.003	(0.004)		
LATERAL DRAINAGE COLLECTED FROM LAYER 11	0.00000	(0.00000)	0.001	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00001	(0.00000)	0.023	0.00002
AVERAGE HEAD ON TOP OF LAYER 12	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 13	0.00000	(0.00001)	0.017	0.00002
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 14	0.000	(0.000)		
PERCOLATION/LEAKAGE THROUGH LAYER 15	0.00000	(0.00000)	0.000	0.00000
CHANGE IN WATER STORAGE	0.003	(0.4914)	12.41	0.012

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	6.15	22324.500
RUNOFF	5.418	19666.3945
DRAINAGE COLLECTED FROM LAYER 3	0.00735	26.68496
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000187	0.67747
AVERAGE HEAD ON TOP OF LAYER 4	22.010	
MAXIMUM HEAD ON TOP OF LAYER 4	32.718	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	88.6 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.00036	1.29222
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00062
AVERAGE HEAD ON TOP OF LAYER 9	0.047	
MAXIMUM HEAD ON TOP OF LAYER 9	0.093	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	2.0 FEET	
DRAINAGE COLLECTED FROM LAYER 11	0.00000	0.00007
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.000000	0.00062
AVERAGE HEAD ON TOP OF LAYER 12	0.000	
MAXIMUM HEAD ON TOP OF LAYER 12	0.002	
LOCATION OF MAXIMUM HEAD IN LAYER 11 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 13	0.00000	0.00068
PERCOLATION/LEAKAGE THROUGH LAYER 14	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 14	0.000	

Written by: M. Zahirul Islam Date: 11/12/10 (MM/DD/YY) Reviewed by: Scott M. Graves Date: 11/14/10 (MM/DD/YY)

Client: Clean Harbors Project: Lone Mountain Facility Project/Proposal No.: TXL0095 Task No: 04

```
MAXIMUM HEAD ON TOP OF LAYER 14              0.000

LOCATION OF MAXIMUM HEAD IN LAYER 13
       (DISTANCE FROM DRAIN)                 0.0 FEET

PERCOLATION/LEAKAGE THROUGH LAYER 15         0.000000          0.00000

SNOW WATER                                   1.36           4939.7363


MAXIMUM VEG. SOIL WATER (VOL/VOL)                    0.2905

MINIMUM VEG. SOIL WATER (VOL/VOL)                    0.1186

 ***  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	0.1836	0.0306
2	11.5867	0.3862
3	0.1663	0.8316
4	0.0000	0.0000
5	9.8250	0.4094
6	129.5280	0.2570
7	9.4320	0.3930
8	0.0040	0.0202
9	0.0000	0.0000
10	9.4320	0.3930
11	0.0020	0.0100
12	0.0000	0.0000
13	0.0020	0.0100
14	0.0000	0.0000
15	15.4656	0.4180
SNOW WATER	0.000	

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EXHIBIT F

FINAL CLOSURE DESIGN

Exhibit F-1

Storm Water Management Plan – Final Conditions

Written by: H. Douglas Date: 2/27/14 Reviewed & Revised by: S. Graves Date: 10/10/2014

Client: Clean Harbors Project: Lone Mountain Facility Project No.: TXL0380 Phase No.: 04

LANDFILL CELL 15
SURFACE WATER MANAGEMENT SYSTEM DESIGN – FINAL CONDITIONS

10/20/2014

REGISTERED PROFESSIONAL ENGINEER SCOTT M. GRAVES 19710 OKLAHOMA

Scott M. Graves, P.E.
State of Oklahoma Registration # 19710
Geosyntec Consultants
Oklahoma Certificate of Authorization No. 1996
Exp. 06/30/2016

SEALED FOR CALCULATION PAGES
F1-1 THROUGH F1-84

1. INTRODUCTION

The purpose of this calculation package is to present the analysis and design of the surface water management system for the final re-designed configuration and conditions at closure for Landfill Cell 15 at the Lone Mountain Facility. This package provides calculations of peak design discharges (i.e., hydrology) and design of surface water management system components (i.e., hydraulic design), which include:

- Mid-Slope Drainage Berms;
- Drainage Down-Channels;
- Bottom Drainage Berms;
- Downspouts; and
- Storm Water Pipes (culverts).

2. PROJECT BACKGROUND

The surface water management system for Landfill Cell 15 is composed of the mid-slope drainage berms, drainage down-channels, bottom drainage berms, downspouts, manholes, and storm water pipes (culverts) (Figure F1-1 and Figure F1-2). These features are also shown on the permit drawings (Exhibit A of the Landfill Cell 15 Engineering Report). As shown, the proposed tack-on mid-slope drainage berms will collect and convey storm water runoff from the upper portion of the final cover system. The drainage down-channels will convey water collected by the mid-slope drainage berms to downspouts. The tack-on bottom drainage berms will collect storm water runoff from the final cover system below the mid-slope drainage berms and convey water to the downspouts through the aid of an inlet box (USBR Type IV). From there, the storm water will be conveyed to manholes located along the perimeter access road. Storm water pipes (culverts) will transmit the collected storm water from the manholes and route the storm water to the facility's permitted outfall via the site's permitted runoff system of ponds and perimeter ditches.

3. CALCULATION METHODOLOGY

3.1 Return Period for Design

Surface water management system components are designed for calculated peak discharges from a 100-year design storm event. It is noted that the existing surface water management system features (i.e., areas now built) on Cell 15 and on adjacent areas that contribute runoff including pipes, ponds and perimeter ditches, were initially designed for a 100-year, 24-hour duration design storm event of 7.5 inches (with an average 24-hour intensity of 0.31 inches/hour) (TP-40, 1961). In this calculation package, the existing Cell 15 drainage features that were previously designed for these conditions are considered under the same conditions (i.e. a rainfall intensity of the 100-year, 24-hour storm equal to 0.31 inches/hour is applied to those drainage areas on existing cells that drain to existing pipes). Specifically, this applies to pipes P1, P3, P12, P13, P14, and P15 (identified on figures and tables presented subsequently in this calculation package).

The hydraulic design for the proposed Landfill Cell 15 features summarized here is for the peak flows from a 100-year design storm event with a duration equal to the time of concentration of the contributing drainage area. Using a duration which closely matches the time of concentration is more appropriate for design, as recommended in TR-55 (USDA, 1986). Furthermore, designing for a duration equal to the time of concentration (as opposed to a 24-hour duration) will result in larger calculated peak flows and is therefore more conservative compared to how the previous (now existing) features were designed.

3.2 Hydrology

Intensity of rainfall for design is chosen based on calculations for times of concentration outlined in the TR-55 Urban Hydrology for Small Watersheds manual (USDA, 1986). Peak design intensity and peak discharges are calculated based on the Rational Method, as described in *Applied Hydrology* (Chow et al., 1988) and Hydro-35 (NOAA, 1977).

3.3 Hydraulic Design

Hydraulic design of channels, berms, and culverts are performed using the Manning's equation (Chow, 1959).

4. COMPUTATIONS

4.1 Drainage Areas

Figure F1-2 of this calculation package shows drainage areas delineated for the design of each surface water management system component. The surface water system incorporating Landfill Cell 15 and adjacent areas was divided into 40 drainage areas. The Landfill Cell 15 final cover grading configuration is comprised of 19 drainage areas. The perimeter road on the Landfill Cell 15 embankment and the slopes along the exterior of the embankment are divided into 21 drainage areas. In addition to the drainage areas associated with the Landfill expansion areas, the existing cells that drain to surface water management system components that are shared with the Landfill Cell 15 are divided into 9 drainage areas. As mentioned, these areas were previously designed for a 100-year, 24-hour duration design storm event and were not changed in these calculations. The acreage of each drainage area was measured from the design drawings, as shown in Figure F1-2, and is presented in Tables F1-1, F1-2, F1-3, and F1-4.

4.2 Estimation of Peak Rainfall Intensity for use in Rational Method

Consistent with the existing permit, runoff from a 100-year storm is used to design the drainage channels, berms, and culverts. The design rainfall intensity was calculated based on guidance provided in *Applied Hydrology* (Chow et al., 1988), TR-55 (USDA, 1986), and the National Oceanic and Atmospheric Administration (NOAA) Technical Memorandum Hydro-35 (NOAA, 1977).

The time of concentration is the time for runoff to flow from the most hydraulically remote point of the drainage area to the point under investigation. The time of concentration is estimated by dividing the longest drainage path by the velocity of runoff. The sheet flow velocities were estimated using the Upland Method developed by the Natural Resources Conservation Service (formerly the Soil Conservation Service). The Upland Method utilizes the observed relationship between flow velocity, drainage slope, and surface conditions Equation (1) (HydroCAD, 2006):

$$V = K_v\,(s)^{0.5} \tag{1}$$

where, V = velocity (ft/s),
K_v = velocity factor (ft/s), and
s = slope along flow path (ft/ft)

For design purposes, the surface condition of the final cover is assumed to be similar to a short grass pasture, which corresponds to a K_v value of 7.0 (Table F1-5).

For open channel flow within the mid-slope drainage berms, bottom drainage berms, and drainage down-channels, times of concentration are calculated using a flow velocity of 5 ft/s. A flow velocity of 5 ft/s is the target upper bound for the channels to minimize erosion.

The velocities and times of concentration used in the design are presented in Table F1-1. A minimum time of concentration of 10 minutes was used to calculate the rainfall intensity because small areas with exceedingly short times of concentration could result in design rainfall intensities that are unrealistically high. The Oklahoma Department of Transportation's (ODOT's) Roadway Design Manual specifies a minimum design time of concentration of 10 minutes for rural areas (ODOT, 1992). For the Landfill Cell 15 expansion, all of the contributing drainage areas have calculated times of concentration less than the minimum 10 minute recommendation. Therefore, the surface water management system will be designed for the 10-minute peak intensity corresponding to a 100-year storm event.

The rainfall intensity was estimated from the procedures as recommended in Hydro-35 (NOAA, 1977). The following procedure is used to calculate the 100-year, 10-min storm depth and intensity:

1. 100-year values of design rainfall depth for the duration of 5 and 15 minutes are estimated from the corresponding isopluvial maps (Figures F1-3 and F1-4; NOAA, 1977).
    a. The 100-year, 5-min depth is approximately 0.86 inches.
    b. The 100-year, 15-min depth is approximately 1.83 inches.
    c. It is noted that a United States Geological Survey (USGS) publication by Tortorelli et al. (1999) was used to estimate rainfall depths in Exhibit C: Operation Storm Water Management Design. Tortorelli et al. (1999) provides the 100-year, 15-min depth as 1.65 inches and does not give a rainfall depth for the 100-year, 5-min duration. Therefore, the aforementioned values from NOAA (1977) used in this analysis are conservative in comparison to the Tortorelli et al. (1999) values.
2. Rainfall depth for the intermediate (10-min) duration is calculated using Equation (2) (Chow et al., 1988):

$$100yr, 10\min = 0.59\,(100yr, 15\min depth) + 0.41(100yr, 5\min depth) \qquad (2)$$

The values for 100-year, 15-min rainfall depth and 100–year, 5-min rainfall depth were obtained, as discussed, from NOAA (1977). The 100-year, 10-min rainfall depth in Major County, OK is estimated as 1.43 inches, using the above equation. This rainfall depth corresponds to a rainfall intensity of 8.59 in/hr.

4.3 Estimation of Peak Design Discharges Using the Rational Method

The Rational Method was used to estimate peak discharge rates for each drainage area. The equation for the Rational Method is shown in Equation (3):

$$Q = C \times I \times A \tag{3}$$

where, Q = peak runoff rate (cfs),
C = runoff coefficient,
I = rainfall intensity (in/hr), and
A = drainage area (acres).

A runoff coefficient of 0.51 was selected for the drainage areas on the final cover system. This value was selected based on information in *Applied Hydrology* by Chow et al. (1988) for lawns in good condition with a steep slope for a 100-year return period as shown in Table F1-6. Calculated peak discharges for the 10-minute peak intensity of a 100-year event for each drainage area are provided in Tables F1-1 and F1-2 for the final cover areas and perimeter road areas, respectively. Table F1-4 presents storm water flows from each final cover subbasin draining to a specific drainage system component. Table F1-7 presents the amount of inflow and outflow to each manhole structure.

To obtain the design discharge for a specific point in the surface water management system, the peak discharges for each drainage area upstream of the point were simply added together. This technique slightly overestimates the peak discharge rates because peak flows from upstream drainage areas will likely combine downstream at different times. However, this technique is conservative and appropriate for design given the small drainage areas and short times of concentration. The upstream drainage areas and/or upstream system components for each surface water management system component area are provided in Table F1-8. The corresponding flow rate for each component and cumulative, calculated design discharges are provided in Table F1-9.

4.4 Hydraulic Design

Manning's equation was used to calculate flow depths and capacities for channels, berms, and storm water pipes. Manning's equation (Chow, 1959) is shown in Equation (4):

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2} \tag{4}$$

where: Q = discharge (cfs);
n = Manning's roughness coefficient;
A = area of cross-section of flow (ft^2);
R = hydraulic radius = A/P (ft);
P = wetted perimeter (ft); and
S = longitudinal slope (ft/ft).

The tractive stresses in the channel for various depths of flow are estimated using Equation (5) (Chow, 1959):

$$\tau_o = \gamma_w DS \tag{5}$$

where: τ_o = average tractive stress (lb/ft^2);
γ_w = unit weight of water (lb/ft^3);
D = depth of flow (ft); and
S = channel slope (ft/ft).

The depth of flow, maximum velocity, and tractive stress at each design discharge point for the channels and storm water piping were calculated using Manning's equation and the tractive stress equation. These calculations were performed using the spreadsheets presented in Attachment A of this calculation package. Channels and berms are designed to accommodate the design storm without overtopping. Storm water piping is designed to convey the design peak storm water flow.

The design parameters and results of the hydraulic design of each component of the surface water management system are summarized below. The hydraulic design of the mid-slope drainage berm, bottom drainage berm, and drainage down-channel are evaluated below for the critical case of each drainage component (i.e., using the largest of all the calculated peak flow rates that a given drainage component will convey). All other subbasin areas will, by definition, generate a smaller peak discharge and will, therefore, be properly designed.

For allowable tractive stresses, grass coverage of Retardance Class C vegetation was assumed for the mid-slope and bottom drainage berms, while unvegetated, non-degradable Rolled Erosion Control Products (RECPs) were assumed to be used on the drainage down channels (Fishenich, 2001). Retardance Class C vegetation includes a range of good and fair stands of grass of 6 inches in height or greater. Non-degradable RECPs were selected for the drainage down channels to provide cost-effective erosion resistance to the higher tractive stresses encountered. The calculated average tractive stress corresponds to a 100-year design storm.

Written by: **H. Douglas**	Date: **2/27/14**	Reviewed by: **S. Graves**	Date: **6/12/2014**
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Mid-Slope Drainage Berm (Section of Area 7-U, Table F1-4, Attachment A)

- Critical Design Discharge = 12.5 cfs
- Channel Slope = 2% (Figure F1-1)
- Manning's *n* for Design = 0.033 (Table F1-10)
- Side Slopes = 10H:1V and 2H:1V(Figure F1-5)
- Bottom Width = 0 ft (Figure F1-5)
- Available Depth of Flow = 2.0 ft (Figure F1-5)
- **Calculated Depth of Flow** = 0.79 ft (Attachment A)
- ***Calculated Depth of Flow < Available Depth of Flow***
- Allowable Tractive Stress = 1.0 lb/ft^2 (Table F1-11)
- **Calculated Average Tractive Stress** = 0.98 lb/ft^2 (Attachment A)
- ***Calculated Average Tractive Stress < Allowable Tractive Stress***

Bottom Drainage Berm (Area 28, Table F1-4, Attachment A)

- Critical Design Discharge = 32.4 cfs
- Channel Slope = 0.5% (Figure F1-1)
- Manning's *n* for Design = 0.033 (Table F1-10)
- Side Slopes = 10H:1V and 2H:1V (Figure F1-6)
- Bottom Width = 0 ft (Figure F1-6)
- Available Depth of Flow = 2 ft (Figure F1-6)
- **Calculated Depth of Flow** = 1.46 ft (Attachment A)
- ***Calculated Depth of Flow < Available Depth of Flow***
- Allowable Tractive Stress = 1.0 lb/ft^2 (Table F1-11)
- **Calculated Average Tractive Stress** = 0.45 lb/ft^2 (Attachment A)
- ***Calculated Average Tractive Stress < Allowable Tractive Stress***

Drainage Down-Channel (Area 7-U, Table F1-4, Attachment A)

- Critical Design Discharge = 16.9 cfs
- Channel Slope = 10% (Figure F1-1)
- Manning's *n* for Design = 0.033 (Table F1-10)
- Side Slopes = 2H:1V (Figure F1-7)
- Bottom Width = 10 ft (Figure F1-7)
- Available Depth of Flow = 1.5 ft (Figure F1-7)
- **Calculated Depth of Flow** = 0.28 ft (Attachment A)
- ***Calculated Depth of Flow < Available Depth of Flow***
- Allowable Tractive Stress = 3.0 lb/ft^2 (Table F1-11)
- **Calculated Average Tractive Stress** = 1.72 lb/ft^2 (Attachment A)
- ***Calculated Average Tractive Stress < Allowable Tractive Stress***

Hydraulic design of the downspouts is grouped based on the required number of pipes. Downspouts DS-1 to DS-3, DS-25, DS-26, and DS-30 to DS-32 each require one pipe, whereas downspouts DS-4 to DS-11 and DS-27 to DS-29 each require two pipes. The downspouts with the greatest peak flows are summarized below. DS-25 has the largest peak flow for the single pipe downspouts, and DS-28 has the largest peak flow for the two pipe downspouts.

Downspout (One Pipe)

- Critical Design Discharge = 15.5 cfs (Table F1-13)
- Diameter of Pipe = 18-inches (Table F1-13)
- Longitudinal Slope = 0.10 ft/ft (Figure F1-8)
- Manning's *n* for Design = 0.024 (Table F1-12)
- Depth of Flow = 12.9-inches (Attachment A)
- Maximum Flow Rate for Single Pipe = 18.1 cfs (Attachment A)
- Total Number of Pipes Needed for Design Flow = 1 (minimum)
- **Calculated Maximum Available Flow Rate of Downspout** = 18.1 cfs (Attachment A)
- ***Calculated Design Discharge < Calculated Available Discharge***

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Downspout (Two Pipes)

- Critical Design Discharge = 32.4 cfs (Table F1-13)
- Diameter of Pipe = 18-inches (Table F1-13)
- Longitudinal Slope = 0.10 ft/ft (Figure F1-9)
- Manning's *n* for Design = 0.024 (Table F1-12)
- Depth of Flow = 13.3-inches (Attachment A)
- Maximum Flow Rate for Single Pipe = 18.1 cfs (Attachment A)
- Total Number of Pipes Needed for Design Flow = 2 (minimum)
- **Calculated Maximum Available Flow Rate of Downspout** = 36.2 cfs (Attachment A)
- ***Calculated Design Discharge < Calculated Available Discharge***

The storm water pipes are placed into three groups based on pipe slope. The first group has a slope ranging from 0.5% to 0.6%, the second has a slope of 41.5%, and the third has an intermediate slope of 32.5%. Each storm water pipe is designed based on its respective peak flow. Calculations are presented in Attachment A and the results are summarized below.

<u>Storm Water Pipe (P1, P3, P5, P6, P7, P12, P13, P14, P28, and P30)</u>

- Critical Design Discharge = 1.3 to 166.5 cfs (Table F1-14)
- Diameter of Pipe = 18 to 72 inches Corrugated Plastic Pipe (CPP) (Figure F1-1 and Table F1-14)
- Culvert Slope = 0.5 to 0.6% (Table F1-14)
- Manning's *n* for Design = 0.024 (Table F1-12)
- Calculated Maximum Available Flow Rate of Storm Water Pipe = 178.8 (P30; Attachment A)
- Calculated Maximum Design Flow = 166.5 cfs (P30; Table F1-14)
- ***Calculated Design Discharge < Calculated Available Discharge***

<u>Storm Water Pipe (P2, P4, P8, P9, P10, P11, P25, P26, P27, P29, P31, P32, and P33)</u>

- Critical Design Discharge = 12.0 to 166.5 cfs (Table F1-14)
- Diameter of Pipe = 18 to 36 inches Corrugated Plastic Pipe (CPP) (Attachment A)
- Culvert Slope = 41.5% (Slope of pipe determined in original permit, Table F1-14)
- Manning's n for Design = 0.024 (Table F1-12)
- Calculated Maximum Available Flow Rate of Storm Water Pipe = 234.2 cfs (P33; Attachment A)
- Calculated Maximum Design Flow = 166.5 cfs (P33; Table F1-14)
- ***Calculated Design Discharge < Calculated Available Discharge***

<u>Storm Water Pipe (P15)</u>

- Critical Design Discharge = 33.0 cfs (Table F1-14)
- Diameter of Pipe = 42 inches Corrugated Plastic Pipe (CPP) (Attachment A)
- Culvert Slope = 32.5% (Table F1-14)
- Manning's n for Design = 0.024 (Table F1-12)
- Calculated Maximum Available Flow Rate of Storm Water Pipe = 312.6 cfs (P15; Attachment A)
- Calculated Maximum Design Flow = 33.0 cfs (P15) (Table F1-14)
- ***Calculated Design Discharge < Calculated Available Discharge***

5. CONCLUSIONS

The results presented in this calculation package indicate that the final surface water management system for the proposed Landfill Cell 15 at the Lone Mountain Facility will collect and control the runoff resulting from the 100-year storm event. Existing features were analyzed using the design basis previously permitted, which is using the average intensity from a 100-year, 24-hour storm event. As discussed, for the proposed Landfill Cell 15 features (berms, downspouts, and pipes), a more conservative approach was used, by selecting the 10-minute peak flow rates from a 100-year storm event. The proposed surface water management system includes mid-slope drainage berms which collect runoff from the upper portion of the landfill cell. Runoff is then conveyed through drainage down-channels. Runoff from the lower portion of the landfill cell is collected in the bottom drainage berms. Surface water from the drainage down-channel and bottom drainage berm then enter a USBR Type IV inlet transition box. Downspouts convey the runoff into manholes and either discharge runoff to an outfall on existing ground or discharge into an existing storm water pipe.

6. REFERENCES

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Written by:	H. Douglas	Date:	2/27/14	Reviewed by:	S. Graves	Date:	6/12/2014
Client:	Clean Harbors	Project:	Lone Mountain Facility	Project No.:	TXL0380	Phase No.:	04

TABLES

TABLE F1-1 FINAL COVER DRAINAGE CALCULATIONS.

Lone Mountain Facility

Waynoka, OK

BASIN	AREA	SHEET FLOW - SIDESLOPE				MIDSLOPE BERM FLOW			BOTTOM BERM FLOW			DOWN CHANNEL FLOW			Tc	Tc	I	C	Q
DESIGNATION	(acres)	Length (ft)	Slope (ft/ft)	Avg Vel (ft/s)	Time (min)	Length (ft)	Vel (ft/s)	Time (min)	Length (ft)	Vel (ft/s)	Time (min)	Length (ft)	Vel (ft/s)	Time (min)	Calculated (min)	Design (min)	(in/hr)		(cfs)
A1	1.81	280	0.1	2.3	2.03	-	-		-	-		-	-		2.03	10.00	8.59	0.51	**7.9**
A2	3.19	265	0.1	2.3	1.92	-	-		350	5	1.17	-	-		3.09	10.00	8.59	0.51	**14.0**
A3	3.13	265	0.1	2.3	1.92	-	-		365	5	1.22	-	-		3.14	10.00	8.59	0.51	**13.7**
A4	6.73	320	0.1	2.3	2.32	330	5	1.10	-	-		300	5	1.00	4.42	10.00	8.59	0.51	**29.5**
A5	4.52	345	0.1	2.3	2.50	160	5	0.53	-	-		360	5	1.20	4.23	10.00	8.59	0.51	**19.8**
A6	4.48	320	0.1	2.3	2.32	170	5	0.57	-	-		300	5	1.00	3.89	10.00	8.59	0.51	**19.6**
A7	6.57	300	0.1	2.3	2.17	370	5	1.23	-	-		300	5	1.00	4.41	10.00	8.59	0.51	**28.8**
A8	6.83	325	0.1	2.3	2.36	170	5	0.57	-	-		310	5	1.03	3.96	10.00	8.59	0.51	**29.9**
A9	5.12	325	0.1	2.3	2.36	170	5	0.57	-	-		310	5	1.03	3.96	10.00	8.59	0.51	**22.4**
A10	5.60	310	0.1	2.3	2.25	225	5	0.75	-	-		315	5	1.05	4.05	10.00	8.59	0.51	**24.5**
A11	5.50	275	0.1	2.3	1.99	290	5	0.97	-	-		300	5	1.00	3.96	10.00	8.59	0.51	**24.1**
A25	3.54	225	0.1	2.3	1.63	-	-		-	-		300	5	1.00	2.63	10.00	8.59	0.51	**15.5**
A26	3.39	340	0.1	2.3	2.46	125	5	0.42	-	-		300	5	1.00	3.88	10.00	8.59	0.51	**14.8**
A27	5.47	340	0.1	2.3	2.46	125	5	0.42	-	-		300	5	1.00	3.88	10.00	8.59	0.51	**24.0**
A28	7.40	270	0.1	2.3	1.96				500	5	1.67	-	-		3.62	10.00	8.59	0.51	**32.4**
A29	5.46	250	0.1	2.3	1.81				480	5	1.60	-	-		3.41	10.00	8.59	0.51	**23.9**
A30	3.35	255	0.1	2.3	1.85				405	5	1.35	-	-		3.20	10.00	8.59	0.51	**14.7**
A31	2.84	255	0.1	2.3	1.85				405	5	1.35	-	-		3.20	10.00	8.59	0.51	**12.5**
A32	1.82	275	0.1	2.3	1.99				-	-		-	-		1.99	10.00	8.59	0.51	**8.0**

TABLE F1-2 PERIMETER ROAD DRAINAGE CALCULATIONS
Lone Mountain Facility
Waynoka, OK

BASIN	BELOW BOTTOM BERM				PERIMETER ROAD						TOTAL FLOW
DESIGNATION	Area (acres)	C	I (in/hr)	Q (cfs)	Roadway Length (ft)	Roadway Width (ft)	Area (acres)	C	I (in/hr)	Q (cfs)	Q Total (cfs)
A12	0.56	0.51	8.59	2.43	670	18	0.28	0.51	8.59	1.21	3.65
A13	0.55	0.51	8.59	2.40	610	18	0.25	0.51	8.59	1.10	3.51
A14	0.59	0.51	8.59	2.59	680	18	0.28	0.51	8.59	1.23	3.82
A15	0.66	0.51	8.59	2.89	720	18	0.30	0.51	8.59	1.30	4.19
A16	0.30	0.51	8.59	1.34	50	18	0.02	0.51	8.59	0.09	1.43
A17	0.14	0.51	8.59	0.62	670	18	0.28	0.51	8.59	1.21	1.83
A18	0.36	0.51	8.59	1.59	730	18	0.30	0.51	8.59	1.32	2.92
A19	0.48	0.51	8.59	2.10	730	18	0.30	0.51	8.59	1.32	3.42
A20	0.30	0.51	8.59	1.30	700	18	0.29	0.51	8.59	1.27	2.57
A21	0.62	0.51	8.59	2.70	750	18	0.31	0.51	8.59	1.36	4.06
A22	0.79	0.51	8.59	3.45	820	18	0.34	0.51	8.59	1.49	4.94
A23	-	-	-	-	320	18	0.13	0.51	8.59	0.58	0.58
A24	-	-	-	-	420	18	0.17	0.51	8.59	0.76	0.76
A33	0.55	0.51	8.59	2.41	630	18	0.26	0.51	8.59	1.14	3.56
A34	0.34	0.51	8.59	1.48	390	18	0.16	0.51	8.59	0.71	2.19
A35	0.60	0.51	8.59	2.64	670	18	0.28	0.51	8.59	1.21	3.86
A36	0.87	0.51	8.59	3.82	760	18	0.31	0.51	8.59	1.38	5.20
A37	0.91	0.51	8.59	4.01	760	18	0.31	0.51	8.59	1.38	5.38
A38	0.68	0.51	8.59	3.00	750	18	0.31	0.51	8.59	1.36	4.36
A30	0.53	0.51	8.59	2.33	580	18	0.24	0.51	8.59	1.05	3.38
A40	0.56	0.51	8.59	2.47	630	18	0.26	0.51	8.59	1.14	3.61

TABLE F1-3 EXISTING CELL DRAINAGE CALCULATIONS.
Lone Mountain Facility
Waynoka, OK

BASIN DESIGNATION	Area (acres)	C	I (in/hr)	Q (cfs)
E1	2.45	0.51	0.31	0.39
E2	2.53	0.51	0.31	0.40
E3	2.53	0.51	0.31	0.40
E4	2.46	0.51	0.31	0.39
E5	2.53	0.51	8.59	11.09
E6	2.53	0.51	0.31	0.40
E7	2.52	0.51	0.31	0.40
E8	2.52	0.51	8.59	11.04
E9	2.53	0.51	8.59	11.09

TABLE F1-4 FINAL COVER SUBBASIN DRAINAGE CALCULATIONS

Lone Mountain Facility

SUBBASIN DESIGNATION	(acres)	I (in/hr)	C	Q (cfs)
1	1.81	8.59	0.51	**7.9**
2	3.19	8.59	0.51	**14.0**
3	3.13	8.59	0.51	**13.7**
4-LS	2.63	8.59	0.51	**11.5**
4-LN	2.52	8.59	0.51	**11.0**
4-U	1.58	8.59	0.51	**6.9**
5-LW	0.95	8.59	0.51	**4.2**
5-LE	2.14	8.59	0.51	**9.4**
5-U	1.43	8.59	0.51	**6.3**
6-LW	0.89	8.59	0.51	**3.9**
6-LE	1.24	8.59	0.51	**5.4**
6-U	2.34	8.59	0.51	**10.3**
7-LW	0.00	8.59	0.51	**0.0**
7-LE	2.71	8.59	0.51	**11.9**
7-U	3.85	8.59	0.51	**16.9**
8-LW	2.43	8.59	0.51	**10.7**
8-LE	1.24	8.59	0.51	**5.4**
8-U	3.15	8.59	0.51	**13.8**
9-LW	1.24	8.59	0.51	**5.4**
9-LE	1.24	8.59	0.51	**5.4**
9-U	2.64	8.59	0.51	**11.6**
10-LW	1.72	8.59	0.51	**7.5**
10-LE	2.28	8.59	0.51	**10.0**
10-U	1.60	8.59	0.51	**7.0**
11-LS	2.76	8.59	0.51	**12.1**
11-LN	1.44	8.59	0.51	**6.3**
11-U	1.30	8.59	0.51	**5.7**

U:	UPPER	L:	LOWER
N:	NORTH	S:	SOUTH
W:	WEST	E:	EAST

SUBBASIN DESIGNATION	(acres)	I (in/hr)	C	Q (cfs)
25-LW	1.49	8.59	0.51	**6.5**
25-LE	1.25	8.59	0.51	**5.5**
25-U	0.80	8.59	0.51	**3.5**
26-LS	0.88	8.59	0.51	**3.9**
26-LN	1.34	8.59	0.51	**5.9**
26-U	1.17	8.59	0.51	**5.1**
27-LS	3.08	8.59	0.51	**13.5**
27-LN	0.89	8.59	0.51	**3.9**
27-U	1.51	8.59	0.51	**6.6**
28	7.40	8.59	0.51	**32.4**
29	5.46	8.59	0.51	**23.9**
30	3.35	8.59	0.51	**14.7**
31	2.84	8.59	0.51	**12.5**
32	1.82	8.59	0.51	**8.0**

TABLE F1-5. UPLAND METHOD VELOCITY FACTORS
(from HydroCAD, 2006)

Surface Description	K_V [ft/sec]	K_V [m/sec]
Paved	20.33	6.2
Unpaved	16.13	4.92
Grassed Waterway	15.0	4.57
Nearly Bare & Untilled	10.0	3.05
Cultivated Straight Rows	9.0	2.74
Short Grass Pasture	7.0	2.13
Woodland	5.0	1.52
Forest w/Heavy Litter	2.5	0.76

TABLE F1-6. RUNOFF COEFFICIENTS FOR USE IN THE RATIONAL METHOD
(from Chow et al., 1988)

	Return Period (years)						
Character of surface	**2**	**5**	**10**	**25**	**50**	**100**	**500**
Developed							
Asphaltic	0.73	0.77	0.81	0.86	0.90	0.95	1.00
Concrete/roof	0.75	0.80	0.83	0.88	0.92	0.97	1.00
Grass areas (lawns, parks, etc.)							
Poor condition (grass cover less than 50% of the area)							
Flat, 0–2%	0.32	0.34	0.37	0.40	0.44	0.47	0.58
Average, 2–7%	0.37	0.40	0.43	0.46	0.49	0.53	0.61
Steep, over 7%	0.40	0.43	0.45	0.49	0.52	0.55	0.62
Fair condition (grass cover on 50% to 75% of the area)							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Good condition (grass cover larger than 75% of the area)							
Flat, 0–2%	0.21	0.23	0.25	0.29	0.32	0.36	0.49
Average, 2–7%	0.29	0.32	0.35	0.39	0.42	0.46	0.56
Steep, over 7%	0.34	0.37	0.40	0.44	0.47	0.51	0.58
Undeveloped							
Cultivated Land							
Flat, 0–2%	0.31	0.34	0.36	0.40	0.43	0.47	0.57
Average, 2–7%	0.35	0.38	0.41	0.44	0.48	0.51	0.60
Steep, over 7%	0.39	0.42	0.44	0.48	0.51	0.54	0.61
Pasture/Range							
Flat, 0–2%	0.25	0.28	0.30	0.34	0.37	0.41	0.53
Average, 2–7%	0.33	0.36	0.38	0.42	0.45	0.49	0.58
Steep, over 7%	0.37	0.40	0.42	0.46	0.49	0.53	0.60
Forest/Woodlands							
Flat, 0–2%	0.22	0.25	0.28	0.31	0.35	0.39	0.48
Average, 2–7%	0.31	0.34	0.36	0.40	0.43	0.47	0.56
Steep, over 7%	0.35	0.39	0.41	0.45	0.48	0.52	0.58

Note: The values in the table are the standards used by the City of Austin, Texas. Used with permission.

TABLE F1-7 MANHOLE SUMMARY
Lone Mountain Facility
Waynoka, OK

MANHOLE DESIGNATION	INFLOW					OUTFLOW
	Downspout Flow (cfs)	Below Berm Flow (cfs)	Perimeter Road Flow (cfs)	Existing Area Flow (cfs)	Inflow from Stormwater Piping (cfs)	Outflow from Manhole (cfs)
MH-1	7.94	2.43	1.2	0.4	20.9	32.8
MH-2	14.00	2.40	1.1		-	17.5
MH-3	13.73	2.59	1.2	0.4	-	17.9
MH-4	29.49	2.89	1.3		-	33.7
MH-5	19.82	1.34	0.1		-	21.3
MH-6	19.62	0.62	1.2	11.0	21.3	53.7
MH-7	28.78	1.59	1.3		53.7	85.4
MH-8	29.92	2.10	1.3		-	33.3
MH-9	22.44	1.30	1.3		-	25.0
MH-10	24.53	2.70	1.4		-	28.6
MH-11	24.10	3.45	1.5		-	29.0
MH-12	-	-	0.6	0.8	-	1.4
MH-13	-	-	0.8	0.8	-	1.6
MH-14	-	-	-		20.9	20.9
MH-15	-	-	-		32.8	32.8
MH-25	15.53	2.41	1.1		-	19.1
MH-26	14.84	1.48	0.7		-	17.0
MH-27	23.98	2.64	1.2		-	27.8
MH-28	32.44	3.82	1.4	11.1	85	134.2
MH-29	23.91	4.01	1.4		-	29.3
MH-30	14.69	3.00	1.4	11.1	134.2	164.3
MH-31	12.46	2.33	1.1		-	15.8
MH-32	7.96	2.47	1.1		-	11.6

TABLE F1-8. Drainage Areas Upstream of Storm Water Management System Component

System Component	Drainage Components Upstream of Storm Water Management System						System Component	Drainage Components Upstream of Storm Water Management System Component					
DS-1	A1						DS-25	A25					
DS-2	A2						DS-26	A26					
DS-3	A3						DS-27	A27					
DS-4	A4						DS-28	A28					
DS-5	A5						DS-29	A29					
DS-6	A6						DS-30	A30					
DS-7	A7						DS-31	A31					
DS-8	A8						DS-32	A32					
DS-9	A9						P25	MH-25					
DS-10	A10						P26	MH-26					
DS-11	A11						P27	MH-27					
P1	MH-1						P28	MH-28					
P2	MH-2						P29	MH-29					
P3	MH-3						P30	MH-30					
P4	MH-4						P31	MH-31					
P5	MH-5						P32	MH-32					
P6	MH-6						P33	P30					
P7	MH-7						MH-25	DS-25	A33				
P8	MH-8						MH-26	DS-26	A34				
P9	MH-9						MH-27	DS-27	A35				
P10	MH-10						MH-28	DS-28	A36	P7	E9		
P11	MH-11						MH-29	DS-29	A37				
P12	MH-12						MH-30	DS-30	A38	P28	E5		
P13	MH-13						MH-31	DS-31	A39				
P14	MH-14						MH-32	DS-32	A40				
P15	MH-15												
MH-1	DS-1	A12	P14	E1									
MH-2	DS-2	A13											
MH-3	DS-3	A14	E6										
MH-4	DS-4	A15											
MH-5	DS-5	A16											
MH-6	DS-6	P5	A17	E8									
MH-7	DS-7	A18	P6										
MH-8	DS-8	A19											
MH-9	DS-9	A20											
MH-10	DS-10	A21											
MH-11	DS-11	A22											
MH-12	A23	E4	E7										
MH-13	A24	E2	E3										
MH-14	P3	P12	P13										
MH-15	P1												

TABLE F1-9. Flow Rates from Drainage Areas Upstream of Storm Water Management System Component

System Component	Flow Rates from Drainage Components Upstream of Storm Water Management						Total Flow (cfs)
DS-1	7.9						7.9
DS-2	14.0						14.0
DS-3	13.7						13.7
DS-4	29.5						29.5
DS-5	19.8						19.8
DS-6	19.6						19.6
DS-7	28.8						28.8
DS-8	29.9						29.9
DS-9	22.4						22.4
DS-10	24.5						24.5
DS-11	24.1						24.1
P1	32.8						32.8
P2	17.5						17.5
P3	17.9						17.9
P4	33.7						33.7
P5	21.3						21.3
P6	53.7						53.7
P7	85.4						85.4
P8	33.3						33.3
P9	25.0						25.0
P10	28.6						28.6
P11	29.0						29.0
P12	1.4						1.4
P13	1.6						1.6
P14	20.9						20.9
P15	32.8						32.8
MH-1	7.9	3.6	20.9	0.4			32.8
MH-2	14.0	3.5					17.5
MH-3	13.7	3.8	0.4				17.9
MH-4	29.5	4.2					33.7
MH-5	19.8	1.4					21.3
MH-6	19.6	21.3	1.8	11.0			53.7
MH-7	28.8	2.9	53.7				85.4
MH-8	29.9	3.4					33.3
MH-9	22.4	2.6					25.0
MH-10	24.5	4.1					28.6
MH-11	24.1	4.9					29.0
MH-12	0.6	0.4	0.4				1.4
MH-13	0.8	0.4	0.4				1.6
MH-14	17.9	1.4	1.6				20.9
MH-15	32.8						32.8

System Component	Flow Rates from Drainage Components Upstream of Storm Water Management						Total Flow (cfs)
DS-25	15.5						15.5
DS-26	14.8						14.8
DS-27	24.0						24.0
DS-28	32.4						32.4
DS-29	23.9						23.9
DS-30	14.7						14.7
DS-31	12.5						12.5
DS-32	8.0						8.0
P25	19.1						19.1
P26	17.0						17.0
P27	27.8						27.8
P28	134.2						134.2
P29	29.3						29.3
P30	164.3						164.3
P31	15.8						15.8
P32	11.6						11.6
P33	164.3						164.3
MH-25	15.5	3.6					19.1
MH-26	14.8	2.2					17.0
MH-27	24.0	3.9					27.8
MH-28	32.4	5.2	85.4	11.1			134.2
MH-29	23.9	5.4					29.3
MH-30	14.7	4.4	134.2	11.1			164.3
MH-31	12.5	3.4					15.8
MH-32	8.0	3.6					11.6

Table F1-10. Manning's Roughness Coefficients for Channels

(from Chow, 1959)

TABLE 5-6. VALUES OF THE ROUGHNESS COEFFICIENT *n* (*continued*)

Type of channel and description	Minimum	Normal	Maximum
C. EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	**0.022**	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0.035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush uncut			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same, highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
D. NATURAL STREAMS			
D-1. Minor streams (top width at flood stage <100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	**0.030**	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, lower stages, more ineffective slopes and sections	0.040	0.048	0.055
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150

TABLE F1-11. PERMISSIBLE SHEAR AND VELOCITY FOR SELECTED LINING MATERIALS

(From Fishenich, 2011)

Boundary Category	Boundary Type	Permissible Shear Stress (lb/sq ft)	Permissible Velocity (ft/sec)	Citation(s)
Soils	Fine colloidal sand	0.02 - 0.03	1.5	A
	Sandy loam (noncolloidal)	0.03 - 0.04	1.75	A
	Alluvial silt (noncolloidal)	0.045 - 0.05	2	A
	Silty loam (noncolloidal)	0.045 - 0.05	1.75 – 2.25	A
	Firm loam	0.075	2.5	A
	Fine gravels	0.075	2.5	A
	Stiff clay	0.26	3 – 4.5	A, F
	Alluvial silt (colloidal)	0.26	3.75	A
	Graded loam to cobbles	0.38	3.75	A
	Graded silts to cobbles	0.43	4	A
	Shales and hardpan	0.67	6	A
Gravel/Cobble	1-in.	0.33	2.5 – 5	A
	2-in.	0.67	3 – 6	A
	6-in.	2.0	4 – 7.5	A
	12-in.	4.0	5.5 – 12	A
Vegetation	Class A turf	3.7	6 – 8	E, N
	Class B turf	2.1	4 - 7	E, N
	Class C turf	1.0	3.5	E, N
	Long native grasses	1.2 – 1.7	4 – 6	G, H, L, N
	Short native and bunch grass	0.7 - 0.95	3 – 4	G, H, L, N
	Reed plantings	0.1-0.6	N/A	E, N
	Hardwood tree plantings	0.41-2.5	N/A	E, N
Temporary Degradable RECPs	Jute net	0.45	1 – 2.5	E, H, M
	Straw with net	1.5 – 1.65	1 – 3	E, H, M
	Coconut fiber with net	2.25	3 – 4	E, M
	Fiberglass roving	2.00	2.5 – 7	E, H, M
Non-Degradable RECPs	Unvegetated	3.00	5 – 7	E, G, M
	Partially established	4.0-6.0	7.5 – 15	E, G, M
	Fully vegetated	8.00	8 – 21	F, L, M
Riprap	6 – in. d_{50}	2.5	5 – 10	H
	9 – in. d_{50}	3.8	7 – 11	H
	12 – in. d_{50}	5.1	10 – 13	H
	18 – in. d_{50}	7.6	12 – 16	H
	24 – in. d_{50}	10.1	14 – 18	E
Soil Bioengineering	Wattles	0.2 – 1.0	3	C, I, J, N
	Reed fascine	0.6-1.25	5	E
	Coir roll	3 - 5	8	E, M, N
	Vegetated coir mat	4 - 8	9.5	E, M, N
	Live brush mattress (initial)	0.4 – 4.1	4	B, E, I
	Live brush mattress (grown)	3.90-8.2	12	B, C, E, I, N
	Brush layering (initial/grown)	0.4 – 6.25	12	E, I, N
	Live fascine	1.25-3.10	6 – 8	C, E, I, J
	Live willow stakes	2.10-3.10	3 – 10	E, N, O
Hard Surfacing	Gabions	10	14 – 19	D
	Concrete	12.5	>18	H

[1] Ranges of values generally reflect multiple sources of data or different testing conditions.

A. Chang, H.H. (1988).
B. Florineth. (1982)
C. Gerstgraser, C. (1998).
D. Goff, K. (1999).
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J. Schoklitsch, A. (1937).
K. Sprague, C.J. (1999).
L. Temple, D.M. (1980).
M. TXDOT (1999)
N. Data from Author (2001)
O. USACE (1997).

Table F1-12. Manning's Roughness Coefficients for Pipes
(from FHWA, 2001)

Type of Culvert	Roughness or Corrugation	Manning's n	Reference
Concrete Pipe	Smooth	0.010-0.011	(64, 66, 67, 70)
Concrete Boxes	Smooth	0.012-0.015	(23)
Spiral Rib Metal Pipe	Smooth	0.012-0.013	(65, 69)
Corrugated Metal Pipe, Pipe-Arch and Box (Annular and Helical corrugations -- see Figure B-3, Manning's n varies with barrel size)	68 by 13 mm 2-2/3 by 1/2 in Annular	0.022-0.027	(25)
	68 by 13 mm 2-2/3 by 1/2 in Helical	0.011-0.023	(25, 68)
	150 by 25 mm 6 by 1 in Helical	0.022-0.025	(25)
	125 by 25 mm 5 by 1 in	0.025-0.026	(25)
	75 by 25 mm 3 by 1 in	0.027-0.028	(25)
	150 by 50 mm 6 by 2 in Structural Plate	0.033-0.035	(25)
	230 by 64 mm 9 by 2-1/2 in Structural Plate	0.033-0.037	(25)
Corrugated Polyethylene	Smooth	0.009-0.015	(71, 72)
Corrugated Polyethylene	Corrugated	0.018-0.025	(73, 74)
Polyvinyl chloride (PVC)	Smooth	0.009-0.011	(75, 76)

*NOTE: The Manning's n values indicated in this table were obtained in the laboratory and are supported by the provided reference. Actual field values for culverts may vary depending on the effect of abrasion, corrosion, deflection, and joint conditions.

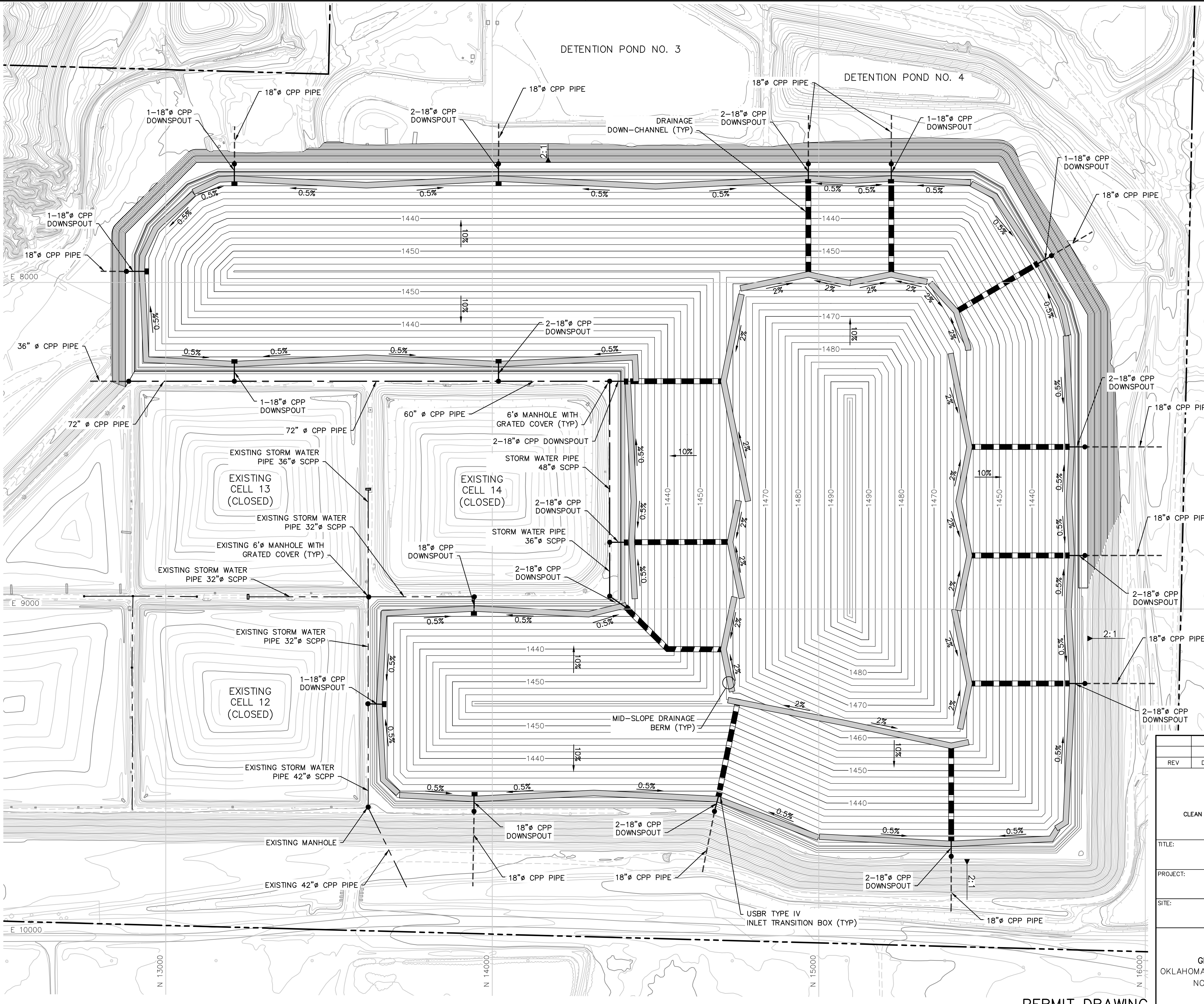
TABLE F1-13 DOWNSPOUT SUMMARY

Downspout	Contributing Area	Flow Rate	Number and Size of Downspout Pipes
No.	acres	cfs	
DS-1	1.81	7.94	1-18" Dia
DS-2	3.19	14.00	1-18" Dia
DS-3	3.13	13.73	1-18" Dia
DS-4	6.73	29.49	2-18" Dia
DS-5	4.52	19.82	2-18" Dia
DS-6	4.48	19.62	2-18" Dia
DS-7	6.57	28.78	2-18" Dia
DS-8	6.83	29.92	2-18" Dia
DS-9	5.12	22.44	2-18" Dia
DS-10	5.60	24.53	2-18" Dia
DS-11	5.50	24.10	2-18" Dia
DS-25	3.54	15.53	1-18" Dia
DS-26	3.39	14.84	1-18" Dia
DS-27	5.47	23.98	2-18" Dia
DS-28	7.40	32.44	2-18" Dia
DS-29	5.46	23.91	2-18" Dia
DS-30	3.35	14.69	1-18" Dia
DS-31	2.84	12.46	1-18" Dia
DS-32	1.82	7.96	1-18" Dia

TABLE F1-14 STORMWATER PIPE SUMMARY

Pipe No.	Flow Rate	Pipe Size	Pipe Slope
No.	cfs	inches	%
P1	32.8	42	0.5
P2	17.5	18	41.5
P3	17.9	32	0.5
P4	33.7	18	41.5
P5	21.3	32	0.6
P6	53.7	48	0.6
P7	85.4	60	0.5
P8	33.3	18	41.5
P9	25.0	18	41.5
P10	28.6	18	41.5
P11	29.0	18	41.5
P12	1.4	18	0.5
P13	1.6	18	0.5
P14	20.9	36	0.5
P15	32.8	42	32.5
P25	19.1	18	41.5
P26	17.0	18	41.5
P27	27.8	18	41.5
P28	134.2	72	0.5
P29	29.3	18	41.5
P30	164.3	72	0.6
P31	15.8	18	41.5
P32	11.6	18	41.5
P33	164.3	36	41.5

FIGURES



LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTE 1)
E 8000 N 15000	STATE PLANE COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
1480	PROPOSED TOP OF FINAL COVER ELEVATION (FEET) (NOTE 3)
	PROPOSED DRAINAGE BERM
	PROPOSED DRAINAGE DOWN-CHANNEL
	PROPOSED STORM WATER PIPE
	EXISTING STORM WATER PIPE

0 150' 300'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. WITHIN THE LIMIT OF WASTE, TOP OF FINAL COVER ELEVATIONS REFER TO PROPOSED FINISHED GRADE (TOP OF THE TOPSOIL COMPONENT OF FINAL COVER SYSTEM). OUTSIDE THE LIMIT OF LINER, THE PROPOSED CONTOURS REFER TO FINISHED GRADE.
4. REFER TO EXHIBIT E1 OF THE CELL 15 ENGINEERING REPORT FOR DESIGNATIONS AND DESIGN CALCULATIONS OF THE STORM WATER CONVEYANCES SHOWN ON THIS DRAWING.

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors
ENVIRONMENTAL SERVICES, INC.
CLEAN HARBORS ENVIRONMENTAL SERVICES, INC.
ROUTE 2, BOX 170
WAYNOKA, OKLAHOMA 73860-9622
PHONE: 405.697.3500

Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
8217 SHOAL CREEK BLVD, SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

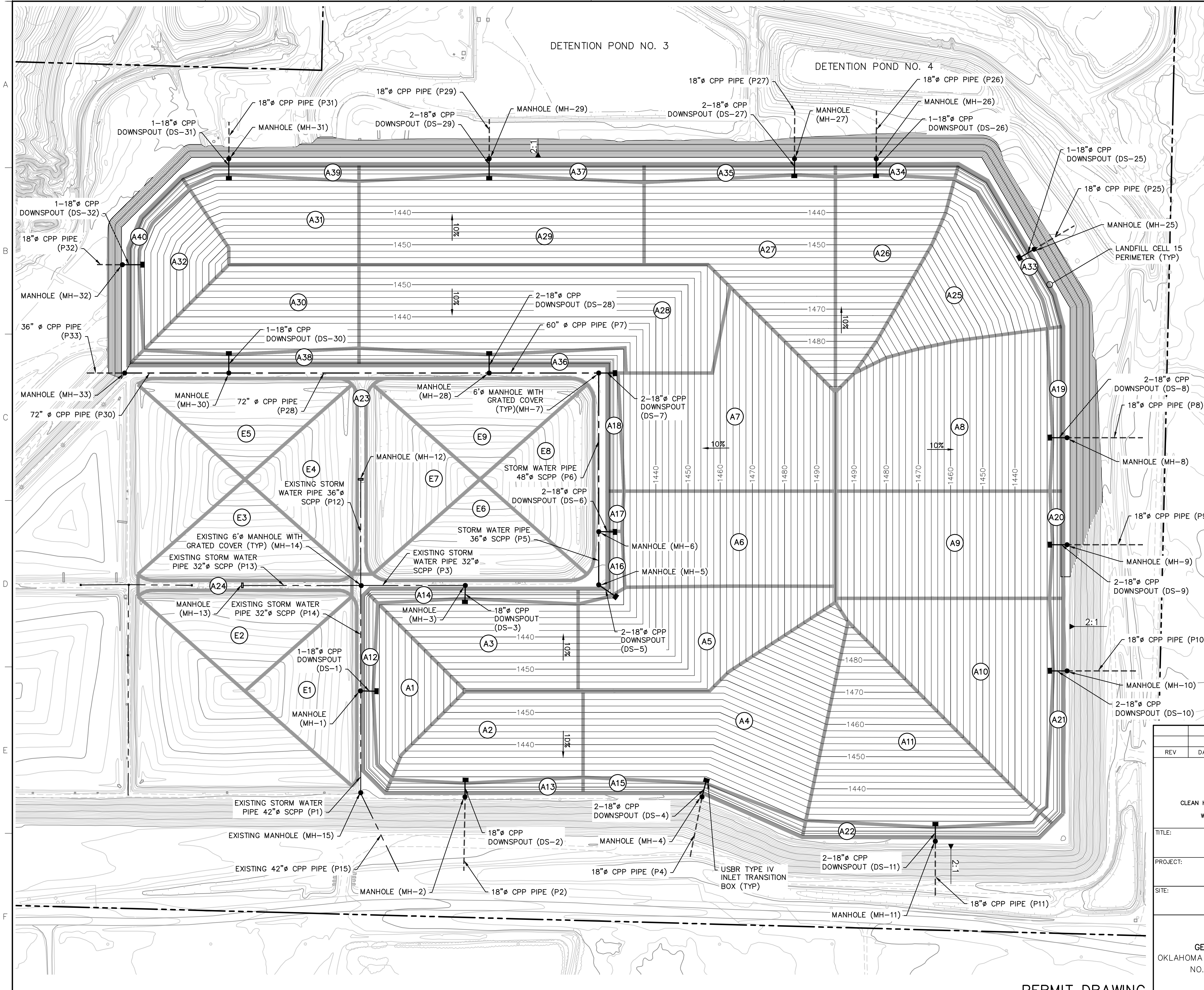
TITLE: FINAL CELL 15 STORM WATER MANAGEMENT PLAN

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY: HD	DATE: JUNE 2014
DRAWN BY: JJV	PROJECT NO.: TXL0380
CHECKED BY: SMG	FILE: TXL038004-F-1
REVIEWED BY: RG	FIGURE:
APPROVED BY: SMG	F1-1



LEGEND

- 1400 — EXISTING GROUND ELEVATION (FEET) (NOTE 1)
- PROPERTY BOUNDARY
- 1480 — PROPOSED TOP OF FINAL COVER ELEVATION (FEET) (NOTE 3)
- (A25) DRAINAGE AREA DESIGNATION
- DRAINAGE AREA BOUNDARY
- EXISTING STORM WATER PIPE
- PROPOSED STORM WATER PIPE

0 150' 300'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. WITHIN THE LIMIT OF WASTE, TOP OF FINAL COVER ELEVATIONS REFER TO PROPOSED FINISHED GRADE (TOP OF THE TOPSOIL COMPONENT OF FINAL COVER SYSTEM). OUTSIDE THE LIMIT OF LINER, THE PROPOSED CONTOURS REFER TO FINISHED GRADE.
3. REFER TO EXHIBIT E1 OF THE CELL 15 ENGINEERING REPORT FOR DESIGNATIONS AND DESIGN CALCULATIONS OF THE STORM WATER CONVEYANCES SHOWN ON THIS DRAWING.

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors ENVIRONMENTAL SERVICES, INC.
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ROUTE 2, BOX 170
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Geosyntec consultants
GEOSYNTEC CONSULTANTS, INC.
8217 SHOAL CREEK BLVD, SUITE 200
AUSTIN, TEXAS 78757
PHONE: 512.451.4003

TITLE: FINAL CELL 15 STORM WATER SYSTEM DRAINAGE AREAS AND LAYOUT

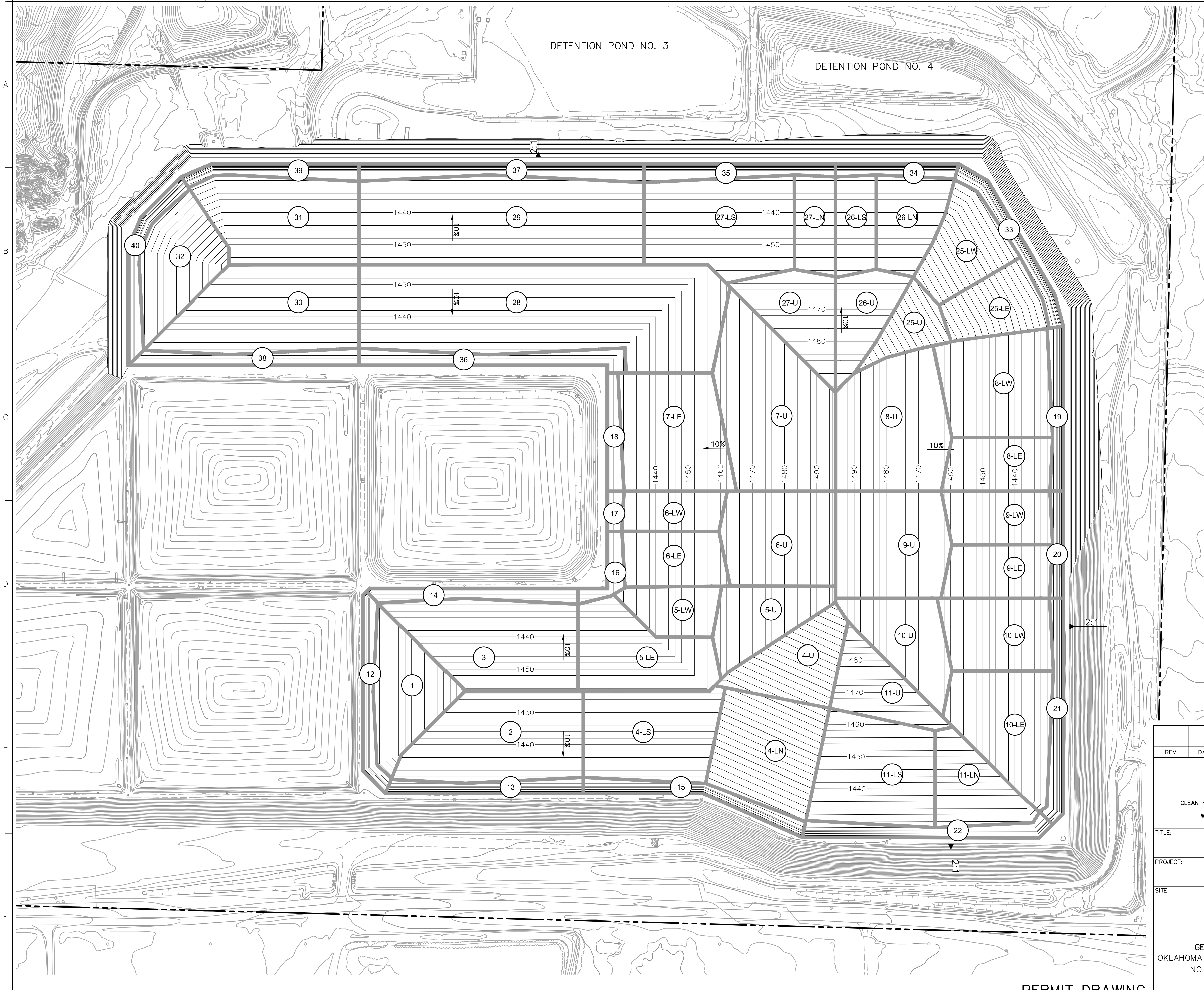
PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2014

DESIGN BY:	HD	DATE:	JUNE 2014
DRAWN BY:	JJV	PROJECT NO.:	TXL0380
CHECKED BY:	SMG	FILE:	TXL038004-F-2
REVIEWED BY:	RG	FIGURE:	
APPROVED BY:	SMG		F1-2

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST – TXL0380\FIGURES\TXL038004-F-2.dwg PLOTTED: Jun 05, 2014 – 12:05pm



N

0 150' 300'
SCALE IN FEET

LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTE 1)
	PROPERTY BOUNDARY
1480	PROPOSED TOP OF FINAL COVER ELEVATION (FEET) (NOTE 3)
33	SUBBASIN DRAINAGE AREA DESIGNATION
	SUBBASIN DRAINAGE AREA BOUNDARY

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. WITHIN THE LIMIT OF WASTE, TOP OF FINAL COVER ELEVATIONS REFER TO PROPOSED FINISHED GRADE (TOP OF THE TOPSOIL COMPONENT OF FINAL COVER SYSTEM). OUTSIDE THE LIMIT OF LINER, THE PROPOSED CONTOURS REFER TO FINISHED GRADE.
3. REFER TO EXHIBIT E1 OF THE CELL 15 ENGINEERING REPORT FOR DESIGNATIONS AND DESIGN CALCULATIONS OF THE STORM WATER CONVEYANCES SHOWN ON THIS DRAWING.

REV	DATE	DESCRIPTION	DRN	APP

CleanHarbors
ENVIRONMENTAL SERVICES, INC.
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PHONE: 512.451.4003

TITLE: CELL 15 SURFACE WATER SUBBASIN DRAINAGE AREAS AND LAYOUT

PROJECT: LANDFILL CELL 15 – WESTWARD EXPANSION CLASS 3 PERMIT MODIFICATION

SITE: LONE MOUNTAIN FACILITY WAYNOKA, OKLAHOMA

GEOSYNTEC CONSULTANTS
OKLAHOMA CERTIFICATE OF AUTHORIZATION
NO. 1996 EXP. 06/30/2016

DESIGN BY: YB		DATE:	OCTOBER 2014
DRAWN BY: JJV		PROJECT NO.:	TXL0380
CHECKED BY: SMG		FILE:	TXL038004-F-2B
REVIEWED BY: RG		FIGURE:	
APPROVED BY: SMG			F1-2B

PERMIT DRAWING

DRAWING: Austin P:\CADD\Projects\L\Lone Mountain Facility\Permit\EXPANSION APP MOD CELL 15 WEST – TXL0380\FIGURES\TXL038004-F-2b.dwg PLOTTED: Oct 20, 2014 – 4:49pm

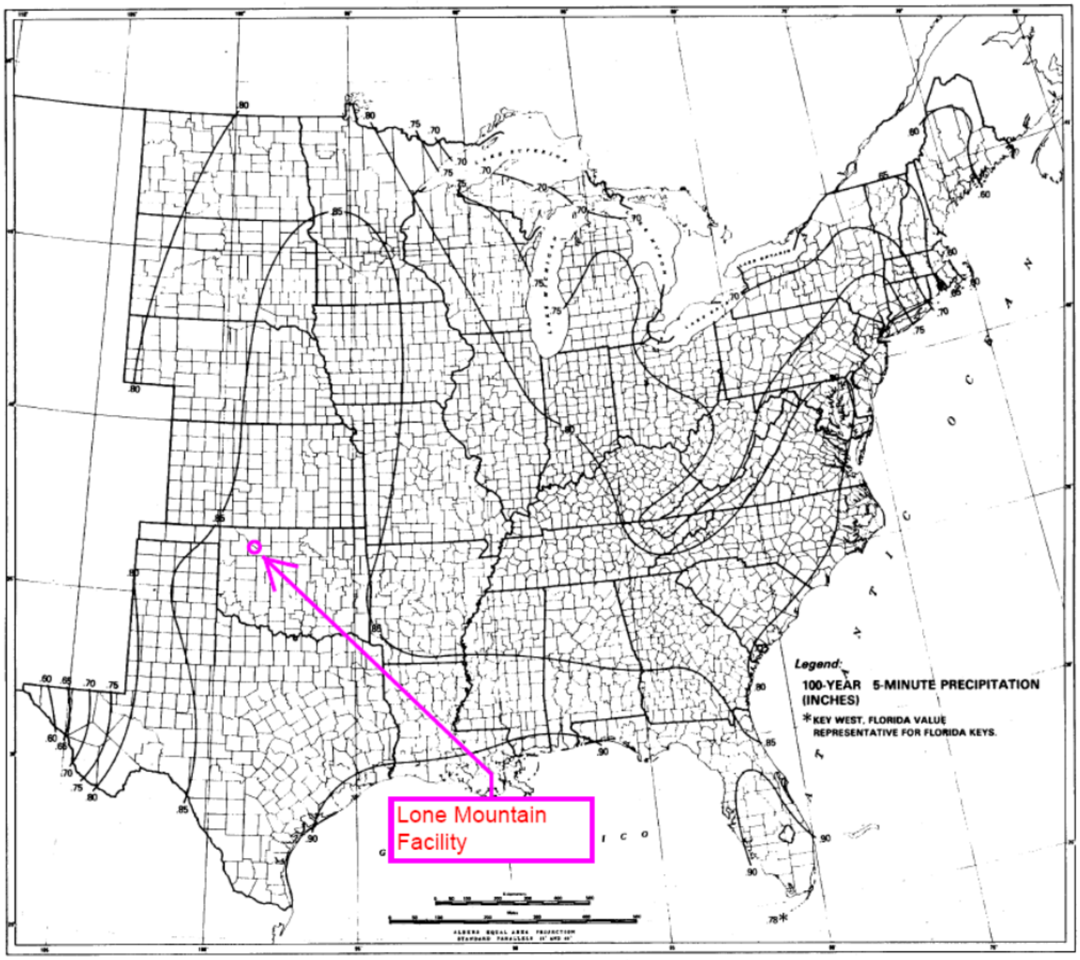


Figure 7.--100-year 5-minute precipitation (inches)--adjusted to partial-duration series.

FIGURE F1-3. 100–YEAR, 5-MIN ISOPLUVIAL MAP (NOAA, 1977)

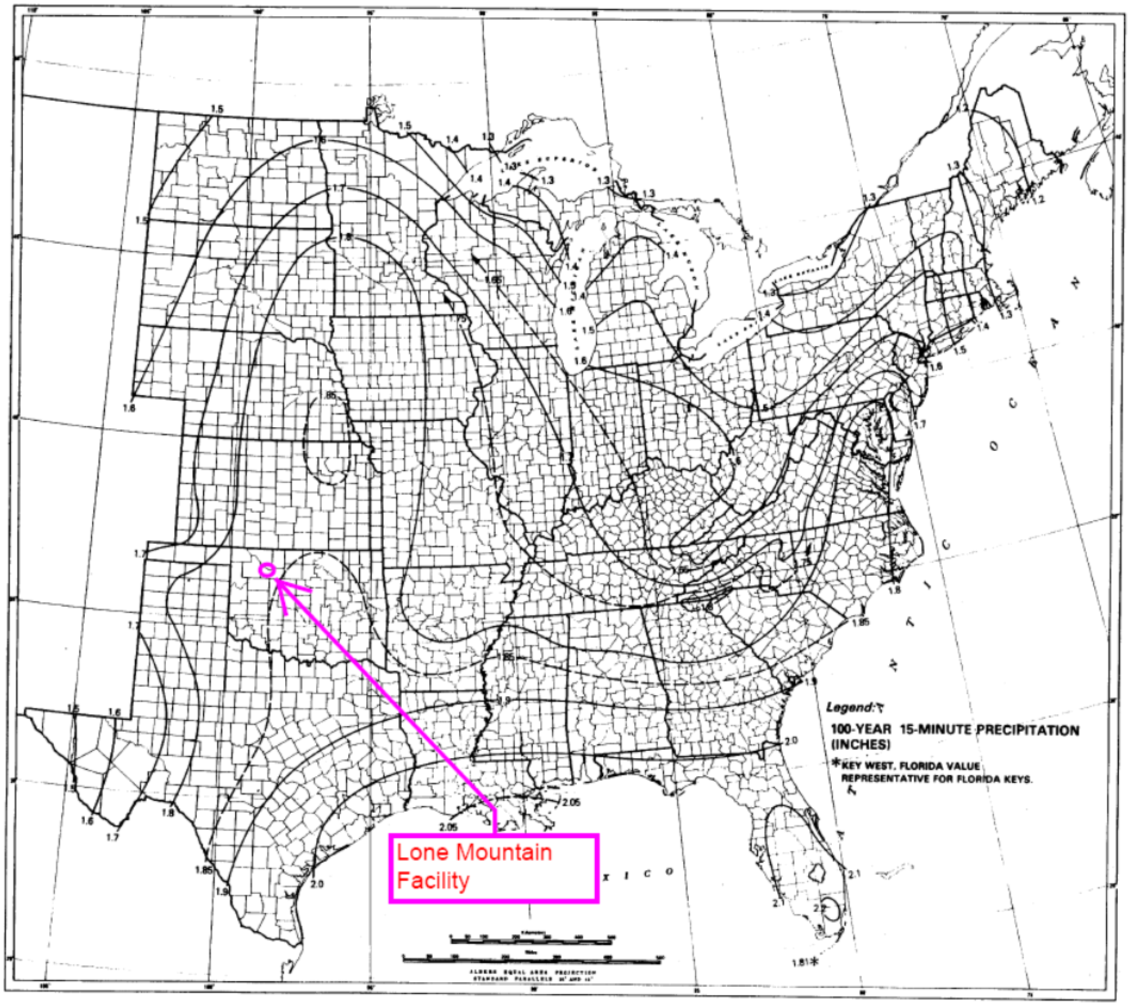


Figure 9.--100-year 15-minute precipitation (inches)--adjusted to partial-duration series.

FIGURE F1-4. 100–YEAR, 15-MIN ISOPLUVIAL MAP (NOAA, 1977)

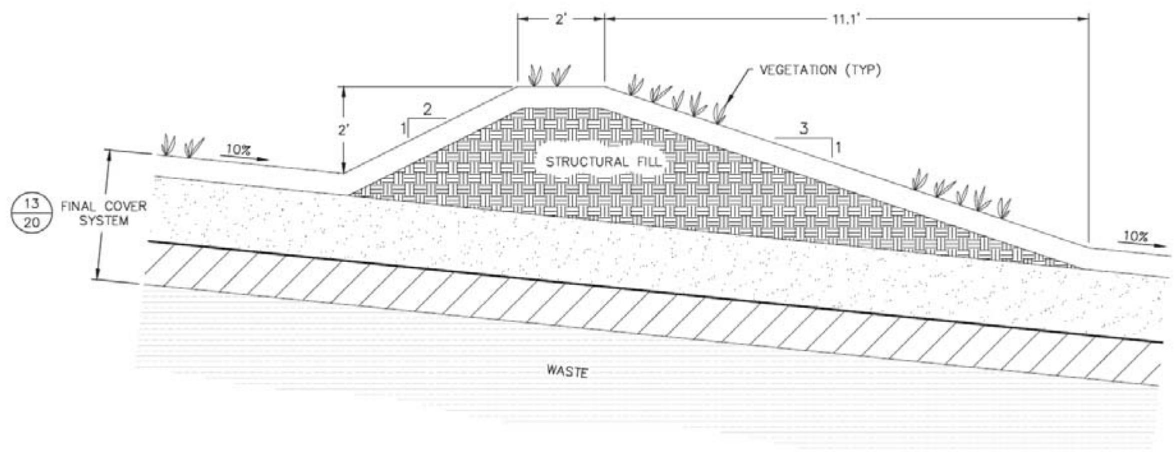


FIGURE F1-5. MID-SLOPE DRAINAGE BERM

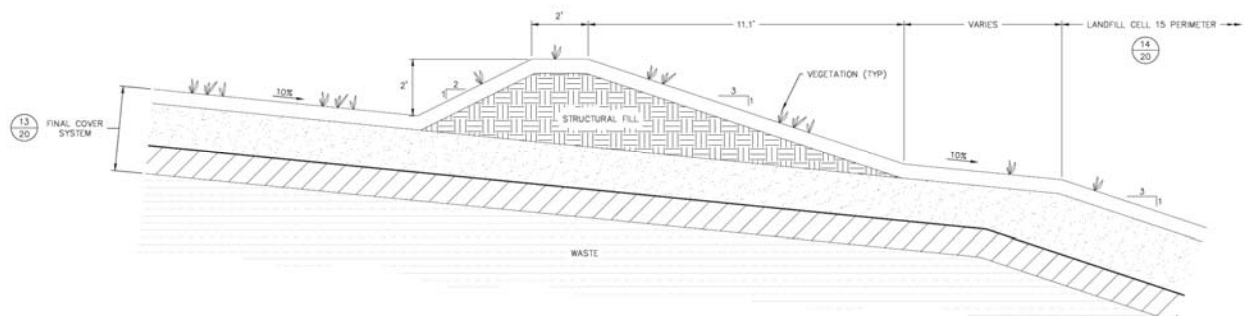


FIGURE F1-6. BOTTOM DRAINAGE BERM

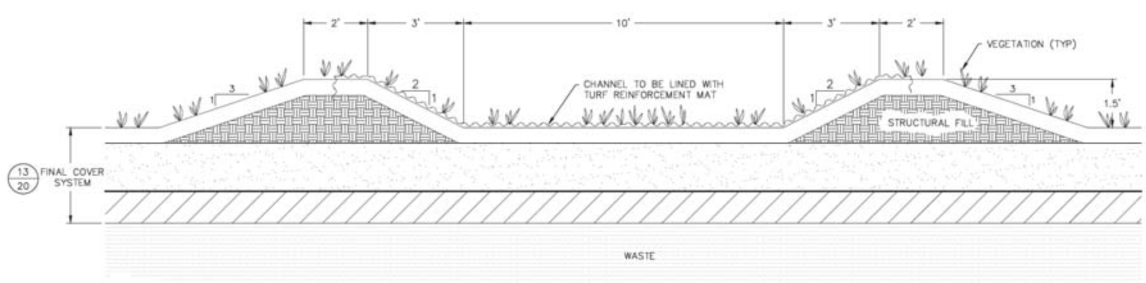


FIGURE F1-7. DRAINAGE DOWN-CHANNEL

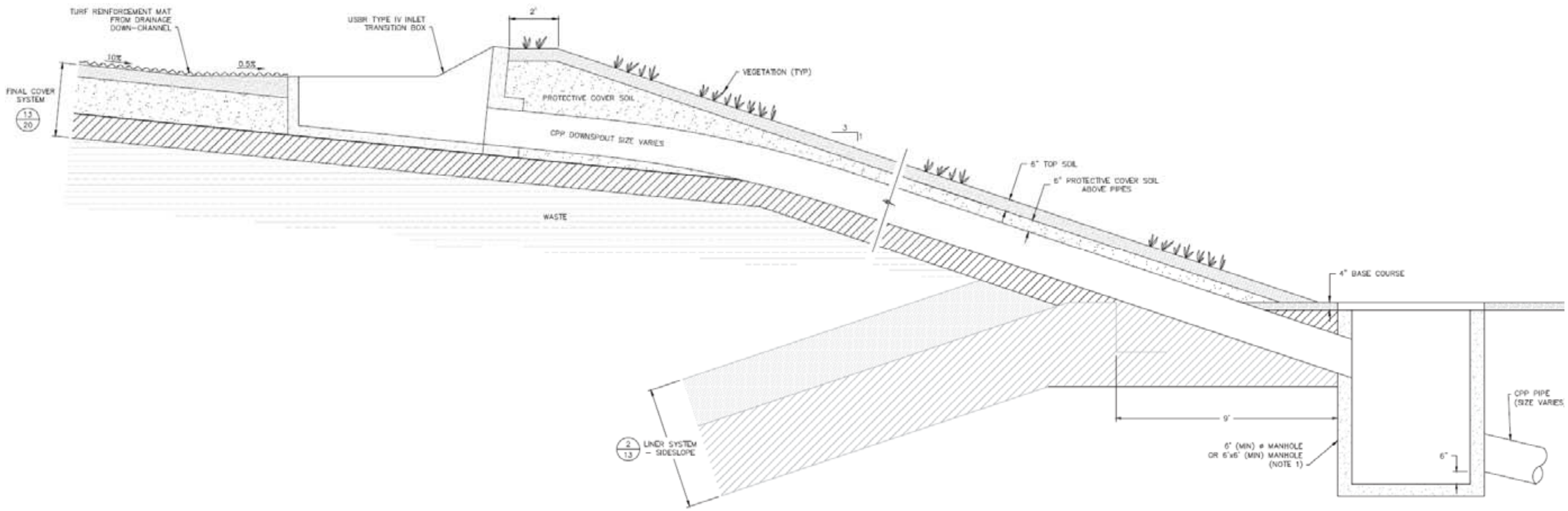


FIGURE F1-8. FINAL COVER SYSTEM INLET BOX, DOWNSPOUT, AND MANHOLE

ATTACHMENT A
MANNING'S EQUATION CALCULATIONS

DRAINAGE CHANNELS

Midslope Drainage Berms, Bottom Drainage Berms, and Drainage Down Channels

Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

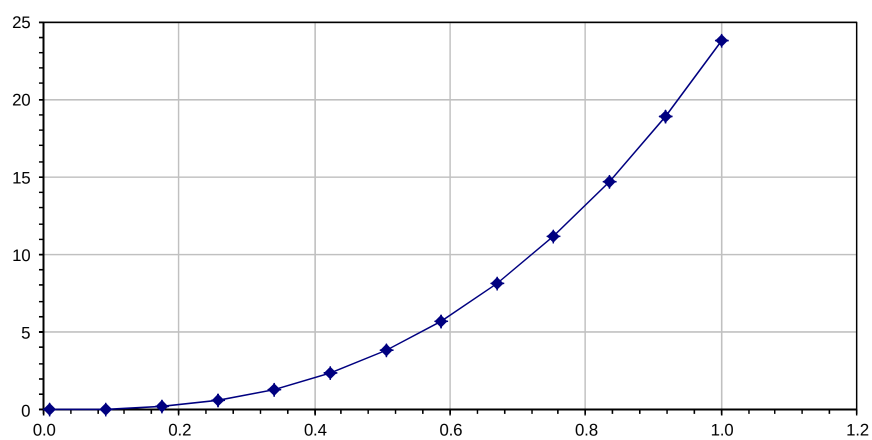
Project: Lone Mountain Facility

Ditch ID: **Midslope Berm**

Peak Discharge, Q_{max}=	12.53	cfs
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	10.00	horizontal :1 vertical
Right Side Slope, Z_2 =	2.00	horizontal :1 vertical
Manning's Roughness Coeff., n =	0.033	
Longitudinal Channel Slope, S_o =	0.0200	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Channel Slope ft/ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.12	0.00	0.020	0.18	0.0	0.01	
0.09	0.05	1.14	0.05	0.020	0.81	0.0	0.12	
0.18	0.18	2.15	0.09	0.020	1.24	0.2	0.22	
0.26	0.40	3.16	0.13	0.020	1.60	0.6	0.32	
0.34	0.69	4.18	0.17	0.020	1.93	1.3	0.42	
0.42	1.07	5.19	0.21	0.020	2.23	2.4	0.53	
0.51	1.53	6.20	0.25	0.020	2.51	3.8	0.63	
0.59	2.07	7.22	0.29	0.020	2.78	5.8	0.73	
0.67	2.69	8.23	0.33	0.020	3.03	8.2	0.84	
0.75	3.40	9.25	0.37	0.020	3.27	11.1	0.94	
0.84	4.18	10.26	0.41	0.020	3.51	14.7	1.04	
0.92	5.05	11.27	0.45	0.020	3.74	18.9	1.15	
1.00	6.00	12.29	0.49	0.020	3.96	23.8	1.25	
0.79	3.71	9.67	0.38	0.02	3.37	12.53	0.98	DESIGN Q

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

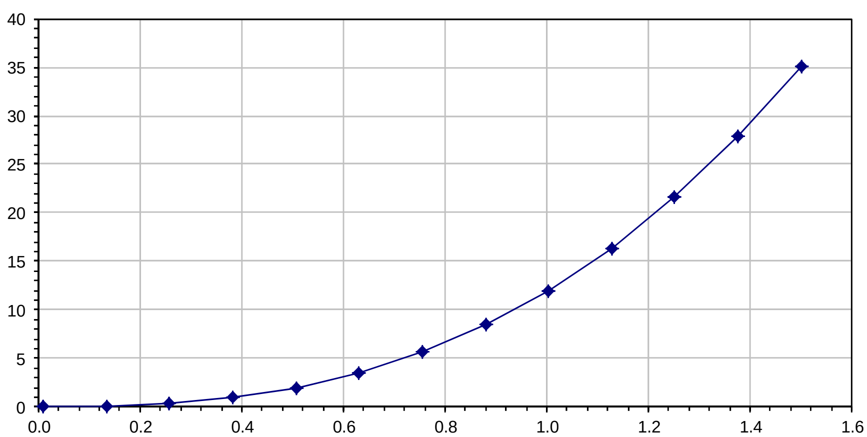
Project: Lone Mountain Facility

Ditch ID: **Bottom Berm**

Peak Discharge, Q_{max}=	32.44	cfs
Bottom Width, B =	0.00	ft
Left Side Slope, Z_1 =	10.00	horizontal :1 vertical
Right Side Slope, Z_2 =	2.00	horizontal :1 vertical
Manning's Roughness Coeff., n =	0.033	
Longitudinal Channel Slope, S_o =	0.0050	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Channel Slope ft/ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.00	0.12	0.00	0.005	0.09	0.0	0.00	
0.13	0.11	1.65	0.07	0.005	0.52	0.1	0.04	
0.26	0.40	3.17	0.13	0.005	0.80	0.3	0.08	
0.38	0.88	4.70	0.19	0.005	1.04	0.9	0.12	
0.51	1.54	6.22	0.25	0.005	1.26	1.9	0.16	
0.63	2.39	7.75	0.31	0.005	1.46	3.5	0.20	
0.76	3.42	9.28	0.37	0.005	1.64	5.6	0.24	
0.88	4.64	10.80	0.43	0.005	1.82	8.4	0.27	
1.00	6.04	12.33	0.49	0.005	1.98	12.0	0.31	
1.13	7.63	13.85	0.55	0.005	2.14	16.4	0.35	
1.25	9.40	15.38	0.61	0.005	2.30	21.6	0.39	
1.38	11.36	16.90	0.67	0.005	2.45	27.8	0.43	
1.50	13.50	18.43	0.73	0.005	2.59	35.0	0.47	
1.46	12.75	17.91	0.71	0.01	2.54	32.44	0.45	DESIGN Q

Discharge versus Depth Relationship



Design/Check: Trapezoidal/Triangular Channel

Methodology: Manning's Equation

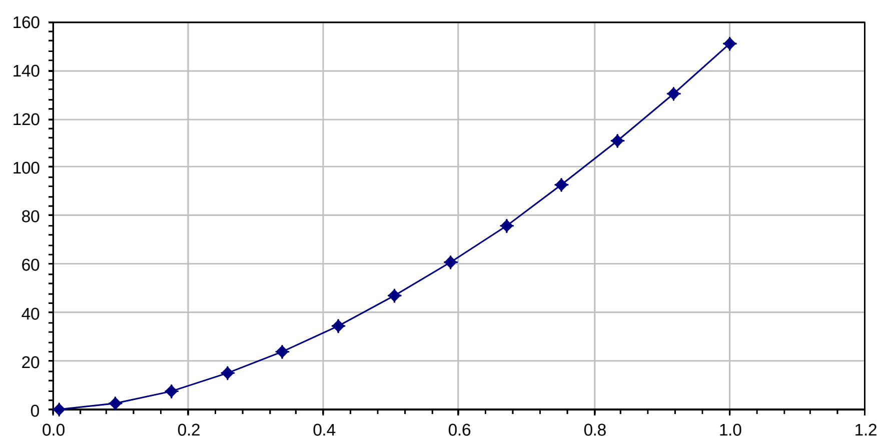
Project: Lone Mountain Facility

Ditch ID: **Down Channel**

Peak Discharge, Q_{max}=	16.89	cfs
Bottom Width, B =	10.00	ft
Left Side Slope, Z_1 =	2.00	horizontal :1 vertical
Right Side Slope, Z_2 =	2.00	horizontal :1 vertical
Manning's Roughness Coeff., n =	0.033	
Longitudinal Channel Slope, S_o =	0.1000	ft/ft

Depth of Flow Y ft	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R=A/P ft	Channel Slope ft/ft	Average Velocity V ft/s	Discharge (Flow Rate) Q=AV ft^3/s	Avg. Tractive Stress τ_o lb/ft^2	Comments
0.01	0.10	10.04	0.01	0.100	0.66	0.1	0.06	
0.09	0.94	10.41	0.09	0.100	2.88	2.7	0.58	
0.18	1.81	10.78	0.17	0.100	4.34	7.9	1.09	
0.26	2.71	11.15	0.24	0.100	5.55	15.0	1.61	
0.34	3.63	11.52	0.32	0.100	6.61	24.0	2.12	
0.42	4.58	11.89	0.39	0.100	7.56	34.6	2.64	
0.51	5.56	12.26	0.45	0.100	8.43	46.9	3.15	
0.59	6.57	12.63	0.52	0.100	9.23	60.6	3.67	
0.67	7.60	13.00	0.58	0.100	9.98	75.8	4.18	
0.75	8.66	13.37	0.65	0.100	10.69	92.5	4.70	
0.84	9.74	13.73	0.71	0.100	11.36	110.7	5.21	
0.92	10.86	14.10	0.77	0.100	11.99	130.2	5.73	
1.00	12.00	14.47	0.83	0.100	12.60	151.2	6.24	
0.28	2.91	11.23	0.26	0.10	5.80	16.89	1.72	DESIGN Q

Discharge versus Depth Relationship



DOWNSPOUTS

Downspout DS1
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	4.0	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.19	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.1	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.16	110.4	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.5	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.86	199.5	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.7	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.9	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.8	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.5	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.9	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.75	421.8	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.2	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.41	425.2	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.5	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.5	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.59	379.5	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.11	359.9	
3.00	172	8.4	0.803	2.25	0.36	9.9	7.94	152.1	Design Q

Downspout DS2
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.80	218	11.9	1.241	2.85	0.44	11.3	14.00	306.3	Design Q

Downspout DS3
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.76	216	11.7	1.222	2.82	0.43	11.2	13.73	299.3	Design Q

Downspout DS4
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.09	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.0	0.04	0.1	
1.00	57	1.1	0.045	0.75	0.06	2.8	0.13	0.7	
1.25	72	1.7	0.085	0.94	0.09	3.7	0.32	2.3	
1.50	86	2.4	0.141	1.13	0.13	4.7	0.66	6.0	
1.75	100	3.2	0.215	1.31	0.16	5.6	1.20	13.0	
2.00	115	4.1	0.307	1.50	0.20	6.5	1.98	24.8	
2.25	129	5.1	0.414	1.69	0.25	7.3	3.02	42.7	
2.50	143	6.2	0.535	1.88	0.29	8.1	4.31	67.5	
2.75	158	7.2	0.666	2.06	0.32	8.8	5.84	99.2	
3.00	172	8.4	0.804	2.25	0.36	9.4	7.54	137.1	
3.25	186	9.5	0.944	2.44	0.39	9.9	9.35	179.4	
3.50	201	10.6	1.083	2.63	0.41	10.3	11.18	223.7	
3.75	215	11.7	1.215	2.81	0.43	10.6	12.94	267.1	
4.00	229	12.7	1.338	3.00	0.45	10.9	14.54	306.6	
4.25	244	13.7	1.447	3.19	0.45	11.0	15.92	339.6	
4.50	258	14.7	1.541	3.38	0.46	11.0	17.01	364.2	
4.75	272	15.5	1.617	3.56	0.45	11.0	17.78	379.4	
5.00	286	16.2	1.676	3.75	0.45	10.9	18.24	385.2	
5.25	301	16.8	1.718	3.94	0.44	10.7	18.40	382.5	
5.50	315	17.3	1.745	4.13	0.42	10.5	18.32	372.9	
5.75	329	17.7	1.760	4.31	0.41	10.2	18.03	358.4	
6.00	344	17.9	1.766	4.50	0.39	10.0	17.63	341.3	
6.25	358	18.0	1.767	4.69	0.38	9.7	17.17	323.7	
4.03	231	12.9	1.353	3.02	0.45	10.9	14.74	311.5	Design Q

DESIGN FLOW: 29.49 ONE PIPE: 14.74

USE TWO-18" PIPES.

Downspout DS5
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.07	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.4	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.0	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	1.7	0.03	0.1	
1.00	57	1.1	0.045	0.75	0.06	2.5	0.11	0.5	
1.25	72	1.7	0.085	0.94	0.09	3.3	0.28	1.8	
1.50	86	2.4	0.141	1.13	0.13	4.1	0.58	4.6	
1.75	100	3.2	0.215	1.31	0.16	4.9	1.06	10.1	
2.00	115	4.1	0.307	1.50	0.20	5.7	1.75	19.3	
2.25	129	5.1	0.414	1.69	0.25	6.4	2.66	33.2	
2.50	143	6.2	0.535	1.88	0.29	7.1	3.80	52.5	
2.75	158	7.2	0.666	2.06	0.32	7.7	5.15	77.2	
3.00	172	8.4	0.804	2.25	0.36	8.3	6.65	106.7	
3.25	186	9.5	0.944	2.44	0.39	8.7	8.24	139.6	
3.50	201	10.6	1.083	2.63	0.41	9.1	9.86	174.0	
3.75	215	11.7	1.215	2.81	0.43	9.4	11.41	207.7	
4.00	229	12.7	1.338	3.00	0.45	9.6	12.82	238.5	
4.25	244	13.7	1.447	3.19	0.45	9.7	14.04	264.1	
4.50	258	14.7	1.541	3.38	0.46	9.7	15.00	283.3	
4.75	272	15.5	1.617	3.56	0.45	9.7	15.68	295.1	
5.00	286	16.2	1.676	3.75	0.45	9.6	16.09	299.6	
5.25	301	16.8	1.718	3.94	0.44	9.4	16.23	297.5	
5.50	315	17.3	1.745	4.13	0.42	9.3	16.15	290.0	
5.75	329	17.7	1.760	4.31	0.41	9.0	15.90	278.8	
6.00	344	17.9	1.766	4.50	0.39	8.8	15.55	265.5	
6.25	358	18.0	1.767	4.69	0.38	8.6	15.14	251.7	
3.51	201	10.6	1.087	2.63	0.41	9.1	9.91	175.2	Design Q

DESIGN FLOW: 19.82 ONE PIPE: 9.91

USE TWO-18" PIPES.

Downspout DS6
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.24	186	9.5	0.941	2.43	0.39	10.4	9.81	198.4	Design Q

DESIGN FLOW: 19.62 ONE PIPE: 9.81

USE TWO-18" PIPES.

Downspout DS7
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.86	221	12.2	1.269	2.89	0.44	11.3	14.39	316.5	Design Q

DESIGN FLOW: 28.78 ONE PIPE: 14.39

USE TWO-18" PIPES.

Downspout DS8
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.94	226	12.5	1.311	2.96	0.44	11.4	14.96	331.3	Design Q

DESIGN FLOW: 29.92 ONE PIPE: 14.96

USE TWO-18" PIPES.

Downspout DS9
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.43	196	10.3	1.043	2.57	0.41	10.8	11.22	234.2	Design Q

DESIGN FLOW: 22.44 ONE PIPE: 11.22

USE TWO-18" PIPES.

Downspout DS10
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.56	204	10.9	1.118	2.67	0.42	11.0	12.27	261.3	Design Q

DESIGN FLOW: 24.53 ONE PIPE: 12.27

USE TWO-18" PIPES.

Downspout DS11
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.53	203	10.8	1.102	2.65	0.42	10.9	12.05	255.6	Design Q

DESIGN FLOW: 24.10 ONE PIPE: 12.05

USE TWO-18" PIPES.

Downspout DS25
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
4.03	231	12.9	1.353	3.02	0.45	11.5	15.53	346.0	Design Q

Downspout DS26
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.92	225	12.4	1.302	2.94	0.44	11.4	14.84	328.1	Design Q

Downspout DS27
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.53	202	10.7	1.098	2.65	0.41	10.9	11.99	254.1	Design Q

DESIGN FLOW: 23.98 ONE PIPE: 11.99

USE TWO-18" PIPES.

Downspout DS28
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
4.15	238	13.3	1.404	3.11	0.45	11.6	16.22	363.5	Design Q

DESIGN FLOW: 32.44 ONE PIPE: 16.22

USE TWO-18" PIPES.

Downspout DS29
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.52	202	10.7	1.096	2.64	0.41	10.9	11.96	253.3	Design Q

DESIGN FLOW: 23.91 ONE PIPE: 11.96

USE TWO-18" PIPES.

Downspout DS30
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.90	224	12.3	1.291	2.93	0.44	11.4	14.69	324.2	Design Q

Downspout DS31
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.59	206	11.0	1.131	2.69	0.42	11.0	12.46	266.3	Design Q

Downspout DS32
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.1	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.5	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	1.2	0.01	0.0	
0.75	43	0.6	0.019	0.56	0.03	2.1	0.04	0.2	
1.00	57	1.1	0.045	0.75	0.06	3.0	0.13	0.8	
1.25	72	1.7	0.085	0.94	0.09	3.9	0.33	2.6	
1.50	86	2.4	0.141	1.13	0.13	4.9	0.70	6.6	
1.75	100	3.2	0.215	1.31	0.16	5.9	1.27	14.5	
2.00	115	4.1	0.307	1.50	0.20	6.8	2.09	27.6	
2.25	129	5.1	0.414	1.69	0.25	7.7	3.18	47.5	
2.50	143	6.2	0.535	1.88	0.29	8.5	4.55	75.0	
2.75	158	7.2	0.666	2.06	0.32	9.2	6.15	110.3	
3.00	172	8.4	0.804	2.25	0.36	9.9	7.95	152.4	
3.25	186	9.5	0.944	2.44	0.39	10.4	9.85	199.4	
3.50	201	10.6	1.083	2.63	0.41	10.9	11.78	248.6	
3.75	215	11.7	1.215	2.81	0.43	11.2	13.64	296.8	
4.00	229	12.7	1.338	3.00	0.45	11.5	15.33	340.6	
4.25	244	13.7	1.447	3.19	0.45	11.6	16.78	377.3	
4.50	258	14.7	1.541	3.38	0.46	11.6	17.93	404.6	
4.75	272	15.5	1.617	3.56	0.45	11.6	18.74	421.5	
5.00	286	16.2	1.676	3.75	0.45	11.5	19.23	428.0	
5.25	301	16.8	1.718	3.94	0.44	11.3	19.40	425.0	
5.50	315	17.3	1.745	4.13	0.42	11.1	19.31	414.3	
5.75	329	17.7	1.760	4.31	0.41	10.8	19.01	398.2	
6.00	344	17.9	1.766	4.50	0.39	10.5	18.58	379.2	
6.25	358	18.0	1.767	4.69	0.38	10.2	18.10	359.6	
3.00	172	8.4	0.805	2.25	0.36	9.9	7.96	152.8	Design Q

STORM WATER PIPE

PIPE 1
Flow Through Circular Pipe

Diameter of pipe, D=	42	inches
Longitudinal Slope, So=	0.005	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.2	0.004	0.44	0.01	0.2	0.00	0.0	
0.50	29	0.7	0.032	0.88	0.04	0.5	0.02	0.0	
0.75	43	1.5	0.105	1.31	0.08	0.8	0.09	0.1	
1.00	57	2.6	0.243	1.75	0.14	1.2	0.29	0.7	
1.25	72	4.0	0.461	2.19	0.21	1.6	0.72	2.2	
1.50	86	5.6	0.769	2.63	0.29	1.9	1.49	5.6	
1.75	100	7.5	1.173	3.06	0.38	2.3	2.71	12.2	
2.00	115	9.7	1.670	3.50	0.48	2.7	4.48	23.3	
2.25	129	11.9	2.254	3.94	0.57	3.0	6.82	40.0	
2.50	143	14.4	2.912	4.38	0.67	3.3	9.74	63.2	
2.75	158	16.9	3.627	4.81	0.75	3.6	13.18	93.0	
3.00	172	19.5	4.378	5.25	0.83	3.9	17.02	128.4	
3.25	186	22.1	5.142	5.69	0.90	4.1	21.11	168.1	
3.50	201	24.7	5.897	6.13	0.96	4.3	25.24	209.6	
3.75	215	27.3	6.617	6.56	1.01	4.4	29.21	250.2	
4.00	229	29.7	7.284	7.00	1.04	4.5	32.83	287.2	
4.25	244	32.1	7.878	7.44	1.06	4.6	35.94	318.1	
4.50	258	34.2	8.387	7.88	1.07	4.6	38.40	341.1	
4.75	272	36.1	8.804	8.31	1.06	4.6	40.16	355.3	
5.00	286	37.8	9.125	8.75	1.04	4.5	41.19	360.8	
5.25	301	39.3	9.354	9.19	1.02	4.4	41.56	358.2	
5.50	315	40.4	9.502	9.63	0.99	4.4	41.36	349.2	
5.75	329	41.3	9.583	10.06	0.95	4.2	40.72	335.7	
6.00	344	41.8	9.615	10.50	0.92	4.1	39.80	319.7	
6.25	358	42.0	9.621	10.94	0.88	4.0	38.77	303.1	
4.00	229	29.7	7.286	7.00	1.04	4.5	32.85	287.3	Design Q

PIPE 2
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
3.09	177	8.7	0.852	2.31	0.37	20.5	17.51	697.7	Design Q

PIPE 3
Flow Through Circular Pipe

Diameter of pipe, D=	32	inches
Longitudinal Slope, So=	0.005	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.002	0.33	0.01	0.2	0.00	0.0	
0.50	29	0.5	0.018	0.67	0.03	0.4	0.01	0.0	
0.75	43	1.1	0.061	1.00	0.06	0.7	0.04	0.1	
1.00	57	2.0	0.141	1.33	0.11	1.0	0.14	0.3	
1.25	72	3.0	0.268	1.67	0.16	1.3	0.35	0.9	
1.50	86	4.3	0.447	2.00	0.22	1.6	0.72	2.3	
1.75	100	5.7	0.681	2.33	0.29	1.9	1.31	4.9	
2.00	115	7.4	0.970	2.67	0.36	2.2	2.17	9.4	
2.25	129	9.1	1.308	3.00	0.44	2.5	3.30	16.2	
2.50	143	11.0	1.690	3.33	0.51	2.8	4.72	25.5	
2.75	158	12.9	2.105	3.67	0.57	3.0	6.38	37.5	
3.00	172	14.9	2.541	4.00	0.64	3.2	8.24	51.9	
3.25	186	16.9	2.985	4.33	0.69	3.4	10.22	67.9	
3.50	201	18.9	3.423	4.67	0.73	3.6	12.22	84.6	
3.75	215	20.8	3.841	5.00	0.77	3.7	14.14	101.0	
4.00	229	22.7	4.228	5.33	0.79	3.8	15.90	116.0	
4.25	244	24.4	4.573	5.67	0.81	3.8	17.40	128.5	
4.50	258	26.1	4.869	6.00	0.81	3.8	18.59	137.8	
4.75	272	27.5	5.110	6.33	0.81	3.8	19.44	143.5	
5.00	286	28.8	5.297	6.67	0.79	3.8	19.95	145.7	
5.25	301	29.9	5.430	7.00	0.78	3.7	20.12	144.7	
5.50	315	30.8	5.516	7.33	0.75	3.6	20.03	141.0	
5.75	329	31.4	5.563	7.67	0.73	3.5	19.72	135.6	
6.00	344	31.8	5.582	8.00	0.70	3.5	19.27	129.1	
6.25	358	32.0	5.585	8.33	0.67	3.4	18.77	122.4	
4.36	250	25.1	4.704	5.81	0.81	3.8	17.95	132.8	Design Q

PIPE 4
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
4.20	241	13.6	1.428	3.15	0.45	23.6	33.68	1541.4	Design Q

PIPE 5
Flow Through Circular Pipe

Diameter of pipe, D=	32	inches
Longitudinal Slope, So=	0.006	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.002	0.33	0.01	0.2	0.00	0.0	
0.50	29	0.5	0.018	0.67	0.03	0.4	0.01	0.0	
0.75	43	1.1	0.061	1.00	0.06	0.7	0.05	0.1	
1.00	57	2.0	0.141	1.33	0.11	1.1	0.15	0.3	
1.25	72	3.0	0.268	1.67	0.16	1.4	0.38	1.0	
1.50	86	4.3	0.447	2.00	0.22	1.8	0.79	2.7	
1.75	100	5.7	0.681	2.33	0.29	2.1	1.44	5.9	
2.00	115	7.4	0.970	2.67	0.36	2.4	2.37	11.3	
2.25	129	9.1	1.308	3.00	0.44	2.8	3.62	19.4	
2.50	143	11.0	1.690	3.33	0.51	3.1	5.17	30.6	
2.75	158	12.9	2.105	3.67	0.57	3.3	6.99	45.1	
3.00	172	14.9	2.541	4.00	0.64	3.6	9.03	62.2	
3.25	186	16.9	2.985	4.33	0.69	3.8	11.20	81.5	
3.50	201	18.9	3.423	4.67	0.73	3.9	13.39	101.6	
3.75	215	20.8	3.841	5.00	0.77	4.0	15.49	121.2	
4.00	229	22.7	4.228	5.33	0.79	4.1	17.42	139.2	
4.25	244	24.4	4.573	5.67	0.81	4.2	19.06	154.2	
4.50	258	26.1	4.869	6.00	0.81	4.2	20.37	165.3	
4.75	272	27.5	5.110	6.33	0.81	4.2	21.30	172.2	
5.00	286	28.8	5.297	6.67	0.79	4.1	21.85	174.8	
5.25	301	29.9	5.430	7.00	0.78	4.1	22.04	173.6	
5.50	315	30.8	5.516	7.33	0.75	4.0	21.94	169.3	
5.75	329	31.4	5.563	7.67	0.73	3.9	21.60	162.7	
6.00	344	31.8	5.582	8.00	0.70	3.8	21.11	154.9	
6.25	358	32.0	5.585	8.33	0.67	3.7	20.57	146.9	
4.73	271	27.4	5.096	6.31	0.81	4.2	21.25	171.9	Design Q

PIPE 6
Flow Through Circular Pipe

Diameter of pipe, D=	48	inches
Longitudinal Slope, So=	0.006	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.2	0.005	0.50	0.01	0.2	0.00	0.0	
0.50	29	0.7	0.041	1.00	0.04	0.6	0.02	0.0	
0.75	43	1.7	0.137	1.50	0.09	1.0	0.13	0.3	
1.00	57	2.9	0.317	2.00	0.16	1.4	0.45	1.2	
1.25	72	4.5	0.602	2.50	0.24	1.9	1.12	4.0	
1.50	86	6.4	1.005	3.00	0.34	2.3	2.33	10.5	
1.75	100	8.6	1.532	3.50	0.44	2.8	4.25	22.8	
2.00	115	11.0	2.181	4.00	0.55	3.2	7.00	43.6	
2.25	129	13.7	2.944	4.50	0.65	3.6	10.67	75.0	
2.50	143	16.4	3.803	5.00	0.76	4.0	15.24	118.4	
2.75	158	19.3	4.737	5.50	0.86	4.4	20.62	174.1	
3.00	172	22.3	5.718	6.00	0.95	4.7	26.63	240.6	
3.25	186	25.3	6.716	6.50	1.03	4.9	33.01	314.8	
3.50	201	28.3	7.702	7.00	1.10	5.1	39.47	392.5	
3.75	215	31.2	8.643	7.50	1.15	5.3	45.69	468.6	
4.00	229	34.0	9.514	8.00	1.19	5.4	51.36	537.8	
4.25	244	36.6	10.290	8.50	1.21	5.5	56.21	595.7	
4.50	258	39.1	10.955	9.00	1.22	5.5	60.06	638.9	
4.75	272	41.3	11.499	9.50	1.21	5.5	62.81	665.5	
5.00	286	43.2	11.918	10.00	1.19	5.4	64.43	675.7	
5.25	301	44.9	12.218	10.50	1.16	5.3	65.00	670.9	
5.50	315	46.2	12.411	11.00	1.13	5.2	64.69	654.1	
5.75	329	47.2	12.517	11.50	1.09	5.1	63.69	628.7	
6.00	344	47.8	12.559	12.00	1.05	5.0	62.26	598.7	
6.25	358	48.0	12.566	12.50	1.01	4.8	60.64	567.8	
4.12	236	35.2	9.890	8.23	1.20	5.4	53.74	566.5	Design Q

PIPE 7
Flow Through Circular Pipe

Diameter of pipe, D=	60	inches
Longitudinal Slope, So=	0.005	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.2	0.008	0.63	0.01	0.2	0.00	0.0	
0.50	29	0.9	0.064	1.25	0.05	0.6	0.04	0.0	
0.75	43	2.1	0.214	1.88	0.11	1.0	0.22	0.4	
1.00	57	3.7	0.495	2.50	0.20	1.5	0.74	2.1	
1.25	72	5.7	0.941	3.13	0.30	2.0	1.85	7.1	
1.50	86	8.0	1.570	3.75	0.42	2.5	3.86	18.4	
1.75	100	10.8	2.394	4.38	0.55	2.9	7.03	40.0	
2.00	115	13.8	3.408	5.00	0.68	3.4	11.59	76.4	
2.25	129	17.1	4.600	5.63	0.82	3.8	17.66	131.5	
2.50	143	20.5	5.942	6.25	0.95	4.2	25.22	207.7	
2.75	158	24.2	7.401	6.88	1.08	4.6	34.13	305.3	
3.00	172	27.9	8.934	7.50	1.19	4.9	44.07	421.8	
3.25	186	31.6	10.494	8.13	1.29	5.2	54.64	552.0	
3.50	201	35.3	12.034	8.75	1.38	5.4	65.34	688.2	
3.75	215	39.0	13.505	9.38	1.44	5.6	75.63	821.6	
4.00	229	42.5	14.865	10.00	1.49	5.7	85.01	943.1	
4.25	244	45.8	16.078	10.63	1.51	5.8	93.04	1044.6	
4.50	258	48.8	17.117	11.25	1.52	5.8	99.42	1120.3	
4.75	272	51.6	17.967	11.88	1.51	5.8	103.96	1167.0	
5.00	286	54.0	18.622	12.50	1.49	5.7	106.65	1184.9	
5.25	301	56.1	19.090	13.13	1.45	5.6	107.60	1176.5	
5.50	315	57.7	19.392	13.75	1.41	5.5	107.08	1147.0	
5.75	329	58.9	19.557	14.38	1.36	5.4	105.42	1102.5	
6.00	344	59.7	19.623	15.00	1.31	5.3	103.05	1049.9	
6.25	358	60.0	19.635	15.63	1.26	5.1	100.38	995.6	
4.01	230	42.7	14.930	10.03	1.49	5.7	85.44	948.5	Design Q

PIPE 8
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
4.17	239	13.4	1.415	3.13	0.45	23.6	33.35	1524.1	Design Q

PIPE 9
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
3.56	204	10.9	1.118	2.67	0.42	22.4	25.01	1085.2	Design Q

PIPE 10
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
3.81	218	11.9	1.244	2.85	0.44	23.0	28.59	1274.9	Design Q

PIPE 11
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
3.84	220	12.1	1.260	2.88	0.44	23.1	29.04	1298.9	Design Q

PIPE 12
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.005	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.1	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	0.3	0.00	0.0	
0.75	43	0.6	0.019	0.56	0.03	0.5	0.01	0.0	
1.00	57	1.1	0.045	0.75	0.06	0.7	0.03	0.0	
1.25	72	1.7	0.085	0.94	0.09	0.9	0.07	0.1	
1.50	86	2.4	0.141	1.13	0.13	1.1	0.16	0.3	
1.75	100	3.2	0.215	1.31	0.16	1.3	0.28	0.7	
2.00	115	4.1	0.307	1.50	0.20	1.5	0.47	1.4	
2.25	129	5.1	0.414	1.69	0.25	1.7	0.71	2.4	
2.50	143	6.2	0.535	1.88	0.29	1.9	1.02	3.8	
2.75	158	7.2	0.666	2.06	0.32	2.1	1.38	5.5	
3.00	172	8.4	0.804	2.25	0.36	2.2	1.78	7.6	
3.25	186	9.5	0.944	2.44	0.39	2.3	2.20	10.0	
3.50	201	10.6	1.083	2.63	0.41	2.4	2.63	12.4	
3.75	215	11.7	1.215	2.81	0.43	2.5	3.05	14.8	
4.00	229	12.7	1.338	3.00	0.45	2.6	3.43	17.0	
4.25	244	13.7	1.447	3.19	0.45	2.6	3.75	18.9	
4.50	258	14.7	1.541	3.38	0.46	2.6	4.01	20.2	
4.75	272	15.5	1.617	3.56	0.45	2.6	4.19	21.1	
5.00	286	16.2	1.676	3.75	0.45	2.6	4.30	21.4	
5.25	301	16.8	1.718	3.94	0.44	2.5	4.34	21.2	
5.50	315	17.3	1.745	4.13	0.42	2.5	4.32	20.7	
5.75	329	17.7	1.760	4.31	0.41	2.4	4.25	19.9	
6.00	344	17.9	1.766	4.50	0.39	2.4	4.15	19.0	
6.25	358	18.0	1.767	4.69	0.38	2.3	4.05	18.0	
2.74	157	7.2	0.663	2.06	0.32	2.1	1.37	5.5	Design Q

PIPE 13
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.005	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	0.1	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	0.3	0.00	0.0	
0.75	43	0.6	0.019	0.56	0.03	0.5	0.01	0.0	
1.00	57	1.1	0.045	0.75	0.06	0.7	0.03	0.0	
1.25	72	1.7	0.085	0.94	0.09	0.9	0.07	0.1	
1.50	86	2.4	0.141	1.13	0.13	1.1	0.16	0.3	
1.75	100	3.2	0.215	1.31	0.16	1.3	0.28	0.7	
2.00	115	4.1	0.307	1.50	0.20	1.5	0.47	1.4	
2.25	129	5.1	0.414	1.69	0.25	1.7	0.71	2.4	
2.50	143	6.2	0.535	1.88	0.29	1.9	1.02	3.8	
2.75	158	7.2	0.666	2.06	0.32	2.1	1.38	5.5	
3.00	172	8.4	0.804	2.25	0.36	2.2	1.78	7.6	
3.25	186	9.5	0.944	2.44	0.39	2.3	2.20	10.0	
3.50	201	10.6	1.083	2.63	0.41	2.4	2.63	12.4	
3.75	215	11.7	1.215	2.81	0.43	2.5	3.05	14.8	
4.00	229	12.7	1.338	3.00	0.45	2.6	3.43	17.0	
4.25	244	13.7	1.447	3.19	0.45	2.6	3.75	18.9	
4.50	258	14.7	1.541	3.38	0.46	2.6	4.01	20.2	
4.75	272	15.5	1.617	3.56	0.45	2.6	4.19	21.1	
5.00	286	16.2	1.676	3.75	0.45	2.6	4.30	21.4	
5.25	301	16.8	1.718	3.94	0.44	2.5	4.34	21.2	
5.50	315	17.3	1.745	4.13	0.42	2.5	4.32	20.7	
5.75	329	17.7	1.760	4.31	0.41	2.4	4.25	19.9	
6.00	344	17.9	1.766	4.50	0.39	2.4	4.15	19.0	
6.25	358	18.0	1.767	4.69	0.38	2.3	4.05	18.0	
2.87	164	7.8	0.730	2.15	0.34	2.1	1.56	6.5	Design Q

PIPE 14
Flow Through Circular Pipe

Diameter of pipe, D=	36	inches
Longitudinal Slope, So=	0.005	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.003	0.38	0.01	0.2	0.00	0.0	
0.50	29	0.6	0.023	0.75	0.03	0.4	0.01	0.0	
0.75	43	1.3	0.077	1.13	0.07	0.7	0.06	0.1	
1.00	57	2.2	0.178	1.50	0.12	1.1	0.19	0.4	
1.25	72	3.4	0.339	1.88	0.18	1.4	0.47	1.3	
1.50	86	4.8	0.565	2.25	0.25	1.7	0.99	3.3	
1.75	100	6.5	0.862	2.63	0.33	2.1	1.80	7.3	
2.00	115	8.3	1.227	3.00	0.41	2.4	2.97	13.9	
2.25	129	10.2	1.656	3.38	0.49	2.7	4.52	23.9	
2.50	143	12.3	2.139	3.75	0.57	3.0	6.46	37.8	
2.75	158	14.5	2.664	4.13	0.65	3.3	8.74	55.6	
3.00	172	16.7	3.216	4.50	0.71	3.5	11.29	76.8	
3.25	186	19.0	3.778	4.88	0.77	3.7	13.99	100.5	
3.50	201	21.2	4.332	5.25	0.83	3.9	16.73	125.3	
3.75	215	23.4	4.862	5.63	0.86	4.0	19.36	149.6	
4.00	229	25.5	5.351	6.00	0.89	4.1	21.77	171.8	
4.25	244	27.5	5.788	6.38	0.91	4.1	23.82	190.2	
4.50	258	29.3	6.162	6.75	0.91	4.1	25.46	204.0	
4.75	272	31.0	6.468	7.13	0.91	4.1	26.62	212.5	
5.00	286	32.4	6.704	7.50	0.89	4.1	27.31	215.8	
5.25	301	33.7	6.873	7.88	0.87	4.0	27.55	214.3	
5.50	315	34.6	6.981	8.25	0.85	3.9	27.42	208.9	
5.75	329	35.4	7.041	8.63	0.82	3.8	26.99	200.8	
6.00	344	35.8	7.064	9.00	0.78	3.7	26.39	191.2	
6.25	358	36.0	7.069	9.38	0.75	3.6	25.70	181.3	
3.90	224	24.7	5.168	5.85	0.88	4.0	20.87	163.6	Design Q

PIPE 15
Flow Through Circular Pipe

Diameter of pipe, D=	42	inches
Longitudinal Slope, So=	0.325	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.2	0.004	0.44	0.01	1.5	0.01	0.0	
0.50	29	0.7	0.032	0.88	0.04	3.9	0.12	0.9	
0.75	43	1.5	0.105	1.31	0.08	6.6	0.69	8.7	
1.00	57	2.6	0.243	1.75	0.14	9.5	2.30	42.3	
1.25	72	4.0	0.461	2.19	0.21	12.5	5.77	140.3	
1.50	86	5.6	0.769	2.63	0.29	15.6	12.01	363.8	
1.75	100	7.5	1.173	3.06	0.38	18.7	21.89	792.3	
2.00	115	9.7	1.670	3.50	0.48	21.6	36.09	1512.7	
2.25	129	11.9	2.254	3.94	0.57	24.4	54.98	2602.3	
2.50	143	14.4	2.912	4.38	0.67	27.0	78.55	4110.5	
2.75	158	16.9	3.627	4.81	0.75	29.3	106.28	6042.3	
3.00	172	19.5	4.378	5.25	0.83	31.4	137.25	8348.4	
3.25	186	22.1	5.142	5.69	0.90	33.1	170.17	10924.4	
3.50	201	24.7	5.897	6.13	0.96	34.5	203.47	13620.9	
3.75	215	27.3	6.617	6.56	1.01	35.6	235.51	16261.0	
4.00	229	29.7	7.284	7.00	1.04	36.3	264.72	18664.9	
4.25	244	32.1	7.878	7.44	1.06	36.8	289.75	20673.8	
4.50	258	34.2	8.387	7.88	1.07	36.9	309.61	22171.3	
4.75	272	36.1	8.804	8.31	1.06	36.8	323.75	23096.7	
5.00	286	37.8	9.125	8.75	1.04	36.4	332.10	23449.6	
5.25	301	39.3	9.354	9.19	1.02	35.8	335.07	23284.7	
5.50	315	40.4	9.502	9.63	0.99	35.1	333.44	22699.9	
5.75	329	41.3	9.583	10.06	0.95	34.3	328.30	21819.7	
6.00	344	41.8	9.615	10.50	0.92	33.4	320.91	20778.3	
6.25	358	42.0	9.621	10.94	0.88	32.5	312.60	19704.6	
1.95	112	9.2	1.562	3.41	0.46	21.0	32.85	1339.8	Design Q

PIPE 25
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
3.19	183	9.2	0.909	2.39	0.38	21.0	19.09	777.6	Design Q

PIPE 26
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
3.05	175	8.6	0.835	2.29	0.36	20.4	17.03	673.9	Design Q

PIPE 27
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
3.75	215	11.7	1.217	2.82	0.43	22.9	27.84	1235.0	Design Q

PIPE 28
Flow Through Circular Pipe

Diameter of pipe, D=	72	inches
Longitudinal Slope, So=	0.005	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.3	0.012	0.75	0.02	0.3	0.00	0.0	
0.50	29	1.1	0.093	1.50	0.06	0.7	0.06	0.1	
0.75	43	2.5	0.308	2.25	0.14	1.2	0.36	0.8	
1.00	57	4.4	0.713	3.00	0.24	1.7	1.20	3.9	
1.25	72	6.8	1.355	3.75	0.36	2.2	3.02	13.0	
1.50	86	9.7	2.261	4.50	0.50	2.8	6.27	33.8	
1.75	100	12.9	3.447	5.25	0.66	3.3	11.43	73.5	
2.00	115	16.5	4.908	6.00	0.82	3.8	18.84	140.4	
2.25	129	20.5	6.624	6.75	0.98	4.3	28.71	241.5	
2.50	143	24.6	8.557	7.50	1.14	4.8	41.02	381.4	
2.75	158	29.0	10.658	8.25	1.29	5.2	55.50	560.7	
3.00	172	33.5	12.865	9.00	1.43	5.6	71.67	774.7	
3.25	186	38.0	15.112	9.75	1.55	5.9	88.86	1013.7	
3.50	201	42.4	17.329	10.50	1.65	6.1	106.25	1263.9	
3.75	215	46.8	19.447	11.25	1.73	6.3	122.99	1508.9	
4.00	229	51.0	21.406	12.00	1.78	6.5	138.24	1732.0	
4.25	244	54.9	23.152	12.75	1.82	6.5	151.31	1918.4	
4.50	258	58.6	24.649	13.50	1.83	6.6	161.68	2057.4	
4.75	272	61.9	25.872	14.25	1.82	6.5	169.06	2143.2	
5.00	286	64.8	26.815	15.00	1.79	6.5	173.43	2176.0	
5.25	301	67.3	27.490	15.75	1.75	6.4	174.98	2160.7	
5.50	315	69.3	27.925	16.50	1.69	6.2	174.13	2106.4	
5.75	329	70.7	28.162	17.25	1.63	6.1	171.44	2024.7	
6.00	344	71.6	28.257	18.00	1.57	5.9	167.58	1928.1	
6.25	358	72.0	28.274	18.75	1.51	5.8	163.24	1828.5	
3.93	225	49.8	20.879	11.79	1.77	6.4	134.16	1672.3	Design Q

PIPE 29
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
3.86	221	12.1	1.269	2.89	0.44	23.1	29.29	1312.2	Design Q

PIPE 30
Flow Through Circular Pipe

Diameter of pipe, D=	72	inches
Longitudinal Slope, So=	0.006	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.3	0.012	0.75	0.02	0.3	0.00	0.0	
0.50	29	1.1	0.093	1.50	0.06	0.8	0.07	0.1	
0.75	43	2.5	0.308	2.25	0.14	1.3	0.39	1.0	
1.00	57	4.4	0.713	3.00	0.24	1.8	1.32	4.7	
1.25	72	6.8	1.355	3.75	0.36	2.4	3.30	15.6	
1.50	86	9.7	2.261	4.50	0.50	3.0	6.87	40.5	
1.75	100	12.9	3.447	5.25	0.66	3.6	12.52	88.2	
2.00	115	16.5	4.908	6.00	0.82	4.2	20.64	168.4	
2.25	129	20.5	6.624	6.75	0.98	4.7	31.45	289.8	
2.50	143	24.6	8.557	7.50	1.14	5.3	44.93	457.7	
2.75	158	29.0	10.658	8.25	1.29	5.7	60.80	672.8	
3.00	172	33.5	12.865	9.00	1.43	6.1	78.52	929.6	
3.25	186	38.0	15.112	9.75	1.55	6.4	97.34	1216.5	
3.50	201	42.4	17.329	10.50	1.65	6.7	116.39	1516.7	
3.75	215	46.8	19.447	11.25	1.73	6.9	134.73	1810.7	
4.00	229	51.0	21.406	12.00	1.78	7.1	151.44	2078.4	
4.25	244	54.9	23.152	12.75	1.82	7.2	165.75	2302.1	
4.50	258	58.6	24.649	13.50	1.83	7.2	177.11	2468.8	
4.75	272	61.9	25.872	14.25	1.82	7.2	185.20	2571.9	
5.00	286	64.8	26.815	15.00	1.79	7.1	189.98	2611.2	
5.25	301	67.3	27.490	15.75	1.75	7.0	191.68	2592.8	
5.50	315	69.3	27.925	16.50	1.69	6.8	190.75	2527.7	
5.75	329	70.7	28.162	17.25	1.63	6.7	187.81	2429.7	
6.00	344	71.6	28.257	18.00	1.57	6.5	183.58	2313.7	
6.25	358	72.0	28.274	18.75	1.51	6.3	178.83	2194.2	
4.22	242	54.5	22.974	12.67	1.81	7.2	164.29	2279.4	Design Q

PIPE 31
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
2.98	171	8.3	0.791	2.23	0.35	20.0	15.84	615.6	Design Q

PIPE 32
Flow Through Circular Pipe

Diameter of pipe, D=	18	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.001	0.19	0.00	1.0	0.00	0.0	
0.50	29	0.3	0.006	0.38	0.02	2.5	0.01	0.1	
0.75	43	0.6	0.019	0.56	0.03	4.2	0.08	0.7	
1.00	57	1.1	0.045	0.75	0.06	6.1	0.27	3.2	
1.25	72	1.7	0.085	0.94	0.09	8.0	0.68	10.6	
1.50	86	2.4	0.141	1.13	0.13	10.0	1.42	27.6	
1.75	100	3.2	0.215	1.31	0.16	12.0	2.58	60.0	
2.00	115	4.1	0.307	1.50	0.20	13.9	4.26	114.6	
2.25	129	5.1	0.414	1.69	0.25	15.7	6.49	197.1	
2.50	143	6.2	0.535	1.88	0.29	17.3	9.26	311.3	
2.75	158	7.2	0.666	2.06	0.32	18.8	12.54	457.6	
3.00	172	8.4	0.804	2.25	0.36	20.1	16.19	632.3	
3.25	186	9.5	0.944	2.44	0.39	21.3	20.07	827.4	
3.50	201	10.6	1.083	2.63	0.41	22.2	24.00	1031.7	
3.75	215	11.7	1.215	2.81	0.43	22.9	27.78	1231.6	
4.00	229	12.7	1.338	3.00	0.45	23.3	31.22	1413.7	
4.25	244	13.7	1.447	3.19	0.45	23.6	34.18	1565.9	
4.50	258	14.7	1.541	3.38	0.46	23.7	36.52	1679.3	
4.75	272	15.5	1.617	3.56	0.45	23.6	38.19	1749.4	
5.00	286	16.2	1.676	3.75	0.45	23.4	39.17	1776.1	
5.25	301	16.8	1.718	3.94	0.44	23.0	39.52	1763.6	
5.50	315	17.3	1.745	4.13	0.42	22.5	39.33	1719.3	
5.75	329	17.7	1.760	4.31	0.41	22.0	38.72	1652.6	
6.00	344	17.9	1.766	4.50	0.39	21.4	37.85	1573.8	
6.25	358	18.0	1.767	4.69	0.38	20.9	36.87	1492.4	
2.68	154	6.9	0.628	2.01	0.31	18.4	11.57	413.7	Design Q

PIPE 33
Flow Through Circular Pipe

Diameter of pipe, D=	36	inches
Longitudinal Slope, So=	0.415	ft/ft
Manning's n=	0.024	
Density of flowing liquid, rho=	1.94	slugs/ft^3

Theta radians	Theta degrees	Depth of Flow y inches	Area of Flow A ft^2	Wetted Perimeter P ft	Hydraulic Radius R ft	Average Velocity V ft/s	Discharge Q=A*V cfs	Force F lbf	
0.00	0	0.0	0.000	0.00		0.0	0.00	0.0	
0.25	14	0.1	0.003	0.38	0.01	1.6	0.00	0.0	
0.50	29	0.6	0.023	0.75	0.03	3.9	0.09	0.7	
0.75	43	1.3	0.077	1.13	0.07	6.7	0.51	6.7	
1.00	57	2.2	0.178	1.50	0.12	9.7	1.72	32.3	
1.25	72	3.4	0.339	1.88	0.18	12.8	4.32	107.2	
1.50	86	4.8	0.565	2.25	0.25	15.9	9.00	277.9	
1.75	100	6.5	0.862	2.63	0.33	19.0	16.40	605.2	
2.00	115	8.3	1.227	3.00	0.41	22.0	27.03	1155.4	
2.25	129	10.2	1.656	3.38	0.49	24.9	41.19	1987.6	
2.50	143	12.3	2.139	3.75	0.57	27.5	58.84	3139.5	
2.75	158	14.5	2.664	4.13	0.65	29.9	79.61	4614.9	
3.00	172	16.7	3.216	4.50	0.71	32.0	102.81	6376.3	
3.25	186	19.0	3.778	4.88	0.77	33.7	127.47	8343.8	
3.50	201	21.2	4.332	5.25	0.83	35.2	152.42	10403.2	
3.75	215	23.4	4.862	5.63	0.86	36.3	176.42	12419.7	
4.00	229	25.5	5.351	6.00	0.89	37.1	198.30	14255.7	
4.25	244	27.5	5.788	6.38	0.91	37.5	217.05	15790.1	
4.50	258	29.3	6.162	6.75	0.91	37.6	231.92	16933.8	
4.75	272	31.0	6.468	7.13	0.91	37.5	242.52	17640.7	
5.00	286	32.4	6.704	7.50	0.89	37.1	248.78	17910.2	
5.25	301	33.7	6.873	7.88	0.87	36.5	251.00	17784.2	
5.50	315	34.6	6.981	8.25	0.85	35.8	249.78	17337.6	
5.75	329	35.4	7.041	8.63	0.82	34.9	245.93	16665.3	
6.00	344	35.8	7.064	9.00	0.78	34.0	240.39	15869.9	
6.25	358	36.0	7.069	9.38	0.75	33.1	234.17	15049.8	
3.62	208	22.3	4.594	5.43	0.85	35.8	164.29	11399.2	Design Q

Exhibit F-2

Final Cover System Drainage Layer Design

Written by: **Y. Bholat**	Date: **2/6/2014**	Reviewed by: **S. Graves**	Date: **3/4/2014**
Client: **Clean Harbors**	Project: **Lone Mountain Facility**	Project No.: **TXL0380**	Phase No.: **04**

FINAL COVER GEOSYNTHETIC DRAINAGE LAYER DESIGN

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
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OKLAHOMA

6/13/2014

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State of Oklahoma Registration # 19710
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SEALED FOR CALCULATION PAGES
F2-1 THROUGH F2-14

1. PURPOSE

The purpose of this calculation package is to present the design of the geosynthetic drainage layer of the proposed final cover system for Landfill Cell 15 at the Lone Mountain Facility. As shown on the engineering details presented on the Drawings in Attachment A of the Engineering Report, the geocomposite drainage layer of the final cover system will be comprised of an HDPE geonet core with a needle punched non-woven geotextile bonded on to its top and bottom surfaces (i.e., a double-sided geocomposite). It is important to note that this calculation package does not limit the type of geocomposite to single-sided or double-sided; instead a required index transmissivity will be calculated herein, irrespective of the type of geocomposite drainage product. Refer to the Drawings in Exhibit A of the Engineering Report, and the CQA Plan, for the material specifications and required type of geocomposite drainage layer.

The items evaluated in this design evaluation include: (i) filtration capability and specifications for the geotextile component of the geocomposite drainage layer; (ii) survivability specifications for the geotextile component; and (iii) hydraulic capacities of the geocomposite drainage layer and testing conditions for verifying that the required hydraulic capacities are achieved.

2. METHODS OF ANALYSIS

2.1 Geotextile Filtration

The filtration characteristics of the geotextile component of the geocomposite layer will be evaluated using a retention criterion, a permeability criterion, and an anti-clogging criterion, based on methods presented in the following technical literature: Christopher and Holtz (1984), Giroud (1982), Koerner et al. (1994), USEPA (1987).

2.2 Geotextile Survivability

Survivability requirements (grab, tear, and puncture strengths) will also be considered so that the geotextile component of the geocomposite will have adequate resistance to stresses applied on the geotextile during construction (i.e., when concentrated stresses should be the highest), using the method presented in GRI-GT13 (2004).

As each criterion is evaluated and minimum specifications are derived, characteristics of geotextile products on the current market are checked to ensure the specification is reasonable and that products are available that can meet the specification. Also, this calculation package presents minimum required properties. The Landfill Cell 15 CQA Plan presents the required properties that shall be met for the final cover system geocomposite, which must at least meet the minimum values specified herein; but may in some cases be more stringent.

2.3 Drainage Layer Hydraulic Capacity

The drainage layer hydraulic capacity design evaluation is performed using the design-by-function concept presented by Koerner (2005) and based on Darcy's equation (flow rate = hydraulic conductivity × hydraulic gradients × cross-sectional area of flow) for hydraulic flow in porous, saturated media. The approach herein then follows the design methodologies presented in Giroud et al. (2000) and GRI-GC8 (2001).

The design method involves the following steps:

Step 1) Calculate the required (design) transmissivity (θ_{req}) based on results of impingement rate calculations through the final cover using the USEPA Hydrologic Evaluation of Landfill Performance (*HELP*) model.

Step 2) Apply a global factor of safety (FS) of 2 to find the allowable flow rate and corresponding "Long-Term In-Soil" (LTIS) transmissivity (θ_{LTIS}).

Step 3) Apply partial reduction factors (RFs) for creep, chemical clogging, and biological clogging to account for the long-term decrease in flow capacity behavior, and calculate the baseline flow rate and corresponding baseline transmissivity (θ_{100}).

Step 4) Determine the critical operation case for θ_{100} by comparing required θ_{100} to typical θ_{100} for biplanar geocomposites at various loading conditions.

Step 5) Identify GRI-GC8 test conditions to measure θ_{100}. The resulting θ_{100} from Step 4 is a product specification for the baseline laboratory test transmissivity that should be achieved if tested in accordance with GRI-GC8, Part 6 (2001). Therefore, it is necessary to identify test conditions which simulate site-specific loading conditions and boundary conditions.

Step 6) Calculate the index transmissivity (θ_{INDEX}) that corresponds to the baseline transmissivity from previous steps. Geocomposite manufacturers typically provide product index transmissivities based on laboratory tests in which the drainage layer is sandwiched between two steel plates as opposed to site specific boundary conditions. The index transmissivity is determined by applying a reduction factor to θ_{100} to account for geotextile/soil intrusion.

3. FILTRATION EVALUATION RESULTS

The filtration criteria used for the drainage layer design are presented below in Table F2-1, followed by a description justifying selection of the required design values.

Table F2-1. Filtration Criteria for Geotextile Components (adapted from Christopher and Holtz, 1984; Giroud, 1982; Koerner et al., 1994; and USEPA, 1987)

1. Retention Criterion

1.1. Soils with less than 50% particles < 0.075 mm (US Sieve No. 200)

Density index of the soil (Relative density)		Linear coefficient of uniformity of the soil	
		$1 < C'_u < 3$	$C'_u > 3$
loose soil	$I_D < 35\%$	$O_{95} < C'_u\, d_{50}$	$O_{95} < \frac{9}{C'_u} d_{50}$
medium dense soil	$35\% < I_D < 65\%$	$\boxed{O_{95} < 1.5\, C'_u\, d_{50}}$	$O_{95} < \frac{13.5}{C'_u} d_{50}$
dense soil	$I_D > 65\%$	$O_{95} < 2\, C'_u\, d_{50}$	$O_{95} < \frac{18}{C'_u} d_{50}$

1.2. Soils with more than 50% particles < 0.075 mm (US Sieve No. 200)
$O_{95} \leq 210$ µm (US Sieve No. 70)

Table F2-1 (Continued). Filtration Criteria for Geotextile Components

2. Permeability Criterion

2.1. Critical and/or Severe Applications
$k_{geotextile} > 10\ k_{soil}$

2.2. Noncritical and Nonsevere Applications
$k_{geotextile} > k_{soil}$

3. Anti-Clogging Criterion

Nonwoven geotextiles: porosity, $n_g > 30\%$

Notes:
- O_{95} is the apparent opening size (AOS) of the geotextile
- C'_u = linear coefficient of uniformity = $\sqrt{d'_{100} / d'_0}$
  where d'_{100} and d'_0 are the top and bottom extremities, respectively, of a line drawn through the soil particle-size distribution curve and tangent at d_{50}.
- d_{50} and d_{85} are soil particle sizes for which 50% and 85%, respectively, of particles are finer by weight
- I_D = relative density or density index = $(e - e_{min})/(e_{max} - e_{min})$, where e = soil void ratio; e_{min} = soil minimum void ratio, and e_{max} = soil maximum void ratio
- $k_{geotextile}$ = geotextile hydraulic conductivity; k_{soil} = soil hydraulic conductivity
- porosity, n_g (dimensionless) is calculated as follows: $n_g = 1 - \mu_g/(\rho_g\ t_g)$, where: μ_g = geotextile mass per unit area, ρ_g = polymer density, and t_g = geotextile thickness.

3.1 <u>Geotextile Retention</u>

The geotextile must have openings that are small enough to retain fine-grained soil particles to avoid clogging or flow capacity reduction of the drainage material that it filters. Therefore, the apparent opening size (AOS, hereafter referred to as O_{95}) of the geotextile must be less than a required maximum value. The retention criterion is given in Table F2-1.

The geocomposite drainage layer in the final cover system will overlay a geomembrane surface and will, itself, be overlain by a protective cover layer assumed to be moderately-compacted fine-grained clayey on-site soil. As described in Exhibit B-1, the site soils are primarily classified as clays (USCS classification of CL) and, by definition, have more than 50% particles finer than 0.075mm (U.S. Sieve No. 200). As shown in Table F2-1, for soils classified as clays, the geotextile retention criterion is as follows:

$$O_{95} \leq 210\ \mu m \text{ (U.S. Sieve No. 70)}$$

The range of geotextile mass per unit areas anticipated for use as a filtration layer or drainage layer component are 6 to 16 oz/yd^2 (200 to 540 g/m^2). Typical O_{95} for 6 to 16 oz/yd^2 geotextiles on the current market range from 90 to 210 μm (IFAI, 2008); thus, products are available that can meet this specification.

3.2 Geotextile Permeability

The geotextile must have openings that are large enough to allow liquid to pass through the retained soil/geotextile interface without significant flow impedance. Thus, the hydraulic conductivity or permeability of the geotextile must be greater than a minimum required value. The permeability criterion is given in Table F2-1. For severe or critical applications, the hydraulic conductivity of the geotextile $k_{geotextile}$ should be more than ten times greater than the hydraulic conductivity of the retained soil k_{soil}.

The material retained by the geotextile component of the geocomposite drainage layer in the final cover system is clay cover soil. Given the importance of long-term function of the drainage layers, the geotextile components are designed so that ($k_{geotextile} > 100\ k_{soil}$).

The hydraulic conductivity of the moderately-compacted cover soil was assumed to be 1.9×10^{-6} cm/s, as discussed in the "*Materials Data*" section of Exhibit E-1. Therefore, the geotextile permeability criterion is as follows:

$$k_{geotextile} > 100 \text{ x } (1.9 \text{ x } 10^{-6} \text{ cm/s}) = 1.9 \text{ x } 10^{-4} \text{ cm/s}$$

Note that some manufacturers report the permeability property as "permittivity" (Ψ), which is defined as $\Psi = k/t$. Based on the range of geotextile mass per unit areas and thicknesses anticipated for the project (6 to 16 oz/yd^2 (200 to 540 g/m^2) and 1.3 to 5.7 mm, respectively), typical $k_{geotextile}$ values (calculated from typical permittivities and thicknesses) for needle punched non-woven geotextiles are 0.2 to 0.4 cm/sec. Therefore, needle punched non-woven geotextiles within the anticipated range for this project are well above the minimum required permeability value recommended to prevent excessive flow impedance or pore-water pressure development in the retained material.

3.3 Geotextile Anti-Clogging

The geotextile filter must have enough openings so that blocking some of them will not significantly clog the geotextile and inhibit flow into the geonet. Thus, the porosity of the geotextile must be greater than a required minimum value. The clogging criterion is given in Table F2-1. As shown in Table F2-1, for non-woven geotextiles, the geotextile porosity n_g is required to be:

$$n_g > 30\%$$

The clogging criterion requirements apply for the geotextile component of the geocomposite drainage layer. Geotextile porosity is not a property that is directly measured or reported by manufacturers, however it can be calculated as indicated in Table F2-1 (i.e., $n_g = 1 - \mu_g/(\rho_g\ t_g)$). Typical resulting n_g values for non-woven geotextiles are 50 to 95%. Based on the geotextile density of polypropylene or polyethylene and the range of mass per unit areas and thicknesses anticipated for the project (6 to 16 oz/yd^2 (200 to 540 g/m^2) and 1.3 to 5.7 mm, respectively), the calculated n_g values range from approximately 80% to 90%, which is well in excess of the minimum required porosity required to prevent clogging.

4. SURVIVABILITY EVALUATION RESULTS

Survivability refers to the ability of the geotextile to withstand the stresses during installation and handling in the field. The survivability criteria used for the drainage layer design are presented below in Tables F2-2 and F2-3 using a two-step method outlined by GRI-GT13 (2004), followed by a discussion on the assumptions used to select the required design values.

Table F2-2. Required Degree of Survivability as a Function of Subgrade Conditions and Construction Equipment (GRI-GT13)*

Subgrade Conditions	Low ground-pressure equipment (≤ 25 kPa)	Medium ground-pressure equipment (> 25 kPa, ≤ 50 kPa)	High ground-pressure equipment (> 50 kPa)
Subgrade has been cleared of all obstacles except grass, leaves, and fine wood debris. Surface is smooth and level so that any shallow depressions and humps do not exceed 450 mm in depth or height. All larger depressions are filled. Alternatively, a smooth working table may be placed.	Low	Moderate	High
Subgrade has been cleared of obstacles larger than small to moderate-sized tree limbs and rocks. Tree trunks and stumps should be removed or covered with a partial working table. Depressions and humps should not exceed 450 mm in depth or height. Larger depressions should be filled.	Moderate	High	Very High
Minimal site preparation is required. Trees may be felled, delimbed, and left in place. Stumps should be cut to project not more than ± 150 mm above subgrade. Fabric may be draped directly over the tree trunks, stumps, large depressions and humps, holes, stream channels, and large boulders. Items should be removed only if placing the fabric and cover material over them will distort the finished road surface.	High	Very High	Not Recommended

* Recommendations are for 150 to 300 mm initial lift thickness. For other initial lift thicknesses:
  - 300 to 450 mm: reduce survivability requirement one level;
  - 450 to 600 mm: reduce survivability requirement two levels;
  - > 600 mm: reduce survivability requirement three levels

For special construction techniques such as prerutting, increase the fabric survivability requirement one level. Placement of excessive initial cover material thickness may cause bearing failure of the soft subgrade.

As shown above, the degree of survivability is first evaluated using Table F2-2 with the anticipated installation conditions. The following conditions are conservatively assumed to apply: (i) smooth and level subgrade condition; (ii) thickness of soil placed above geotextile is 24 in.; and (iii) maximum equipment ground pressure of 5 psi (35 kPa) (i.e., medium ground-pressure equipment is used). Using Table F2-2, a "moderate" degree of survivability is used.

Table F2-3. GRI-GT13 Geotextile Strength Property Requirements

Tests	Test Methods	Units	Class 1 (high) Elongation < 50%	Class 1 (high) Elongation ≥ 50%	Class 2 (moderate) Elongation < 50%	Class 2 (moderate) Elongation ≥ 50%	Class 3 (low) Elongation < 50%	Class 3 (low) Elongation ≥ 50%
			Geotextile Classification (1)					
Grab strength	ASTM D 4632	N	1400	900	1100	700	800	500
Trapezoid Tear strength	ASTM D 4533	N	500	350	400	250	300	180
CBR Puncture strength	ASTM D 6241	N	2800	2000	2250	1400	1700	1000
Permittivity	ASTM D 4491	s^{-1}	0.02	0.02	0.02	0.02	0.02	0.02
Apparent opening size	ASTM D 4751	mm	0.6	0.6	0.6	0.6	0.6	0.6
Ultraviolet stability (2)	ASTM D 4355	% Ret. @ 500 hrs	50	50	50	50	50	50

Notes: (1) All values are MARV except UV stability (which is a minimum value) and AOS which is a maximum value).
(2) Evaluation to be on 50 mm strip tensile specimens after 500 hours exposure.

In the second step, the minimum required values for the mechanical properties of the geotextile are established from Table F2-3 based on the "moderate" or "Class 2" survivability requirement. The chart provides minimum required values for two ranges of geotextile extensibility. Values were selected for the more extensible range because this range is applicable to non-woven materials that are required for the geotextile. These survivability requirements apply for the geotextile component of the geocomposite drainage layer.

5. HYDRAULIC CAPACITY EVALUATION

5.1 Step 1: Calculate Required (Design) Transmissivity, θ_{req}

As presented in Exhibit E1, the *HELP* model was used to calculate the required (design) in-plane hydraulic conductivity and equivalent transmissivity of the final cover drainage layer. The required transmissivity is based on maintaining the peak daily average head on the geomembrane liner of the sideslope final cover at less than or equal to the approximate thickness of the drainage layer. Maintaining the head within the geocomposite thickness is appropriate for veneer stability of the final cover system on the side slope, as discussed in Exhibit B-2 of the Landfill Cell 15 Engineering Report. The required (design) transmissivity, θ_{req}, was calculated from the side slope condition at final grades (Case FC-S presented in Exhibit E1 of the Permit Application). The design transmissivity (θ_{req}) was back-calculated to be 2.2×10^{-5} m^2/s.

5.2 Step 2: Calculate Allowable "Long Term In Soil" Transmissivity, θ_{LTIS}

The allowable "Long Term In Soil" transmissivity, θ_{LTIS}, is calculated by applying a factor of safety to increase the minimum required transmissivity. For leachate drainage layers, a factor of safety (FS) of 2 is assumed in the analysis for the final cover drainage layer. The θ_{LTIS} was calculated as shown below:

$$\theta_{LTIS} = \theta_{req} \times FS \qquad \text{(Eqn. 1)}$$

$$\theta_{LTIS} = 2.2\times10^{-5} \times 2 = 4.4 \times10^{-5}\ m^2/s$$

5.3 Step 3: Calculate Baseline Geocomposite Transmissivity, θ_{100}

Factors which account for additional long-term transmissivity reduction due to creep, chemical clogging, and biological clogging were applied to determine the minimum baseline product transmissivity, θ_{100}, for laboratory testing results as shown in Eqns. 2 and 3.

$$\theta_{LTIS} = \frac{\theta_{100}}{RF_{CR}RF_{CC}RF_{BC}} \qquad \text{(Eqn. 1)}$$

Where RF_{CR} = reduction factor for creep, RF_{CC} = reduction factor for chemical clogging and/or precipitation of chemicals, and RF_{BC} = reduction factor for biological clogging.

Creep is the long-term reduction in thickness of the drainage layer under a sustained compressive stress. For landfill covers, Koerner (2005) recommends that reduction factors for creep range from 1.2 to 1.4. For the final condition (as in Case FC-S), the reduction factor for creep is assumed to be 1.4.

GRI (2001) provides guidance for clogging reduction factors for final cover systems. Chemical and biological clogging is expected to increase over time as infiltrating water passes through the geocomposite. Thus, the reduction factors for clogging are assumed to increase from initial operational conditions through final cover conditions. GRI (2001) recommends a chemical clogging reduction factor between 1.0 and 1.2 and a biological clogging reduction factor between 1.2 and 3.5 at final conditions. Based on recommendations by GRI, the chemical clogging reduction factor was assumed to be 1.0.

Due to the susceptibility of the final cover geocomposite to biological clogging due to root penetrations from the vegetative cover, the biological clogging reduction factor was assumed to be 3.0, which is near the high end of the recommended range (note that Koerner (2005) recommends a value between 1.5 and 2.0).

The θ_{100} was calculated by rearranging Eqn. 2 and substituting θ_{LTIS} and the reduction factors above as follows:

$$\theta_{100} = \theta_{LTIS}\, RF_{CR}\, RF_{CC}\, RF_{BC} \qquad \text{(Eqn. 2)}$$

$$\theta_{100} = 4.4\times10^{-5} \times 1.4 \times 1.0 \times 3.0 = 1.8 \times10^{-4}\ m^2/s$$

5.4 Step 4: Calculate the Critical Operation Case for θ_{100}

Geosyntec contacted SKAPS Industries to obtain θ_{100} data for a common biplanar geocomposite on the market. The data correspond to the product, TN 270-2-8, a geocomposite with non-woven geotextile on both sides of the geonet. This does not constitute specification or endorsement of this product; it is merely intended to compare the required transmissivities to a commercially available product to check reasonableness of the design and availability of products. The TN 270-2-8 geocomposite transmissivity was measured at a gradient of 0.1 while sandwiched between sand and a geomembrane for a seating time of 100 hours under four different normal stresses.

To compare the required θ_{100} to the typical θ_{100} on the market, the normal stress expected for the operational condition must be calculated. The stress can be determined from the thickness of fill to be placed above the drainage layer as follows:

$$p = \gamma_{cover} h_{cover} \qquad \text{(Eqn. 4)}$$

$$p = 120\ (pcf) \times 2\ (ft) = 240\ psf$$

The required (minimum) θ_{100} is plotted versus the calculated stress in Figure F2-1. The expected θ_{100} data for typical biplanar geocomposites is shown for reference. As shown in Figure F2-1, the required θ_{100} for the operational case is less than θ_{100} for a typical biplanar geocomposite at the corresponding stress condition. Therefore, the geocomposite should provide adequate hydraulic capacity for the operational condition. The required θ_{100} is $1.8 \times 10^{-4}\ m^2/s$ for a normal stress of approximately 240 psf.

Written by: **Y. Bholat** Date: **2/6/2014** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

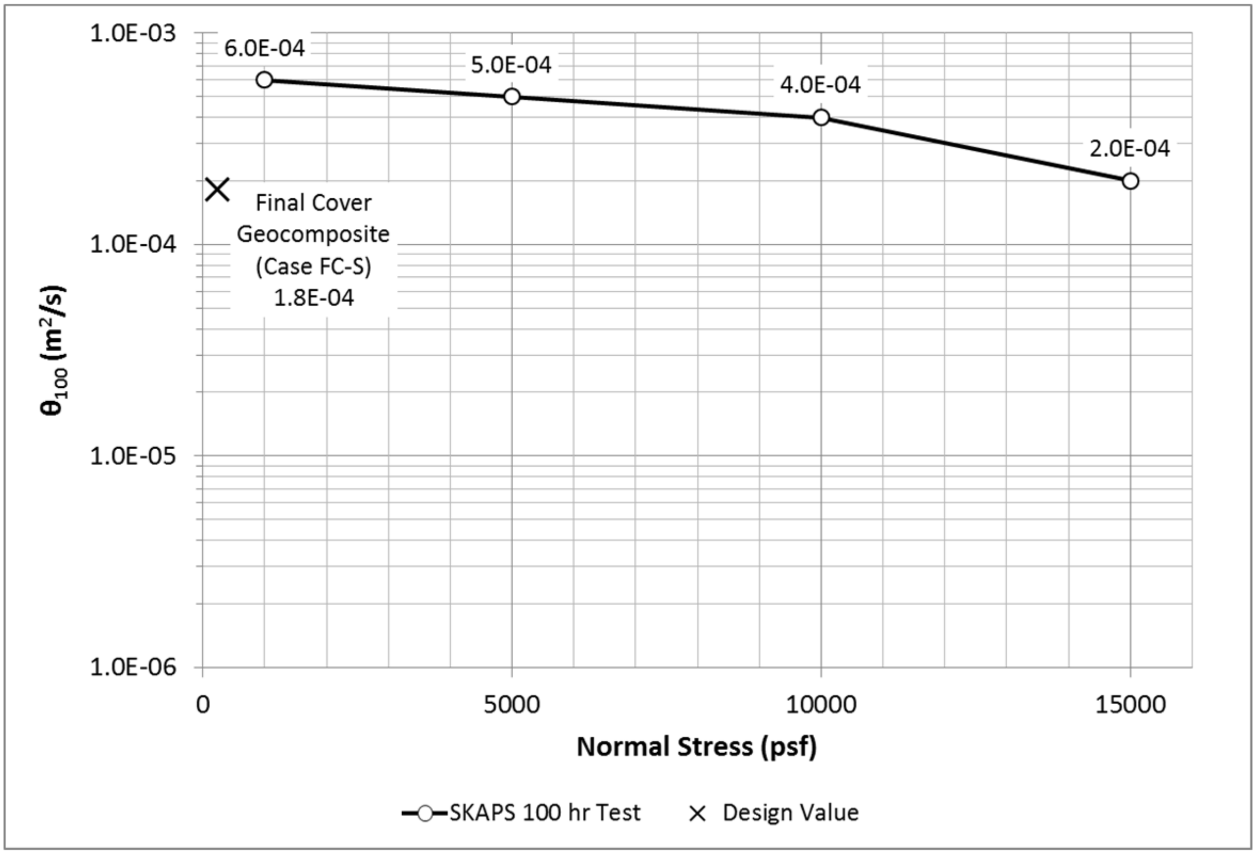

Figure F2-1. Comparison of Required θ_{100} to Typical θ_{100} Test Results at Various Normal Stresses. Note: The typical product information shown does not constitute an endorsement of these products, nor does this require the use of any specific manufacturer or product. This information is presented for comparison purposes only.

5.5 Step 5: Specify Testing Conditions for Evaluating θ_{100}

The testing conditions to be used in evaluating θ_{100} using GRI Standard GC8, Part 6 are: (i) the testing configuration (i.e., stratum configuration); (ii) the applied stress; and (iii) the hydraulic gradient. These conditions are specified below.

- The recommended testing configuration for transmissivity testing of the final cover drainage layer should consist of a 60-mil HDPE geomembrane on one side of the geocomposite specimen (to simulate site-specific liner design) and compacted clay soil material on the other side of the geocomposite specimen.
- The stress to be applied in testing the final cover drainage layer should be equivalent to the *in-situ* stress expected on the geocomposite as defined in Step 4. Therefore, the stress on the geocomposite drainage layer material to be used in determining θ_{100} is 240 psf.

- The geocomposite drainage layer slopes at about 10% on the sideslope of the final cover system. Therefore, the hydraulic gradient to be used in determining θ_{100} for the geocomposite is 0.10.

5.6 Step 6: Determine Index Transmissivity, θ_{INDEX}, Equivalent to θ_{100}

While the θ_{100} given above is suitable for use as a specification if desired, it is usually more convenient to report the transmissivity between two steel plates for a short duration test since manufacturers of geocomposite drainage materials often present the hydraulic capacities of their product in this manner. These transmissivities are usually higher than those that would be obtained using the site specific boundary conditions of soil on one side and a geomembrane on the other side. This is because the short duration test not completely account for the time-delayed intrusion of the geotextile into the transmissive core resulting from the deformation of the geotextile under sustained loading. Additionally, the steel plate boundary condition of the short duration test will not account for a reduction in transmissivity due to particle migration into the transmissive core.

To compare the specified θ_{100} of the final cover drainage layer with index values reported by the manufacturer, a factor can be applied to account for the reduction of the transmissivity that may be experienced due to intrusion and particulate clogging when testing the drainage layer with boundary materials other than steel plates. The index transmissivity, θ_{INDEX}, which accounts for intrusion and particulate clogging can be determined as shown in Eqn. 5:

$$\theta_{INDEX} = \theta_{100} \times RF_{INT} \times RF_{PC} \qquad \text{(Eqn. 5)}$$

Koerner (2005) recommends using an intrusion reduction factor (RF_{INT}) between 1.3 and 1.5 for landfill covers. An intrusion factor of 1.4 was assumed for final cover system conditions. The geotextile is expected to adequately retain particulates to avoid potential clogging of the transmissive core, as discussed in section 3; however, a particulate clogging reduction factor (RF_{PC}) of 1.1 is applied. The index transmissivity, θ_{INDEX}, for the geocomposite at the condition specified in step 4 (final condition FC-S) is found to be:

$$\theta_{INDEX} = 1.8 \times 10^{-4}\ (m^2/s) \times 1.4 \times 1.1$$
$$\theta_{INDEX} = 2.8 \times 10^{-4}\ m^2/s$$

6. CONCLUSIONS

Based on the evaluations herein, the following specifications are recommended for the final cover system drainage layer.

- Retention and Filtration of Geotextile Components:
    - Apparent Opening Size, $O_{95} \leq 210\ \mu m$ (U.S. Sieve No. 70)
    - Geotextile Water Permeability, $k_{geotextile} \geq 1.9 \times 10^{-4}$ cm/s for the geotextile component of the geocomposite drainage layer
- Survivability (Mechanical) Properties of Geotextile Components:
    - Grab Strength = 700 N (157 lbs)
    - Trapezoid Tear Strength = 250 N (56 lbs)
    - CBR Puncture Strength = 1400 N (315 lbs)
- Hydraulic Capacity (Transmissivity) of Geocomposite Drainage Layer:
    - $\theta_{INDEX} = 2.8 \times 10^{-4}\ m^2/s$ (when tested for 15 minutes between two steel plates with an applied stress of 240 psf at a gradient of 0.10)
    - An index transmissivity equal to or greater than this value should be specified in the Landfill Cell 15 CQA Plan for the final cover system geocomposite.

7. REFERENCES

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Exhibit F-3

Final Cover System Erosion Analysis

Written by: **Hunter Douglas** Date: **2/27/14** Reviewed by: **S. Graves** Date: **3/4/2014**

Client: **Clean Harbors** Project: **Lone Mountain Facility** Project No.: **TXL0380** Phase No.: **04**

FINAL COVER SOIL EROSION LOSS CALCULATIONS

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SEALED FOR CALCULATION PAGES
F3-1 THROUGH F3-12

1. PURPOSE

The purpose of this calculation package is to present the evaluation of the long term effects of erosion and soil loss for the proposed Landfill Cell 15 final cover system at the Lone Mountain Facility. The effects of erosion were evaluated over the final cover system slopes that will be graded to have slopes of 10:1 (horizontal:vertical) and 3:1 (horizontal:vertical) as shown on the permit drawings in Exhibit A of the Engineering Report. The estimated amount of erosion was calculated using the Revised Universal Soil Loss Equation (RUSLE).

2. FINAL COVER SOIL EROSION LOSS CALCULATION METHODOLOGY

The method to calculate the soil erosion loss over the project area was obtained from the guidance document *Predicting Soil Erosion by Water: A Guide to Conservation Planning With the Revised Universal Soil Loss Equation (RUSLE)* (USDA, 1997), as well as previously published information provided by USDA. This document presents the RUSLE methodology and guidance for each of the equation's parameters. The RUSLE is described as follows:

$$A = R \times K \times LS \times C \times P$$

where: A = the computed spatial average annual soil loss (tons/acre/year),

R = the average annual rainfall runoff erosivity factor,

K = the soil erodibility factor,

LS = the topographic factor,

C = the cover management factor, and

P = the erosion control practice factor.

3. RUSLE INPUT PARAMETERS

3.1 Rainfall Runoff Erosivity Factor (R)

The rainfall runoff erosivity factor is defined as the average annual rainfall erosion index specific for the project area. Based on USDA (1997), the value was determined to be approximately 170 for the site, as shown in Figure F3-1.

3.2 Soil Erodibility Factor (K)

The soil erodibility factor is a function of the physical and chemical properties of the soil and is specific to the source of the cover material. The soil erodibility factor can be thought of as the ease with which soil is detached by splash during rainfall or by surface flow. The soils expected to be used for the cover system of the Lone Mountain Facility are the native soils found at the project site. These soils at the project location were assessed from the Web Soil Survey for Major County as: Beckman clay (Cy), Vernon clay (VcB), and Knoco clay (VnB). Soil survey information on the native soils at the Lone Mountain Facility is presented in Figure F3-2.

The Web Soil Survey (NRCS, 2014) was consulted for the site area to determine the corresponding soil erodibility factors. It is expected that near-surface soils will be used for the final cover system. The maximum value of K for the project location soils near the surface was listed as 0.43, where the estimate considers the erodibility of fine-earth fraction for material less than two mm in size (using the Kf erosion factor provided in Table F3-1).

3.3 Topographic Factor (LS)

The slope length factor and slope steepness factor are typically combined into one topographic factor, LS, to facilitate field application of these equation components. USDA (1997) presents values of the LS factor for slope lengths in feet up to 1,000 feet and percent slopes up to 60%, as shown in Table F3-2, for soils with vegetated cover.

The longest slope length for the side slope of the final cover system was used to select the LS factor for each area of different slope, and these lengths were applied to compute the soil loss for both portions of the landfill. The final cover system will consist of 10H:1V (10%) side slopes with mid-slope and bottom drainage berms built on top of the side slope, and 3H:1V (33%) side slopes below the bottom drainage berms. The maximum length of 10% side slope between or above the berms is 366 ft., and the maximum length of 33% side slope is 33 ft. Based on these slope lengths, the following LS factors were selected (and interpolated if necessary) from Table F3-2:

- Side Slopes – 10H:1V (10%) over the maximum Lone Mountain Landfill design slope length (between/above berms) of 366 ft, LS = 2.06
- Top Deck – 33% slope over the maximum Lone Mountain Landfill design slope length of 33 ft, LS = 3.19

3.4 Cover Management Factor (C)

The cover management factor is a function of the type of land cover, based on three factors: (i) the vegetative cover in direct contact with the soil surface, (ii) the canopy cover, and (iii) the effects at and beneath the surface. It is assumed that the final cover system of the Lone Mountain Facility is categorized as having no appreciable canopy with a vegetated cover of grass, grass-like plants, decaying compacted duff or litter at least 2 inches deep. The ground cover is estimated to be 95-100%. As shown in Table F3-3 (USDA, 1977), this results in a value C = 0.003.

3.5 Erosion Control Practice Factor (P)

The erosion control practice factor considers topographical practices that will reduce erosion by altering runoff drainage patterns. This factor generally applies to agricultural cropping practices and is not anticipated for the landfill. Therefore, the P factor is assumed to be equal to one (P = 1).

4. SOIL EROSION LOSS RESULTS

Applying the RUSLE with the parameters defined above, the computed soil loss in tons/acre/year is calculated as follows:

$$A = R \times K \times LS \times C \times P$$

- Side Slopes, Actual Design Case:
  $A = 170 \times 0.43 \times 2.06 \times 0.003 \times 1 = 0.45$ tons/acre/year
- Bottom Side Slopes, Actual Design Case:
  $A = 170 \times 0.43 \times 3.19 \times 0.003 \times 1 = 0.70$ tons/acre/year

As shown above, the calculated soil loss from the final cover on the external side slopes as-designed (0.45 tons/acre/year) and bottom side slopes as designed (0.70 tons/acre/year) are less than the 2 tons/acre/year recommended in the EPA guidance document "Design and Construction of RCRA/CERCLA Final Covers" (1991). It is also noted that the above results demonstrate that a lower amount of vegetative ground coverage than assumed in this calculation package would still be predicted to result in acceptable long-term soil loss results. Calculations for other assumed ground coverage percentages were not within the scope of this analysis, but could be performed to evaluate the effect of a lower ground coverage assumption.

5. SUMMARY AND CONCLUSIONS

Based on the analyses presented herein, the calculated soil loss from the final cover system design is less than the permissible soil loss of 2 tons/acre/year and is considered acceptable.

Written by: **Hunter Douglas**	Date: **2/27/14**	Reviewed by: **S. Graves**	Date: **3/4/2014**
Client: **Clean Harbors**	Project: **Lone Mountain Facility**	Project No.: **TXL0380**	Phase No.: **04**

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TABLES

- Table F3-1. Soil Erodibility Factor K for Site Soils (from NRCS, 2014)
- Table F3-2. Values for Topographic Factor, LS, for Low Ratio of Rill to Interrill Erosion (from USDA, 1997)
- Table F3-3. C Factor Cover Values for Permanent Pasture, Rangeland, Idle Land, and Grazed Woodland (from USDA, 1977)

Table F3-1. Soil Erodibility Factor K for Site Soils (from NRCS, 2014)

RUSLE2 Related Attributes

Major County, Oklahoma

[This report shows only the major soils in each map unit]

Map symbol and soil name	Pct. of map unit	Hydrologic group	Kf	T factor	Representative value		
					% Sand	% Silt	% Clay
Cy:							
Beckman	100	D	.37	5	22.1	27.9	50.0
VcB:							
Vernon	100	D	.43	3	30.2	32.3	37.5
VnB:							
Knoco	65	D	.43	1	30.2	32.3	37.5
Badland	35	D	---	---	---	---	---

Table F3-2. Values for Topographic Factor, LS, for Low Ratio of Rill to Interrill Erosion[1] (from USDA, 1997)

Values for topographic factor, LS, for low ratio of rill to interrill erosion.[1]

Slope (%)	Horizontal slope length (ft) <3	6	9	12	15	25	50	75	100	150	200	250	300	400	600	800	1000
0.2	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
0.5	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.09
1.0	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.14	0.14	0.15	0.15	0.15	0.15	0.16	0.16	0.17	0.17
2.0	0.20	0.20	0.20	0.20	0.20	0.21	0.23	0.25	0.26	0.27	0.28	0.29	0.30	0.31	0.33	0.34	0.35
3.0	0.26	0.26	0.26	0.26	0.26	0.29	0.33	0.36	0.38	0.40	0.43	0.44	0.46	0.48	0.52	0.55	0.57
4.0	0.33	0.33	0.33	0.33	0.33	0.36	0.43	0.46	0.50	0.54	0.58	0.61	0.63	0.67	0.74	0.78	0.82
5.0	0.38	0.38	0.38	0.38	0.38	0.44	0.52	0.57	0.62	0.68	0.73	0.78	0.81	0.87	0.97	1.04	1.10
6.0	0.44	0.44	0.44	0.44	0.44	0.50	0.61	0.68	0.74	0.83	0.90	0.95	1.00	1.08	1.21	1.31	1.40
8.0	0.54	0.54	0.54	0.54	0.54	0.64	0.79	0.90	0.99	1.12	1.23	1.32	1.40	1.53	1.74	1.91	2.05
10.0	0.60	0.63	0.65	0.66	0.68	0.81	1.03	1.19	1.31	1.51	1.67	1.80	1.92	2.13	2.45	2.71	2.93
12.0	0.61	0.70	0.75	0.80	0.83	1.01	1.31	1.52	1.69	1.97	2.20	2.39	2.56	2.85	3.32	3.70	4.02
14.0	0.63	0.76	0.85	0.92	0.98	1.20	1.58	1.85	2.08	2.44	2.73	2.99	3.21	3.60	4.23	4.74	5.18
16.0	0.65	0.82	0.94	1.04	1.12	1.38	1.85	2.18	2.46	2.91	3.28	3.60	3.88	4.37	5.17	5.82	6.39
20.0	0.68	0.93	1.11	1.26	1.39	1.74	2.37	2.84	3.22	3.85	4.38	4.83	5.24	5.95	7.13	8.10	8.94
25.0	0.73	1.05	1.30	1.51	1.70	2.17	3.00	3.63	4.16	5.03	5.76	6.39	6.96	7.97	9.65	11.04	12.26
30.0	0.77	1.16	1.48	1.75	2.00	2.57	3.60	4.40	5.06	6.18	7.11	7.94	8.68	9.99	12.19	14.04	15.66
40.0	0.85	1.36	1.79	2.17	2.53	3.30	4.73	5.84	6.78	8.37	9.71	10.91	11.99	13.92	17.19	19.96	22.41
50.0	0.91	1.52	2.06	2.54	3.00	3.95	5.74	7.14	8.33	10.37	12.11	13.65	15.06	17.59	21.88	25.55	28.82
60.0	0.97	1.67	2.29	2.86	3.41	4.52	6.63	8.29	9.72	12.16	14.26	16.13	17.84	20.92	26.17	30.68	34.71

[1]Such as for rangeland and other consolidated soil conditions with cover (applicable to thawing soil where both interrill and rill erosion are significant).

Table F3-3. C Factor Cover Values for Permanent Pasture, Rangeland, Idle Land, and Grazed Woodland[1]
(from USDA, 1977)

Vegetal Canopy		Cover That Contacts the Surface						
Type and Height of Raised Canopy[2/]	Canopy Cover[3/] %	Type[4/]	Percent Ground Cover					
			0	20	40	60	80	95-100
No appreciable canopy		G	.45	.20	.10	.042	.013	.003
		W	.45	.24	.15	.090	.043	.011
Canopy of tall weeds or short brush (0.5 m fall ht.)	25	G	.36	.17	.09	.038	.012	.003
		W	.36	.20	.13	.082	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.075	.039	.011
	75	G	.17	.10	.06	.031	.011	.003
		W	.17	.12	.09	.067	.038	.011
Appreciable brush or bushes (2 m fall ht.)	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.085	.042	.011
	50	G	.34	.16	.085	.038	.012	.003
		W	.34	.19	.13	.081	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.077	.040	.011
Trees but no appreciable low brush (4 m fall ht.)	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.087	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.085	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.083	.041	.011

[1/] All values shown assume: (1) random distribution of mulch or vegetation, and (2) mulch of appreciable depth where it exists. Idle land refers to land with undisturbed profiles for at least a period of three consecutive years. Also to be used for burned forest land and forest land that has been harvested less than three years ago.

[2/] Average fall height of waterdrops from canopy to soil surface: m = meters.

[3/] Portion of total-area surface that would be hidden from view by canopy in a vertical projection, (a bird's-eye view).

[4/] G: Cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 inches deep.

W: Cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface), and/or undecayed residue.

FIGURES

- Figure F3-1. Average Annual Erosivity Factor, R, Isoerodent Map (from USDA, 1997)
- Figure F3-2. Soil Types in Vicinity of Site (from NRCS, 2014)

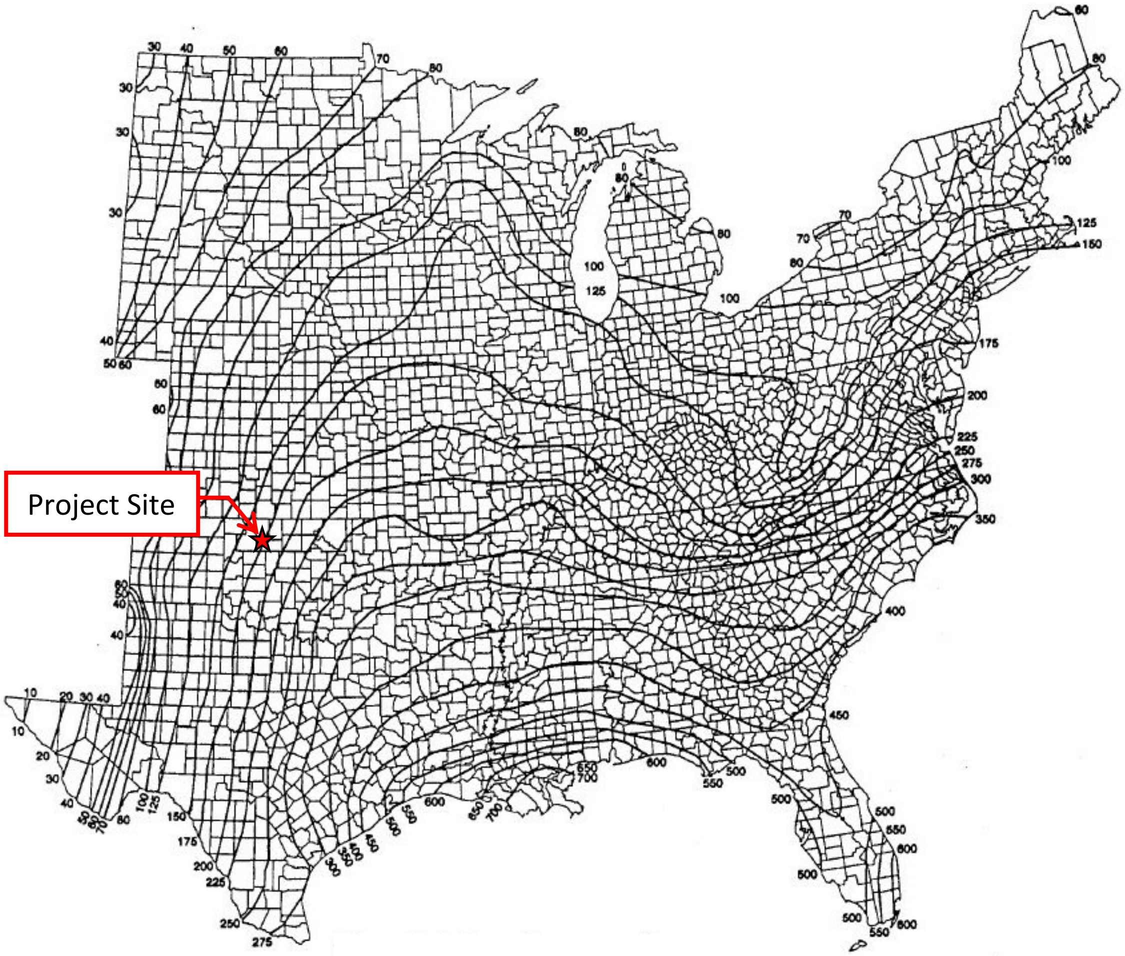

Figure F3-1. Average Annual Rainfall Runoff Erosivity Factor, R, Isoerodent Map (from USDA, 1997)

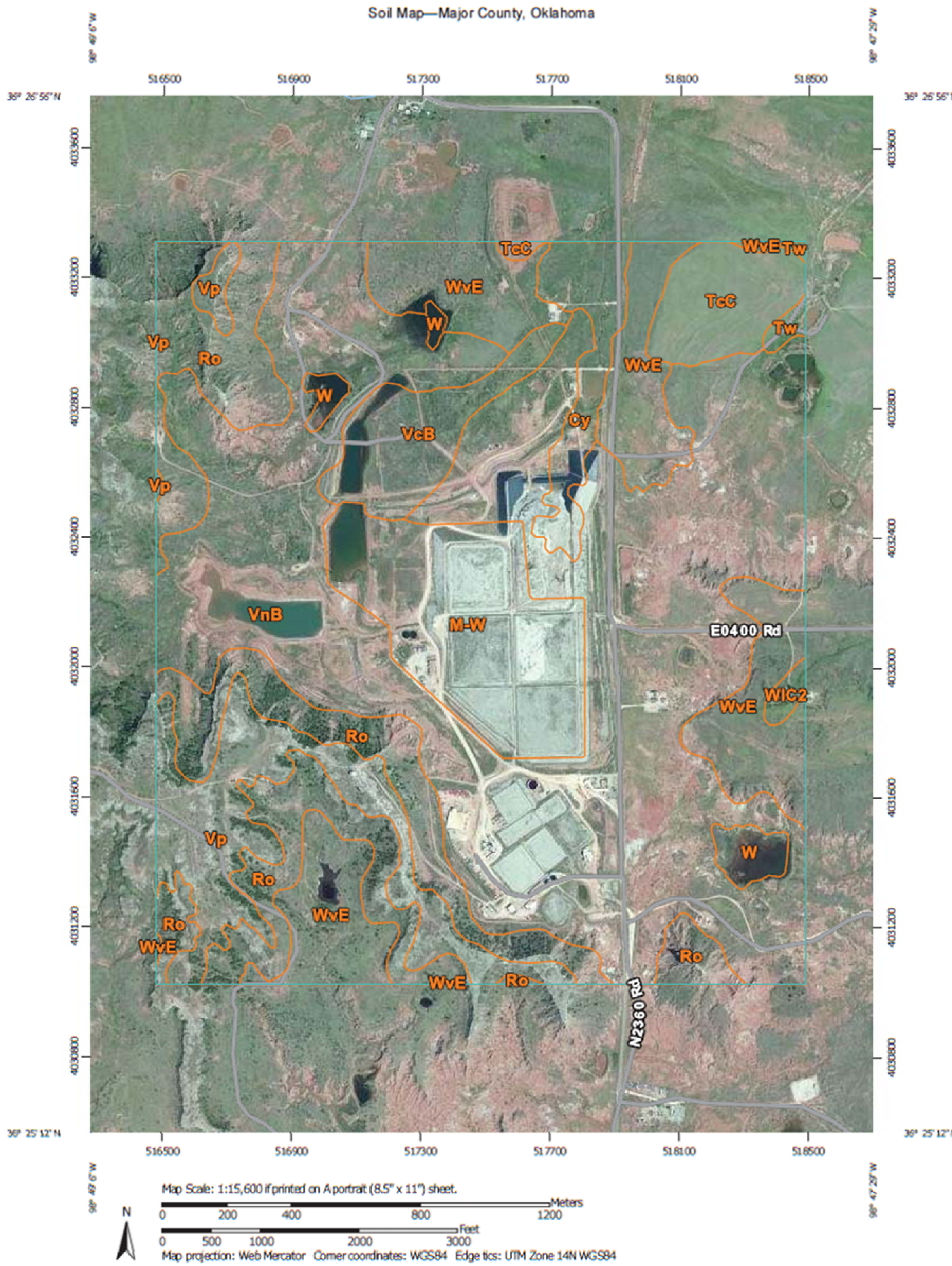

Figure F3-2. Soil Types in Vicinity of Site (from NRCS, 2014)

EXHIBIT G

CLOSURE PLAN

CLOSURE PLAN

LANDFILL CELL 15
LONE MOUNTAIN FACILITY

Prepared for:

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Route 2, Box 170
Waynoka, OK 73860-9622

Prepared by:

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6/13/2014

REGISTERED PROFESSIONAL ENGINEER
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June 2014

Geosyntec Consultants
Oklahoma Certificate of Authorization No. 1996
Exp. 06/30/2014

TABLE OF CONTENTS

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

6/13/2014

1. INTRODUCTION

1.1 Overview

This document presents the Closure Plan for Landfill Cell 15 at the Lone Mountain Facility, located near Waynoka, Major County, Oklahoma, in Section 28, T23N, R15W. Cell 15 is currently permitted and in operation as a Resource Conservation and Recovery Act (RCRA) Subtitle "C" landfill disposal cell, in accordance with Federal and State regulations including the design requirements of Code of Federal Regulations (CFR) 40 CFR 264 and Oklahoma Administrative Code (OAC) 252:205. In general, closure will involve the construction of a final cover system that minimizes infiltration of precipitation into the closed landfill area, minimizes erosion of the cover, promotes drainage, and functions with relatively low maintenance to promote protection of human health and the environment.

The remainder of this plan addresses the following:

- general information on the landfill;
- a final contour map of the proposed final cover grading plan and identifying the closure phases;
- description of closure performance standards;
- description of the final cover system design;
- method and procedures to install the final cover system and provide construction quality assurance (CQA);
- landfill closure sequence and schedule; and
- notification and certification requirements.

2. GENERAL INFORMATION

2.1 Waste Volume

The estimated maximum inventory of waste in Landfill Cell 15, using the calculated volume available for waste disposal, is 8,065,500 yd^3. Information on how this estimated waste volume was calculated is provided in the Landfill Cell 15 Engineering Report.

2.2 Final Contour Plan

A final contour plan, showing the proposed final cover grading plan, is attached at the end of this report as Figure 1. It is noted that additional information on the layout and design of the surface water management features is provided on the Engineering Drawings in Exhibit A of the Landfill Cell 15 Engineering Report.

2.3 Closure Phases and Areas

Landfill Cell 15, once fully developed, will have a plan area of 95.0 acres based on the limit of liner. Since the final cover system will extend slightly beyond the limit of liner (per the perimeter details on the Engineering Drawings in Exhibit A of the Landfill Cell 15 Engineering Report), the final cover system area is larger, with a plan area of 97.3 acres. Closure of the Landfill Cell 15 (i.e., installation of the final cover system) will be performed incrementally as landfill areas reach final grade, as discussed further in Section 5.1 of this Closure Plan. Figure 1 of this Closure Plan shows the locations of the sequential phases of closure. The plan areas of the sequences of closure are tabulated below.

TABLE 1
AREAS OF SEQUENTIAL CLOSURE PHASES

Closure Phase No.	**Plan Area** (acres)
1	7.6
2	3.3
3	11.3
4	11.9
5	10.6
6	14.8
7	12.1
8	13.2
9	12.5

3. FINAL COVER SYSTEM DESIGN

3.1 Closure Performance Standards

The general closure performance standard for hazardous waste management facilities is specified in the RCRA regulations, and requires that the facility owner/operator must close the facility in a manner which:

- Minimizes the need for further maintenance; and
- Controls, minimizes or eliminates, to the extent necessary to protect human health and the environment, post-closure escape of hazardous waste, hazardous waste constituents, leachate, contaminated rainfall, or waste decomposition products to the ground water, or surface waters, or to the atmosphere.

The Landfill Cell 15 engineering design of the final cover system and associated components and features has been performed by Geosyntec Consultants (Geosyntec) to meet the closure requirements of ODEQ and the USEPA's 40 CFR §264.310. The closure design performed by Geosyntec Consultants meets the following performance criteria:

- Provide Long term minimization of migration of liquids through the closed landfill;
- Function with minimum 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 barrier layer with permeability less than or equal to the permeability of any bottom liner system.

Geosyntec's design analyses and evaluations demonstrating that these criteria are met are presented in the Landfill Cell 15 Engineering Report.

3.2 Final Cover System Description

The Landfill Cell 15 final cover system will be composed of (from bottom to top):

- 12-in. thick interim cover clay (bedding clay);
- geosynthetic clay liner (GCL);
- 60-mil HDPE textured geomembrane;
- double-sided geocomposite drainage layer;
- 1.5-ft thick protective cover soil layer;
- 6-in. thick topsoil; and
- grassy vegetation (on 10% slopes), and grassy vegetation or rip rap (on 3H:1V final cover slopes).

Typical cross sections are provided in Engineering Drawings in Exhibit A of the Landfill Cell 15 Engineering Report. Geosyntec's Engineering Report and attached Exhibits include the engineering analyses necessary for design of the final cover system components. The analyses include evaluation of slope stability of the final cover system, cap infiltration/leachate generation after final cover system installation, drainage layer design, erosion (soil loss) evaluation, and storm water management calculations and layout/sizing of features. Material specifications and CQA requirements are provided in the Landfill Cell 15 CQA Plan in Exhibit H of the Engineering Report.

4. FINAL COVER SYSTEM INSTALLATION

4.1 Pre-Final Cover Construction Preparation of the Waste Mound

As noted previously, the final cover system will be installed incrementally, in phases. In each area of Cell 15, the top of waste will be brought to final grades by landfill operations prior to final cover system construction of that phase. The final surface of waste will be free of sharp objects and debris in order to protect the overlying GCL and HDPE liner from accidental puncture. The cell will be progressively shaped and contoured to conform to the Top of Final Waste Grading Plan presented on Drawing 8 of the Engineering Drawings in Exhibit A of the Landfill Cell 15 Engineering Report. As shown on this drawing and Detail 6 on Drawing 15, the cap will be graded with a small length of 3 horizontal to 1 vertical (3H:1V) slope around the perimeter, with most of the cap sloped at 10 percent to form a “triangular prism” configuration. This contouring of the waste should reduce the subsequent need for additional fill material, facilitate grading of the cap, and reduce the possible effects of settlement and formation of depressions that could pond water.

When waste reaches its final grades, a 1-ft thick interim cover clay layer and interim erosion control features will be installed on top of the waste surface by landfill operations. These interim features will cover the waste and allow storm water runoff to be managed as uncontaminated water.

4.2 Interim Cover Clay (Bedding Clay)

As noted, the bottom layer of the final cover system is a 1-ft thick layer of interim cover clay, also referred to as bedding clay. This layer will act as a buffer between the waste and the GCL, to help prevent damage due to accidental puncture. It is envisioned that this layer will be placed by landfill operations since it will likely be constructed in advance of final cover system installation. Then, as part of final cover system construction (just prior to the overlying GCL installation), the upper 6-inches of the bedding clay layer will be re-worked and re-compacted in order to prepare the surface for geosynthetics installation. The material, installation, and CQA requirements of the interim cover clay (bedding clay) layer are set forth in the Landfill Cell 15 CQA Plan.

4.3 Geosynthetic Clay Liner (GCL)

Upon satisfactory completion of preparation of the bedding clay surface, the GCL component of the final cover system will be installed. Placement of the GCL will be initiated and will progress such that runoff from the closure cap and from the adjacent waste material will be away from the GCL. The HDPE liner will immediately be placed above the GCL to prevent moisture resulting from precipitation from coming into contact with the GCL and potentially causing premature hydration. At the toe of the slope around the perimeter, where the final cover system terminates, the GCL shall be placed into a final cover system anchor trench, located just outside of the liner system anchor trench, as shown on the engineering details in Exhibit A of the Engineering

Report. The material, installation, and CQA requirements of the GCL are set forth in the Landfill Cell 15 CQA Plan.

4.4 HDPE Geomembrane

Upon completion of the GCL, a 60-mil HDPE geomembrane will be installed above the GCL to form a composite barrier. The HDPE geomembrane in conjunction with the underlying GCL will provide for the long-term minimization of liquid migration through the closed cell. At the toe of the slope around the perimeter, where the final cover system terminates, the HDPE geomembrane shall be placed into a final cover system anchor trench, located just outside of the liner system anchor trench, as shown on the engineering details in Exhibit A of the Engineering Report. The material, installation, and CQA requirements of the HDPE geomembrane are set forth in the Landfill Cell 15 CQA Plan.

4.5 Geocomposite Drainage Layer

A double-sided geocomposite drainage layer will be installed above the HDPE geomembrane to function as a lateral drainage media for water that infiltrates into the overlying soil cover. The geonet component will transmit the collected flow, and the filter fabric (geotextile) component is present to prevent clogging of the geonet by the overlying soil. At the toe of the slope around the perimeter, where the final cover system terminates, the geocomposite drainage layer will not be placed into the final cover system anchor trench, but rather will “daylight” (i.e., extend through the soil cover at the toe of the slope of the cap to allow discharge from the drainage net to drain freely. The material, installation, and CQA requirements of the geocomposite drainage layer are set forth in the Landfill Cell 15 CQA Plan.

4.6 Protective Cover Soil

A 1.5-ft thick protective cover soil layer will be placed over the drainage layer. This layer will provide protection of the underlying GCL from freeze/thaw, and will also provide a buffer layer that protects the underlying final cover system components from erosion and biological intrusion. This layer will be placed using low ground pressure equipment to prevent damage to the underlying geosynthetics. In conjunction with installation of this layer, the final drainage features (drainage berms and channels) that are “tacked-on” (i.e. added above) the protective cover soil, will be constructed out of compacted soil. The material, installation, and CQA requirements of the protective cover soil layer are set forth in the Landfill Cell 15 CQA Plan.

4.7 Topsoil and Vegetation (on 10% Slopes) and Vegetation or Riprap (on 3H:1V Slopes)

The final component of the final cover system is a 6-inch thick topsoil layer, which will be placed above the protective cover soil layer and also over the earthen drainage features, to promote the establishment of and to sustain grassy vegetation. Upon completion of placement, the topsoil will be seeded or sodded (unless riprap is to be placed as discussed below). Temporary erosion and sediment controls (e.g., silt fence, check dams, hay bales, etc.) will also be installed and maintained while the permanent vegetation is being established. On the 3H:1V portions of the final cover sideslopes (which are minor areas around the cap perimeter), the vegetation may be substituted with a 6-inch thick layer of Type V riprap. The material, installation, and CQA requirements of the topsoil layer, seeding/sodding, and riprap are set forth in the Landfill Cell 15 CQA Plan.

It is also noted that the ancillary permanent drainage features (i.e., drainage berms, down-channels, turf-reinforcement mat channel lining, manholes, downspout pipes, and culverts) will be constructed as part of the end of final cover system construction.

5. CLOSURE SEQUENCE, SCHEDULE, AND NOTIFICATIONS

5.1 Closure Sequence

As discussed in the Landfill Cell 15 Engineering Report, waste filling will take place incrementally, and as it progresses, areas of Cell 15 will progressively be filled to reach their final waste grades over time. Accordingly, closure through construction of the final cover system will also occur incrementally in phases, as portions of the landfill reach final waste grades. The sequential phases of Cell 15 closure are shown on Figure 1 of this Closure Plan.

Regarding the phases shown on Figure 1, it is noted that to-date, waste grades corresponding roughly to the Subcells 1 through 3 areas have reached final grades and the final cover system over these subcells has been installed (i.e. Closure Phase 1 and 2 as shown on Figure 1 have been completed). With respect to future final cover system capping events, as the eastern portion of the landfill is filled, filling to final waste grades will progress westward and then southward, with the area in the southwest corner of Cell 15 (overlying Subcell 22) being the last area to reach final waste grades. Therefore, it is anticipated that incremental construction of the final cover system will continue to follow this pattern, with the next phase being Closure Phase 3 (see Figure 1). It is noted that the closure areas for each phase are those currently anticipated, and may be increased or decreased based on market demand, with prior approval from ODEQ.

For each phase of closure, the final cover system will be installed in accordance with the construction activities and requirements described previously in Section 4 of this Closure Plan.

5.2 Closure Schedule and Notifications

The following schedule will be followed for each phase of closure for Cell 15:

- A “*Notice of Intent to Close"* will be sent to the Oklahoma Department of Environmental Quality (ODEQ) at least 60 days prior to the date that the start of the phase of Cell 15 closure construction is anticipated to begin. This notice will be accompanied by a copy of the closure schedule and construction plans and will indicate the date closure activities are expected to commence. The notice will specify the portion of Cell 15 to be closed and the anticipated closure date of that portion.
- Applicable construction plans will accompany the Notice of Intent to Close, and the notice will indicate whether a modification is being requested. If a modification is being requested or the plans deviate from those previously approved, the phase of closure will not be implemented until approval by ODEQ or other authorized agencies has been received.
- Final cover system construction will then commence after the required notices have been made and any approvals have been received. The estimated time for construction of a typical phase of closure project for Cell 15 is on the order of 6 months, depending on the acreage to be capped, season, and weather conditions.

- For the last phase of Cell 15 closure, the facility will begin final closure activities no later than 90 days after the unit receives the final volume of hazardous wastes or within 90 days of agency approval of plans/modifications. It is planned that final closure activities will be completed within 180 days following initiation of said activities. In the event of extenuating circumstances such as adverse weather conditions or relatively large areas to be final closed, it may not be feasible to complete final closure within 180 days; if this happens the facility will inform ODEQ and request a time extension in accordance with extended closure times allowed by 40 CFR §264.113(b)(1)(i), as soon as it is apparent that more time is needed to complete the last phase of Cell 15 closure.
- Within 60 days of completion of each phase of Cell 15 closure, the Lone Mountain Facility will submit the certification of that phase of closure to the ODEQ. This certification by a registered professional engineer will contain the information identified in Section 6 of this Closure Plan, and will attest that the portion of Cell 15 that was closed was completed in accordance with the required Closure Plan and applicable CQA Plan and specifications.

6. CLOSURE CERTIFICATION AND SUBMITTAL REQUIREMENTS

6.1 Closure Certification

For each phase of closure, the facility will submit a certification report documenting construction of the final cover in accordance with this Closure Plan and applicable requirements referenced herein, within 60 days of completion of closure. This certification by a registered professional engineer will attest that the portion of Cell 15 that was closed was completed in accordance with the required Closure Plan and applicable CQA Plan and specifications. The certification report will contain the results of the construction quality control and quality assurance observations and tests specified by the CQA Plan. The certification report will, at a minimum, contain the following engineering plans and test results:

- Scaled as-built record drawings showing the final top of interim cover clay surface and top of final cover (topsoil layer), which accurately depict the area boundaries and dimensions of the cover; surrounding natural ground surface elevations; minimum, maximum, and representative elevations and final cover layer thicknesses, extent, and materials of component parts of the cover system.
- For the GCL and soil components of the final cover system, all tests required and at the frequency specified in accordance with the CQA Plan.
- For the HDPE geomembrane, all tests required as specified in the CQA Plan including manufacturer quality control (MQC) testing, conformance testing, destructive and non-destructive testing, panel placement, calibration certificates, pre-weld trial test logs and as-built panel layout record drawing.

6.2 Final Facility Closure Survey Plat

For the final closure of the entire Lone Mountain Facility, no later than the submission date of the certification of final facility closure, the facility will submit to the ODEQ and to the Major County Land Office, a survey plat prepared by a professional land surveyor indicating the location and dimensions of landfill cells and other permanent structures with respect to permanently surveyed benchmarks. The plat will include an attachment, which states the facility's obligation to prevent disturbance of the facility. A record of the type, location, and quantity of wastes disposed within each cell will be submitted to the agencies. The facility will record a notation on the property deed indicating that the facility has been used to dispose of hazardous wastes, and that land usage is restricted to activities that will not disturb the wastes.

FIGURE 1

TOP OF FINAL COVER - PHASED CLOSURE PLAN
LANDFILL CELL 15 LATERAL EXPANSION
LONE MOUNTAIN FACILITY

N

LEGEND

1400	EXISTING GROUND ELEVATION (FEET) (NOTE 1)
	EXISTING ROAD
	EXISTING FENCE
E 8000 N 15000	STATE PLANE COORDINATES (NOTE 2)
	PROPERTY BOUNDARY
1400	PROPOSED TOP OF FINAL COVER ELEVATION (FEET) (NOTE 3)

0 200' 400'
SCALE IN FEET

NOTES:

1. THE TOPOGRAPHIC BASE MAP SHOWN WAS COMPILED USING AN AERIAL SURVEY DATED 2013 PROVIDED BY JIVIDENS LAND SURVEY CO., INC. ELEVATIONS ARE IN FEET ABOVE MEAN SEA LEVEL (MSL).
2. HORIZONTAL COORDINATE VALUES BASED ON A LOCAL COORDINATE SYSTEM ESTABLISHED FOR THIS FACILITY, CONSISTENT WITH PREVIOUS PERMIT AND CONSTRUCTION SUBMITTALS.
3. TOP OF FINAL COVER ELEVATIONS REFER TO PROPOSED FINISHED GRADE (TOP OF THE TOPSOIL COMPONENT OF FINAL COVER SYSTEM).
4. CLOSURE AREAS FOR EACH PHASE MAY BE INCREASED OR DECREASED BASED ON MARKET DEMAND WITH PRIOR APPROVAL FROM ODEQ.

Geosyntec consultants

AUSTIN, TX

DATE:	JUNE 2014	SCALE:	1" = 400'
PROJECT NO.	TXL0380	FILE NO.	TXL038004-FIG1
DOCUMENT NO.		FIGURE NO.	1

P:\CADD\PROJECTS\L\LONE MOUNTAIN FACILITY\PERMIT\EXPANSION APP MOD CELL 15 WEST - TXL0380\FIGURES\TXL038004-FIG1

REVISED CLOSURE COST ESTIMATE

Table 1A
Closure Cost Summary Table

Item	Cell 15, Phase 1	Cell 15, Phase 2	Cell 15, Phase 3	Cell 15, Phase 4	Cell 15, Phase 5	Cell 15, Phase 6	Cell 15, Phase 7	Cell 15, Phase 8	Cell 15, Phase 9	WWTS	Stabilization Tank System	Drum Dock	Container Management Bldg	Roadway & Equipment Decontamination
Waste Inventory Management	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 561,150.95	$ 8,650.55	$ 1,790.12	$ 13,407.74	$ 5,088.89
Waste Grading	$ 125,000.00	$ 125,000.00	$ 125,000.00	$ 125,000.00	$ 125,000.00	$ 125,000.00	$ 125,000.00	$ 125,000.00	$ 125,000.00	$ -	$ -	$ -	$ -	$ -
Earthwork	$ 625,705.31	$ 257,099.31	$ 771,643.86	$ 867,363.95	$ 722,322.21	$ 1,054,804.64	$ 816,189.38	$ 931,760.58	$ 967,358.97	$ -	$ -	$ -	$ -	$ -
Geosynthetics	$ 591,547.31	$ 265,664.50	$ 883,494.79	$ 934,487.45	$ 838,337.32	$ 1,158,243.77	$ 949,234.79	$ 1,031,156.42	$ 981,059.34	$ -	$ -	$ -	$ -	$ -
Tank Decontamination	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 128,321.03	$ 7,773.32	$ -	$ -	$ -
Concrete Decontamination	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 29,154.60	$ 6,675.09	$ 4,738.84	$ 23,535.14	$ -
Roadway Decontamination	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,800.00
Equipment Decontamination	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 3,685.71
Labor Cost	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 53,153.33	$ 17,792.00	$ 9,723.20	$ 48,289.60	$ -
Laboratory/Analytical Cost	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 6,080.00	$ 6,080.00	$ 6,080.00	$ 6,080.00	$ -
Project Management	$ 191,934.73	$ 87,039.14	$ 275,249.43	$ 293,317.13	$ 259,958.53	$ 361,593.37	$ 293,477.07	$ 321,678.77	$ 310,717.10	$ -	$ -	$ -	$ -	$ -
Closure Certification	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 4,510.00	$ 4,510.00	$ 4,510.00	$ 4,510.00	$ -
Closure Cost Subtotals	**$ -**	**$ -**	**$ 2,055,388.08**	**$ 2,220,168.54**	**$ 1,945,618.05**	**$ 2,699,641.77**	**$ 2,183,901.24**	**$ 2,409,595.77**	**$ 2,384,135.41**	**$ 782,369.91**	**$ 51,480.96**	**$ 26,842.17**	**$ 95,822.49**	**$ 13,574.60**

SUBTOTAL CLOSURE COST FOR THE FACILITY: $ 16,868,538.98
20% CONTINGENCY: $ 3,373,707.80
TOTAL CLOSURE COST FOR THE FACILITY[(1)]: $ 20,242,246.78

[(1)] Total closure cost for the facility is the sum of the closure cost subtotals on this table plus an overall assumed contingency. Because not all subcells of Cell 15 are currently constructed, and because Cell 15 will be closed in phases, the total is not representative of the financial assurance amount required. Refer to Table 1B for a breakdown of closure costs as Cell 15 is developed in subcells.

Table 1B
Facility Closure Costs Expressed On A Cell 15 Subcell Basis, for Financial Assurance Guidance(1)

Estimated Closure Costs - Remainder of Cell 15 (Phases 3 through 9):	$	15,898,448.86
Remaining Plan Area of Cell 15 Final Cap (Acres):		86.42
Unit Cost of Cell 15 Final Capping ($ per Acre basis):	$	183,967.24

Closure Costs of Currently-Existing(2) Features

Item	Plan Area of Final Cap (Acres)	Unit Cost of Final Capping ($/Acre)	Subtotal Closure Cost	20% Contingency	Total Closure Cost
WWTS	N/A	N/A	$ 782,369.91	$ 156,473.98	$ 938,843.89
Stabilization Tank System	N/A	N/A	$ 51,480.96	$ 10,296.19	$ 61,777.15
Drum Dock	N/A	N/A	$ 26,842.17	$ 5,368.43	$ 32,210.60
Container Mgmt Bldg	N/A	N/A	$ 95,822.49	$ 19,164.50	$ 114,986.98
Equipment Decontamination	N/A	N/A	$ 13,574.60	$ 2,714.92	$ 16,289.52
Subcells 1 through 4 (3)	10.5	$0	$ -	$ -	$ -
Subcells 5 through 11	35.3	$183,967	$ 6,491,816.59	$ 1,298,363.32	$ 7,790,179.91
Totals			**$ 7,461,906.71**	**$ 1,492,381.34**	**$ 8,954,288.05**

Closure Costs of Yet-to-be-Constructed(2) Cell 15 Subcells

Item	Plan Area of Final Cap (Acres)	Unit Cost of Final Capping ($/Acre)	Subtotal Closure Cost	20% Contingency	Total Closure Cost
Subcell 12	4.7	$183,967	$ 856,319.09	$ 171,263.82	$ 1,027,582.91
Subcell 13	3.7	$183,967	$ 688,908.90	$ 137,781.78	$ 826,690.68
Subcell 14	5.9	$183,967	$ 1,082,598.79	$ 216,519.76	$ 1,299,118.55
Subcell 15	6.0	$183,967	$ 1,100,995.52	$ 220,199.10	$ 1,321,194.62
Subcell 16	4.9	$183,967	$ 902,310.90	$ 180,462.18	$ 1,082,773.08
Subcell 17	4.9	$183,967	$ 909,669.59	$ 181,933.92	$ 1,091,603.51
Subcell 18	4.3	$183,967	$ 791,930.55	$ 158,386.11	$ 950,316.67
Subcell 19	4.3	$183,967	$ 791,930.55	$ 158,386.11	$ 950,316.67
Subcell 20	4.3	$183,967	$ 791,930.55	$ 158,386.11	$ 950,316.67
Subcell 21	4.3	$183,967	$ 791,930.55	$ 158,386.11	$ 950,316.67
Subcell 22	3.8	$183,967	$ 698,107.26	$ 139,621.45	$ 837,728.71
Totals			**$ 9,406,632.27**	**$ 1,881,326.45**	**$ 11,287,958.72**

Math Check, Combined Total (should match Table 1A Total Closure Cost for Facility): $ 20,242,246.78

(1) The purpose of Table 1B is to present a breakdown of costs that would be required for the closure of the currently-existing features, as well as for each subsequent feature (Cell 15 subcell) that is constructed. This can be used as guidance for calculation of Facility Closure Financial Assurance amounts at different points in time as Landfill Cell 15 is developed in phased subcells. For example, at the time of this submittal, financial assurance would need to be provided for closure of only the currently-existing features. As additional subcells are constructed, the cost of closing those subcells should be added to the total. Similarly, any features that are closed will be deducted from the total (i.e., as incremental capping occurs in phases).

(2) Currently-existing and yet-to-be-constructed features are based on their status as of the date of submittal of this cost estimate.

(3) Subcells 1 through 3 have been closed as part of Closure Phases 1 and 2 dated October 2012 and May 2014, respectively.

Table 2
Closure Cost Estimate Rate Schedule

Item		Rates	Units	Comments
Landfill Earthwork Unit Rates				
(from Apr 2012 Price Quote for Phase 1 Closure provided by earthwork contractor Fretco, Inc., unless otherwise specified)				
Waste Grading	$	75,000.00	lump sum	(per phase/project), rate is from Feb 2011 quote
Surveying	$	50,000.00	lump sum	(per phase/project)
Mob/Demob	$	20,000.00	lump sum	(per phase/project)
Drainage Berm Construction	$	10.00	cu.yd	
Unclassified Soil/Structural Fill Soil	$	6.40	cu. yd	Rate is from Feb 2011 Quote
Anchor Trench Excavation & Backfill	$	20.00	linear foot	
Construct 1' Interim Clay Cover	$	7.50	cu. yd	
Prepare Interim Clay Bedding Soil Surface	$	0.20	square foot	(preparing top 6-inches of existing interim cover soil), rate is from Feb 2011 quote
Soil Protective Cover	$	10.00	cu. yd	
Topsoil	$	6.00	cu. yd	
Seeding	$	6,400.00	acre	(for seed, mulch, and fertilizer)
Rip Rap	$	100.00	cu. yd	(installed cost of rip rap) rate is from Jan 2014 quote
Settlement Monument	$	200.00	each	Rate is from Feb 2011 quote
18" HDPE Pipe	$	35.00	linear foot	
Unload Geosynthetics	$	10,000.00	lump sum	(per phase/project)
Concrete Inlets	$	6,000.00	each	
Landfill Geosynthetics Unit Rates				
(from Apr 2012 Price Quote for Phase 1 Closure provided by geosynthetics installer Texas Environmental Plastics, Inc.)				
60 mil HDPE Material	$	0.419	square foot	Rate includes 4.75% sales tax.
60 mil HDPE Installation	$	0.110	square foot	
GCL Material	$	0.456	square foot	Rate includes 4.75% sales tax.
GCL Installation	$	0.090	square foot	
Double-Sided Geocomposite Material	$	0.403	square foot	Rate includes 4.75% sales tax.
Double-Sided Geocomposite Installation	$	0.087	square foot	
Mob/demob	$	5,500.00	lump sum	(per phase/project)
Extrusion Weld (LinerTie-in)	$	5.50	linear foot	
Landfill Project Management Unit Rates				
(based on cost of Phase 1 Closure in 2012 as provided by Envirotech Engineering and Consulting, Inc.)				
Project Management	$	5,943.91	acre	
Quality Control	$	7,099.67	acre	
Quality Assurance	$	3,467.28	acre	
Design/Bid Documents		5%	percentage	Percentage of total project cost
Waste Management Unit Rates				
Stablization Cost (Lone Mtn current cost)	$	0.96	per gallon	
Off-site Deep Well Injection T&D	$	0.72	per gallon	Rate only applicable for WWTS Closure
Landfilling cost (load & transport to landfill)	$	2.29	cu. yd	
Waste Water Treatment Cost	$	0.394	per gallon	Rates applicable for Stabilization Tank, Drum Dock & ContainerMngmt Bldg Closure
Off-site cement kiln disposal for fuel	$	0.25	per gallon	
Decontamination Costs				
Steam Clean Tank Interior in Level B PPE	$	2.82	square foot	
Steam Clean Tank Interior in Level C PPE	$	0.57	square foot	
Pressure wash concrete secondary containment				
Earthmoving Equipment Decon Cost	$	175.51	each	
Earthmoving Equipment Costs				
CAT Motor Grader	$	40.00	hour	
Loader - 3 yd bucket	$	39.00	hour	
Dump Truck - 10 yd dump bed	$	26.00	hour	
Laboratory Analytical Costs				
Rinsate samples analysis -liquid	$	360.00	each	
Soil samples analysis	$	1,340.00	each	
Labor Rates				
Laborer	$	15.00	per hour	
Professional Engineer	$	74.00	per hour	
Staff Engineer	$	57.00	per hour	
Clerical Administrative	$	25.00	per hour	

Table 3
Closure Cost Estimate for Cell 15 Phase 1

Area to be Final Capped: 7.56 Acres (Phase 1 Closure is Complete)

Item	Item Description	Unit	Quantity	Rates	Total Cost
1.0	**Waste Grading (Quotes Received from Fretco, Inc.)**				
1.1	Grade Preparation	lump sum	1	$ 75,000.00	$ 75,000.00
1.2	Surveying	lump sum	1	$ 50,000.00	$ 50,000.00
1.3	**Total Waste Grading Cost**				**$ 125,000.00**
2.0	**Earthwork (Quotes Received from Fretco, Inc.)**				
2.1	Mob/Demob	lump sum	1	$ 20,000.00	$ 20,000.00
2.2	Perimeter Anchor Trench and Backfill	linear foot	1,630	$ 20.00	$ 32,600.00
2.3	Construct 1-ft thick Interim Clay Cover	cu. yd	12,197	$ 7.50	$ 91,476.00
2.4	Prepare Interim Clay Bedding Soil Surface	square foot	329,314	$ 0.20	$ 65,862.72
2.5	1.5-ft thick Soil Protective Cover	cu. yd	18,295	$ 10.00	$ 182,952.00
2.6	0.5-ft thick Topsoil	cu. yd	6,098	$ 6.00	$ 36,590.40
2.7	Drainage Berm Construction	cu. yd	1,310	$ 10.00	$ 13,100.00
2.8	Seeding	acre	7.6	$ 6,400.00	$ 48,384.00
2.9	Rip Rap	cu. yd	925.7	$ 100.00	$ 92,565.19
2.10	18" HDPE Downspout Pipe	linear foot	405	$ 35.00	$ 14,175.00
2.11	Concrete Drop Inlets	each	3	$ 6,000.00	$ 18,000.00
2.12	Unload Geosynthetics	lump sum	1	$ 10,000.00	$ 10,000.00
2.13	**Total Earthwork Cost**				**$ 625,705.31**
3.0	**Geosynthetics (Quotes Received from Texas Environmental Plastics, Inc.)**				
3.1	60 mil Textured HDPE - Material	square foot	378,711	$ 0.419	$ 158,679.76
3.2	60 mil Textured HDPE - Installation	square foot	355,659	$ 0.110	$ 39,122.46
3.3	GCL - Material	square foot	378,711	$ 0.456	$ 172,564.24
3.4	GCL - Installation	square foot	355,659	$ 0.090	$ 32,009.28
3.5	Double-Sided Geocomposite - Material	square foot	378,711	$ 0.403	$ 152,729.27
3.6	Double-Sided Geocomposite - Installation	square foot	355,659	$ 0.087	$ 30,942.31
3.7	Mob/demob	linear foot	1	$ 5,500.00	$ 5,500.00
3.8	Extrusion Weld (Liner Tie-in)	linear foot	0	$ 5.50	$ -
3.9	**Total Geoysnthetics Cost**				**$ 591,547.31**
3.0	**Total Construction Cost (1.3 + 2.13 + 3.9)**				**$ 1,342,252.61**
4.0	**Project Management (from Envirotech for Items 4.1, 4.2, & 4.3)**				
4.1	Project Management	acre	7.56	$ 5,943.91	$ 44,935.96
4.2	Quality Control and Quality Assurance	acre	7.56	$ 7,099.67	$ 53,673.50
4.3	Quality Assurance - see Item 4.2	acre	7.56	$ 3,467.28	$ 26,212.64
4.4	Design/Bid Documents	%	$ 1,342,252.61	5%	$ 67,112.63
4.5	**Total Project Management Cost**				**$ 191,934.73**
5.0	**Total Closure Cost (3.0 + 4.5)**				**$ 1,534,187.34**

Note: Geosynthetics material quantities inflated by 15% to account for overlaps and waste. Installation quantities inflated by 8% for field additions and differences.

Table 4
Closure Cost Estimate for Cell 15 Phase 2

Area to be Final Capped: 3.31 Acres (Phase 2 Closure is Near Complete)

Item	Item Description	Unit	Quantity	Rates	Total Cost
1.0	**Waste Grading (Quotes Received from Fretco, Inc.)**				
1.1	Grade Preparation	lump sum	1	$ 75,000.00	$ 75,000.00
1.2	Surveying	lump sum	1	$ 50,000.00	$ 50,000.00
1.3	**Total Waste Grading Cost**				**$ 125,000.00**
2.0	**Earthwork (Quotes Received from Fretco, Inc.)**				
2.1	Mob/Demob	lump sum	1	$ 20,000.00	$ 20,000.00
2.2	Perimeter Anchor Trench and Backfill	linear foot	460	$ 20.00	$ 9,200.00
2.3	Construct 1-ft thick Interim Clay Cover	cu. yd	5,340	$ 7.50	$ 40,051.00
2.4	Prepare Interim Clay Bedding Soil Surface	square foot	144,184	$ 0.20	$ 28,836.72
2.5	1.5-ft thick Soil Protective Cover	cu. yd	8,010	$ 10.00	$ 80,102.00
2.6	0.5-ft thick Topsoil	cu. yd	2,670	$ 6.00	$ 16,020.40
2.7	Drainage Berm Construction	cu. yd	410	$ 10.00	$ 4,100.00
2.8	Seeding	acre	3.3	$ 6,400.00	$ 21,184.00
2.9	Rip Rap	cu. yd	276.1	$ 100.00	$ 27,605.19
2.10	18" HDPE Downspout Pipe	linear foot	0	$ 35.00	$ -
2.11	Concrete Drop Inlets	each	0	$ 6,000.00	$ -
2.12	Unload Geosynthetics	lump sum	1	$ 10,000.00	$ 10,000.00
2.13	**Total Earthwork Cost**				**$ 257,099.31**
3.0	**Geosynthetics (Quotes Received from Texas Environmental Plastics, Inc.)**				
3.1	60 mil Textured HDPE - Material	square foot	165,811	$ 0.419	$ 69,474.87
3.2	60 mil Textured HDPE - Installation	square foot	155,718	$ 0.110	$ 17,129.01
3.3	GCL - Material	square foot	165,811	$ 0.456	$ 75,553.92
3.4	GCL - Installation	square foot	155,718	$ 0.090	$ 14,014.65
3.5	Double-Sided Geocomposite - Material	square foot	165,811	$ 0.403	$ 66,869.56
3.6	Double-Sided Geocomposite - Installation	square foot	155,718	$ 0.087	$ 13,547.49
3.7	Mob/demob	linear foot	1	$ 5,500.00	$ 5,500.00
3.8	Extrusion Weld (Liner Tie-in)	linear foot	650	$ 5.50	$ 3,575.00
3.9	**Total Geoysnthetics Cost**				**$ 265,664.50**
3.0	**Total Construction Cost (1.3 + 2.13 + 3.9)**				**$ 647,763.80**
4.0	**Project Management (from Envirotech for Items 4.1, 4.2, & 4.3)**				
4.1	Project Management	acre	3.31	$ 5,943.91	$ 19,674.34
4.2	Quality Control and Quality Assurance	acre	3.31	$ 7,099.67	$ 23,499.91
4.3	Quality Assurance - see Item 4.2	acre	3.31	$ 3,467.28	$ 11,476.70
4.4	Design/Bid Documents	%	$ 647,763.80	5%	$ 32,388.19
4.5	**Total Project Management Cost**				**$ 87,039.14**
5.0	**Total Closure Cost (3.0 + 4.5)**				**$ 734,802.94**

Note: Geosynthetics material quantities inflated by 15% to account for overlaps and waste. Installation quantities inflated by 8% for field additions and differences.

Table 5
Closure Cost Estimate for Cell 15 Phase 3

Area to be Final Capped: 11.28 Acres

Item	Item Description	Unit	Quantity	Rates	Total Cost
1.0	**Waste Grading (Quotes Received from Fretco, Inc.)**				
1.1	Grade Preparation	lump sum	1	$ 75,000.00	$ 75,000.00
1.2	Surveying	lump sum	1	$ 50,000.00	$ 50,000.00
1.3	**Total Waste Grading Cost**				**$ 125,000.00**
2.0	**Earthwork (Quotes Received from Fretco, Inc.)**				
2.1	Mob/Demob	lump sum	1	$ 20,000.00	$ 20,000.00
2.2	Perimeter Anchor Trench and Backfill	linear foot	770	$ 20.00	$ 15,400.00
2.3	Construct 1-ft thick Interim Clay Cover	cu. yd	18,198	$ 7.50	$ 136,488.00
2.4	Prepare Interim Clay Bedding Soil Surface	square foot	491,357	$ 0.20	$ 98,271.36
2.5	1.5-ft thick Soil Protective Cover	cu. yd	27,298	$ 10.00	$ 272,976.00
2.6	0.5-ft thick Topsoil	cu. yd	9,099	$ 6.00	$ 54,595.20
2.7	Drainage Berm Construction	cu. yd	1,710	$ 10.00	$ 17,100.00
2.8	Seeding	acre	11.3	$ 6,400.00	$ 72,192.00
2.9	Rip Rap	cu. yd	480.6	$ 100.00	$ 48,061.30
2.10	18" HDPE Downspout Pipe	linear foot	416	$ 35.00	$ 14,560.00
2.11	Concrete Drop Inlets	each	2	$ 6,000.00	$ 12,000.00
2.12	Unload Geosynthetics	lump sum	1	$ 10,000.00	$ 10,000.00
2.13	**Total Earthwork Cost**				**$ 771,643.86**
3.0	**Geosynthetics (Quotes Received from Texas Environmental Plastics, Inc.)**				
3.1	60 mil Textured HDPE - Material	square foot	565,060	$ 0.419	$ 236,760.27
3.2	60 mil Textured HDPE - Installation	square foot	530,665	$ 0.110	$ 58,373.19
3.3	GCL - Material	square foot	565,060	$ 0.456	$ 257,476.80
3.4	GCL - Installation	square foot	530,665	$ 0.090	$ 47,759.88
3.5	Double-Sided Geocomposite - Material	square foot	565,060	$ 0.403	$ 227,881.76
3.6	Double-Sided Geocomposite - Installation	square foot	530,665	$ 0.087	$ 46,167.88
3.7	Mob/demob	linear foot	1	$ 5,500.00	$ 5,500.00
3.8	Extrusion Weld (Liner Tie-in)	linear foot	650	$ 5.50	$ 3,575.00
3.9	**Total Geoysnthetics Cost**				**$ 883,494.79**
3.0	**Total Construction Cost (1.3 + 2.13 + 3.9)**				**$ 1,780,138.65**
4.0	**Project Management (from Envirotech for Items 4.1, 4.2, & 4.3)**				
4.1	Project Management	acre	11.28	$ 5,943.91	$ 67,047.30
4.2	Quality Control and Quality Assurance	acre	11.28	$ 7,099.67	$ 80,084.28
4.3	Quality Assurance - see Item 4.2	acre	11.28	$ 3,467.28	$ 39,110.93
4.4	Design/Bid Documents	%	$ 1,780,138.65	5%	$ 89,006.93
4.5	**Total Project Management Cost**				**$ 275,249.43**
5.0	**Total Closure Cost (3.0 + 4.5)**				**$ 2,055,388.08**

Note: Geosynthetics material quantities inflated by 15% to account for overlaps and waste. Installation quantities inflated by 8% for field additions and differences.

Table 6
Closure Cost Estimate for Cell 15 Phase 4

Area to be Final Capped: 11.93 Acres

Item	Item Description	Unit	Quantity	Rates	Total Cost
1.0	**Waste Grading (Quotes Received from Fretco, Inc.)**				
1.1	Grade Preparation	lump sum	1	$ 75,000.00	$ 75,000.00
1.2	Surveying	lump sum	1	$ 50,000.00	$ 50,000.00
1.3	**Total Waste Grading Cost**				**$ 125,000.00**
2.0	**Earthwork (Quotes Received from Fretco, Inc.)**				
2.1	Mob/Demob	lump sum	1	$ 20,000.00	$ 20,000.00
2.2	Perimeter Anchor Trench and Backfill	linear foot	1,410	$ 20.00	$ 28,200.00
2.3	Construct 1-ft thick Interim Clay Cover	cu. yd	19,247	$ 7.50	$ 144,353.00
2.4	Prepare Interim Clay Bedding Soil Surface	square foot	519,671	$ 0.20	$ 103,934.16
2.5	1.5-ft thick Soil Protective Cover	cu. yd	28,871	$ 10.00	$ 288,706.00
2.6	0.5-ft thick Topsoil	cu. yd	9,624	$ 6.00	$ 57,741.20
2.7	Drainage Berm Construction	cu. yd	2,190	$ 10.00	$ 21,900.00
2.8	Seeding	acre	11.9	$ 6,400.00	$ 76,352.00
2.9	Rip Rap	cu. yd	823.0	$ 100.00	$ 82,302.59
2.10	18" HDPE Downspout Pipe	linear foot	625	$ 35.00	$ 21,875.00
2.11	Concrete Drop Inlets	each	2	$ 6,000.00	$ 12,000.00
2.12	Unload Geosynthetics	lump sum	1	$ 10,000.00	$ 10,000.00
2.13	**Total Earthwork Cost**				**$ 867,363.95**
3.0	**Geosynthetics (Quotes Received from Texas Environmental Plastics, Inc.)**				
3.1	60 mil Textured HDPE - Material	square foot	597,621	$ 0.419	$ 250,403.37
3.2	60 mil Textured HDPE - Installation	square foot	561,244	$ 0.110	$ 61,736.89
3.3	GCL - Material	square foot	597,621	$ 0.456	$ 272,313.67
3.4	GCL - Installation	square foot	561,244	$ 0.090	$ 50,512.00
3.5	Double-Sided Geocomposite - Material	square foot	597,621	$ 0.403	$ 241,013.25
3.6	Double-Sided Geocomposite - Installation	square foot	561,244	$ 0.087	$ 48,828.27
3.7	Mob/demob	linear foot	1	$ 5,500.00	$ 5,500.00
3.8	Extrusion Weld (Liner Tie-in)	linear foot	760	$ 5.50	$ 4,180.00
3.9	**Total Geoysnthetics Cost**				**$ 934,487.45**
3.0	**Total Construction Cost (1.3 + 2.13 + 3.9)**				**$ 1,926,851.41**
4.0	**Project Management (from Envirotech for Items 4.1, 4.2, & 4.3)**				
4.1	Project Management	acre	11.93	$ 5,943.91	$ 70,910.84
4.2	Quality Control and Quality Assurance	acre	11.93	$ 7,099.67	$ 84,699.06
4.3	Quality Assurance - see Item 4.2	acre	11.93	$ 3,467.28	$ 41,364.66
4.4	Design/Bid Documents	%	$ 1,926,851.41	5%	$ 96,342.57
4.5	**Total Project Management Cost**				**$ 293,317.13**
5.0	**Total Closure Cost (3.0 + 4.5)**				**$ 2,220,168.54**

Note: Geosynthetics material quantities inflated by 15% to account for overlaps and waste. Installation quantities inflated by 8% for field additions and differences.

Table 7
Closure Cost Estimate for Cell 15 Phase 5

Area to be Final Capped: 10.64 Acres

Item	Item Description	Unit	Quantity	Rates	Total Cost
1.0	**Waste Grading (Quotes Received from Fretco, Inc.)**				
1.1	Grade Preparation	lump sum	1	$ 75,000.00	$ 75,000.00
1.2	Surveying	lump sum	1	$ 50,000.00	$ 50,000.00
1.3	**Total Waste Grading Cost**				**$ 125,000.00**
2.0	**Earthwork (Quotes Received from Fretco, Inc.)**				
2.1	Mob/Demob	lump sum	1	$ 20,000.00	$ 20,000.00
2.2	Perimeter Anchor Trench and Backfill	linear foot	560	$ 20.00	$ 11,200.00
2.3	Construct 1-ft thick Interim Clay Cover	cu. yd	17,166	$ 7.50	$ 128,744.00
2.4	Prepare Interim Clay Bedding Soil Surface	square foot	463,478	$ 0.20	$ 92,695.68
2.5	1.5-ft thick Soil Protective Cover	cu. yd	25,749	$ 10.00	$ 257,488.00
2.6	0.5-ft thick Topsoil	cu. yd	8,583	$ 6.00	$ 51,497.60
2.7	Drainage Berm Construction	cu. yd	1,520	$ 10.00	$ 15,200.00
2.8	Seeding	acre	10.6	$ 6,400.00	$ 68,096.00
2.9	Rip Rap	cu. yd	391.3	$ 100.00	$ 39,125.93
2.10	18" HDPE Downspout Pipe	linear foot	465	$ 35.00	$ 16,275.00
2.11	Concrete Drop Inlets	each	2	$ 6,000.00	$ 12,000.00
2.12	Unload Geosynthetics	lump sum	1	$ 10,000.00	$ 10,000.00
2.13	**Total Earthwork Cost**				**$ 722,322.21**
3.0	**Geosynthetics (Quotes Received from Texas Environmental Plastics, Inc.)**				
3.1	60 mil Textured HDPE - Material	square foot	533,000	$ 0.419	$ 223,327.07
3.2	60 mil Textured HDPE - Installation	square foot	500,557	$ 0.110	$ 55,061.23
3.3	GCL - Material	square foot	533,000	$ 0.456	$ 242,868.19
3.4	GCL - Installation	square foot	500,557	$ 0.090	$ 45,050.10
3.5	Double-Sided Geocomposite - Material	square foot	533,000	$ 0.403	$ 214,952.30
3.6	Double-Sided Geocomposite - Installation	square foot	500,557	$ 0.087	$ 43,548.43
3.7	Mob/demob	linear foot	1	$ 5,500.00	$ 5,500.00
3.8	Extrusion Weld (Liner Tie-in)	linear foot	1460	$ 5.50	$ 8,030.00
3.9	**Total Geoysnthetics Cost**				**$ 838,337.32**
3.0	**Total Construction Cost (1.3 + 2.13 + 3.9)**				**$ 1,685,659.53**
4.0	**Project Management (from Envirotech for Items 4.1, 4.2, & 4.3)**				
4.1	Project Management	acre	10.64	$ 5,943.91	$ 63,243.20
4.2	Quality Control and Quality Assurance	acre	10.64	$ 7,099.67	$ 75,540.49
4.3	Quality Assurance - see Item 4.2	acre	10.64	$ 3,467.28	$ 36,891.87
4.4	Design/Bid Documents	%	$ 1,685,659.53	5%	$ 84,282.98
4.5	**Total Project Management Cost**				**$ 259,958.53**
5.0	**Total Closure Cost (3.0 + 4.5)**				**$ 1,945,618.05**

Note: Geosynthetics material quantities inflated by 15% to account for overlaps and waste. Installation quantities inflated by 8% for field additions and differences.

Table 8
Closure Cost Estimate for Cell 15 Phase 6

Area to be Final Capped: 14.82 Acres

Item	Item Description	Unit	Quantity	Rates	Total Cost
1.0	**Waste Grading (Quotes Received from Fretco, Inc.)**				
1.1	Grade Preparation	lump sum	1	$ 75,000.00	$ 75,000.00
1.2	Surveying	lump sum	1	$ 50,000.00	$ 50,000.00
1.3	**Total Waste Grading Cost**				**$ 125,000.00**
2.0	**Earthwork (Quotes Received from Fretco, Inc.)**				
2.1	Mob/Demob	lump sum	1	$ 20,000.00	$ 20,000.00
2.2	Perimeter Anchor Trench and Backfill	linear foot	1,510	$ 20.00	$ 30,200.00
2.3	Construct 1-ft thick Interim Clay Cover	cu. yd	23,910	$ 7.50	$ 179,322.00
2.4	Prepare Interim Clay Bedding Soil Surface	square foot	645,559	$ 0.20	$ 129,111.84
2.5	1.5-ft thick Soil Protective Cover	cu. yd	35,864	$ 10.00	$ 358,644.00
2.6	0.5-ft thick Topsoil	cu. yd	11,955	$ 6.00	$ 71,728.80
2.7	Drainage Berm Construction	cu. yd	2,640	$ 10.00	$ 26,400.00
2.8	Seeding	acre	14.8	$ 6,400.00	$ 94,848.00
2.9	Rip Rap	cu. yd	893.6	$ 100.00	$ 89,355.00
2.10	18" HDPE Downspout Pipe	linear foot	777	$ 35.00	$ 27,195.00
2.11	Concrete Drop Inlets	each	3	$ 6,000.00	$ 18,000.00
2.12	Unload Geosynthetics	lump sum	1	$ 10,000.00	$ 10,000.00
2.13	**Total Earthwork Cost**				**$ 1,054,804.64**
3.0	**Geosynthetics (Quotes Received from Texas Environmental Plastics, Inc.)**				
3.1	60 mil Textured HDPE - Material	square foot	742,393	$ 0.419	$ 311,062.70
3.2	60 mil Textured HDPE - Installation	square foot	697,204	$ 0.110	$ 76,692.43
3.3	GCL - Material	square foot	742,393	$ 0.456	$ 338,280.69
3.4	GCL - Installation	square foot	697,204	$ 0.090	$ 62,748.35
3.5	Double-Sided Geocomposite - Material	square foot	742,393	$ 0.403	$ 299,397.85
3.6	Double-Sided Geocomposite - Installation	square foot	697,204	$ 0.087	$ 60,656.74
3.7	Mob/demob	linear foot	1	$ 5,500.00	$ 5,500.00
3.8	Extrusion Weld (Liner Tie-in)	linear foot	710	$ 5.50	$ 3,905.00
3.9	**Total Geoysnthetics Cost**				**$ 1,158,243.77**
3.0	**Total Construction Cost (1.3 + 2.13 + 3.9)**				**$ 2,338,048.41**
4.0	**Project Management (from Envirotech for Items 4.1, 4.2, & 4.3)**				
4.1	Project Management	acre	14.82	$ 5,943.91	$ 88,088.74
4.2	Quality Control and Quality Assurance	acre	14.82	$ 7,099.67	$ 105,217.11
4.3	Quality Assurance - see Item 4.2	acre	14.82	$ 3,467.28	$ 51,385.10
4.4	Design/Bid Documents	%	$ 2,338,048.41	5%	$ 116,902.42
4.5	**Total Project Management Cost**				**$ 361,593.37**
5.0	**Total Closure Cost (3.0 + 4.5)**				**$ 2,699,641.77**

Note: Geosynthetics material quantities inflated by 15% to account for overlaps and waste. Installation quantities inflated by 8% for field additions and differences.

Table 9
Closure Cost Estimate for Cell 15 Phase 7

Area to be Final Capped: 12.05 Acres

Item	Item Description	Unit	Quantity	Rates	Total Cost
1.0	**Waste Grading (Quotes Received from Fretco, Inc.)**				
1.1	Grade Preparation	lump sum	1	$ 75,000.00	$ 75,000.00
1.2	Surveying	lump sum	1	$ 50,000.00	$ 50,000.00
1.3	**Total Waste Grading Cost**				**$ 125,000.00**
2.0	**Earthwork (Quotes Received from Fretco, Inc.)**				
2.1	Mob/Demob	lump sum	1	$ 20,000.00	$ 20,000.00
2.2	Perimeter Anchor Trench and Backfill	linear foot	790	$ 20.00	$ 15,800.00
2.3	Construct 1-ft thick Interim Clay Cover	cu. yd	19,441	$ 7.50	$ 145,805.00
2.4	Prepare Interim Clay Bedding Soil Surface	square foot	524,898	$ 0.20	$ 104,979.60
2.5	1.5-ft thick Soil Protective Cover	cu. yd	29,161	$ 10.00	$ 291,610.00
2.6	0.5-ft thick Topsoil	cu. yd	9,720	$ 6.00	$ 58,322.00
2.7	Drainage Berm Construction	cu. yd	1,950	$ 10.00	$ 19,500.00
2.8	Seeding	acre	12.1	$ 6,400.00	$ 77,120.00
2.9	Rip Rap	cu. yd	479.6	$ 100.00	$ 47,962.78
2.10	18" HDPE Downspout Pipe	linear foot	374	$ 35.00	$ 13,090.00
2.11	Concrete Drop Inlets	each	2	$ 6,000.00	$ 12,000.00
2.12	Unload Geosynthetics	lump sum	1	$ 10,000.00	$ 10,000.00
2.13	**Total Earthwork Cost**				**$ 816,189.38**
3.0	**Geosynthetics (Quotes Received from Texas Environmental Plastics, Inc.)**				
3.1	60 mil Textured HDPE - Material	square foot	603,633	$ 0.419	$ 252,922.10
3.2	60 mil Textured HDPE - Installation	square foot	566,890	$ 0.110	$ 62,357.88
3.3	GCL - Material	square foot	603,633	$ 0.456	$ 275,052.79
3.4	GCL - Installation	square foot	566,890	$ 0.090	$ 51,020.09
3.5	Double-Sided Geocomposite - Material	square foot	603,633	$ 0.403	$ 243,437.52
3.6	Double-Sided Geocomposite - Installation	square foot	566,890	$ 0.087	$ 49,319.42
3.7	Mob/demob	linear foot	1	$ 5,500.00	$ 5,500.00
3.8	Extrusion Weld (Liner Tie-in)	linear foot	1750	$ 5.50	$ 9,625.00
3.9	**Total Geoysnthetics Cost**				**$ 949,234.79**
3.0	**Total Construction Cost (1.3 + 2.13 + 3.9)**				**$ 1,890,424.17**
4.0	**Project Management (from Envirotech for Items 4.1, 4.2, & 4.3)**				
4.1	Project Management	acre	12.05	$ 5,943.91	$ 71,624.11
4.2	Quality Control and Quality Assurance	acre	12.05	$ 7,099.67	$ 85,551.02
4.3	Quality Assurance - see Item 4.2	acre	12.05	$ 3,467.28	$ 41,780.73
4.4	Design/Bid Documents	%	$ 1,890,424.17	5%	$ 94,521.21
4.5	**Total Project Management Cost**				**$ 293,477.07**
5.0	**Total Closure Cost (3.0 + 4.5)**				**$ 2,183,901.24**

Note: Geosynthetics material quantities inflated by 15% to account for overlaps and waste. Installation quantities inflated by 8% for field additions and differences.

Table 10
Closure Cost Estimate for Cell 15 Phase 8

Area to be Final Capped: 13.16 Acres

Item	Item Description	Unit	Quantity	Rates	Total Cost
1.0	**Waste Grading (Quotes Received from Fretco, Inc.)**				
1.1	Grade Preparation	lump sum	1	$ 75,000.00	$ 75,000.00
1.2	Surveying	lump sum	1	$ 50,000.00	$ 50,000.00
1.3	**Total Waste Grading Cost**				**$ 125,000.00**
2.0	**Earthwork (Quotes Received from Fretco, Inc.)**				
2.1	Mob/Demob	lump sum	1	$ 20,000.00	$ 20,000.00
2.2	Perimeter Anchor Trench and Backfill	linear foot	1,480	$ 20.00	$ 29,600.00
2.3	Construct 1-ft thick Interim Clay Cover	cu. yd	21,231	$ 7.50	$ 159,236.00
2.4	Prepare Interim Clay Bedding Soil Surface	square foot	573,250	$ 0.20	$ 114,649.92
2.5	1.5-ft thick Soil Protective Cover	cu. yd	31,847	$ 10.00	$ 318,472.00
2.6	0.5-ft thick Topsoil	cu. yd	10,616	$ 6.00	$ 63,694.40
2.7	Drainage Berm Construction	cu. yd	1,410	$ 10.00	$ 14,100.00
2.8	Seeding	acre	13.2	$ 6,400.00	$ 84,224.00
2.9	Rip Rap	cu. yd	937.1	$ 100.00	$ 93,709.26
2.10	18" HDPE Downspout Pipe	linear foot	345	$ 35.00	$ 12,075.00
2.11	Concrete Drop Inlets	each	2	$ 6,000.00	$ 12,000.00
2.12	Unload Geosynthetics	lump sum	1	$ 10,000.00	$ 10,000.00
2.13	**Total Earthwork Cost**				**$ 931,760.58**
3.0	**Geosynthetics (Quotes Received from Texas Environmental Plastics, Inc.)**				
3.1	60 mil Textured HDPE - Material	square foot	659,237	$ 0.419	$ 276,220.32
3.2	60 mil Textured HDPE - Installation	square foot	619,110	$ 0.110	$ 68,102.05
3.3	GCL - Material	square foot	659,237	$ 0.456	$ 300,389.60
3.4	GCL - Installation	square foot	619,110	$ 0.090	$ 55,719.86
3.5	Double-Sided Geocomposite - Material	square foot	659,237	$ 0.403	$ 265,862.06
3.6	Double-Sided Geocomposite - Installation	square foot	619,110	$ 0.087	$ 53,862.53
3.7	Mob/demob	linear foot	1	$ 5,500.00	$ 5,500.00
3.8	Extrusion Weld (Liner Tie-in)	linear foot	1000	$ 5.50	$ 5,500.00
3.9	**Total Geoysnthetics Cost**				**$ 1,031,156.42**
3.0	**Total Construction Cost (1.3 + 2.13 + 3.9)**				**$ 2,087,917.00**
4.0	**Project Management (from Envirotech for Items 4.1, 4.2, & 4.3)**				
4.1	Project Management	acre	13.16	$ 5,943.91	$ 78,221.85
4.2	Quality Control and Quality Assurance	acre	13.16	$ 7,099.67	$ 93,431.65
4.3	Quality Assurance - see Item 4.2	acre	13.16	$ 3,467.28	$ 45,629.41
4.4	Design/Bid Documents	%	$ 2,087,917.00	5%	$ 104,395.85
4.5	**Total Project Management Cost**				**$ 321,678.77**
5.0	**Total Closure Cost (3.0 + 4.5)**				**$ 2,409,595.77**

Note: Geosynthetics material quantities inflated by 15% to account for overlaps and waste. Installation quantities inflated by 8% for field additions and differences.

Table 11
Closure Cost Estimate for Cell 15 Phase 9

Area to be Final Capped: 12.54 Acres

Item	Item Description	Unit	Quantity	Rates	Total Cost
1.0	**Waste Grading (Quotes Received from Fretco, Inc.)**				
1.1	Grade Preparation	lump sum	1	$ 75,000.00	$ 75,000.00
1.2	Surveying	lump sum	1	$ 50,000.00	$ 50,000.00
1.3	**Total Waste Grading Cost**				**$ 125,000.00**
2.0	**Earthwork (Quotes Received from Fretco, Inc.)**				
2.1	Mob/Demob	lump sum	1	$ 20,000.00	$ 20,000.00
2.2	Perimeter Anchor Trench and Backfill	linear foot	2,310	$ 20.00	$ 46,200.00
2.3	Construct 1-ft thick Interim Clay Cover	cu. yd	20,231	$ 7.50	$ 151,734.00
2.4	Prepare Interim Clay Bedding Soil Surface	square foot	546,242	$ 0.20	$ 109,248.48
2.5	1.5-ft thick Soil Protective Cover	cu. yd	30,347	$ 10.00	$ 303,468.00
2.6	0.5-ft thick Topsoil	cu. yd	10,116	$ 6.00	$ 60,693.60
2.7	Drainage Berm Construction	cu. yd	1,920	$ 10.00	$ 19,200.00
2.8	Seeding	acre	12.5	$ 6,400.00	$ 80,256.00
2.9	Rip Rap	cu. yd	1,356.1	$ 100.00	$ 135,608.89
2.10	18" HDPE Downspout Pipe	linear foot	370	$ 35.00	$ 12,950.00
2.11	Concrete Drop Inlets	each	3	$ 6,000.00	$ 18,000.00
2.12	Unload Geosynthetics	lump sum	1	$ 10,000.00	$ 10,000.00
2.13	**Total Earthwork Cost**				**$ 967,358.97**
3.0	**Geosynthetics (Quotes Received from Texas Environmental Plastics, Inc.)**				
3.1	60 mil Textured HDPE - Material	square foot	628,179	$ 0.419	$ 263,206.90
3.2	60 mil Textured HDPE - Installation	square foot	589,942	$ 0.110	$ 64,893.60
3.3	GCL - Material	square foot	628,179	$ 0.456	$ 286,237.50
3.4	GCL - Installation	square foot	589,942	$ 0.090	$ 53,094.76
3.5	Double-Sided Geocomposite - Material	square foot	628,179	$ 0.403	$ 253,336.64
3.6	Double-Sided Geocomposite - Installation	square foot	589,942	$ 0.087	$ 51,324.94
3.7	Mob/demob	linear foot	1	$ 5,500.00	$ 5,500.00
3.8	Extrusion Weld (Liner Tie-in)	linear foot	630	$ 5.50	$ 3,465.00
3.9	**Total Geoysnthetics Cost**				**$ 981,059.34**
3.0	**Total Construction Cost (1.3 + 2.13 + 3.9)**				**$ 2,073,418.31**
4.0	**Project Management (from Envirotech for Items 4.1, 4.2, & 4.3)**				
4.1	Project Management	acre	12.54	$ 5,943.91	$ 74,536.63
4.2	Quality Control and Quality Assurance	acre	12.54	$ 7,099.67	$ 89,029.86
4.3	Quality Assurance - see Item 4.2	acre	12.54	$ 3,467.28	$ 43,479.70
4.4	Design/Bid Documents	%	$ 2,073,418.31	5%	$ 103,670.92
4.5	**Total Project Management Cost**				**$ 310,717.10**
5.0	**Total Closure Cost (3.0 + 4.5)**				**$ 2,384,135.41**

Note: Geosynthetics material quantities inflated by 15% to account for overlaps and waste. Installation quantities inflated by 8% for field additions and differences.

Table 12
Closure Cost Estimate for Wastewater Treatment System

Item	Item Description	Unit	Quantity	Unit Cost	Total Cost
1.0	**Inventory Management**				
1.1	Total Tank Inventory	gallons	2,329,050		
1.2	40% of the volume is sludge which can be stabilized and landfilled.	cu. yds	4,613	$ 2.29	$ 10,563.53
1.3	60% of the volume is liquid which can be treated in the wastewater treatment system.	gallons	1,397,430	$ 0.394	$ 550,587.42
1.4	**Total Inventory Management Cost**				**$ 561,150.95**
2.0	**Tank Decontamination**				
2.1	Total internal surface area to be decontaminated	square feet	42,260		
2.2	Rinsate production from metal washing (factor)	gallons/sq ft	0.30		
2.3	Rinsate disposal volume - liquid	gallons	42,260	0.30	12,678.05
2.4	Rinsate disposal cost (Off-site deep well)	$	12,678	$ 0.72	$ 9,128.20
2.5	Solids production from metal washing (factor)	gallons/sq ft	0.04		
2.6	Solids disposal volume (convert gallons to cubic yards)	cu. yds	42,260	0.04	8.37
2.7	Solids disposal costs	$	8.37	$ 2.29	$ 19.17
2.8	Steam cleaner costs - Level B	$/square ft	42,260	$ 2.82	$ 119,173.67
2.9	**Total Tank Decontamination Cost (2.4 +2.7+ 2.8)**				**$ 128,321.03**
3.0	**Concrete Decontamination**				
3.1	Surface area of WWTS to be decontaminated	square feet	33,221		
3.2	Rinsate production from concrete washing.	gallons/sq ft	0.30		
3.3	Rinsate disposal volume - liquid	gallons	33,221	$ 0.30	9,966.2
3.4	Rinsate disposal cost - (Off-site deep well)	$/gal	9,966	$ 0.72	$ 7,175.70
3.5	Solids production from concrete washing.	gallons/sq ft	0.04		
3.6	Solids disposal volume (convert gallons to cubic yards)	cu. yds	33,221	0.04	1,329
3.7	Solids disposal cost	$/cyd	1,329	$ 2.29	$ 3,043.03
3.8	Steam cleaner cost - Level C	$/square ft	33,221	$ 0.57	$ 18,935.87
3.9	**Total Concrete Decontamination Cost (3.4 + 3.7 + 3.8)**				**$ 29,154.60**
4.0	**Labor Cost**				
4.1	Assume 4 labors @ 8 hrs/day (see note 4)	days	**111**		
4.2	Labor hours need to decontaminate WWTS.	hours	3,544		
4.3	**Total Labor Cost**	$/hr	3,544	$ 15.00	**$ 53,153.33**
5.0	**Laboratory Costs**				
5.1	Number of rinsate samples -liquid	sample	2	$ 360.00	$ 720.00
5.2	Number of soil samples	sample	4	$ 1,340.00	$ 5,360.00
5.3	**Total Laboratory Costs**				**$ 6,080.00**
6.0	**Certification of Final Closure**				
6.1	Professional Engineer	man-hour	20	$ 74.00	$ 1,480.00
6.2	Staff Engineer	man-hour	40	$ 57.00	$ 2,280.00
6.3	Clerical Administrative	man-hour	20	$ 25.00	$ 500.00
6.4	Supplies	lump sum	1	$ 250.00	$ 250.00
6.5	**Cost of Professional Certification**				**$ 4,510.00**
7.0	**Total Cost for Construction and Certification**	**Total**			**$782,370**

Notes:

1) Assumes 40% of the volume is sludge which can be stabilized and landfilled.
2) Assumes 60% of the volume is liquids which can be treated in the wastewater treatment system.
3) Concrete surfaces will be washed and rinsed with residual liquid and solid production being the same for tanks containment area. Liquids will be treated through the wastewater treatment system and solids will be landfilled.
4) Costs assume a 4-man crew working 8 hours/day at a rate of 300 square feet/day.
5) Rinsate samples will be analyzed for Oil & Grease, Phenols, RCRA metals, TOX, TOC, and cyanides as required by closure plan.

Table 13
Closure Cost Estimate for Stabilization Tank System

Item	Item Description	Unit	Quantity	Unit Cost	Total Cost
1.0	**Inventory Management**				
1.1	Tank Volumes are listed below:				
1.2	Total Tank Inventory	gallons	35,904		
1.3	40% of the volume is sludge which can be stabilized and landfilled.	cu. yds	71	$ 2.29	$ 162.84
1.4	60% of the volume is liquid which can be treated in the wastewater treatment system.	gallons	21,542.40	$ 0.394	$ 8,487.71
1.5	**Total Inventory Management Cost**	**$**			**$ 8,650.55**
2.0	**Tank Decontamination**				
2.1	Total internal surface area to be decontaminated	square feet	2,560		
2.2	Rinsate production from metal washing (factor)	gallons/sq ft	0.30		
2.3	Rinsate disposal volume - liquid	gallons	2,560	0.30	768.00
2.4	Rinsate disposal cost (Off-site deep well)	$	768	$ 0.72	$ 552.96
2.5	Solids production from metal washing (factor)	gallons/sq ft	0.04		
2.6	Solids disposal volume (convert gallons to cubic yards)	cu. yds	2,560	0.04	0.51
2.7	Solids disposal costs	$	0.51	$ 2.29	$ 1.16
2.8	Steam cleaner costs - Level B	$/square ft	2,560	$ 2.82	$ 7,219.20
2.9	**Total Tank Decontamination Cost (2.4 +2.7+ 2.8)**	$			**$ 7,773.32**
3.0	**Concrete Decontamination**				
3.1	Surface area of WWTS to be decontaminated is ~24.5 ft x 22 ft x 6 f.t	square feet	8,560		
3.2	Rinsate production from concrete washing.	gallons/sq ft	0.30		
3.3	Rinsate disposal volume - liquid	gallons	8,560	0.30	2,568.0
3.4	Rinsate disposal cost - (WWTP)	$/gal	2,568	$ 0.394	$ 1,011.79
3.5	Solids production from concrete washing.	gallons/sq ft	0.04		
3.6	Solids disposal volume (convert gallons to cubic yards)	cu. yds	8,560	0.04	342
3.7	Solids disposal cost	$/cyd	342	$ 2.29	$ 784.10
3.8	Steam cleaner cost - Level C	$/square ft	8,560	$ 0.57	$ 4,879.20
3.9	**Total Concrete Decontamination Cost (3.4 + 3.7 +3.8)**	**$**			**$ 6,675.09**
4.0	**Labor Cost**				
4.1	Assume 4 labors @ 8 hrs/day	days	37		
4.2	Labor hours need to decontaminate Stabilization Tanks.	hours	1,186		
4.3	**Total Labor Cost**	$	1,186	$ 15.00	**$ 17,792.00**
5.0	**Laboratory Costs**				
5.1	Number of rinsate samples -liquid	sample	2	$ 360.00	$ 720.00
5.2	Number of soil samples	sample	4	$ 1,340.00	$ 5,360.00
5.3	**Total Laboratory Costs**	**$**			**$ 6,080.00**
6.0	**Certification of Final Closure**				
6.1	Professional Engineer	man-hour	20	$ 74.00	$ 1,480.00
6.2	Staff Engineer	man-hour	40	$ 57.00	$ 2,280.00
6.3	Clerical Administrative	man-hour	20	$ 25.00	$ 500.00
6.4	Supplies	lump sum	1	$ 250.00	$ 250.00
6.5	**Cost of Professional Certification**	**$**			**$ 4,510.00**
7.0	**Total Cost for Construction and Certification**				**$ 51,480.96**

Notes:

1) Assumes 40% of the volume is sludge which can be stabilized and landfilled.
2) Assumesrinsate & 60% of the inventory volume is liquids which can be treated in the wastewater treatment system.
3) Concrete surfaces will be washed and rinsed with residual liquid and solid production being the same for tanks containment area. Liquids will be treated through the wastewater treatment system and solids will be landfilled.
4) Costs assume a 4-man crew working 8 hours/day at a rate of 300 square feet/day.
5) Rinsate samples will be analyzed for Oil & Grease, Phenols, RCRA metals, TOX, TOC, and cyanides as required by closure plan.

Table 14
Closure Cost Estimate for Drum Dock

Item	Item Description	Unit	Quantity	Unit Cost	Total Cost
1.0	**Inventory Management**				
1.1	Drum dock maximum inventory	gallons	24,365		
1.2	20% of Inventory is solid, dispose in landfill (convert gallons to cubic yards)	cyds	24	$ 2.29	$ 55.25
1.3	60% of inventory will contain solids or sludge which can be stabilized and landfilled (convert gallons to cubic yards).	cyds	72	$ 2.29	$ 165.76
1.4	10% of inventory will contain organic liquids which will be shipped off-site for use as fuel.	gal	2,437	$ 0.250	$ 609.13
1.5	10% of inventory will contain inorganic liquids which can be treated in the wastewater treatment system.	gal	2,437	$ 0.394	$ 959.98
1.6	**Inventory Management Cost**				**$ 1,790.12**
2.0	**Concrete Decontamination**				
2.1	Surface area drum dock to be decontaminated	square feet	6,077		
2.2	Rinsate production from concrete washing.	gallons/sq ft	0.30		
2.3	Rinsate disposal volume - liquid	gallons	6,077	0.30	1,823.1
2.4	Rinsate disposal cost - (WWTPl)	$/gal	1,823.1	$ 0.394	$ 718.30
2.5	Solids production from concrete washing.	gallons/sq ft	0.04		
2.6	Solids disposal volume (convert gallons to cubic yards)	cu. yds	6,077	0.04	243
2.7	Solids disposal cost	$/cyd	243	$ 2.29	$ 556.65
2.8	Steam cleaner cost - Level C	$/square ft	6,077	$ 0.57	$ 3,463.89
2.9	**Total Concrete Decontamination Cost (2.4 + 2.7 +2.8)**				**$ 4,738.84**
3.0	**Labor Cost**				
3.1	Assume 4 labors @ 8 hrs/day (see note 3)				
3.2	Labor hours need to decontaminate drum dock.	hours	648		
3.3	**Labor to decontaminate drum dock concrete.**	$/hr	648	$ 15.00	**$ 9,723.20**
4.0	**Laboratory Costs**				
4.1	Number of rinsate samples -liquid	sample	2	$ 360.00	$ 720.00
4.2	Number of soil samles	sample	4	$ 1,340.00	$ 5,360.00
4.3	**Laboratory Costs**				**$ 6,080.00**
5.0	**Certification of Final Closure**				
5.1	Professional Engineer	man-hour	20	$ 74.00	$ 1,480.00
5.2	Staff Engineer	man-hour	40	$ 57.00	$ 2,280.00
5.3	Clerical Administrative	man-hour	20	$ 25.00	$ 500.00
5.4	Supplies	lump sum	1	$ 250.00	$ 250.00
5.5	**Cost of Professional Certification**				**$ 4,510.00**
6.0	**Total Drum Dock Closure Cost**				**$ 26,842.17**

Notes:

1) Closure plan assumes the following conditions:
   a) 20% of all containers will contain solids having no free liquids an can be landfill disposed.
   b) 60% of all containers will contain solids or sludges which can be stabilized and landfilled.
   c) 10% of all containers will organic liquids which will be shipped off-stie for use as fuel.
   d) Assumes Rinsate & 10% of all containers will contain inorganic liquid which can be treated in the wastewater treatment system.
2) Concrete surfaces will be washed and rinsed with residual liquid and solid production being the same for tanks containment area. Liquids will be treated through the wastewater treatment system and solids will be landfilled.
3) Costs assume a 4-man crew working 8 hours/day at a rate of 300 square feet/day.
4) Rinsate samples will be analyzed for Oil & Grease, Phenols, RCRA metals, TOX, TOC, and cyanides as required by closure plan.
5) Soil samples will analyzed for Appendix IX constituents.

Table 15
Closure Cost Estimate for Container Management Building

Item	Item Description	Unit	Quantity	Unit Cost	Total Cost
1.0	**Inventory Management**				
1.1	Container Management Max1 Inventory	gallons	182,490		
1.2	20% of Inventory is solid, dispose in landfill (convert gallons to cubic yards)	cyds	181	$ 2.29	$ 413.85
1.3	60% of inventory will contain solids or sludge which can be stabilized and landfilled (convert gallons to cubic yards).	cyds	542	$ 2.29	$ 1,241.54
1.4	10% of inventory will contain organic liquids which will be shipped off-site for use as fuel at a cement kiln.	gal	18,249	$ 0.250	$ 4,562.25
1.5	10% of inventory will contain inorganic liquids which can be treated in the wastewater treatment system.	gal	18,249	$ 0.394	$ 7,190.11
1.6	**Inventory Management Cost**				**$ 13,407.74**
2.0	**Concrete Decontamination**				
2.1	Surface area of container management building to be deconed.	square feet	30,181		
2.2	Rinsate production from concrete washing.	gallons/sq ft	0.30		
2.3	Rinsate disposal volume - liquid	gallons	30,181	0.30	9,054.3
2.4	Rinsate disposal cost - (WWTP)	$/gal	9,054.3	$ 0.394	$ 3,567.39
2.5	Solids production from concrete washing.	gallons/sq ft	0.04		
2.6	Solids disposal volume (convert gallons to cubic yards)	cu. yds	30,181	0.04	1,207
2.7	Solids disposal cost	$/cyd	1,207	$ 2.29	$ 2,764.58
2.8	Steam cleaner cost - Level C	$/square ft	30,181	$ 0.57	$ 17,203.17
2.9	**Total Concrete Decontamination Cost (2.4 + 2.7 +2.8)**				**$ 23,535.14**
3.0	**Labor Cost**				
3.1	Assume 4 labors @ 8 hrs/day (See Note 3)	3,219			
3.2	Labor hours need to decontaminate drum dock.	hours	3,219		
3.3	**Labor to decontaminate drum dock concrete.**	$/hr	3,219	$ 15.00	**$ 48,289.60**
4.0	**Laboratory Costs**				
4.1	Number of rinsate samples -liquid	sample	2	$ 360.00	$ 720.00
4.2	Number of soil samles	sample	4	$ 1,340.00	$ 5,360.00
4.3	**Laboratory Costs**				**$ 6,080.00**
5.0	**Certification of Final Closure**				
5.1	Professional Engineer	man-hour	20	$ 74.00	$ 1,480.00
5.2	Staff Engineer	man-hour	40	$ 57.00	$ 2,280.00
5.3	Clerical Administrative	man-hour	20	$ 25.00	$ 500.00
5.4	Supplies	lump sum	1	$ 250.00	$ 250.00
5.5	**Cost of Professional Certification**				**$ 4,510.00**
6.0	**Total Drum Container Management Building Closure Cost**				**$ 95,822.49**

Notes:

1) Closure plan assumes the following conditions:
   a) 20% of all containers will contain solids having no free liquids an can be landfill disposed.
   b) 60% of all containers will contain solids or sludges which can be stabilized and landfilled.
   c) 10% of all containers will organic liquids which will be shipped off-stie for use as fuel.
   d) Assumes Rinsate & 10% of all containers will contain inorganic liquid which can be treated in the wastewater treatment system.
2) Concrete surfaces will be washed and rinsed with residual liquid and solid production being the same for tanks containment area. Liquids will be treated through the wastewater treatment system and solids will be landfilled.
3) Costs assume a 4-man crew working 8 hours/day at a rate of 300 square feet/day.
4) Rinsate samples will be analyzed for Oil & Grease, Phenols, RCRA metals, TOX, TOC, and cyanides as required by closure plan.
5) Soil samples will analyzed for Appendix IX constituents.

Table 16
Closure Cost Estimate for Roadway & Equipment Decontamination

Item	Item Description	Unit	Quantity	Unit Cost	Total Cost
1.0	**Roadway Soil Disposal Cost**				
1.1	Roadway surface area (30,000 ft long x 24 ft wide)	square feet	720,000		
1.2	Assume average soil depth removed is 1 inch.	inches	1		
1.3	Volume of soil to be excavated	cyds	2,222		
1.4	**Total Roadway Soil Disposal Cost**	$	2,222	$ 2.29	**$ 5,088.89**
2.0	**Roadway Decontamination Cost**				
2.1	The following earthmoving equipment will be used to remove the soil from the roads. Estimate assumes it will take four (4) days to do the work.				
2.2	CAT Motor Grader	hours	32	$ 40.00	$ 1,280.00
2.3	CAT Front End Loader - 3 yd bucket	hours	32	$ 39.00	$ 1,248.00
2.4	Dump truck - 10 yd truck	hours	32	$ 26.00	$ 832.00
2.5	Laborer/Operator	hours	96	$ 15.00	$ 1,440.00
2.6	**Total Roadway Decontamination Cost**				**$ 4,800.00**
3.0	**Equipment Decontamination Cost**				
3.1	Dozers	pieces	2		
3.2	Excavators (trackhoes)	pieces	4		
3.3	Off-road Dump Trucks	pieces	3		
3.4	Compactors	pieces	1		
3.5	Screeners	pieces	2		
3.6	Water Trucks	pieces	3		
3.7	Motor Graders	pieces	1		
3.8	Loaders	pieces	2		
3.9	Shredders	pieces	2		
3.10	Vacuum Trucks	pieces	1		
3.11	**Total Pieces of Equipment to be Decontaminated**	pieces	21	$ 175.51	**$ 3,685.71**
4.0	**Total Roadway & Equipment Decontamination Cost**				**$ 13,574.60**

Tank and Secondary Containment Quantity Information

					Tank Dimensions		
Tank Number	Maximum Tank Volume (gal)	Area or Containment Number	Containment Volume (gal)	Concrete Containment Surface Area (ft^2)	Tank Diameter (ft)	Height or Length (ft)	Surface Area (ft^2)
WASTEWATER PRETREATMENT SYSTEM							
Truckwash/Unloading Area							
UT1	1,191	1	9,045	2,700.00	5'w x 9'l x 4.5'h		216.00
Neutralization Reactor							
NR1	2,538	3	3,790	386.50	6	13.2	305.36
Rotary Drum Filter							
RF1	330	6	914	374.00	3	6	63.62
RF2	175	6	n/a		2.6	4.6	48.19
RF3	255	6	n/a		3.1	5.7	63.06
Acid Tanks							
AT1	8,253	7	27,841	2,052.00	12	10	603.19
AT2	13,194	7	n/a		12	14.5	772.83
AO1	211	7	n/a		3	4	51.84
WW1	18,109	7	n/a		12	22	1,055.58
Caustic/Reactives							
CT3	33,108	8	49,187	$ 3,198.00	12.75	36.5	1,717.38
CT1	33,108	8	n/a		12.75	36.5	1,717.38
CT2	33,108	8	n/a		12.75	36.5	1,717.38
CT4	33,108	8	n/a		12.75	36.5	1,717.38
Final EffluentLeachate Storage Area							
EF1	357,422	9	565,415	17,416.33	60	16.9	6,013.02
EF2	357,422	9	n/a		60	16.9	6,013.02
WASTEWATER FINAL TREATMENT SYSTEM							
Evaporator Area							
FT1	2,234	13A	5,124	3,807.00	6.33	31	679.42
FT2	2,234	13A	n/a		6.33	31	679.42
FT3	2,234	13A	n/a		6.33	31	679.42
EF4	1,625	13A	n/a		6.33	12	301.58
EB2	1,017	13A	n/a		5	12	227.77
Distillation Area							
DF1	176	13B	8,292	1,974.00	3	3.33	38.45
EF3	1,625	13B	n/a		6.4	12	305.61
EB1	1,059	13B	n/a		5	10	196.35
CF1	1,075	13B	n/a		4	10	150.80
CF2	1,075	13B	n/a		4	10	150.80
CF3	1,075	13B	n/a		4	10	150.80
CF4	1,075	13B	n/a		4	10	150.80
CF5	1,075	13B	n/a		4	10	150.80
CF6	1,253	13B	n/a		4	12	175.93
CF7	1,075	13B	n/a		4	10	150.80
CF8	1,075	13B	n/a		4	10	150.80
CF9	1,075	13B	n/a		4	10	150.80
Evaporator Overflow							
EO1	5,514	14	6,735	513.00	6.87	20.51	516.80
Miscellaneous Tank Systems							
T6	1,409,947	19	1,644,562	NA - Double Wall Tank	100	24	15,393.84
T6 Unload Pad				800.00			
Total	**2,329,050**		**Total**	**33,220.83**		**Total**	**42,260.17**
WASTE STABILIZATION SYSTEM							
Stabilization Tanks							
ST1	17,952	20	23,338	8,560.00	20'w x 20'l x 6'h		1,280.00
ST2	17,952	21	23,338		20'w x 20'l x 6'h		1,280.00
Total	**35,904**		**Total**	**8,560.00**		**Total**	**2,560.00**

REVISED POST-CLOSURE COST ESTIMATE

Table 1
Post-Closure Cost Estimate Summary Table

Waste Management Unit	Year That Post-Closure Care Began	Post-Closure Time Remaining (years)	Annual Ground Water Monitoring Cost ($/year)	Annual Leachate Management Cost ($/year)	Annual Maintenance Cost ($/year)	Total Post-Closure Cost for Remaining Years ($)	Final Post-Closure Certification	Total Post-Closure Cost
Drum Cell	1987	3	$ 16,539.60	$ 57,000.00	$ 6,355.00	$ 239,683.80	$ 7,920.00	**$ 247,603.80**
Cell 1	1989	5	$ -	$ 6,080.00	$ 2,261.00	$ 41,705.00	$ 7,920.00	**$ 49,625.00**
Cell 2	1989	5	$ -	$ 8,360.00	$ 2,561.00	$ 54,605.00	$ 7,920.00	**$ 62,525.00**
Cell 3	1989	5	$ -	$ 15,960.00	$ 2,561.00	$ 92,605.00	$ 7,920.00	**$ 100,525.00**
Cell 4	1990	6	$ -	$ 157,320.00	$ 2,261.00	$ 957,486.00	$ 7,920.00	**$ 965,406.00**
Cell 5	1987	3	$ 7,518.00	$ 94,240.00	$ 2,511.00	$ 312,807.00	$ 7,920.00	**$ 320,727.00**
Cell 6	1992	8	$ 6,014.40	$ 31,160.00	$ 2,461.00	$ 317,083.20	$ 7,920.00	**$ 325,003.20**
Cell 7	1990	6	$ -	$ 99,560.00	$ 2,261.00	$ 610,926.00	$ 7,920.00	**$ 618,846.00**
Cell 8	1990	6	$ 7,518.00	$ 20,520.00	$ 2,511.00	$ 183,294.00	$ 7,920.00	**$ 191,214.00**
Cell 10	1994	10	$ 9,021.60	$ 12,920.00	$ 4,661.00	$ 266,026.00	$ 7,920.00	**$ 273,946.00**
Cell 11	1994	10	$ 13,532.40	$ 121,600.00	$ 6,011.00	$ 1,411,434.00	$ 7,920.00	**$ 1,419,354.00**
Cell 12	1999	15	$ 6,014.40	$ 70,680.00	$ 5,761.00	$ 1,236,831.00	$ 7,920.00	**$ 1,244,751.00**
Cell 13	1999	15	$ 6,014.40	$ 26,600.00	$ 5,761.00	$ 575,631.00	$ 7,920.00	**$ 583,551.00**
Cell 14	2002	18	$ 6,014.40	$ 35,720.00	$ 5,761.00	$ 854,917.20	$ 7,920.00	**$ 862,837.20**
Cell 15	Operational	30	$ 23,499.80	$ 76,000.00	$ 36,379.00	$ 4,076,364.00	$ 7,920.00	**$ 4,084,284.00**
Cell 5 GW Corrective Action	1995	11	$ 207,093.00	$ -	$ -	$ -	$ -	**$ 2,278,023.00**
SUBTOTALS			**$ 308,780.00**	**$ 833,720.00**	**$ 90,077.00**	**$ 11,231,398.20**	**$ 118,800.00**	**$ 13,628,221.20**
							15% CONTINGENCY:	**$ 2,044,233.18**
							TOTAL POST-CLOSURE COST FOR THE FACILITY:	**$15,672,454.38**

Table 2
Post -Closure Cost Estimate Rate Schedule

Item		Rates	Units	Comments
Ground Water Monitoring				
Analytical Cost - Background Well	$	122.00	per sample	
Analytical Cost - Downgradient Well	$	432.00	per sample	
Sample shipping cost	$	50.00	per sample	
Cell 5 - VOC analytical cost	$	75.00	per sample	
Leachate Management Unit Costs				
Onsite Treatment Cost	$	1.16	per gallons	
Offstie Treatment Cost - deep well injection	$	1.16	per gallons	
Disposal at TM Deer Park Services, LP (TMI)	$	0.15	per gallon	8-2010 quote
Trans to Deer Park, TX	$	0.53	per gallon	$2,439 /5000 gallons - Triad Quote
Labor to collect lechate on site	$	0.03	per gallon	$15/hr x 1 person/day x 365days/year/1,348,000 gal/yr
Truck to collect leachate on site	$	0.05	per gallon	$24/hr X 1 truck/day x 365 days/year/1,348,000 gal/yr
	$	0.76	per gallon	Driver can do other labor on site as well
Labor Rates				
Maintenance	$	20.00	per hour	
Operator	$	15.00	per hour	
Truck Driver	$	15.00	per hour	
Laborer	$	8.00	per hour	
Inspector	$	18.00	per hour	
Professional Engineer	$	74.00	per hour	
Technical Staff	$	57.00	per hour	
Technician	$	30.00	per hour	
Clerical	$	25.00	per hour	
Equipment Rates				
Well pump replacement cost	$	1,500.00	each	
Leachate pump replacement cost - 1 Hp	$	600.00	each	
Leachate pump replacement cost - 3 Hp	$	600.00	each	
Leachate pump replacement cost - 6 Hp	$	2,500.00	each	
Backhoe/loader cost	$	19.00	per hour	
Pickup	$	7.00	per hour	
3500 Gallon Water Truck	$	24.00	per hour	
Cell 15 Vegetation Maintenance Rates				
Mowing and Spot Re-Seeding Event	$	100.00	per acre of cap	

Table 3
Post Closure Cost Estimate - Drum Cell

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost are assigned to Cell 15	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	11	$ 432.00	$ 4,752.00
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ 4,752.00	$ 712.80
1.4	Sampling shipping cost	sample	11.0	$ 50.00	$ 550.00
1.5	Ground Water Sampling Field Labor Cost - technician	hours/well	2.0	$ 30.00	$ 660.00
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ 1,567.50
1.7	Reproduction cost	wells	11.0	$2.50	$ 27.50
1.8	Total Ground Water Montoring Cost per Event	$/event			$ 8,269.80
1.9	Sampling events per year	event/yr	2	$8,269.80	$ 16,539.60
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ 16,539.60**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	75,000	$ 0.76	$ 57,000.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 57,000.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year)	hours/well/evnt	5.0	$ 30.00	$ 3,300.00
	- One pump per well replaced during 30 year post closure period	pumps/year	0.4	$ 1,500.00	$ 550.00
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ 3,850.00**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 1 Hp pump	each	1	$ 600.00	$ 600.00
	- Total Annual Pump Cost	$/yr			**$ 600.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer	hours/yr	8	$ 8.00	$ 64.00
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 272.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 6,355.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 79,894.60
4.2	Number of years remaining in post-closure	years	3		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**3**	**$ 79,894.60**	**$ 239,683.80**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	$/hr	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	$/hr	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Post-Closure**	**$**			**$ 247,603.80**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed. Downgradient wells have been assigned to other landfll that will end post-closure after Cell 1.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.

Table 4
Post Closure Cost Estimate - Cell 1

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	-	$ 432.00	$ -
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ -	$ -
1.4	Sampling shipping cost	sample	-	$ 50.00	$ -
1.5	Ground Water Sampling Field Labor Cost - technician	hours/well	2.0	$ 30.00	$ -
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ -
1.7	Reproduction cost	wells	-	$2.50	$ -
1.8	Total Ground Water Montoring Cost per Event	$/event			$ -
1.9	Sampling events per year	event/yr	2	$0.00	$ -
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ -**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	8,000	$ 0.76	$ 6,080.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 6,080.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	-	$ 1,500.00	$ -
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ -**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 1 Hp pump	each	0.5	$ 600.00	$ 300.00
	- Total Annual Pump Cost	$/yr			**$ 300.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 2,261.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 8,341.00
4.2	Number of years remaining in post-closure	years	5		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**5**	**$ 8,341.00**	**$ 41,705.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	$/hr	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	$/hr	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Post-Closure**	**$**			**$ 49,625.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed. Downgradient wells have been assigned to other landfll that will end post-closure after Cell 1.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.

Table 5
Post Closure Cost Estimate - Cell 2

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	-	$ 432.00	$ -
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ -	$ -
1.4	Sampling shipping cost	sample	-	$ 50.00	$ -
1.5	Ground Water Sampling Field Labor Cost - technician	hours/well	2.0	$ 30.00	$ -
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ -
1.7	Reproduction cost	wells	-	$2.50	$ -
1.8	Total Ground Water Montoring Cost per Event	$/event			$ -
1.9	Sampling events per year	event/yr	2	$0.00	$ -
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ -**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	11,000	$ 0.76	$ 8,360.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 8,360.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	-	$ 1,500.00	$ -
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ -**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 1 Hp pump	each	1	$ 600.00	$ 600.00
	- Total Annual Pump Cost	$/yr			**$ 600.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 2,561.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 10,921.00
4.2	Number of years remaining in post-closure	years	5		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**5**	**$ 10,921.00**	**$ 54,605.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	$/hr	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	$/hr	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Post-Closure**	**$**			**$ 62,525.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed. Downgradient wells have been assigned to other landflls that will end post-closure after Cell 2.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.

Table 6
Post Closure Cost Estimate - Cell 3

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	-	$ 432.00	$ -
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ -	$ -
1.4	Sampling shipping cost	sample	-	$ 50.00	$ -
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ -
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ -
1.7	Reproduction cost	wells	-	$2.50	$ -
1.8	Total Ground Water Montoring Cost per Event	$/event			$ -
1.9	Sampling events per year	event/yr	2	$0.00	$ -
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ -**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	21,000	$ 0.76	$ 15,960.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 15,960.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	-	$ 1,500.00	$ -
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ -**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 1 Hp pump	each	1	$ 600.00	$ 600.00
	- Total Annual Pump Cost	$/yr			**$ 600.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 2,561.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 18,521.00
4.2	Number of years remaining in post-closure	years	5		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**5**	**$ 18,521.00**	**$ 92,605.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Construction and Certification**	**$**			**$ 100,525.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed. Downgradient wells have been assigned to other landflls that will end post-closure after Cell 3.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 7
Post Closure Cost Estimate - Cell 4

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	-	$ 432.00	$ -
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ -	$ -
1.4	Sampling shipping cost	sample	-	$ 50.00	$ -
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ -
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ -
1.7	Reproduction cost	wells	-	$ 2.50	$ -
1.8	Total Ground Water Montoring Cost per Event	$/event			$ -
1.9	Sampling events per year	event/yr	2	$ -	$ -
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ -**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	207,000	$ 0.76	$ 157,320.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 157,320.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	-	$ 1,500.00	$ -
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ -**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 1 Hp pump	each	0.5	$ 600.00	$ 300.00
	- Total Annual Pump Cost	$/yr			**$ 300.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 2,261.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 159,581.00
4.2	Number of years remaining in post-closure	years	6		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**6**	**$ 159,581.00**	**$ 957,486.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Construction and Certification**	**$**			**$ 965,406.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed. Downgradient wells have been assigned to other landflls that will end post-closure after Cell 4.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 8
Post Closure Cost Estimate - Cell 5

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	5.0	$ 432.00	$ 2,160.00
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ 2,160.00	$ 324.00
1.4	Sampling shipping cost	sample	5.0	$ 50.00	$ 250.00
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ 300.00
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ 712.50
1.7	Reproduction cost	wells	5.0	$ 2.50	$ 12.50
1.8	Total Ground Water Montoring Cost per Event	$/event			$ 3,759.00
1.9	Sampling events per year	event/yr	2	$ 3,759.00	$ 7,518.00
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ 7,518.00**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	124,000	$ 0.76	$ 94,240.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 94,240.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	0.2	$ 1,500.00	$ 250.00
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ 250.00**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 1 Hp pump	each	0.5	$ 600.00	$ 300.00
	- Total Annual Pump Cost	$/yr			**$ 300.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 2,511.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 104,269.00
4.2	Number of years remaining in post-closure	years	3		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**3**	**$ 104,269.00**	**$ 312,807.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Construction and Certification**	**$**			**$ 320,727.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed. Cell 5 corrective action monitoring cost are inclued in another cost spreadsheet.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 9
Post Closure Cost Estimate - Cell 6

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	4.0	$ 432.00	$ 1,728.00
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ 1,728.00	$ 259.20
1.4	Sampling shipping cost	sample	4.0	$ 50.00	$ 200.00
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ 240.00
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ 570.00
1.7	Reproduction cost	wells	4.0	$ 2.50	$ 10.00
1.8	Total Ground Water Montoring Cost per Event	$/event			$ 3,007.20
1.9	Sampling events per year	event/yr	2	$ 3,007.20	$ 6,014.40
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ 6,014.40**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	41,000	$ 0.76	$ 31,160.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 31,160.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	0.1	$ 1,500.00	$ 200.00
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ 200.00**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 1 Hp pump	each	0.5	$ 600.00	$ 300.00
	- Total Annual Pump Cost	$/yr			**$ 300.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 2,461.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 39,635.40
4.2	Number of years remaining in post-closure	years	8		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**8**	**$ 39,635.40**	**$ 317,083.20**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$5,920
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$2,000
5.3	**Final Post-Closure Certification Cost**	**$**			**$7,920**
6.0	**Total Cost for Construction and Certification**	**$**			**$325,003**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 10
Post Closure Cost Estimate - Cell 7

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	-	$ 432.00	$ -
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ -	$ -
1.4	Sampling shipping cost	sample	-	$ 50.00	$ -
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ -
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ -
1.7	Reproduction cost	wells	-	$ 2.50	$ -
1.8	Total Ground Water Montoring Cost per Event	$/event			$ -
1.9	Sampling events per year	event/yr	2	$ -	$ -
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ -**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	131,000	$ 0.76	$ 99,560.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 99,560.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	-	$ 1,500.00	$ -
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ -**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 1 Hp pump	each	0.5	$ 600.00	$ 300.00
	- Total Annual Pump Cost	$/yr			**$ 300.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 2,261.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 101,821.00
4.2	Number of years remaining in post-closure	years	6		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**6**	**$ 101,821.00**	**$ 610,926.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Construction and Certification**	**$**			**$ 618,846.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed. Downgradient wells have been assigned to other landflls that will end post-closure after Cell 7.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 11
Post Closure Cost Estimate - Cell 8

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	5	$ 432.00	$ 2,160.00
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ 2,160.00	$ 324.00
1.4	Sampling shipping cost	sample	5.0	$ 50.00	$ 250.00
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ 300.00
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ 712.50
1.7	Reproduction cost	wells	5.0	$ 2.50	$ 12.50
1.8	Total Ground Water Montoring Cost per Event	$/event			$ 3,759.00
1.9	Sampling events per year	event/yr	2	$ 3,759.00	$ 7,518.00
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ 7,518.00**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	27,000	$ 0.76	$ 20,520.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 20,520.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	0.2	$ 1,500.00	$ 250.00
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ 250.00**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 1 Hp pump	each	0.5	$ 600.00	$ 300.00
	- Total Annual Pump Cost	$/yr			**$ 300.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 2,511.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 30,549.00
4.2	Number of years remaining in post-closure	years	6		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**6**	**$ 30,549.00**	**$ 183,294.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Construction and Certification**	**$**			**$ 191,214.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 12
Post Closure Cost Estimate - Cell 10

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	6	$ 432.00	$ 2,592.00
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ 2,592.00	$ 388.80
1.4	Sampling shipping cost	$/sample	6.0	$ 50.00	$ 300.00
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ 360.00
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ 855.00
1.7	Reproduction cost	$/wells	6.0	$ 2.50	$ 15.00
1.8	Total Ground Water Montoring Cost per Event	$/event			$ 4,510.80
1.9	Sampling events per year	event/yr	2	$ 4,510.80	$ 9,021.60
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ 9,021.60**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	17,000	$ 0.76	$ 12,920.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 12,920.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	0.2	$ 1,500.00	$ 300.00
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ 300.00**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 3 Hp pump	each	4	$ 600.00	$ 2,400.00
	- Total Annual Pump Cost	$/yr			**$ 2,400.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 4,661.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 26,602.60
4.2	Number of years remaining in post-closure	years	10		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**10**	**$ 26,602.60**	**$ 266,026.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Construction and Certification**	**$**			**$ 273,946.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 13
Post Closure Cost Estimate - Cell 11

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	9	$ 432.00	$ 3,888.00
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ 3,888.00	$ 583.20
1.4	Sampling shipping cost	$/sample	9.0	$ 50.00	$ 450.00
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ 540.00
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ 1,282.50
1.7	Reproduction cost	$/wells	9.0	$ 2.50	$ 22.50
1.8	Total Ground Water Montoring Cost per Event	$/event			$ 6,766.20
1.9	Sampling events per year	event/yr	2	$ 6,766.20	$ 13,532.40
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ 13,532.40**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	160,000	$ 0.76	$ 121,600.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 121,600.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	0.3	$ 1,500.00	$ 450.00
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ 450.00**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 3 Hp pump	each	6	$ 600.00	$ 3,600.00
	- Total Annual Pump Cost	$/yr			**$ 3,600.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 6,011.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 141,143.40
4.2	Number of years remaining in post-closure	years	10		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**10**	**$ 141,143.40**	**$ 1,411,434.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Construction and Certification**	**$**			**$ 1,419,354.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 14
Post Closure Cost Estimate - Cell 12

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	4	$ 432.00	$ 1,728.00
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ 1,728.00	$ 259.20
1.4	Sampling shipping cost	$/sample	4.0	$ 50.00	$ 200.00
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ 240.00
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ 570.00
1.7	Reproduction cost	$/wells	4.0	$ 2.50	$ 10.00
1.8	Total Ground Water Montoring Cost per Event	$/event			$ 3,007.20
1.9	Sampling events per year	event/yr	2	$ 3,007.20	$ 6,014.40
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ 6,014.40**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	93,000	$ 0.76	$ 70,680.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 70,680.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	0.1	$ 1,500.00	$ 200.00
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ 200.00**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 3 Hp pump	each	6	$ 600.00	$ 3,600.00
	- Total Annual Pump Cost	$/yr			**$ 3,600.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 5,761.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 82,455.40
4.2	Number of years remaining in post-closure	years	15		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**15**	**$ 82,455.40**	**$ 1,236,831.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Construction and Certification**	**$**			**$ 1,244,751.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 15
Post Closure Cost Estimate - Cell 13

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	4	$ 432.00	$ 1,728.00
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ 1,728.00	$ 259.20
1.4	Sampling shipping cost	$/sample	4.0	$ 50.00	$ 200.00
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ 240.00
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ 570.00
1.7	Reproduction cost	$/wells	4.0	$ 2.50	$ 10.00
1.8	Total Ground Water Montoring Cost per Event	$/event			$ 3,007.20
1.9	Sampling events per year	event/yr	2	$ 3,007.20	$ 6,014.40
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ 6,014.40**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	35,000	$ 0.76	$ 26,600.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 26,600.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	0.1	$ 1,500.00	$ 200.00
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ 200.00**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 3 Hp pump	each	6	$ 600.00	$ 3,600.00
	- Total Annual Pump Cost	$/yr			**$ 3,600.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 5,761.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 38,375.40
4.2	Number of years remaining in post-closure	years	15		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**15**	**$ 38,375.40**	**$ 575,631.00**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Construction and Certification**	**$**			**$ 583,551.00**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 16
Post Closure Cost Estimate - Cell 14

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	-	$ 122.00	$ -
1.2	Downgradient wells analytical cost	wells	4	$ 432.00	$ 1,728.00
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ 1,728.00	$ 259.20
1.4	Sampling shipping cost	$/sample	4.0	$ 50.00	$ 200.00
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ 240.00
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ 570.00
1.7	Reproduction cost	$/wells	4.0	$ 2.50	$ 10.00
1.8	Total Ground Water Montoring Cost per Event	$/event			$ 3,007.20
1.9	Sampling events per year	event/yr	2	$ 3,007.20	$ 6,014.40
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ 6,014.40**
2.0	**Leachate Management Cost**				
2.1	Four year average leachate generation rate.	gallons/year	47,000	$ 0.76	$ 35,720.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 35,720.00**
3.0	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	0.1	$ 1,500.00	$ 200.00
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ 200.00**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 3 Hp pump	each	6	$ 600.00	$ 3,600.00
	- Total Annual Pump Cost	$/yr			**$ 3,600.00**
3.3	**Final Cover Maintenance**				
	- Backhoe/loader	hours/yr	8	$ 19.00	$ 152.00
	- Operator	hours/yr	8	$ 15.00	$ 120.00
	- Pickup	hours/yr	8	$ 7.00	$ 56.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	8	$ -	$ -
	- Total Final Cover Maintenance Cost per year	**$/yr**			**$ 328.00**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector (Included in Leachate Disp. Cost)	hours/wk	1	$ -	$ -
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 364.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 5,761.00**
4.0	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 47,495.40
4.2	Number of years remaining in post-closure	years	18		
4.3	**Total Post-Closure for the Years Remaining**	**$**	**18**	**$ 47,495.40**	**$ 854,917.20**
5.0	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6.0	**Total Cost for Construction and Certification**	**$**			**$ 862,837.20**

Notes:

1) Assumes two (2) sampling events per year for 5 background and 35 downgradient wells
2) Background wells sampling costs are assigned to Cell 15, a landfill that has not been closed.
3) This cost estimate assumes it will take 9 hours/day for 9 days to sample 40 wells which equals 2 hours/wells.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 17
Post Closure Cost Estimate - Cell 15

Item	Item Description	Unit	Quantity	Rate	Total Cost
1	**Ground Water Monitoring**				
1.1	Background wells analytical cost	wells	5	$ 122.00	$ 610.00
1.2	Downgradient wells analytical cost	wells	13	$ 432.00	$ 5,616.00
1.3	QA/QC cost - 15% of analytical cost	percentage	15%	$ 6,226.00	$ 933.90
1.4	Sampling shipping cost	$/sample	18.0	$ 50.00	$ 900.00
1.5	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ 1,080.00
1.6	Administrative/Reporting Cost - technical staff	hours/well	2.5	$ 57.00	$ 2,565.00
1.7	Reproduction cost	$/wells	18	$ 2.50	$ 45.00
1.8	Total Ground Water Montoring Cost per Event	$/event			$ 11,749.90
1.9	Sampling events per year	event/yr	2	$ 11,749.90	$ 23,499.80
1.10	**Total Ground Water Montoring Cost per year**	**$/year**			**$ 23,499.80**
2	**Leachate Management Cost**				
2.1	Assume average leachate generation rate.	gallons/year	100,000	$ 0.76	$ 76,000.00
2.2	3500 Gallon Water Truck (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.3	Truck Driver (Included in Leachate Disp. Cost)	hrs/day	1	$ -	$ -
2.4	**Total Leachate Collection Cost per year**	**$/year**			**$ 76,000.00**
3	**Annual Maintenance Costs**				
3.1	**Ground water monitoring system maintenance**				
	- Technician (2 events/year) (Included in Leachate Disp. Cost)	hours/well/evnt	5.0	$ -	$ -
	- One pump per well replaced during 30 year post closure period	pumps/year	0.6	$ 1,500.00	$ 900.00
	-Total Ground Water Maintenance Cost per year	**$/yr**			**$ 900.00**
3.2	**Leachate System Maintenance**				
	- LCRS pump replacement - 6 Hp pump	each	13	$ 2,500.00	$ 32,500.00
	- Total Annual Pump Cost	$/yr			**$ 32,500.00**
3.3(a)	**Final Cover Erosion/Repairs Maintenance**				
	- Backhoe/loader	hours/yr	10	$ 19.00	$ 190.00
	- Operator	hours/yr	10	$ 15.00	$ 150.00
	- Pickup	hours/yr	10	$ 7.00	$ 70.00
	- Laborer (Included in Leachate Disp. Cost)	hours/yr	10	$ -	$ -
	- Total Final Cover Erosion Maintenance Cost per year	**$/yr**			**$ 410.00**
3.3(b)	**Final Cover Vegetation Maintenance**				
	- Mowing and Spot Re-Seeding per Event	per acre	97.1	$ 100.00	$ 9,712.00
	- Inspector (Included in Leachate Disp. Cost)	event/yr	2	$ -	$ -
	- Total Final Cover Vegetation Maintenance Cost per year	**$/yr**			**$ -**
3.4	**Weekly Inspections**				
	- Pickup	hours/wk	1	$ 7.00	$ 7.00
	- Inspector	hours/wk	1	$ 18.00	$ 18.00
	- Total Weekly Inspection Cost per year (weekly x 52)	**$/yr**			**$ 1,300.00**
3.5	**Annual Administrative Review/Reporting**				
	- Professional Engineer	hours	4	$ 74.00	$ 296.00
	- Technical Staff Observation	hours	14	$ 57.00	$ 798.00
	- Clerical	hours	7	$ 25.00	$ 175.00
	- Total Administrative Review/Reporting cost/year	**$/yr**			**$ 1,269.00**
3.6	**Total Annual Maintenance Cost**	**$/yr**			**$ 36,379.00**
4	**Total Post-Closure Cost per year**				
4.1	Cost per year (1.10 + 2.4 + 3.6)	$/yr			$ 135,878.80
4.2	Number of years remaining in post-closure	years	30		
4.3	**Total Post-Closure for the Years Remaining**	**$**	30	**$ 135,878.80**	**$ 4,076,364.00**
5	**Final Post-Closure Certification**				
5.1	- Professional Engineer	man-hour	80	$ 74.00	$ 5,920.00
5.2	- Clerical Administrative	man-hour	80	$ 25.00	$ 2,000.00
5.3	**Final Post-Closure Certification Cost**	**$**			**$ 7,920.00**
6	**Total Cost for Construction and Certification**	**$**			**$ 4,084,284.00**

Notes:

1) Assumes two (2) sampling events per year for five (5) facility background wells and thirteen (13) Cell 15 downgradient wells
2) Facility background wells sampling costs are assigned to Cell 15, a landfill that has not been closed.
3) This cost estimate assumes it will take 2 hours/well to sample the well network.
4) This cost estimate assumes that 200 hours per year for administration and reporting which equals 2.5 hours/well
5) This cost estimate assumes shipping cost is $200/day.
5) Soil samples will analyzed for Appendix IX constituents.

Table 18
Post Closure Cost Estimate - Cell 5 Corrective Action

Item	Item Description	Unit	Quantity	Rate	Total Cost
1.0	**Ground Water Monitoring**				
1.1	Monitoring analytical cost	wells	21	$ 75.00	$ 1,575.00
1.2	QA/QC cost - 15% of analytical cost	percentage	15%	$ 1,575.00	$ 236.25
1.3	Sampling shipping cost	$/sample	21	$ 50.00	$ 1,050.00
1.4	Ground Water Sampling Field Labor Cost	hours/well	2.0	$ 30.00	$ 1,260.00
1.5	Total Ground Water Montoring Cost per Event	$/event			$ 4,121.25
1.6	**Total Monitoring Cost per year**	**$/yr**	**2**	**$ 4,121.25**	**$ 8,242.50**
2.0	**Ground Water Pumping Cost**				
2.1	Four year average volume of water pump	gallons/year	251,000.0		
2.2	**Disposal at TMI in Deer Park, TX**	**$/yr**	**251,000.0**	**$ 0.76**	**$ 190,760.00**
3.0	**Maintenance Cost**				
3.1	Pump replacement cost	$/year	0.33	**$ 600.00**	**$ 198.00**
4.0	**Administrative Review & Reporting**				
4.1	Technician Staff	$/yr	120	$ 57.00	$ 6,840.00
4.2	Clerical	$/yr	40	$ 25.00	$ 1,000.00
4.3	Reproduction cost	well	21	$ 2.50	$ 52.50
4.4	**Total Administrative Review and Reporting Cost**	$/yr			**$ 7,892.50**
5	**Total Cost for Cell 5 Corrective Action**				
5.1	Total cost per year	$/yr			**$ 207,093.00**
5.2	**Total Cost**	**$**	11	**$ 207,093.00**	**$ 2,278,023.00**

Notes:

1) Assumes two (2) sampling events per year. Total monitoring length is estimated to be 30 year, which started in mid-1995.
2) There are 14 corrective action well to be monitored. MW 5-A2 and MW 5-A3 will be monitored for Cell 5 corrective action purposes as part of the routine semi-annual Cell 5 detection monitoring program.
3) This cost estimate assumes the samples will be analyzed for four(4) volatile organic compounds (VOCs) by SW-846, Methods 8240 or 8260 or equivalent test method should analytical methods change in the future.
4) RFI-14 wil be pumped continuously at a rate equal to the average production for 2008.
5) Use onsite water water treatment plant cost for estimate. It is estimated there will be 16 years remaining on the clean-up. Since the life expectancy of the facility is greater than the clean-up time, onsite disposal costs were used.
6) Maintenance of the pumping system is minimal. Pump replacement is estimated to occur once every 3 years (0.33 pumps/year) and the pump cost is estimated to be ~$1,500 each.
7) Semi-annual Cell 5 reports must be submitted to ODEQ. The reports include the ground water monitoring results. Approximately 120 hours per year of effort will be required for corrective action activiites

EXHIBIT H

CQA PLAN

LONE MOUNTAIN FACILITY

CONSTRUCTION QUALITY ASSURANCE PLAN

FOR

LANDFILL CONSTRUCTION AND CLOSURE

6/13/2014

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

Geosyntec Consultants
Oklahoma Certificate of Authorization No. 1996
Exp. 06/30/2014

Rev 0, July 2010
Rev 1, May 2012
Rev 2, June 2014

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REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

6/13/2014

TABLES

REGISTERED PROFESSIONAL ENGINEER
SCOTT M. GRAVES
19710
OKLAHOMA

6/13/2014

FIGURES

APPENDICES

1. INTRODUCTION

Clean Harbors Lone Mountain, LLC (CHLM) has developed this Construction Quality Assurance (CQA) Plan to ensure that its Lone Mountain Facility complies with the applicable EPA and Oklahoma Department of Environmental Quality (ODEQ) regulations and demonstrates that the regulatory requirements for the construction of the landfills and closure caps, including the inspection of liners, will be met. The plan is intended as a reference for both construction and regulatory personnel. The CQA Plan has been organized following the outline recommended in the EPA Technical Guidance Document entitled "Quality Assurance and Quality Control for Waste Containment Facilities". The plan first discusses the project organization, responsibilities, and authority of the various personnel involved. It describes the qualifications of personnel involved in the administration and implementation of the CQA Plan. The inspection activities associated with the project are defined. The plan discusses meetings that should be held during the project. Finally, the plan details the documentation required to provide evidence of adherence to this plan. When the various components of this plan are combined, the resulting efforts will produce a well-constructed and operational project.

This CQA Plan is devoted to Construction Quality Assurance. In the context of this document, Construction Quality Assurance and Construction Quality Control are defined as follows:

<u>Construction Quality Assurance (CQA)</u> - A planned and systematic pattern of means and actions designed to periodically monitor and document the overall activities to assure adequate confidence that materials and/or services meet contractual and regulatory requirements and will perform satisfactorily in service.

<u>Construction Quality Control (CQC)</u> - Those actions which provide a means to directly observe, monitor, test, measure, document, and regulate the characteristics of an item or service in relation to contractual and regulatory requirements.

In the context of this document:

- CQA refers to means and actions employed by the CQA Consultant to assure conformity of the Project "Work" with this CQA Plan, the Construction Drawings and Project Specifications; and
- Construction Quality Control refers to those actions taken by the Contractor, Manufacturer, or Geosynthetic Installer to verify that the materials and the workmanship meet the requirements of this CQA Plan, the Construction

Drawings, and the Project Specifications. In the case of soil components, CQC is combined with CQA and is provided by the CQA Consultant. In the case of the geosynthetic components and piping of the Work, CQC is provided by the Manufacturer and Geosynthetic Installer and the Contractor. CQA testing of soil, pipe, concrete, and geosynthetic components is provided by the CQA Consultant.

This plan provides construction quality assurance activities for the construction of the landfill cells as well as for the construction of the closure caps for the cells. Many of the activities described in this plan are the same for both landfill cell construction and closure construction. In cases where landfill cell construction and closure construction activities differ, the applicable inspection activities will be clearly identified. Applicable inspection activities associated with both the construction of the landfill cell and the construction of the closure cap are described in the first table of the "Inspection Activities" section of this plan.

Until approved by the ODEQ, a revised CQA Plan will not be in effect, and the current ODEQ-approved CQA Plan will remain in force. When approved by the ODEQ, a revised CQA Plan will be implemented for the next cell or cap to be constructed; however, if approved during the time of landfill cell or cap construction, the revised plan can be implemented immediately.

2. ORGANIZATION, RESPONSIBILITY, AND AUTHORITY

Clean Harbors Lone Mountain, LLC (CHLM) is the operator of the Lone Mountain Facility. As such, it recognizes that it is ultimately responsible for the design, construction, and operation of the land disposal facilities at the site. CHLM recognizes that it is responsible for complying with the requirements of the permitting agency in these activities, including providing the proper documentation that the facility was constructed as specified in the CQA Plan. CHLM has the authority and responsibility to determine what individuals or organizations will be responsible for the design, CQA, and construction activities. CHLM also has the authority and responsibility for determining the organizational structure for these activities.

2.1 Organization and Authority

CHLM has assigned the above-indicated responsibilities of overseeing all activities associated with the design and construction of their hazardous waste landfills and closure caps, with specific emphasis to the CQA program, to the Vice President, Technology (aka Engineering). The organizational structure for the CQA program is illustrated in Figure 1. The solid lines on Figure 1 represent the lines of authority; whereas, the dashed lines indicate lines of communication. As illustrated in Figure 1, the Vice President, Technology is ultimately responsible for all activities associated with the successful construction of the waste landfill cells and closure caps. The construction quality assurance program has been organized so that all individuals involved in construction will ultimately report to the CQA Officer, who will be an employee and report to the Vice President, Technology.

The implementation of the CQA Plan occurs through the CQA Officer. Functioning under the CQA Officer will be the Certifying Engineer. The CQA personnel will be responsible for ensuring that the work items indicated above associated with the landfill are constructed in accordance with the plans and the specifications defined herein. CQA personnel will be responsible for reviewing Contractor submittals, performing field observations, conducting the various tests and making observations as specified in the CQA Plan, for documenting those tests, and for reporting and reviewing the test results.

2.2 Responsibilities

The specific responsibilities of the various individuals or entities presented in the organizational chart of Figure 1 are presented below.

2.2.1 Vice President, Technology

As indicated, the Vice President, Technology (aka Engineering) has the responsibility for overseeing all aspects associated with the design and construction of the landfills and closure caps at the Lone Mountain Facility. The Vice President, Technology assumes the responsibilities of the facility owner. Thus, the responsibilities include ensuring that the design and construction of the cells and closure caps comply with the requirements of the permitting agency as well as with operational needs. He has the authority to select and dismiss organizations or individuals charged with the design, CQA, and construction activities.

2.2.2 Construction Manager

The Construction Manager is responsible for implementing the construction, and overseeing contractors. The Construction Manager may be a representative of CHLM or a sub consultant.

2.2.3 CQA Officer

The Vice President, Technology has assigned the CQA Officer the specific responsibility of overseeing the construction quality assurance aspects of the project. The CQA Officer coordinates aspects of the CQA Plan with the Certifying Engineer; however, the CQA Officer reports to the Vice President, Technology, and thus, functions independently from the certifying and design engineers or the construction contractors. The CQA Officer has the authority to stop any aspect of the work that is not in compliance with the CQA Plan. Work would then be resumed with the approval of the CQA Officer once corrective action has been approved and taken to correct any defective work. In the absence of the CQA Officer from the work site, the duties and responsibilities of the CQA Officer shall be delegated to one of the CQA personnel. The specific responsibilities of the CQA Officer include:

1. Review the design documents and plans to ensure that the CQA Plan can be implemented.
2. Train CQA personnel on CQA requirements and procedures.
3. Schedule and coordinate CQA inspection activities.
4. Direct and support the CQA personnel by confirming that regular calibration of testing equipment is properly conducted and recorded; confirming that testing equipment, personnel, and procedures do not change over time or by ensuring that any changes do not adversely impact the inspection process; confirming that test data are accurately recorded and maintained; and verifying that raw data are properly recorded, validated, reduced, summarized, and interpreted.

5. On at least a monthly basis, provide to the Vice President, Technology a summary report documenting the following:

    a. CQA activities completed during the preceding month.

    b. A summary of all non-conforming or suspected non-conforming work and corrective actions taken during the preceding month.

    c. Identification of work that the CQA Officer has accepted.

    d. An indication that to the best of his/her knowledge and based on the CQA activities completed to date, the construction is being accomplished in accordance with the CQA Plan.

    e. An evaluation of the degree of reconciliation between non-conforming work and the specifications as defined in the CQA Plan, and the ability of the CQA program to meet the quality objectives of the CQA Plan.

6. Verify that the CQA personnel are completing and properly documenting all on-site observations and tests required to ensure compliance with the CQA Plan.

7. Approve specific corrective measures to be implemented during construction where deviation occurs from the CQA Plan.

8. Review, coordinate, and approve CQA activities to ensure that testing and documentation are complete and accurate.

9. During the course of construction and following completion of the project, maintain a project CQA file for maintaining and storing the originals or copies of all data sheets and reports that are generated in carrying out the CQA Plan as identified herein. A complete copy of these reports will be maintained on-site.

10. Oversee preparation of the final construction report at the completion of the project, which will be a compilation of all of the daily reports generated during the course of construction, as well as a summary report of all CQC and CQA activities.

2.2.4 Design Engineer

The responsibilities of the Design Engineer include those design activities that occur during the construction of the project. The specific responsibilities include the following:

1. Review and approve design changes to the landfill (including closure cap) to meet the operational requirements of the owner and the permitting requirements

of the agencies.

2. Coordinate design changes with the CQA Officer.

3. Approve corrective measures to be implemented where deviation occurs during construction from the design.

The Design Engineer has authority to work within the framework of the design and CQA Plan. The Design Engineer does not have the authority to make any decisions that would alter the design and the CQA Plan for the facility without the express approval of the CQA Officer (refer to Section VI - Change Control Procedures) and the regulatory agency (ODEQ), where applicable.

2.2.5 Certifying Engineer

The responsibilities of the Certifying Engineer include certifying that construction of the cell or cap was accomplished in accordance with the design documents and CQA Plan. The specific responsibilities include the following:

1. Review and approve the CQA documentation.

2. Document corrective measures to be implemented where deviation from the CQA Plan occurs during construction. Document action to the CQA file.

The Certifying Engineer has the authority to work within the framework of the design and the CQA Plan. The Certifying Engineer does not have the authority to make any decisions that would alter the design and the CQA Plan for the facility without the express approval of the CQA Officer (refer to Section VI - Change Control Procedures) and the regulatory agency (ODEQ), where applicable.

2.2.6 Construction Quality Assurance (CQA) Personnel

The Construction Quality Assurance (CQA) personnel will work under the direction of the CQA Officer and Certifying Engineer to ensure that the CQA Plan is executed properly. The authority of the CQA personnel will be limited to the performance of required testing, observation, and documentation requirements of the CQA Plan. The CQA personnel will have authority to stop work as per the directive of the CQA Officer. Specific responsibilities of the CQA personnel include the following:

1. Perform on-site observation, testing, and documentation of the work in progress to monitor/document compliance with the CQA Plan.

2. Verify that the equipment used in testing has been calibrated.

3. Conduct required testing as defined in the CQA Plan.

4. Record results of all observations and tests daily. Work that fails to meet the

CQA Plan after corrective action has been taken should be reported immediately to the Construction Manager so that alternate corrective action can be determined. This reporting shall be included in the daily construction reports.

5. Verify that corrective action has been taken (where required) and recorded on the daily construction reports.
6. Prepare and assemble the required documentation of the results of on-site observations, testing, and reviews conducted by CQA personnel.
7. Provide the results of on-site observations, testing, and documentation of the work in progress to the CQA Officer and Certifying Engineer.

3. PROJECT MEETINGS

Meetings should be held during the project to enhance communications between personnel responsible for design, inspection, and construction of the project. These meetings will include a pre-construction CQA meeting and monthly CQA meetings.

3.1 Pre-Construction CQA Meetings

Pre-construction CQA meetings should be held prior to the commencement of soils-related construction activities and geosynthetics-related installation activities for the project. Those to attend should include the CQA Officer, the Certifying Engineer, CQA personnel, and the soils construction contractor and/or liner installation contractor, as appropriate. Copies of the CQA Plan should be distributed to the above-indicated parties prior to the pre-construction CQA meeting. Minutes of the meeting should be prepared and transmitted to all personnel in attendance. The CQA Officer should notify the Oklahoma Department of Environmental Quality (ODEQ) of the proposed pre-construction meeting date. Items to be discussed in this meeting should include, but not be limited to:

1. Familiarizing each organization with the CQA Plan and their role relative to the CQA Plan.
2. Reviewing the responsibilities, lines of authority, and communication of each organization.
3. Discussing the procedures for observations and testing.
4. Discussing procedures for handling construction deficiencies, repairs, and retesting.
5. Reviewing methods for reporting and documenting testing and inspection activities.
6. Reviewing methods for distributing and storing documents and reports.
7. Identifying work areas and equipment and materials storage areas.
8. Identifying required submittals for the project.
9. Discussing procedures employed by soils contractor and/or geosynthetics installer to train their operators and/or technicians to provide a quality work product.

3.2 Monthly CQA Meetings

Meetings should be held approximately once per month to discuss the progress of the project. Those to attend should include the CQA Officer, the Certifying Engineer, a representative of the CQA personnel, and a representative of the contractors (as needed). Items to be discussed in this meeting should include, but not be limited to:

1. Discussing the CQA, and construction activities and accomplishments of the previous month.
2. Exchanging, reviewing, and discussing required documentation of construction, observation, and testing activities.
3. Defining and discussing problems or deficiencies associated with the work and CQA activities. Documenting problems or deficiencies discussed in the CQA file.
4. Reviewing alternative solutions.
5. Implementing corrective actions to resolve problems or deficiencies.

CQA personnel should prepare minutes of the meeting for distribution to all attending parties.

4. PERSONNEL QUALIFICATIONS

In order to ensure that the various individuals associated with the CQA Plan are properly qualified, general qualifications have been developed for each position. This should ensure that participating individuals are properly qualified for the performance of their assigned tasks. The following details each position and the generally expected qualifications. Note that the qualifications listed below are not absolutes. They are presented as a general guideline for the relative education, experience, and knowledge of the personnel.

1. CQA Officer
   a. Undergraduate technical degree, preferably in engineering, engineering geology, or closely associated disciplines.
   b. Registered Professional Engineer.
   c. Three years experience in the waste industry.
2. Design Engineer
   a. Undergraduate engineering degree.
   b. Professional Engineer registered in the state of Oklahoma.
   c. Three years experience in the waste industry.
3. Certifying Engineer
   a. Undergraduate engineering degree.
   b. Professional Engineer registered in the State of Oklahoma.
   c. Three years experience in the waste industry.
4. Surveyor
   a. Registered land surveyor in the State of Oklahoma.
5. CQA Personnel
   a. Previous experience in executing the required inspection activities or working under the direct supervision of another CQA individual with previous experience.

5. INSPECTION ACTIVITIES

This section of the CQA Plan describes the inspection activities (observations and tests) that will be performed by the CQA personnel during the construction and installation of the work elements associated with the project.

The major work elements that comprise the project; the specifications governing each work element; and the CQA activities to be performed in a timely manner to ensure a quality outcome of each work element are identified in Table 1 for landfill cell construction and closure. Table 1 identifies the observations and tests to be conducted by the CQA personnel, the frequency of observations and tests, the acceptance/rejection criteria that will be used in the evaluation of the tests, and how the observations and tests are to be recorded and documented.

Measuring and testing equipment (M&T) used for critical items of construction must be controlled in order to ensure the quality outcome of the project. M&T equipment used for critical items of construction include the nuclear gage, scales, sealed single ring infiltrometer, two-stage boutwell test, large-scale block sampling & testing etc. used by the CQA personnel associated with the testing of the soils-related aspects of the project, surveying equipment used by the surveyor in checking and controlling construction grades, pressure gages used in the non-destructive testing of the HDPE liner welds, and tensiometers for peel and shear tests of HDPE welds. This equipment is to be calibrated in accordance with manufacturer recommendations and annually at a minimum. At the beginning of the project, Contractor will provide the CQA personnel with documentation confirming that the equipment has been calibrated. This documentation will be included in the construction documentation report at the completion of construction of the project.

6. CHANGE CONTROL PROCEDURES

This section describes the procedure for initiating and approving minor changes in a timely manner necessary to maintain or enhance quality during construction. As the need for minor changes occurs, they must be controlled by both the permittee and by the regulatory agency. The types of changes will be divided into two categories: (1) Change Control Procedures, and (2) Class 1 Permit Modifications.

In either case, mutual agreement between the regulatory authority and the permittee as to the proposed change type will normally occur prior to submission of supporting documentation to the regulatory agency for processing. Verbal communication of the proposed change will aid in this determination, and the following procedures will be applicable to both types of changes:

1. Design engineering and construction changes will be initiated by, but not limited to, CQA personnel, the CQA Officer, the Vice President, Technology, or other parties which the Vice President, Technology designates.
2. All proposed design engineering and construction changes will be reviewed and approved by the Design Engineer. If approved, the Design Engineer will provide documentation to the CQA Officer indicating that the proposed change(s) will meet the minimum quality requirements of the project.
3. The CQA Officer will review and approve or disapprove the proposed change(s) based on the documentation and recommendation of the Design Engineer.
4. If the CQA Officer approves the proposed change(s), verbal notification of the proposal should be made to the Oklahoma Department of Environmental Quality (ODEQ). The scope of the proposal will be discussed to obtain a mutual understanding and agreement as to the proper type of change action. If the decision indicates a Class 1 Permit Modification, the appropriate application package format will be assembled and submitted to the ODEQ for approval. The requirements of 40 CFR 270.42 will be followed in this scenario. If the determination allows a change control procedure, then the documentation of the change should be submitted to the ODEQ within 48 hours of verbal notification.
5. All documentation submitted to the agency regarding change(s) will be included in the construction documentation report. As-built details of the project will be prepared that will reflect approved changes.

7. DOCUMENTATION

Documentation of construction and inspection activities associated with the CQA Plan will consist of daily recordkeeping and a final report to be prepared under the direction of the CQA Officer. Daily reporting procedures associated with the CQA activities are described based on specific work elements in Table 1 of the inspection activities section and are to be performed in a timely manner.

The results of testing and observations as recorded on the daily construction reports will be reviewed and accepted by the CQA Officer or his designee. Acceptance of the daily construction reports will consist of either counter-signing the forms directly or having one of the CQA personnel sign the forms indicating that they have been reviewed and accepted on behalf of the CQA Officer. During the construction of the facility, the CQA Officer will be responsible for maintaining and storing the originals or copies of all data sheets and reports that are generated in carrying out the CQA Plan as identified herein. A complete copy of these reports will be maintained on-site during the course of construction.

The CQA Officer will direct the preparation of a final construction documentation report at the completion of the project. The CQA report will provide a summary of CQA activities and will demonstrate that the construction satisfied the CQA Plan and applicable State and Federal regulations. The CQA report will provide an evaluation of the degree of reconciliation between non-conforming work and the specifications as defined in the CQA Plan and the ability of the CQA program to meet the quality objectives of the CQA Plan.

The CQA Report will also include an overall summary of construction activities associated with the project. The Certifying Engineer will certify that construction within the inside edge of the anchor trench was accomplished in accordance with the CQA Plan and any field design, engineering, or construction changes were made in accordance with the change control procedure and/or a Class 1 Permit Modification.

The CQA Report will provide a summary of the soils observation and testing aspects of the construction or closure project. The report will certify that the soils portions of the cell or closure cap were constructed in accordance with the CQA Plan and any field design, engineering, or construction changes made in accordance with the change control procedure and/or a Class 1 Permit Modification.

The CQA Report will include a summary of the geosynthetic liner observation and testing aspects of the project. The report will certify that the geosynthetic liner portions of the cell are constructed in accordance with the CQA Plan and any field design, engineering, or construction changes made in accordance with the change control procedure and/or a Class 1 Permit Modification.

The Final CQA Report will be certified by the Lone Mountain Facility Manager and will be submitted to the ODEQ within sixty (60) days of completion of the project. The completion of the project will be defined as the date when the CQA Officer notifies the Facility Manager in writing that the project is complete. The CQA Officer must certify that the CQA Plan has been successfully carried out, and that the unit meets the requirements of 40 CFR 264.301 (c) or (d).

TABLES

TABLE 1
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
CELL FOUNDATION PREPARATION		Review geotechnical investigation report to become familiar with the expected site conditions.
	CLEARING & GRUBBING: Remove vegetation, debris, organic, or deleterious material from below areas to receive embankment material. Soft and yielding spots shall be corrected by drying and recompacting the material or shall be removed and disposed of as directed by the CQA Officer. Material so removed shall be replaced with a suitable material and shall be compacted to the density requirements.	Observe the clearing and grubbing operation. Document that clearing and grubbing is complete and that vegetation, roots, and highly organic soil within appropriate areas is removed.
	SCARIFICATION & COMPACTION: Foundation area – Scarify to a depth of at least 8 inches. Moisten and compact to at least 95.0% of the Standard Proctor density as determined by ASTM D-698 with a moisture content of minus (-) 2.0% to plus (+) 4.0% of the optimum moisture content.	Observe and document that required activities are performed. Perform compaction testing on recompacted subgrade using applicable methods indicated in Appendix A at a minimum frequency of one per 12,000 sf. The location of the tests shall be chosen on a random basis. Report any deficiencies to the Construction Manager and confirm that deficient areas are reworked and meet the specification. Obtain signature and approval of geosynthetic subgrade acceptance from Geosynthetic Installer, as appropriate.
	Remove unsuitable material as required. Foundation approval.	Identify soft and yielding areas of subgrade and report to Construction Manager for overexcavation and removal. Identify areas of unsuitable material for removal from project area. Observe and document that required activities are performed. Perform compaction testing on recompacted subgrade using applicable methods indicated in Appendix A at a minimum frequency presented in Table 2. Report any deficiencies to the Construction Manager and confirm that deficient areas are reworked and meet the specification. Obtain signature and approval of geosynthetic subgrade acceptance from Geosynthetic Installer, as appropriate.
BORROW PREPARATION	Remove vegetation, debris, organic, or deleterious material from borrow areas.	Observe the clearing and grubbing operation. Document that clearing and grubbing is complete and that vegetation, roots, and highly organic soil within appropriate areas is removed.
CELL EMBANKMENT, ROADWAYS, AND RAMP	**BORROW:** Satisfactory embankment materials are defined as those complying with the Unified Soil Classification of CL, ML, SM, SC, or combinations of these materials.	Perform and document visual classification of borrow source materials. Notify Construction Manager of soils not meeting the specifications. Obtain laboratory moisture-density relationship (Proctor) and classification tests on every 10,000 cubic yards or change in material based on the Unified Soil Classification System (see Table 2). Applicable testing methods are referenced in Appendix A.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
CELL EMBANKMENT, ROADWAYS, AND RAMP (Cont.)	**EMBANKMENT AND BACKFILL:** Embankment and backfill material will be placed with heavy construction equipment and will be compacted to at least 95% of the Standard Proctor density as determined by ASTM D-698 with a moisture content of minus (-) 2.0% to plus (+) 4.0% of the optimum moisture content. Material compacted with hand operated tampers will be compacted to 95% of the maximum dry density as determined by ASTM D698 with a moisture content of minus (-) 2.0% to plus (+) 4.0% of the optimum moisture content.	Perform and document compaction testing on embankment and backfill using applicable methods indicated in Appendix A at a minimum frequency of one per 12,000 square feet per lift. These tests will be performed on the roadways and ramps at a frequency of one test per 300 linear feet per lift. The location of the tests shall be chosen on a random basis. Report any deficiencies to the Construction Manager and confirm that deficient areas are reworked and meet the specification.
	PLACEMENT: Backfill and fill shall be placed in uniform lifts. A lift is defined as 8 inches or less in loose depth for material compacted by heavy compaction equipment, and 4 inches or less in loose depth for material compacted by hand-operated tampers. In anchor trenches, the first lift shall be placed not more than 12 inches in loose depth with subsequent lifts placed 4 inches in loose depth. Where backfill is placed around pipes, the first lift will be placed to a depth slightly higher than the spring-line of the pipe, to prevent displacement of the pipe. When fill is to be placed and the work area is covered with snow, the snow must be removed. If the top layer of the embankment becomes frozen or if frozen material is delivered to the embankment, the frozen material must be removed.	Observe and document fill and backfill placement and compaction operations. Report any deficiencies to the Construction Manager and confirm that deficient areas are reworked and meet the specification. Observe and document that snow is removed and that conditions meet the specifications. Report any deficiencies to the Construction Manager and confirm corrective actions are implemented in deficient areas.
	GRADING: In-place embankment materials and natural soils shall be fine graded to the design elevation and typical sections. Acceptable grading tolerance limits for finished embankment surfaces shall be as follows: Interior embankment slopes and the cell floor (subgrade for the clay liner): zero to minus 0.8 of a foot. All other embankment slopes: + or - 0.2 of a foot Perform survey measurement at completion by licensed surveyor. Survey points shall be on at least a 60 foot grid and at all control points. Surveyor shall indicate where the embankment meets the design line and grade. Submit survey data to design engineer, Construction Manager and CQA Officer.	Review certified as-built survey for compliance to CQA Plan and design documents. Notify Construction Manager of deficiencies. Review final survey data. Verify the frequency of survey measuring points. Verify that the surveyor certified that the construction is to the specified line and grade.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
CLAY LINER	**BORROW:** Satisfactory clay liner material is defined as CL, CH, ML, and MH soils or combinations of these materials based on the Unified Soil Classification with at least 50 percent passing the No. 200 sieve and having a compacted permeability of less than or equal to 1 x 10^{-7} cm/sec.	Test compacted clay liner material in accordance with minimum frequencies listed in Table 2. Observe and document sampling locations and confirm that samples are representative of source material. Notify Construction Manager of unacceptable material and observe and document that this material is not utilized. For every 10,000 cubic yards or change in material, based on the Unified Soil Classification System, develop water content - density acceptance criteria, “Acceptable Zone”, based on EPA Technical Guidance Document EPA/600/R-93/182. This procedure involves preparing and compacting each sample with standard compaction procedures (6 moisture density points each), testing each compacted specimen per ASTM D5084, and plotting the dry unit weights, molding water contents, and permeability of each moisture density point. Finally, the “Acceptable Zone” will be determined based on hydraulic conductivity alone and will be ultimately determined by the CQA Officer.
	PROCESSING: These procedures are necessary to provide suitable material for construction of the low permeable soil layer. 1. Mine satisfactory clay soil from the borrow area. 2. If needed to achieve a permeability of 1 x 10^{-7} cm/sec., uniformly apply deflocculant to the clay soils at a rate of at least 3 pounds per 50 cubic feet of loose clay soil, or at a lesser rate if approved by the Design Engineer, the Certifying Engineer and the CQA Officer. 3. Mix the deflocculant thoroughly into the clay soil using a “Bomag-type” mixer. 4. Add moisture to the clay soil to bring it near the optimum moisture content. 5. Mix and break up the material to maintain dry clod sizes smaller than 1 inch. Continue to mix and break up the material to produce a homogeneous material.	Observe and document processing operations, including but not limited to, deflocculant application rates, equipment used, clod size, uniformity of moisture content. Confirm that all soil mixing provides a homogeneous soil. Report any deficiencies to the Construction Manager and confirm that all deficient areas/soil are reworked and meet the specification.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
TEST FILL	A "large test fill" pad with plan dimensions of at least 60 by 75 feet by 3-ft thick is to be constructed to establish the procedure to be used during construction of the clay liner. In addition, the contractor shall construct at least one additional large test fill for each additional process proposed for use during placement and compaction of clay liner material using large compaction equipment. A "small test fill" pad with plan dimensions of at least 5 by 5 feet by 2-ft thick is to be constructed for each process proposed for use during placement and compaction of clay liner material using small self-propelled or hand-operated compaction equipment. The test fills are to be constructed and tested in accordance with the following specifications: 1. For the large test fill, a minimum of five lifts of prepared clay shall be placed. The first lift is defined as 12 inches or less of loose material and subsequent lifts are defined as 6 inches or less of loose material (with the additional stipulation that the subsequent lifts cannot be greater than 2 inches thicker than the length of the feet on the sheepsfoot compactor). 2. For the small test fill, a lift is defined as 4 inches or less of loose material. 3. The clay is to be compacted by equipment proposed for use during construction of the clay liner. In the large test fill, a minimum of one pass of the sheepsfoot compactor or soil disk will be required over the previously compacted lift of soil to tie the new lift into the preceding lift. Compaction of the test fills are to be accomplished by at least four passes of suitable compaction equipment. 4. The clay is to be compacted so that each moisture/density test falls in the "Acceptable Zone" as determined by the Project Engineer based on water content-density criteria after EPA Technical Guidance Document EPA/600/R-93/182. 5. The clay is to be compacted to provide a permeability of less than 1×10^{-7} cm/sec. 6. In the large test fill, a minimum of one pass of the smooth-drum roller will be required on the final lift to simulate finishing procedures. 7. Procedures used to construct the test fills must be reviewed and approved by the CQA Officer and Certifying Engineer prior to allowing clay to be placed inside the landfill.	Observe, document and test the construction of the clay liner test fills. Verify that the same or similar equipment will be used in clay liner construction. Perform field and laboratory testing at the minimum frequencies in Table 2 for the Test Fill. Field test locations shall be chosen on a random basis. Notify Construction Manager of unacceptable material and observe and document that this material is not utilized. Report any deficiencies to the Construction Manager and confirm that all deficient areas/soil are reworked and meet the specification. Perform in-situ hydraulic conductivity tests to measure the vertical hydraulic conductivity of the test fill using either: (i) sealed single ring infiltrometer; (ii) Stage 1 of a Two-Stage Borehole (Boutwell) test per ASTM D 6391; or (iii) large scale block sampling (see Appendix A.2). If the Two-Stage Borehole method is used, as stated in ASTM D 6391, Stage 2 may be omitted since the objective is to measure the vertical hydraulic conductivity. For the large test fill: if either the single-ring infiltrometer or large scale test block methods are used, perform the testing at a frequency of one per test pad. If the Two-Stage Borehole test method is used, perform one test series per test pad (comprised of a group of five borehole tests), as recommended by ASTM D 6391. For a small test fill, perform one test per test pad using any of the above three methods. Approval of clay test pad shall require a passing single-ring infiltrometer or large-scale block test; or if a two-stage borehole method is used, three passing field permeability test results. Prepare memorandum summarizing test fill construction procedures and test results.

TABLE 1 Continued

LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
CLAY LINER PLACEMENT	The clay liner will be prepared, placed, and compacted using the same equipment, and mixing and compacting procedures that were approved in the test fill pads.	Observe, document and clay liner during placement and compaction operations. Document that procedures used follow the same procedures used to construct the test fill pads. Report any deficiencies to the Construction Manager and confirm that all deficient areas/soil are reworked and meet the specification.
	Clay liner material will be constructed so that each moisture/density test falls in the "Acceptable Zone" as previously determined by water content-density criteria (EPA Technical Guidance Document EPA/600/R-93/182). The probe hole from density testing shall be filled with compacted bentonite by filling the hole in approximately 3-inch loose lifts and compacting each lift.	Observe, document and clay liner during placement and compaction operations. Perform tests at minimum frequencies presented in Table 2. Location of tests shall be chosen on a random basis. Report any deficiencies to the Construction Manager and confirm that all deficient areas/soil are reworked and meet the specification.
	The depth of the first lift of uncompacted material shall be no greater than 12 inches. The depth of subsequent lifts of uncompacted material shall be no greater than 6 inches with the additional stipulation that the subsequent lifts shall not be greater than 2 inches thicker than the length of the feet on the sheepsfoot compactor. The loose lift depth will be no greater than 4 inches for hand operated compactors. A minimum of one pass of the sheepsfoot compactor or disk will be required over the previously compacted lift of soil to tie the new lift into the preceding lift. Compaction of the clay liner is to be accomplished by at least four passes of suitable compaction equipment. To prevent the clay surface from drying, water will be applied to the clay surface as necessary or as directed by the CQC/CQA personnel. When clay liner/clay cap material is to be placed and the work area is covered with snow, the snow must be removed.	Observe and document that compaction lift thickness specifications and the requirement for passage of the sheepsfoot compactor are met during clay liner placement/compaction operations. Observe clay liner surface for drying. Observe and document that corrective actions are accomplished, as necessary. Observe and document site conditions. Confirm that all deficient areas/snow are removed and replaced or reworked to meet the specification.
	No fill may be placed on frozen material. The frozen material may be removed so that fill may be placed. No frozen material may be incorporated in the fill. The clay liner/clay cap material shall not become contaminated with other soils or debris.	Observe and document site conditions. Confirm that all deficient areas/soil are removed and replaced or reworked to meet the specification. Observe soil conditions throughout excavation, stockpiling, unloading, placement and compaction. Notify Construction Manager of unacceptable material and observe and document that this material is removed and not utilized.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
CLAY LINER PLACEMENT (Cont.)	**GRADING**: During cell construction final grading of the surface of the clay liner on the cell floor shall be zero (0) to plus two (2) tenths of a foot above design grade, the surface of the clay liner placed on the interior slopes shall be zero (0) to plus three (3) tenths of a foot above design grade provided that no depression in the clay liner surface exceed one inch. Clay liner beneath the leachate withdrawal pipes in sump areas must be at design grade with no deviations. The grading tolerance limits for the clay liner at the inside toe of the embankment shall provide for a gradually rounded surface rather than the strict 3H:1V slope. Final grading for clay cap construction shall be greater than or equal to design grade provided that no depression in the clay liner exceeds one inch. Conduct survey measurement at completion by a licensed surveyor. Survey points shall be on at least a 60 foot grid and at all control points. Surveyor shall indicate where the clay liner/clay cap meets design line and grade. Final grading and finishing efforts on the surface of the clay liner shall leave the surface free of sharp objects and deleterious material that might damage the overlying geosynthetics. Finishing efforts on the surface of the completed clay liner shall be accomplished by at least one pass of the smooth-drum roller and be relatively smooth (i.e., ≤ a one inch vertical drop). The surface shall provide a firm foundation (i.e., remolded by strong finger pressure). Rocks that can be seen are to be removed. Desiccation cracks larger than one-fourth inch wide and one inch deep shall be filled with dry powdered bentonite.	Review and approve survey data. Notify Contractor of areas not meet design specifications and requirements. Observe, approve and document final grading and finishing efforts for compliance with specification. Report any deficiencies to the Construction Manager and confirm that all deficient areas are reworked and meet the specification.
INTERIM CLAY COVER (BEDDING CLAY) FOR CAP GEOSYNTHETIC CLAY LINER (GCL)	**BORROW:** The Geosynthetic Clay Liner (GCL) component of the final cap shall be underlain by a layer of interim clay cover soil at least twelve (12) inches thick. This interim cover layer will be placed above the graded waste, incrementally by landfill operations or during closure construction, to serve as both interim cover prior to cap construction, and also as bedding material for the GCL. This soil layer will meet the same specifications as the embankment material, except that it will also have a maximum particle size of one inch.	Test borrow source material in accordance with requirements in Table 2. Applicable testing methods are referenced in Appendix A. Review test results for compliance with specifications and approve material for use, as appropriate.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
INTERIM CLAY COVER (BEDDING CLAY) FOR CAP GEOSYNTHETIC CLAY LINER (GCL) (Cont.)	Since the upper part of the layer will serve as bedding material for the GCL, the upper 6-inches of the interim clay cover will be placed and compacted to $\geq$95.0% of the maximum dry density as determined by ASTM D-698 with a moisture content of minus (-) 4.0% to plus (+) 2.0 % of the optimum moisture content. If the interim clay cover material has already been placed by landfill operations, the upper 6-inches shall be reworked and re-compacted to meet this specified density and moisture range as part of final cap construction (i.e., just prior to GCL installation). The feet on sheepsfoot compactors, if used to compact interim clay cover bedding material, shall be less than or equal to 6 inches in length.	As part of cap CQA just prior to GCL installation: Observe and document re-working/re-compacting of the upper 6-inches of this layer for compliance with specifications. Perform and document in-place density tests in accordance with the requirements in Table 2. The location of the tests shall be chosen on a random basis. Report any deficiencies to the Construction Manager and confirm that all deficient areas are reworked and meet the specification.
	GRADING: In-place interim clay cover bedding material shall be graded to the designed elevation and typical sections. Acceptable grading tolerance limits for finished surfaces shall be plus two (2) tenths (+0.2') to minus zero (0) tenths of a foot (-0.0'). Survey measurements shall be performed at completion by licensed surveyor. Survey points shall be on at least a 60 foot grid and at all control points. Surveyor shall indicate where the bedding clay surface meets the design line and grade.	Review survey data and verify that the survey documents for the interim clay cover bedding layer meet the grading tolerances of the CQA Plan. Notify the Construction Manager of any deficiencies and confirm that all deficient areas are reworked and meet the specification.
	PLACEMENT: A minimum of twelve (12) inches of interim clay cover (bedding clay) material is required. Placement of the layer is to be done in such a manner as to not incorporate the underlying waste into the material. The interim clay cover (bedding clay) material is to be free of deleterious materials. The layer will be graded to conform to the planned final drainage patterns. The surface will be shaped to avoid forming any depressions that might pond water. Just prior to cap construction, before GCL installation, he thickness of the interim clay cover bedding layer should be verified through direct measurement on a grid no greater than 100 feet square. Just prior to GCL installation, the surface of the interim clay cover (bedding clay) material shall be proof-rolled to a smooth condition, with no protrusions, ridge marks, or abrupt grade changes. Any minor depressions, holes, etc. may be filled with soil or bentonite. The interim clay cover (bedding clay) layer shall not be saturated immediately prior to the placement of the overlying GCL.	Observe and document Re-working/re-compaction of the upper 6-inches of the interim clay cover (bedding clay) layer as part of cap construction. Review measurement of layer thickness, notify Construction Manager of deficiencies and confirm that all deficient areas are reworked and meet the specification. Observe and document proof rolling of surface of the interim clay cover (bedding clay) prior to GCL placement.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
GEOSYNTHETIC CLAY LINER (GCL)	**REQUIREMENTS PRIOR TO GCL PLACEMENT:** Prior to GCL installation, the liner contractor shall provide to the CQC and CQA personnel: 1. Quality Control Certificates: Submit conformance testing results in accordance with requirements of Table 3. Materials shall meet minimum requirements in Table 3. GCL whose certificates indicate material which does not meet the specifications are to be marked conspicuously and removed from the construction area. 2. GCL Panel Placement Plan: The installer is to provide a GCL panel placement plan to the CQA Officer prior to the placement of the GCL. 3. GCL rolls shall be identified, handled and stored in accordance with ASTM D5888. Each roll shall be identified and labeled with a unique identification number.	Review required submittals for compliance with specifications. Reject rolls not meeting the minimum specifications. Confirm that rejected rolls are removed from the project area and are unused. Observe and document material handling procedures and equipment. Review, comment and approve GCL panel layout as appropriate. Observe panel installation for conformance with panel layout plan.
	GCL SUBGRADE SURFACE PREPARATION: The surface onto which the GCL is to be placed shall be free of sharp objects and visible rocks in the surface. The surface shall be regular with no abrupt changes in grade greater than a one (1) inch vertical drop. Final rolling of the soil surface shall be by pneumatic tired equipment, vibratory roller, or steel wheel roller. The soil surface onto which the GCL is to be placed shall not have standing water.	Observe and document subgrade conditions prior to placement of GCL panels for compliance with specification. Notify Construction Manager of deficiencies and confirm that all deficient areas are reworked and meet the specification.
	GCL PLACEMENT: The GCL panels are to be placed as closely as practical to the GCL panel placement plan approved by the CQA Officer. No GCL seams should be placed parallel to the direction of toe on slopes greater than 5%. No equipment shall be allowed on the surface of the GCL that will cause damage. GCL shall be placed in general accordance with ASTM D 6102. The installation of GCL must start at the ridge line and proceed down the slope with the upper end extending at least three feet beyond the ridge line. The GCL shall be covered by HDPE liner the same working day that the GCL is placed. HDPE liner shall extend at least one foot beyond the edge of the GCL.	Observe and document that panels are placed in general accordance with the approved GCL placement plan and specifications. Approve any minor alterations to the placement plan prior to the change being made. Maintain an as-built drawing showing the general placement of the panels. Notify Construction Manager of deficiencies and confirm that all deficient areas are reworked and meet the specification. Document all corrective actions.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
GEOSYNTHETIC CLAY LINER (GCL) (Cont.)	Rolls of GCL are to be inspected for defects as they are unwound. Defects may include, but are not limited to: equipment damage, holes, thin spots, areas where the bentonite does not adhere to the support fabric, or the support fabric has become separated, signs of contamination by foreign material, or areas where the GCL has become completely hydrated.	Observe condition of GCL rolls during deployment and identify areas of damage to Construction Manager.
	Defective areas in the GCL shall be repaired with an additional piece of GCL placed over the area with a minimum overlap of twelve (12) inches beyond the defective area.	Observe and document the repair of defective areas and verify that the repair is in conformance with the specification items.
	GCL shall be installed in a dry condition and shall be protected from becoming wet. GCL that is allowed to become wet shall be removed and replaced with GCL that is dry. GCL seams shall maintain a minimum of six (6) inches of overlap along the edges and twelve (12) inches at end joints at all times regardless of shrinkage. Seams shall be free of foreign material. Seams shall run parallel with the greatest slope. For seams across the slope, the uphill panel should overlap the downhill panel.	Observe and document subgrade conditions meet the specifications prior to GCL deployment. Identify any GCL panels that have become wet for removal. Verify and document that adequate overlap has been provided and maintained. Verify that corrective actions have been taken where required.
	The GCL shall be installed so as to provide a surface with minimal creases or irregularities.	Observe condition of GCL rolls during deployment. Identify areas of damage, creasing, or irregularities to Construction Manager. Verify that corrective actions have been taken where required.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
FLEXIBLE MEMBRANE LINERS	**REQUIREMENTS PRIOR TO LINER PLACEMENT:** Prior to HDPE liner installation, the HDPE manufacturer shall provide a list of at least five previous projects totaling a minimum of 1,000,000 square feet for which the manufacturer provided HDPE, or if the manufacturer has previously provided their services at the facility, the submittal of the above items is not required since these will have been submitted for previous projects. The HDPE liner contractor shall provide a summary of previous installations and previous warranty work, or if the liner contractor has previously provided their services at the facility, the submittal of the above items is not required since these will have been submitted for previous projects. Prior to HDPE liner installation, the liner contractor shall provide the CQA and CQC personnel: 1) Conformance testing results in accordance with requirements of Table 4. Materials shall meet minimum requirements in Table 3. Rolls that do not meet project requirements shall be marked conspicuously and removed from the construction area. Manufacturer shall submit a statement that the following is true for the geomembrane to be used for this project: No post-consumer resin is used. The addition of reworked polymer (from the manufacturing process) to resin shall be permitted if it does not exceed 2% by weight, contains no encapsulated scrim, and is performed with appropriate cleanliness. Rolls shall not be deployed until approval from the CQA Consultant has been received. 2) Polymer Raw Material Certificates: The liner manufacturer is to supply certification that the resin meets the density specification defined in Table 4. 3) Welding Rod Certification: The welding rod manufacturer is to provide certification that the rod is of the same polymer as the sheet. 4) Résumé of Installation Superintendent: Installation superintendent is to have prior experience supervising installation of a minimum of one (1) million square feet of liner. 5) Résumés of Welding Technicians: There will be one welding supervisor designated per welding crew. The welding supervisor is to have experience welding a minimum of one (1) million square feet of liner. Welding technicians shall not be allowed to weld until approval has been received from the CQA personnel indicating that the welding technicians have been approved based on the required submittals.	Review submittals for conformance with specification. Reject any submittals that do not comply with specifications. Review manufacturer conformance testing frequencies and results in accordance with Table 4. Reject rolls not meeting the minimum specifications. Confirm that rejected rolls are removed from the project area and are unused.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
FLEXIBLE MEMBRANE LINERS (Cont.)	**LINER SURFACE PREPARATION:** The surface of the clay liner/clay cap or soil protective cover beneath the HDPE liner is to be free of sharp objects and deleterious material that might damage the overlying geosynthetics. Rocks that can be seen in the liner are to be removed. The surface of the completed clay liner/clay cap or soil protective cover shall be generally smooth (i.e., ≤ a one inch vertical drop). The surface shall provide a firm foundation. Desiccation cracks larger than one-fourth inch wide and one inch deep shall be filled with dry powdered bentonite. No standing water shall be allowed. Prior to the installation of HDPE liner, two conditions must be met, unless an alternative is specifically authorized by the ODEQ: 1. A minimum of one-eighth (1/8) of a cell/cap (or less if the ODEQ on-site inspector agrees) must be available for approval. 2. The ODEQ on-site inspector must be provided with the required elevation data for the top of the clay liner. Note: The material properties sheet and quality control certificates shall be signed by a responsible HDPE liner manufacturer employee and shall be notarized.	Observe the subgrade for the HDPE liner for conformance with specifications. Notify Construction Manager of any deficiencies and document corrective actions have been taken. Record findings of observations, review and actions taken.
	HANDLING OF HDPE LINER: Geomembrane rolls shall be identified, handled and stored in accordance with ASTM D4873. Each roll shall be identified and labeled with a unique identification number. HDPE liner shall be labeled with manufacturer, thickness, and roll number prior to shipment to the site. When transported to the site, the HDPE liner shall be handled by appropriate means so that no damage is caused to the liner. Transportation to the site shall be the responsibility of the installer. On-site unloading, storage, and handling is the responsibility of the installer. Liner materials shall be stored in a location away from possible sources of deterioration. Appropriate handling equipment shall be used to move HDPE liner. The liner shall not be dragged on the ground.	Observe and document material handling procedures and equipment. Notify Construction Manager of any deficiencies. Confirm and document that any damaged or improperly labeled rolls are removed from the construction area.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
FLEXIBLE MEMBRANE LINERS (Cont.)	**LINER PLACEMENT:** Prior to installation, the liner contractor shall present to the CQA Officer a liner placement plan. The plan shall indicate the panel configuration and location of seams. Seams shall be oriented parallel to the line of the maximum slope. Seams placed in high stress areas will be minimized (i.e., cell corners, parallel with the top of the embankment, or at the toe of the side slopes). No seams shall be placed parallel to and within 3 feet of the toe of the slope. To minimize the risk of damage by wind during placement, adequate loading on the HDPE liner to prevent uplift by wind shall be provided by sand bags or other means which will not damage the liner. Liner placement shall not proceed at an ambient temperature below 1^{o} C (34^{o} F) or above 40^{o} C (104^{o} F), unless approved by the CQA Officer and acceptable results are produced. The liner is to be placed as closely as practical to the liner placement plan. The as-built drawing will reflect modifications to the liner placement plan. Care shall be exercised to not damage the HDPE liner during installation.	Review and approve the panel placement plan. Notify the Construction Manager of any deficiencies. Observe and document that the liner is placed in accordance with the approved liner placement plan. Review and approve any modifications to the proposed placement plan during construction. If rejected, an alternative plan must be proposed and accepted or the previously approved plan must be followed.
	Rolls are to be inspected as they are unwound for equipment damage, holes, blisters, thin spots, undispersed raw materials, or any signs of contamination by foreign material. Note: In several instances, visual defects (such as blisters) are small enough that the repair of a visual defect may consist of placing a bead of extrudate from the extrusion welding gun over the visual defect. Welding beads placed to repair such visual defects are not considered extrusion welding and therefore do not require vacuum testing. Any form of hole or penetration through the liner must be patched with a liner cap which must be vacuum tested.	Observe the rolls during handling and placement for conformance to specifications. Notify Construction Manager of any damage or deficiencies. Confirm and document that corrective actions are performed, as required.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
FLEXIBLE MEMBRANE LINERS (Cont.)	**WELDING:** Field welding is to be accomplished by either the fusion method or the extrusion welding method. Prior to any welding (using either welding method) in both the morning and afternoon, a pre-weld test will be run for each technician/equipment combination. After cooling, coupons will be taken and will be tested for peel and shear. If any pre-weld test fails, then an additional pre-weld sample will be made and tested. After any second pre-weld test failure, two consecutive pre-weld samples must be made, tested, and have passing results before that particular technician/equipment combination is put into production welding. Shear testing stresses the top sheet in relation to the bottom sheet in a direction away from the weld. A passing result will occur when the upper or lower sheet fails. A failing result will occur when the weld fails. Peel testing stresses the top sheet in relation to the overlapped edge of the lower sheet in an effort to peel away the weld. A passing result will occur when the liner fails. A failing result will occur when the weld peels.	Observe and document welding procedures, including the type of weld, welded date, and the welding technician for each seam. Observe, document and review test welds. Approve test weld results and report deficiencies to Construction Manager and observe and document corrective actions.
	Seams shall be clean, dry, and have adequate overlap (minimum 3 inches) prior to welding. Overlap placement in high stress locations, such as cell corners, parallel with the top of the embankment, or at the toe of the side slopes, shall be minimized. No overlaps shall be placed parallel to and within 3 feet of the toe of the embankment. Seams must be aligned with the fewest amount of wrinkles or "fishmouths".	Observe the condition of the seam for conformance with specifications and report deficiencies to Construction Manager and observe and document corrective actions.
	NON-DESTRUCTIVE SEAM TESTING: Geosynthetic Installer shall perform non-destructive testing on all production fusion welds in accordance with ASTM D5820 and on all extrusion welds in accordance with ASTM D5641.	Observe and document non-destructive testing activities. Where defective results are obtained, require and verify that the seams are repaired in accordance with specifications for repair and/or patching.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
FLEXIBLE MEMBRANE LINERS (Cont.)	**DESTRUCTIVE SEAM TESTING:** Geosynthetic Installer shall perform destructive testing at a minimum frequency of every 500 lf (with a minimum of one sample per equipment/welder combination each shift). Locations shall be selected by CQA Consultant and shall be at non-critical locations such as anchor trench locations or leachate collection sumps whenever possible. Sample shall be a minimum of 38 inches by 12 inches. Samples shall be numbered consecutively. Remove two coupons of one-inch in width from the sample for field testing in the peel and shear modes. Field test the strips for peel and shear with a digital field tensiometer capable of quantitatively measuring shear and peel strengths. If one or more field tests fail in either peel or shear, implement procedures provided below. If the samples pass the field test, divide the sample into three approximately 12 inch x 12 inch samples (one portion to Geosynthetic Installer's independent laboratory for testing; one portion for the Owner's independent laboratory for testing; and one portion to the Owner for archiving). One sample shall be sent to an approved laboratory for peel and shear testing (ASTM D6392) by the Geosynthetic Installer. At least five replicate specimens should be tested for each test method. To be acceptable, four of the five replicates shall pass seam strength and peel adhesion criteria (Table 3). If destructive test seam failure is identified, the following procedures shall apply: a. Reconstruct the seam between any two passes test locations, or: b. Retrace the welding path to intermediate location, at 10 ft minimum from location of failed test in each direction and take samples for additional field tests. If the second test passes, then seam shall be either reconstructed or cap stripped between the two passes locations. If any sample fails, the process shall be repeated. **c.** The boundary samples shall be tested in the same manner as the original sample. In any case, acceptable seams shall be bounded by two pass test locations (i.e., above procedures shall be followed in both directions from original failed location. d. In the event that seam sample fails laboratory destructive test, then above procedures shall be followed considering laboratory tests exclusively. Because final seam must be bounded by two passing test locations, it may be necessary to take one or more samples for laboratory testing. e. Each sample hole and coupon hole shall be patched, along with the entire length of the defective seam.	Identify destructive sampling locations. Record locations on liner placement plan. Collect two 12x12 inch samples from Geosynthetic Installer. Test one sample (minimum 5 replicate specimens) for seam strength and peel adhesion. Archive remaining samples as directed by Owner. Review, document, and approve seams. Notify Construction Manager of any deficiencies and review and document corrective actions. Observe, review and document seam failures and corrective actions. Review laboratory test results for compliance with specifications and notify Construction Manager of passing tests and failures.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
FLEXIBLE MEMBRANE LINERS (Cont.)	Any sample holes in a fusion-welded seam shall be repaired by sealing the air space between the wedge tracks at both ends of the sample hole using a leister instrument and vice grips. A patch will be welded over any sample holes using the extrusion welding technique. Patches shall be circular or oval in shape, be of the same HDPE material as the liner, and extend a minimum of six (6) inches over the edge of the sample hole. The corners of the patches will have a radius of not less than three inches. Caps over seams shall also be extrusion welded. The welds on the patches and caps shall be non-destructive tested.	Observe patching and capping activities to confirm that seams for patches and caps are clean, dry and have adequate overlaps in accordance with specifications prior to welding. Observe and document non-destructive testing activities on seams of patches and caps. Where defective results are obtained, require, verify and document that seams are repaired. Record all repair locations on the liner placement plan.
DRAINAGE NET	**REQUIREMENTS PRIOR TO DRAINAGE NET INSTALLATION:** Prior to installation, the manufacturer shall provide the CQA personnel quality control certificates pertaining to the drainage net. The material properties of testing performed to demonstrate compliance with specifications are presented in Table 5. A QC certificate must be provided in accordance with the minimum MQC frequencies presented in Table 5. A certificate must be provided for each roll that is not produced consecutively. Each roll must have a unique manufacturing identification number.	Review and approve required submittals for compliance with specifications. Approve and document materials meeting project specifications. Notify Construction Manager of any deficiencies and confirm that all failing rolls are moved from the construction area.
	DEPLOYMENT: Prior to deployment of the drainage net, the underlying HDPE liner is to be cleared of soil or debris. The drainage net shall then be covered and maintained free from blowing sand or soil material. Sand or soil material in the drainage net, whether placed by machine or weather related, shall be removed from the drainage net.	Observe and document drainage net placement. Observe HDPE liner prior to drainage net placement for dust and debris. Observe drainage net prior to placement of overlying HDPE liner or filter fabric for compliance with the requirement that the drainage net be maintained free of blowing sand and other soil material. Report deficiencies to Construction Manager and confirm and document any corrective actions.
	The drainage net shall be installed by hand to prevent damage to the underlying surface(s). Adjacent rolls shall be joined by overlapping the edges by a minimum of four inches. The upslope net is to overlap the downslope net, where possible. Adjacent rolls shall be connected by spot welding or tying adjacent net rolls together. If tying material is used, the tying material shall be a polymer braid or polymer cable ties of a different colored material than the drainage net. The edges of the net shall be tied or secured at no greater than five foot intervals along the sides of the nets and two-foot intervals along the ends of the rolls.	Observe placement for compliance with specifications and damage to drainage net or other geosynthetic materials. Observe and document that overlapping and tying or welding meets the project specifications. Report deficiencies to Construction Manager and confirm and document any corrective actions.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
FILTER FABRIC	**REQUIREMENTS PRIOR TO FILTER FABRIC INSTALLATION:** Prior to installation, the manufacturer shall provide the CQA Consultant quality control certificates pertaining to the filter fabric and receive approval from the CQA Consultant. The material properties of testing performed to demonstrate compliance with specifications are presented in Table 6. A QC certificate must be at the minimum frequencies presented in Table 6. A certificate must be provided for each roll that is not produced consecutively. Geotextile rolls shall be identified, handled and stored in accordance with ASTM D4873. Each roll shall be identified and labeled with a unique identification number.	Review required submittals for compliance with specification. Observe and document the condition, handling and storage of filter fabric materials. Notify Construction Manager of any materials that do not meet the project specification. Confirm and document that rejected rolls/material is removed from the construction area.
	DEPLOYMENT: The filter fabric shall be installed by hand to prevent damage to the underlying surface. The rolls of geotextile filter fabric shall be placed to provide a minimum width of 12 inches of overlap for each joint, or the overlap shall not be less than 3 inches for joining the adjacent sheets by either the sewing or the fusion weld methods. The overlap shall be glued together or otherwise fastened or secured. The fabric shall be placed such that the upslope fabric will overlap the downslope fabric, if possible.	Observe and document filter fabric placement, overlapping and joining for conformance with specifications. Report deficiencies to Construction Manager and confirm and document any corrective actions.
PROTECTIVE COVER	Satisfactory liner protective cover will be screened waste, soil, or combination thereof. The maximum particle size shall be 3 inches. Satisfactory soil protective cover materials for the closure cap are defined as those complying with the Unified Soil Classification of CL, SM, SC, SP, or SW materials, or combination thereof.	**For Closure Cap Construction:** Collect and sample soil in accordance with requirements of Table 2. Notify Contractor of acceptable materials. Applicable testing methods are referenced in Appendix B.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
PROTECTIVE COVER (Cont.)	**PLACEMENT:** The size of equipment shall be limited to ensure that the bearing pressure of the equipment does not exceed the bearing capacity of the underlying system. Equipment used during the placement of the protective cover shall be restricted to: a. Rubber tire dozer tractors with tire pressures not to exceed 40 psi. b. Track-type tractor/dozers with ground pressures not to exceed 8 psi. c. Three & one-quarter yard bucket (or smaller). d. Wheel loaders with tire pressures not to exceed 40 psi. e. Three and one-quarter yard bucket (or smaller) track-type loaders with ground pressures not to exceed 10 psi. f. Motor graders with tire pressures not to exceed 40 psi. g. Track-type excavators/backhoes with ground pressures not to exceed 10 psi. h. Wheel-type excavators/backhoes with tire pressures not to exceed 40 psi. i. Trucks that do not exceed maximum highway wheel loads specified by AASHTO for an HS20 truck. j. Smooth-drum rollers with a ground pressure not to exceed 8 psi. **For Closure Cap Construction:** No equipment will be allowed on the cover system until an adequate thickness of protective cover is in place to support the equipment and its movement. All equipment to be used in placing and compacting soil protective cover not stated above must be approved by the CQA Officer and Certifying Engineer. The contractors shall provide a list of the equipment to be used for placing the soil protective cover and the necessary technical information on each piece of equipment to be approved.	**For Closure Cap Construction:** Observe and document equipment used to place protective cover. Report deficiencies to Contractor and confirm and document any corrective actions.
	The protective cover shall be pushed out in front of the equipment used to place the protective cover such that the following minimum cover thickness is maintained at all times between the geomembrane and/or geotextile and the wheels or tracks of the equipment used to place the cover: 1. Two (2) feet for dozer tractors, front end loaders, motor graders, and excavator/ backhoes. 2. Two (2) feet for trucks hauling the soil cover into the cell for placement. 3. One (1) foot for small self-propelled smooth drum rollers and small rubber tire loaders. 4. Four (4) inches for hand compactors.	**For Closure Cap Construction:** Observe and document soil protective cover placement operations. Report deficiencies to Contractor and confirm and document any corrective actions.

TABLE 1 Continued

LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
PROTECTIVE COVER (Cont.)	No compaction or moisture requirements are specified for the soil cover except in the designated zone around the leachate withdrawal pipes, the access ramp into the interior of the cell, and the berm around the perimeter of the cap. Compaction requirements for the soil protective cover berm are $\geq$ 95.0% of the maximum Standard Proctor Density (ASTM D-698) at a moisture content within plus or minus ($\pm$) 2% of optimum moisture content. Compaction requirements for around the leachate withdrawal pipes and the access ramp are $\geq$ 90.0% of the maximum Standard Proctor Density (ASTM D-698) at a moisture content within plus or minus ($\pm$) 2% of optimum moisture content.	Observe, test, and document compaction of soil cover is performed as required by the specifications. A minimum of one nuclear density test shall be performed per 30 feet of pipe length, in the case of the ramp down into the cell, a minimum of two tests per lift, or in the case of the soil protective cover berm, on test per 300 linear feet per lift. Report deficiencies to Contractor and retest and document any corrective actions.
	The grading tolerance limit for the surface of the soil protective cover during cap construction is greater than or equal to minus one tenth of a foot. Grade for the soil protective cover will be established by installing PVC pipe grade poles or methods approved by the CQA Officer that can adequately determine the thickness of the soil protective cover on at least a 70-foot grid and at all control points. The PVC grade poles must be supplied with a removable tee or flat plate to be placed on the bottom of the pole against the underlying filter fabric or HDPE liner. The grade poles must be marked at the 1.5-foot line to establish the grade. After the grade for the soil protective cover has been checked and approved by the CQC and CQA personnel, the grade poles shall be removed. Other methods may be used to control the thickness of the SPC if approved by the CQA Officer (i.e. radial prism laser).	**For Closure Cap Construction:** Confirm that the grade poles are installed as the soil cover is placed in order to provide the control for ensuring cover requirements, as necessary. Verify and document that the required grading tolerance is achieved. Report deficiencies to Contractor and retest and document any corrective actions. Confirm that all grade poles are removed after approval of cover placement.
ACCESS RAMP CONCRETE	Concrete for the access ramp shall have a minimum 28-day compressive strength of 2,000 pounds per square inch and a slump between 2 and 5 inches.	Observe and document concrete placement operations. Take samples of concrete for strength and slump tests in accordance with ASTM C 172. Make four test cylinders for every 40 cubic yards of concrete placed or once a day in accordance with ASTM C 39. Conduct a slump test each time a set of cylinders are made in accordance with ASTM C 143. Test one cylinder at seven days and three cylinders at 28 days. Notify Construction Manager of deficiencies and observe and document that corrective action has been taken where required.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
TOPSOIL	**MATERIAL:** Topsoil for the final cover system shall be earthen material with a 3-in. diameter maximum particle size, and without deleterious materials that could damage the underlying components of the final cover system or impede their performance as designed. In addition, the topsoil shall have suitable properties that provide a layer capable of sustaining native grassy vegetation.	Collect and sample topsoil in accordance with requirements of Table 2. Notify Contractor of acceptable materials. Applicable testing methods are referenced in Appendix B.
	PLACEMENT: Place as a single lift and give relatively low compactive effort such as that from a bulldozer.	Observe and document equipment used to place topsoil. Report deficiencies to Contractor and confirm and document any corrective actions.
	GRADING: Surface of topsoil layer shall be fine graded to the design elevation and typical sections/minimum layer thickness. Acceptable grading tolerance limits for finished embankment surfaces shall be + or - 0.2 of a foot. Survey measurements shall be performed at completion by licensed surveyor. Survey points shall be on at least a 60 foot grid and at all control points. Surveyor shall indicate where the topsoil surface meets the design line and grade. Submit survey data to design engineer, Construction Manager and CQA Officer.	Review certified as-built survey for compliance to CQA Plan and design documents. Notify Construction Manager of deficiencies. Review final survey data. Verify the frequency of survey measuring points. Verify that the surveyor certified that the construction is to the specified thickness.
CAP VEGETATION	The permanent vegetation for the cap shall be established by seeding or strip sodding. For seeding, the permanent seed mix shall be 40 lbs/acre of Bermuda Grass (Pure live seed) and 10 lbs/acre of Buffalograss (without hulls). Seeding shall be performed with a drill that will ensure seed to soil contact. Light mulching with hay, straw or other applicable organic material is recommended. Supplemental water is recommended if seeding or sodding occurs between June and October. Hydromulch may be used to facilitate the seeding / mulching process. The quantities of seed in this mix are a minimum, and additional seed may be added to achieve good vegetation. Fertilizer may be added to facilitate vegetative establishment and growth. If the final cover is constructed outside of the recommended planting season for the permanent seed, a seed mix for temporary establishment of vegetation shall be used, and the topsoil layer shall be seeded with the permanent seed mix specified above for as soon as practicable. For strip sodding, the area to be vegetated shall be covered with sod strips composed of either Common Bermuda sod or Buffalograss sod placed perpendicular to the slopes (i.e., perpendicular to the surface water flow direction), to achieve a 50% sod coverage. This method typically takes a growing season to achieve full coverage.	Observe and document seeding/sodding activities for seed mix, sod coverage and positioning (if applicable) and methods used. Observe and document application rates and adequate coverage. Report deficiencies to Contractor and confirm and document any corrective actions.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
RIP-RAP AND GRANULAR FILTER MATERIAL	**MATERIAL**: Rip-rap and Type II granular filter materials used as slope protective cover shall consist of quarry stone and shall conform to the following requirements: <u>Standard</u> <u>Requirements</u> <u>Method</u> Magnesium Sulfate Soundness, Max % Loss ≤25 ASTM C 88 Los Angeles Abrasion, Max % Loss ≤55 ASTM C 535 Submit results of a Magnesium Sulfate Soundness and L.A. Abrasion test on the proposed rip-rap and Type II granular filter material by a certified laboratory for review by the CQA Consultant	Review submittals and verify the acceptability of the materials based on compliance with specifications.
	GRADATION: Rip-rap shall conform to the gradation requirements in Table 7, based on the visual evaluation method in Appendix A.1. Type I granular filter shall consist of natural sand or other approved inert material conforming to the gradation requirements in Table 8. Type II granular filter shall consist of hard, durable, and rough angular fragments of screened or broken stone, gravel, or slag conforming to the gradation requirements in Table 9. Note: Type II granular filter material shall conform to the above requirements for Magnesium Sulfate Soundness and L.A. Abrasion.	Perform and document visual gradation evaluation of the rip-rap at least three (3) times per construction or closure project in accordance with visual evaluation method in Appendix A.1. As a minimum, perform and document gradation analyses of the Type I and Type II granular filters on the steeper slopes (2H:1V - 3H:1V) for every 1,000 cubic feet of material placed. As a minimum, perform and document gradation analyses of the Type II granular filter on the 10% and flatter closure cap slopes for every 500 cubic yards of material placed. Observe the placement of all materials to detect non-conformity. Verify the acceptability of the materials based on compliance with specifications. Notify the Construction Manager of any deficiencies or non-conformance. Confirm that deficiencies are reworked or that non-conforming material is removed from the project area.
	PLACEMENT: The rip-rap shall be placed to at least the minimum thickness specified in the design plans. The Type I granular filter material shall be placed at no more than the maximum thickness and within the tolerance range specified in the design plans. The Type II granular filter shall be placed to a thickness within the tolerance range specified in the design plans. Verify that the required thickness of rip-rap and granular filter material is achieved by the excavating to the bottom of the layer and measure the thickness on a grid of not less than 100 feet.	Review and document excavated areas to confirm thickness of rip-rap and granular filter material. Notify Construction Manager of any areas not meeting the criteria and confirm that these areas are reworked and meet the specifications.
	SLOPE: The rip-rap and granular filter materials shall be placed at a slope not steeper than that specified in the design plans	Review survey data and verify that the slope constructed is not steeper than specified in the design plans. Define areas not meeting design specifications and notify Construction Manager of deficiencies. Observe and document any corrective actions.

TABLE 1 Continued
LANDFILL CELL CONSTRUCTION / CLOSURE INSPECTION CQA ACTIVITIES

WORK ELEMENT	SPECIFICATION	CONSTRUCTION QUALITY ASSURANCE (CQA)
LEACHATE WITHDRAWAL PIPES	The high density polyethylene (HDPE) pipe shall have a minimum pressure rating of 100 psi and a maximum SDR of 17 as specified in the design plans. The HDPE pipe shall be installed according to the requirements of ASTM D-2321. The HDPE pipe shall be pre-welded and installed in one continuous pipe. Welded seams shall be smooth and even with no irregularities or weld lip. The pipe shall be installed with uniform bearing under the full length of the pipe. Where designated on the design plans, backfill around the pipe shall be compacted to 90.0% of the maximum dry density as determined by ASTM D-698 with a moisture content of minus (-) 2.0% to plus (+) 2.0% of the optimum moisture content.	Observe and document installation of the leachate withdrawal pipes. Review quality control certificates for compliance with specification. Observe welded seams to ensure these are smooth and even with no irregularities or weld lip. Conduct in-place moisture and density tests. Testing is to be conducted using applicable methods indicated in Appendix A. In-place moisture and density tests will be performed on the backfill at a minimum rate of one test per 30 linear feet of HDPE pipe. Notify Construction Manager of deficiencies and confirm that all deficient areas/soil are reworked and meet the specification.
SUMPS	**BACKFILL:** The granular backfill for the sump shall conform to the gradation requirements in Table 10. Submit gradation (ASTM D422) test result from a certified laboratory of proposed material (minimum one per source if all material is delivered at once or at least once per sump) to the CQA Consultant for approval. **PIPING SYSTEM:** The piping system shall be constructed and installed in accordance with the design plans. Piping must conform with the specifications listed for Leachate Withdrawal Pipes, where applicable. Other materials (e.g., filter fabric) utilized in the sumps must conform with the standards and specifications applicable to the material.	Review submittals for conformance with specification. Observe and document installation of the sumps for conformance with the specifications. Notify Construction Manager of deficiencies and confirm that all deficient areas/soil are reworked/removed and meet the specification. Observe and document that the installation of the piping system within and leading into the sumps was completed in accordance with the design plans. Review and document that materials utilized all meet the applicable specifications. Inspect piping system for damage prior to, during and after installation. Notify Construction Manager of any deficiencies. Confirm and document that any deficient areas are repaired or replaced and meet the specifications.
ANCILLARY CONSTRUCTION WORK NOT OTHERWISE SPECIFIED	**GENERAL:** For any work which may impact the construction or performance of a landfill cell (or its closure), specifications will be developed. These specifications must be approved by the CQA Officer prior to commencement of the work.	As part of the development of the specifications, CQA shall include testing, measurements, inspections or other evaluations, as necessary, to demonstrate that the work has been performed as required by the specifications.

TABLE 2
EARTHWORK CONFORMANCE TESTING

MATERIAL TYPE	TEST METHOD		MIN CQA FREQUENCY
Foundation/Subgrade Recompaction	Nuclear Density/Moisture Content	ASTM D6938	1 per 12,000 square feet (sf)
	Standard Proctor	ASTM D698	1 per material type
Compacted Soil/Engineered Fill	Nuclear Density/Moisture Content	ASTM D6938	1 per 1,000 cy (min 1 per lift)
	Standard Proctor	ASTM D698	1 per 12,000 sf per lift, or 1 per 300 linear feet (lf) per lift on roadways and ramps
	Visual Classification	ASTM D2488	1 per 10,000 cy (min 1 per material type)
Clay Liner Borrow Source	Standard Proctor	ASTM D698	1 per 5,000 cy (min 1per material type)
	Modified Proctor	ASTM D1557	1 pre-construction test per material type
	Atterberg Limits	ASTM D4318	1 per 5,000 cy (min 1per material type)
	Sieve Analysis	ASTM D422	1 per 5,000 cy (min 1per material type)
	Visual Classification	ASTM D2488	1 per 1,000 cy (min 1per material type)
	Laboratory Hydraulic Conductivity	ASTM D5084	10 remolded samples per material type (See Note 1)
	Laboratory Hydraulic Conductivity (Ongoing Construction Conformance Testing)	ASTM D5084	2 remolded samples per 10,000 cy (See Note 2)
Clay Liner Test Fill	Nuclear Density/Moisture Content	ASTM D6938	1 per 1,500 sf per lift (or min 1 per lift for small test pad)
	Field Hydraulic Conductivity	Allowable methods: (i) Single-Ring Infiltrometer per Appendix A.2 of this plan; (ii) Large-Scale Block Sampling/Testing per Appendix A.3 of this plan); or (iii) Stage 1 of the Two-Stage Borehole method per ASTM D 6391	For single-ring infiltrometer and large-scale block methods: Min 1 per test pad (also min 1 for small test pad) For Two-Stage Borehole method: One test series (comprised of a group of 5 individual borehole tests) per test pad (or for a small test pad - one borehole test)
	Laboratory Hydraulic Conductivity	ASTM D5084	Min 1 per lift (min 1 for small test pad)

TABLE 2 Continued
EARTHWORK CONFORMANCE TESTING

MATERIAL TYPE	TEST METHOD		MIN CQA FREQUENCY
Compacted Clay Liner	Nuclear Density/Moisture Content	ASTM D6938	1 per 8,000 sf
Upper 6-inches of Re-worked/re-compacted Interim Clay Cover (Bedding Clay) Beneath Cap GCL	Grain Size Analyses	ASTM D422	1 per 10,000 cy (min 1 per material type)
	Nuclear Density/Moisture Content	ASTM D6938	1 per 12,000 sf per lift
	Standard Proctor	ASTM D698	1 per 10,000 cy (min 1 per material type)
	Visual Classification	ASTM D2488	1 per 10,000 cy (min 1 per material type)
Protective Cover Soil for Cap	Visual Classification	ASTM D2488	1 per 10,000 cy (min 1 per material type)
	Standard Proctor[3]	ASTM D698	1 per 10,000 cy (min 1 per material type)
	Nuclear Density/Moisture Content[3]	ASTM D6938	See Note 3
Topsoil	Visual Classification	ASTM D2488	1 per 10,000 cy (min 1 per material type)
Rip-Rap	Visual Classification	See Appendix A.1	Minimum 3 tests per construction project
Type I and Type II Granular Filter	Visual Classification	See Appendix A.1	1 per 1,000 cy

Notes:

1. Pre-construction laboratory hydraulic conductivity testing (ASTM D5084) of a clay borrow source shall be performed at a confining stress as directed by the Design Engineer at the following variable moisture content and density conditions: (i) five (5) tests remolded to the moisture/density conditions that were used to define the modified Proctor curve; and (ii) five (5) tests remolded to the moisture/density conditions that were used to define the standard Proctor curve. Each of the resulting ten (10) compacted (remolded) specimens shall be permeated per ASTM D5084. The CQA Consultant shall use the results to define the “Acceptable Zone”, consistent with EPA Technical Guidance Document EPA/600/R-93/182, by plotting the dry unit weights, molding water contents, and permeability of each of the ten (10) moisture-density points. The “Acceptable Zone” will be determined based on the acceptable range of compaction criteria to obtain an as-compacted hydraulic conductivity of no greater than $1x10^{-7}$ cm/s.
2. Ongoing Laboratory hydraulic conductivity testing (during construction) of the clay borrow source for which the Acceptable Zone is already defined through pre-construction testing described in Note 1shall be performed. The confining stress shall be the same as used for the pre-construction hydraulic conductivity tests. A minimum of two (2) specimens shall be remolded to variable target moisture content and density conditions specified by the CQA Consultant. Each of the resulting two (2) compacted (remolded) specimens shall be permeated per ASTM D5084. The CQA Consultant will use the results to confirm the applicability of the previously-defined Acceptable Zone (i.e., the results are within an acceptable range of compaction criteria to obtain an as-compacted hydraulic conductivity of no greater than $1x10^{-7}$ cm/s).
3. Soil protective cover testing for field compaction is only required for cap shoulder construction (one per 300 linear feet) and for cell ramps (minimum 2 tests per lift) and leachate riser trenches (minimum one test per 30 feet of pipe).

TABLE 3
MATERIAL PROPERTIES AND CONFORMANCE TESTING FOR GEOSYNTHETIC CLAY LINER

PROPERTIES	QUALIFIERS	UNITS	SPECIFIED VALUES (1)	TEST METHOD (4)	MQC FREQENCY	CQA FREQUENCY
Bentonite Content(3)	minimum	lb/ft^3	0.75	ASTM D5993	5,000 yd^2	100,000 ft^2
Hydraulic Index Flux	maximum	cm^3/cm^2-s	1 x 10^{-6}	ASTM D5887	30,000 yd^2	400,000 ft^2
Bentonite Swell Index	minimum	mL/2g	24	ASTM D5890	50 tonnes	--
Bentonite Fluid Loss	maximum	mL	18	ASTM D5891	50 tonnes	--

Notes: (1) All values represent minimum average roll values (i.e., any roll in a lot should meet or exceed the values in this table).
(2) Hydraulic flux testing shall be performed under an effective confining stress of 5 pounds per square inch.
(3) Measured at a moisture content of 0 percent; also known as mass per unit area
(4) Material requirements and manufacturer conformance testing frequency are based on the most recent version of GRI Specification GCL-3.

TABLE 4
MATERIAL PROPERTIES AND CONFORMANCE TESTING FOR HDPE LINER

PROPERTIES	QUALIFIERS	UNITS	60 MILS TEXTURED	ASTM TEST METHOD	MQC FREQUENCY	CQA FREQUENCY
Physical Properties						
Thickness	Average Minimum	mils	54	ASTM D 5199	Per roll	100,000 ft^2
Carbon Black Content	Range	%	2-3	ASTM D 1603	20,000 lb	100,000 ft^2
Carbon Black Dispersion	N/A	none	Note 2	ASTM D 5596	45,000 lb	100,000 ft^2
Density	Minimum	g/cc	0.94	ASTM D 792 Method A or ASTM D 1505	200,000 lb	100,000 ft^2
Mechanical Properties Tensile Properties (each direction) 1. Tensile (Break) Strength 2. Elongation at Break 3. Tensile (Yield) Strength 4. Elongation at Yield	Minimum	lb/in % lb/in %	90 100 126 12	ASTM D 638	20,000 lbs	100,000 ft^2
Tear Resistance (min ave.)	Minimum	lb	42	ASTM D 1004	45,000 lbs	100,000 ft^2
Puncture Resistance	Minimum	lb	90	ASTM D4833	45,000 lbs	100,000 ft^2
Stress Crack Resistance	Minimum	hr	300	ASTM D 5397	Per GRI-GM10	--
Oxidative Induction Time Standard OIT, - or - High Pressure OIT	Minimum Average	Minutes	100 400	ASTM D 3895 ASTM D 5885	200,000 lb	--
Oven Aging at 85 degrees C Standard OIT - % retained after 90 days, - or - High Pressure OIT - % retained after 90 days	Minimum Average	%	55 80	ASTM 5721 ASTM D 5885	Per each formulation	--

TABLE 4 Continued
MATERIAL PROPERTIES AND CONFORMANCE TESTING FOR HDPE LINER

PROPERTIES	QUALIFIERS	UNITS	60 MILS TEXTURED	ASTM TEST METHOD	MQC FREQUENCY	CQA FREQUENCY
REQUIRED GEOMEMBRANE SEAM PROPERTIES(5)						
Seam Shear Strength(3)						
Fusion	Minimum	lb/in	120	ASTM D 6392	NA	500 linear feet
Extrusion	Minimum	lb/in	120	ASTM D 6392	NA	500 linear feet
Peel Ahesion						
FTB(4)				Visual Observation		500 linear feet
Fusion	Minimum	lb/in	91	ASTM D 6392	NA	500 linear feet
Extrusion	Minimum	lb/in	78	ASTM D 6392	NA	500 linear feet
REQUIRED GEOMEMBRANE-CLAY LINER INTERFACE STRENGTH PROPERTIES(6), (7)						
Interface Shear Strength	Minimum	psf	(6)	ASTM D 5321	NA	(7)

Notes: (1) Material requirements, manufacturer conformance testing frequency and minimum seam properties are based on the most recent version of Geosynthetic Research Institute (GRI) Specifications GM13 and GM19.

(2) Minimum 9 of 10 in Categories 1 or 2; 10 in Categories 1, 2, or 3.

(3) Also called “Bonded Seam Strength”.

(4) FTB = Film Tear Bond means that failure is in the parent material, not the seam. The maximum seam separation is 25 percent of the seam area.

(5) Four of five specimens per destructive sample must pass both the shear and peel strength tests.

(6) Interface shear strength shall be measured as part of the liner CQA program. The shear strength of the geomembrane-to-clay liner interface shall be measured, and shall have peak and large-displacement effective stress strength that meets or exceeds an envelope of:

	Normal Stress (psf)	Peak Effective-Stress Interface Strength		Large-Displacement Effective-Stress Interface Strength	
		Shear Strength (psf)	Equivalent Secant Friction Angle (°)	Shear Strength (psf)	Equivalent Secant Friction Angle (°)
Liner System	240	40.4	9.7	20.9	5.0
	6,000	1,021.3	9.8	627.2	6.0
Final Cover System	240	26.8	6.4	18.4	4.4

Interface shear tests shall be conducted at the normal stresses indicated above, using fresh specimens for each normal stress increment, and using a maximum shear rate of 1 mm/minute. Clay liner material shall be re-compacted in the lab to approximately 95% of the standard Proctor maximum dry density, and 4% wet of optimum moisture content.

(7) CQA testing of interface shear strength shall be performed at a frequency of one per source/product combination. Therefore, passing interface strength tests for a specific interface (same clay source and geomembrane product) are applicable from project-to-project and need not be repeated provided that the materials do not change and remain representative of those tested.

TABLE 5
MATERIAL PROPERTIES AND CONFORMANCE TESTING FOR DRAINAGE GEONET/GEOCOMPOSITE

PROPERTIES	QUALIFIERS	UNITS	SPECIFIED(1) VALUES	TEST METHOD	MQC FREQUENCY	CQA FREQUENCY
Geonet Resin Density	Minimum	g/cc	0.94	ASTM D792 or D1505	Per Resin Batch/Lot	Not Required
Geonet Carbon Black Content	Range	%	2.0 – 3.0	ASTM D1603 or D4218	100,000 ft^2	200,000 ft^2
Geonet Thickness	Minimum	mils	205	ASTM D5199	100,000 ft^2	200,000 ft^2
Liner System Geocomposite Index Transmissivity(2)	Minimum	m^2 / sec	4.2 x 10^{-4}	ASTM D4716	100,000 ft^2	200,000 ft^2
Final Cover System Geocomposite Index Transmissivity(3)	Minimum	m^2 / sec	2.8 x 10^{-4}	ASTM D4716	100,000 ft^2	200,000 ft^2

Notes: (1) All values (except transmissivity) represent average roll values.

(2) Index transmissivity of the liner system geocomposite (geonet bonded to geotextiles on each side), shall be measured using water at 68°F with a gradient of 0.02 under a confining pressure of 11,500 psf. The geocomposite shall be placed in the testing device between two steel plates. Measurements shall be taken fifteen minutes after application of confining pressure.

(3) Index transmissivity of the final cover system geocomposite (geonet bonded to geotextiles on each side), shall be measured using water at 68°F with a gradient of 0.1 under a confining pressure of 240 psf. The geocomposite shall be placed in the testing device between two steel plates. Measurements shall be taken fifteen minutes after application of confining pressure.

TABLE 6
MATERIAL PROPERTIES AND CONFORMANCE TESTING FOR FILTER FABRIC

PROPERTIES	QUALIFIERS	UNITS	SPECIFIED(1) VALUES	TEST METHOD	MQC FREQUENCY	CQA FREQUENCY
Mass per Unit Area	Minimum	oz/yd^2	8	ASTM D5261	130,000 ft^2	Not Required
Grab Tensile Strength	Minimum	lbs	200	ASTM D4632	130,000 ft^2	1 test per 200,000 ft^2
Puncture Resistance	Minimum	lbs	120	ASTM D4833	130,000 ft^2	1 test per 200,000 ft^2
Permittivity	Maximum	s^{-1}	1.3	ASTM D4491	540,000 ft^2	1 test per 200,000 ft^2
Apparent Opening Size	Maximum U.S. Standard Sieve	--	70	ASTM D4751	540,000 ft^2	1 test per 200,000 ft^2

TABLE 7
RIP-RAP GRADATION SPECIFICATIONS

<table>
<tr><td></td><td></td><td></td><td colspan="3">Intermediate Rock Weight Dimension*</td><td></td></tr>
<tr><td>Rip-Rap Thickness (Inches) Typical</td><td>Rip-Rap Type Designation</td><td>% Smaller Than Given Size By Weight</td><td>(Lbs)</td><td colspan="2">(Inches)</td><td>D_{50}** (Inches)</td></tr>
<tr><td>6</td><td>Type V</td><td>70-100
50-70
35-50
2-10
0-1</td><td>43
18
5.3
0.7</td><td colspan="2">8
6
4
2
¾</td><td>4</td></tr>
<tr><td>12</td><td>Type VL</td><td>100
50
20
0-1</td><td>150
30-50
20</td><td colspan="2">11.6
6.8-8.1
5.9
¾</td><td>6</td></tr>
<tr><td>18</td><td>Type L</td><td>100
50
20
0-1</td><td>350
70-125
30</td><td><u>Embankments</u>
16.2
9.4-11.5
7.1
¾</td><td><u>Channels</u>
15.4
9.0-10.9
6.8
¾</td><td>9</td></tr>
</table>

* Dimension based on volume of cube and SG=2.30 for Type V and Type L rip-rap used on cell caps and outer embankments, and SG=2.65 for Type VL and Type L rip-rap used in channels.
** D_{50} = Nominal particle size

TABLE 8
TYPE I GRANULAR FILTER GRADATION SPECIFICATIONS

U.S. Standard Sieve Size	Percent Passing by Weight
3/8 inches	100
No. 4	95-100
No. 16	45-85
No. 50	5-30
No. 100	0-10
No. 200	0-3

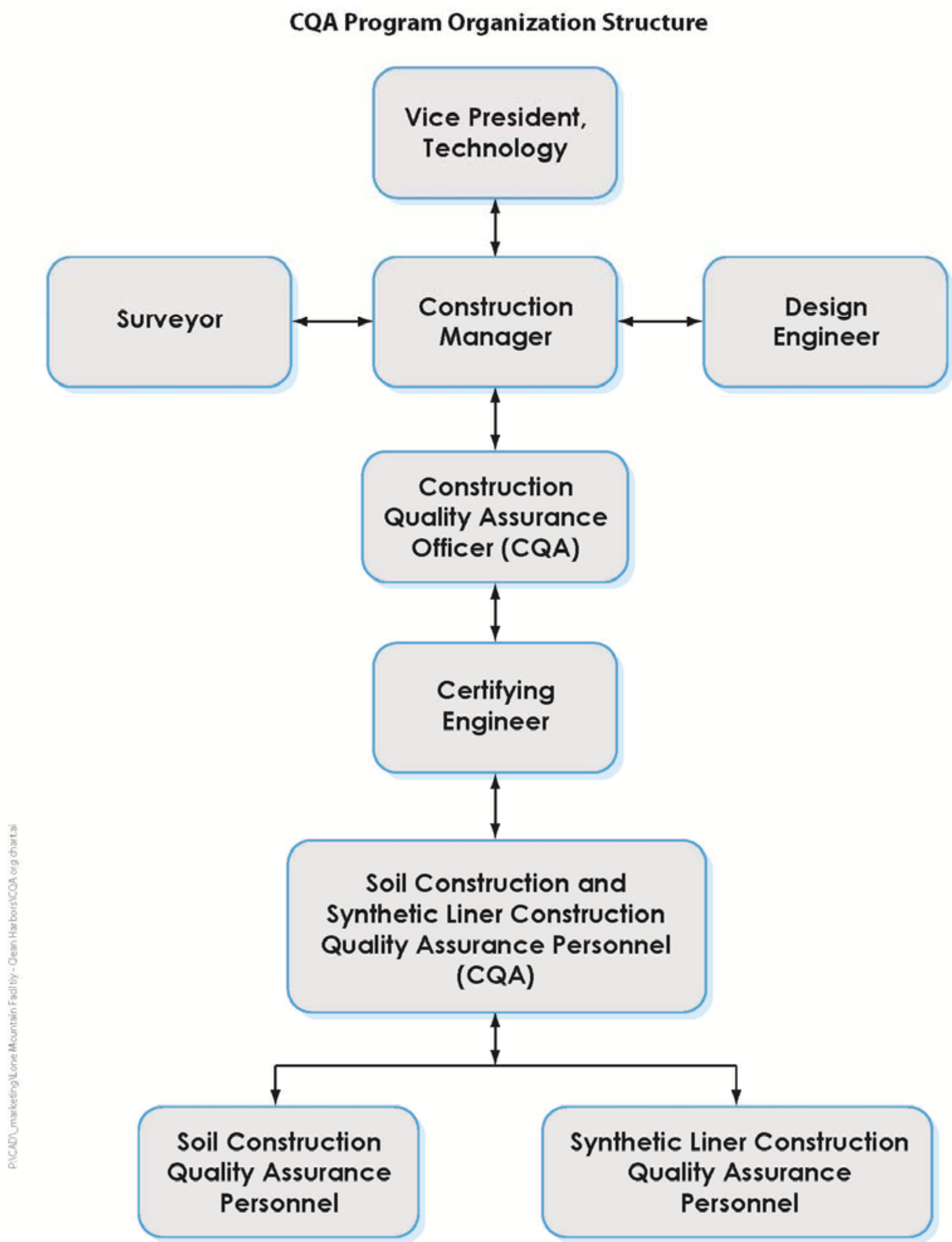
TABLE 9
TYPE II GRANULAR FILTER GRADATION SPECIFICATIONS

U.S. Standard Sieve Size	Percent Passing by Weight
3 inches	90-100
3/4 inches	35-90
No. 4	0-30
No. 16	0-15
No. 200	0-3

TABLE 10
SUMP ROCK GRADATION SPECIFICATIONS

U.S. Standard Sieve Size	Percent Passing by Weight
1-1/2 inches	100
3/8 inches	0-40
No. 200	0-3

FIGURES



Lone Mountain Facility
Landfill Cell Construction & Closure
Quality Assurance Plan

Figure 1

APPENDICES

APPENDIX A
SOIL TESTING METHODS

A.1 Soil Testing Methods

Soil testing methods are outlined in the following table.

Description	Test Method*
Nuclear Density/Moisture Content (Rapid Method)	ASTM D 6938
Moisture Content of Soil by Microwave Oven Method	ASTM D 4643
Soil Classification	ASTM D 2488
Particle - Size Analysis of Soils	ASTM D 422
Test Method for Material Finer than the #200 Sieve	ASTM D 1140
Test Method for Atterberg Limits	ASTM D 4318
Moisture - Density Relationship (Standard Proctor)	ASTM D 698
Moisture - Density Relationship (Modified Proctor)	ASTM D 1557
Thin-Walled Tube Sampling of Soils	ASTM D 1587
Laboratory Permeability Testing of Soils	ASTM D 5084
Field Permeability Testing of Soils by Sealed Single Ring Infiltrometer	See Appendix A.2
Two-Stage Borehole (TSB, i.e.; “Boutwell”) Tests	ASTM D 6391
Large-Scale Block Sampling & Testing	See Appendix A.3
Particle - Size Analysis of Natural and Man Made Rip-Rap Materials	Independent visual evaluation by CQA**
Direct Shear Interface Strength Testing, Soil-Geosynthetic Interfaces	ASTM D 5321

Note: Calibration of testing equipment must meet the requirements of the applicable standards

* Most Current Published ASTM Method

** Independent visual evaluations must yield acceptable (i.e., material meets specifications) results prior to placement of rip-rap. If either independent evaluation determines rip-rap does not meet the specification in Table 7, material must be rejected and not used on the cells. To adequately evaluate the fine material fractions of the rip-rap, sample(s) of rip-rap must be spread out in a layer having an average approximate thickness of the applicable D_{50} size material (see Table 7). Minimum sample size required for visual rip-rap gradation evaluation is as follows:

Type L 7,000 pd.
Type VL 3,000 pd.
Type V 860 pd.

A.2 Sealed Single Ring Infiltrometer Field Permeability Test

NOTE: *This procedure describes the methodology for utilizing a sealed single ring apparatus provided by Trautwein Soil Testing Equipment. Other SSRI equipment manufacturers may have different set-ups and procedures.*

1. Equipment

(a) **Infiltrometer.** Metal square (24-in. x 24-in.) frame with Plexiglas top and no bottom.

(b) **Small Garden Shovel or Tool.** An approximate 2-in.-wide trench will need to be excavated in a square such that the Infiltrometer fits into the trench approximately 4- to 5-in.-deep with 1-in. of open space on each side of the Infiltrometer sides.

(c) **Nuts, Washers, and Bolts.** These attach the Infiltrometer to the Plexiglas.

(d) **Seals (2).** The seals prevent leaking and are placed on the bottom and top of the Plexiglas.

(e) **Granular Bentonite.** Used to seal the Infiltrometer to the ground surface.

(f) **Marriotte Bottle.** Bottle used to measure the amount of water that moves into the Infiltrometer, therefore measuring the amount of water that infiltrates through the soil.

(g) **Stand.** Holds the Marriotte Bottle above the Infiltrometer to provide head.

(h) **Tubing.** Approximately 2-ft. Tygon® plastic tubing to connect the Marriotte Bottle to the Infiltrometer. Approximately 6-in. of tubing that connects a water reservoir to the Marriotte Bottle for filling. Approximately 6-in. of tubing that provides a release for water at the high end of the Infiltrometer. Approximately 6-in. of tubing to provide an air release for the Marriotte Bottle.

(i) **Tubing Clamps (4).** Placed on the tubing to restrict flow into or out of the Marriotte Bottle and the Infiltrometer.

(j) **Shovel or Plate.** Allows water to fill the Infiltrometer without disturbing the ground surface.

(k) **Level.** Measures the low corner of the Infiltrometer identifying which corner of the Marriotte Bottle should be located.

(l) **Plastic or Visquin.** This material should be placed around the Infiltrometer to keep the ground surrounding the test area from desiccating.

(m) **Cinder Blocks.** These keep the Infiltrometer from raising out of the ground.

2. Equipment Setup and Procedure

(a) Place the Infiltrometer on the ground surface where the test will be conducted. Trace the outer perimeter of the Infiltrometer on the ground. Excavate a 2-in.-wide, 5- to 6-in.-deep trench around the perimeter tracing.

(b) Place the Infiltrometer into the trench. Ensure a void space exists on both sides of the Infiltrometer. Establish a low corner using the level. Remove the Infiltrometer from the trench.

(c) Place a 1-in.-thick lift or layer of granular bentonite in the bottom of the trench. Tamp the bentonite to prevent air voids. Add water. Place the Infiltrometer into the trench and continue to add bentonite in 1-in. lifts with water on the outside of the Infiltrometer until the bentonite is even with the ground surface.

(d) Add bentonite and water in 1-in. layers to the area on the inside of the Infiltrometer until even with the ground surface. Be sure that no bentonite is on the ground surface inside the Infiltrometer as it will affect the permeability of the soil.

(e) Place a shovel or plate inside the Infiltrometer and add water by pouring onto the flat part of the plate or shovel until the water level reaches the top of the Infiltrometer.

(f) Place a seal, then the Plexiglas, another seal, and finally the metal square on top of the Infiltrometer. The Plexiglas needs to be oriented such that the connections for the tubing are on the low and high corners. Attach the seals and Plexiglas to the Infiltrometer using the nuts, bolts, and washers.

(g) Attach the Marriotte Bottle to the Stand. It should be placed next to the low corner. Attach approximately 2-ft. of tubing between the Marriotte Bottle and the Infiltrometer; attach 6-in. of tubing between the water reservoir and the Marriotte Bottle to fill the bottle; attach 6-in. of tubing to provide a release for water at the high corner of the Infiltrometer; and finally, attach 6-in. of tubing to provide an air release for the Marriotte Bottle.

(h) Allow the Infiltrometer to sit overnight so that the bentonite establishes a seal.

(i) Fill the Marriotte Bottle until the water level reaches approximately 30-cm. When finished, be sure that all of the clamps are closed except for the one between the Marriotte Bottle and the Infiltrometer. This clamp should be left open to allow the volume in the Marriotte Bottle to adjust with the rate of infiltration. Place concrete cinder blocks on top of the Infiltrometer to prevent uplift movement.

(j) Measure the distance from the bottom of the tube inside the Marriotte Bottle to the ground test pad surface (this measure is the head of water placed on the test section.) Take your first reading from the Marriotte Bottle (read the water level in the bottle.) Be sure to check the tubing connecting the Marriotte Bottle to the Infiltrometer for bubbles. Tap on the tubing to move the bubbles up through the Marriotte Bottle.

(k) Saturate the ground around the Infiltrometer and cover with plastic or Visquin.

(l) Continue taking readings approximately every hour for the rest of the workday. For the next workday, take readings approximately every 2 hours. For the third workday, take approximately 3 to 4 readings throughout the course of the day. Continue this until the permeability stabilizes. Refill the Marriotte Bottle, as required.

(m) Once the Infiltrometer is removed, measure the wetting front. This is done with a spade and visual inspection. Utilize a tape for the actual measurement.

3. **<u>Documentation and Data Recording</u>**

(a) Test Number (e.g., SSRI-1)
(b) Description (location, lift, etc.)
(c) Area of the Infiltrometer (cm^2) - measured once during test.
(d) Marriotte Bottle Calibration (ml/cm) - measured once.
(e) Head (cm) - measured once at the beginning when starting to take readings.
(f) Wetting Front - measured at the end of the test.

(g) Date and Time - taken at each reading.

(h) Infiltrometer Reading - taken at each reading.

(i) From (g) and (h) above, the test time (days), the interval time (seconds), the volume (ml), the cumulative volume (ml), the infiltration (cm/s), and the permeability (cm/s) can be calculated.

Volume (ml) = [Infiltrometer Reading (cm)] * [Marriotte Bottle Calibration (ml/cm)]

Infiltration (cm/s) = [Δ (Volume (ml))] / {[Interval Time (s)] * [Area of the Infiltrometer (cm^2)]}

Permeability (cm/s) = [Infiltration (cm/s] / {[Head (cm) + Wetting Front (cm)] / [Wetting Front (cm)]}

A.3 Procedure for Obtaining Large Scale Block Samples

This procedure is intended for guidance only. Actual procedures may be modified by the Project Manager and CQA Engineer. This procedure is based on an approximately 12- to 14-in. diameter block sample.

Step 1. Put the sample ring on to the ground where block sample will be carved. (Fig. 1)

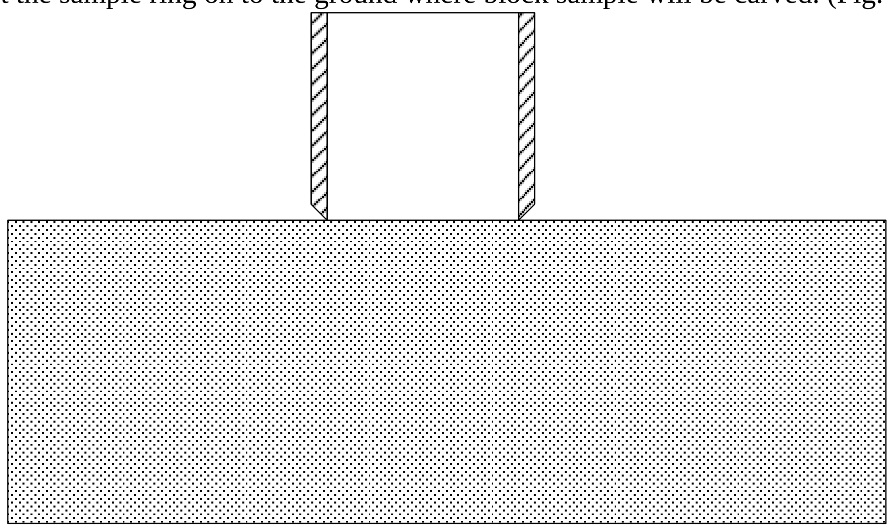


Figure 1.

Step 2. Carefully dig soil around the sample ring about 10" to 16" depth, leave about 14" – 15" soil core. (Fig. 2)

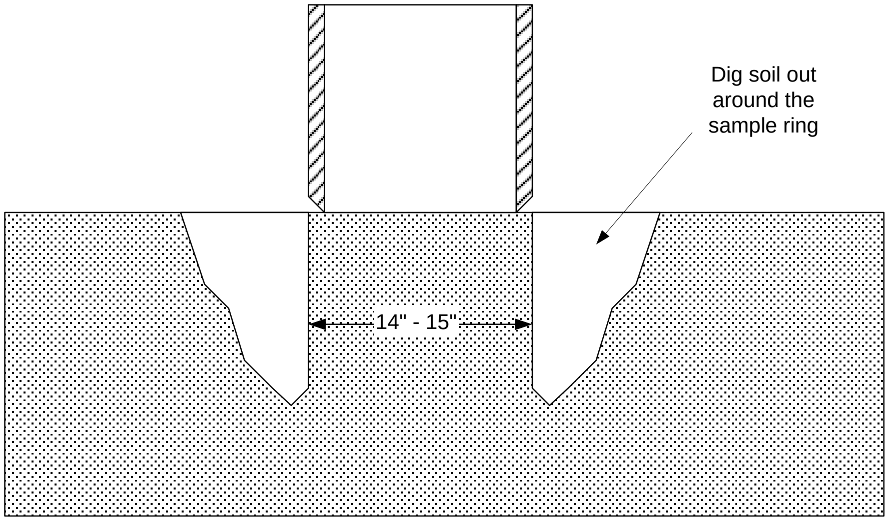


Figure 2.

Step 3. Use a small knife or spatula carefully trim soil about 1” down around bottom edge of sample ring and then push the ring down (Fig. 3)

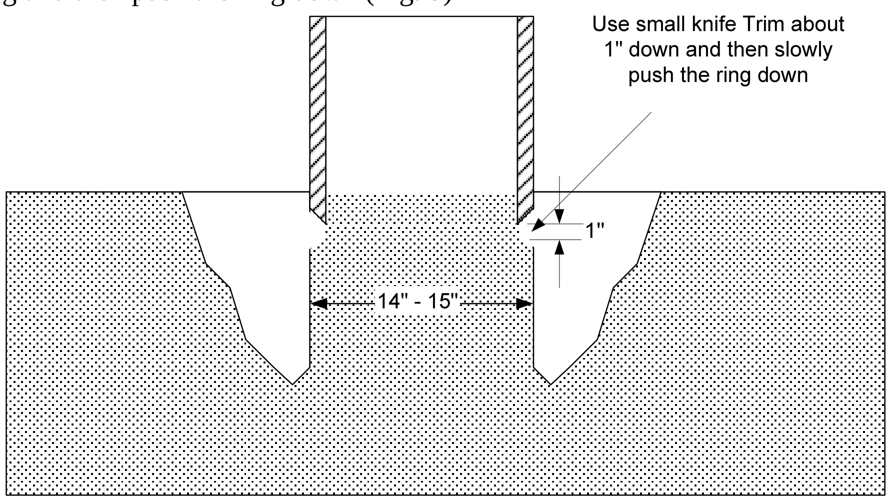


Figure 3.

Step 4. Continue step 3, until soil fits inside the sample ring. (Fig. 4, 5)

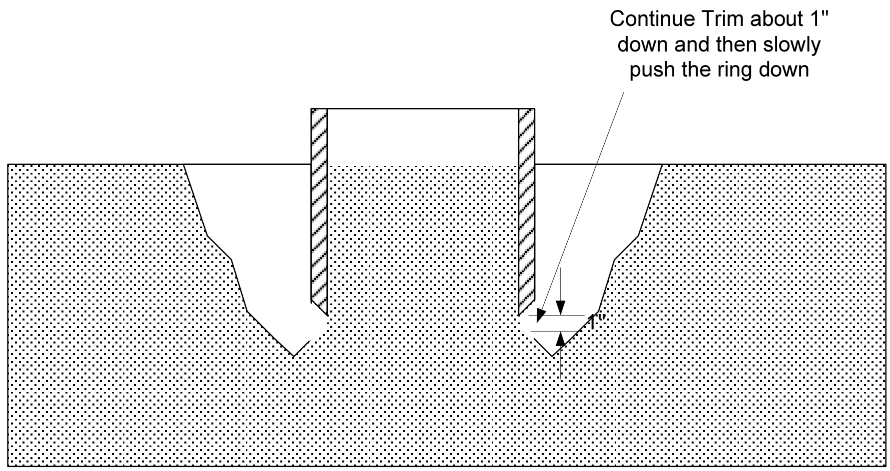


Figure 4.

NOTE: Steps 3 and 4 may be combined into a single alternate step whereby the trimming process may be eliminated and instead the ring may be carefully pushed to its full depth in one step to yield the configuration shown below (Fig. 5).

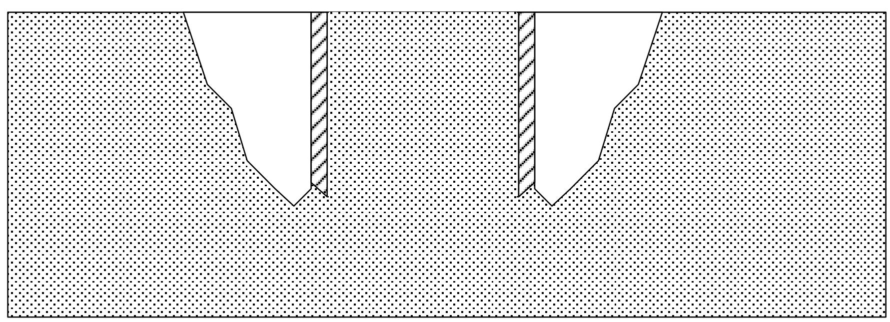


Figure 5.

Step 5. Put 2 layer of plastic sheet on to top of the sample ring, and then use duct tape wrap it around the ring. (Fig. 6)

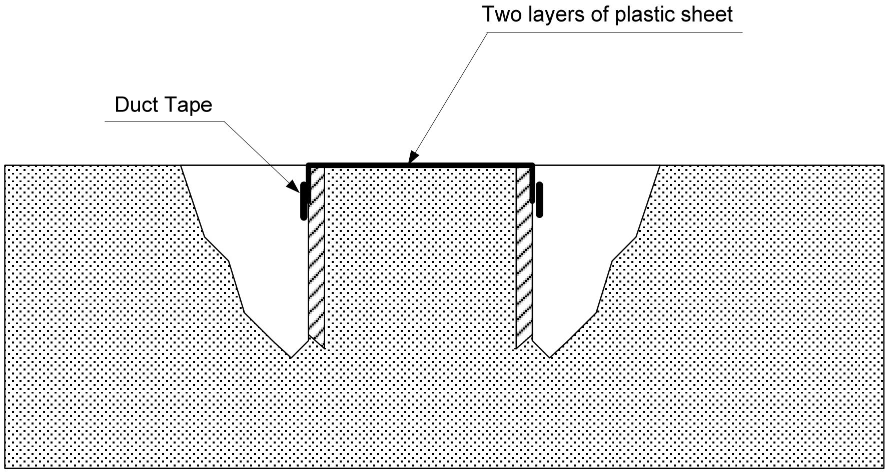


Figure 6.

Step 6. Use a shovel dig soil at the bottom of the ring for whole around the sample ring.

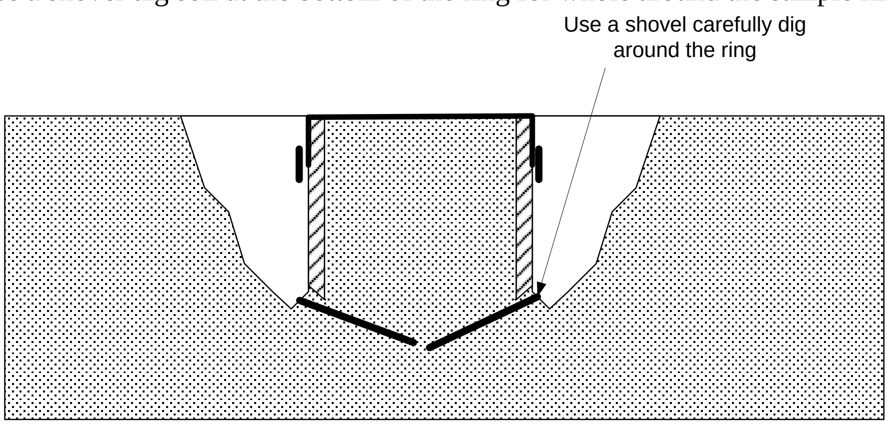


Figure 6.

Step 7. Carefully move the sample ring with soil out of the pit, flip over and carefully trim soil at bottom end.

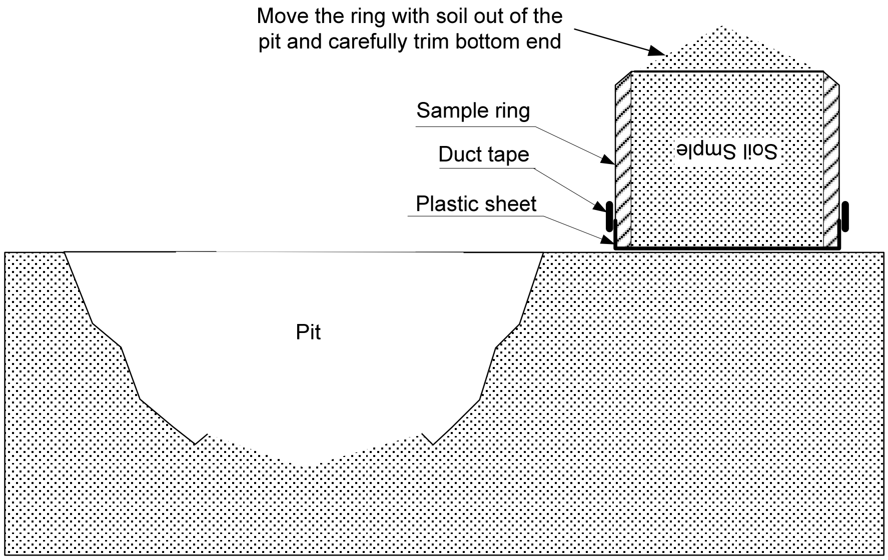
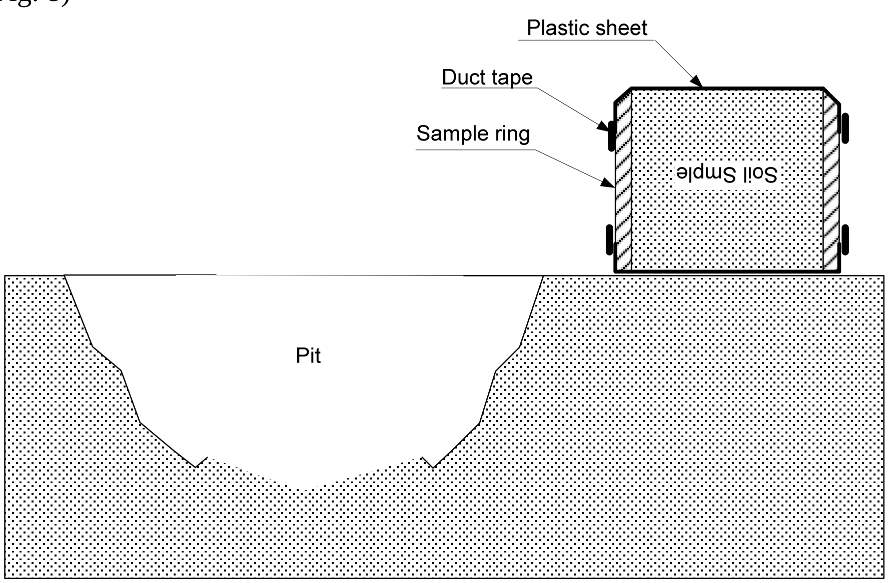
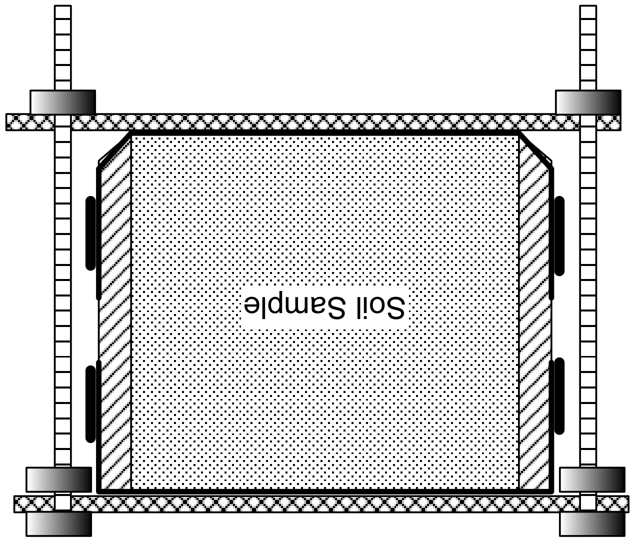


Figure 7.

Step 8. Put 2 layer of plastic sheet on to the sample ring, and then use duct tape wrap it around the ring. (Fig. 8)



Step 9. Finally, pack and bolt the sample ring between two boards (see below), or using other packing methods, to keep the sample secure and protected for shipping.


Soil Sample

APPENDIX B
HDPE TESTING METHODS

B. HDPE Testing Methods

HDPE testing methods are outlined in the following table.

PROPERTIES	TEST METHOD
Thickness	ASTM D 5199
Carbon Black Percent	ASTM D 1603
Carbon Black Dispersion	ASTM D 5596
Density	ASTM D 792 Method A or ASTM D 1505
Tensile Properties	ASTM D 6693
Tear Resistance	ASTM D 1004
Puncture Resistance	ASTM D 4833
Stress Crack Resistance	ASTM D 5397
Oxidative Induction Time	ASTM D 3895
Oven Aging at 85 degrees C	ASTM D 5885
Standard OIT - % retained after 90 days, - or - High Pressure OIT - % retained after 90 days	ASTM 5721 ASTM D 5885
Direct Shear Interface Strength Testing, Soil-Geosynthetic Interfaces	ASTM D 5321
GEOMEMBRANE SEAM PROPERTIES	
Shear and Peel Strength Properties	ASTM D 6392
Pressured Air Channel Evaluation	ASTM D 5820
Vacuum Testing	ASTM D 5641

APPENDIX C
GEOSYNTHETIC CLAY LINER TESTING METHODS

C. Geosynthetic Clay Liner Testing Methods

Geosynthetic Clay Liner testing methods are outlined in the following table.

Description	Method
Bentonite Mass Per Unit Area	ASTM D5993
GCL Index Flux	ASTM D5887
Bentonite Swell Index	ASTM D5890
Bentonite Fluid Loss	ASTM D5891

APPENDIX D
GEOTEXTILE FILTER FABRIC TESTING METHODS

D. Geotextile Filter Fabric Testing Methods

Geotextile filter fabric testing methods are outlined in the following table.

Description	Method
Mass Per Unit Area	ASTM D5261
Grab Tensile Strength	ASTM D4632
Puncture Resistance	ASTM D4833
Permittivity	ASTM D4491
Apparent Opening Size	ASTM D4751