CITY OF EDINBURG SOLID WASTE MANAGEMENT

PERMIT AMENDMENT APPLICATION

Part III, Attachment 3

WASTE MANAGEMENT UNIT DESIGN

Edinburg Regional Disposal Facility

Edinburg, Hidalgo County, Texas

TCEQ Permit MSW-956C

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EXECUTIVE SUMMARY

30 TAC §330.63(d)(4)(G)

This Waste Management Unit Design Report including a Liner Quality Control Plan is prepared under the direction of a licensed professional engineer in accordance with 30 TAC §330.63(d)(4), and applicable sections of 30 TAC, Chapter 330, Subchapter H "Liner System Design and Operation." The Edinburg Regional Disposal Facility (facility) has been designed to safeguard the health, welfare, and physical property of the people and the environment through various design considerations, which include volume and site life calculations, geotechnical analyses, liner design, leachate management, all-weather access, and other operational considerations.

1.0 LANDFILL UNITS

1.1 All-Weather Operation

30 TAC §30 TAC §330.63(d)(4)(A)

The facility makes provisions for all-weather operation and regularly maintain all-weather roads constructed for access to unloading areas designated for wet-weather operations.

1.1.1 Publicly Owned Routes to the Facility

The facility entrance is located at 8601 Jasman Rd north of FM 2812 and is shared with the City's Type IV Landfill TCEQ Permit MSW-2302. Access to the facility entrance from US Hwy 281 is eastbound on FM 2812 and north onto Jasman Rd. Access roads to the facility entrance are constructed with an asphaltic concrete pavement surface overlaying a limed caliche base.

1.1.2 Facility Entrance to Unloading Areas and Interior Access Roads

Access roads from the gatehouse and scales at the facility entrance to unloading areas and interior access roads are characteristically surfaced with caliche. Other all-weather road building materials such as compacted gravel, crushed stone, asphalt, or concrete may be used by the facility. Interior road locations are depicted on Figure III3-1, Facility Layout Plan.

1.1.3 Tracking of Mud Minimization

As discussed in §4.16.2, Tracking of Mud Minimization of Part IV, Site Operating Plan, the tracking of mud onto public roadways from the facility will be minimized. Traffic leaving the facility will travel southbound on Jasman Road for a quarter-mile to FM 2812. Mud at the facility entrance road and interior access roads will be removed by spraying water from the site water truck, scraping with a site bulldozer or maintainer, using a rotary broom street sweeper, or otherwise deploying site personnel with appropriate on-site materials, tools and equipment. Jasman Road, an asphaltic-concrete-paved road, will be inspected for any tracked mud and associated debris daily. As necessary, mud will be removed from Jasman Road in a similar manner to control the further tracking of mud onto FM 2812. The SM will have authority to implement additional measures (e.g., wheel shakers, wheel washes, etc.) if the preceding measures are not reasonably effective.

1.2 Landfill Method

30 TAC §330.63(d)(4)(B)

The pattern of waste disposal will be governed by the area fill disposal method. Landfilling will occur below grade and above grade, depending on the stage of operational development and operational considerations. Initially, filling will occur above grade over the existing constructed fill areas to attain the

design top of waste grades. New landfill cells will be developed adjacent to existing filled areas and waste placement operations will continue below grade.

1.3 Landfill Unit Elevations

30 TAC §330.63(d)(4)(C)

Figure III3-1, Facility Layout Plan illustrates an outline of the solid waste management units. Waste within Pre-Subtitle D Units 1-4 will either be relocated for development of Unit 8 or an Overliner- will be constructed for vertical expansion. Figure III3-2A, Subgrade Layout Plan – Overliner Option depicts the subgrade elevations of the lateral expansion cells within Unit 7 and Overliner. Likewise Figure III3-2B, Subgrade Layout Plan –Unit 8 Option, depicts the subgrade elevations of the lateral expansion cells within Unit 7 and Unit 8. The elevation of deepest excavation is 70 ft-msl.

Figure III3-3, Final Contour Map depicts the maximum final cover elevation of approximately 398 ft-msl. The maximum waste elevation is the final cover elevation minus the thickness of final cover and is dependent on thickness of the final cover lining option used. Part III7, Closure Plan details final cover lining options.

1.4 Estimated Rate of Solid Waste Deposition and Operating Life

30 TAC §330.63(d)(4)(D)

The maximum total disposal capacity of the facility is 87,301,156 cubic yards, and the maximum remaining disposal capacity will be 76,304,934 cubic yards of waste and daily cover, based on the FY 2016 MSW Annual Report. It is anticipated that the rate of waste disposal will reach approximately 1,500,000 tons per year and that the facility will have a site life of approximately 63.5 years. The total disposal capacity and operational life calculations are provided in Appendix III3A, Volume and Site Life Calculations.

As population, economic conditions, and available landfill disposal capacity change within the region, the volume of incoming waste could vary considerably. The facility will maintain quarterly records to document waste acceptance rates. If the rate exceeds the estimated rate and is not due to a temporary occurrence, the City will file a permit modification application consistent with 30 TAC §330.125(h). As provided by rule, the estimated waste acceptance rate is not a limiting parameter of the permit.

1.5 Landfill Unit Cross-Sections

30 TAC §330.63(d)(4)(E) & (F)

Figure III3-4A, Fill Cross-Sections Location Map is a map showing a sufficient number of cross-sections across the facility, both latitudinally and longitudinally, so as to accurately depict the existing and proposed depths of all fill areas within the site. These fill cross-sections go through or very near soil borings where

boring logs obtained from Part III4B, Soil Boring Logs are shown on the plan profiles, Figures III3-4B – III3-4E, Fill Cross-Sections. These plan profile figures provide an inset key map of the fill cross-section plan and clearly show the following content provided in Table III3-1.

Table III3-1: Fill Cross-Section Figures III3-4B – III3-4E

Plan Profile Content	A – A'	B – B'	C – C'	D – D'
Plan Inset Key Map	✓	✓	✓	✓
Boring Logs	✓	✓	✓	✓
Top of Levee	✓	✓	✓	✓
Top of Proposed Fill (Top of Final Cover)	✓	✓	✓	✓
Maximum Elevation of Proposed Fill	✓	✓	✓	✓
Top of the Wastes	✓	✓	✓	✓
Existing Ground	✓	✓	✓	✓
Bottom of the Excavations (Subgrade)	✓	✓	✓	✓
Side Slopes of Trenches and Fill Areas	✓	✓	✓	✓
Gas Vents or Wells	✓		✓	
Groundwater Monitoring Wells	✓	✓	✓	✓
Initial and Static Levels of Any Water Encountered	✓	✓	✓	✓
Compacted Perimeter Berms	✓	✓	✓	✓

Notes: 1. Items not checked are not applicable.
2. Perimeter berm design dimensions shown on figures.

2.0 WASTE MANAGEMENT UNIT ENGINEERING ANALYSES

Analyses were performed to assess the performance of the landfill with respect to settlement and slope stability. Each of these analyses is described in detail in the following sections.

2.1 Settlement Analysis

Facility floor settlement will occur in Strata I through III. Review of the excavation plan indicates that much of Stratum I will be removed prior to construction of the liner system and that much of the Edinburg Regional Disposal Facility floor will be founded on a thin layer of remaining Stratum I. For this analysis, settlement critical cross-sections are cut through a section of the Edinburg Regional Disposal Facility with the thickest waste above and the most critical subsurface conditions. Intermittent points along the critical cross-section are analyzed for settlement and post-settlement to define slopes. The cross-section location is referred to as Line A, located in Unit 7, Cell 2A and 2B on a north-south direction. The cross-section begins at the facility perimeter and progress toward the facility center where the proposed final elevation is highest.

The settlement analyses indicate that the minimum total settlement will be approximately 4 feet and the minimum post-settlement grade on the floor will be 0.6%. The post-settlement grade was used in the leachate header pipe sizing calculations (Appendix III3D-3A).

The post-settlement floor grades will maintain positive drainage and allow the leachate to drain towards the leachate collection system under the conditions analyzed. The results of the settlement analysis are presented in Appendix III3B-1.

2.2 Stability Analysis

The results of the stability analyses indicate that the proposed slopes are stable under the conditions analyzed. For each condition analyzed, the minimum calculated factor of safety exceeds the recommended factor of safety.

Slope stability analyses were performed using limit equilibrium methods to assess the stability of the proposed landfill. In particular, stability of the proposed excavated landfill sideslopes, stability of the protective cover on landfill sideslopes, stability of the interior waste slopes, overall stability of the final filled landfill, and stability of the final cover system were evaluated.

In general, the analyses consist of the following:

- Characterization of the critical cross-section (e.g., the geometry, geology, geosynthetic interfaces, and groundwater conditions).
- Selection of appropriate strength parameters.
- Analysis under anticipated critical conditions.

The analyses are summarized in the following sections.

2.2.1 Stability Analysis of Excavated Slopes

A stability analysis was performed to consider potential failure surfaces for excavation of waste management units. The excavation is a 3H:1V slope with a crest elevation of 95 ft-msl and the minimum excavation elevation is 70 ft-msl.

Potential failure surfaces were analyzed and the minimum factor of safety was computed based on limit equilibrium methods following Spencer's and GLE/Morgenstern-Price methods of analysis using SLIDE Version 7.0, an integrated slope stability analysis program for personal computers.

Results from the method providing the least factor of safety is presented Appendix III3B-2A. The factor of safety is 4.2 for the total stress condition and 2.0 for the effective stress condition. These values indicate the excavation slopes will be stable.

2.2.2 Stability of Sideslope Liner

A stability analysis was performed to consider potential veneer failure of the sideslope liner. The sideslope is a 3H:1V slope with a crest elevation of 95 ft-msl, a minimum elevation of 70 ft-msl, and a maximum length of 75 ft.

The critical interface on the slope was analyzed and the minimum factor of safety was computed using an infinite slope analysis. Based on a review of the literature and unpublished data on similar materials under similar loading conditions, the critical interface shear strength within the sideslope alternative liner system was estimated to be 24 degrees. According to Appendix III3B-2B-2, the maximum head over the geomembrane is less than the thickness of the geocomposite drainage layer because the double-sided geocomposite drainage layer will have a transmissivity adequate to convey water infiltrating through the protective cover over the maximum sideslope length.

Results from the analysis is presented Appendix III3B-2B. The factor of safety for veneer slope stability is 1.34 with the use of conservative parameters in the analysis. This value indicates the sideslope liner will be stable.

2.2.3 Stability of the Interior Waste Slopes

Interior waste slope stability analyses were performed using the limit equilibrium slope stability method to determine the factor of safety against sliding along the liner. Based on a review of the floor grades and filling sequence, it was identified that the interior waste slope in Unit 7, Cells 6B through 9B is the most critical case, where the filling and floor slope occur in the same direction with no buttress effect from existing waste or the floor gradient.

Potential failure surfaces were analyzed and the minimum factor of safety was computed based on limit equilibrium methods following Spencer's and GLE/Morgenstern-Price methods of analysis using SLIDE Version 7.0, an integrated slope stability analysis program. Two possible waste filling slopes were considered; a continuous 3H:1V temporary waste slope with no benches, and a 3H:1V temporary waste slope with one bench at the middle of the slope. The maximum waste height is conservatively assumed at 400 ft-msl which is greater than the proposed waste thickness. The strength parameters were either conservatively chosen from published studies or based on test results for similar conditions.

Results from the method providing the least factor of safety are presented in Appendix III3B-2C. Under the assumed conservative scenarios, results indicate that the interior waste slope at 3H:1V may be filled up to the final elevation with an acceptable factor of safety. However, to facilitate site operations and to account for any operational uncertainties, a 100-foot wide bench at the midpoint of the 3H:1V interior slope is advised. Slope stability analyses for this condition are also presented in Appendix III3B-2C.

2.2.4 Stability of Final Filled Configuration

Final filled configuration stability analyses were performed using limit equilibrium methods to determine the factors of safety against sliding or failure. Based on a review of the design grades, two reasonable worst-case configurations were considered: a section along Unit 7, Cell 2, having 3H:1V excavation sideslopes

and 4H:1V final cover slopes to a crest elevation at 400 feet msl; and a section along Unit 7 with similar slopes running west to east along Cells 1B through 5A.

Potential failure surfaces were analyzed and the minimum factor of safety was computed based on limit equilibrium methods following Spencer's and GLE/Morgenstern-Price methods of analysis using SLIDE Version 7.0, an integrated slope stability analysis program for personal computers. The strength parameters are conservatively estimated or based on test results for similar conditions, and the reasonable worst case configuration.

Results from the method providing the least factor of safety are presented in Appendix III3B-2D. Along Section A the factor of safety is 1.9 for block sliding and 2.9 for circular failure. The corresponded factor of safety for Section B is 2.0 for block sliding and 2.9 for circular failure. These values indicate the final-filled configuration will be stable.

2.2.5 Stability of Final Cover System

A stability analysis of the final cover liner system was performed using an infinite slope analysis to estimate the potential for sliding to occur following closure of the landfill cells. A worst-case section, consisting of a 1,200-foot long, 25% slope was analyzed. Based on a review of the literature and unpublished data on similar materials under similar loading conditions, the critical interface shear strength within the final cover liner system was estimated to be 21 degrees.

The analyses are included in Appendix III3B-2E and indicate that, provided the geocomposite drainage layer is adequate to convey drainage without building up pore water pressures in the geocomposite, the factor of safety against sliding will be approximately 1.5.

Additional analyses (also included in Appendix III3B-2E) were performed to determine the geocomposite drainage layer transmissivity required to adequately convey surface water infiltration over the maximum final cover slope length. If the minimum measured transmissivity value reported in Appendix III3-2E is not met, the maximum flow length must be reduced (i.e., the geocomposite drainage layer must be “daylighted”) in direct proportion to the ratio of the actual measured transmissivity and the required measured transmissivity. A detail depicting “daylighting” is included as detail 4 in Attachment 7, Closure Plan, Figure III7-3A, Conventional Composite Final Cover Details.

2.3 Overliner

Waste within Pre-Subtitle D Units 1 – 4 will either be relocated for development of Unit 8 or an overliner will be constructed for vertical expansion. The subgrade of the overliner will be the in-place final cover grades previously permitted and extend to Unit 6 as depicted on Figure III3-9A, Overliner Subgrade Layout. Details

of the overliner design are presented on Figures III3-7A, III3-9C, and III3-9D. Overliner design analyses are included in Appendix IIIB-3, Overliner.

2.3.1 Settlement

Appendix III3B-3A, Settlement Analysis demonstrates positive drainage is maintained for the leachate collection and removal system.

Settlement for the overliner system will primarily be the result of compression of the underlying old waste and, to a lesser extent, consolidation of the foundation soil layers due to increased loads from the new waste and final cover placement. Old waste settlement consists of two components: 1) time-dependent secondary compression (or creep), and 2) primary settlement caused by the stress increase from new waste and final cover. Secondary compression within the foundation material will be very small; therefore, only consolidation settlement was evaluated below the landfill.

Settlement below the overliner was estimated and used to determine the post-settlement grades of the overliner. The minimum post-settlement grade in the direction of leachate flow is approximately 0.4 percent; therefore, positive drainage will remain at the end of the 30-year post-closure period.

2.3.2 Strain Analysis

Appendix III3B-3B, Strain Analysis demonstrates the induced tensile strain due to differential settlement of existing waste and the formation of a localized depression beneath the liner system is below the minimum allowable strain of the liner components.

Using settlement results, the difference in liner length between prior and post settlement was analyzed. The evaluation showed the liner will mainly be under compression with liner shortening. A very limited portion will experience a lengthening with a strain of 0.3 percent, well below the allowable strain of 5 percent.

An evaluation of strain in the overliner due to localized depressions (subsidence) near the surface of the old waste was performed, and is included as Appendix III3B-3B, Strain Analysis. A parametric analysis, comparing the diameter of the subsidence area and depth at its center to the allowable strain of the overliner components, indicates that the ratio of depth to diameter is approximately 0.14 for 5 percent strain and 0.20 for 10 percent strain.

Depressions of this magnitude would only be expected if voids or highly compressible material are present immediately below the overliner. To reduce the potential for subsidence below the overliner system, the existing waste will be surcharged by placing at least 20 feet of soil for a minimum 3-month period. The surcharge will collapse voids and compress the underlying material.

2.3.3 Stability Analysis

Final filled configuration stability analyses were performed using limit equilibrium methods to determine the factors of safety against sliding or failure. Based on a review of the design grades, the reasonable worst-case configuration was assumed to consist of a section along the western side of Units 3 and 4, having 4H:1V final cover slopes to a crest and maximum fill elevation of approximately 312.6 ft-msl. Compared to other sections through the pre-Subtitle D area, the chosen section exhibits thicker existing waste. Additionally, the toe of the future waste along the chosen section is less supported by the perimeter berm.

Potential failure surfaces were analyzed and the minimum factor of safety was computed based on limit equilibrium methods following Spencer's and GLE/Morgenstern-Price methods of analysis using SLIDE Version 7.0, an integrated slope stability analysis program for personal computers. The strength parameters are conservatively estimated or based on test results for similar conditions, and the reasonable worst case configuration.

The results from the method providing the least factor of safety is presented Appendix III3B-3C. The factor of safety is 2.0 for block sliding and 3.0 for circular failure. These values indicate the final-filled configuration will be stable.

3.0 LINER DESIGN CRITERIA

30 TAC §§330.331(a)(2) & 330.331(b)

The liner design for the facility is not composed of “composite liner” components defined by 30 TAC §330.331(b); consisting of at least a 2-foot layer of re-compacted soil with a hydraulic conductivity of no more than $1x10^{-7}$ cm/s and a 60-mil high density polyethylene (HDPE) geomembrane liner component.

An alternative liner design is currently approved under permit TCEQ Permit MSW-956B for remaining Subtitle D construction and is the liner design to be used for expansion cells in Unit 7 and Unit 8. The alternative liner design consists of, from bottom up, a geosynthetic clay liner (GCL), a 60-mil high-density polyethylene (HDPE) geomembrane liner, double-side geocomposite composed of a geonet bonded to geotextile on both sides, and 2 feet of protective cover soil. The overliner design discussed in §2.3, Overliner will use 60-mil linear low-density polyethylene (LLDPE) instead of HDPE because its elastic properties are better suited for potential waste settlement. Alternative liner details are included on Figure III3-7, Alternative Liner System Details. Overliner design details and cross-sections are shown on Figures III3-9B, III3-9C, and III3-9D.

As discussed in §4.0, Leachate Collection and Removal System (LCRS) is designed to maintain less than a 30-centimeter depth of leachate over the alternative liner system.

Portions of the landfill excavation extend below the seasonal high water table. Consistent with current practice at the site, toe drains and a geocomposite underdrain along the sideslopes will be installed to control groundwater. The underdrain will be maintained and operated until sufficient ballast is in place to resist the uplift pressures below the liner system. The underdrain analyses are included in Appendix III3E-2. The underdrain system layout and details are shown on Figures III3-6A, III3-6B, and III3-8.

3.1 Alternative Liner Design

30 TAC §330.335

Alternative liner designs, which must include a leachate management system, may be authorized by the TCEQ if a demonstration by computerized design modeling that the maximum contaminant levels detailed in 30 TAC §330.331, Table 1 will not be exceeded at the point of compliance. At the discretion of the TCEQ, a field demonstration may be required to prove the practicality and performance capabilities of an alternative liner design.

3.2 Point of Compliance Demonstration

30 TAC §330.331(a)(1)

The liner design ensures the concentration values listed in Table 1 of 30 TAC §330.331(a)(1) will not be exceeded in the uppermost aquifer at the point of compliance, as determined in 30 TAC §330.403. The alternative liner design was evaluated to demonstrate that it provides a level of groundwater protection that is greater than or equal to the level of protection provided by a “composite liner” system. The evaluation presented in Appendix III3C-1, Point of Compliance Demonstration indicates that substituting the clay component with a geosynthetic clay liner (GCL) will provide a greater or equivalent level of groundwater protection at the facility. In addition, fate and transport modeling performed on the alternative liner system demonstrates that the maximum contaminant levels detailed in 30 TAC §330.331(a)(1) will not be exceeded at the point of compliance as a result of hypothetical leakage through the liner system.

3.3 Constructed of Chemically Resistant Materials

30 TAC §330.333(1)

The alternative liner system will be constructed of materials including HDPE (or LLDPE for the overliner system) and polyester or polypropylene are chemically resistant to leachate characteristically generated by municipal solid waste facilities. HDPE or LLDPE materials are used for the geomembrane and polyester or polypropylene materials are used in the geotextile component of the GCL and geocomposite drainage layer.

3.4 Liner Design Considerations

30 TAC §330.331(c)

When approving an alternative liner design that ensures the concentration values listed in Table 1 of 30 TAC §330.331(a)(1) will not be exceeded in the uppermost aquifer at the point of compliance, as determined in 30 TAC §330.403, the TCEQ may consider, but is not limited to, the following factors:

- the hydrogeologic characteristics of the facility and surrounding land;
- the climatic factors of the area;
- the volume and physical and chemical characteristics of the leachate;
- the quantity, quality, and direction of flow of groundwater;
- the proximity and withdrawal rate of the groundwater users;
- the availability of alternative drinking water supplies;
- the existing quality of the groundwater, including other sources of contamination and their cumulative impacts on the groundwater and whether groundwater is currently used or reasonably expected to be used for drinking water;
- public health, safety, and welfare effects; and
- practicable capability of the owner or operator.

The alternative liner design is currently approved under permit TCEQ Permit MSW-956B. The aforementioned factors and any factors not addressed in this application shall be provided to the TCEQ upon request to aid in considerations.

4.0 LEACHATE COLLECTION AND REMOVAL SYSTEM

30 TAC §§330.331(a)(2) & 330.333

The leachate collection and removal system (LCRS) is designed and constructed to maintain less than a 30-centimeter depth of leachate over the alternative liner system and eliminate potential migration of landfill leachate into groundwater and to meet the requirements of 30 TAC §330.333. The LCRS will collect and remove leachate from the top of the alternative liner, channel leachate to designated leachate collection sumps, and pump leachate from the leachate collection sump into a leachate force main for disposal.

The LCRS drainage layer is comprised of a double-sided geocomposite: a high density polyethylene (HDPE) geonet bonded with geotextile on both sides. The leachate collection system details are presented on Figure III3-8. Leachate is collected from the drainage layers into a leachate collection trench constructed of perforated HDPE piping encased by a drainage aggregate and wrapped in a geotextile filter. The leachate collection trench discharges into leachate collection sumps likewise constructed of drainage aggregate and wrapped in geotextile filter. From with the leachate collection sumps, an HDPE upslope

riser pipe houses a pump that removes accumulated leachate from within the leachate collection sumps into a leachate force main for discharge to the public sewer system as depicted on Figures III3-5A and III3-5B.

The LCRS is designed and operated to function through the scheduled closure and post-closure care period of the landfill considering the following factors:

- constructed of materials that are chemically resistant to the leachate expected to be generated
- of sufficient strength and thickness to prevent collapse under the pressures exerted by overlying wastes, waste cover materials, and by any equipment used at the landfill
- estimated rate of leachate removal;
- capacity of sumps;
- pipe material and strength, if used;
- pipe network spacing and grading, if used;
- collection sump materials and strength;
- drainage media specifications and performance; and
- demonstration that pipes and perforations will be resistant to clogging and can be cleaned.

4.1 Groundwater Inflow

30 TAC §330.337(d)

The LCRS is designed to handle both the leachate generated and the groundwater inflow from materials beneath and lateral to the liner system. Appendix III3D-2, Groundwater Inflow demonstrates the calculated maximum volume of groundwater inflow based on determination of the permeability and potentiometric conditions of the alternative liner system and of the materials surrounding the liner system. Groundwater inflow into the leachate collection system using the alternative liner system is negligible relative to leachate production rates.

4.2 Rate of Leachate Removal

30 TAC §330.333(3)(A)

The estimated rate of leachate removal is operationally equivalent to the leachate production rate. The HELP Model (Hydraulic Evaluation of Landfill Performance, US Army Corps of Engineers, Waterways Experiment Station, Version 3.07, November, 1997) was used to determine the leachate production rate (impingement rate) for various conditions during the life of the landfill. A summary of HELP model results is provided in Appendix III3D-1, HELP Model Evaluations. The maximum rate of leachate removal is 962 cf/ac/day.

4.3 Drainage Media Specifications and Performance

30 TAC §330.333(F)

Drainage media used in the LCRS include double-sided geocomposite and perforated HDPE header piping encased by a drainage aggregate wrapped in a filter geotextile. Evaluations of performance and required specifications of drainage media are provided in Appendix III3D-3, Drainage Media Specifications and Performance.

4.3.1 Constructed of Chemically Resistant Materials

30 TAC §330.333(1)

The LCRS will be constructed of materials including HDPE, polyester or polypropylene, and drainage aggregate that are chemically resistant to the leachate expected to be generated by municipal solid waste facilities. HDPE materials are used in the geonet component of the double-sided geocomposite drainage layer and piping within the leachate collection trench and leachate collection sump. Drainage material used within the leachate collection trench and leachate collection sump is required to be resistant to carbonate loss. The geotextile component of the double-sided geocomposite drainage layer, leachate collection trench, and leachate collection sump utilize 100-percent continuous-filament polyester or polypropylene.

4.3.2 Double-sided Geocomposite Drainage Layer

The double-sided geocomposite drainage media is a high density polyethylene (HDPE) geonet bonded with geotextile on both sides. Appendix III3D-1, HELP Model Evaluation demonstrates the design transmissivity using the impingement rate under the worst case scenario and the maximum lengths and slopes from the subgrade layout plan presented in Figures III3-2A and III3-2B. Also provided are transmissivity specification requirements for the double-sided geocomposite to be used; reduction factors were applied to consider potential long-term creep, chemical clogging, biological clogging, and intrusion of geotextile into the geonet component.

4.3.3 Leachate Collection Trench Header Pipe Sizing

The leachate collection trench is a perforated HDPE header pipe encased by a drainage aggregate wrapped in a filter geotextile. Appendix III3D-3A, Header Pipe Sizing evaluates the size of header pipe required to convey the maximum anticipated leachate generated using the maximum impingement rate from the worst case scenario provided by Appendix III3D-1, Help Model Evaluation, the slope of header pipe post-settlement provided by Appendix III3B-1, Settlement, and the maximum contributing area from the subgrade layout plan presented in Figures III3-2A and III3-2B. The header pipe sizing is more than adequate for the maximum leachate generated.

4.3.4 Leachate Collection Trench Header Pipe Perforations

Appendix III3D-3B, Header Pipe Perforations evaluates the perforation size required to convey the maximum leachate generated using the maximum leachate generation rate from the worst case scenario provided by Appendix III3D-1, Help Model Evaluation. The inflow rates into the header pipe perforations exceeds the maximum leachate generated.

4.3.5 Pipe Material and Strength

30 TAC §§330.333(3)(C) & 330.333(3)(E)

Pipes used in the LCRS are of HDPE material. Appendix III3D-3C, HDPE Pipe Structural Design evaluates the structural integrity of the leachate collection trench header pipes and sump riser pipes to withstand maximum overburden pressures exerted by overlying wastes, waste cover materials, and by any equipment used at the landfill.

The vertical pressures were determined for overburden pressures of the overlying wastes and waste cover materials and for equipment loading over the pipe with 5 feet of waste and 2 feet of protective cover. Overburden pressures were greater than that of equipment loading, thus overburden was used for analysis of structural integrity of the designed HDPE header pipe and sump riser pipe which include wall crushing, wall buckling and ring deflection.

Review of the results shows that both pipes have satisfactory factors of safety against wall crushing and buckling and pipe deflections are lower than the allowable. Therefore the HDPE pipes can withstand the vertical pressure exerted.

4.3.6 Sufficient Strength and Thickness

30 TAC §330.333(2)

The leachate collection and removal system (LCRS) will be of sufficient strength and thickness to prevent collapse under the pressures exerted by overlying wastes, waste cover materials, and by any equipment used at the landfill. As previously discussed in the §4.3.5, the HDPE header and riser pipes are of sufficient strength and thickness. The double-sided geocomposite drainage layer and drainage aggregate used in the LCRS have a compressive strength much greater than the vertical pressures calculated in Appendix III3D-3D, HDPE Pipe Structural Design.

4.3.7 Drainage Aggregate

Drainage aggregate wrapped in a filter geotextile is used in both the leachate collection trenches and leachate collection sumps. The aggregate used shall consist of durable particles of crushed stone, natural gravel, or light weight aggregate free of silt, clay, or other unsuitable materials and shall have a loss mass due to calcium carbonate of less than 15 percent. To prevent potential clogging of aggregate into the header

pipe perforations, the gradation of aggregate shall be such that the ratio of 85 percent size of aggregate to the header pipe perforation size is greater than 1.7.

4.3.8 Pipe Perforations Resistant to Clogging

30 TAC §330.33(G)

Pipe perforations will be resistant to clogging because leachate collection pipes are encased by a drainage aggregate with a gradation sizing described in §4.3.4 wrapped in a filter geotextile. The longest length of leachate collection trench as shown on the subgrade layout plans presented in Figures III3-2A and III3-2B is approximately 1900 ft. According to industry standard, the current practice of hydro-jetting can clean header pipes to a distance greater than 2000 ft.

4.3.9 Leachate Collection Trench Spacing and Grading

30 TAC §330.333(3)(D)

Leachate collection trenches are graded at 1% along subgrade low lines created from the convergence of 2% floors as shown on the subgrade layout plans presented in Figures III3-2A and III3-2B.

4.3.10 Leachate Collection Sump Capacity

30 TAC §330.333(3)(B)

Appendix III3D-4, Sump Capacity Calculations utilizes typical sump dimensions and porosity of the drainage aggregate to determine leachate capacity. The maximum leachate generated, based on the maximum contributing area and the maximum leachate generation rate provided by Appendix III3D-1, Help Model Evaluation was compared to the sump leachate capacity to determine an estimated time to fill the sump. Based on results, the leachate collection sump design provides adequate capacity and cycle time for leachate pumping.

5.0 BALLAST AND DEWATERING SYSTEM

30 TAC §330.337(e)

Waste management unit excavations extend below the seasonal high water table resulting in upward or inward hydrostatic forces on the alternative liner. The alternative liner and the waste placed above it will provide the ballast (weight) to protect the liner system from uplift forces from groundwater. To offset hydrostatic uplift during construction, an active dewatering system will be constructed and operated until sufficient ballast is in place.

5.1 Ballast

30 TAC §330.337(b)(1)

To offset hydrostatic uplift, the weight of the alternative liner and the waste placed above it will provide the ballast (weight) to protect the liner system from uplift forces from groundwater. The ballast counteracting the hydrostatic forces include the soil materials from the leachate collection system components, the protective cover, waste above the liner and leachate collection system, and the soil materials from the interim cover. The weight of the geosynthetic components of the leachate collection system and any geosynthetic components of the interim cover is considered negligible. Appendix III3E-1, Ballast Calculations demonstrate that the ballast, including waste, offset hydrostatic uplift by a factor greater than 1.5.

5.2 Dewatering System

30 TAC §330.337(b)(2)

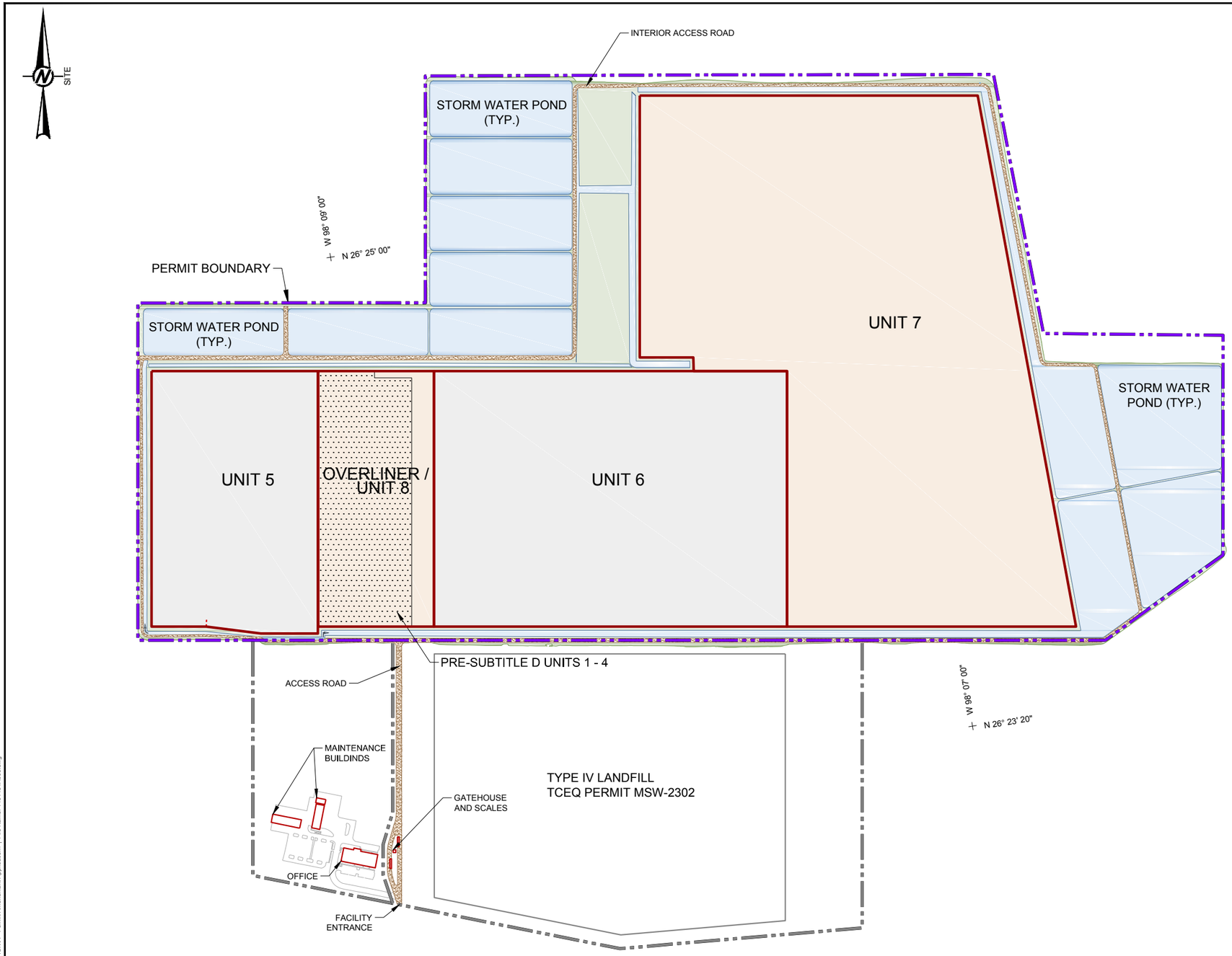
During construction of the alternative liner, groundwater will be controlled by installing an active dewatering system, which includes an underdrain composed of toe drains, a geocomposite along the sideslopes, and an underdrain sump. Appendix III3E-2, Dewatering System Calculations estimates groundwater flow into the underdrain using SEEP/W, a 2-dimensional finite element analysis program, using the worst-case scenario and designs the underdrain system to reduce upward or inward hydrostatic forces on the alternative liner to achieve factor of safety greater than 1.2 against uplift. Figures III3-6A, III3-6B, and III3-8 present design layout and details of the dewatering system.

6.0 LINER QUALITY CONTROL PLAN

30 TAC §330.339(a)

Appendix III3F, Liner Quality Control Plan (LQCP), is prepared under the direction of a licensed professional engineer by a Professional Engineer, and it shall be the basis for the type and rate of quality control testing performance and reported in the geosynthetic liner evaluation report (GLER) as required in §30 TAC §330.341. The plan provides operating personnel adequate procedural guidance for assuring continuous compliance with groundwater protection requirements. The plan specifies construction methods employing good engineering practices for installation and testing of components of the alternative liner including geosynthetic clay liner (GCL), geomembrane (GM), leachate collection and removal system (LCRS), and protective cover soil. As discussed in §3.1, the alternative liner design does not include at least a 2-foot layer of re-compacted soil with a hydraulic conductivity of no more than $1x10^{-7}$ cm/s; therefore, liner quality control testing procedures for a compacted clay liner are not provided within the LQCP in accordance with 30 TAC §330.339. Also included within the LQCP are special considerations for excavations below the seasonal high groundwater table.

FIGURES



LEGEND

- PERMIT BOUNDARY
- UNIT BOUNDARY
- EXISTING PRE-SUBTITLE D UNITS 1 - 4
- ROADS

NOTE(S)

1. ACCESS ROADS FROM THE GATEHOUSE AND SCALES AT FACILITY ENTRANCE TO THE UNLOADING AREAS AND OTHER INTERIOR ACCESS ROADS ARE CHARACTERISTILY SURFACED WITH THE CALICHE.
2. INTERIOR ACCESS ROAD WILL BE EITHER SOIL SURFACED OR SURFACED WITH CALICHE.
3. OTHER ALL-WEATHER ROAD BUILDING MATERIALS SUCH AS COMPACTED GRAVEL, CRUSHED STONE, ASPHALT, OR CONCRETE MAY BE USED BY THE FACILITY.
4. ALL-WEATHER ROADS WILL BE CONSTRUCTED FOR ACCESS TO UNLOADING AREAS DESIGNATED FOR WET-WEATHER OPERATIONS.

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0 300 600
1" = 600' FEET

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0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	TDS	MX	JBF

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STATE OF TEXAS
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
FACILITY LAYOUT PLAN

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3	0	1 of 19	III3-1

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LEGEND

- PERIMETER BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- ROADS
- 1A CELL DESIGNATION

NOTE(S)

1. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
2. SUBGRADE ELEVATIONS SHOWN.
3. TOP OF THE LINER ELEVATIONS IN THE BOTTOM OF THE LEACHATE COLLECTION SUMPS ARE 2 ft LOWER THAN ELEVATION OF THE LOW POINT ON THE LINER.
4. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 72 ft-msl IN UNIT 7.
5. EXISTING TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED 07/24/2014.

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0 300 600
1" = 600' FEET

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
SUBGRADE LAYOUT PLAN *OVERLINER OPTION*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3	0	2 of 19	III3-2A

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LEGEND

- PERIMETER BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- ROADS
- 1A CELL DESIGNATION

NOTE(S)

1. UNIT 8 OPTION (WASTE EXCAVATION) SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
2. SUBGRADE ELEVATIONS SHOWN.
3. TOP OF THE LINER ELEVATIONS IN THE BOTTOM OF THE LEACHATE COLLECTION SUMPS ARE 2 ft LOWER THAN ELEVATION OF THE LOW POINT ON THE LINER.
4. EXISTING TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED 07/24/2014.
5. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 72 ft-msl IN UNIT 7.
6. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 70 ft-msl IN UNIT 8.

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
SUBGRADE LAYOUT PLAN *UNIT 8 OPTION*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3	0	3 of 19	III3-2B

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LEGEND

- PERMIT BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- FINAL COVER 25 ft CONTOUR
- FINAL COVER 5 ft CONTOUR
- ACCESS ROADS
- GP-107 GAS PROBE
- MW-107 GROUNDWATER MONITORING WELL
- SURFACE WATER PERIMETER CHANNEL FLOW DIRECTION
- SURFACE WATER PERIMETER CHANNEL FLOW DIRECTION
- SURFACE WATER PERIMETER CHANNEL FLOW DIRECTION

NOTE(S)

1. TOP OF FINAL COVER GRADES ARE SHOWN ON THIS SHEET.
2. TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED 07/24/2014.
3. SEE PART III2, SURFACE WATER DRAINAGE REPORT, FOR DETAILS OF STORMWATER MANAGEMENT FEATURES.

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PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
FINAL CONTOUR MAP

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3	0	4 of 19	III3-3

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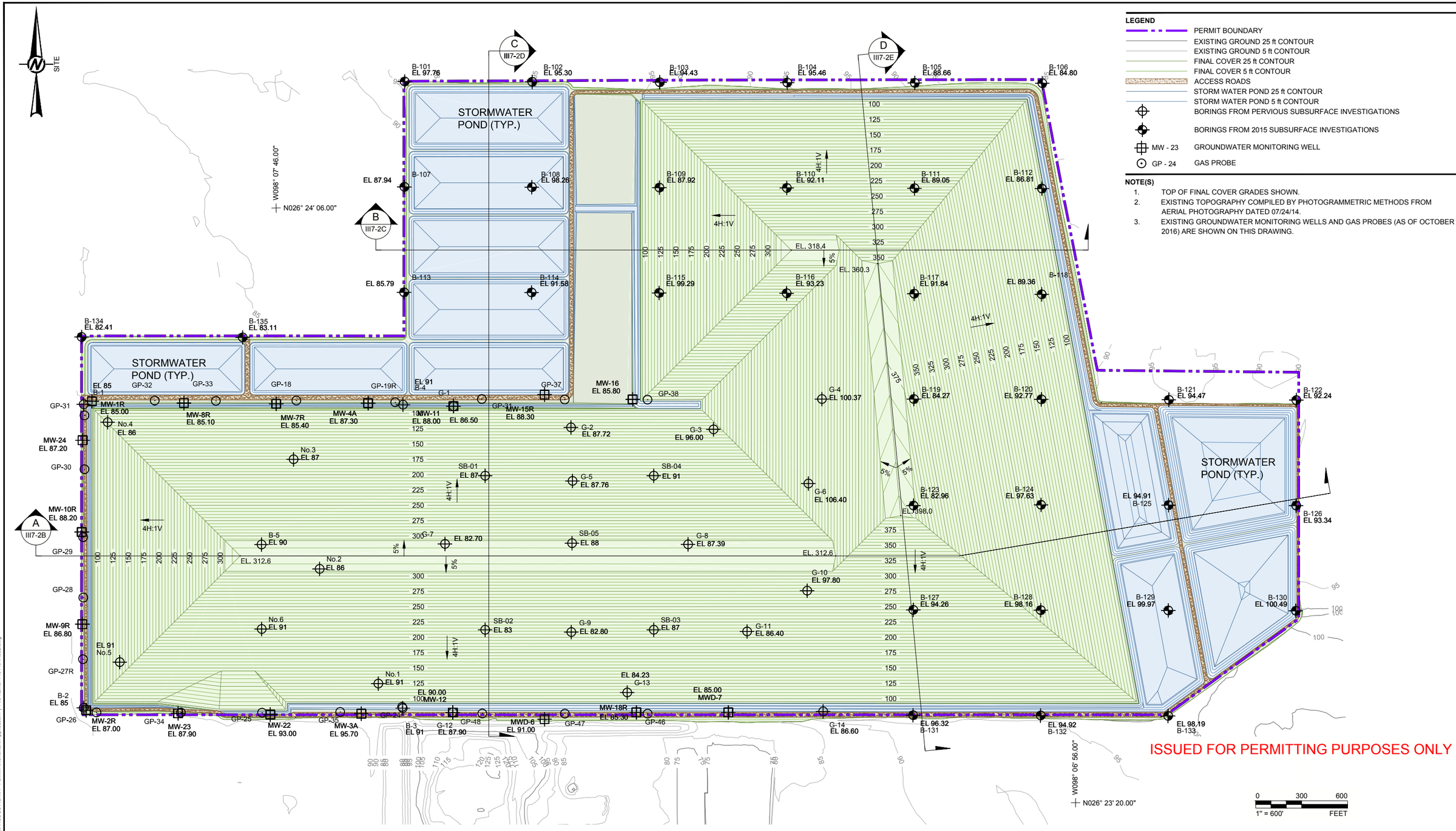

LEGEND

- PERMIT BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- FINAL COVER 25 ft CONTOUR
- FINAL COVER 5 ft CONTOUR
- ACCESS ROADS
- STORM WATER POND 25 ft CONTOUR
- STORM WATER POND 5 ft CONTOUR
- BORINGS FROM PERVIOUS SUBSURFACE INVESTIGATIONS
- BORINGS FROM 2015 SUBSURFACE INVESTIGATIONS
- MW - 23 GROUNDWATER MONITORING WELL
- GP - 24 GAS PROBE

NOTE(S)

1. TOP OF FINAL COVER GRADES SHOWN.
2. EXISTING TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED 07/24/14.
3. EXISTING GROUNDWATER MONITORING WELLS AND GAS PROBES (AS OF OCTOBER 2016) ARE SHOWN ON THIS DRAWING.

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PROJECT
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PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
FILL CROSS-SECTIONS LOCATION MAP

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3	0	5 of 19	III3-4A

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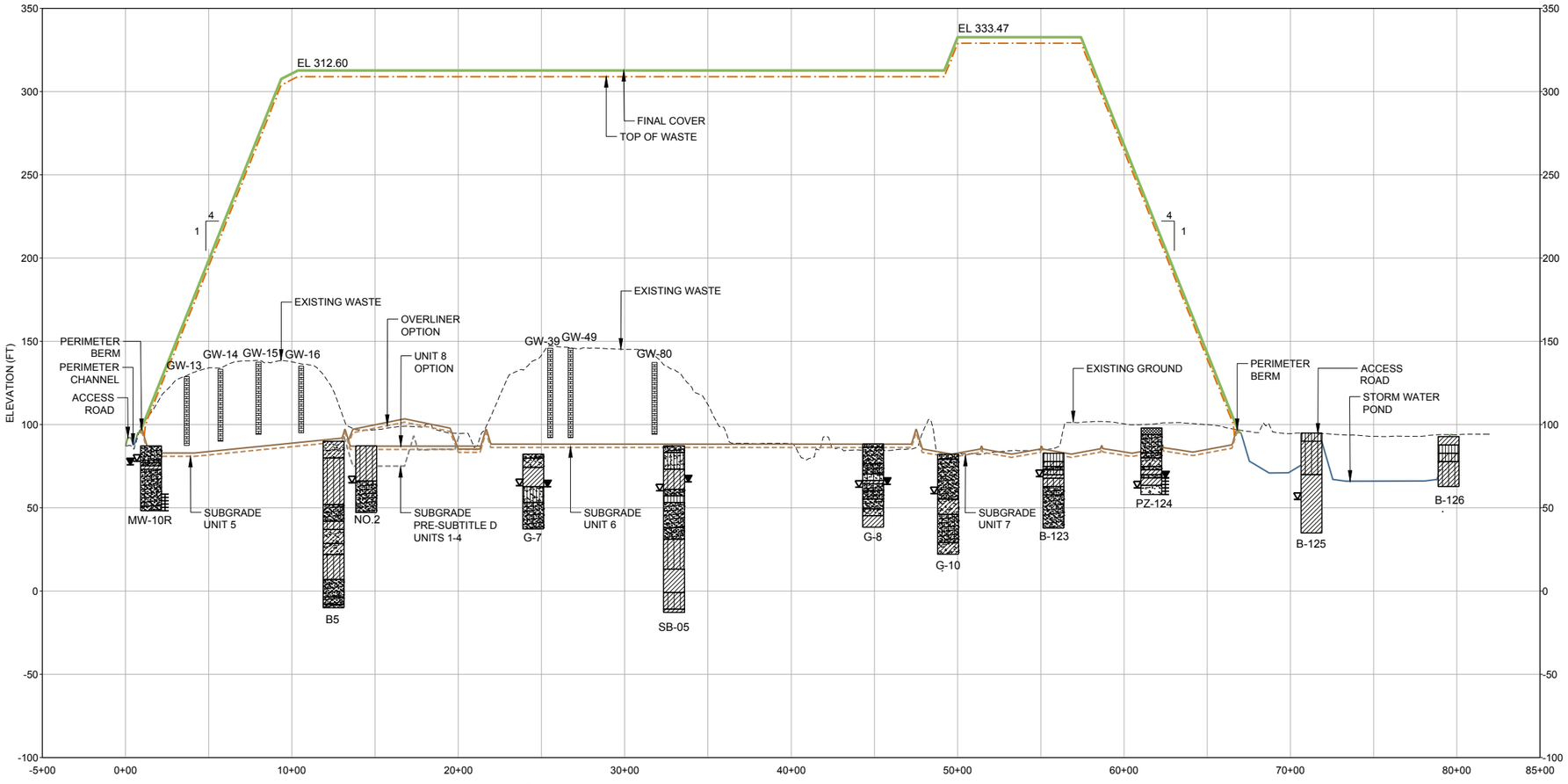
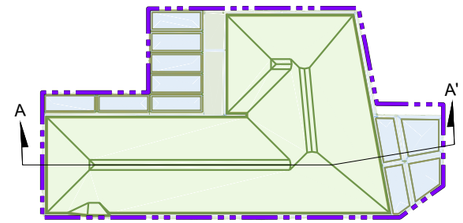


SCALE 1" = 800'
VERT. SCALE 1" = 80'

A III3-4B FILL CROSS-SECTION A

KEY MAP



LEGEND

- FINAL COVER
- TOP OF WASTE
- EXISTING GRADE
- SUBGRADE
- EXISTING SUBGRADE
- STORM WATER POND AND DITCH

- SILT
- SAND
- CLAY
- SILTY SAND
- SILTY CLAY
- SANDY SILT
- SANDY CLAY
- CLAYEY SAND
- CLAYEY SILT
- SANDY SILTY CLAY
- SILTY CLAYEY SAND
- STATIC WATER LEVEL
- INITIAL WATER LEVEL
- SCREENED INTERVAL

NOTE(S)

1. GAS WELL DATA BASED ON INFORMATION FROM DESIGN AND AS BUILT DRAWINGS.
2. EXISTING TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHTOGRAPHY DATED 07/24/2014.
3. THERE ARE NO INITIAL WATER LEVEL DTATA FOR THE BORINGS SHOWN ON THIS CROSS-SECTION. THE INITIAL WATER LEVEL IS THAT LEVEL AT THE TIME OF DRILLING AS REPORTED ON THE BORING LOG. THE STATIC WATER LEVEL IS THAT LEVEL SOMETIME AFTER DRILLING AS REPORTED ON THE BORING LOG.
4. THE SIDESLOPES SHOWN ARE NOMINAL; THE ACTUAL SIDESLOPES ON THESE CROSS-SECTIONS WILL VARY DUE TO THE ANGULAR PROJECTION OF THE SECTIONS.
5. GAS WELL LOCATIONS ARE SHOWN ON III6, LANDFILL GAS MANAGEMENT PLAN, FIGURE III6-3
6. MONITORING WELL LOCATIONS ARE SHOWN ON III3, FILL CROSS-SECTION LOCATION MAP, FIGURE III3-4A.
7. SECTION SHOWN FOR UNIT 8 OPTION IS THROUGH THE INTERCELL BERM.

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0 400 800
1" = 800' FEET

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PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
FILL CROSS-SECTION A

PROJECT NO.	APPLICATION SECTION	REV.	6 of 19	FIGURE
1401491	III3	0		III3-4B

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1 in

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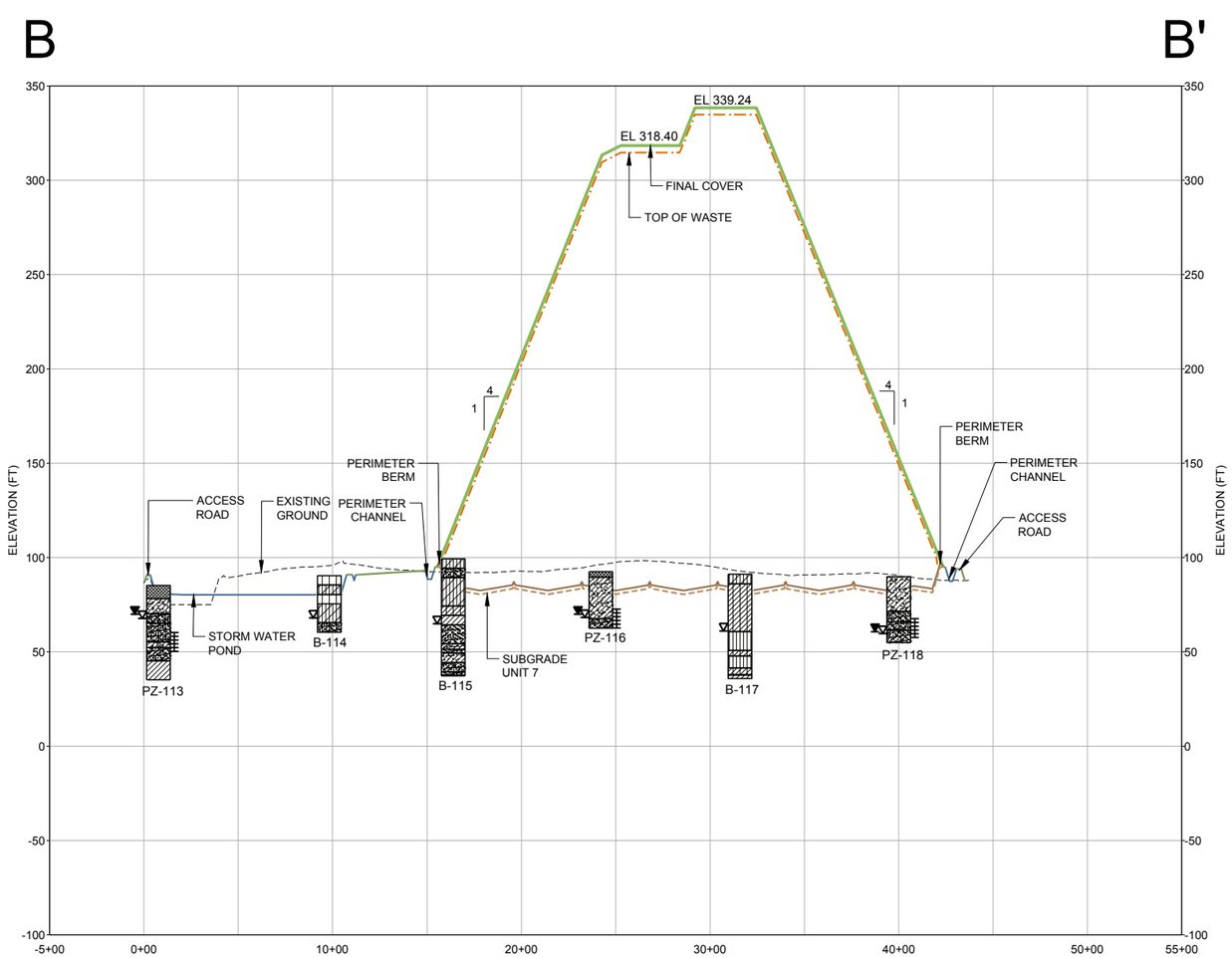
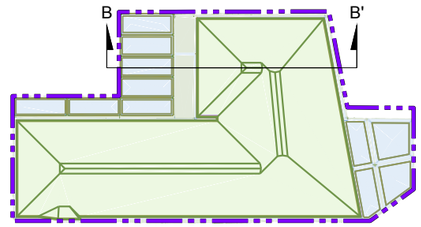


SCALE 1" = 800' / VERT. SCALE 1" = 80' — B / III3-4C — FILL CROSS-SECTION B

KEY MAP



LEGEND

- FINAL COVER
- TOP OF WASTE
- EXISTING GRADE
- SUBGRADE
- STORM WATER POND AND DITCH

- SILT
- SAND
- CLAY
- SILTY SAND
- SILTY CLAY
- SANDY SILT
- SANDY CLAY
- CLAYEY SAND
- CLAYEY SILT
- SANDY SILTY CLAY
- SILTY CLAYEY SAND
- STATIC WATER LEVEL
- INITIAL WATER LEVEL
- SCREENED INTERVAL

NOTE(S)

1. GAS WELL DATA BASED ON INFORMATION FROM DESIGN AND AS BUILT DRAWINGS.
2. EXISTING TOPOGRAPHY COMPILED BY PHOTOGRAMMETRIC METHODS FROM AERIAL PHTOGRAPHY DATED 07/24/2014.
3. THERE ARE NO INITIAL WATER LEVEL DTATA FOR THE BORINGS SHOWN ON THIS CROSS-SECTION. THE INITIAL WATER LEVEL IS THAT LEVEL AT THE TIME OF DRILLING AS REPORTED ON THE BORING LOG. THE STATIC WATER LEVEL IS THAT LEVEL SOMETIME AFTER DRILLING AS REPORTED ON THE BORING LOG.
4. THE SIDESLOPES SHOWN ARE NOMINAL; THE ACTUAL SIDESLOPES ON THESE CROSS-SECTIONS WILL VARY DUE TO THE ANGULAR PROJECTION OF THE SECTIONS.
5. GAS WELL LOCATIONS ARE SHOWN ON III6, LANDFILL GAS MANAGEMENT PLAN, FIGURE III6-3
6. MONITORING WELL LOCATIONS ARE SHOWN ON III3, FILL CROSS-SECTION LOCATION MAP, FIGURE III3-4A.

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0 400 800
1" = 800' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

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STATE OF TEXAS — JEFFREY B. FASSETT — 85675 — LICENSED — PROFESSIONAL ENGINEER

GOLDER ASSOCIATES INC.
TEXAS REGISTRATION F-2578

CLIENT

CITY OF EDINBURG SOLID WASTE MANAGEMENT

CONSULTANT

Golder Associates

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
FILL CROSS-SECTION B

PROJECT NO.	APPLICATION SECTION	REV.	FIGURE
1401491	III3	0	7 of 19 III3-4C

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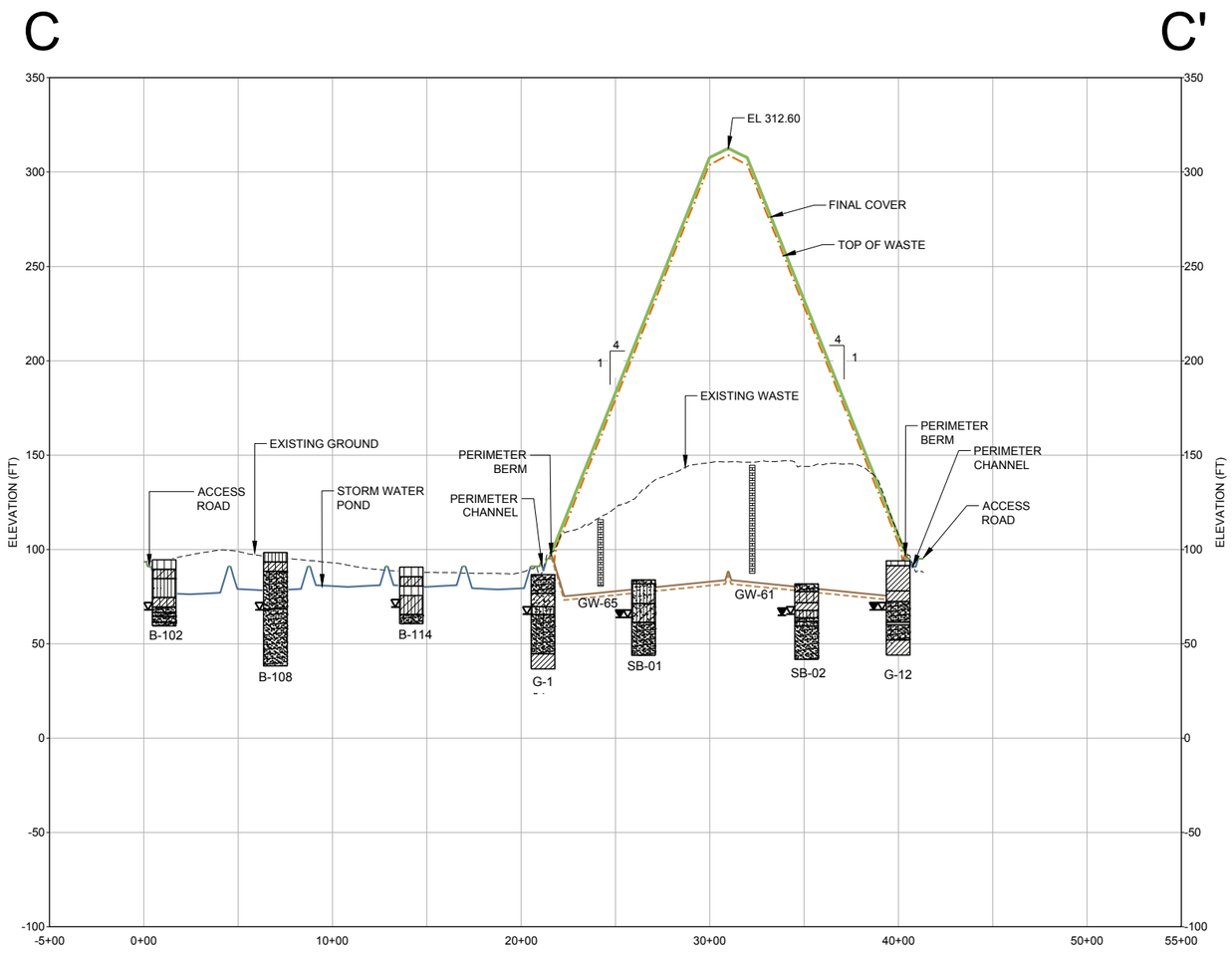
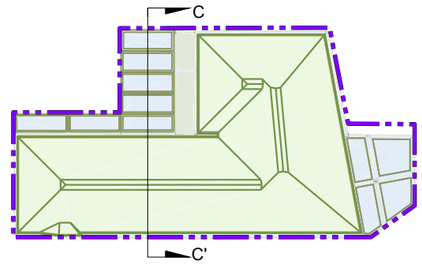


SCALE 1" = 800'
VERT. SCALE 1" = 80'

C
III3-4D

FILL CROSS-SECTION C

KEY MAP



LEGEND

- FINAL COVER
- TOP OF WASTE
- EXISTING GRADE
- SUBGRADE
- STORM WATER POND AND DITCH

- SILT
- SAND
- CLAY
- SILTY SAND
- SILTY CLAY
- SANDY SILT
- SANDY CLAY
- CLAYEY SAND
- CLAYEY SILT
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NOTE(S)

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6. MONITORING WELL LOCATIONS ARE SHOWN ON III3, FILL CROSS-SECTION LOCATION, FIGURE III3-4A.

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0 400 800
1" = 800' FEET

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
FILL CROSS SECTION C

PROJECT NO.	APPLICATION SECTION	REV.	FIGURE
1401491	III3	0	III3-4D

8 of 19

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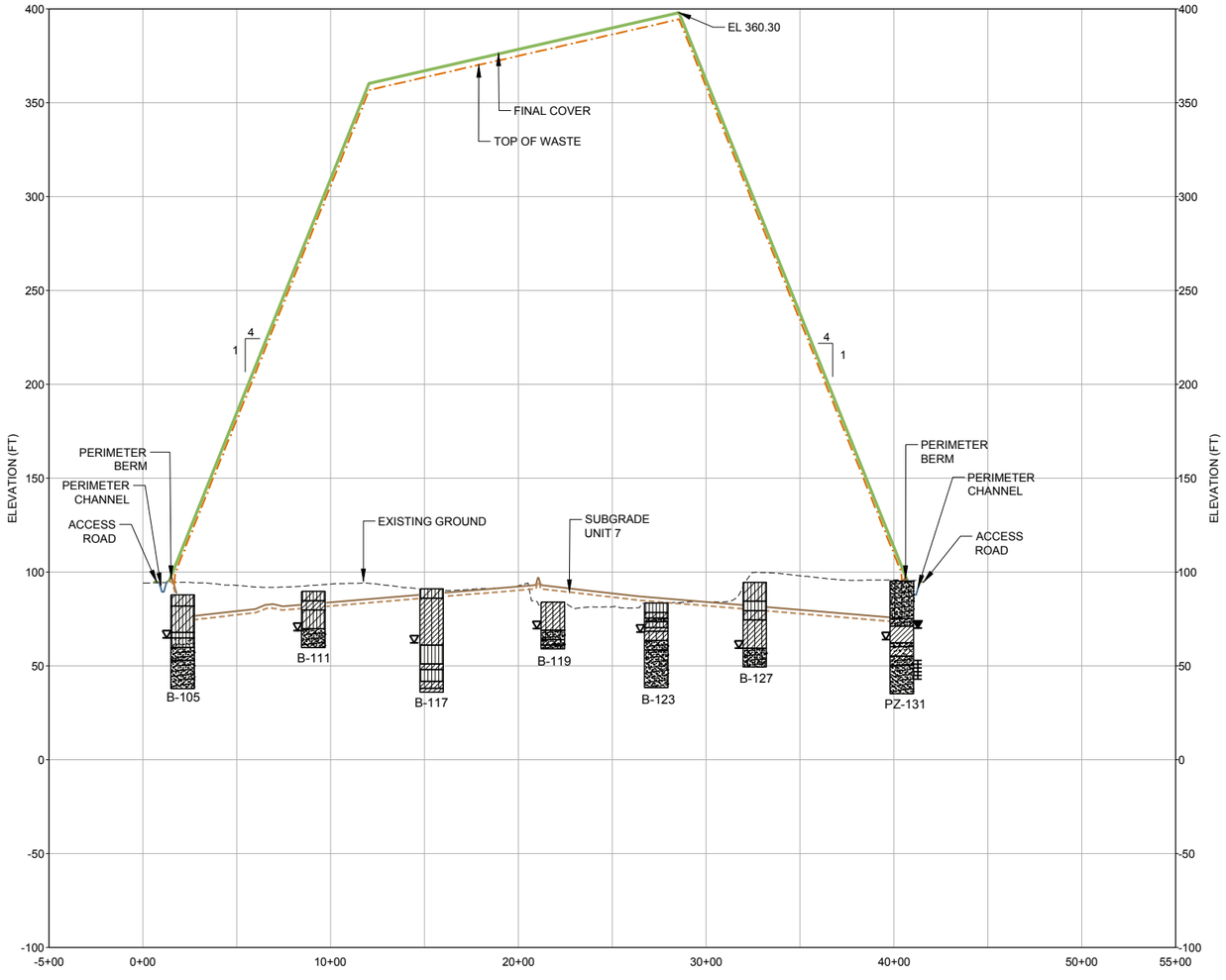
D

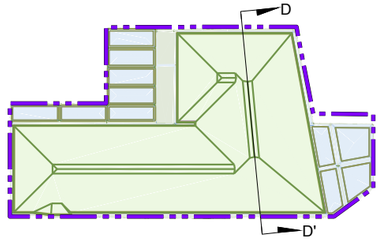
D'



SCALE 1" = 800'
VERT. SCALE 1" = 80'

D III3-4E FILL CROSS-SECTION D

KEY MAP



LEGEND

- FINAL COVER
- TOP OF WASTE
- EXISTING GRADE
- SUBGRADE
- STORM WATER POND AND DITCH

- SILT
- SAND
- CLAY
- SILTY SAND
- SILTY CLAY
- SANDY SILT
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- STATIC WATER LEVEL
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
FILL CROSS-SECTION D

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3	0	9 of 19	III3-4E

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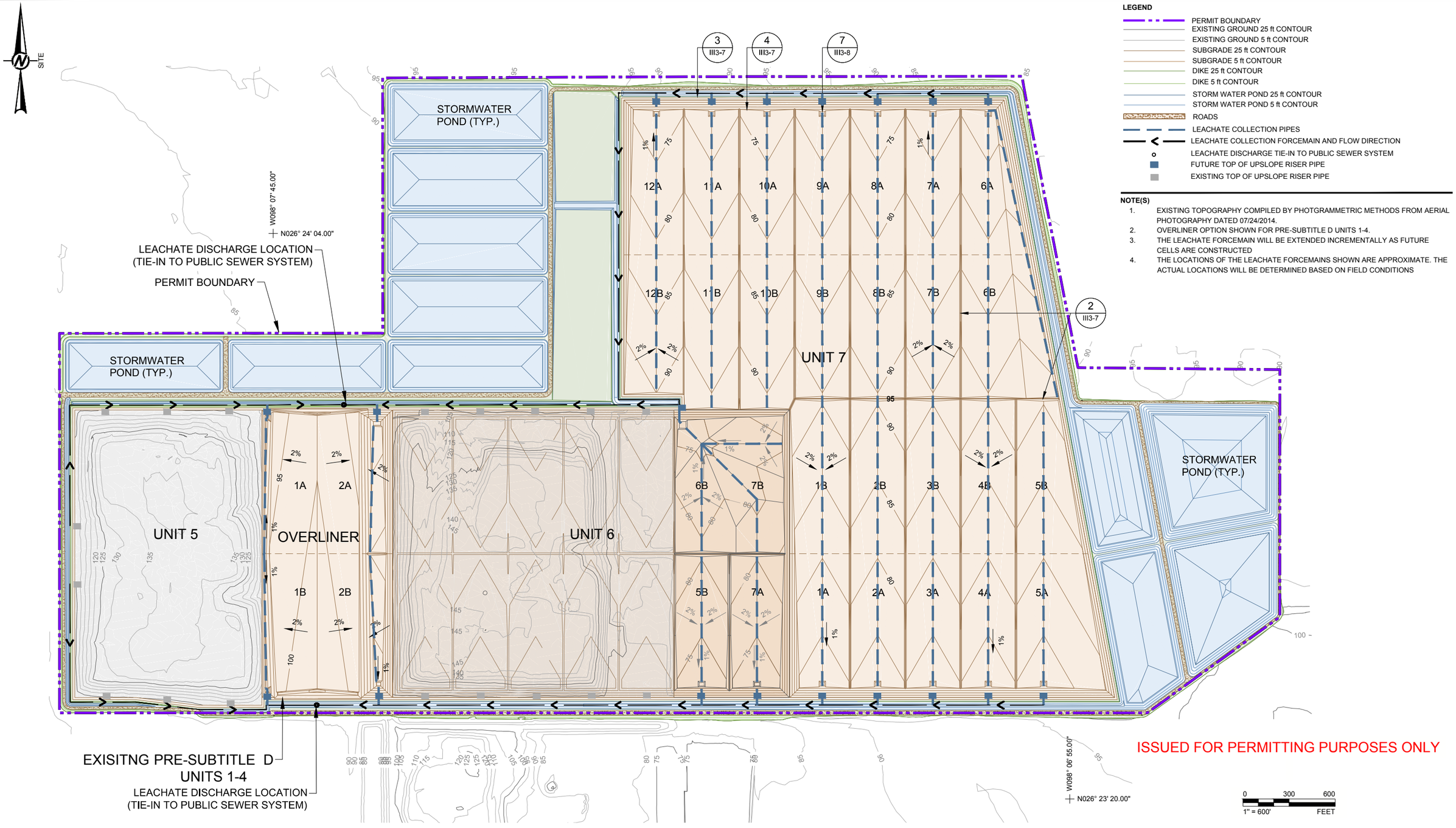

LEGEND

- PERMIT BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- DIKE 25 ft CONTOUR
- DIKE 5 ft CONTOUR
- STORM WATER POND 25 ft CONTOUR
- STORM WATER POND 5 ft CONTOUR
- ROADS
- LEACHATE COLLECTION PIPES
- LEACHATE COLLECTION FORCEMAIN AND FLOW DIRECTION
- LEACHATE DISCHARGE TIE-IN TO PUBLIC SEWER SYSTEM
- FUTURE TOP OF UPSLOPE RISER PIPE
- EXISTING TOP OF UPSLOPE RISER PIPE

NOTE(S)

1. EXISTING TOPOGRAPHY COMPILED BY PHOTGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED 07/24/2014.
2. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
3. THE LEACHATE FORCEMAIN WILL BE EXTENDED INCREMENTALLY AS FUTURE CELLS ARE CONSTRUCTED
4. THE LOCATIONS OF THE LEACHATE FORCEMAINS SHOWN ARE APPROXIMATE. THE ACTUAL LOCATIONS WILL BE DETERMINED BASED ON FIELD CONDITIONS

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REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
LEACHATE COLLECTION SYSTEM DISCHARGE PLAN
OVERLINER OPTION

PROJECT NO.	APPLICATION SECTION	REV.	10 of 19	FIGURE
1401491	III3	0		III3-5A

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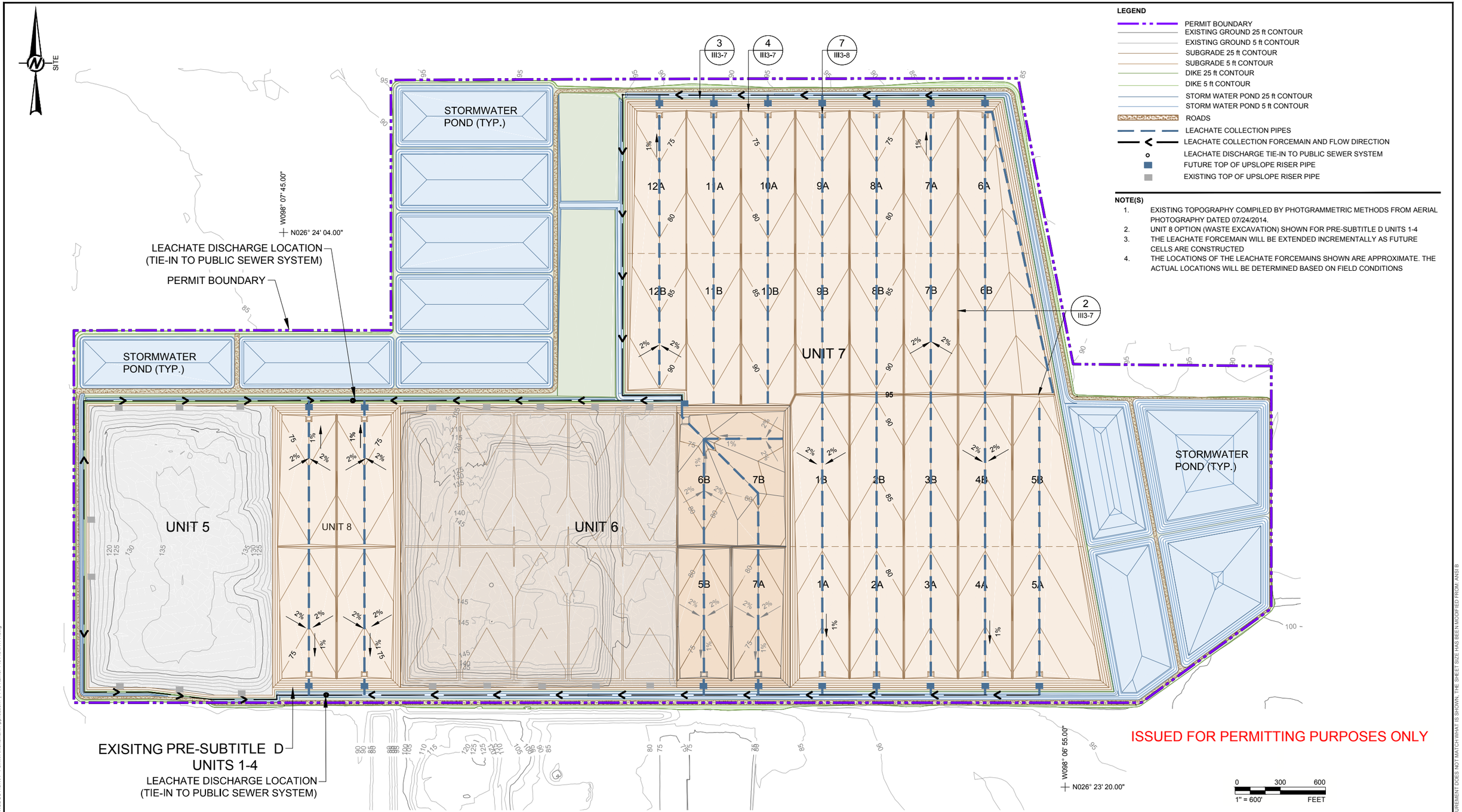

LEGEND

- PERMIT BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- DIKE 25 ft CONTOUR
- DIKE 5 ft CONTOUR
- STORM WATER POND 25 ft CONTOUR
- STORM WATER POND 5 ft CONTOUR
- ROADS
- LEACHATE COLLECTION PIPES
- LEACHATE COLLECTION FORCEMAIN AND FLOW DIRECTION
- LEACHATE DISCHARGE TIE-IN TO PUBLIC SEWER SYSTEM
- FUTURE TOP OF UPSLOPE RISER PIPE
- EXISTING TOP OF UPSLOPE RISER PIPE

NOTE(S)

1. EXISTING TOPOGRAPHY COMPILED BY PHOTGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED 07/24/2014.
2. UNIT 8 OPTION (WASTE EXCAVATION) SHOWN FOR PRE-SUBTITLE D UNITS 1-4
3. THE LEACHATE FORCEMAIN WILL BE EXTENDED INCREMENTALLY AS FUTURE CELLS ARE CONSTRUCTED
4. THE LOCATIONS OF THE LEACHATE FORCEMAINS SHOWN ARE APPROXIMATE. THE ACTUAL LOCATIONS WILL BE DETERMINED BASED ON FIELD CONDITIONS

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REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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85675
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
LEACHATE COLLECTION SYSTEM DISCHARGE PLAN
UNIT 8 OPTION

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3	0	11 of 19	III3-5B

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LEGEND

- PERMIT BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- DIKE 25 ft CONTOUR
- DIKE 5 ft CONTOUR
- STORM WATER POND 25 ft CONTOUR
- STORM WATER POND 5 ft CONTOUR
- ROADS
- TOE DRAIN UNDERDRAIN (SEE FIGURE III3F-5 FOR DETAILS)
- 1A CELL DESIGNATION

NOTE(S)

1. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4
2. SUBGRADE ELEVATIONS SHOWN
3. TOP OF THE LINER ELEVATIONS IN THE BOTTOM OF THE LEACHATE COLLECTION SUMPS ARE 2 ft LOWER THAN ELEVATION OF THE LOW POINT ON THE LINER.
4. EXISTING TOPOGRAPHY COMPILED BY PHTOGRAMMETRIC METHODS FROM AERIAL PHOTOGRAPHY DATED 07/24/2014.

ISSUED FOR PERMITTING PURPOSES ONLY

0 300 600
1" = 600' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
UNDERDRAIN SYSTEM LAYOUT
OVERLINER OPTION

PROJECT NO.	APPLICATION SECTION	REV.	12 of 19	FIGURE
1401491	III3	0		III3-6A

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LEGEND

- PERMIT BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- DIKE 25 ft CONTOUR
- DIKE 5 ft CONTOUR
- STORM WATER POND 25 ft CONTOUR
- STORM WATER POND 5 ft CONTOUR
- ROADS
- TOE DRAIN UNDERDRAIN (SEE FIGURE III3F-5 FOR DETAILS)
- 1A CELL DESIGNATION

NOTE(S)

1. UNIT 8 OPTION (WASTE EXCAVATION) SHOWN FOR PRE-SUBTITLE D UNITS 1-4
2. SUBGRADE ELEVATIONS SHOWN
3. TOP OF THE LINER ELEVATIONS IN THE BOTTOM OF THE LEACHATE COLLECTION SUMPS ARE 2 ft LOWER THAN ELEVATION OF THE LOW POINT ON THE LINER.
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0 300 600
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
UNDERDRAIN SYSTEM LAYOUT
UNIT 8 OPTION

PROJECT NO.	APPLICATION SECTION	REV.	13 of 19	FIGURE
1401491	III3	0		III3-6B

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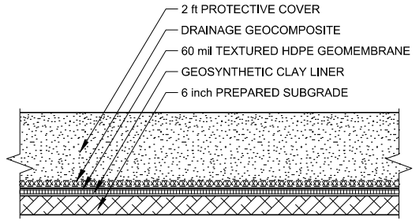
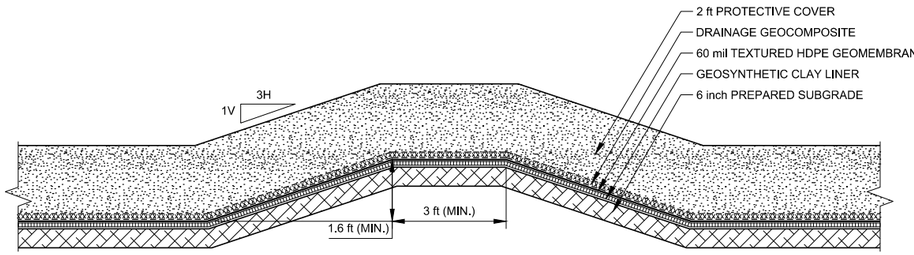
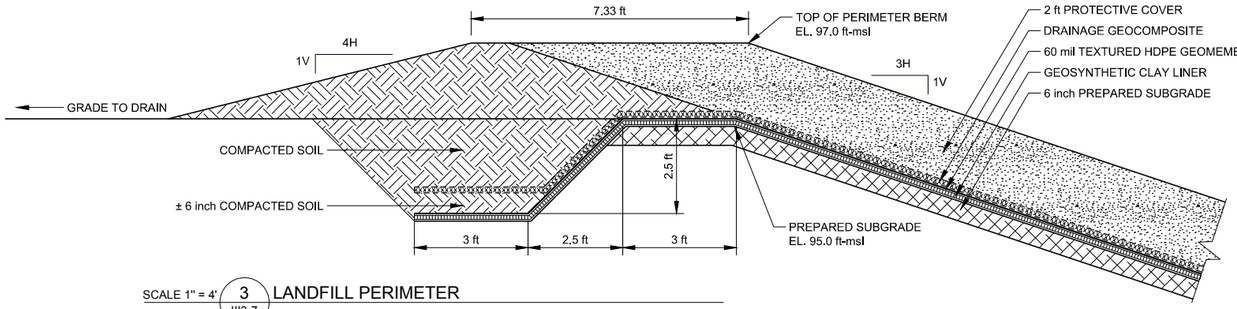


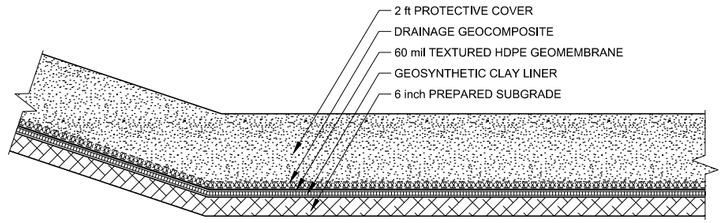
SCALE 1" = 4' 1 III3-7 ALTERNATIVE LINER SYSTEM



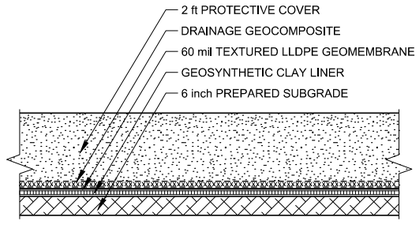
SCALE 1" = 4' 2 III3-7 INTERCELL BERM



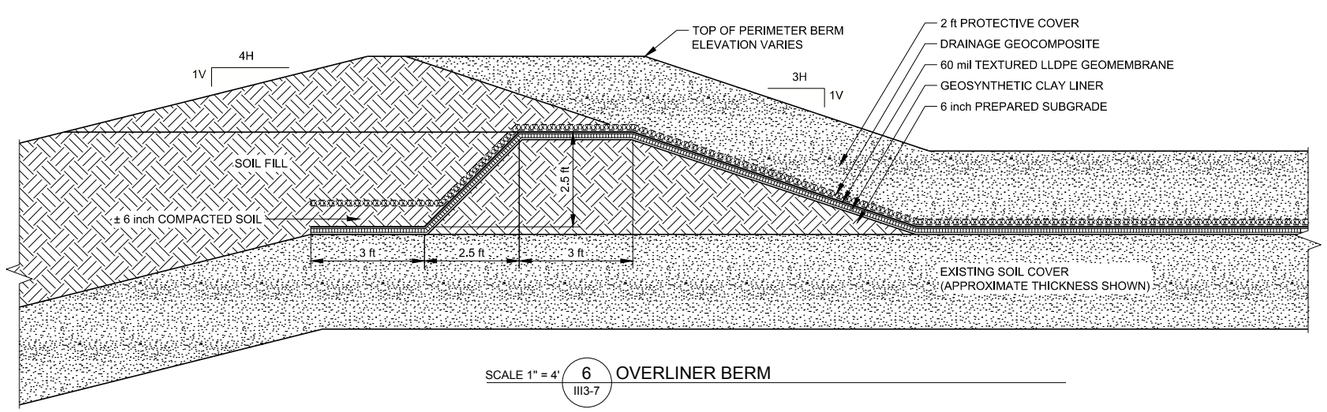
SCALE 1" = 4' 3 III3-7 LANDFILL PERIMETER



SCALE 1" = 4' 4 III3-7 LANDFILL TOE



SCALE 1" = 4' 5 III3-7 OVERLINER ALTERNATIVE LINER SYSTEM



SCALE 1" = 4' 6 III3-7 OVERLINER BERM

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0 2 4
1" = 4' FEET

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
ALTERNATIVE LINER SYSTEM DETAILS

PROJECT NO.	APPLICATION SECTION	REV.	14 of 19	FIGURE
1401491	III3	0		III3-7

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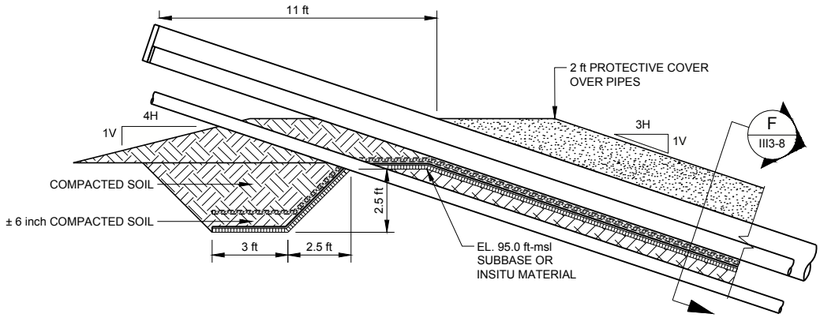
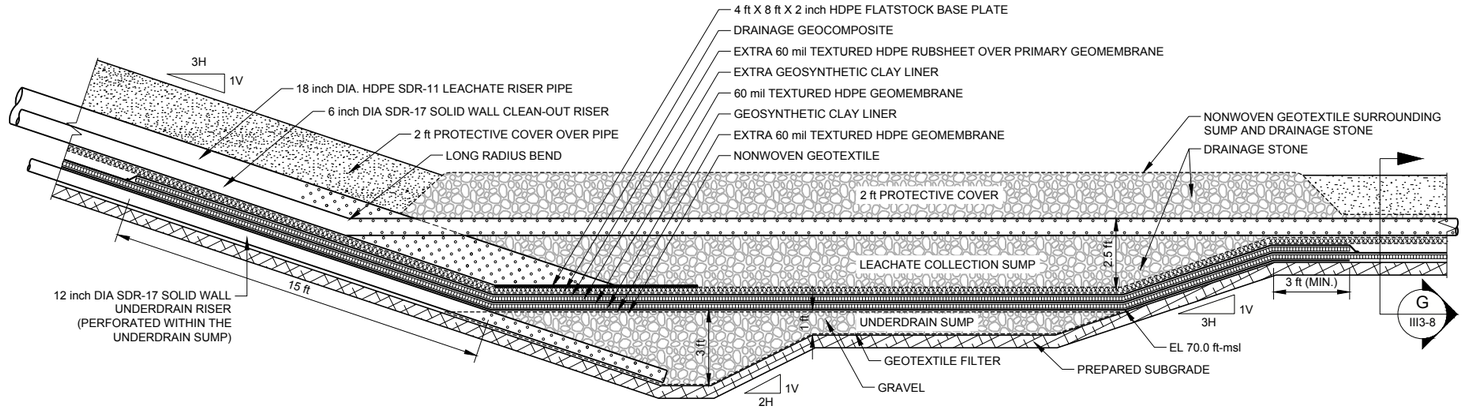
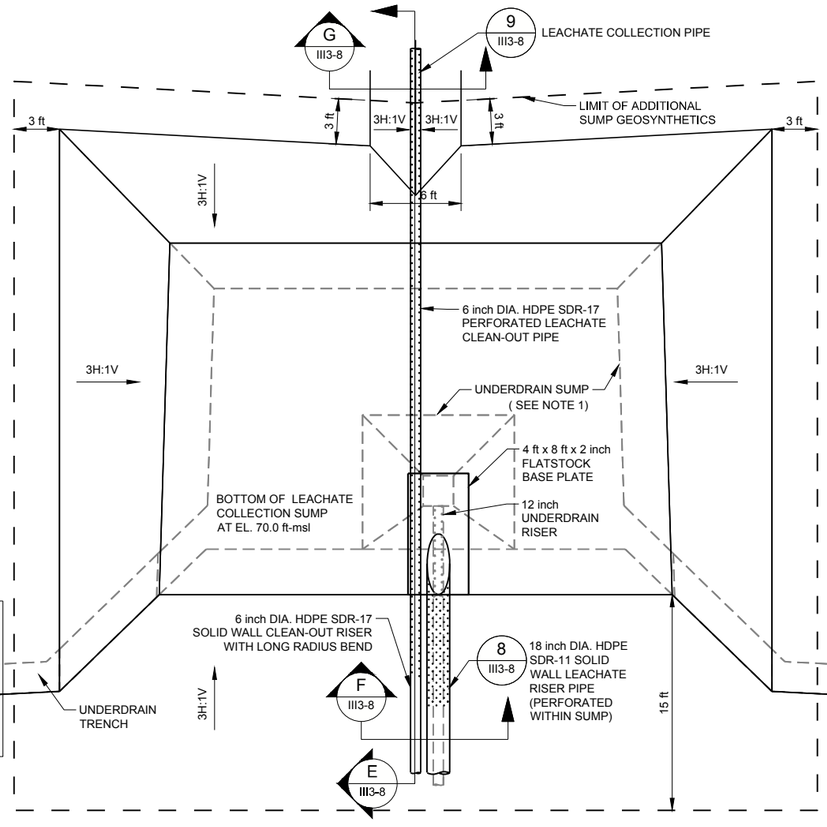
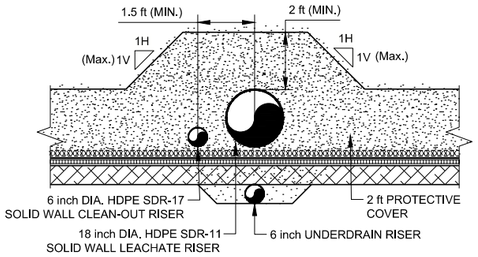




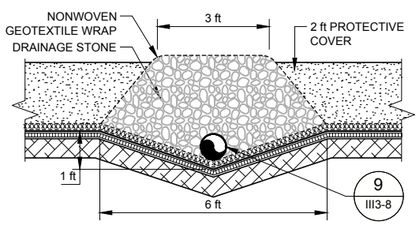
SCALE 1" = 6' E III3-8 LEACHATE COLLECTION AND UNDERDRAIN SUMPS



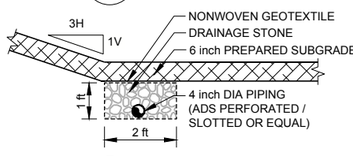
SCALE 1" = 10' 7 III3-8 LEACHATE COLLECTION AND DEWATERING SUMPS



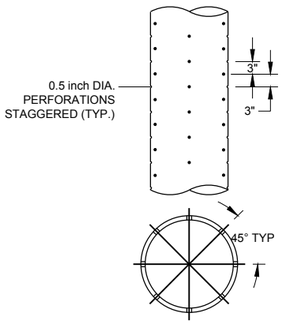
SCALE 1" = 4' F III3-8 SIDESLOPE RISER PIPES



SCALE 1" = 4' G III3-8 LEACHATE COLLECTION TRENCH

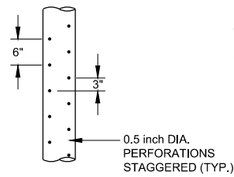


SCALE 1" = 4' H III3-8 DEWATERING TRENCH



LEACHATE COLLECTION SUMP RISER PIPE PERFORATION

SCALE 1" = 3' 8 III3-8



LEACHATE COLLECTION PIPE PERFORATION

SCALE 1" = 3' 9 III3-8

NOTE(S)

1. DEWATERING SUMP EXISTS ONLY IN CELLS WITH DEWATERING TOE DRAIN.

ISSUED FOR PERMITTING PURPOSES ONLY

0 2 4 — 1" = 4' FEET

0 2 4 — 1" = 4' FEET

0 3 6 — 1" = 6' FEET

0 0.5 10 — 1" = 10' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

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STATE OF TEXAS — JEFFREY B. FASSETT — 85675 — LICENSED — PROFESSIONAL ENGINEER

GOLDER ASSOCIATES INC.
TEXAS REGISTRATION F-2578

CLIENT

CITY OF EDINBURG SOLID WASTE MANAGEMENT

CONSULTANT

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www.golder.com

PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
LEACHATE COLLECTION AND REMOVAL SYSTEM AND UNDERDRAIN DETAILS

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3	0	15 of 19	III3-8

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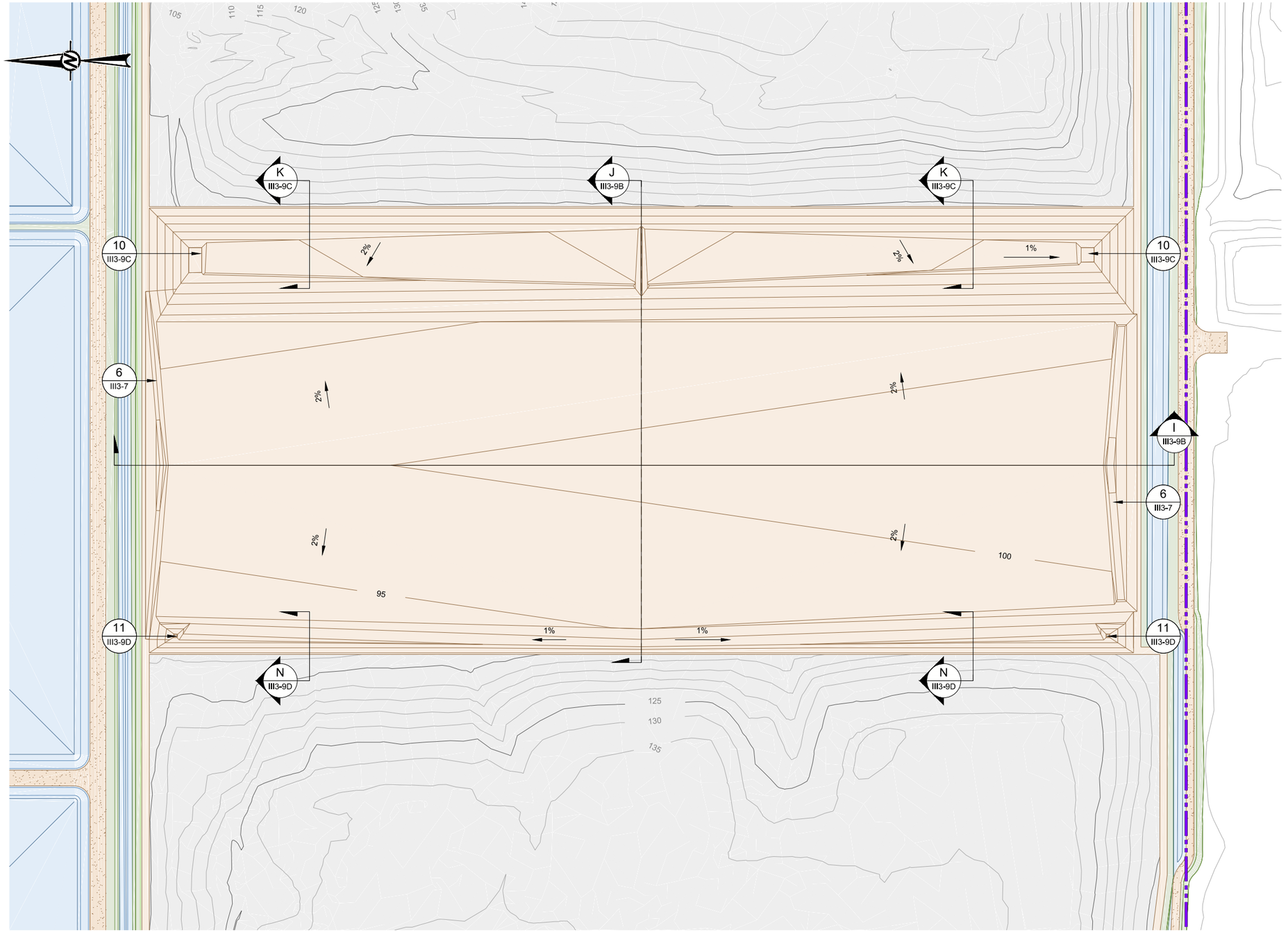

LEGEND

- PERIMETER BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- ROADS

NOTE(S)

1. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
2. SUBGRADE ELEVATIONS SHOWN.
3. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 70 ft-msl IN OVERLINER EAST.
4. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 79.50 ft-msl IN OVERLINER WEST.

ISSUED FOR PERMITTING PURPOSES ONLY

0 150 300
1" = 300' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
OVERLINER SUBGRADE LAYOUT PLAN

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3	0	16 of 19	III3-9A

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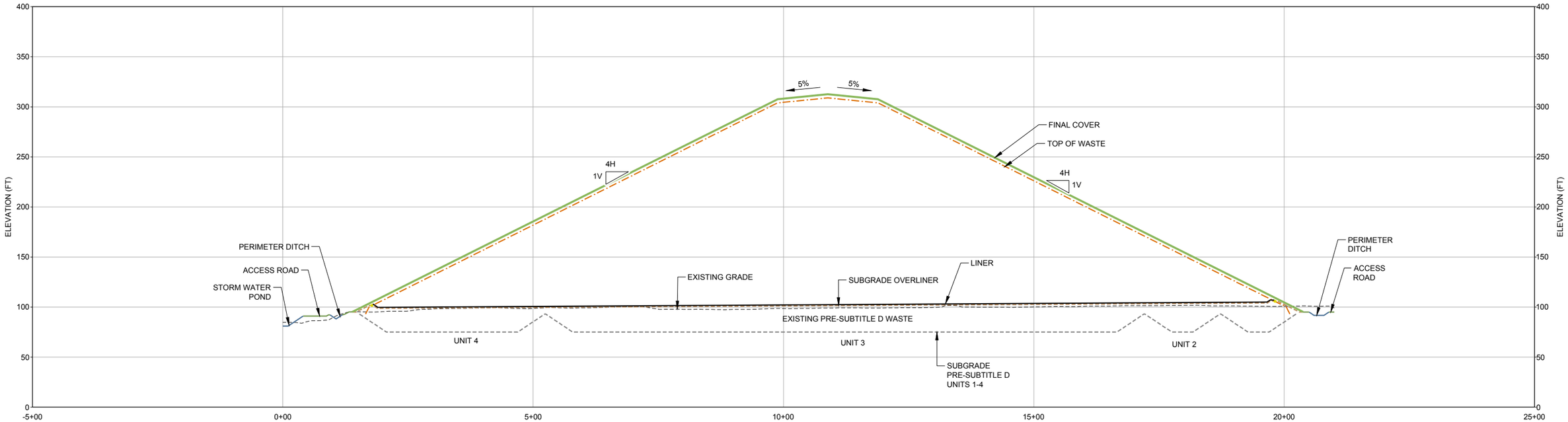
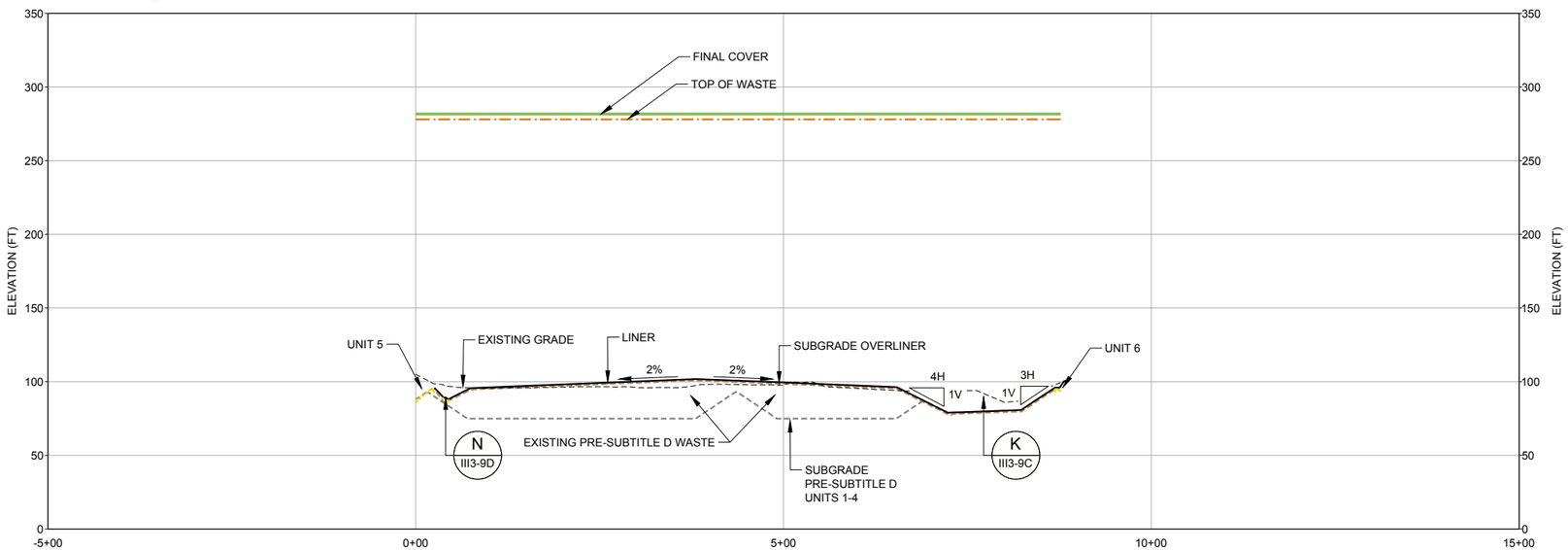


SCALE 1" = 200' (I / III3-9B) OVERLINER CROSS SECTION



SCALE 1" = 200' (J / III3-9B) OVERLINER CROSS SECTION

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0 100 200
1" = 200' FEET

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
OVERLINER CROSS-SECTIONS

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3	0	17 of 19	III3-9B

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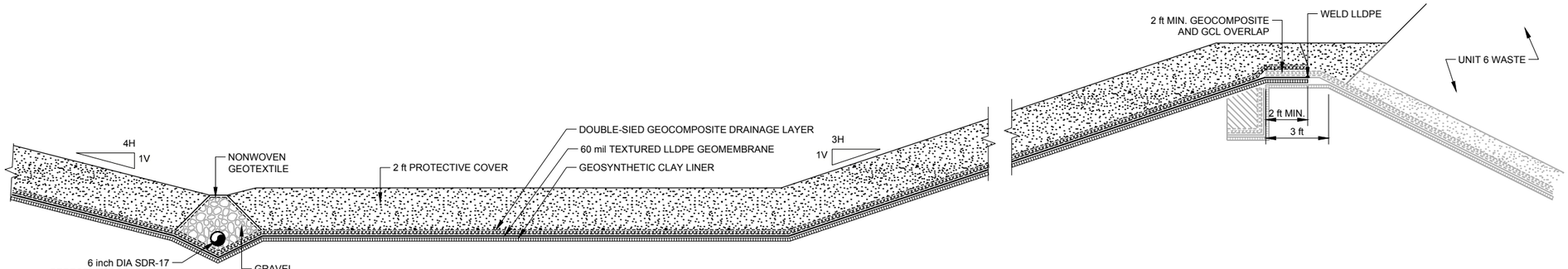
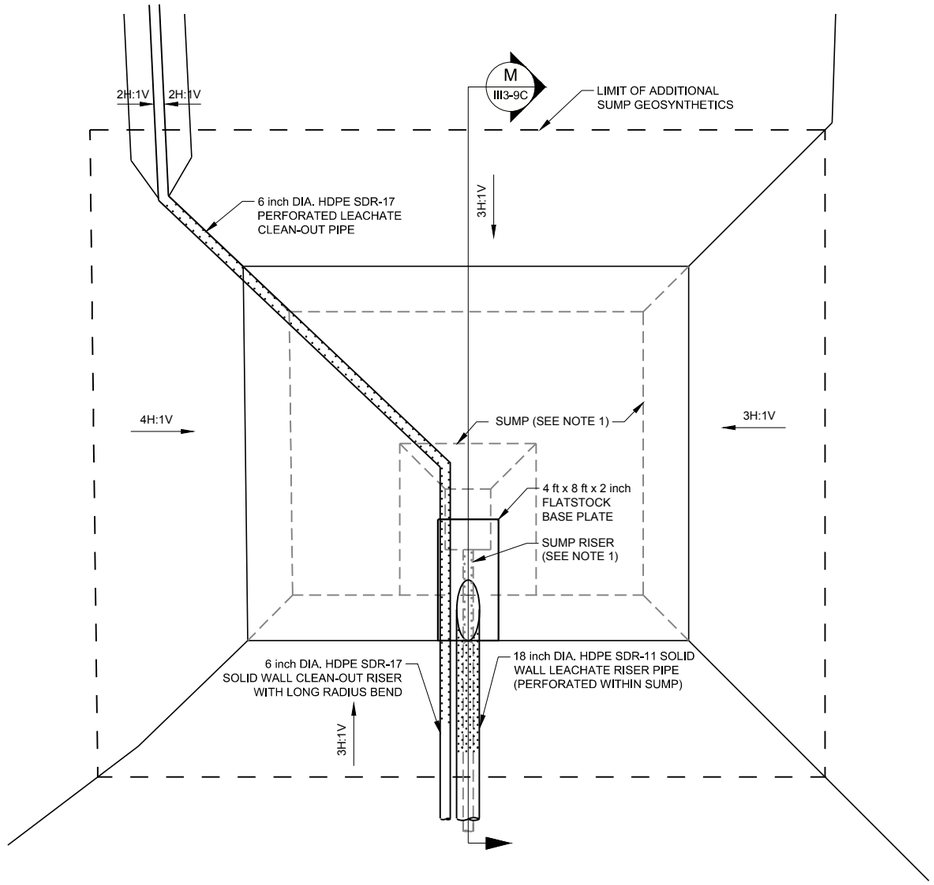


SCALE 1" = 6' K III3-9A EAST OVERLINER LEACHATE COLLECTION TRENCH



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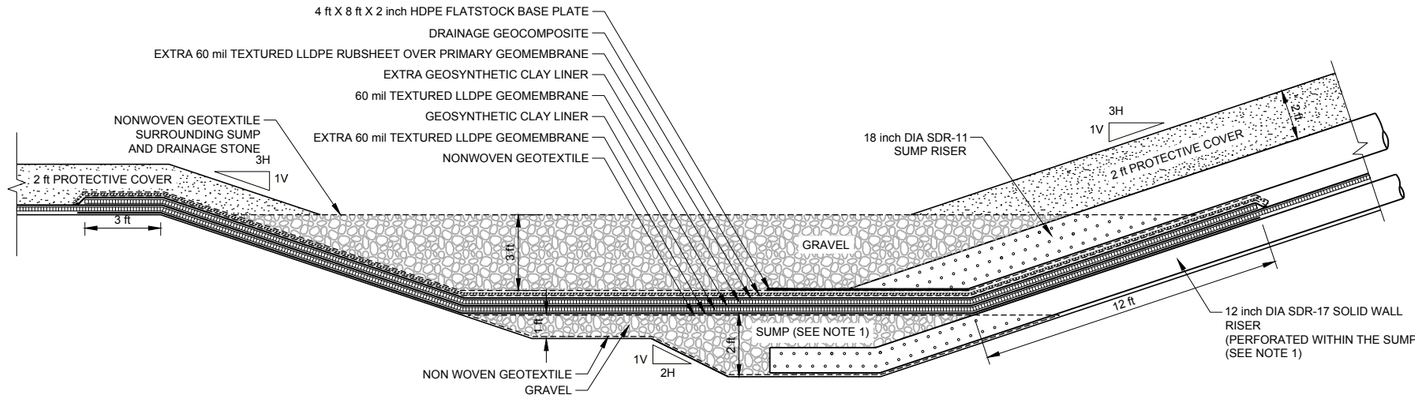

SCALE 1" = 6' M III3-9A EAST OVERLINER LEACHATE COLLECTION AND UNDERDRAIN SUMP

NOTE(S)

1. AN ADDITIONAL SUMP WILL BE INSTALLED BELOW THE OVERLINER TO COLLECT LEACHATE, IF ANY, FROM THE EXISTING WASTE IN THE PRE-SUBTITLE D CELLS.

ISSUED FOR PERMITTING PURPOSES ONLY

0 3 6
1" = 6' FEET

0 0.5 10
1" = 10' FEET

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
EAST OVERLINER LEACHATE COLLECTION AND UNDERDRAIN DETAILS

PROJECT NO.	APPLICATION SECTION	REV.	18 of 19	FIGURE
1401491	III3	0		III3-9C

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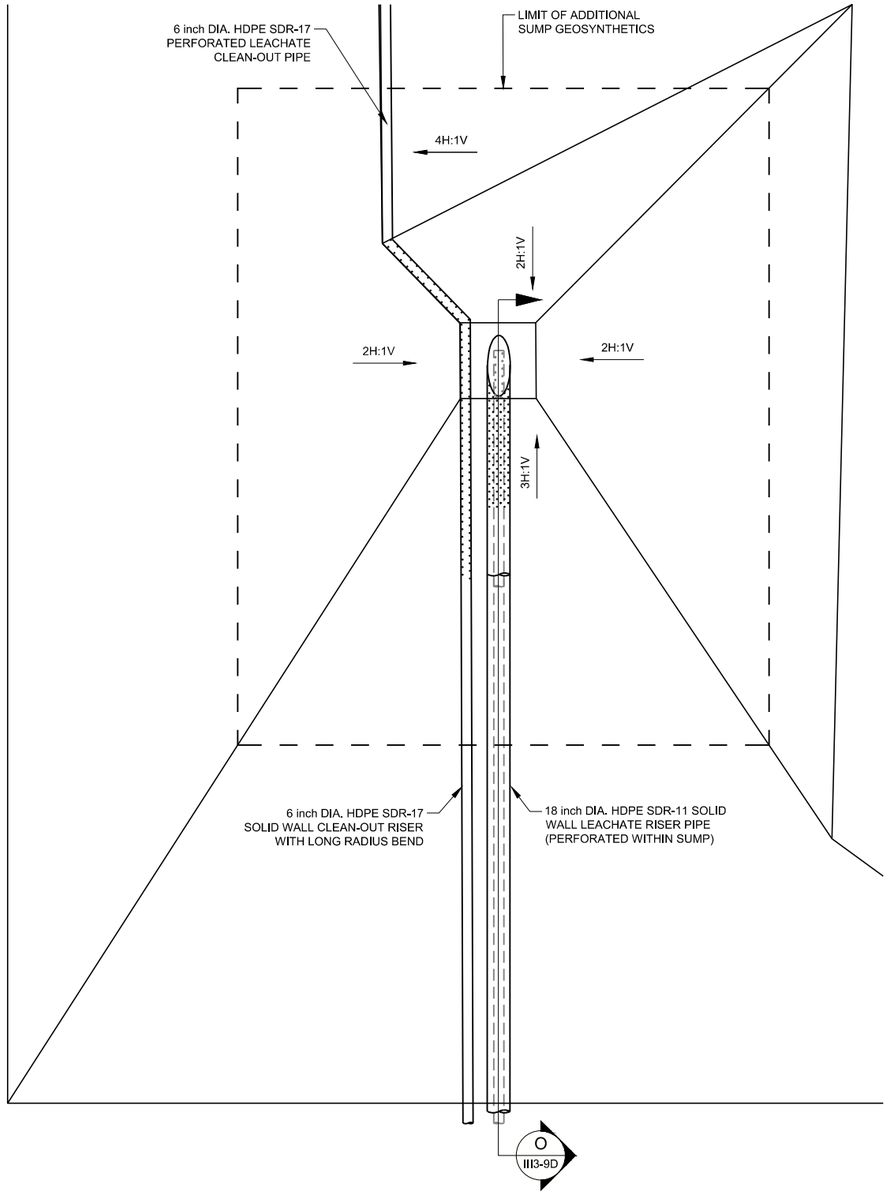

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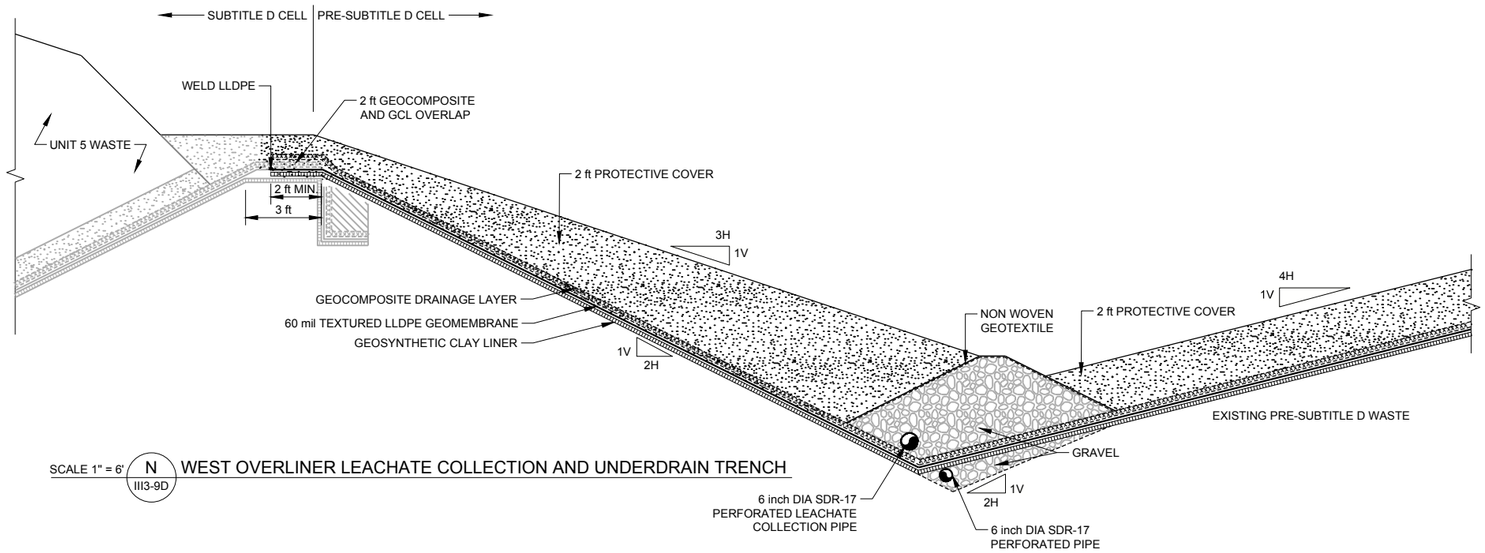

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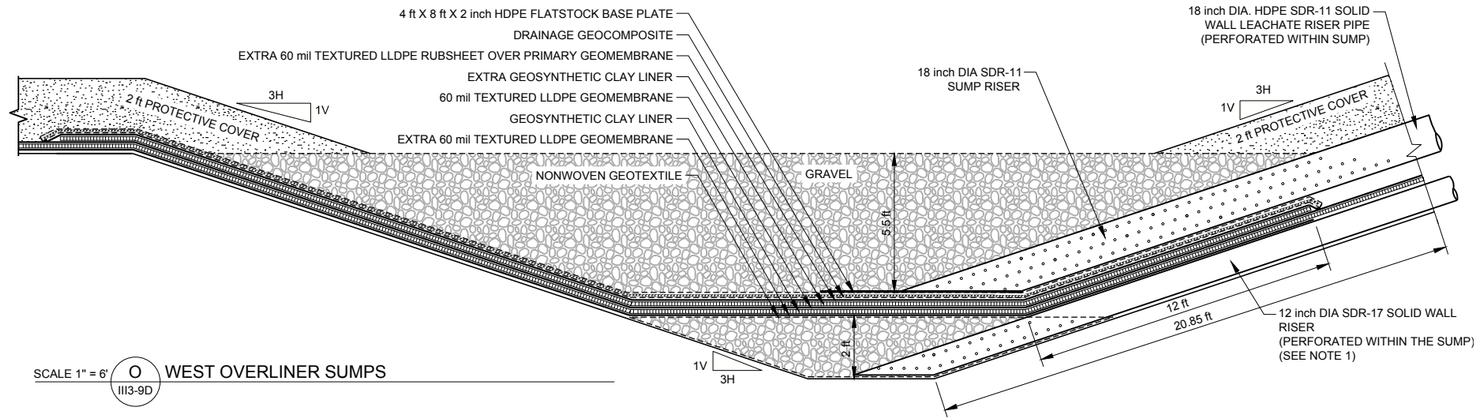

SCALE 1" = 6' O III3-9D WEST OVERLINER SUMPS

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0 3 6
1" = 6' FEET

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
WEST OVERLINER LEACHATE COLLECTION DETAILS

PROJECT NO.	APPLICATION SECTION	REV.	19 of 19	FIGURE
1401491	III3	0		III3-9D

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APPENDIX III3A

VOLUME AND SITE LIFE CALCULATIONS

APPENDIX III3A-1

VOLUME CALCULATIONS

VOLUME CALCULATIONS

Made by: JCW
Checked by: CEI
Reviewed by: JBF

1.0 SUMMARY

The table below summarizes total airspace capacity options for the landfill expansion.

Total Airspace (CY)		Construction Options	
		Overliner	*Unit 8*
Final Cover Options	*Standard*	84,997,400	84,831,321
	Alternative	85,981,680	85,815,599
	Closure Turf	87,301,156	87,135,076



GOLDER ASSOCIATES INC.
Professional Engineering Firm
Registration Number F-2578

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2.0 OBJECTIVE

To determine the airpsace gained from the expansion of Edinburg Regional Disposal Facilty for two options for the Pre-Subtitle D Units 1 through 4: construction of an overliner above existing Units 1 - 4, and relocation of existing Pre-Subtitle D waste and construction of Unit 8. In addition, three final cover options outlined in Part III7, Closure Plan are considered in the volume calculation.

3.0 GIVEN

Approved TCEQ Permit MSW-956B final cover grades and composite lining system grades, expansion design top of waste grades and top of composite lining system grades, and total airspace for approved TCEQ Permits MSW-956A and MSW-956B.

4.0 METHOD

Use AutoCAD Civil 3D, a civil engineering software, to compare the expansion top of waste grades to the top of permitted waste grades combined with expansion top of composite lining system grades.

5.0 CALCULATIONS

5.1 Previously Approved Airspace Capacities

Permit	Capacity (CY)	Description
956A	1,027,858	Pre-Subtitle D Units 1-4
956B	16,734,913	Addition of Units 5 and 6

5.2 Expansion Airspace Gained

To determine the expansion volume gained, two surface models are compared: bottom of waste surface developed by combining top of approved TCEQ Permit MSW-956B waste surfaces with expansion top of protective cover surface, and expansion top of waste surfaces.

5.2.1 Construction of Overliner option

Comparison of developed bottom of waste surface (combination of expansion protective cover grades including Overliner with TCEQ Permit MSW-956B waste grades) to expansion top of waste grades (developed from expansion final cover grades and thicknesses of the final cover options).

Final Cover	Thickness (ft)	Capacity (CY)
Standard	3.5	68,262,487
Alternative	2	69,246,767
Closure Turf	0	70,566,243

5.2.2 Relocation of Pre-Subtitle D waste and construction of Unit 8 option

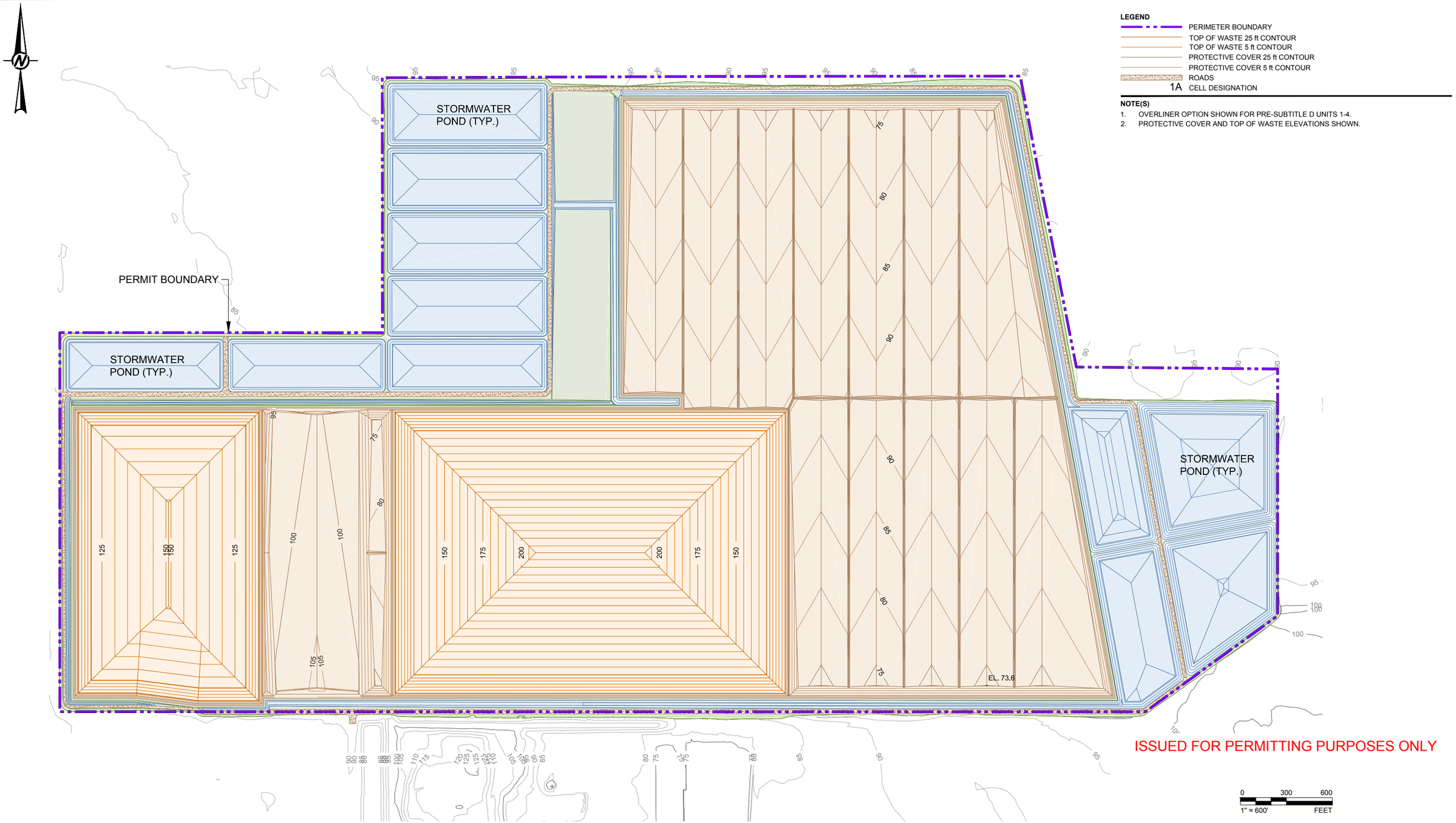
Comparison of developed bottom of waste surface (combination of expansion protective cover grades including Unit 8 with TCEQ Permit MSW-956B waste grades) to expansion top of waste grades (developed from expansion final cover grades and thicknesses of the final cover options). Please note that airspace gained will be reduced by volume of relocated Pre-Subtile D waste.

Final Cover	Thickness (ft)	Volume (CY)	Capacity (CY)
Standard	3.5	69,124,266	68,096,408
Alternative	2	70,108,544	69,080,686
Closure Turf	0	71,428,021	70,400,163

6.0 CONCLUSION

The total airspace capacity is the sum of TCEQ Permit MSW-956B and expansion airspace gained.

Total Airspace (CY)		Construction Options	
		Overliner	*Unit 8*
Final Cover Options	*Standard*	84,997,400	84,831,321
	Alternative	85,981,680	85,815,599
	Closure Turf	87,301,156	87,135,076



LEGEND

- PERIMETER BOUNDARY
- TOP OF WASTE 25 ft CONTOUR
- TOP OF WASTE 5 ft CONTOUR
- PROTECTIVE COVER 25 ft CONTOUR
- PROTECTIVE COVER 5 ft CONTOUR
- ROADS
- 1A CELL DESIGNATION

NOTE(S)

1. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
2. PROTECTIVE COVER AND TOP OF WASTE ELEVATIONS SHOWN.

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0 300 600
1" = 600' FEET

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
BOTTOM OF WASTE LAYOUT *OVERLINER OPTION*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3A-1	0	1 of 5	III3A-1-1

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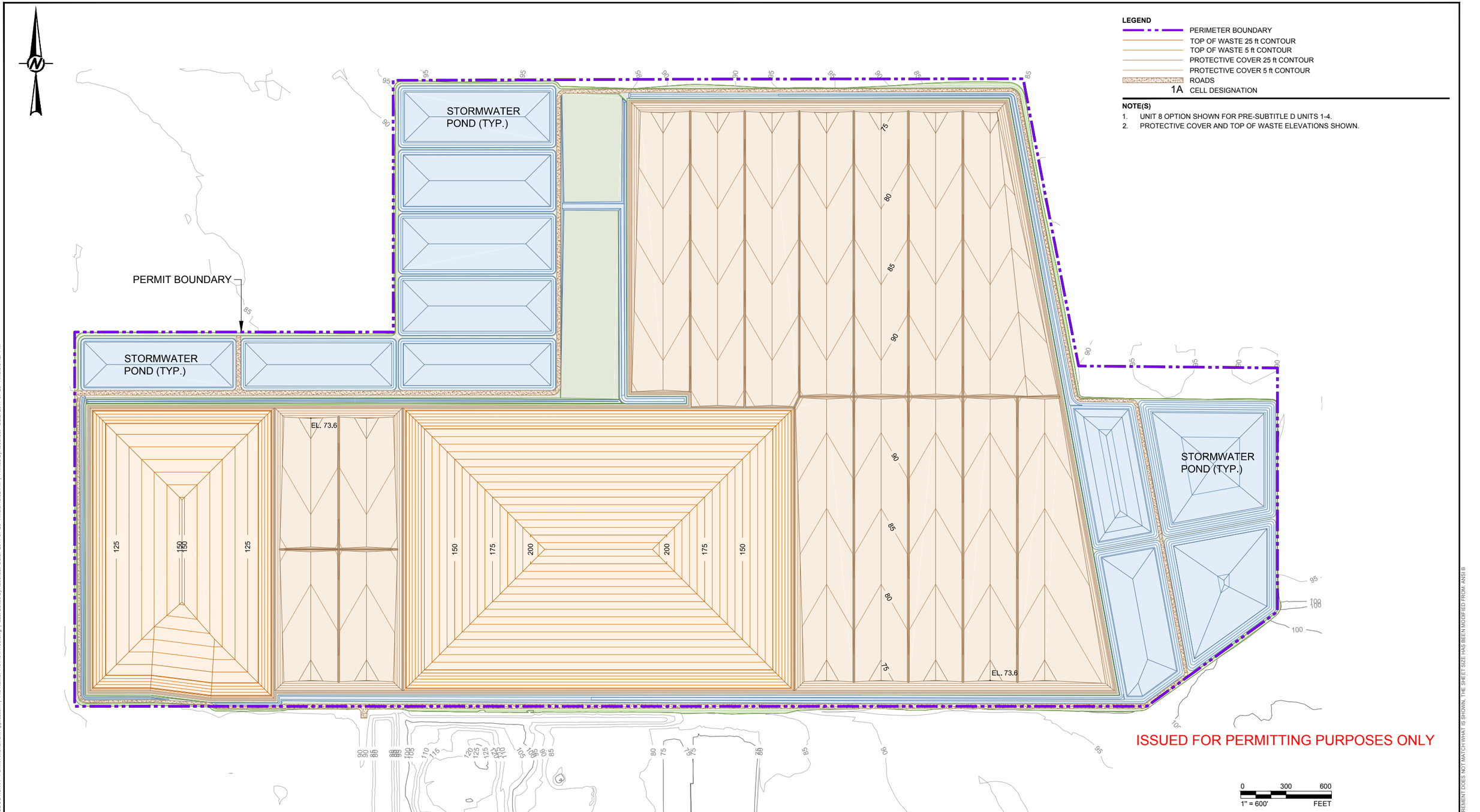

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
BOTTOM OF WASTE LAYOUT *UNIT 8 OPTION*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3A-1	0	2 of 5	III3A-1-2

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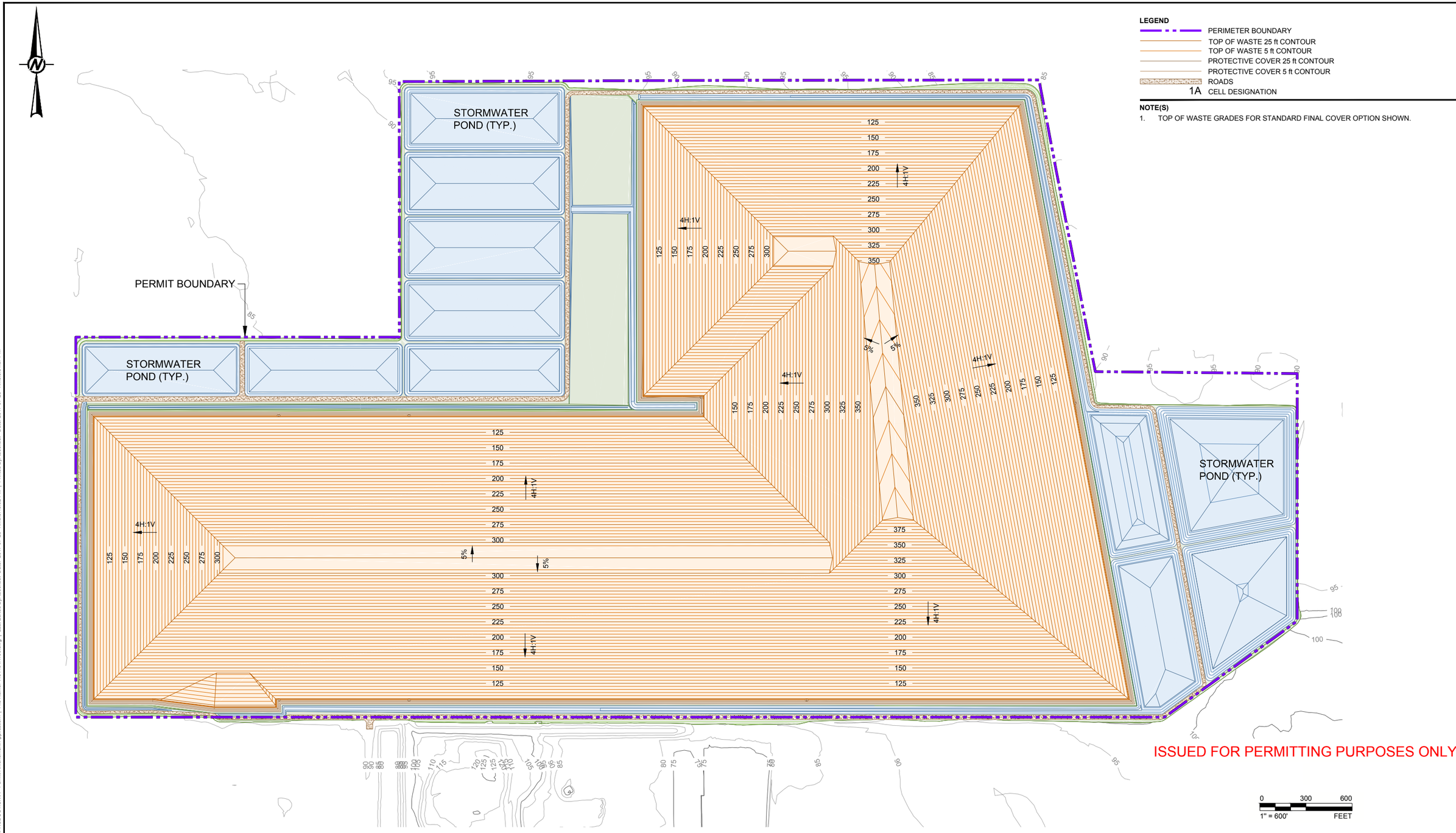

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
TOP OF WASTE LAYOUT *STANDARD FINAL COVER OPTION*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3A-1	0	3 of 5	III3A-1-3

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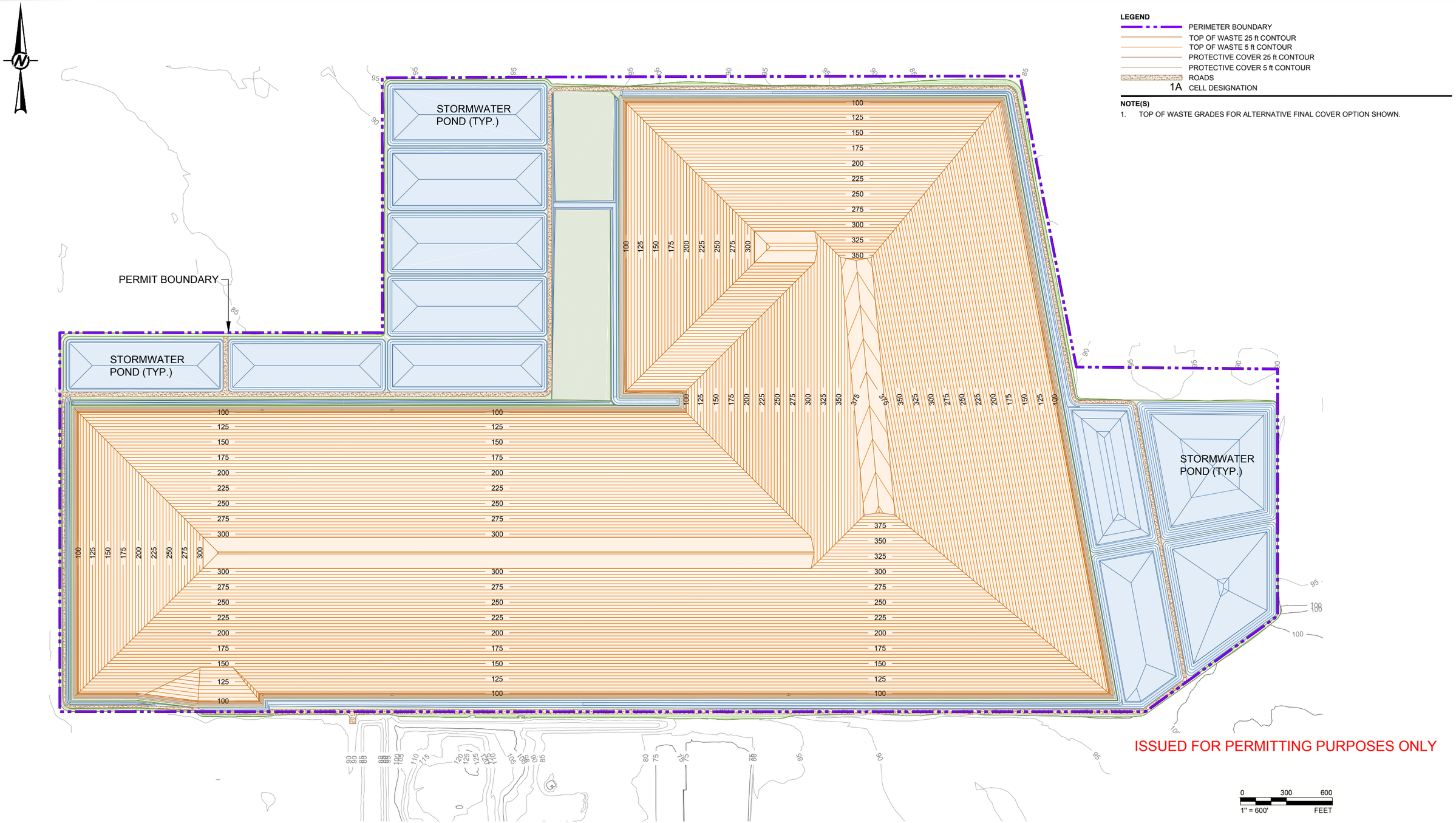

LEGEND

- PERIMETER BOUNDARY
- TOP OF WASTE 25 ft CONTOUR
- TOP OF WASTE 5 ft CONTOUR
- PROTECTIVE COVER 25 ft CONTOUR
- PROTECTIVE COVER 5 ft CONTOUR
- ROADS
- 1A CELL DESIGNATION

NOTE(S)

1. TOP OF WASTE GRADES FOR ALTERNATIVE FINAL COVER OPTION SHOWN.

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0 300 600
1" = 600' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

SEAL

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
TOP OF WASTE LAYOUT *ALTERNATIVE FINAL COVER OPTION*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3A-1	0	4 of 5	III3A-1-4

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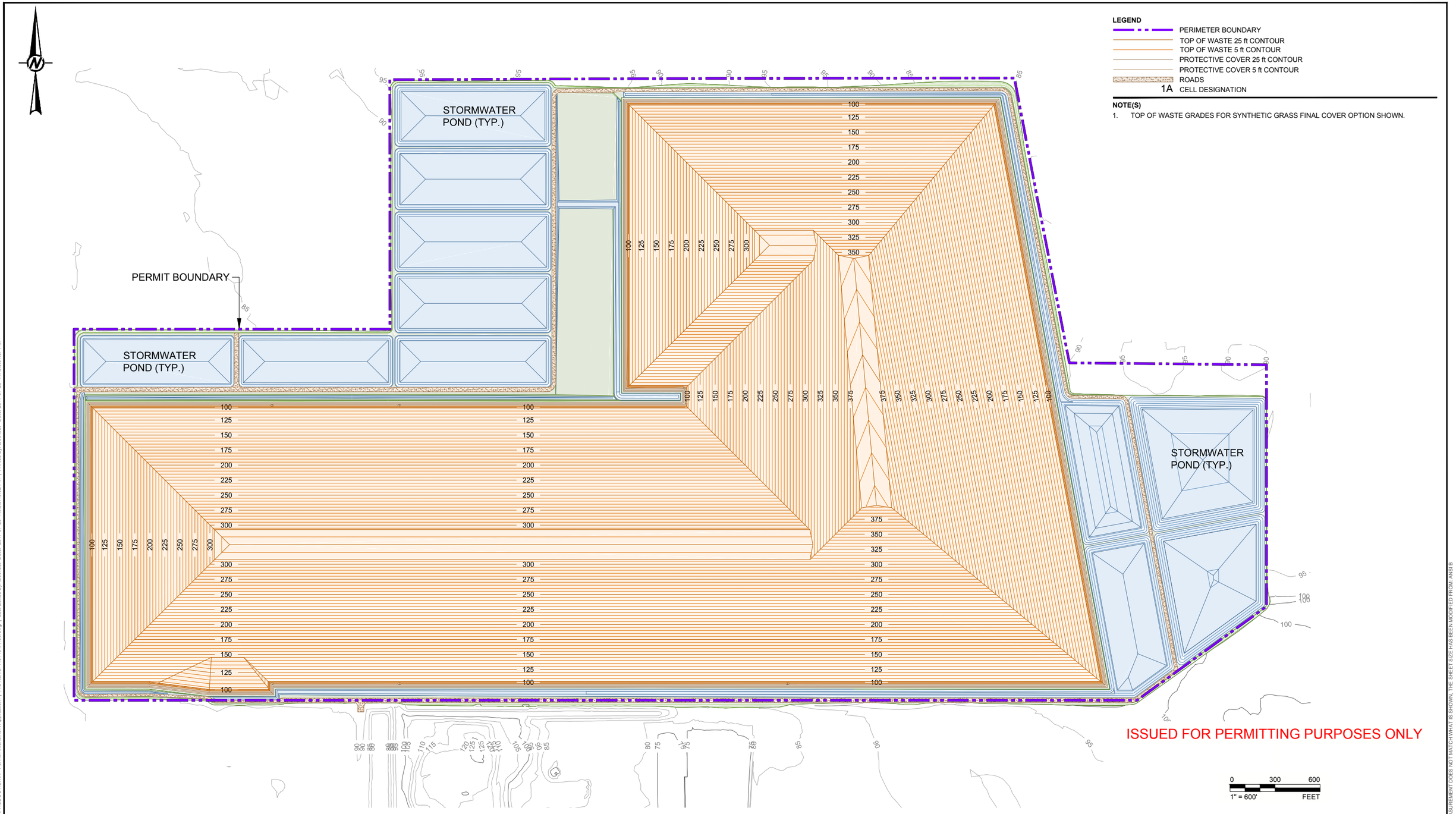

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0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
TOP OF WASTE LAYOUT *SYNTHETIC GRASS FINAL COVER OPTION*

PROJECT NO.	APPLICATION SECTION	REV.	5 of 5	FIGURE
1401491	III3A-1	0		III3A-1-5

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APPENDIX III3A-2

SITE LIFE CALCULATIONS

SITE LIFE CALCULATIONS

Made by: CEI
Checked by: MX
Reviewed by: JBF

1.0 SUMMARY

The site life is: 63.5 yrs or until Feb 2080

2.0 OBJECTIVE

To determine the anticipated site life based on airspace volume calculations, current airspace comsumed, estimated waste receipts, and projected growth rates.



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3.0 GIVEN

FY 2015 Annual Report MSW-956B	**Date**	**8/31/2016**
Current annual waste receipt	494,319	tons
Compacted waste density	1215	lbs/CY
Total Airspace	16,734,913	CY
Remaining Capacity	5,738,691	CY
Airspace Consumed	10,996,222	CY

Total Airspace		**Construction Options**	
		Overliner	*Unit 8*
Final Cover Options	*Prescriptive*	84,997,400	84,831,321
	Alternate	85,981,680	85,815,599
	Closure Turf	87,301,156	87,135,076

4.0 ASSUMPTIONS

Growth Rate	1.75%
Compacted in-place waste density	1,500 lbs/CY

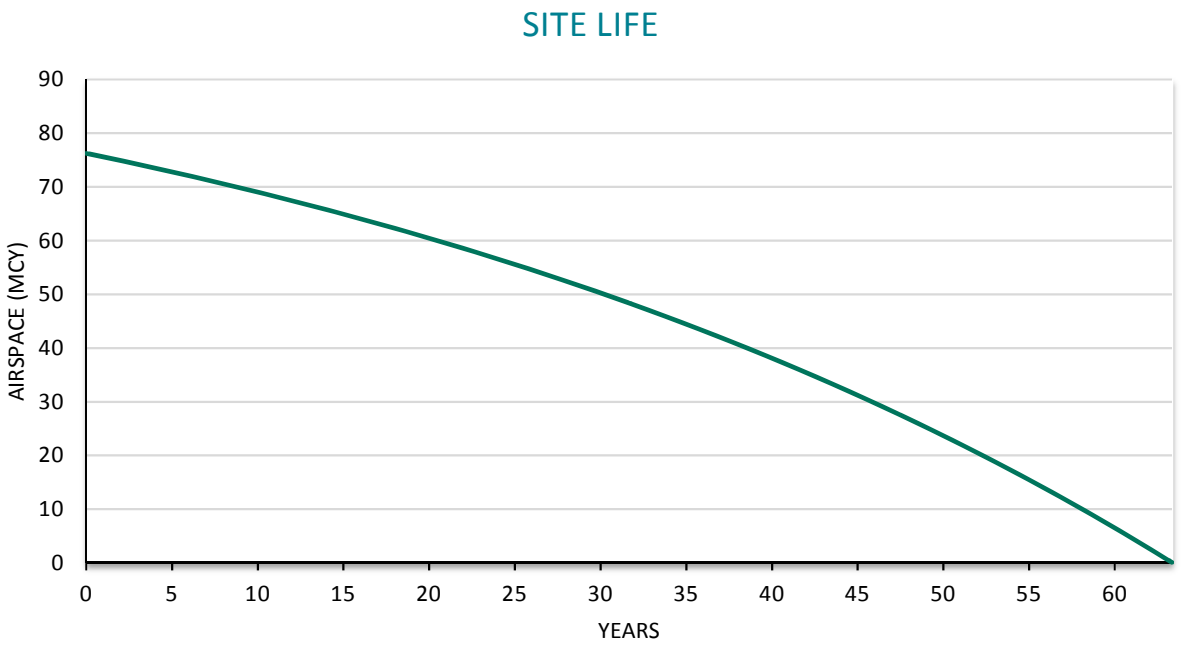
5.0 CALCULATIONS

The site life, number of years to consume total airspace, can be determined by solving the following equation:

$$A_T = \sum_n A_C(1+R)^n$$

where

A_T = Total remaining airspace — A_T = 76,304,934 CY
A_C = Initial annual airspace consumed — A_C = 659,092 CY/yr
R = Growth Rate — R = 1.02
n = Site life in years — *n* = **63.5** years


SITE LIFE
AIRSPACE (MCY)
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
30
35
40
45
50
55
60
YEARS

APPENDIX III3B

WASTE MANAGEMENT UNIT DESIGN ANALYSES

APPENDIX III3B-1

SETTLEMENT ANALYSIS

SETTLEMENT ANALYSIS

Made by: JCW
Checked by: CEI
Reviewed by: JBF

1.0 OBJECTIVE

To estimate the amount of settlement and the post-settlement floor grades for landfill development, and evaluate the impact of settlement on the leachate flow and liner system.



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2.0 GIVEN

2.1 Site Conditions

The subsurface stratigraphy of the site includes three units, Stratum I, Stratum II, and Stratum III. The units are comprised of primarily of sandy clays and clayey sands (Stratum I), silty fine sand or sand (Stratum II), and hard clay (Stratum III). Facility floor settlement may occur in each soil unit.

Review of the excavation plan indicates that a significant portion of Stratum I will be removed prior to construction of the liner system and that much of the landfill floor will be founded on a layer of remaining Stratum I and Stratum II.

For this analysis, the most critical cross-section for settlement was cut through the landfill where there is maximum waste thickness under the final configuration slope. Subsurface stratigraphy unit thicknesses for Stratum II are observed to be relatively uniform in the footprint of the landfill and are depicted with approximate unit thicknesses in the critical cross-section. Intermittent points along the critical cross sections were analyzed for settlement and to define post-settlement slopes. Figures III3B-1-1 and III3B-1-2, depict the most critical cross-section for settlement located in Unit 7, Cell 2. The section begins at the facility's southern perimeter and progresses north aligned where the final elevation is highest.

3.0 PRIMARY COMPRESSION EQUATION

3.1 Calculation Methodolgy

Settlement for the landfill floor is expected from primary compression of the foundation soil units, which will be loaded by the waste and final cover placement. Equations 1, 2, and 3 below were used to calculate primary settlement of the landfill floor caused by the stress increase from the waste fill and final cover. Stratum I and Stratum III are modeled as overconsolidated clays under this methology and use Equations 1 and 2, for which the applied maximum overburden vertical stress will be either lower, equal to or greater than the preconsolidation stress depending on the location along the critical cross-section [See Ref. 1]. Stratum II is modeled as an elastic soil and estimated elastic settlement, Se, is calculated using Equation 3 [Ref. 2].

For $\sigma_0 + \Delta\sigma < \sigma_p$ $$S_c = C_{r\varepsilon} \cdot H \cdot \log\frac{(\sigma_0 + \Delta\sigma)}{\sigma_o}$$ Equation (1)

For $\sigma_0 + \Delta\sigma > \sigma_p$ $$S_c = C_{r\varepsilon} \cdot H \cdot \log\frac{(\sigma_p)}{(\sigma_0)} + C_{c\varepsilon} \cdot H \cdot \log\frac{\sigma_o + \Delta\sigma}{\sigma_p}$$ Equation (2)

Where: σ_0 = Initial average effective vertical stress for the layer of concern
$\Delta\sigma$ = Vertical stress increase from new waste and final cover
σ_p = Preconsolidation stress
C_{re} = Modified recompression index
C_{ce} = Modified compression index
H_0 = Layer thickness

For Elastic Settlement: $Se = \varepsilon * Ho$ Equation (3)

Where: Ho = initial thickness of sublayer and the strain in each sublayer is calculated :
$\varepsilon = \Delta\sigma/E$
E = elastic modulus $E / P_a = 5N_{60}$ (sands with fines), [Ref. 2]
where P_a is the atmospheric pressure constant
ε = strain

3.2 Assumptions

1) For the settlement calculations, it is assumed that the entire block of new waste is instantaneously applied above the liner. This assumption is conservative, as it will induce greater settlement.

2) The thickness of Stratum I varies with the floor elevation of the landfill. The thickness of Stratum II is approximately 20 feet based on boring observations with an N_{60} value of 34. Stratum III is modeled as a uniform thickness of 200 feet; this is considered conservative because a previous soil boring indicated that Stratum III is less than 200 ft thick and is underlain by a dense sand layer.

3) For overconsolidated, inorganic clays, settlement due to secondary compression (creep) is not a concern.

4) The 5 to 15 feet of Soil Layer 1 excavation for cell construction was omitted from the initial vertical stress calcualtions because the subsequent cell is typically used as a soil borrow source and excavated well in advance of cell liner construction.

5) The groundwater level elevation is conservatively set at 75 feet above mean sea level.

4.0 MATERIAL PARAMETERS

Final cover soil Unit Weight: = 115 pcf (conservatively assumed)
Protective cover soil Unit Weight: = 115 pcf (conservatively assumed)
Waste: = 65 pcf (conservatively assumed)

Stratum Properties		Stratum I	Stratum II	Stratum III	
Unit Weight	(pcf)	121	108	113	(lab testing)
Saturated Unit Weight	(pcf)	130	138	133	(lab testing)
Preconsolidation Stress	σ_p	22,000	-	20,000	(lab testing)
Modified Compression Index	C_{ce}	0.074	-	0.076	(lab testing)
Modified Recompression Index	C_{re}	0.010	-	0.014	(lab testing)
Youngs (Elastic) Modulus	E (ksf)	-	360	-	(field tests)

5.0 CALCULATIONS AND RESULTS

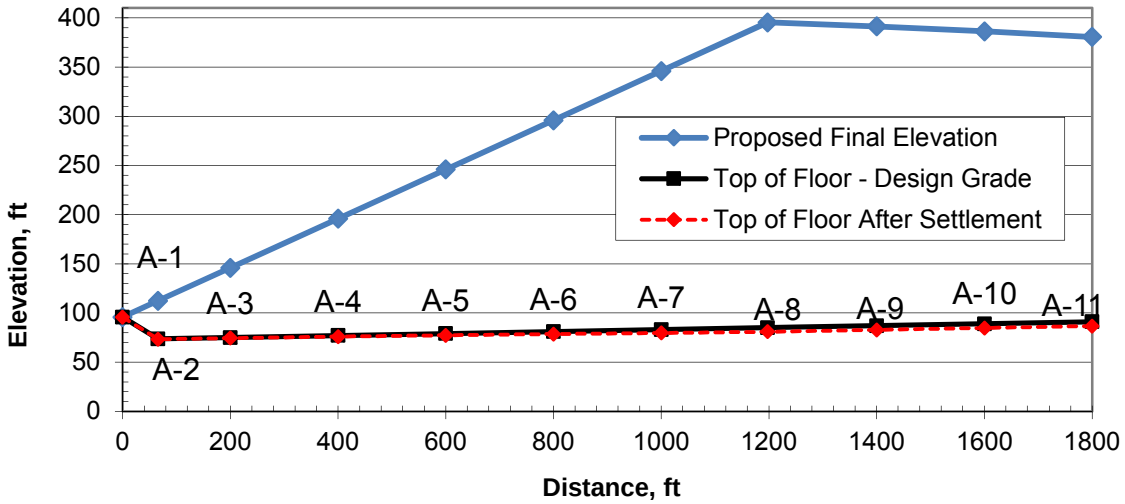
A 2-dimensional numerical analysis was used to estimate the stress distribution resulting form the placement of waste. The waste mass is treated as an embankment load using Boussinesq Analytical Solution for Embankment [Ref. 3].

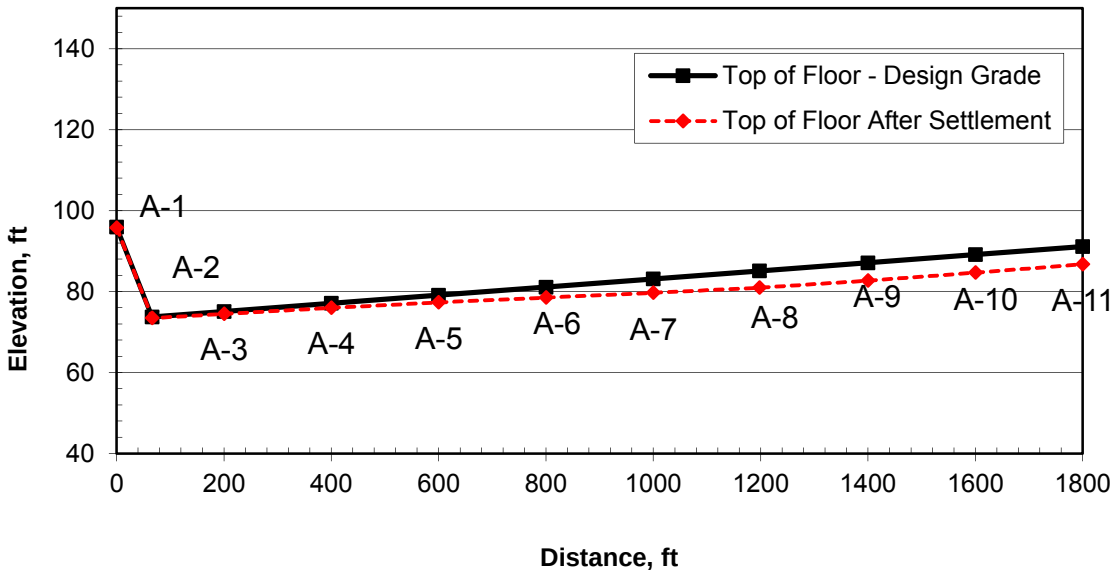
The equations and methods outlined in prior sections were implemented using Excel spreadsheets to perform the settlement calculations. Key and representative analytical points were selected along cross-section D. The resulting settlement and post-settlement floor grade changes due to differential settlement are summarized in Table 1, and shown graphically in following charts.

6.0 CONCLUSIONS

A conservative estimate of minimum post-settlement slope is 0.6%. The post-settlement floor grades maintain positive drainage and allow the leachate to drain towards the leachate collection system under the conditions analyzed.

Settlement	Subgrade Elevation (ft)		Difference in Elev. (ft)	Slope of Subgrade		
	Pre	Post	Pre - Post		Pre	Post
A-1	95.9	95.8	0.1			
A-2	73.8	73.5	0.3	**A-1 → A-2**	-33.6%	-33.8%
A-3	75.1	74.5	0.6	**A-2 → A-3**	1.0%	0.8%
A-4	77.1	76.0	1.1	**A-3 → A-4**	1.0%	0.7%
A-5	79.1	77.4	1.7	**A-4 → A-5**	1.0%	0.7%
A-6	81.1	78.6	2.5	**A-5 → A-6**	1.0%	**0.6%**
A-7	83.1	79.7	3.4	**A-6 → A-7**	1.0%	**0.6%**
A-8	85.1	81.0	4.1	**A-7 → A-8**	1.0%	0.7%
A-9	87.1	82.8	4.3	**A-8 → A-9**	1.0%	0.9%
A-10	89.1	84.7	4.4	**A-9 → A-10**	1.0%	1.0%
A-11	91.1	86.7	4.4	**A-10 → A-11**	1.0%	1.0%





7.0 REFERENCES

1. One Dimensional Consolidation Test Results for Stratum I and III, March 2015.
2. Manual on Estimating Soil Properties for Foundation Design, Electric Power Research Institute, California, 1990.
3. Settle3D - Stress Analysis Verification Manual, Rocscience Inc., 2012.
4. Das, Principles of Geotechnical Engineering, 4th Ed., PWS Publishing Co., 1998.



LEGEND

- PERIMETER BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- ROADS
- 1A CELL DESIGNATION

NOTE(S)

1. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
2. SUBGRADE ELEVATIONS SHOWN.
3. TOP OF THE LINER ELEVATIONS IN THE BOTTOM OF THE LEACHATE COLLECTION SUMPS ARE 2 ft LOWER THAN ELEVATION OF THE LOW POINT ON THE LINER.
4. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 72 ft-msl IN UNIT 7.

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0 300 600
1" = 600' FEET

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
SETTLEMENT ANALYSIS *SUBGRADE LAYOUT*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3B-1	0	1 of 2	III3B-1-1

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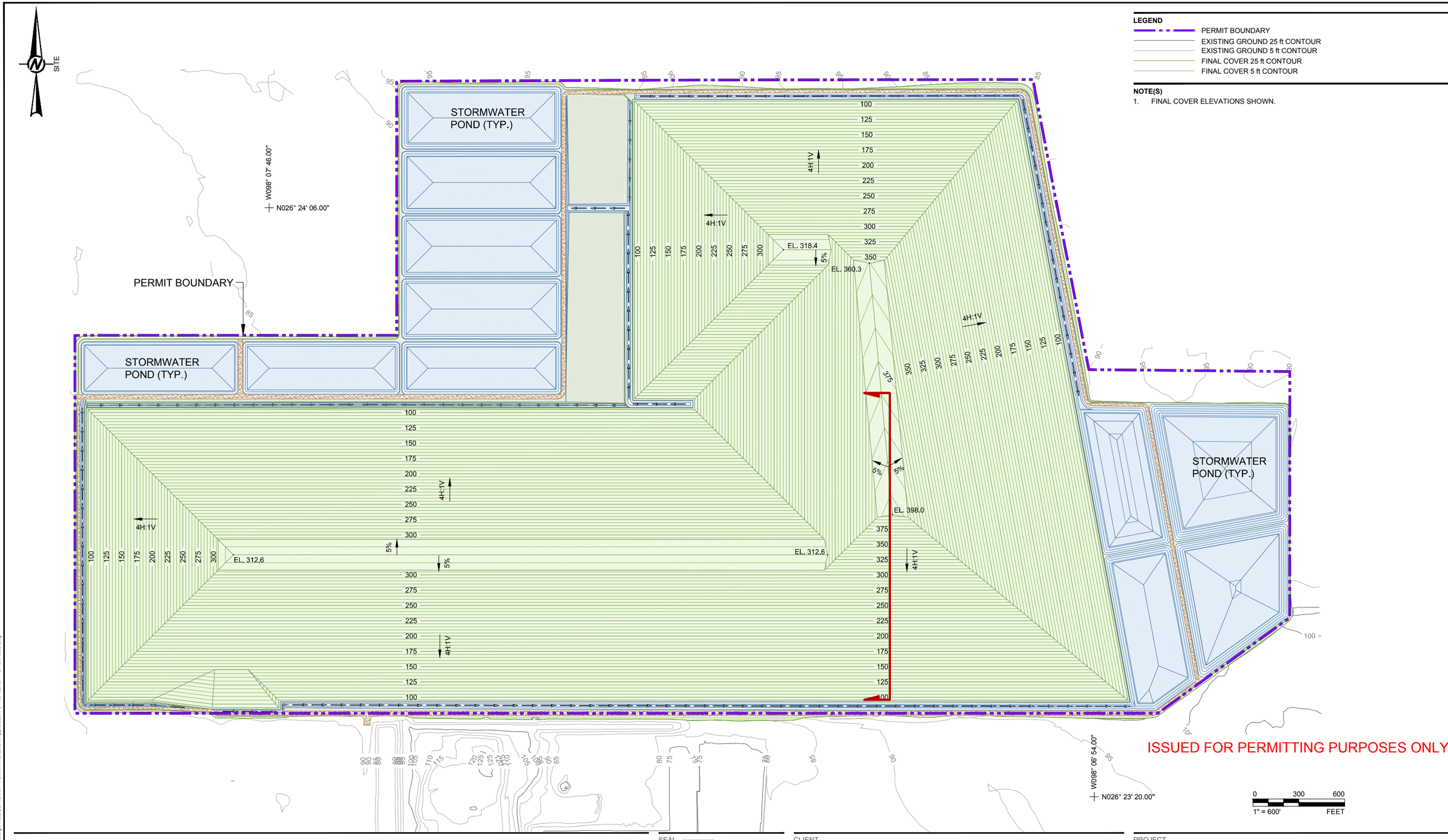

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EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
SETTLEMENT ANALYSIS *FINAL CONTOUR MAP*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3B-1	0	2 of 2	III3B-1-2

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APPENDIX III3B-2

STABILITY ANALYSIS

CITY OF EDINBURG SOLID WASTE MANAGEMENT

PERMIT AMENDMENT APPLICATION

Part III, Attachment 3, Appendix B-2

STABILITY ANALYSIS

Edinburg Regional Disposal Facility

Edinburg, Hidalgo County, Texas

TCEQ Permit MSW-956C

Submitted To: City of Edinburg
Department of Solid Waste Management
8601 North Jasman Road
Edinburg, Texas 78542 USA

Submitted By: Golder Associates Inc.
500 Century Plaza Drive, Suite 190
Houston, TX 77073 USA



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July 2017

Project No. 1401491

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III3B-2E-1 Final Cover System Stability
III3B-2E-2 Final Cover Drainage Layer Capacity



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1.0 PARAMETERS

As detailed in Part III4, Geology Report the site is underlain by three distinct strata, identified below in order from ground surface down:

- Stratum I: sandy clays or clayey sands, with layers of silty clay, silty sand, or clayey silt.
- Stratum II: sands/silty sands, fine, poorly graded, and is the uppermost water-bearing unit (uppermost aquifer).
- Stratum III: predominantly clay, with some amounts of sandy clay or silty clay, high plasticity, hard, brown, and dry, and is the confining unit underlying the uppermost water-bearing unit (lower confining unit).

Table III3B-2-1: Soil Unit Weight and Strength Parameters

Soil	Unit Weight (pcf)		Strength Parameters		Analysis Stress State	Reference
	Moist	Saturated	ϕ (degrees)	c (psf)		
Stratum I	121	130	0	2644	Total	Golder
			31	100	Effective	Lambe & Whitman, 1969
Stratum II	108	138	34	0	Total	Golder
			34	0	Effective	Lambe & Whitman, 1969
Stratum III	113	133	0	5040	Total	Golder
			27	300	Effective	Lambe & Whitman, 1969

Reference:
Golder – Laboratory testing data from 2015 subsurface investigation.
Lambe & Whitman, 1969 - Lambe, T.W. and Whitman, R.V. (1969). Soil Mechanics, John Wiley & Sons, New York.

Table III3B-2-2: Alternative Liner Component Interface Unit Weight and Strength Parameters

Soil	Unit Weight (pcf)		Strength Parameters		Reference
	Moist	Saturated	ϕ (degrees)	c (psf)	
Protective Cover	115	132	28	0	Estimate
Protective Cover/Geocomposite	–	–	28	0	Golder
Geocomposite/Textured Geomembrane	–	–	24	0	Golder
Textured Geomembrane/GCL	–	–	24	0	Golder
GCL/Subgrade	–	–	30	0	Golder

Reference:
Golder - Based on unpublished data from tests performed in Golder's laboratory, on similar geosynthetic materials. Strength parameters were conservatively assigned to be equal to or a percentage of the peak strength (lower bound) to account for testing material variability.

The shear strength parameters indicate that the critical interface occurs at the geocomposite/geomembrane or geomembrane/GCL interface, with a friction angle of 24 degrees.

2.0 STABILITY ANALYSIS

The results of the stability analyses indicate that the slopes are stable under the conditions analyzed. For each condition analyzed, the minimum calculated factor of safety exceeds the recommended factor of safety.

Slope stability analyses were performed using limit equilibrium methods to assess the stability of the landfill. In particular, stability of the excavated landfill sideslopes, stability of the protective cover on landfill sideslopes, stability of the interior waste slopes, overall stability of the final filled landfill, and stability of the final cover system were evaluated.

In general, the analyses consist of the following:

- Characterization of the critical cross-section (e.g., the geometry, geology, geosynthetic interfaces, and groundwater conditions).
- Selection of appropriate strength parameters.
- Analysis under anticipated critical conditions.

The analyses are summarized in the following sections.

2.1 Stability Analysis of Excavated Slopes

A stability analysis was performed to consider potential failure surfaces after excavation to build the waste cells. Based on a review of the design grades, the longest proposed excavated slope occurs within Unit 7, Cell 2A. The cross-section in this area is shown in Figure III3B-1-2 and consists of a 3H:1V slope from approximate elevation of 95 ft-msl to the toe at an approximate elevation of 70 ft-msl.

A conservatively generalized subsurface stratigraphy was developed for this analysis based on available laboratory test data and field data from boring logs. The subsurface stratigraphy has been developed using three layers from top to bottom: sandy clays and clayey sands (Stratum I), silty fine sand or sand (Stratum II), and hard clay (Stratum III). The analysis was conducted for both total stress and effective stress conditions. The stratigraphy and strength data for the in situ soils were developed from borings and laboratory testing described above.

Groundwater level was conservatively assumed to be approximately 76.5 ft-msl, based on the available piezometer data. Within the excavation, the phreatic surface was conservatively assumed to correspond to the excavation grade.

SLIDE Version 7.0, an integrated slope stability analysis program for personal computers, was used for the analysis. The slope geometry for the critical section of the landfill was input into the program along with the

unit weight and strength parameters. Potential failure surfaces were analyzed and the minimum factor of safety was computed. The calculations are presented in Appendix III3B-2A.

The factor of safety against instability for the slope analyzed is 4.2 for the total stress condition and 2.0 for the effective stress condition. These values indicate the slopes will be stable and are therefore adequate. The factors of safety will also increase as waste is placed within the landfill cells.

2.2 Stability of Protective Cover on the Cell Sideslopes

An analysis of the stability of the cell sideslope liner system was performed using an infinite slope analysis. Based on a review of the literature and unpublished data on similar materials under similar loading conditions, the critical interface shear strength within the sideslope liner system was estimated to be 24 degrees. The maximum length of slope is 75 feet with a 3H:1V slope.

The analyses, included as Appendix III3B-2B-1, indicate that, provided the geocomposite drainage layer is adequate to convey drainage without building up pore water pressures, the factor of safety is found to be at least 1.34, and likely to be higher due to the use of conservative parameters in the analysis. This factor of safety is considered adequate and will increase as waste is placed within the cell.

Additional analyses (included in Appendix III3B-2B-2) were performed demonstrating that a standard double-sided geocomposite drainage layer will have a transmissivity adequate to convey water infiltrating through the protective cover over the maximum sideslope length.

2.3 Stability of the Interior Waste Slopes

Interior waste slope stability analyses were performed using the limit equilibrium slope stability method to determine the factor of safety against sliding along the liner. Based on a review of the floor grades and filling sequence, it was identified that the interior waste slope in Unit 7, Cells 6 through 9 is the most critical case, where the filling and floor slope occur in the same direction with no buttress effect from existing waste or the floor gradient. A review of the literature and data on the liner system components under similar loading conditions indicate that the weakest interfaces in the liner system occur between the geocomposite and the textured geomembrane. These interfaces were used in the analysis.

The analyses were performed using SLIDE. Two possible waste filling slopes were considered: 1) continuous 3H:1V temporary waste slopes with no benches; and 2) continuous 3H:1V temporary waste slopes with one bench at the middle of the slope. The maximum waste elevation is conservatively assumed at 400 feet-msl which is the approximate peak elevation of the final landfill design.

The strength parameters were either conservatively chosen from published studies or based on test results for similar conditions, and the slope geometries correspond to the reasonable worst case scenarios.

Results of the analysis under the assumed conservative scenarios indicate that the interior waste slope at 3H:1V may be filled up to the final elevation with an acceptable factor of safety. However, to facilitate site operations and to account for any operational uncertainties, a 100-foot wide bend at the midpoint of the 3H:1V interior slope is advised. The calculations are presented in Appendix III3B-2C.

2.4 Stability of Final Filled Configuration

Final filled configuration stability analyses were performed using limit equilibrium methods to determine the factors of safety against sliding or failure. Based on a review of the design grades, two reasonable worst-case configurations were considered: a section along Unit 7, Cell 2, having 3H:1V excavation sideslopes and 4H:1V final cover slopes to a crest elevation at 400 feet msl; and a section along Unit 7 with similar slopes running west to east along Cells 1 through 5. The cross-sections are is shown in Figure III3B-2D-1 AND -2. The calculations are presented in Appendix III3B-2D.

Using strength parameters that are conservatively estimated or based on test results for similar conditions, and the reasonable worst case configuration, the analysis indicates that the final-filled configuration will be stable with minimum factors of safety of 1.94 for block sliding and 2.90 for circular failure.

2.5 Stability of Final Cover System

A stability analysis of the final cover liner system was performed using an infinite slope analysis to estimate the potential for sliding to occur following closure of the landfill cells. A worst-case section, consisting of a 1,300-foot long, 25-percent slope was analyzed. Based on a review of the literature and unpublished data on similar materials under similar loading conditions, the critical interface shear strength within the final cover liner system was estimated to be 21 degrees.

The analyses are included in Appendix III3B-2E-1 and indicate that, provided the geocomposite drainage layer is adequate to convey drainage without building up pore water pressures in the geocomposite, the factor of safety against sliding will be approximately 1.54.

Additional analyses (included in Appendix III3B-2E-2) were performed to determine the geocomposite drainage layer transmissivity required to adequately convey surface water infiltration over the maximum final cover slope length. If the minimum measured transmissivity value reported in Appendix III-3D is not met, the maximum flow length must be reduced (i.e., the geocomposite drainage layer must be “daylighted”) in direct proportion to the ratio of the actual measured transmissivity and the required measured transmissivity. A detail depicting “daylighting” is included as detail 4 in Attachment 7, Closure Plan, Figure III7-3A, Conventional Composite Final Cover Details.

APPENDIX III3B-2A

EXCAVATION STABILITY

EXCAVATION STABILITY

Made by: JCW
Checked by: CEI
Reviewed by: JBF

1.0 SUMMARY

Evaluate the slope stability of the excavated slopes.

2.0 GIVEN

A stability analysis was performed to consider potential failure surfaces for excavation of waste management units. The excavation is a 3H:1V slope with a crest elevation of 95 ft-msl and a maximum excavation elevation is 70 ft-msl.

As detailed in Part III4, Geology Report the site is underlain by three distinct strata, identified below in order from ground surface down:



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Stratum I: sandy clays or clayey sands, with layers of silty clay, silty sand, or clayey silt.
Stratum II: sands/silty sands, fine, poorly graded, and is the uppermost water-bearing unit (uppermost aquifer).
Stratum III: predominantly clay, with some amounts of sandy clay or silty clay, high plasticity, hard, brown, and dry, and is the confining unit underlying the uppermost water-bearing unit (lower confining unit).

Material	Unit Weight (pcf)		Strength Parameters		Analysis Stress State	Reference
	Moist	Saturated	ϕ (degrees)	c (psf)		
Stratum I	121	130	0	2644	Total	Golder
			31	100	Effective	Lambe & Whitman, 1969
Stratum II	108	138	34	0	Total	Golder
			34	0	Effective	Lambe & Whitman, 1969
Stratum III	113	133	0	5040	Total	Golder
			27	300	Effective	Lambe & Whitman, 1969

Based on groundwater elevation data collected, a conservation elevation of groundwater used is 76.5 ft-msl and the phreatic surface was conservatively assumed to correspond to the excavation grade.

3.0 METHOD

Use SLIDE v.7.0 [Ref. 3] to analyze excavation stability, based on limit equilibrium methods following Spencer's and GLE/Morgenstern-Price methods of analysis. The results from the method providing the least factor of safety is presented.

Based on the Corps of Engineers "Design and Constuction of Levees" manual (EM 1110-2-1913), the recommended factors of safety are 1.3 for short-term (total stress) and 1.5 for long-term (effective stress) conditions, respectively.

4.0 RESULTS

SLIDE output files attached to this calculation. The factor of safety for the slope analyzed is 4.2 for the total stress condition and 2.0 for the effective stress condition. These values are acceptable.

5.0 CONCLUSION

Using the anticipated maximum excavation slope and soil unit weight and strength parameters, the analysis indicates that the excavated slopes will be stable.

6.0 REFERENCES

1. Golder 2016 Geotechnical Testing Data for Edinburg Investigation.
2. Lambe, T.W. and Whitman, R.V. (1969). Soil Mechanics, John Wiley & Sons, New York.
3. Rocscience 2015, SLIDE - 2D Limit Equilibrium Slope Stability for Soil and Rock Slopes.



REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

SEAL

STATE OF TEXAS
JEFFREY B. FASSETT
85675
LICENSED
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
EXCAVATION STABILITY *SUBGRADE LAYOUT*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3B-2A	0	1 of 1	III3B-2A-1

Path: \\houston\drafting_2014\1401491 - city of edinburg\PRODUCTION\A - Permit Amendment Application\ | File Name: 1401491A051.dwg

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

APPENDIX III3B-2A-1

TOTAL STRESS ANALYSIS

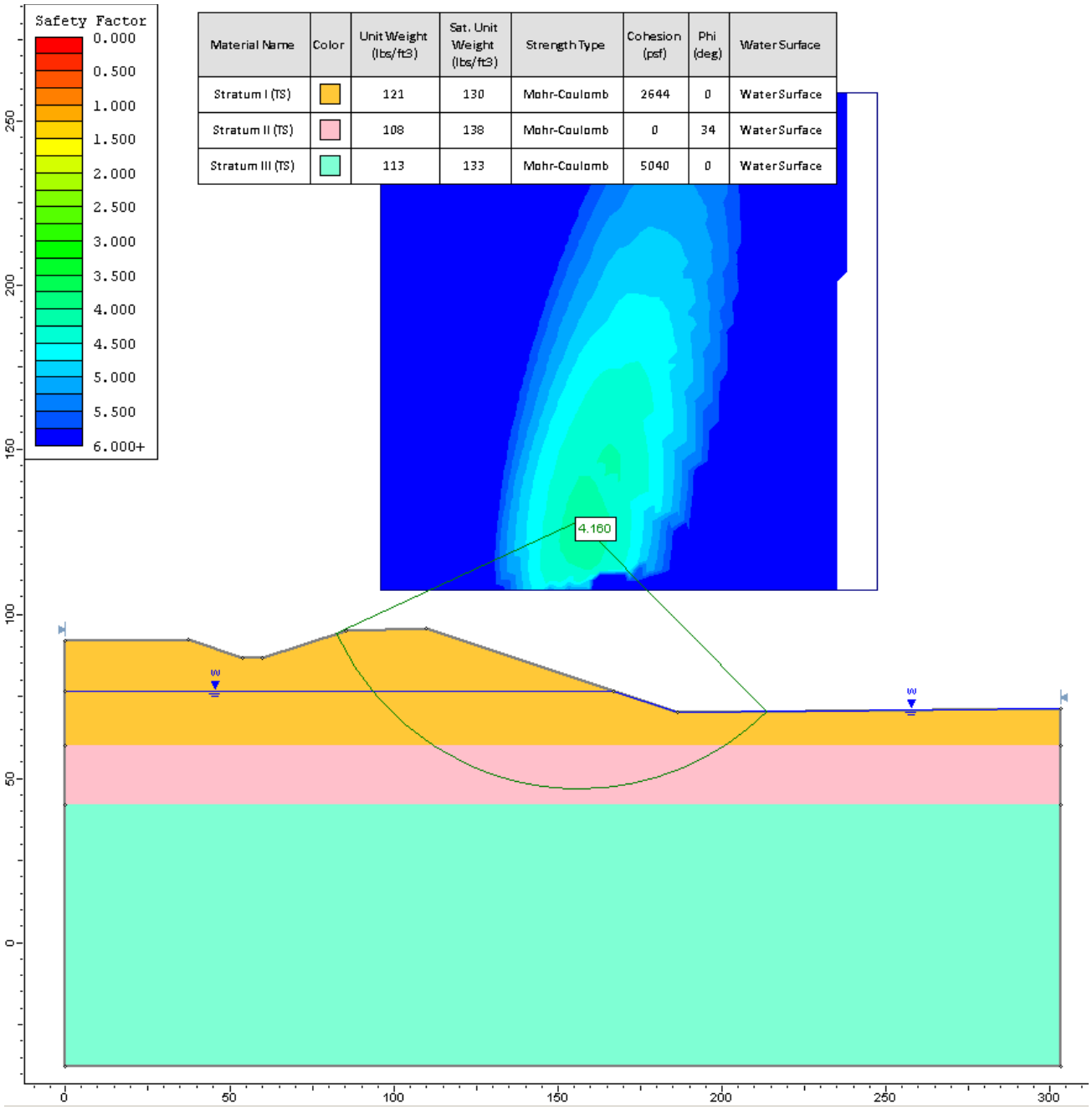


FIGURE **III3B-2A-1**

Excavation Stability - Total Stress Analysis

Edinburg Regional Disposal Facility, Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-2A, Excavation Stability

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	Edinburg_Excavation_TS.slim
Slide Modeler Version:	7.014
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	1/29/2016, 4:56:33 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
GLE/Morgenstern-Price with interslice force function:	Half Sine 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 [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Enabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined
Minimum Area: Not Defined
Minimum Weight: Not Defined

Seismic

Advanced seismic analysis: No
Staged pseudostatic analysis: No

Material Properties

Property	Stratum I (TS)	Stratum II (TS)	Stratum III (TS)
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113
Saturated Unit Weight [lbs/ft3]	130	138	133
Cohesion [psf]	2644	0	5040
Friction Angle [deg]	0	34	0
Water Surface	Water Table	Water Table	Water Table
Hu Value	Automatically Calculated	1	1

Global Minimums

Method: spencer

FS	4.159730
Center:	156.612, 128.505
Radius:	81.771
Left Slip Surface Endpoint:	82.464, 94.030
Right Slip Surface Endpoint:	214.044, 70.297
Resisting Moment:	2.54293e+007 lb-ft
Driving Moment:	6.1132e+006 lb-ft
Resisting Horizontal Force:	251364 lb
Driving Horizontal Force:	60428 lb
Total Slice Area:	3314.55 ft2
Surface Horizontal Width:	131.581 ft
Surface Average Height:	25.1903 ft

Method: gle/morgenstern-price

FS	4.163350
Center:	156.612, 128.505
Radius:	81.771
Left Slip Surface Endpoint:	82.464, 94.030
Right Slip Surface Endpoint:	214.044, 70.297
Resisting Moment:	2.54514e+007 lb-ft
Driving Moment:	6.1132e+006 lb-ft
Resisting Horizontal Force:	251561 lb
Driving Horizontal Force:	60422.8 lb
Total Slice Area:	3314.55 ft2
Surface Horizontal Width:	131.581 ft
Surface Average Height:	25.1903 ft

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 23815
Number of Invalid Surfaces: 4796

Error Codes:

Error Code -107 reported for 4217 surfaces
Error Code -108 reported for 576 surfaces
Error Code -111 reported for 3 surfaces

Method: gle/morgenstern-price

Number of Valid Surfaces: 23815
Number of Invalid Surfaces: 4796

Error Codes:

Error Code -107 reported for 4217 surfaces
Error Code -108 reported for 579 surfaces

Error Codes

The following errors were encountered during the computation:

-107 = Total driving moment or total driving force is negative. This will occur if the wrong failure direction is specified, or if high external or anchor loads are applied against the failure direction.
-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).
-111 = safety factor equation did not converge

Slice Data

Global Minimum Query (spencer) - Safety Factor: 4.15973

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	4.91643	3100.11	-61.4571	Stratum I (TS)	2644	0	635.618	2644	-493.962	0	-493.962
2	4.91643	8089.19	-54.8563	Stratum I (TS)	2644	0	635.618	2644	729.783	0	729.783
3	4.91643	11993.9	-49.2244	Stratum I (TS)	2644	0	635.618	2644	1663.9	83.8179	1580.08
4	4.91643	15397.3	-44.1835	Stratum I (TS)	2644	0	635.618	2644	2461.92	410.76	2051.16
5	4.91643	18285.1	-39.5466	Stratum I (TS)	2644	0	635.618	2644	3136.5	686.499	2450
6	4.91643	20652.5	-35.2039	Stratum I (TS)	2644	0	635.618	2644	3693.99	921.378	2772.61
7	5.25294	23487.1	-30.9491	Stratum II (TS)	0	34	485.428	2019.25	4121.54	1127.88	2993.66
8	5.25294	24475.4	-26.7416	Stratum II (TS)	0	34	494.748	2058.02	4359.89	1308.73	3051.16
9	5.25294	25117.9	-22.6854	Stratum II (TS)	0	34	498.198	2072.37	4532.25	1459.82	3072.43
10	5.25294	25447.3	-18.7465	Stratum II (TS)	0	34	496.21	2064.1	4644.11	1583.95	3060.16
11	5.25294	25487.3	-14.8981	Stratum II (TS)	0	34	489.089	2034.48	4699.41	1683.18	3016.23
12	5.25294	25255.3	-11.1175	Stratum II (TS)	0	34	477.036	1984.34	4700.9	1758.98	2941.92
13	5.25294	24763.5	-7.3856	Stratum II (TS)	0	34	460.172	1914.19	4650.34	1812.44	2837.9
14	5.25294	24020.3	-3.6851	Stratum II (TS)	0	34	438.54	1824.21	4548.75	1844.23	2704.52
15	5.25294	23030.2	0	Stratum II (TS)	0	34	412.123	1714.32	4396.36	1854.79	2541.57
16	5.25294	21794.9	3.6851	Stratum II (TS)	0	34	380.818	1584.1	4192.77	1844.23	2348.54
17	5.25294	20300.5	7.3856	Stratum II (TS)	0	34	344.873	1434.58	3934.46	1807.62	2126.84
18	5.25294	18492.8	11.1175	Stratum II (TS)	0	34	319.203	1327.8	3613.48	1644.94	1968.54
19	5.25294	16416.6	14.8981	Stratum II (TS)	0	34	287.944	1197.77	3235.65	1459.89	1775.76
20	5.25294	14068.5	18.7465	Stratum II (TS)	0	34	250.896	1043.66	2798.72	1251.43	1547.29
21	5.25294	11863.1	22.6854	Stratum II (TS)	0	34	215.339	895.753	2384.06	1056.05	1328.01
22	5.25294	10128.7	26.7416	Stratum II (TS)	0	34	186.441	775.546	2058.14	908.356	1149.79
23	5.25294	8064.78	30.9491	Stratum II (TS)	0	34	150.54	626.206	1659.29	730.891	928.394
24	6.391	6554.06	35.8592	Stratum I (TS)	2644	0	635.618	2644	1536.65	492.194	1044.46
25	6.391	2331.28	41.6194	Stratum I (TS)	2644	0	635.618	2644	974.17	175.074	799.096

Global Minimum Query (gle/morgenstern-price) - Safety Factor: 4.16335

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	4.91643	3100.11	-61.4571	Stratum I (TS)	2644	0	635.066	2644	-530.837	0	-530.837
2	4.91643	8089.19	-54.8563	Stratum I (TS)	2644	0	635.066	2644	745.822	0	745.822
3	4.91643	11993.9	-49.2244	Stratum I (TS)	2644	0	635.066	2644	1690.97	83.8179	1607.16
4	4.91643	15397.3	-44.1835	Stratum I (TS)	2644	0	635.066	2644	2484.42	410.76	2073.66
5	4.91643	18285.1	-39.5466	Stratum I (TS)	2644	0	635.066	2644	3147.91	686.499	2461.42
6	4.91643	20652.5	-35.2039	Stratum I (TS)	2644	0	635.066	2644	3692.83	921.378	2771.45
7	5.25294	23487.1	-30.9491	Stratum II (TS)	0	34	483.176	2011.63	4110.25	1127.88	2982.37
8	5.25294	24475.4	-26.7416	Stratum II (TS)	0	34	491.126	2044.73	4340.17	1308.73	3031.44
9	5.25294	25117.9	-22.6854	Stratum II (TS)	0	34	493.941	2056.45	4508.62	1459.82	3048.8
10	5.25294	25447.3	-18.7465	Stratum II (TS)	0	34	492.015	2048.43	4620.87	1583.95	3036.92
11	5.25294	25487.3	-14.8981	Stratum II (TS)	0	34	485.551	2021.52	4680.21	1683.18	2997.03
12	5.25294	25255.3	-11.1175	Stratum II (TS)	0	34	474.613	1975.98	4688.5	1758.98	2929.52
13	5.25294	24763.5	-7.3856	Stratum II (TS)	0	34	459.147	1911.59	4646.49	1812.44	2834.05
14	5.25294	24020.3	-3.6851	Stratum II (TS)	0	34	439.021	1827.8	4554.07	1844.23	2709.84
15	5.25294	23030.2	0	Stratum II (TS)	0	34	414.03	1723.75	4410.37	1854.79	2555.58
16	5.25294	21794.9	3.6851	Stratum II (TS)	0	34	383.914	1598.37	4213.92	1844.23	2369.69
17	5.25294	20300.5	7.3856	Stratum II (TS)	0	34	348.779	1452.09	3960.44	1807.62	2152.82
18	5.25294	18492.8	11.1175	Stratum II (TS)	0	34	323.446	1346.62	3641.39	1644.94	1996.45
19	5.25294	16416.6	14.8981	Stratum II (TS)	0	34	292.017	1215.77	3262.35	1459.89	1802.46
20	5.25294	14068.5	18.7465	Stratum II (TS)	0	34	254.36	1058.99	2821.45	1251.43	1570.02
21	5.25294	11863.1	22.6854	Stratum II (TS)	0	34	217.841	906.95	2400.66	1056.05	1344.61
22	5.25294	10128.7	26.7416	Stratum II (TS)	0	34	187.64	781.212	2066.56	908.356	1158.2
23	5.25294	8064.78	30.9491	Stratum II (TS)	0	34	150.437	626.323	1659.45	730.891	928.557
24	6.391	6554.06	35.8592	Stratum I (TS)	2644	0	635.066	2644	1511.61	492.194	1019.41
25	6.391	2331.28	41.6194	Stratum I (TS)	2644	0	635.066	2644	937.453	175.074	762.379

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 4.15973

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	82.4637	94.0299	0	0	0
2	87.3801	84.9911	-7592.62	-223.04	1.68263
3	92.2965	78.0071	-5623.6	-165.198	1.68263
4	97.2129	72.3064	733.912	21.5593	1.68263
5	102.129	67.5282	9369.77	275.245	1.68263
6	107.046	63.4687	18974.6	557.397	1.68263
7	111.962	60	28660	841.914	1.68263
8	117.215	56.8501	39090.4	1148.32	1.68264
9	122.468	54.2033	48028.6	1410.88	1.68263
10	127.721	52.0076	55361	1626.28	1.68263
11	132.974	50.2248	61031.5	1792.85	1.68263
12	138.227	48.8273	65027.5	1910.24	1.68263
13	143.48	47.795	67371.9	1979.11	1.68263
14	148.733	47.1141	68118.8	2001.05	1.68263
15	153.986	46.7758	67352	1978.53	1.68263
16	159.239	46.7758	65185.2	1914.87	1.68263
17	164.492	47.1141	61764.5	1814.39	1.68263
18	169.745	47.795	57272.3	1682.42	1.68263
19	174.997	48.8273	51864	1523.55	1.68263
20	180.25	50.2248	45828.2	1346.24	1.68263
21	185.503	52.0076	39519.6	1160.92	1.68263
22	190.756	54.2033	33152.6	973.886	1.68263
23	196.009	56.8501	26724.9	785.069	1.68263
24	201.262	60	20706.8	608.281	1.68263
25	207.653	64.6194	9542.51	280.32	1.68263
26	214.044	70.2974	0	0	0

Global Minimum Query (gle/morgenstern-price) - Safety Factor: 4.16335

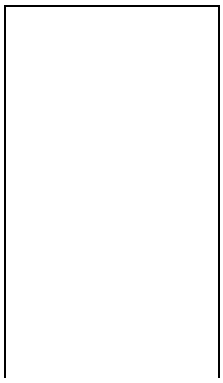
Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	82.4637	94.0299	0	0	0
2	87.3801	84.9911	-7922.22	-33.7041	0.243756
3	92.2965	78.0071	-5837.48	-49.3279	0.48415
4	97.2129	72.3064	678.033	8.49557	0.717863
5	102.129	67.5282	9425.13	154.919	0.941675
6	107.046	63.4687	19080	383.845	1.1525
7	111.962	60	28765	676.601	1.34744
8	117.215	56.8501	39172.5	1049.81	1.53514
9	122.468	54.2033	48078.4	1425.86	1.69872
10	127.721	52.0076	55382.1	1774.9	1.8356
11	132.974	50.2248	61034.1	2071.25	1.94364
12	138.227	48.8273	65022.6	2294.69	2.02117
13	143.48	47.795	67367.7	2431.37	2.06697
14	148.733	47.1141	68118.2	2474.35	2.08032
15	153.986	46.7758	67351.4	2423.78	2.06102
16	159.239	46.7758	65175.3	2286.64	2.00937
17	164.492	47.1141	61731.7	2076.08	1.92617
18	169.745	47.795	57201.9	1810.37	1.81274
19	174.997	48.8273	51743	1509.32	1.67082
20	180.25	50.2248	45649	1197.47	1.50265
21	185.503	52.0076	39282.1	898.872	1.31084
22	190.756	54.2033	32865.8	630.152	1.09843
23	196.009	56.8501	26409.9	400.462	0.868728
24	201.262	60	20392	222.577	0.625354
25	207.653	64.6194	9348.27	51.6176	0.316362
26	214.044	70.2974	0	0	0

List Of Coordinates

Water Table

X	Y
0	76.5
166.887	76.5
186.358	70.011
303.43	71.2222

External Boundary



X	Y
0	92.0955
0	60
0	42
0	-37.4519
303.43	-37.4519
303.43	42
303.43	60
303.43	71.2222
186.358	70.011
109.784	95.53
85.374	95
59.9719	86.5326
53.9719	86.5326
37.4765	92.2153

Material Boundary

X	Y
0	60
303.43	60

Material Boundary

X	Y
0	42
303.43	42

APPENDIX III3B-2A-2

EFFECTIVE STRESS ANALYSIS

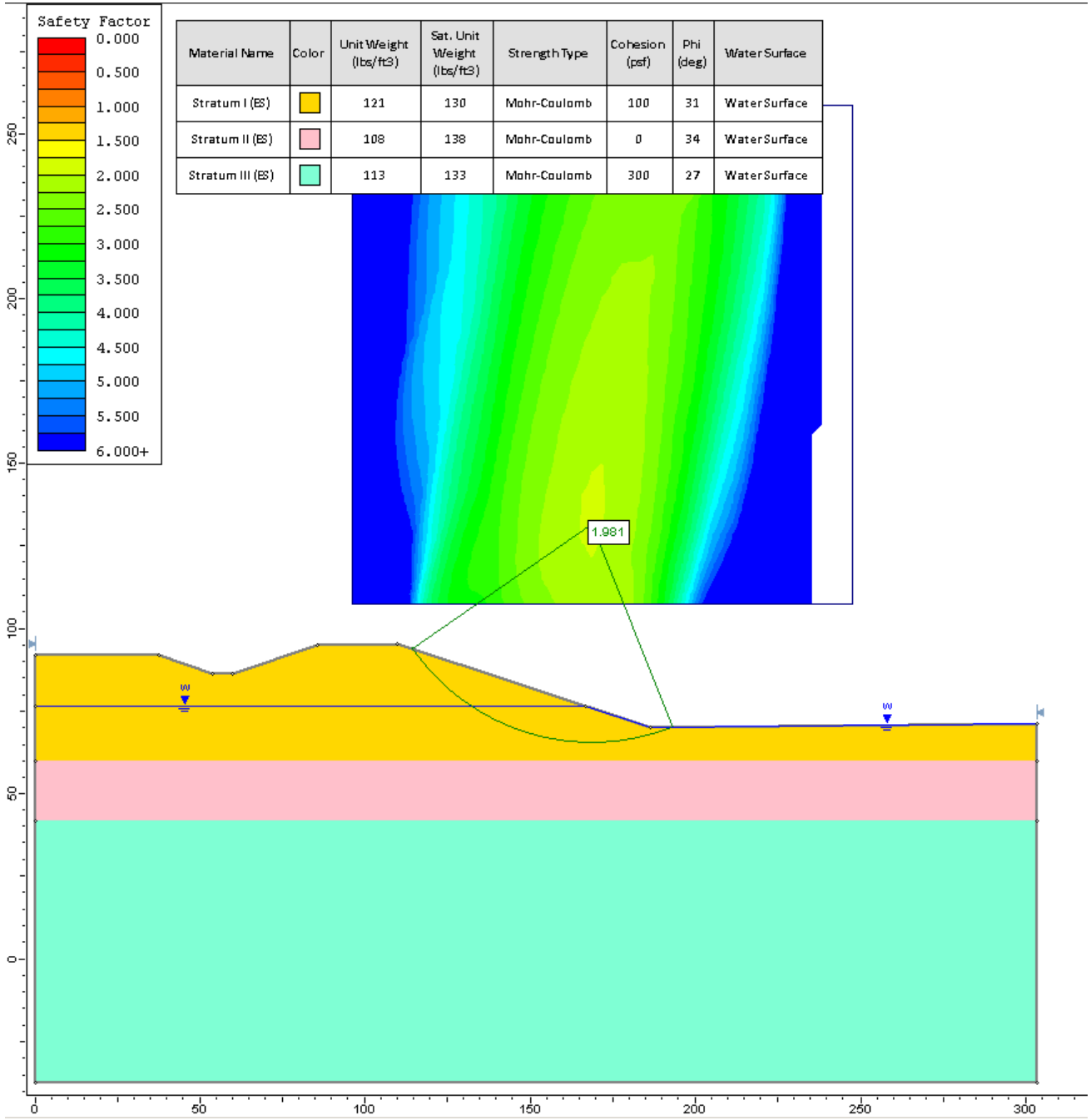


FIGURE **III3B-2A-2**

Excavation Stability - Effective Stress Analysis

Edinburg Regional Disposal Facility, Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-2A, Excavation Stability

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	Edinburg_Excavation_ES.slim
Slide Modeler Version:	7.014
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	1/29/2016, 4:56:33 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
GLE/Morgenstern-Price with interslice force function:	Half Sine 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 [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Enabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined
Minimum Area: Not Defined
Minimum Weight: Not Defined

Seismic

Advanced seismic analysis: No
Staged pseudostatic analysis: No

Material Properties

Property	Stratum I (ES)	Stratum II (ES)	Stratum III (ES)
Color			
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113
Saturated Unit Weight [lbs/ft3]	130	138	133
Cohesion [psf]	100	0	300
Friction Angle [deg]	31	34	27
Water Surface	Water Table	Water Table	Water Table
Hu Value	Automatically Calculated	1	1

Global Minimums

Method: spencer

FS	1.980760
Center:	168.714, 131.530
Radius:	66.059
Left Slip Surface Endpoint:	114.344, 94.010
Right Slip Surface Endpoint:	192.954, 70.079
Resisting Moment:	3.18716e+006 lb-ft
Driving Moment:	1.60906e+006 lb-ft
Resisting Horizontal Force:	43775.8 lb
Driving Horizontal Force:	22100.5 lb
Total Slice Area:	720.741 ft2
Surface Horizontal Width:	78.6093 ft
Surface Average Height:	9.16865 ft

Method: gle/morgenstern-price

FS	1.981120
Center:	168.714, 131.530
Radius:	66.059
Left Slip Surface Endpoint:	114.344, 94.010
Right Slip Surface Endpoint:	192.954, 70.079
Resisting Moment:	3.18775e+006 lb-ft
Driving Moment:	1.60906e+006 lb-ft
Resisting Horizontal Force:	43788 lb
Driving Horizontal Force:	22102.6 lb
Total Slice Area:	720.741 ft2
Surface Horizontal Width:	78.6093 ft
Surface Average Height:	9.16865 ft

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 24310
Number of Invalid Surfaces: 4301

Error Codes:

Error Code -107 reported for 4218 surfaces
Error Code -108 reported for 77 surfaces
Error Code -111 reported for 1 surface
Error Code -112 reported for 5 surfaces

Method: gle/morgenstern-price

Number of Valid Surfaces: 24304
Number of Invalid Surfaces: 4307

Error Codes:

Error Code -107 reported for 4218 surfaces
Error Code -108 reported for 84 surfaces
Error Code -112 reported for 5 surfaces

Error Codes

The following errors were encountered during the computation:

-107 = Total driving moment or total driving force is negative. This will occur if the wrong failure direction is specified, or if high external or anchor loads are applied against the failure direction.
-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).
-111 = safety factor equation did not converge
-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.98076

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	3.14437	597.862	-53.118	Stratum I (ES)	100	31	75.1322	148.819	81.2483	0	81.2483
2	3.14437	1679.08	-48.7757	Stratum I (ES)	100	31	145.863	288.92	314.415	0	314.415
3	3.14437	2556.77	-44.7845	Stratum I (ES)	100	31	210.177	416.311	526.43	0	526.43
4	3.14437	3272.74	-41.0543	Stratum I (ES)	100	31	268.19	531.221	717.673	0	717.673
5	3.14437	3854.44	-37.526	Stratum I (ES)	100	31	320.076	633.994	888.717	0	888.717
6	3.14437	4324.09	-34.1582	Stratum I (ES)	100	31	366.227	725.408	1040.85	0	1040.85
7	3.14437	4732.33	-30.9203	Stratum I (ES)	100	31	381.577	755.812	1192.47	101.015	1091.46
8	3.14437	5057.26	-27.789	Stratum I (ES)	100	31	388.39	769.307	1325.39	211.478	1113.91
9	3.14437	5293.46	-24.7458	Stratum I (ES)	100	31	392.174	776.802	1434.78	308.396	1126.39
10	3.14437	5447.71	-21.7755	Stratum I (ES)	100	31	392.84	778.121	1521.39	392.804	1128.58
11	3.14437	5525.35	-18.8658	Stratum I (ES)	100	31	390.284	773.059	1585.68	465.518	1120.16
12	3.14437	5530.61	-16.0058	Stratum I (ES)	100	31	384.385	761.375	1627.89	527.183	1100.71
13	3.14437	5466.85	-13.1864	Stratum I (ES)	100	31	374.996	742.777	1648.07	578.31	1069.76
14	3.14437	5336.67	-10.3992	Stratum I (ES)	100	31	361.941	716.918	1646.02	619.3	1026.72
15	3.14437	5142.09	-7.63667	Stratum I (ES)	100	31	345.007	683.377	1621.36	650.458	970.903
16	3.14437	4884.57	-4.89197	Stratum I (ES)	100	31	323.941	641.65	1573.46	672.008	901.455
17	3.14437	4562.63	-2.15851	Stratum I (ES)	100	31	298.18	590.623	1500.64	684.103	816.534
18	3.14437	4157.7	0.570034	Stratum I (ES)	100	31	304.585	603.309	1405.32	567.671	837.647
19	3.14437	3686.48	3.29987	Stratum I (ES)	100	31	285.642	565.788	1278.95	503.749	775.2
20	3.14437	3153.69	6.03725	Stratum I (ES)	100	31	261.098	517.173	1125.62	431.334	694.29
21	3.14437	2558.6	8.78857	Stratum I (ES)	100	31	230.303	456.174	943.098	350.325	592.773
22	3.14437	1900.02	11.5605	Stratum I (ES)	100	31	192.44	381.177	728.517	260.561	467.956
23	3.14437	1178.36	14.3603	Stratum I (ES)	100	31	146.731	290.639	479.083	161.806	317.277
24	3.14437	648.663	17.1956	Stratum I (ES)	100	31	107.938	213.8	288.405	99.0102	189.395
25	3.14437	228.215	20.0751	Stratum I (ES)	100	31	80.4737	159.399	133.691	34.8341	98.8567

Global Minimum Query (gle/morgenstern-price) - Safety Factor: 1.98112

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	3.14437	597.862	-53.118	Stratum I (ES)	100	31	76.6972	151.946	86.4532	0	86.4532
2	3.14437	1679.08	-48.7757	Stratum I (ES)	100	31	153.412	303.927	339.391	0	339.391
3	3.14437	2556.77	-44.7845	Stratum I (ES)	100	31	217.254	430.407	549.89	0	549.89
4	3.14437	3272.74	-41.0543	Stratum I (ES)	100	31	271.545	537.963	728.892	0	728.892
5	3.14437	3854.44	-37.526	Stratum I (ES)	100	31	318.543	631.072	883.851	0	883.851
6	3.14437	4324.09	-34.1582	Stratum I (ES)	100	31	360.026	713.254	1020.63	0	1020.63
7	3.14437	4732.33	-30.9203	Stratum I (ES)	100	31	371.908	736.794	1160.82	101.015	1059.81
8	3.14437	5057.26	-27.789	Stratum I (ES)	100	31	376.299	745.493	1285.76	211.478	1074.28
9	3.14437	5293.46	-24.7458	Stratum I (ES)	100	31	379.167	751.175	1392.13	308.396	1083.74
10	3.14437	5447.71	-21.7755	Stratum I (ES)	100	31	380.705	754.223	1481.62	392.804	1088.81
11	3.14437	5525.35	-18.8658	Stratum I (ES)	100	31	380.801	754.413	1554.65	465.518	1089.13
12	3.14437	5530.61	-16.0058	Stratum I (ES)	100	31	379.059	750.961	1610.56	527.183	1083.38
13	3.14437	5466.85	-13.1864	Stratum I (ES)	100	31	374.834	742.591	1647.76	578.31	1069.45
14	3.14437	5336.67	-10.3992	Stratum I (ES)	100	31	367.282	727.63	1663.85	619.3	1044.55
15	3.14437	5142.09	-7.63667	Stratum I (ES)	100	31	355.432	704.154	1655.94	650.458	1005.48
16	3.14437	4884.57	-4.89197	Stratum I (ES)	100	31	338.278	670.169	1620.93	672.008	948.922
17	3.14437	4562.63	-2.15851	Stratum I (ES)	100	31	314.63	623.319	1555.05	684.103	870.949
18	3.14437	4157.7	0.570034	Stratum I (ES)	100	31	320.838	635.618	1459.09	567.671	891.417
19	3.14437	3686.48	3.29987	Stratum I (ES)	100	31	298.807	591.973	1322.53	503.749	818.781
20	3.14437	3153.69	6.03725	Stratum I (ES)	100	31	268.866	532.656	1151.39	431.334	720.06
21	3.14437	2558.6	8.78857	Stratum I (ES)	100	31	231.358	458.347	946.715	350.325	596.39
22	3.14437	1900.02	11.5605	Stratum I (ES)	100	31	187.13	370.727	711.125	260.561	450.564
23	3.14437	1178.36	14.3603	Stratum I (ES)	100	31	137.728	272.855	449.485	161.806	287.679
24	3.14437	648.663	17.1956	Stratum I (ES)	100	31	97.5777	193.313	254.31	99.0102	155.299
25	3.14437	228.215	20.0751	Stratum I (ES)	100	31	71.0933	140.844	102.811	34.8341	67.9764

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.98076

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	114.344	94.0102	0	0	0
2	117.489	89.8196	103.654	26.0079	14.0853
3	120.633	86.2308	772.218	193.757	14.0853
4	123.777	83.11	1752.59	439.742	14.0853
5	126.922	80.3714	2872.62	720.769	14.0853
6	130.066	77.9564	4009.96	1006.14	14.0853
7	133.211	75.8229	5076.27	1273.69	14.0853
8	136.355	73.9395	6119.36	1535.41	14.0853
9	139.499	72.2824	7091.35	1779.29	14.0853
10	142.644	70.8331	7934.58	1990.86	14.0853
11	145.788	69.577	8607.3	2159.66	14.0853
12	148.932	68.5025	9080.81	2278.47	14.0853
13	152.077	67.6006	9337.49	2342.87	14.0853
14	155.221	66.8638	9369.61	2350.93	14.0853
15	158.366	66.2868	9178.55	2302.99	14.0853
16	161.51	65.8652	8774.59	2201.63	14.0853
17	164.654	65.5961	8176.93	2051.67	14.0853
18	167.799	65.4776	7414.86	1860.46	14.0853
19	170.943	65.5088	6410.8	1608.53	14.0853
20	174.087	65.6901	5278.54	1324.44	14.0853
21	177.232	66.0227	4081.18	1024.01	14.0853
22	180.376	66.5088	2896.76	726.826	14.0853
23	183.521	67.152	1821.59	457.054	14.0853
24	186.665	67.957	973.397	244.235	14.0853
25	189.809	68.9301	352.516	88.4497	14.0853
26	192.954	70.0792	0	0	0

Global Minimum Query (gle/morgenstern-price) - Safety Factor: 1.98112

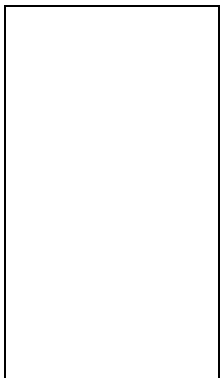
Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	114.344	94.0102	0	0	0
2	117.489	89.8196	121.206	4.72621	2.23301
3	120.633	86.2308	856.952	66.3034	4.42423
4	123.777	83.11	1890.13	216.475	6.53357
5	126.922	80.3714	3032.7	454.544	8.5241
6	130.066	77.9564	4165.92	761.817	10.3631
7	133.211	75.8229	5211.79	1109.97	12.0228
8	136.355	73.9395	6229	1493.21	13.4805
9	139.499	72.2824	7176.74	1885.21	14.7181
10	142.644	70.8331	8002.48	2252.74	15.7222
11	145.788	69.577	8666.83	2564.41	16.4828
12	148.932	68.5025	9140.23	2793.29	16.9934
13	152.077	67.6006	9401.39	2919.14	17.2496
14	155.221	66.8638	9437.08	2930.22	17.2496
15	158.366	66.2868	9242.7	2824.61	16.9934
16	161.51	65.8652	8823.57	2610.79	16.4829
17	164.654	65.5961	8196.46	2307.35	15.7222
18	167.799	65.4776	7391.76	1941.69	14.7181
19	170.943	65.5088	6337.59	1519.24	13.4805
20	174.087	65.6901	5158.55	1098.63	12.0228
21	177.232	66.0227	3930.5	718.766	10.3631
22	180.376	66.5088	2743.03	411.127	8.52408
23	183.521	67.152	1697.41	194.403	6.53357
24	186.665	67.957	902.641	69.8384	4.42423
25	189.809	68.9301	348.452	13.5872	2.233
26	192.954	70.0792	0	0	0

List Of Coordinates

Water Table

X	Y
0	76.5
166.5	76.5
186.358	70.011
303.43	71.2222

External Boundary



X	Y
0	92.0955
0	60
0	42
0	-37.4519
303.43	-37.4519
303.43	42
303.43	60
303.43	71.2222
186.358	70.011
109.784	95.53
85.374	95
59.9719	86.5326
53.9719	86.5326
37.4765	92.2153

Material Boundary

X	Y
0	60
303.43	60

Material Boundary

X	Y
0	42
303.43	42

APPENDIX III3B-2B

SIDESLOPE LINER SYSTEM STABILITY

APPENDIX III3B-2B-1

SIDESLOPE LINER STABILITY

SIDESLOPE LINER STABILITY

Made by: VK
Checked by: CEI
Reviewed by: JBF

1.0 OBJECTIVE

Evaluate the stability of the liner system along the cell sideslope.



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2.0 GIVEN

The maximum head over the geomembrane is less than the thickness of the geocomposite drainage layer as demonstrated in Appendix III3B-2B-2, Sideslope Drainage Layer Capacity.

The failure mechanism will be sliding along one of the liner interfaces. The alternative liner consists of (from top to bottom):

24 inches of protective cover
Double-sided geocomposite
60-mil textured HDPE geomembrane
Geosynthetic Clay Liner (GCL)
Subgrade

Based on a review of available data at low normal stresses, the following parameters were assigned to the materials.

Table III3B-2B-1: Alternative Liner Component Interface Unit Weight and Strength Parameters

Soil	Unit Weight (pcf)		Strength Parameters		Reference
	Moist	Saturated	ϕ degrees	c (psf)	
Protective Cover	115	132	28	0	Estimate
Protective Cover/Geocomposite	–	–	28	0	Golder*
Geocomposite/Textured Geomembrane	–	–	24	0	Golder*
Textured Geomembrane/GCL	–	–	24	0	Golder*
GCL/Subgrade	–	–	30	0	Golder*

* Based on unpublished data from tests performed in Golder's laboratory, on similar geosynthetic materials. Strength parameters were conservatively assigned to be equal to or a percentage of the peak strength (lower bound) to account for testing material variability (see pages 3 and 4).

The shear strength parameters indicate that the critical interface occurs at the geocomposite/ geomembrane or geomembrane/GCL interface, with a friction angle of 24 degrees.

4.0 METHOD

Create a model representing the sideslope situation and use it in conjunction with limit equilibrium concepts to determine the minimum factor of safety against a sliding block failure along the critical interface.

Infinite Slope Analysis

$$FS = \frac{c + (\gamma b \cos\beta - \gamma_w d \cos\beta)\tan\phi}{\gamma b \sin\beta}$$

Sliding Along Sideslope Liner System

ϕ =	24	interface friction angle
β =	18.4	slope angle (degrees)
c =	0	adhesion (psf)
γ =	115	unit weight of soil (pcf)
b =	2.0	thickness (ft)
d =	0	water depth in cover (ft)
γ_w =	62.4	unit weight of water (pcf)
FS =	**1.34**	

5.0 RESULTS

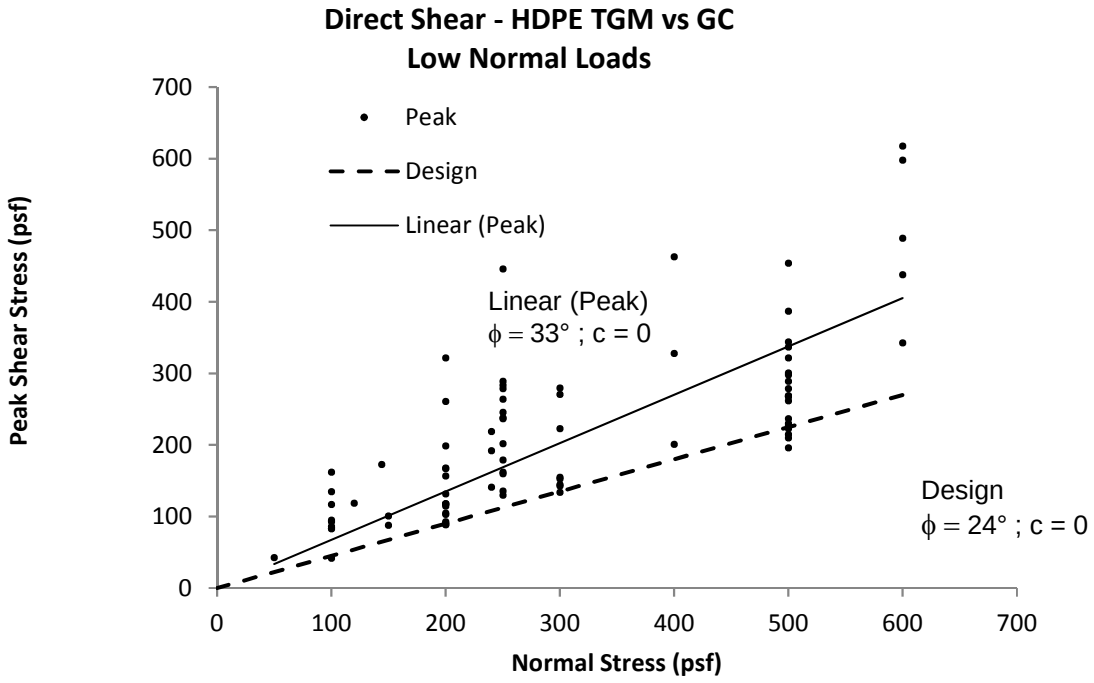
By using limit equilibrium analysis for an infinite slope condition, the factor of safety is found to be at least 1.3, and likely to be higher due to the use of conservative parameters in the analysis.

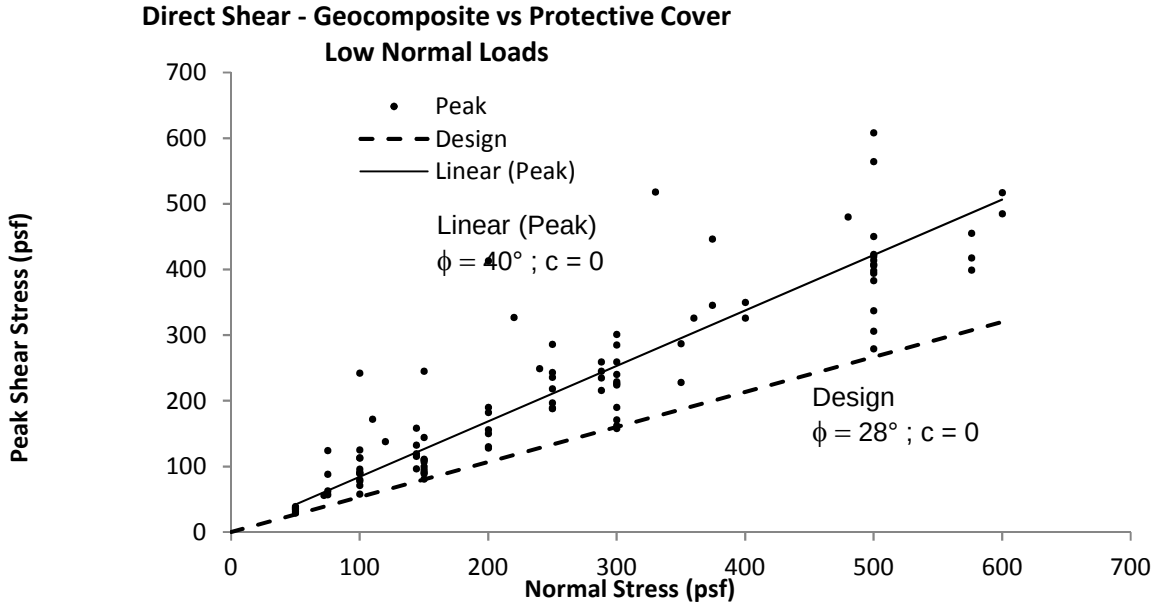
6.0 CONCLUSION

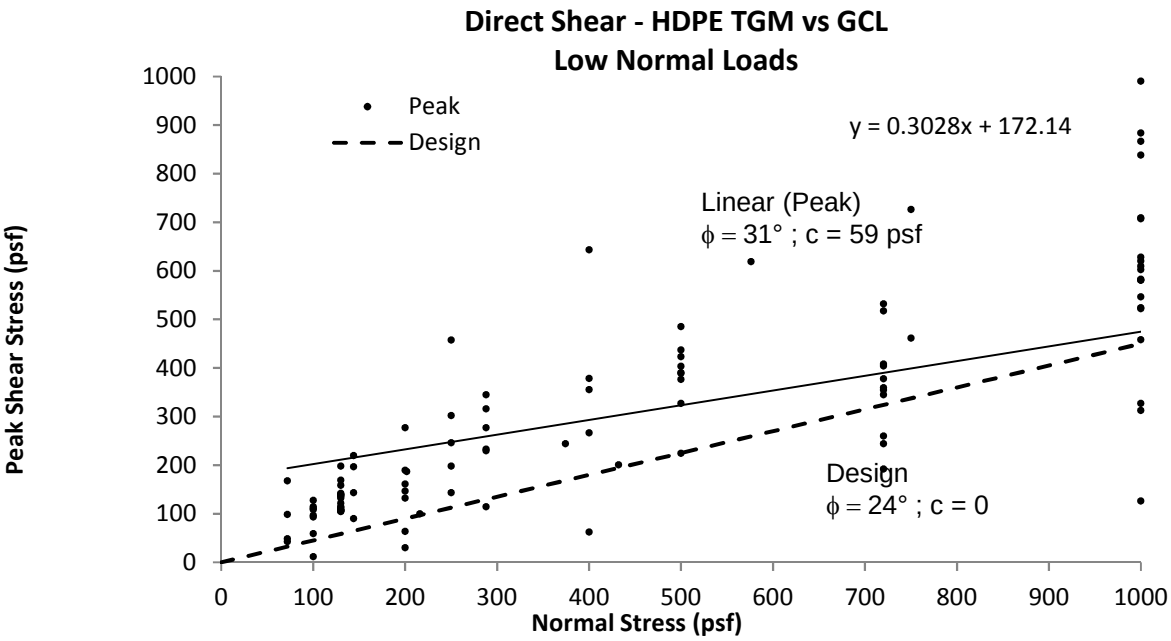
Through analysis of the alternative liner, this temporary condition is found to be stable.

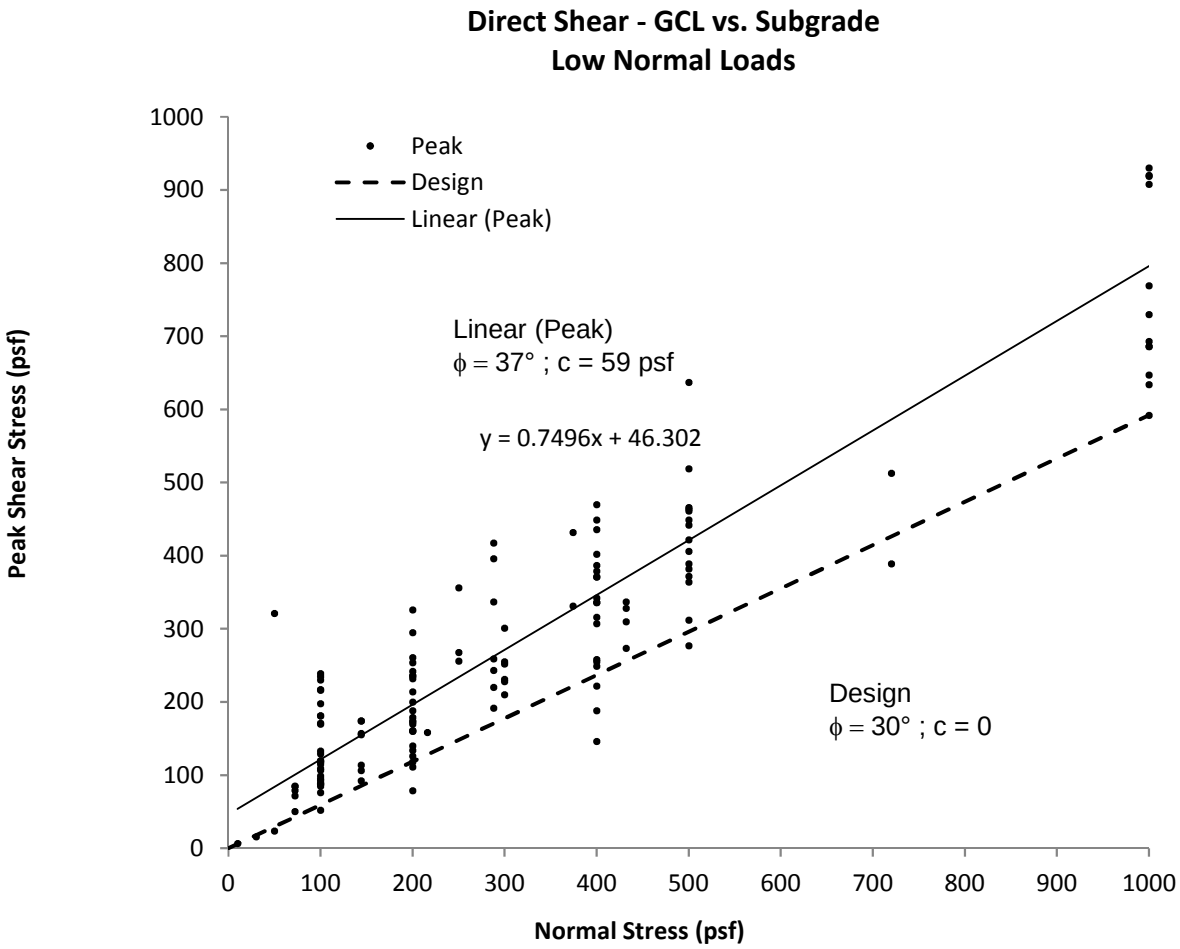
7.0 REFERENCES

Shear-Normal plots from unpublished data from tests performed in Golder's laboratory.




Direct Shear - Geocomposite vs Protective Cover
Low Normal Loads
Peak
Design
Linear (Peak)
Linear (Peak)
ϕ = 40° ; c = 0
Design
ϕ = 28° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
100
200
300
400
500
600
700


Direct Shear - HDPE TGM vs GCL
Low Normal Loads
Peak
Design
y = 0.3028x + 172.14
Linear (Peak)
ϕ = 31° ; c = 59 psf
Design
ϕ = 24° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
100
200
300
400
500
600
700
800
900
1000


Direct Shear - GCL vs. Subgrade
Low Normal Loads
Peak
Design
Linear (Peak)
Linear (Peak)
ϕ = 37° ; c = 59 psf
y = 0.7496x + 46.302
Design
ϕ = 30° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
100
200
300
400
500
600
700
800
900
1000

APPENDIX III3B-2B-2

SIDESLOPE DRAINAGE LAYER CAPACITY

SIDESLOPE DRAINAGE LAYER CAPACITY

Made By: VK
Checked by: CEI
Reviewed by: JBF

1.0 OBJECTIVE

I) Determine the required transmissivity of the sideslope drainage layer (double-sided geocomposite) on the maximum slope length.

II) Based on published data, determine the geosynthetic drainage layer type that will meet the required transmissivity.



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2.0 GIVEN

Maximum length of the 3H:1V slope is approximately (L) = 75 ft.

The permeability of the protective cover, K_{prot} = 1.0E-05 cm/s
(same as HELP model)

The worst case condition occurs when the protective cover is exposed (i.e. prior to waste placement), which is a short-term condition.

3.0 METHOD

Determine the design transmissivity of geocomposite layer on the sideslope. The design criterion is that the geocomposite should have adequate capacity to transmit all surface water infiltration from the protective cover soil (i.e. avoid any head build) up in the protective cover.

$$\theta_{design} = \frac{q_i L}{sin\beta} = \frac{q_i L}{Slope}$$ [Ref. 1]

Where: θ_{design} = design transmissivity (m^2/sec)

q_i = impingement rate (m/sec) = conservatively assume saturated hydraulic conductivity of the protective cover soil and hydraulic gradient of 1 = 1 x 10^{-5} cm/s.
L = horizontal length of slope (m)
β = slope angle (degrees)

Establish a required transmissivity, $\theta_{required}$, by applying reduction factors to the θ_{design}. [Ref. 2]

$$\theta_{required} = \theta_{design} \times [RF_{cr} * RF_{cc} * RF_{bc} * RF_{in}]$$

Where:
RF_{cr} = Reduction factor for short-term creep
RF_{cc} = Reduction factor for chemical clogging
RF_{bc} = Reduction factor for biological clogging
RF_{in} = Reduction factor for intrusion of geotextile or geomembrane

This required transmissivity will be used as material specification for the transmissivity measured in laboratory during construction.

Test Conditions: $i \geq$ 0.33

Normal Stress ≥ 1,000 psf

Boundary Cond'ns = steel plates

Test Time = 1 hour

Reduction Factor	Description	Value [Ref. 2 &3]
RF_{cr} =	Reduction Factor for creep	1.2
RF_{cc} =	Reduction Factor for chemical clogging of geotextile and/or geonet	1.1
RF_{bc} =	Reduction Factor for biological clogging of geotextile and/or geonet	1.0
RF_{in} =	Reduction Factor for intrusion of geotextile into geonet	1.2
	Π(RF) =	1.6

4.0 CALCULATION

I) Transmissivity for maximum flow length

$$\theta_{required} = \textbf{1.2E-04 ft}^3\textbf{/s-ft} = \textbf{1.2E-05 m}^3\textbf{/s-m}$$

II) An industry standard 200-mil double-sided geocompsite has a typical laboratory-measured transmissivity of approximately 1.0E-04 m^2/sec, therefore a typical 200-mil double-sided is expected to be acceptable. Nevertheless, conformance testing will be performed to demonstrate the material can meet the specification.

5.0 CONCLUSION

The geocomposite drainage layer is required to have adequate flow capacity to prevent the development of hydraulic head in the protective cover on the cell sideslopes.

6.0 REFERENCES

1. Giroud, J.P, Zornberg, J.G., and Zhao, A., "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers", Geosynthetics International, Vol. 7, Nos. 4-6, 2000.
2. Robert M. Koerner "Designing with Geosynthetics" Fifth Edition, 2005 Prentice Hall
3. Narejo, D. and Allen, S. 2004 "Using the Stepped Isothermal Method for Geonet Creep Evaluation." Proceedings of EuroGeo3, Third European Geosynthetics Conference, Munich, pp. 539-544.

APPENDIX III3B -2C

INTERIOR WASTE SLOPE STABILITY

INTERIOR WASTE SLOPE STABILITY CALCULATION

Made by: JCW
Checked by: CEI
Reviewed by: JBF

1.0 SUMMARY

Evaluate the stability of the interior waste slopes.

2.0 GIVEN

Based on a review of the floor grades and filling sequence, it was identified that sliding along the liner of Unit 7, Cells 1B through 7B is the most critical case, where the interior waste slopes have no buttress effect from existing waste or the floor slope and the waste thickness is the highest. Along this section, the analysis evaluates two potential temporary interior waste slopes: one with a 3H:1V continuous slope and a second with single bench configuration at the midpoint of the 3H:1V slope. The interior waste slopes in this evaluation are conservatively assumed to have a flat top elevation at 400 feet-msl. These assumptions will result in a lower factor of safety than the actual interior waste slopes. Figure III3-5 depicts the cross-sections of the critical case for the interior waste slope.



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Professional Engineering Firm
Registration Number F-2578

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Figure III3B-2C-1 depicts the cross-sections of the critical case for the interior waste slope.

The cell liner system consists of:

FLOOR & SIDEWALLS: 24 inches of protective cover (clay)
Double-sided geocomposite
60-mil HDPE textured geomembrane
Geosynthetic Clay Liner (GCL)
Subgrade

The following parameters were assigned to the materials based on available data:

Material	Strength Parameters		Unit Weight (pcf)		Reference
	ϕ (deg)	c (psf)	Moist	Saturated	
Waste	Bi-Linear		65	75	[Ref. 1]
Protective cover (soil)	28	0	115	132	Estimate
Prot. cover (soil)/Geocomposite (F/S)	25	0	N/A	N/A	Golder*
Geocomposite/Text. Geomembrane (F/S)	15	0	N/A	N/A	Golder*
Textured Geomembrane/GCL (F/S)	18	0	N/A	N/A	Golder*
GCL Internal Shear (F/S)	23	0	N/A	N/A	Golder*
GCL/Subgrade (F/S)	20	0	N/A	N/A	Golder*

(F) = Floor; (S) Slope

* Based on unpublished data from tests performed in Golder's laboratory, on similar geosynthetic materials. Strength parameters were conservatively assigned to be equal to or a percentage of the peak strength (lower bound) to account for testing data variability and to avoid strains that result in residual interface shear strengths. This data is presented on pages 5, 6, and 7 of this appendix.

Based on the data listed in the above table, the weakest interface in the liner system along the sideslope and floor of the cell is between the geocomposite and textured geomembrane. This interface shear strength was used in the analysis.

Subsurface profiles are determined based on available adjacent borehole information, and the same soil properties as the excavation stability analysis are used. These are shown in the table below.

Material	Unit Weight (pcf)		Strength Parameters		Analysis Stress State	Reference
	Moist	Saturated	ϕ (degrees)	c (psf)		
Stratum I	121	130	31	100	Effective	[Ref. 2]
Stratum II	108	138	34	0	Effective	[Ref. 2]
Stratum III	113	133	27	300	Effective	Lambe & Whitman, 1969

3.0 METHOD

Use limit equilibrium slope stability methods to determine the slope factor of safety for the two conservative interior waste slopes using SLIDE v.7(Ref. 3).

Based on the "EPA Guide to Technical Resources for the Design of Land Disposal Facilities", the recommend factor of safety for waste slope is 1.5 at minimum.

4.0 ASSUMPTIONS

(1) One foot of saturated waste which is conservative because the leachate level will be limited to the geocomposite layer.

5.0 SCENARIOS

Two possible waste filling slopes are considered for interior waste slopes in Unit 7, Cells 1B through 7B:

(1) Continuous 3H:1V temporary waste slope with no benches; maximum waste elevation is conservatively assumed at 400 feet-msl.

(2) 3H:1V temporary waste slope with one 100-foot wide bench at the midpoint of the slope; maximum waste elevation is the same as scenario (1).

Figure 3B2C.1 and 3B2C.2 show the cross-sections of the critical case and benched configurations.

6.0 RESULTS

Minimum factors of safety calculated by SLIDE are summarized below:

Case Considered	Minimum Factor of Safety Block Failure	Minimum Factor of Safety Circular Failure
Continuous 3H:1V slope without bench	1.7	2.3
3H:1V Slope with 100-foot wide bench at midslope	1.8	2.5

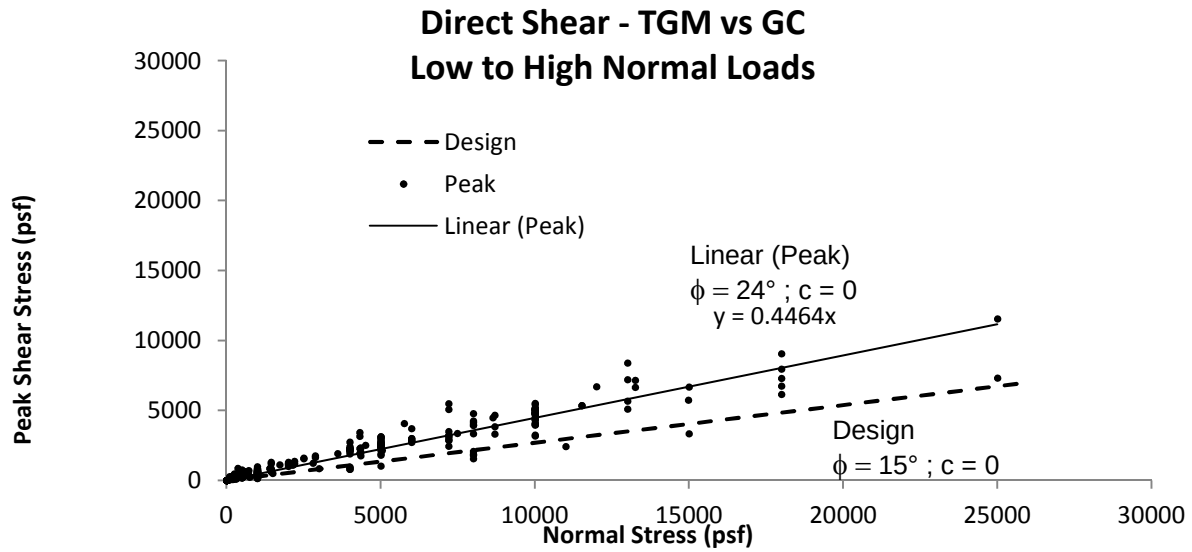
7.0 CONCLUSIONS

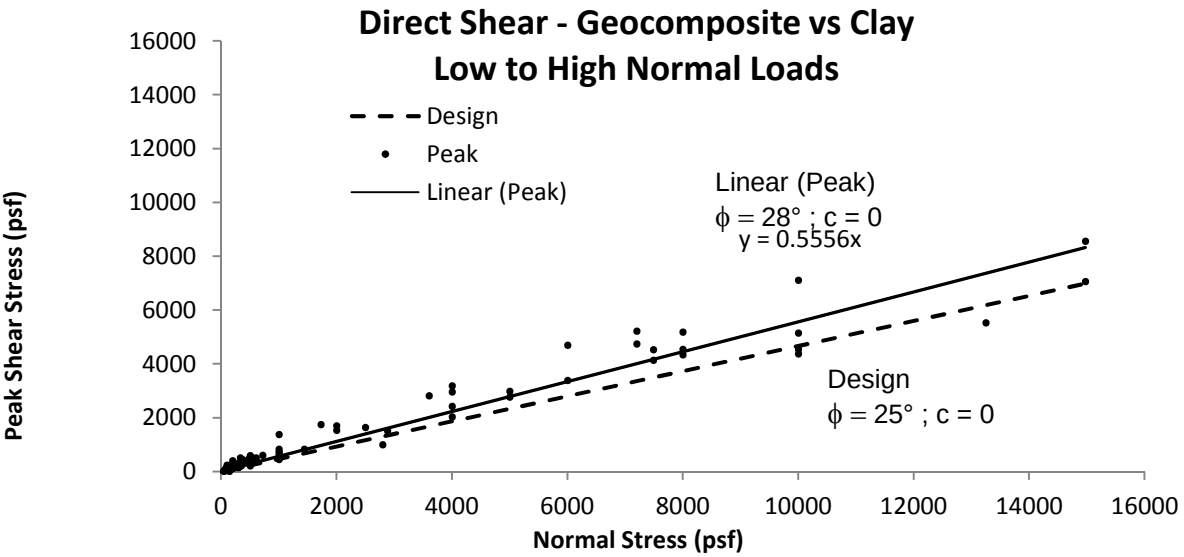
Using the strength parameters that are conservativey chosen from published studies or based on test results of similar conditions, interior waste slope at 3H:1V may be filled up to the peak elevation of 400 feet-msl with an acceptable factor of safety. However, to facilitate site operations and account for the operational uncertainties, a 100-foot wide bench at the midpoint of the 3H:1V slope is advised.

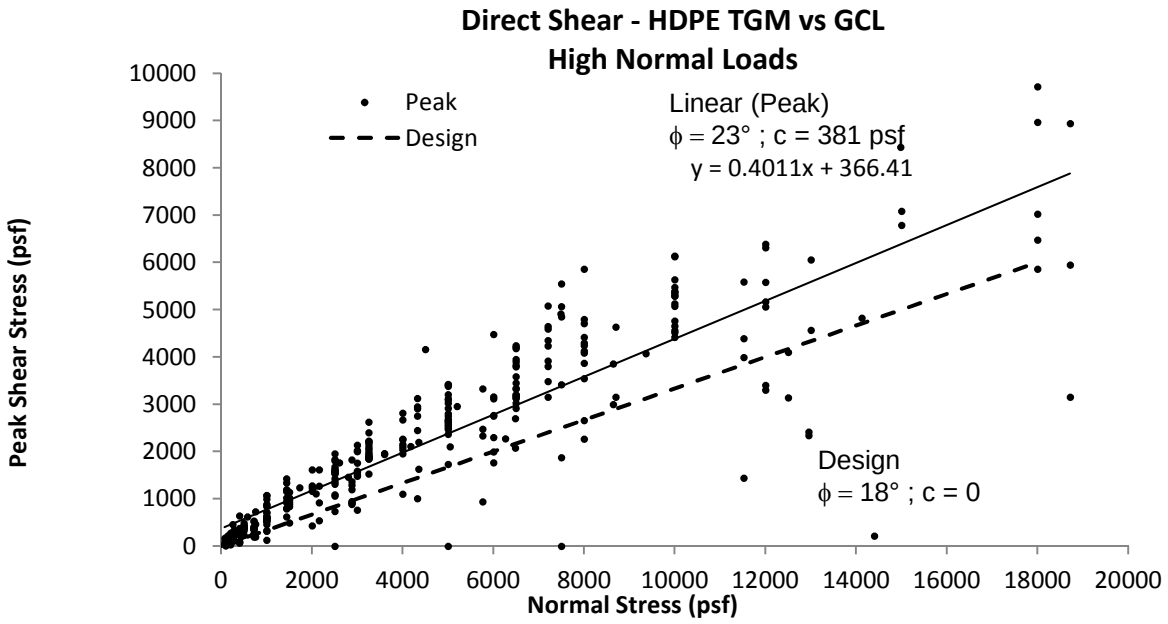
8.0 REFERENCES

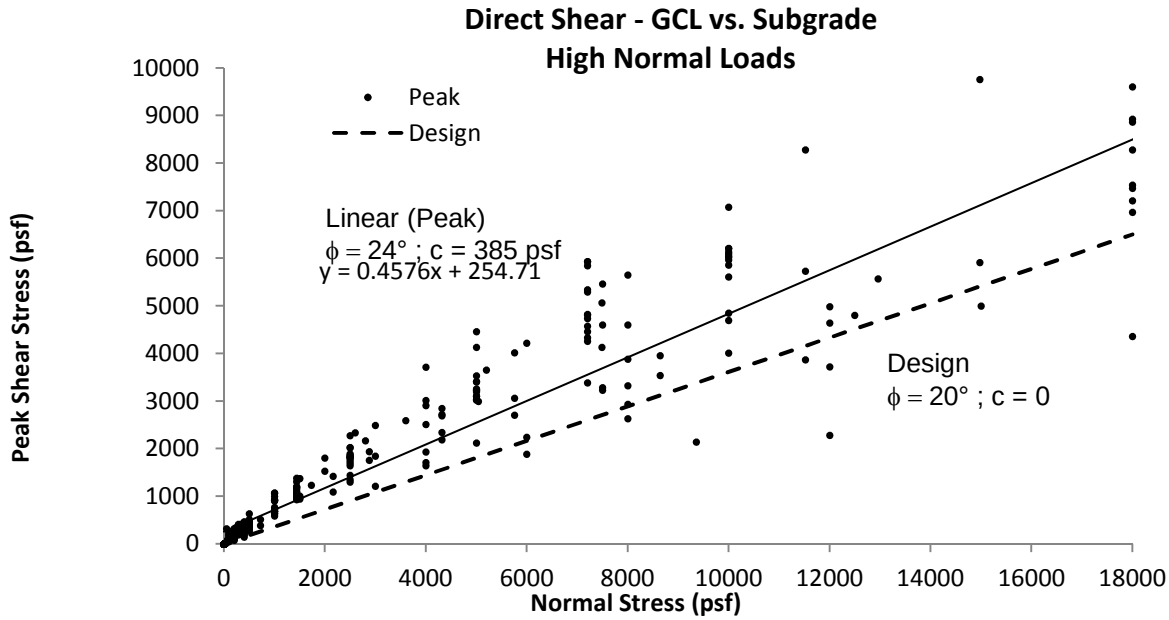
(1) Bray, J.D., D. Zekkos, E. Kavazanjian, Jr., G.A. Athanasopoulos, and F. Riemer. 2009. Shear strength of municipal solid waste. J. Geotech. Geoenviron. Eng. (ASCE) 135(6): 709–22.

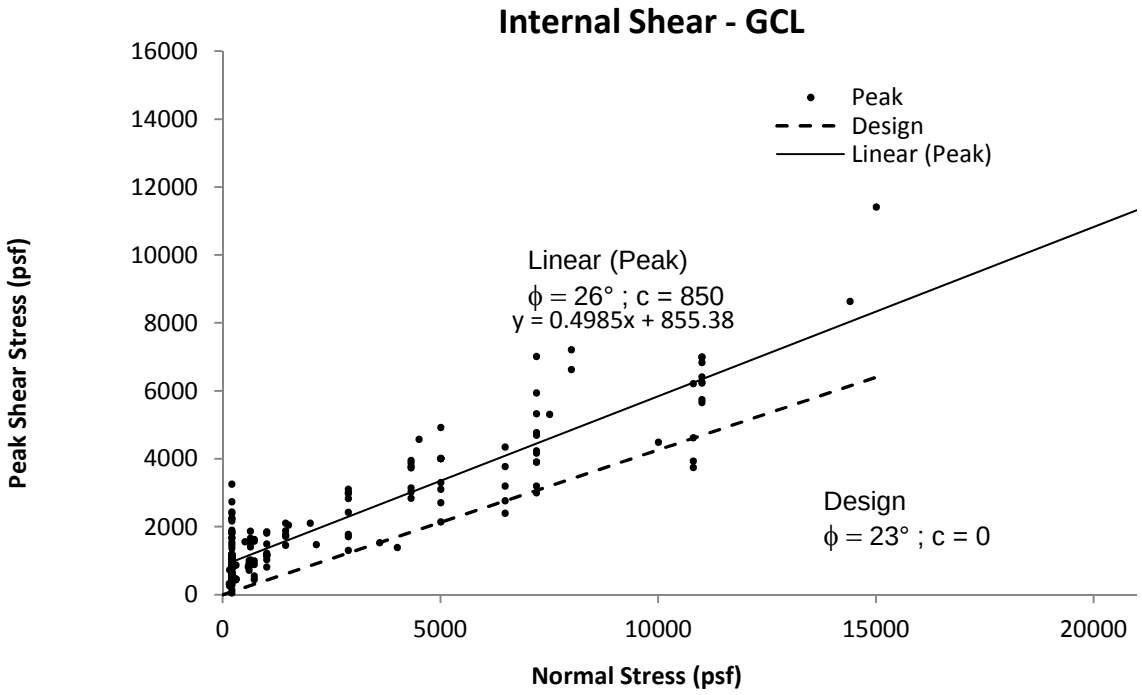
(2) Lambe, T.W. and Whitman, R.V. (1969). Soil Mechanics, John Wiley & Sons, New York. 1 PI correlation
(3) Rocscience 2015, SLIDE - 2D Limit Equilibrium Slope Stability for Soil and Rock Slopes.

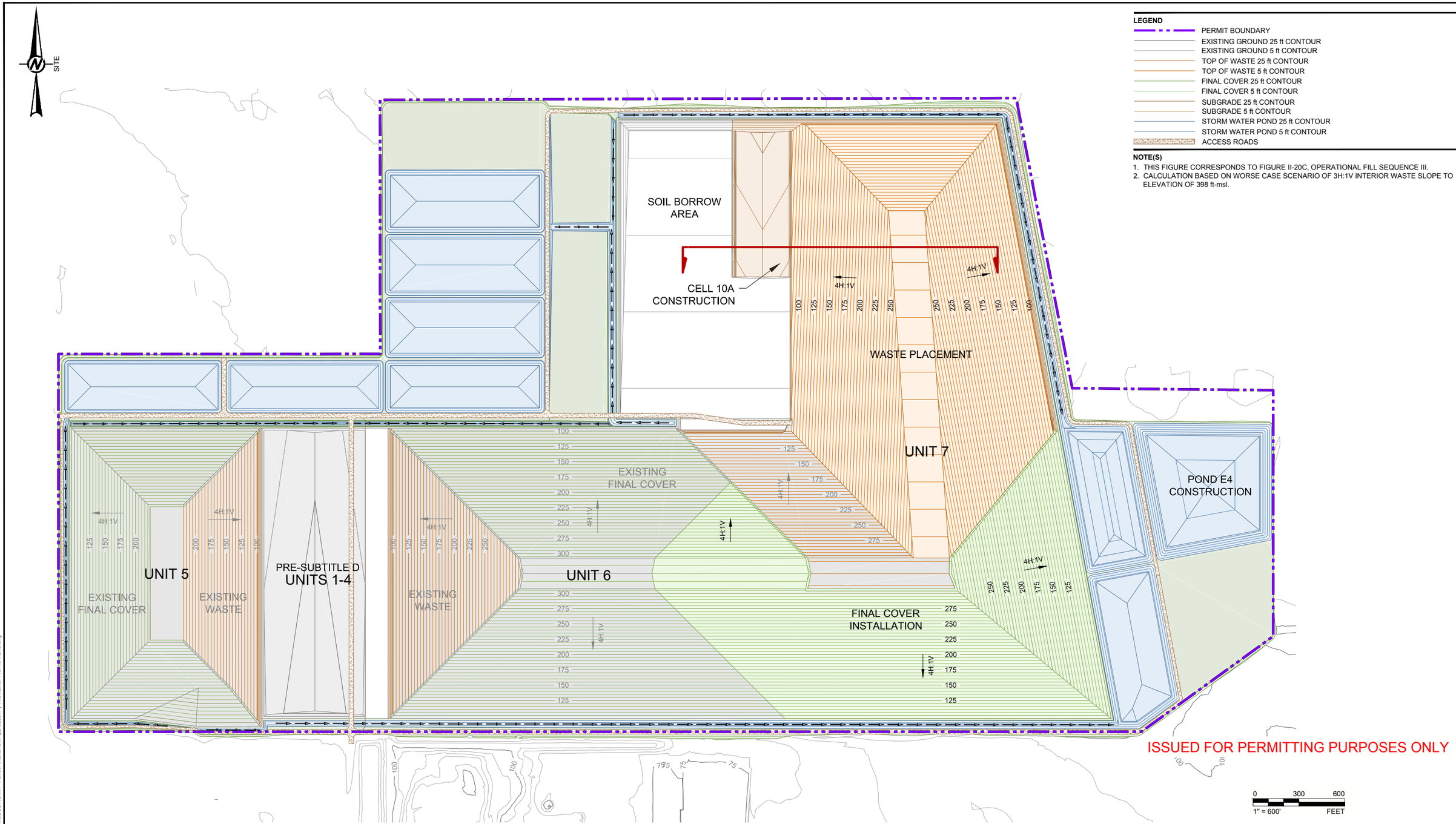





Direct Shear - HDPE TGM vs GCL
High Normal Loads
Peak
Design
Linear (Peak)
ϕ = 23° ; c = 381 psf
y = 0.4011x + 366.41
Design
ϕ = 18° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000


Direct Shear - GCL vs. Subgrade
High Normal Loads
Peak
Design
Linear (Peak)
ϕ = 24° ; c = 385 psf
y = 0.4576x + 254.71
Design
ϕ = 20° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000


Internal Shear - GCL
Peak
Design
Linear (Peak)
Linear (Peak)
ϕ = 26° ; c = 850
y = 0.4985x + 855.38
Design
ϕ = 23° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
16000
14000
12000
10000
8000
6000
4000
2000
0
0
5000
10000
15000
20000



LEGEND

- PERMIT BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- TOP OF WASTE 25 ft CONTOUR
- TOP OF WASTE 5 ft CONTOUR
- FINAL COVER 25 ft CONTOUR
- FINAL COVER 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- STORM WATER POND 25 ft CONTOUR
- STORM WATER POND 5 ft CONTOUR
- ACCESS ROADS

NOTE(S)

1. THIS FIGURE CORRESPONDS TO FIGURE II-20C, OPERATIONAL FILL SEQUENCE III.
2. CALCULATION BASED ON WORSE CASE SCENARIO OF 3H:1V INTERIOR WASTE SLOPE TO ELEVATION OF 398 ft-msl.

ISSUED FOR PERMITTING PURPOSES ONLY

0 300 600
1" = 600' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

SEAL

STATE OF TEXAS
JEFFREY B. FASSETT
85675
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PROFESSIONAL ENGINEER

GOLDER ASSOCIATES INC.
TEXAS REGISTRATION F-2578

CLIENT

CITY OF EDINBURG SOLID WASTE MANAGEMENT

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
INTERIOR WASTE SLOPE STABILITY *OPERATIONAL FILL SEQUENCE III*

PROJECT NO.	APPLICATION SECTION	REV.	FIGURE
1401491	III3B-2C	0	1 of 1 III3B-2C-1

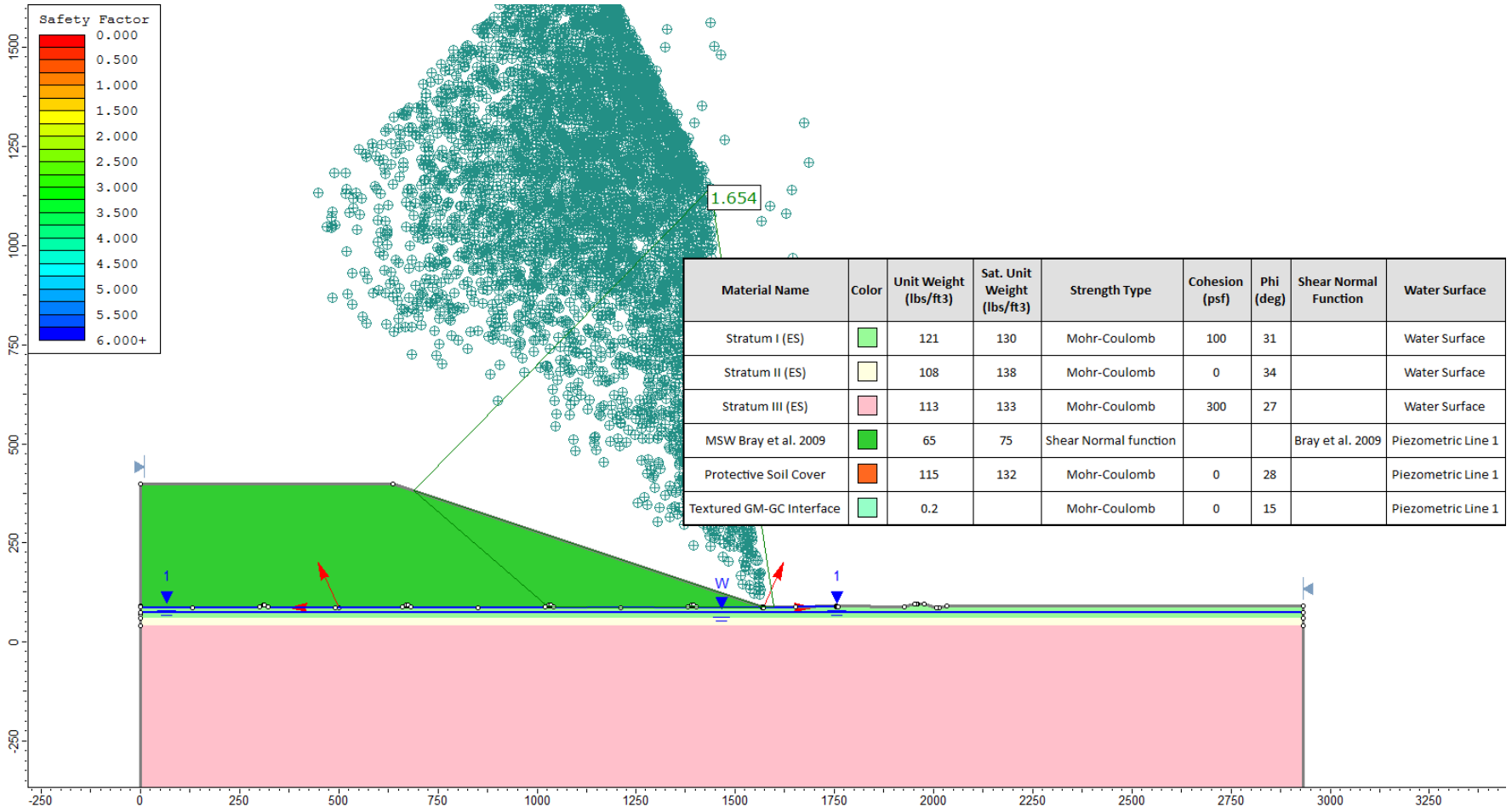
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

1 in
0

Path: \\houstondrafting_20141401491 - city of edinburg\PRODUCTION\A - Permit Amendment Application\ | File Name: 1401491A013.dwg

APPENDIX III3B-2C-1

CONTINUOUS 3H:1V SLOPE WITHOUT BENCH - BLOCK FAILURE



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Water Surface
Stratum I (ES)		121	130	Mohr-Coulomb	100	31		Water Surface
Stratum II (ES)		108	138	Mohr-Coulomb	0	34		Water Surface
Stratum III (ES)		113	133	Mohr-Coulomb	300	27		Water Surface
MSW Bray et al. 2009		65	75	Shear Normal function			Bray et al. 2009	Piezometric Line 1
Protective Soil Cover		115	132	Mohr-Coulomb	0	28		Piezometric Line 1
Textured GM-GC Interface		0.2		Mohr-Coulomb	0	15		Piezometric Line 1

FIGURE **III3B-2C-1**

Continuous 3H:1V without Bench - Block Failure

Edinburg Regional Disposal Facility, Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-2C, Interior Waste Slope Analysis

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	Interior Slope 3H1V Block.slim
Last saved with Slide version:	7.014
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	2/5/2016, 2:33:16 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used
Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Multiple Groups: Disabled
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 115
Left Projection Angle (End Angle): 180
Right Projection Angle (Start Angle): 65
Right Projection Angle (End Angle): 0
Minimum Elevation: Not Defined
Minimum Depth: Not Defined
Minimum Area: Not Defined
Minimum Weight: Not Defined

Seismic

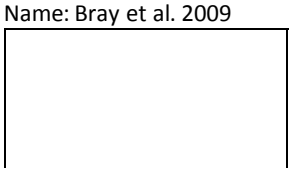
Advanced seismic analysis: No
Staged pseudostatic analysis: No

Material Properties

Property	Stratum I (ES)	Stratum II (ES)	Stratum III (ES)	MSW Bray et al. 2009	Protective Soil Cover	Textured GM-GC Interface
Color						
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Shear Normal function	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113	65	115	
Saturated Unit Weight [lbs/ft3]	130	138	133	75	132	
Cohesion [psf]	100	0	300		0	0
Friction Angle [deg]	31	34	27		28	15
Water Surface	Water Table	Water Table	Water Table	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	Automatically Calculated	1	1	Automatically Calculated	Automatically Calculated	Automatically Calculated

Shear Normal Functions

Name: Bray et al. 2009



Normal (psf)	Shear (psf)
0	310
600	810
5200	3840
6300	4480
7300	5120
8400	5740
16700	10550

List Of Coordinates

Water Table

X	Y
0	75
2933	75

Piezoline

X	Y
0	91.0935
131.436	88.8169
300.354	91.7427
309.368	94.746
313.504	94.746
322.518	91.7427
491.436	88.8169
660.354	91.7427
669.368	94.746
673.504	94.746
682.518	91.7427
851.436	88.8169
1020.35	91.7427
1029.37	94.746
1033.5	94.746
1042.52	91.7427
1211.44	88.8169
1380.35	91.7427
1388.95	94.6084
1393.49	94.7511
1402.52	91.7427
1568.27	88.8717
1571.44	87.8168
1652.35	89.2182
1858.27	89.4292
2005.92	86.0591
2014.08	86.0559

Block Search Polyline

X	Y
1571.44	85.7165
1401.99	88.6514
1393.03	91.6352
1389.51	91.5242
1380.88	88.6514
1211.44	85.7165
1041.99	88.6514
1033	91.646
1029.87	91.646
1020.88	88.6514
851.436	85.7165
681.989	88.6514
673.001	91.646
669.871	91.646
660.883	88.6514
499.527	85.8566

External Boundary

X	Y
0	70
0	60
0	42
0	-420
2932.99	-420
2932.99	42
2932.99	60
2932.99	91.9522
2032.16	91.96
2014.08	86.0559
2005.92	86.0591
1975.27	97
1959.16	96.9955
1957.87	96.9951
1951.76	96.9934
1925.57	88.4253
1754.17	90.9819
1652.35	89.2182
1571.44	87.8168
1568.27	88.8717
635.5	400
0	400
0	91.0935
0	90.0933
0	88.193
0	87.793

Material Boundary

X	Y
0	90.0933
131.436	87.8168
300.525	90.7455
309.53	93.746
313.341	93.746
322.347	90.7455
491.436	87.8168
660.525	90.7455
669.53	93.746
673.341	93.746
682.347	90.7455
851.436	87.8168
1020.52	90.7455
1029.53	93.746
1033.34	93.746
1042.35	90.7455
1211.44	87.8168
1380.52	90.7455
1389.13	93.6135
1393.34	93.746
1402.35	90.7455
1571.44	87.8168

Material Boundary

X	Y
0	60
2932.99	60

Material Boundary

X	Y
0	42
2932.99	42

Material Boundary

X	Y
0	91.0935
131.436	88.8169
300.354	91.7427
309.368	94.746
313.504	94.746
322.518	91.7427
491.436	88.8169
660.354	91.7427
669.368	94.746
673.504	94.746
682.518	91.7427
851.436	88.8169
1020.35	91.7427
1029.37	94.746
1033.5	94.746
1042.52	91.7427
1211.44	88.8169
1380.35	91.7427
1388.95	94.6084
1393.49	94.7511
1402.52	91.7427
1568.27	88.8717

Material Boundary

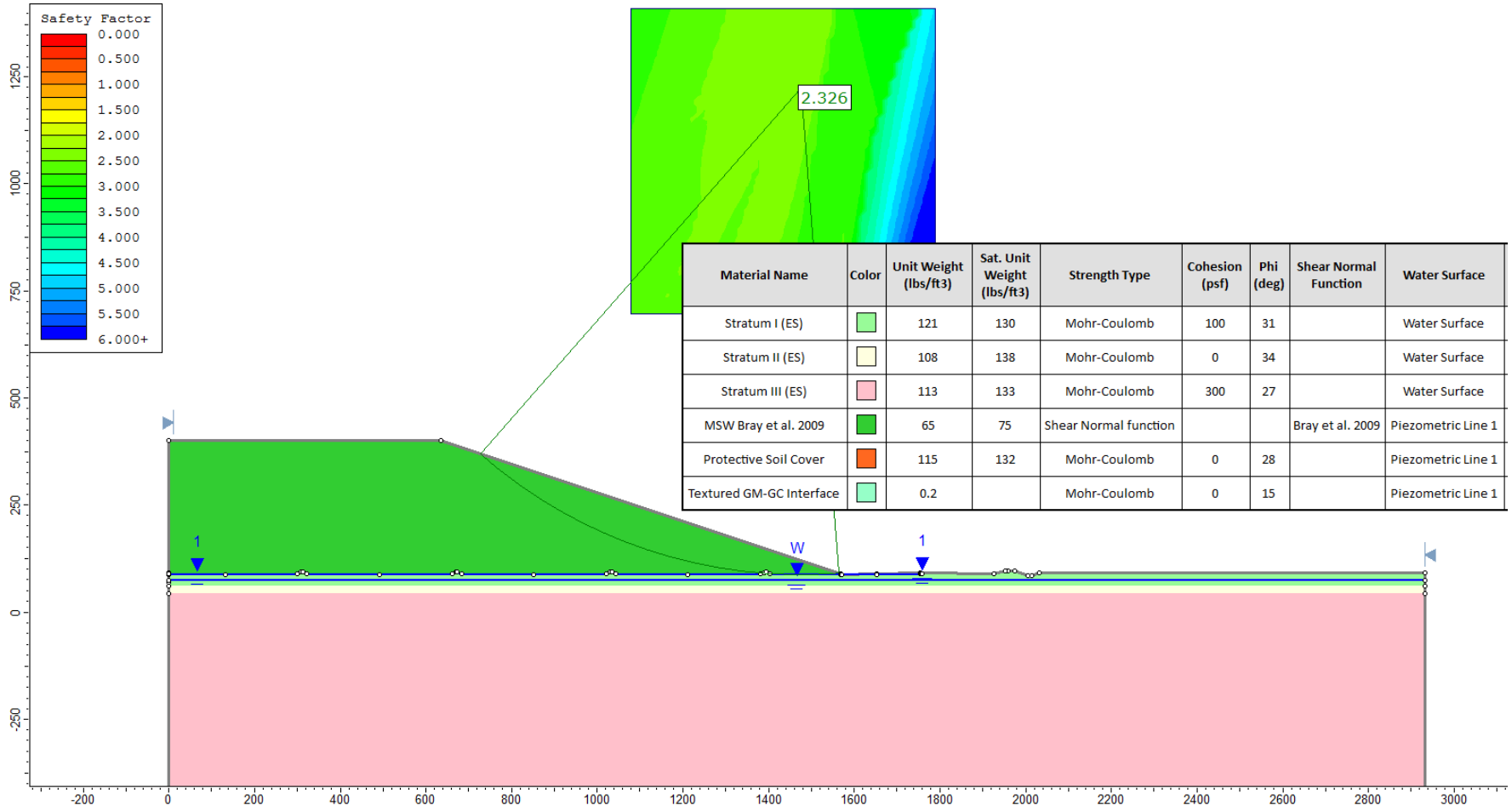
X	Y
0	88.193
131.436	85.9165
300.849	88.8508
309.838	91.846
313.033	91.846
322.023	88.8508
491.436	85.9165
660.849	88.8508
669.838	91.846
673.033	91.846
682.023	88.8508
851.436	85.9165
1020.85	88.8508
1029.84	91.846
1033.03	91.846
1042.02	88.8508
1211.44	85.9165
1380.85	88.8508
1389.47	91.7231
1393.06	91.8363
1402.02	88.8508
1571.44	85.9165
1754.18	89.0817
1925.86	86.5208
1957.87	96.9951

Material Boundary

X	Y
0	87.793
131.436	85.5164
300.917	88.4519
309.903	91.446
312.968	91.446
321.955	88.4519
491.436	85.5164
660.917	88.4519
669.903	91.446
672.968	91.446
681.955	88.4519
851.436	85.5164
1020.92	88.4519
1029.9	91.446
1032.97	91.446
1041.95	88.4519
1211.44	85.5164
1380.92	88.4519
1389.54	91.3252
1393	91.4342
1401.95	88.4519
1571.44	85.5164
1754.18	88.6816
1925.92	86.1199
1959.16	96.9955

APPENDIX III3B-2C-2

CONTINUOUS 3H:1V SLOPE WITHOUT BENCH - CIRCULAR FAILURE



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Water Surface
Stratum I (ES)		121	130	Mohr-Coulomb	100	31		Water Surface
Stratum II (ES)		108	138	Mohr-Coulomb	0	34		Water Surface
Stratum III (ES)		113	133	Mohr-Coulomb	300	27		Water Surface
MSW Bray et al. 2009		65	75	Shear Normal function			Bray et al. 2009	Piezometric Line 1
Protective Soil Cover		115	132	Mohr-Coulomb	0	28		Piezometric Line 1
Textured GM-GC Interface		0.2		Mohr-Coulomb	0	15		Piezometric Line 1

FIGURE **III3B-2C-2**

Continuous 3H:1V without Bench - Circular Failure

Edinburg Regional Disposal Facility, Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-2C, Interior Waste Slope Analysis

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	Interior Slope 3H1V Circular.slim
Last saved with Slide version:	7.014
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	2/5/2016, 2:33:16 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used
Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Enabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined
Minimum Area: Not Defined
Minimum Weight: Not Defined

Seismic

Advanced seismic analysis: No
Staged pseudostatic analysis: No

Material Properties

Property	Stratum I (ES)	Stratum II (ES)	Stratum III (ES)	MSW Bray et al. 2009	Protective Soil Cover	Textured GM-GC Interface
Color						
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Shear Normal function	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113	65	115	
Saturated Unit Weight [lbs/ft3]	130	138	133	75	132	
Cohesion [psf]	100	0	300		0	0
Friction Angle [deg]	31	34	27		28	15
Water Surface	Water Table	Water Table	Water Table	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	Automatically Calculated	1	1	Automatically Calculated	Automatically Calculated	Automatically Calculated

Shear Normal Functions

Name: Bray et al. 2009

Normal (psf)	Shear (psf)
0	310
600	810
5200	3840
6300	4480
7300	5120
8400	5740
16700	10550

List Of Coordinates

Water Table

X	Y
0	75
2933	75

Piezoline

X	Y
0	91.0935
131.436	88.8169
300.354	91.7427
309.368	94.746
313.504	94.746
322.518	91.7427
491.436	88.8169
660.354	91.7427
669.368	94.746
673.504	94.746
682.518	91.7427
851.436	88.8169
1020.35	91.7427
1029.37	94.746
1033.5	94.746
1042.52	91.7427
1211.44	88.8169
1380.35	91.7427
1388.95	94.6084
1393.49	94.7511
1402.52	91.7427
1568.5	88.8678
1571.44	87.8168
1652.35	89.2182
1858.27	89.4292
2005.92	86.0591
2014.08	86.0559

Block Search Polyline

X	Y
499.527	85.8566
660.883	88.6514
669.871	91.646
673.001	91.646
681.989	88.6514
851.436	85.7165
1020.88	88.6514
1029.87	91.646
1033	91.646
1041.99	88.6514
1211.44	85.7165
1380.88	88.6514
1389.51	91.5242
1393.03	91.6352
1401.99	88.6514
1571.44	85.7165
1653.2	87.1327
1656.9	89.297

External Boundary

X	Y
0	70
0	60
0	42
0	-420
2932.99	-420
2932.99	42
2932.99	60
2932.99	91.9522
2032.16	91.96
2014.08	86.0559
2005.92	86.0591
1975.27	97
1959.16	96.9955
1957.87	96.9951
1951.76	96.9934
1925.57	88.4253
1754.17	90.9819
1652.35	89.2182
1571.44	87.8168
1568.5	88.8678
635.5	400
0	400
0	91.0935
0	90.0933
0	88.193
0	87.793

Material Boundary

X	Y
0	90.0933
131.436	87.8168
300.525	90.7455
309.53	93.746
313.341	93.746
322.347	90.7455
491.436	87.8168
660.525	90.7455
669.53	93.746
673.341	93.746
682.347	90.7455
851.436	87.8168
1020.52	90.7455
1029.53	93.746
1033.34	93.746
1042.35	90.7455
1211.44	87.8168
1380.52	90.7455
1389.13	93.6135
1393.34	93.746
1402.35	90.7455
1571.44	87.8168

Material Boundary

X	Y
0	60
2932.99	60

Material Boundary

X	Y
0	42
2932.99	42

Material Boundary

X	Y
0	91.0935
131.436	88.8169
300.354	91.7427
309.368	94.746
313.504	94.746
322.518	91.7427
491.436	88.8169
660.354	91.7427
669.368	94.746
673.504	94.746
682.518	91.7427
851.436	88.8169
1020.35	91.7427
1029.37	94.746
1033.5	94.746
1042.52	91.7427
1211.44	88.8169
1380.35	91.7427
1388.95	94.6084
1393.49	94.7511
1402.52	91.7427
1568.5	88.8678

Material Boundary

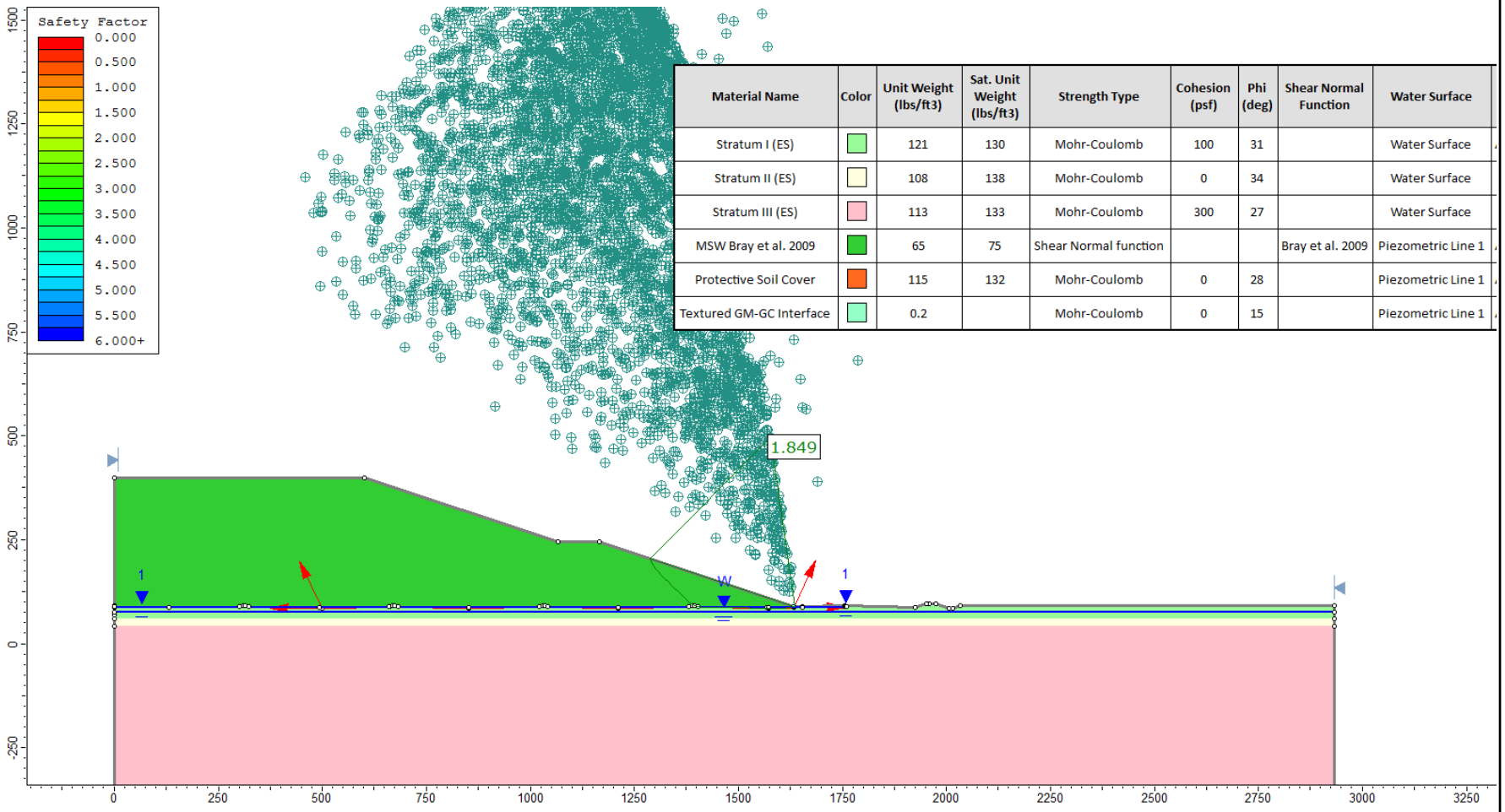
X	Y
0	88.193
131.436	85.9165
300.849	88.8508
309.838	91.846
313.033	91.846
322.023	88.8508
491.436	85.9165
660.849	88.8508
669.838	91.846
673.033	91.846
682.023	88.8508
851.436	85.9165
1020.85	88.8508
1029.84	91.846
1033.03	91.846
1042.02	88.8508
1211.44	85.9165
1380.85	88.8508
1389.47	91.7231
1393.06	91.8363
1402.02	88.8508
1571.44	85.9165
1754.18	89.0817
1925.86	86.5208
1957.87	96.9951

Material Boundary

X	Y
0	87.793
131.436	85.5164
300.917	88.4519
309.903	91.446
312.968	91.446
321.955	88.4519
491.436	85.5164
660.917	88.4519
669.903	91.446
672.968	91.446
681.955	88.4519
851.436	85.5164
1020.92	88.4519
1029.9	91.446
1032.97	91.446
1041.95	88.4519
1211.44	85.5164
1380.92	88.4519
1389.54	91.3252
1393	91.4342
1401.95	88.4519
1571.44	85.5164
1754.18	88.6816
1925.92	86.1199
1959.16	96.9955

APPENDIX III3B-2C-3

3H:1V SLOPE WITH 100-FOOT WIDE BENCH AT MID SLOPE - BLOCK FAILURE



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Water Surface
Stratum I (ES)		121	130	Mohr-Coulomb	100	31		Water Surface
Stratum II (ES)		108	138	Mohr-Coulomb	0	34		Water Surface
Stratum III (ES)		113	133	Mohr-Coulomb	300	27		Water Surface
MSW Bray et al. 2009		65	75	Shear Normal function			Bray et al. 2009	Piezometric Line 1
Protective Soil Cover		115	132	Mohr-Coulomb	0	28		Piezometric Line 1
Textured GM-GC Interface		0.2		Mohr-Coulomb	0	15		Piezometric Line 1

FIGURE **III3B-2C-3**

3H:1V with 100-ft Wide Bench at Mid Slope – – Block Failure

Edinburg Regional Disposal Facility, Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-2C, Interior Waste Slope Analysis

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	Interior Slope 3H1V Block 100 ft bench - Opt.slim
Last saved with Slide version:	7.014
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	2/5/2016, 2:33:16 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used
Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Multiple Groups: Disabled
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 115
Left Projection Angle (End Angle): 180
Right Projection Angle (Start Angle): 65
Right Projection Angle (End Angle): 0
Minimum Elevation: Not Defined
Minimum Depth: Not Defined
Minimum Area: Not Defined
Minimum Weight: Not Defined

Seismic

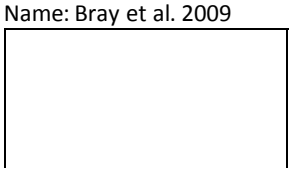
Advanced seismic analysis: No
Staged pseudostatic analysis: No

Material Properties

Property	Stratum I (ES)	Stratum II (ES)	Stratum III (ES)	MSW Bray et al. 2009	Protective Soil Cover	Textured GM-GC Interface
Color						
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Shear Normal function	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113	65	115	
Saturated Unit Weight [lbs/ft3]	130	138	133	75	132	
Cohesion [psf]	100	0	300		0	0
Friction Angle [deg]	31	34	27		28	15
Water Surface	Water Table	Water Table	Water Table	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	Automatically Calculated	1	1	Automatically Calculated	Automatically Calculated	Automatically Calculated

Shear Normal Functions

Name: Bray et al. 2009



Normal (psf)	Shear (psf)
0	310
600	810
5200	3840
6300	4480
7300	5120
8400	5740
16700	10550

List Of Coordinates

Water Table

X	Y
0	75
2933	75

Piezoline

X	Y
0	91.0935
131.436	88.8169
300.354	91.7427
309.368	94.746
313.504	94.746
322.518	91.7427
491.436	88.8169
660.354	91.7427
669.368	94.746
673.504	94.746
682.518	91.7427
851.436	88.8169
1020.35	91.7427
1029.37	94.746
1033.5	94.746
1042.52	91.7427
1211.44	88.8169
1380.35	91.7427
1388.95	94.6084
1393.49	94.7511
1402.52	91.7427
1463.12	90.7571
1571.16	89
1630.77	89.098
1633	89
1858.27	89.4292
2005.92	86.0591
2014.08	86.0559

Block Search Polyline

X	Y
1633.41	86.763
1571.45	85.708
1401.99	88.6514
1393.03	91.6352
1389.51	91.5242
1380.88	88.6514
1211.44	85.7165
1041.99	88.6514
1033	91.646
1029.87	91.646
1020.88	88.6514
851.436	85.7165
681.989	88.6514
673.001	91.646
669.871	91.646
660.883	88.6514
499.527	85.8566

External Boundary

X	Y
0	70
0	60
0	42
0	-420
2932.99	-420
2932.99	42
2932.99	60
2932.99	91.9522
2032.16	91.96
2014.08	86.0559
2005.92	86.0591
1975.27	97
1959.16	96.9955
1957.87	96.9951
1951.76	96.9934
1925.57	88.4253
1754.17	90.9819
1652.35	89.2182
1634.04	89.0117
1633	89
1165	245
1065	245
600	400
0	400
0	91.0935
0	90.0933
0	88.193
0	87.793

Material Boundary

X	Y
0	90.0933
131.436	87.8168
300.525	90.7455
309.53	93.746
313.341	93.746
322.347	90.7455
491.436	87.8168
660.525	90.7455
669.53	93.746
673.341	93.746
682.347	90.7455
851.436	87.8168
1020.52	90.7455
1029.53	93.746
1033.34	93.746
1042.35	90.7455
1211.44	87.8168
1380.52	90.7455
1389.13	93.6135
1393.34	93.746
1402.35	90.7455

Material Boundary

X	Y
0	60
2932.99	60

Material Boundary

X	Y
0	42
2932.99	42

Material Boundary

X	Y
0	91.0935
131.436	88.8169
300.354	91.7427
309.368	94.746
313.504	94.746
322.518	91.7427
491.436	88.8169
660.354	91.7427
669.368	94.746
673.504	94.746
682.518	91.7427
851.436	88.8169
1020.35	91.7427
1029.37	94.746
1033.5	94.746
1042.52	91.7427
1211.44	88.8169
1380.35	91.7427
1388.95	94.6084
1393.49	94.7511
1402.52	91.7427
1571.16	89
1633	89

Material Boundary

X	Y
0	88.193
131.436	85.9165
300.849	88.8508
309.838	91.846
313.033	91.846
322.023	88.8508
491.436	85.9165
660.849	88.8508
669.838	91.846
673.033	91.846
682.023	88.8508
851.436	85.9165
1020.85	88.8508
1029.84	91.846
1033.03	91.846
1042.02	88.8508
1211.44	85.9165
1380.85	88.8508
1389.47	91.7231
1393.06	91.8363
1402.02	88.8508
1571.44	85.9165
1754.18	89.0817
1925.86	86.5208
1957.87	96.9951

Material Boundary

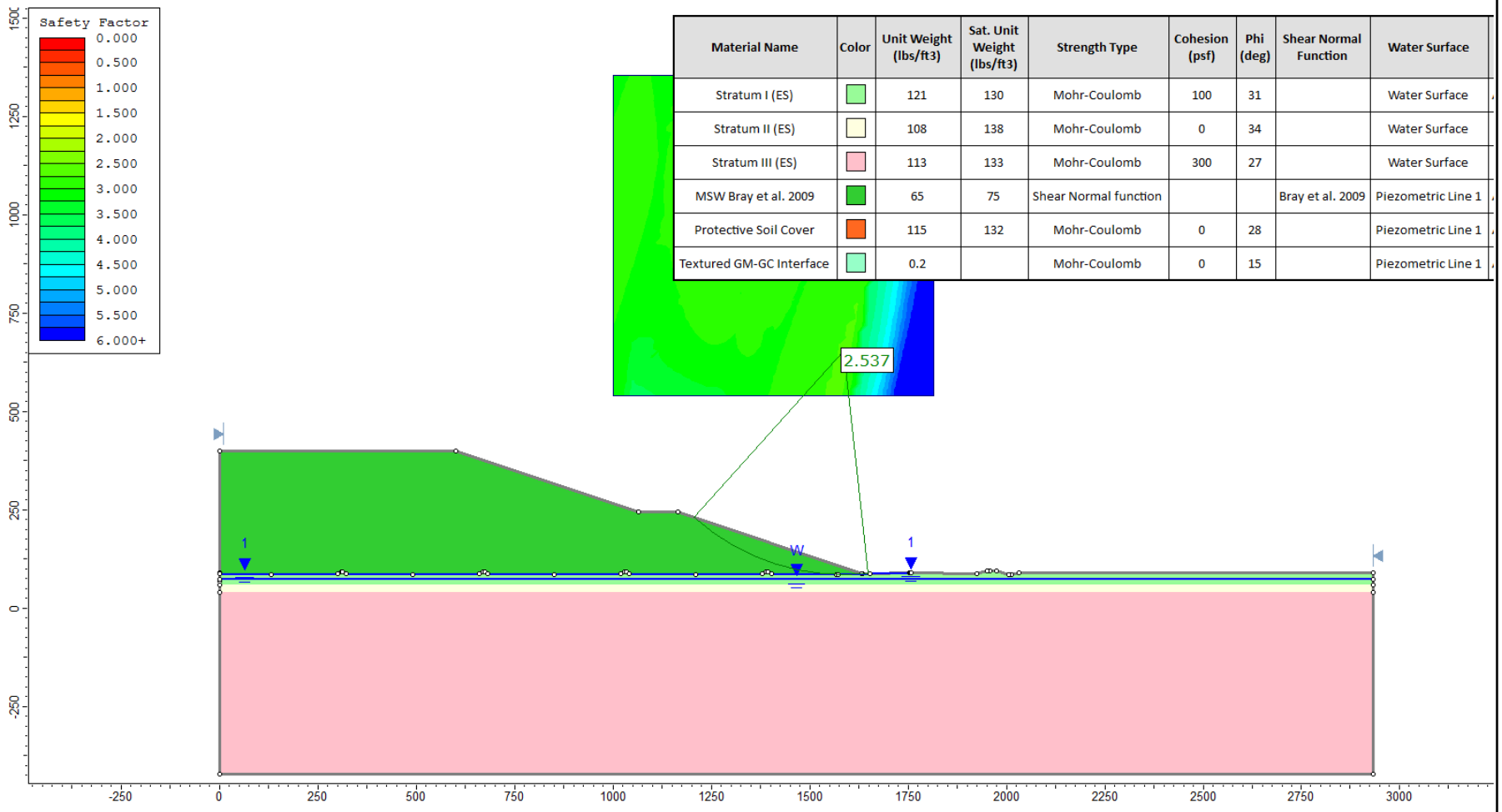
X	Y
0	87.793
131.436	85.5164
300.917	88.4519
309.903	91.446
312.968	91.446
321.955	88.4519
491.436	85.5164
660.917	88.4519
669.903	91.446
672.968	91.446
681.955	88.4519
851.436	85.5164
1020.92	88.4519
1029.9	91.446
1032.97	91.446
1041.95	88.4519
1211.44	85.5164
1380.92	88.4519
1389.54	91.3252
1393	91.4342
1401.95	88.4519
1571.44	85.5164
1754.18	88.6816
1925.92	86.1199
1959.16	96.9955

Material Boundary

X	Y
1402.35	90.7455
1443.5	90
1495.5	89.5
1543.71	88.481
1571.22	88
1606	88
1632.5	88.5
1634	89
1634.04	89.0117

APPENDIX III3B-2C-4

3H:1V SLOPE WITH 100-FOOT WIDE BENCH AT MID SLOPE - CIRCULAR FAILURE



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Water Surface
Stratum I (ES)		121	130	Mohr-Coulomb	100	31		Water Surface
Stratum II (ES)		108	138	Mohr-Coulomb	0	34		Water Surface
Stratum III (ES)		113	133	Mohr-Coulomb	300	27		Water Surface
MSW Bray et al. 2009		65	75	Shear Normal function			Bray et al. 2009	Piezometric Line 1
Protective Soil Cover		115	132	Mohr-Coulomb	0	28		Piezometric Line 1
Textured GM-GC Interface		0.2		Mohr-Coulomb	0	15		Piezometric Line 1

FIGURE **III3B-2C-4**

3H:1V with 100-ft Wide Bench at Mid Slope – Circular Failure

Edinburg Regional Disposal Facility, Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-2C, Interior Waste Slope Analysis

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	Interior Slope 3H1V Circular 100 ft bench.slim
Last saved with Slide version:	7.014
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	2/5/2016, 2:33:16 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Disabled
Reverse Curvature: Invalid Surfaces
Minimum Elevation: Not Defined
Minimum Depth: Not Defined
Minimum Area: Not Defined
Minimum Weight: Not Defined

Seismic

Advanced seismic analysis: No
Staged pseudostatic analysis: No

Material Properties

Property	Stratum I (ES)	Stratum II (ES)	Stratum III (ES)	MSW Bray et al. 2009	Protective Soil Cover	Textured GM-GC Interface
Color						
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Shear Normal function	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113	65	115	
Saturated Unit Weight [lbs/ft3]	130	138	133	75	132	
Cohesion [psf]	100	0	300		0	0
Friction Angle [deg]	31	34	27		28	15
Water Surface	Water Table	Water Table	Water Table	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	Automatically Calculated	1	1	Automatically Calculated	Automatically Calculated	Automatically Calculated

Shear Normal Functions

Name: Bray et al. 2009

Normal (psf)	Shear (psf)
0	310
600	810
5200	3840
6300	4480
7300	5120
8400	5740
16700	10550

List Of Coordinates

Water Table

X	Y
0	75
2933	75

Piezoline

X	Y
0	91.0935
131.436	88.8169
300.354	91.7427
309.368	94.746
313.504	94.746
322.518	91.7427
491.436	88.8169
660.354	91.7427
669.368	94.746
673.504	94.746
682.518	91.7427
851.436	88.8169
1020.35	91.7427
1029.37	94.746
1033.5	94.746
1042.52	91.7427
1211.44	88.8169
1380.35	91.7427
1388.95	94.6084
1393.49	94.7511
1402.52	91.7427
1463.12	90.7571
1571.16	89
1630.77	89.098
1633	89
1858.27	89.4292
2005.92	86.0591
2014.08	86.0559

Block Search Polyline

X	Y
1633.41	86.763
1571.45	85.708
1401.99	88.6514
1393.03	91.6352
1389.51	91.5242
1380.88	88.6514
1211.44	85.7165
1041.99	88.6514
1033	91.646
1029.87	91.646
1020.88	88.6514
851.436	85.7165
681.989	88.6514
673.001	91.646
669.871	91.646
660.883	88.6514
499.527	85.8566

External Boundary

X	Y
0	70
0	60
0	42
0	-420
2932.99	-420
2932.99	42
2932.99	60
2932.99	91.9522
2032.16	91.96
2014.08	86.0559
2005.92	86.0591
1975.27	97
1959.16	96.9955
1957.87	96.9951
1951.76	96.9934
1925.57	88.4253
1754.17	90.9819
1652.35	89.2182
1634.04	89.0117
1633	89
1165	245
1065	245
600	400
0	400
0	91.0935
0	90.0933
0	88.193
0	87.793

Material Boundary

X	Y
0	90.0933
131.436	87.8168
300.525	90.7455
309.53	93.746
313.341	93.746
322.347	90.7455
491.436	87.8168
660.525	90.7455
669.53	93.746
673.341	93.746
682.347	90.7455
851.436	87.8168
1020.52	90.7455
1029.53	93.746
1033.34	93.746
1042.35	90.7455
1211.44	87.8168
1380.52	90.7455
1389.13	93.6135
1393.34	93.746
1402.35	90.7455

Material Boundary

X	Y
0	60
2932.99	60

Material Boundary

X	Y
0	42
2932.99	42

Material Boundary

X	Y
0	91.0935
131.436	88.8169
300.354	91.7427
309.368	94.746
313.504	94.746
322.518	91.7427
491.436	88.8169
660.354	91.7427
669.368	94.746
673.504	94.746
682.518	91.7427
851.436	88.8169
1020.35	91.7427
1029.37	94.746
1033.5	94.746
1042.52	91.7427
1211.44	88.8169
1380.35	91.7427
1388.95	94.6084
1393.49	94.7511
1402.52	91.7427
1571.16	89
1633	89

Material Boundary

X	Y
0	88.193
131.436	85.9165
300.849	88.8508
309.838	91.846
313.033	91.846
322.023	88.8508
491.436	85.9165
660.849	88.8508
669.838	91.846
673.033	91.846
682.023	88.8508
851.436	85.9165
1020.85	88.8508
1029.84	91.846
1033.03	91.846
1042.02	88.8508
1211.44	85.9165
1380.85	88.8508
1389.47	91.7231
1393.06	91.8363
1402.02	88.8508
1571.44	85.9165
1754.18	89.0817
1925.86	86.5208
1957.87	96.9951

Material Boundary

X	Y
0	87.793
131.436	85.5164
300.917	88.4519
309.903	91.446
312.968	91.446
321.955	88.4519
491.436	85.5164
660.917	88.4519
669.903	91.446
672.968	91.446
681.955	88.4519
851.436	85.5164
1020.92	88.4519
1029.9	91.446
1032.97	91.446
1041.95	88.4519
1211.44	85.5164
1380.92	88.4519
1389.54	91.3252
1393	91.4342
1401.95	88.4519
1571.44	85.5164
1754.18	88.6816
1925.92	86.1199
1959.16	96.9955

Material Boundary

X	Y
1402.35	90.7455
1443.5	90
1495.5	89.5
1543.71	88.481
1571.22	88
1606	88
1632.5	88.5
1634	89
1634.04	89.0117

APPENDIX III3B-2D

FINAL-FILLED CONFIGURATION STABILITY

FINAL FILLED CONFIGURATION STABILITY CALCULATION

Made by: JCW
Checked by: CEI
Reviewed by: JBF

1.0 SUMMARY

Evaluate the stability of the of the final-filled configuration.

2.0 GIVEN

Based on a review of the design grades, two potential worst-case configurations are considered. Section A is located in Unit 7 in a north to south direction along Cells 2A and 2B and has 4H:1V final cover slopes to the peak elevation of approximately 400 ft-msl (shown in Figure III3B-2D-1). Section B which is located in Unit 7 running west to east along Cells 1B through 5b, was also analyzed since the east end of this section passes through the slopes of the adjacent stormwater pond. The peak elevation of Sections A and B is approximately 393 ft-msl and the final cover slopes are at 4H:1V (shown in Figure III3B-2D-2).



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One feet of leachate is assumed over the liner interface (conservative because is designed to be contained within the geocomposite drainage layer).

Groundwater elevation at 75 feet above mean sea level.

The cell liner system consists of:

FLOOR & SIDEWALLS: 24 inches of protective cover (clay)
Double-sided geocomposite
60-mil HDPE textured geomembrane
Geosynthetic Clay Liner (GCL)
Subgrade

The following parameters were assigned to the materials based on available data:

Material	Strength Parameters		Unit Weight (pcf)		Reference
	ϕ (deg)	c (psf)	Moist	Saturated	
Waste	Bi-Linear		65	75	[Ref. 1]
Protective cover (soil)	28	0	115	132	Estimate
Prot. cover (soil)/Geocomposite (F/S)	25	0	N/A	N/A	Golder*
Geocomposite/Text. Geomembrane (F/S)	15	0	N/A	N/A	Golder*
Textured Geomembrane/GCL (F/S)	18	0	N/A	N/A	Golder*
GCL Internal Shear (F/S)	23	0	N/A	N/A	Golder*
GCL/Subgrade (F/S)	20	0	N/A	N/A	Golder*

(F) = Floor; (S) Slope

* Based on unpublished data from tests performed in Golder's laboratory, on similar geosynthetic materials. Strength parameters were conservatively assigned to be equal to or a percentage of the peak strength (lower bound) to account for testing data variability and to avoid strains that result in residual interface shear strengths. This data is presented on pages 5, 6, and 7 of this appendix.

Based on the data listed in the above table, the weakest interface in the liner system along the sideslope and floor of the cell is between the geocomposite and textured geomembrane. This interface shear strength was used in the analysis.

Subsurface profiles are determined based on available adjacent borehole information, and the same soil properties as the excavation stability analysis are used. These are shown in the table below.

Material	Unit Weight (pcf)		Strength Parameters		Analysis Stress State	Reference
	Moist	Saturated	ϕ (degrees)	c (psf)		
Stratum I	121	130	31	100	Effective	[Ref. 2]
Stratum II	108	138	34	0	Effective	[Ref. 2]
Stratum III	113	133	27	300	Effective	Lambe & Whitman, 1969

3.0 METHOD

Use limit equilibrium slope stability methods to determine the slope factor of safety for the final filled configguration using SLIDE v.7(Ref. 3).

Based on the "EPA Guide to Technical Resources for the Design of Land Disposal Facilities", the recommend factor of safety for waste slope is 1.5 at minimum.

4.0 RESULTS

Minimum factors of safety calculated by SLIDE are summarized below:

Section	Type of Failure	Global Minimum Factor of Safety
Section 1	Block	1.94
	Circular	2.90
Section 2	Block	2.00
	Circular	2.93

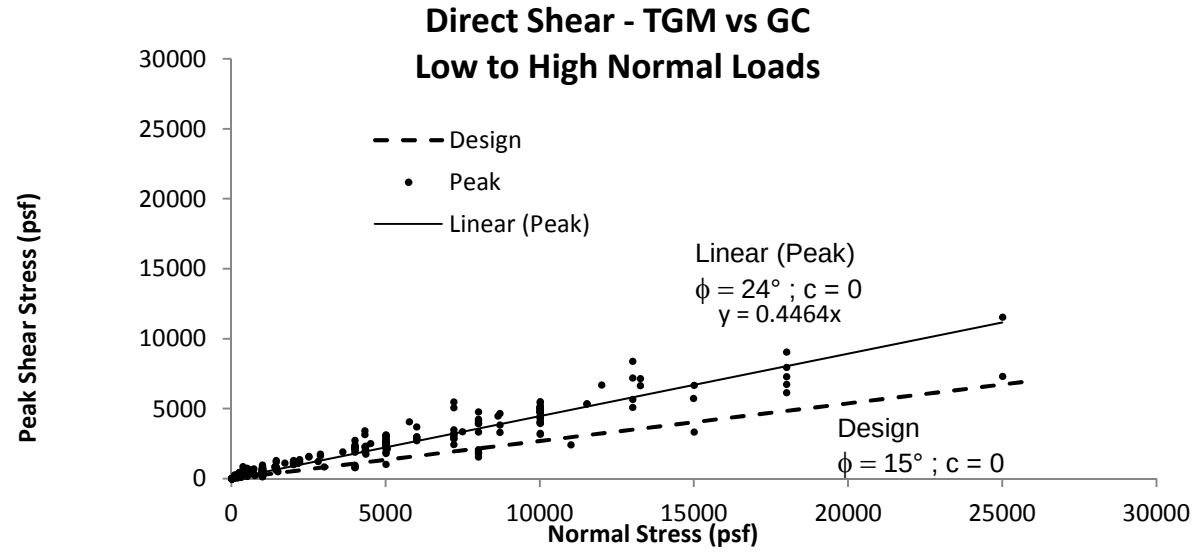
7.0 CONCLUSIONS

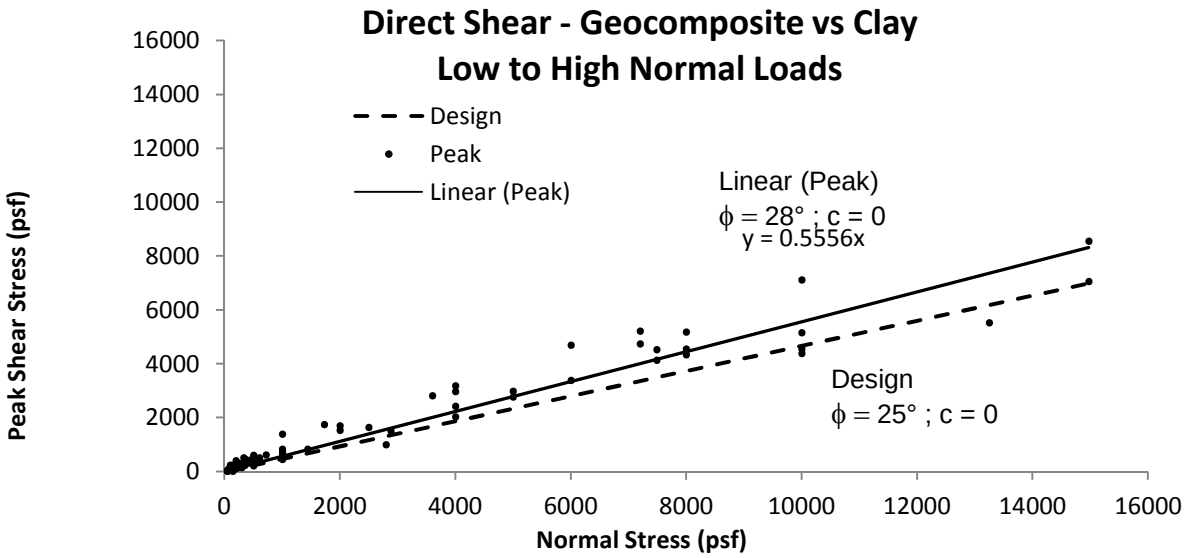
Using strength parameters that are conservatively estimated or based on test results for similar conditions and the reasonable worst-case configurations, the analysis indicates that the final-filled configuration will be stable.

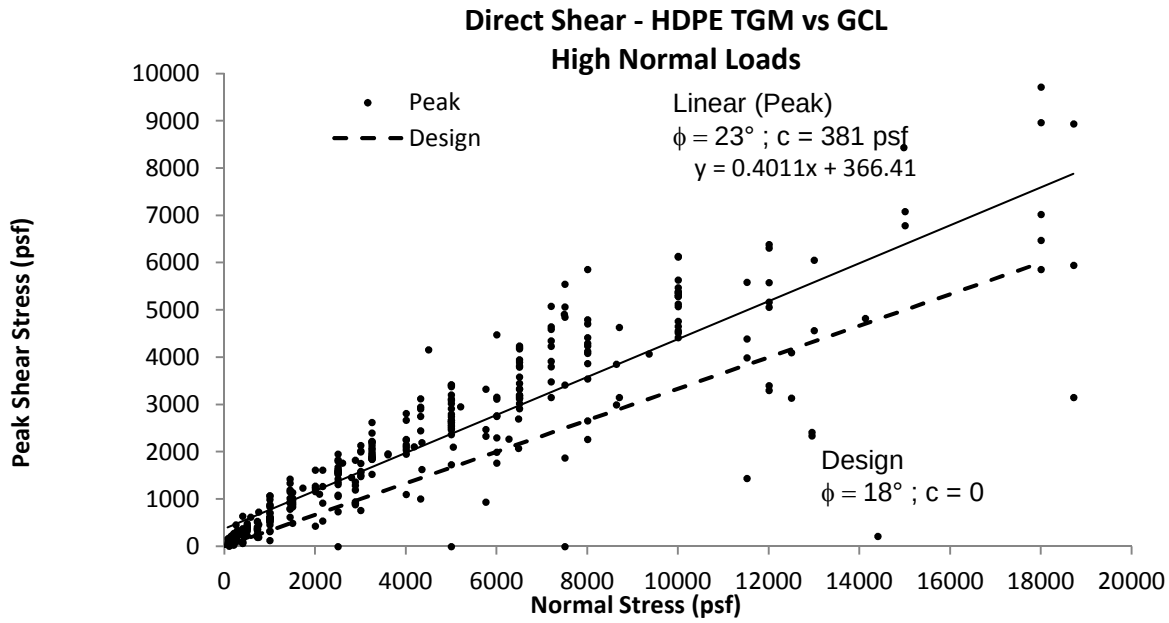
8.0 REFERENCES

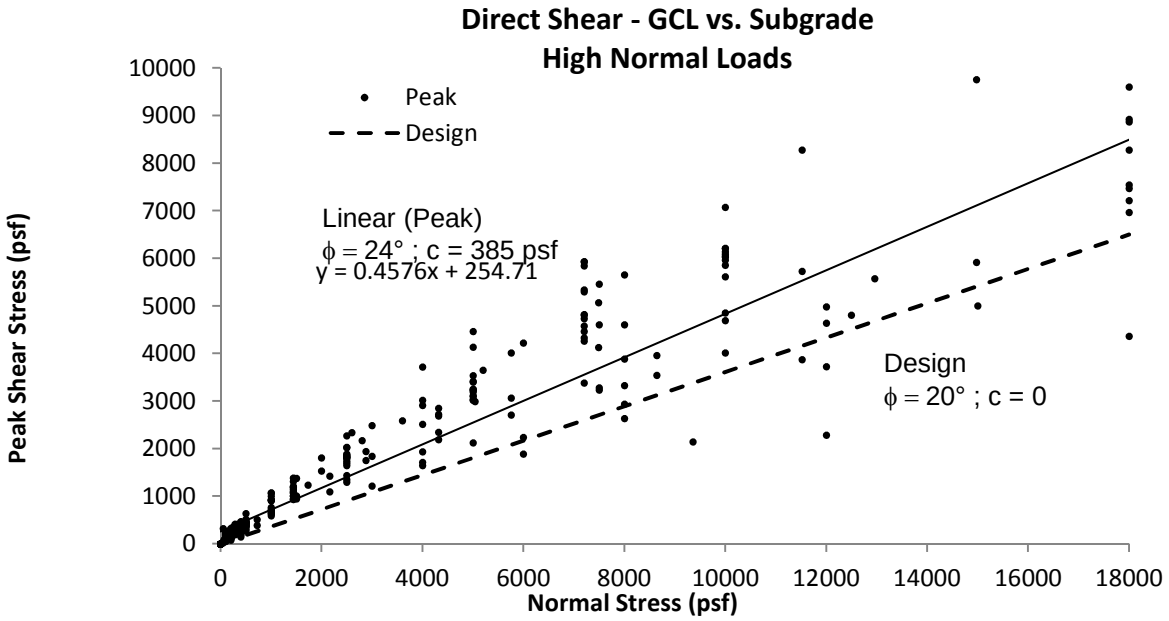
(1) Bray, J.D., D. Zekkos, E. Kavazanjian, Jr., G.A. Athanasopoulos, and F. Riemer. 2009. Shear strength of municipal solid waste. J. Geotech. Geoenviron. Eng. (ASCE) 135(6): 709–22.

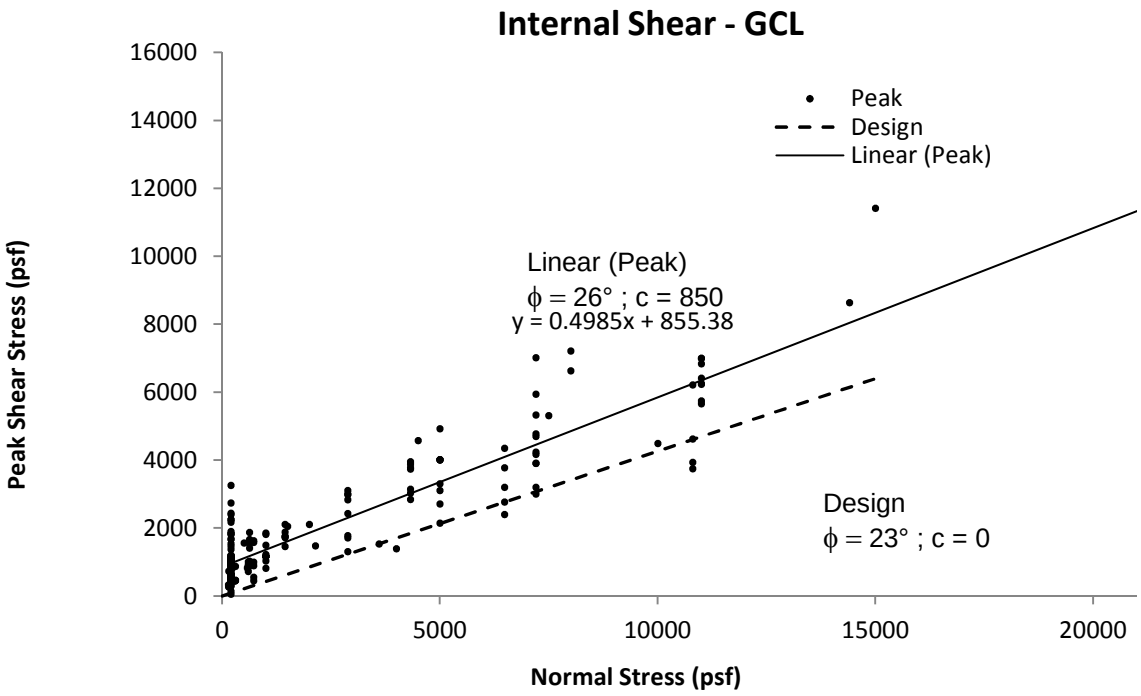
(2) Lambe, T.W. and Whitman, R.V. (1969). Soil Mechanics, John Wiley & Sons, New York. 1 PI correlation
(3) Rocscience 2015, SLIDE - 2D Limit Equilibrium Slope Stability for Soil and Rock Slopes.






Direct Shear - HDPE TGM vs GCL
High Normal Loads
Peak
Design
Linear (Peak)
ϕ = 23° ; c = 381 psf
y = 0.4011x + 366.41
Design
ϕ = 18° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000


Direct Shear - GCL vs. Subgrade
High Normal Loads
Peak
Design
Linear (Peak)
ϕ = 24° ; c = 385 psf
y = 0.4576x + 254.71
Design
ϕ = 20° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000


Internal Shear - GCL
Peak
Design
Linear (Peak)
Linear (Peak)
ϕ = 26° ; c = 850
y = 0.4985x + 855.38
Design
ϕ = 23° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
16000
14000
12000
10000
8000
6000
4000
2000
0
0
5000
10000
15000
20000

LEGEND

- PERMIT BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- FINAL COVER 25 ft CONTOUR
- FINAL COVER 5 ft CONTOUR

NOTE(S)

1. FINAL COVER ELEVATIONS SHOWN.

SITE

PERMIT BOUNDARY

STORMWATER POND (TYP.)

STORMWATER POND (TYP.)

STORMWATER POND (TYP.)

W098° 07' 46.00"

N026° 24' 06.00"

W098° 06' 54.00"

N026° 23' 20.00"

EL. 318.4

EL. 360.3

EL. 312.6

EL. 309.0

EL. 312.6

4H:1V

5%

A

A'

B

B'

ISSUED FOR PERMITTING PURPOSES ONLY

0 300 600

1" = 600' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

SEAL

STATE OF TEXAS
JEFFREY B. FASSETT
85675
LICENSED
PROFESSIONAL ENGINEER

GOLDER ASSOCIATES INC.
TEXAS REGISTRATION F-2578

CLIENT

CITY OF EDINBURG SOLID WASTE MANAGEMENT

CONSULTANT

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www.golder.com

PROJECT

EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE

FINAL FILLED CONFIGURATION STABILITY *SUBGRADE LAYOUT*

PROJECT NO.	APPLICATION SECTION	REV.	FIGURE
1401491	III3B-2D	0	1 of 2 III3B-2D-1

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

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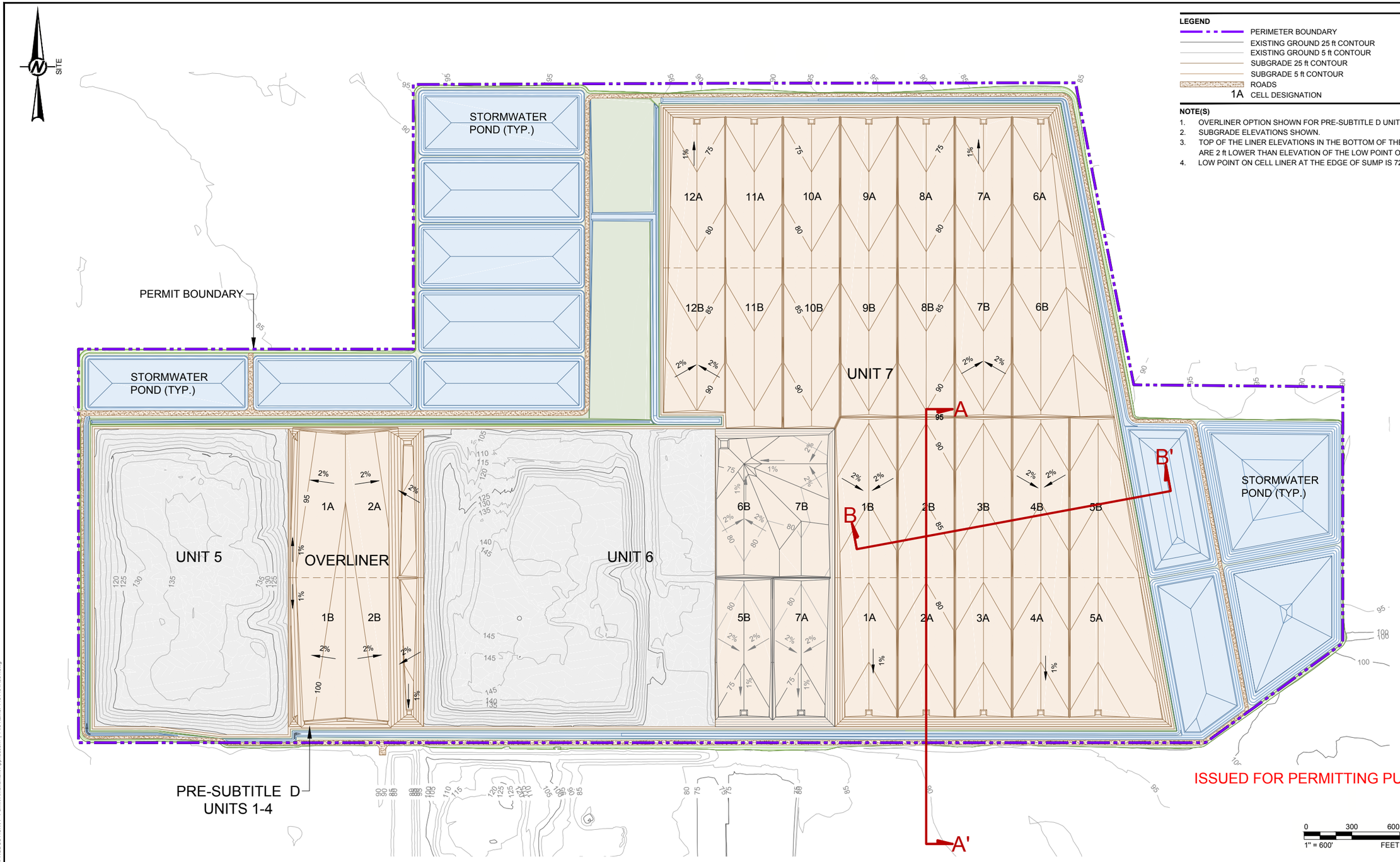

LEGEND

- PERIMETER BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- ROADS
- 1A CELL DESIGNATION

NOTE(S)

1. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
2. SUBGRADE ELEVATIONS SHOWN.
3. TOP OF THE LINER ELEVATIONS IN THE BOTTOM OF THE LEACHATE COLLECTION SUMPS ARE 2 ft LOWER THAN ELEVATION OF THE LOW POINT ON THE LINER.
4. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 72 ft-msl IN UNIT 7.

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

SEAL

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

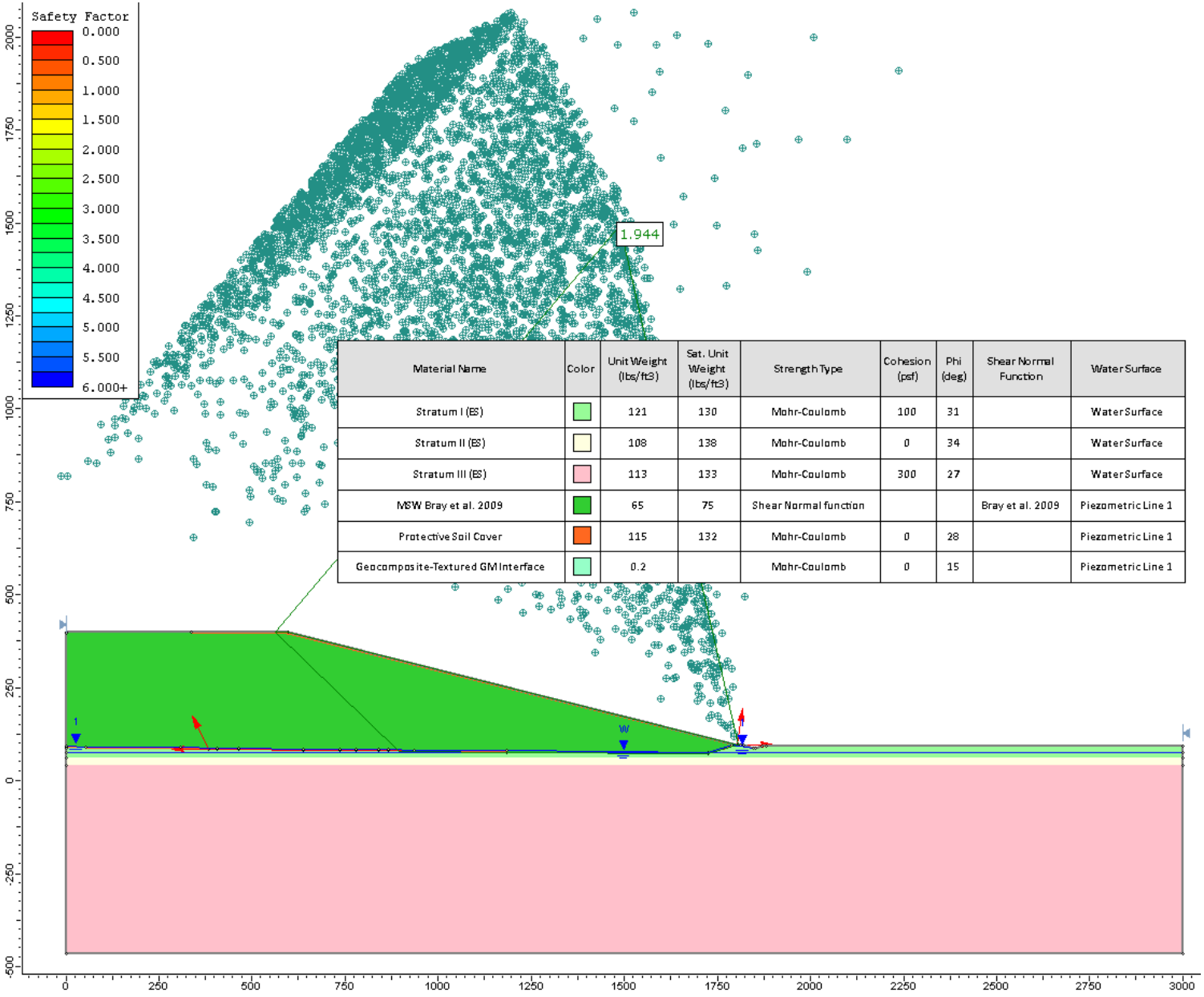
TITLE
FINAL FILLED CONFIGURATION STABILITY *FINAL CONTOUR MAP*

PROJECT NO.	APPLICATION SECTION	REV.	2 of 2	FIGURE
1401491	III3B-2D	0		III3B-2D-2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

APPENDIX III3B-2D-1

SECTION 1 - BLOCK FAILURE



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Water Surface
Stratum I (ES)		121	130	Mohr-Coulomb	100	31		Water Surface
Stratum II (ES)		108	138	Mohr-Coulomb	0	34		Water Surface
Stratum III (ES)		113	133	Mohr-Coulomb	300	27		Water Surface
MSW Bray et al. 2009		65	75	Shear Normal function			Bray et al. 2009	Piezometric Line 1
Protective Soil Cover		115	132	Mohr-Coulomb	0	28		Piezometric Line 1
Geocomposite-Textured GM Interface		0.2		Mohr-Coulomb	0	15		Piezometric Line 1

FIGURE **III3B-2D-1**

Section 1 - Block Failure

Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-2D, Final Filled Configuration Stability Analysis

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	Final Configuration 4h1v - Block - Opt.slim
Slide Modeler Version:	7.014
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	2/5/2016, 4:49:10 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used	
	Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Non-Circular Block Search
Number of Surfaces: 5000
Multiple Groups: Disabled
Pseudo-Random Surfaces: Enabled
Convex Surfaces Only: Disabled
Left Projection Angle (Start Angle): 115
Left Projection Angle (End Angle): 180
Right Projection Angle (Start Angle): 80
Right Projection Angle (End Angle): 0
Minimum Elevation: Not Defined
Minimum Depth: Not Defined
Minimum Area: Not Defined
Minimum Weight: Not Defined

Seismic

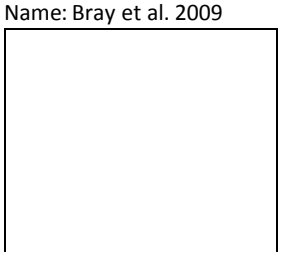
Advanced seismic analysis: No
Staged pseudostatic analysis: No

Material Properties

Property	Stratum I (ES)	Stratum II (ES)	Stratum III (ES)	MSW Bray et al. 2009	Protective Soil Cover	Geocomposite-Textured GM Interface
Color						
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Shear Normal function	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113	65	115	
Saturated Unit Weight [lbs/ft3]	130	138	133	75	132	
Cohesion [psf]	100	0	300		0	0
Friction Angle [deg]	31	34	27		28	15
Water Surface	Water Table	Water Table	Water Table	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	Automatically Calculated	1	1	Automatically Calculated	Automatically Calculated	Automatically Calculated

Shear Normal Functions

Name: Bray et al. 2009



Normal (psf)	Shear (psf)
0	310
600	810
5200	3840
6300	4480
7300	5120
8400	5740
16700	10550

Global Minimums

Method: spencer

FS	1.944430
Axis Location:	1487.301, 1492.592
Left Slip Surface Endpoint:	561.925, 399.002
Right Slip Surface Endpoint:	1806.947, 96.137
Resisting Moment:	5.79977e+009 lb-ft
Driving Moment:	2.98276e+009 lb-ft
Resisting Horizontal Force:	3.55748e+006 lb
Driving Horizontal Force:	1.82957e+006 lb
Total Slice Area:	163641 ft2
Surface Horizontal Width:	1245.02 ft
Surface Average Height:	131.436 ft

Global Minimum Coordinates

Method: spencer

X	Y
561.925	399.002
895.075	79.9482
935.063	79.5483
1183.79	77.0611
1724.61	71.6529
1792.28	94.2104
1806.95	96.1368

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 3413
Number of Invalid Surfaces: 1588

Error Codes:

Error Code -108 reported for 306 surfaces
Error Code -111 reported for 1264 surfaces
Error Code -112 reported for 18 surfaces

Error Codes

The following errors were encountered during the computation:

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).
-111 = safety factor equation did not converge
-112 = The coefficient M-Alpha = cos(alpha)(1+tan(alpha)tan(phi)/F) < 0.2 for the final iteration of the safety factor calculation. This screens out some slip surfaces which may not be valid in the context of the analysis, in particular, deep seated slip surfaces with many high negative base angle slices in the passive zone.

Slice Data

Global Minimum Query (spencer) - Safety Factor: 1.94443

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	3.74182	767.416	-43.7618	Protective Soil Cover	0	28	39.4771	76.7604	144.365	-19395	144.365
2	29.6488	39428.6	-43.7618	MSW Bray et al. 2009	414.783	33.3727	484.472	942.022	800.428	-18407.8	800.428
3	29.6488	88279.7	-43.7618	MSW Bray et al. 2009	414.783	33.3727	864.682	1681.31	1922.79	-16654.7	1922.79
4	29.6488	128724	-43.7618	MSW Bray et al. 2009	414.783	33.3727	1179.46	2293.38	2852	-14901.6	2852
5	29.6488	169161	-43.7618	MSW Bray et al. 2009	414.783	33.3727	1494.18	2905.33	3781.03	-13148.5	3781.03
6	29.6488	209597	-43.7618	MSW Bray et al. 2009	414.783	33.3727	1808.9	3517.27	4710.04	-11395.3	4710.04
7	29.6488	250033	-43.7618	MSW Bray et al. 2009	814.545	30.1916	2108.87	4100.55	5647.82	-9642.2	5647.82
8	29.6488	290469	-43.7618	MSW Bray et al. 2009	448	32.6192	2399.79	4666.22	6590.96	-7889.07	6590.96
9	29.6488	330905	-43.7618	MSW Bray et al. 2009	1005.45	29.4072	2699.51	5249.01	7528.89	-6135.95	7528.89
10	29.6488	371341	-43.7618	MSW Bray et al. 2009	872.048	30.0931	2976.04	5786.7	8480.58	-4382.82	8480.58
11	29.6488	411777	-43.7618	MSW Bray et al. 2009	872.048	30.0931	3258.61	6336.15	9428.69	-2629.69	9428.69
12	29.6488	452213	-43.7618	MSW Bray et al. 2009	872.048	30.0931	3541.19	6885.59	10376.8	-876.564	10376.8
13	1.05525	16840.3	-43.7618	MSW Bray et al. 2009	872.048	30.0931	3679.6	7154.73	10872.4	31.1984	10841.2
14	2.21603	35647.1	-43.7618	Protective Soil Cover	0	28	3066.21	5962.04	11340.9	127.914	11213
15	39.9884	634469	-0.572939	Geocomposite-Textured GM Interface	0	15	2222.56	4321.62	16321.9	193.43	16128.5
16	27.636	423905	-0.572939	Geocomposite-Textured GM Interface	0	15	2147.76	4176.17	15779.1	193.43	15585.7
17	27.636	411990	-0.572939	Geocomposite-Textured GM Interface	0	15	2086.62	4057.29	15335.4	193.43	15142
18	27.636	400076	-0.572939	Geocomposite-Textured GM Interface	0	15	2025.48	3938.41	14891.8	193.43	14698.3
19	27.636	388161	-0.572939	Geocomposite-Textured GM Interface	0	15	1964.34	3819.53	14448.1	193.43	14254.7
20	27.636	376247	-0.572939	Geocomposite-Textured GM Interface	0	15	1903.21	3700.65	14004.4	193.43	13811
21	27.636	364333	-0.572939	Geocomposite-Textured GM Interface	0	15	1842.07	3581.77	13560.8	193.43	13367.4
22	27.636	352418	-0.572939	Geocomposite-Textured GM Interface	0	15	1780.93	3462.89	13117.1	193.43	12923.7
23	27.636	340504	-0.572939	Geocomposite-Textured GM Interface	0	15	1719.79	3344.01	12673.4	193.43	12480

24	27.636	328589	-0.572939	Geocomposite-Textured GM Interface	0	15	1658.65	3225.13	12229.8	193.43	12036.3
25	29.4442	336978	-0.572939	Geocomposite-Textured GM Interface	0	15	1595.51	3102.36	11771.6	193.43	11578.2
26	29.4442	323454	-0.572939	Geocomposite-Textured GM Interface	0	15	1530.37	2975.7	11298.9	193.43	11105.5
27	29.4442	309929	-0.572939	Geocomposite-Textured GM Interface	0	15	1465.23	2849.04	10826.2	193.43	10632.8
28	29.4442	296405	-0.572939	Geocomposite-Textured GM Interface	0	15	1400.09	2722.38	10353.5	193.43	10160.1
29	29.4442	282880	-0.572939	Geocomposite-Textured GM Interface	0	15	1334.96	2595.73	9880.82	193.43	9687.39
30	29.4442	269355	-0.572939	Geocomposite-Textured GM Interface	0	15	1269.82	2469.07	9408.12	193.43	9214.69
31	29.4442	255831	-0.572939	Geocomposite-Textured GM Interface	0	15	1204.68	2342.41	8935.42	193.43	8741.99
32	27.8925	229902	-0.572939	Geocomposite-Textured GM Interface	0	15	1141.39	2219.36	8476.18	193.43	8282.75
33	27.8925	217889	-0.572939	Geocomposite-Textured GM Interface	0	15	1080.32	2100.6	8032.97	193.43	7839.54
34	27.8925	205885	-0.572939	Geocomposite-Textured GM Interface	0	15	1019.28	1981.92	7590.07	193.43	7396.64
35	27.8925	193881	-0.572939	Geocomposite-Textured GM Interface	0	15	958.25	1863.25	7147.15	193.43	6953.72
36	27.8925	181876	-0.572939	Geocomposite-Textured GM Interface	0	15	897.214	1744.57	6704.25	193.43	6510.82
37	27.8925	169872	-0.572939	Geocomposite-Textured GM Interface	0	15	836.178	1625.89	6261.36	193.43	6067.93
38	27.8925	157867	-0.572939	Geocomposite-Textured GM Interface	0	15	775.147	1507.22	5818.43	193.43	5625
39	27.8925	145857	-0.572939	Geocomposite-Textured GM Interface	0	15	714.081	1388.48	5375.33	193.43	5181.9
40	27.8925	133805	-0.572939	Geocomposite-Textured GM Interface	0	15	652.808	1269.34	4930.68	193.43	4737.25
41	27.8925	121747	-0.572939	Geocomposite-Textured GM Interface	0	15	591.5	1150.13	4485.78	193.43	4292.35
42	27.8925	109688	-0.572939	Geocomposite-Textured GM Interface	0	15	530.186	1030.91	4040.84	193.43	3847.41
43	27.8925	97629.8	-0.572939	Geocomposite-Textured GM Interface	0	15	468.882	911.709	3595.98	193.43	3402.55

44	10.0413	30902.8	18.4349	Geocomposite-Textured GM Interface	0	15	474.421	922.478	3626.25	183.513	3442.73
45	28.8156	66724.2	18.4349	Geocomposite-Textured GM Interface	0	15	350.115	680.775	2724.2	183.513	2540.69
46	28.8156	35205.1	18.4349	Geocomposite-Textured GM Interface	0	15	171.681	333.821	1429.35	183.513	1245.83
47	0.521832	320.219	7.48211	Geocomposite-Textured GM Interface	0	15	78.9116	153.438	662.505	89.8688	572.636
48	4.61499	2325.32	7.48211	Stratum I (ES)	100	31	239.796	466.267	609.57	-1221.91	609.57
49	4.13123	1360.14	7.48211	Stratum I (ES)	100	31	176.847	343.866	405.86	-1257.75	405.86
50	5.39981	639.339	7.48211	Protective Soil Cover	0	28	37.2078	72.3479	136.067	-125.906	136.067

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 1.94443

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	561.925	399.002	0	0	0
2	565.666	395.418	369.616	85.7611	13.063
3	595.315	367.024	8733.2	2026.35	13.0631
4	624.964	338.63	37692.5	8745.71	13.0631
5	654.613	310.235	83703.4	19421.5	13.0631
6	684.262	281.841	146762	34052.9	13.0631
7	713.91	253.447	226869	52639.9	13.0631
8	743.559	225.053	324709	75341.6	13.0631
9	773.208	196.658	440704	102256	13.0631
10	802.857	168.264	574445	133287	13.063
11	832.506	139.87	727009	168686	13.063
12	862.155	111.475	898116	208388	13.0631
13	891.803	83.0811	1.08777e+006	252392	13.063
14	892.859	82.0705	1.09487e+006	254040	13.063
15	895.075	79.9482	1.11214e+006	258048	13.0631
16	935.063	79.5483	1.02979e+006	238941	13.0631
17	962.699	79.272	974799	226180	13.063
18	990.335	78.9956	921371	213784	13.0631
19	1017.97	78.7193	869510	201751	13.0631
20	1045.61	78.4429	819217	190081	13.0631
21	1073.24	78.1665	770490	178775	13.0631
22	1100.88	77.8902	723330	167833	13.0631
23	1128.52	77.6138	677738	157254	13.0631
24	1156.15	77.3375	633712	147039	13.0631
25	1183.79	77.0611	591253	137187	13.0631
26	1213.23	76.7666	547741	127091	13.063
27	1242.68	76.4722	506007	117408	13.0631
28	1272.12	76.1778	466052	108137	13.0631
29	1301.56	75.8833	427876	99279.2	13.0631
30	1331.01	75.5889	391479	90834	13.0631
31	1360.45	75.2944	356861	82801.5	13.063
32	1389.9	75	324021	75181.8	13.063
33	1417.79	74.7211	294549	68343.5	13.0631
34	1445.68	74.4421	266657	61871.7	13.063
35	1473.57	74.1632	240343	55766.3	13.0631
36	1501.47	73.8843	215609	50027.2	13.063
37	1529.36	73.6054	192453	44654.5	13.0631
38	1557.25	73.3264	170877	39648.1	13.063
39	1585.14	73.0475	150879	35008	13.063
40	1613.04	72.7686	132461	30734.5	13.063
41	1640.93	72.4897	115627	26828.7	13.0631
42	1668.82	72.2107	100380	23291	13.0631
43	1696.71	71.9318	86718.9	20121.2	13.0631
44	1724.61	71.6529	74643.6	17319.4	13.0631
45	1734.65	75	57742.4	13397.8	13.063
46	1763.46	84.6052	21487.2	4985.62	13.063
47	1792.28	94.2104	2810.92	652.212	13.0631
48	1792.8	94.2789	2724.34	632.122	13.0631
49	1797.42	94.885	1248.21	289.62	13.0631
50	1801.55	95.4276	297.411	69.0075	13.063
51	1806.95	96.1368	0	0	0

List Of Coordinates

Water Table

X	Y
0	75
3000	75

Piezoline

X	Y
0	91.999
51.9097	91.48
307.789	88.9212
405.694	87.9422
462.77	87.3714
636.677	85.6323
735.913	84.64
777.779	84.2213
839.373	83.6054
866.217	83.3369
935.094	82.6482
1183.82	80.1609
1724.12	74.7579
1788.91	96.3553
1845.73	86.5326

Block Search Polyline

X	Y
382.556	85.0734
405.663	84.8423
462.739	84.2716
636.646	82.5325
735.882	81.5401
777.748	81.1215
839.342	80.5055
866.186	80.2371
935.063	79.5483
1183.79	77.0611
1724.61	71.6529
1801.87	97.4066

External Boundary

X	Y
1810.42	95.2692
1803.49	97
596.097	398.849
338	400
0	400
0	396.5
0	91.999
0	90.9991
0	88.999
0	88.799
0	60
0	42
0	-465.592
3000	-465.592
3000	42
3000	60
3000	92.0955
1882.09	92.0957
1868.23	92.2153
1851.73	86.5326
1845.73	86.5326
1820.33	95
1820.14	95.1014

Material Boundary

X	Y
0	90.9991
51.8997	90.4801
307.779	87.9213
405.684	86.9422
462.76	86.3715
636.667	84.6324
735.903	83.64
777.769	83.2214
839.363	82.6054
866.207	82.337
935.084	81.6482
1183.81	79.161
1724.28	73.7563
1790.72	95.9035
1788.91	96.3553
593.181	395.288
337.5	396.5
0	396.5

Material Boundary

X	Y
0	91.999
51.9097	91.48
307.789	88.9212
405.694	87.9422
462.77	87.3714
636.677	85.6323
735.913	84.64
777.779	84.2213
839.373	83.6054
866.217	83.3369
935.094	82.6482
1183.82	80.1609
1724.12	74.7579
1788.91	96.3553

Material Boundary

X	Y
0	88.999
51.8797	88.4802
307.759	85.9214
405.664	84.9423
462.74	84.3716
636.647	82.6325
735.883	81.6401
777.749	81.2215
839.343	80.6055
866.187	80.3371
935.064	79.6483
1183.79	77.1611
1724.59	71.7531
1795.92	95.5281

Material Boundary

X	Y
0	88.799
51.8777	88.2802
307.757	85.7214
405.662	84.7423
462.738	84.1716
636.645	82.4325
735.881	81.4402
777.747	81.0215
839.341	80.4056
866.185	80.1371
935.062	79.4483
1183.79	76.9611
1724.62	71.5527
1796.52	95.5174

Material Boundary

X	Y
1790.72	95.9035
1791.96	95.5987
1795.92	95.5281
1796.52	95.5174
1810.42	95.2692

Material Boundary

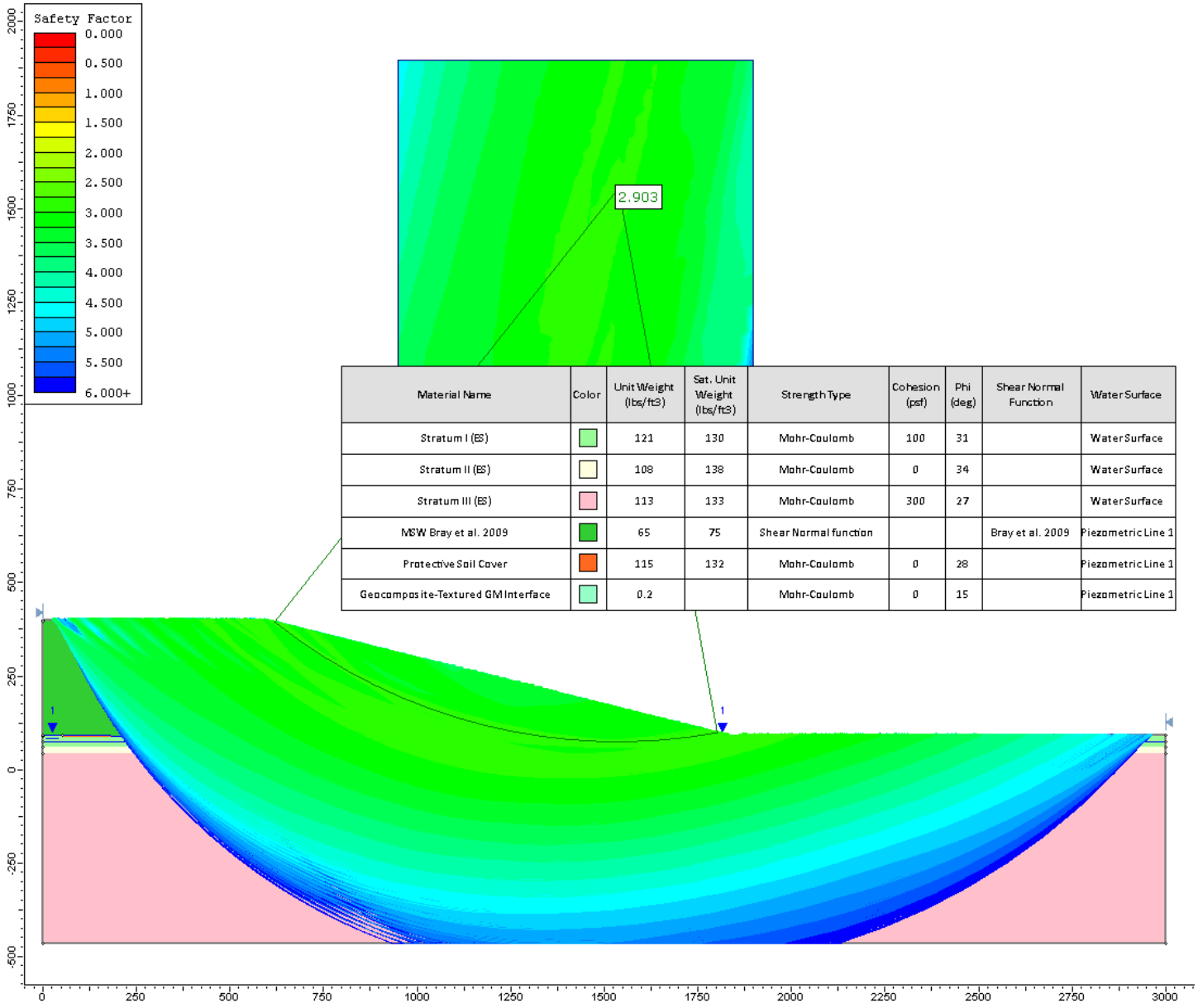
X	Y
0	60
3000	60

Material Boundary

X	Y
0	42
3000	42

APPENDIX III3B-2D-2

SECTION 1 - CIRCULAR FAILURE



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Water Surface
Stratum I (ES)		121	130	Mohr-Coulomb	100	31		Water Surface
Stratum II (ES)		108	138	Mohr-Coulomb	0	34		Water Surface
Stratum III (ES)		113	133	Mohr-Coulomb	300	27		Water Surface
MSW Bray et al. 2009		65	75	Shear Normal function			Bray et al. 2009	Piezometric Line 1
Protective Soil Cover		115	132	Mohr-Coulomb	0	28		Piezometric Line 1
Geocomposite-Textured GM Interface		0.2		Mohr-Coulomb	0	15		Piezometric Line 1

FIGURE **III3B-2D-2**

Section 1 - Circular Failure

Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-2D, Final Filled Configuration Stability Analysis

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	Final Configuration 4h1v - Circular.slim
Slide Modeler Version:	7.014
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	2/5/2016, 4:49:10 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed: 10116
Random Number Generation Method: Park and Miller v.3

Surface Options

Surface Type: Circular
Search Method: Grid Search
Radius Increment: 10
Composite Surfaces: Enabled
Reverse Curvature: Create Tension Crack
Minimum Elevation: Not Defined
Minimum Depth: Not Defined
Minimum Area: Not Defined
Minimum Weight: Not Defined

Seismic

Advanced seismic analysis: No
Staged pseudostatic analysis: No

Material Properties

Property	Stratum I (ES)	Stratum II (ES)	Stratum III (ES)	MSW Bray et al. 2009	Protective Soil Cover	Geocomposite-Textured GM Interface
Color						
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Shear Normal function	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113	65	115	
Saturated Unit Weight [lbs/ft3]	130	138	133	75	132	
Cohesion [psf]	100	0	300		0	0
Friction Angle [deg]	31	34	27		28	15
Water Surface	Water Table	Water Table	Water Table	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	Automatically Calculated	1	1	Automatically Calculated	Automatically Calculated	Automatically Calculated

Shear Normal Functions

Name: Bray et al. 2009

Normal (psf)	Shear (psf)
0	310
600	810
5200	3840
6300	4480
7300	5120
8400	5740
16700	10550

Global Minimums

Method: spencer

FS	2.903360
Center:	1536.951, 1554.645
Radius:	1481.238
Left Slip Surface Endpoint:	617.172, 393.581
Right Slip Surface Endpoint:	1802.139, 97.339
Resisting Moment:	7.18697e+009 lb-ft
Driving Moment:	2.4754e+009 lb-ft
Resisting Horizontal Force:	4.61766e+006 lb
Driving Horizontal Force:	1.59045e+006 lb
Total Slice Area:	108228 ft2
Surface Horizontal Width:	1184.97 ft
Surface Average Height:	91.3345 ft

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 28602
Number of Invalid Surfaces: 9

Error Codes:

Error Code -108 reported for 9 surfaces

Error Codes

The following errors were encountered during the computation:

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).

Slice Data

Global Minimum Query (spencer) - Safety Factor: 2.90336

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	7.99568	1972.6	-38.189	Protective Soil Cover	0	28	35.1672	102.103	192.028	-19008.2	192.028
2	26.6083	24933.9	-37.345	MSW Bray et al. 2009	414.783	33.3727	293.316	851.602	663.157	-18189.4	663.157
3	26.6083	47741.6	-36.061	MSW Bray et al. 2009	414.783	33.3727	447.668	1299.74	1343.5	-16968.1	1343.5
4	26.6083	68982.8	-34.7977	MSW Bray et al. 2009	414.783	33.3727	595.053	1727.65	1993.13	-15803.4	1993.13
5	26.6083	88729.7	-33.5535	MSW Bray et al. 2009	414.783	33.3727	735.487	2135.38	2612.14	-14692.6	2612.14
6	26.6083	107047	-32.3269	MSW Bray et al. 2009	414.783	33.3727	868.998	2523.01	3200.61	-13633.3	3200.61
7	26.6083	123993	-31.1168	MSW Bray et al. 2009	414.783	33.3727	995.603	2890.59	3758.66	-12623.5	3758.66
8	26.6083	139621	-29.9219	MSW Bray et al. 2009	414.783	33.3727	1115.32	3238.17	4286.32	-11661.3	4286.32
9	26.6083	153978	-28.7412	MSW Bray et al. 2009	414.783	33.3727	1228.16	3565.79	4783.7	-10744.9	4783.7
10	26.6083	167108	-27.5737	MSW Bray et al. 2009	814.545	30.1916	1332.9	3869.88	5251.35	-9872.79	5251.35
11	26.6083	179051	-26.4185	MSW Bray et al. 2009	814.545	30.1916	1420.96	4125.55	5690.78	-9043.52	5690.78

12	26.6083	189841	-25.2748	MSW Bray et al. 2009	814.545	30.1916	1502.84	4363.27	6099.38	-8255.79	6099.38
13	26.6083	199514	-24.1417	MSW Bray et al. 2009	448	32.6192	1581.95	4592.97	6476.52	-7508.41	6476.52
14	26.6083	208098	-23.0186	MSW Bray et al. 2009	448	32.6192	1658.22	4814.42	6822.52	-6800.3	6822.52
15	26.6083	215621	-21.9048	MSW Bray et al. 2009	448	32.6192	1727.8	5016.42	7138.15	-6130.45	7138.15
16	26.6083	222109	-20.7996	MSW Bray et al. 2009	1005.45	29.4072	1787.48	5189.71	7423.67	-5497.96	7423.67
17	26.6083	227584	-19.7025	MSW Bray et al. 2009	1005.45	29.4072	1837.03	5333.55	7678.87	-4901.98	7678.87
18	26.6083	232068	-18.6128	MSW Bray et al. 2009	1005.45	29.4072	1880.55	5459.9	7903.05	-4341.76	7903.05
19	26.6083	235581	-17.5301	MSW Bray et al. 2009	1005.45	29.4072	1918.03	5568.72	8096.1	-3816.59	8096.1
20	26.6083	238140	-16.4538	MSW Bray et al. 2009	1005.45	29.4072	1949.44	5659.92	8257.94	-3325.83	8257.94
21	26.6083	239762	-15.3835	MSW Bray et al. 2009	1005.45	29.4072	1974.75	5733.41	8388.34	-2868.89	8388.34
22	26.6083	240461	-14.3186	MSW Bray et al. 2009	872.048	30.0931	1994.41	5790.49	8487.13	-2445.22	8487.13
23	26.6083	240251	-13.2588	MSW Bray et al. 2009	872.048	30.0931	2007.78	5829.3	8554.1	-2054.35	8554.1
24	26.6083	239144	-12.2035	MSW Bray et al. 2009	872.048	30.0931	2014.74	5849.53	8589	-1695.83	8589
25	26.6083	237152	-11.1525	MSW Bray et al. 2009	872.048	30.0931	2015.25	5851	8591.54	-1369.26	8591.54
26	26.6083	234284	-10.1052	MSW Bray et al. 2009	872.048	30.0931	2009.23	5833.51	8561.34	-1074.28	8561.34
27	26.6083	230549	-9.06135	MSW Bray et al. 2009	872.048	30.0931	1996.6	5796.86	8498.13	-810.552	8498.13
28	26.6083	225956	-8.02051	MSW Bray et al. 2009	872.048	30.0931	1977.29	5740.8	8401.37	-577.803	8401.37
29	26.6083	220512	-6.98234	MSW Bray et al. 2009	1005.45	29.4072	1951.93	5667.16	8270.77	-375.777	8270.77
30	26.6083	214221	-5.94646	MSW Bray et al. 2009	1005.45	29.4072	1919.9	5574.17	8105.8	-204.254	8105.8
31	26.6083	207091	-4.91253	MSW Bray et al. 2009	1005.45	29.4072	1881.1	5461.52	7905.91	-63.0461	7905.91
32	16.3069	123058	-4.07982	MSW Bray et al. 2009	1005.45	29.4072	1839.03	5339.36	7720.37	31.1984	7689.18
33	28.5578	208605	-3.21044	Protective Soil Cover	0	28	1345.2	3905.61	7448.84	103.46	7345.38
34	24.2438	170086	-2.188	Protective Soil Cover	0	28	1289.4	3743.6	7206.53	165.857	7040.67
35	12.7372	86300.8	-1.47234	Geocomposite-Textured GM Interface	0	15	615.597	1787.3	6863.71	193.43	6670.28
36	33.7597	216630	-0.572939	Geocomposite-Textured GM Interface	0	15	584.585	1697.26	6533.94	199.67	6334.27
37	12.7412	77186.4	0.326464	Geocomposite-Textured GM Interface	0	15	554.42	1609.68	6200.84	193.43	6007.41
38	26.4208	150743	1.08398	Protective Soil Cover	0	28	1069.94	3106.41	6005.67	163.352	5842.32
39	26.4208	136483	2.10641	Protective Soil Cover	0	28	985.593	2861.53	5482.73	100.955	5381.77
40	1.01952	4965.06	2.6375	MSW Bray et al. 2009	814.545	30.1916	1331.2	3864.97	5303.53	60.6137	5242.92
41	15.3073	72096	2.95368	MSW Bray et al. 2009	414.783	33.3727	1304.11	3786.3	5147.89	29.4152	5118.47
42	26.6102	114071	3.76591	MSW Bray et al. 2009	414.783	33.3727	1215.3	3528.46	4727.05	-62.9443	4727.05
43	26.6102	99117.4	4.79815	MSW Bray et al. 2009	414.783	33.3727	1085.34	3151.14	4154.2	-203.873	4154.2
44	26.6102	83328.4	5.83197	MSW Bray et al. 2009	414.783	33.3727	945.075	2743.89	3535.94	-374.952	3535.94
45	26.6102	66699.4	6.86769	MSW Bray et al. 2009	414.783	33.3727	794.164	2305.74	2870.77	-576.332	2870.77
46	26.6102	49225.2	7.90567	MSW Bray et al. 2009	414.783	33.3727	632.241	1835.62	2157.04	-408.197	2157.04
47	26.6102	30900	8.94627	MSW Bray et al. 2009	414.783	33.3727	458.904	1332.36	1393.02	-131.443	1393.02
48	6.41488	4628.32	9.5931	MSW Bray et al. 2009	414.783	33.3727	338.987	984.201	894.062	29.5989	864.463
49	5.82932	3299.59	9.83335	Protective Soil Cover	0	28	105.074	305.068	634.887	61.1368	573.75
50	9.30263	2133.09	10.1305	Protective Soil Cover	0	28	47.3941	137.602	258.793	-99.0713	258.793

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 2.90336

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	617.172	393.581	0	0	0
2	625.167	387.291	926.561	219.343	13.3183
3	651.776	366.988	6585.72	1559.02	13.3183
4	678.384	347.613	20704.3	4901.29	13.3183
5	704.992	329.121	41726.6	9877.85	13.3183
6	731.601	311.474	68253	16157.4	13.3183
7	758.209	294.635	99023.2	23441.5	13.3183
8	784.817	278.573	132901	31461.5	13.3184
9	811.425	263.259	168864	39974.8	13.3183
10	838.034	248.667	205990	48763.5	13.3183
11	864.642	234.772	243489	57640.6	13.3183
12	891.25	221.553	280905	66498.1	13.3183
13	917.858	208.989	317544	75171.6	13.3183
14	944.467	197.064	352686	83490.7	13.3183
15	971.075	185.759	385689	91303.3	13.3183
16	997.683	175.06	416084	98498.7	13.3183
17	1024.29	164.953	443554	105002	13.3184
18	1050.9	155.424	467839	110751	13.3184
19	1077.51	146.463	488621	115670	13.3183
20	1104.12	138.058	505630	119697	13.3184
21	1130.72	130.2	518651	122779	13.3183
22	1157.33	122.879	527514	124877	13.3183
23	1183.94	116.087	532084	125959	13.3183
24	1210.55	109.817	532290	126008	13.3183
25	1237.16	104.063	528105	125017	13.3183
26	1263.77	98.8172	519549	122992	13.3184
27	1290.37	94.075	506683	119946	13.3183
28	1316.98	89.8315	489617	115906	13.3183
29	1343.59	86.0822	468501	110907	13.3183
30	1370.2	82.8235	443514	104992	13.3183
31	1396.81	80.052	414891	98216.3	13.3183
32	1423.42	77.765	382917	90647	13.3183
33	1439.72	76.6018	361906	85673.3	13.3183
34	1468.28	75	335420	79403.3	13.3183
35	1492.52	74.0737	310834	73583.1	13.3183
36	1505.26	73.7464	305240	72258.8	13.3183
37	1539.02	73.4088	287709	68108.8	13.3183
38	1551.76	73.4814	280195	66329.9	13.3183
39	1578.18	73.9813	248923	58926.9	13.3183
40	1604.6	74.953	217553	51500.9	13.3183
41	1605.62	75	215947	51120.7	13.3183
42	1620.93	75.7898	191918	45432.3	13.3183
43	1647.54	77.5414	151297	35816.3	13.3184
44	1674.15	79.775	113136	26782.3	13.3183
45	1700.76	82.493	78375.2	18553.6	13.3183
46	1727.37	85.698	48040.6	11372.6	13.3184
47	1753.98	89.3931	23245.2	5502.78	13.3183
48	1780.59	93.5822	5197.62	1230.42	13.3183
49	1787.01	94.6664	2053.62	486.149	13.3183
50	1792.84	95.6768	799.599	189.287	13.3183
51	1802.14	97.3389	0	0	0

List Of Coordinates

Water Table

X	Y
0	75
3000	75

Piezoline

X	Y
0	91.999
51.9097	91.48
307.789	88.9212
405.694	87.9422
462.77	87.3714
636.677	85.6323
735.913	84.64
777.779	84.2213
839.373	83.6054
866.217	83.3369
935.094	82.6482
1183.82	80.1609
1724.12	74.7579
1788.91	96.3553
1845.73	86.5326

External Boundary

X	Y
1810.42	95.2692
1803.49	97
596.097	398.849
339	400
0	400
0	396.5
0	91.999
0	90.9991
0	88.999
0	88.799
0	60
0	42
0	-465.592
3000	-465.592
3000	42
3000	60
3000	92.0955
1882.09	92.0957
1868.23	92.2153
1851.73	86.5326
1845.73	86.5326
1820.33	95
1820.14	95.1014

Material Boundary

X	Y
0	90.9991
51.8997	90.4801
307.779	87.9213
405.684	86.9422
462.76	86.3715
636.667	84.6324
735.903	83.64
777.769	83.2214
839.363	82.6054
866.207	82.337
935.084	81.6482
1183.81	79.161
1724.28	73.7563
1790.72	95.9035
1788.91	96.3553
593.181	395.288
339	396.5
0	396.5

Material Boundary

X	Y
0	91.999
51.9097	91.48
307.789	88.9212
405.694	87.9422
462.77	87.3714
636.677	85.6323
735.913	84.64
777.779	84.2213
839.373	83.6054
866.217	83.3369
935.094	82.6482
1183.82	80.1609
1724.12	74.7579
1788.91	96.3553

Material Boundary

X	Y
0	88.999
51.8797	88.4802
307.759	85.9214
405.664	84.9423
462.74	84.3716
636.647	82.6325
735.883	81.6401
777.749	81.2215
839.343	80.6055
866.187	80.3371
935.064	79.6483
1183.79	77.1611
1724.59	71.7531
1795.92	95.5281

Material Boundary

X	Y
0	88.799
51.8777	88.2802
307.757	85.7214
405.662	84.7423
462.738	84.1716
636.645	82.4325
735.881	81.4402
777.747	81.0215
839.341	80.4056
866.185	80.1371
935.062	79.4483
1183.79	76.9611
1724.62	71.5527
1796.52	95.5174

Material Boundary

X	Y
1790.72	95.9035
1791.96	95.5987
1795.92	95.5281
1796.52	95.5174
1810.42	95.2692

Material Boundary

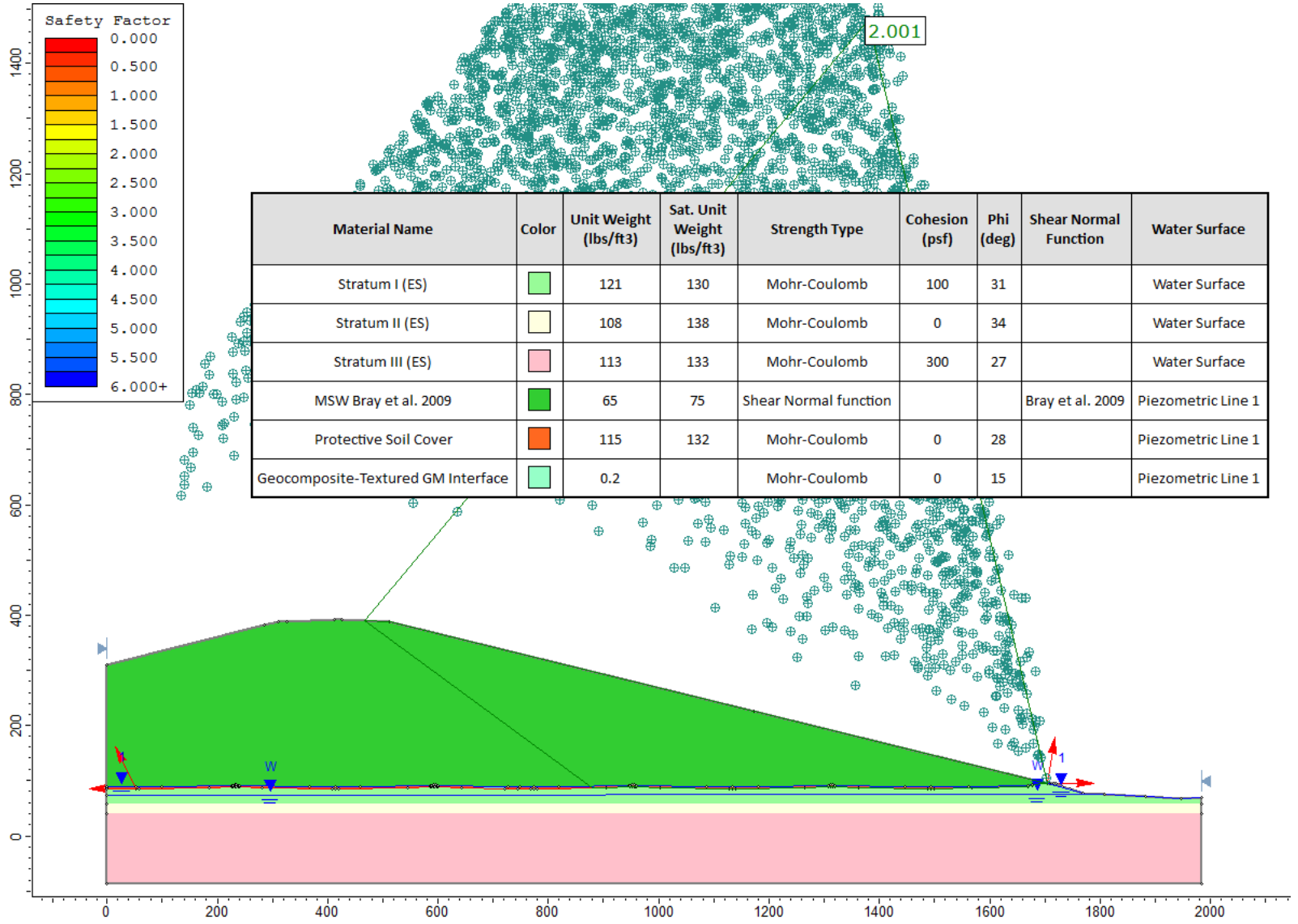
X	Y
0	60
3000	60

Material Boundary

X	Y
0	42
3000	42

APPENDIX III3B-2D-3

SECTION 2 - BLOCK FAILURE



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Water Surface
Stratum I (ES)		121	130	Mohr-Coulomb	100	31		Water Surface
Stratum II (ES)		108	138	Mohr-Coulomb	0	34		Water Surface
Stratum III (ES)		113	133	Mohr-Coulomb	300	27		Water Surface
MSW Bray et al. 2009		65	75	Shear Normal function			Bray et al. 2009	Piezometric Line 1
Protective Soil Cover		115	132	Mohr-Coulomb	0	28		Piezometric Line 1
Geocomposite-Textured GM Interface		0.2		Mohr-Coulomb	0	15		Piezometric Line 1

FIGURE **III3B-2D-3**

Section 2 - Block Failure

Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-2D, Final Filled Configuration Stability Analysis

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	Final Configuration_Section 2 - Block.slim
Slide Modeler Version:	7.011
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	2/28/2017, 3:08:43 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical

Analysis Methods Used
Spencer

Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Surface Type:	Non-Circular Block Search
Number of Surfaces:	5000
Multiple Groups:	Disabled
Pseudo-Random Surfaces:	Enabled
Convex Surfaces Only:	Disabled
Left Projection Angle (Start Angle):	115
Left Projection Angle (End Angle):	180
Right Projection Angle (Start Angle):	80
Right Projection Angle (End Angle):	0
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Material Properties

Property	Stratum I (ES)	Stratum II (ES)	Stratum III (ES)	MSW Bray et al. 2009	Protective Soil Cover	Geocomposite-Textured GM Interface
Color						
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Shear Normal function	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113	65	115	
Saturated Unit Weight [lbs/ft3]	130	138	133	75	132	
Cohesion [psf]	100	0	300		0	0
Friction Angle [deg]	31	34	27		28	15
Water Surface	Water Table	Water Table	Water Table	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	Automatically Calculated	1	1	Automatically Calculated	Automatically Calculated	Automatically Calculated

Shear Normal Functions

Name: Bray et al. 2009

Normal (psf)	Shear (psf)
0	310
600	810
5200	3840
6300	4480
7300	5120
8400	5740
16700	10550

Global Minimums

Method: spencer

FS	2.001160
Axis Location:	1380.587, 1480.007
Left Slip Surface Endpoint:	467.052, 390.350
Right Slip Surface Endpoint:	1704.193, 95.385
Resisting Moment:	4.98787e+009 lb-ft
Driving Moment:	2.49249e+009 lb-ft
Resisting Horizontal Force:	3.16638e+006 lb
Driving Horizontal Force:	1.58227e+006 lb
Total Slice Area:	135472 ft2
Surface Horizontal Width:	1237.14 ft
Surface Average Height:	109.504 ft

Global Minimum Coordinates

Method: spencer

X	Y
467.052	390.35
879.49	87.1824
904.648	87.6181
946.899	88.3499
948.215	88.7886
952.187	89.9761
954.779	89.9761
958.344	88.7886
959.66	88.3499
1001.91	87.6181
1127.49	85.4431
1133.28	85.3428
1139.07	85.4431
1264.65	87.6181
1306.9	88.3499
1308.22	88.7886
1312.19	89.9761
1314.78	89.9761
1318.34	88.7886
1319.66	88.3499
1361.91	87.6181
1487.49	85.4431
1493.28	85.3428
1499.07	85.4431
1567.69	86.6315
1670.08	88.405
1676.8	90.6076
1685.65	93.5082
1690.5	95.1
1703.32	95.3342
1704.19	95.3848

Slice Data

Global Minimum Query (spencer) - Safety Factor: 2.00116

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	40.8583	37591.9	-36.3182	MSW Bray et al. 2009	414.783	33.3727	408.098	816.669	610.124	-17828.9	610.124
2	40.8583	103824	-36.3182	MSW Bray et al. 2009	414.783	33.3727	806.968	1614.87	1821.92	-15911.2	1821.92
3	40.8583	157023	-36.3182	MSW Bray et al. 2009	414.783	33.3727	1127.35	2256	2795.24	-13993.5	2795.24
4	40.8583	210111	-36.3182	MSW Bray et al. 2009	414.783	33.3727	1447.06	2895.79	3766.55	-12112.1	3766.55
5	40.8583	263199	-36.3182	MSW Bray et al. 2009	414.783	33.3727	1766.77	3535.59	4737.85	-10282.7	4737.85
6	40.8583	316287	-36.3182	MSW Bray et al. 2009	814.545	30.1916	2069.17	4140.74	5716.91	-8453.37	5716.91
7	40.8583	369375	-36.3182	MSW Bray et al. 2009	448	32.6192	2365.92	4734.58	6697.78	-6624	6697.78
8	40.8583	422463	-36.3182	MSW Bray et al. 2009	1005.45	29.4072	2665.1	5333.29	7678.43	-4794.17	7678.43
9	40.8583	475551	-36.3182	MSW Bray et al. 2009	872.048	30.0931	2945.52	5894.45	8666.5	-2876.5	8666.5
10	40.8583	528639	-36.3182	MSW Bray et al. 2009	872.048	30.0931	3231.05	6465.86	9652.52	-958.834	9652.52
11	1.32911	18088.1	-36.3182	MSW Bray et al. 2009	872.048	30.0931	3370.43	6744.78	10165	31.1906	10133.8
12	2.52545	34643.1	-36.3182	Protective Soil Cover	0	28	2762.49	5528.18	10518.7	121.647	10397
13	25.1578	341617	0.992293	Geocomposite-Textured GM Interface	0	15	1865.05	3732.26	14109.9	180.912	13929
14	42.2505	549362	0.992293	Geocomposite-Textured GM Interface	0	15	1784.81	3571.69	13510.6	180.912	13329.7
15	1.31666	16618.5	18.4272	Geocomposite-Textured GM Interface	0	15	1972.7	3947.68	14901.9	168.955	14733
16	3.97172	49746.9	16.6463	Geocomposite-Textured GM Interface	0	15	1928.59	3859.42	14575	171.408	14403.5
17	2.59243	32224.9	0	Geocomposite-Textured GM Interface	0	15	1693.75	3389.47	12830.9	181.163	12649.7
18	3.56415	44283.9	-18.4272	Geocomposite-Textured GM Interface	0	15	1501.53	3004.8	11383	168.955	11214
19	1.31666	16377.8	-18.4272	Geocomposite-Textured GM Interface	0	15	1503.25	3008.25	11395.9	168.955	11227
20	42.2505	512223	-0.992293	Geocomposite-Textured GM Interface	0	15	1640.39	3282.69	12432.1	180.912	12251.2
21	41.8586	481325	-0.992293	Geocomposite-Textured GM Interface	0	15	1554.59	3110.98	11791.3	180.912	11610.3

22	41.8586	455301	-0.992293	Geocomposite-Textured GM Interface	0	15	1469.19	2940.08	11153.4	180.912	10972.5
23	41.8586	429277	-0.992293	Geocomposite-Textured GM Interface	0	15	1383.79	2769.18	10515.7	180.912	10334.7
24	5.79298	57359.5	-0.992292	Geocomposite-Textured GM Interface	0	15	1335.18	2671.91	10152.6	180.912	9971.69
25	5.79298	56823.3	0.992293	Geocomposite-Textured GM Interface	0	15	1340.29	2682.13	10190.7	180.912	10009.8
26	41.8586	393532	0.992293	Geocomposite-Textured GM Interface	0	15	1283.56	2568.61	9767.1	180.912	9586.19
27	41.8586	363563	0.992293	Geocomposite-Textured GM Interface	0	15	1183.9	2369.18	9022.82	180.912	8841.91
28	41.8586	333594	0.992293	Geocomposite-Textured GM Interface	0	15	1084.25	2169.75	8278.52	180.912	8097.61
29	42.2505	306328	0.992293	Geocomposite-Textured GM Interface	0	15	984.124	1969.39	7530.77	180.912	7349.86
30	1.31666	9044.74	18.4272	Geocomposite-Textured GM Interface	0	15	1062.42	2126.07	8103.57	168.955	7934.62
31	3.97172	26900.7	16.6463	Geocomposite-Textured GM Interface	0	15	1031.47	2064.13	7874.85	171.408	7703.45
32	2.59244	17312.7	0	Geocomposite-Textured GM Interface	0	15	898.369	1797.78	6890.55	181.163	6709.39
33	3.56415	23782.1	-18.4272	Geocomposite-Textured GM Interface	0	15	796.028	1592.98	6114.04	168.955	5945.09
34	1.31666	8804.07	-18.4272	Geocomposite-Textured GM Interface	0	15	797.757	1596.44	6126.94	168.955	5957.98
35	42.2505	269189	-0.992293	Geocomposite-Textured GM Interface	0	15	850.237	1701.46	6530.87	180.912	6349.95
36	41.8586	240545	-0.992293	Geocomposite-Textured GM Interface	0	15	764.432	1529.75	5890.03	180.912	5709.12
37	41.8586	214521	-0.992293	Geocomposite-Textured GM Interface	0	15	679.031	1358.85	5252.21	180.912	5071.3
38	41.8586	188498	-0.992293	Geocomposite-Textured GM Interface	0	15	593.631	1187.95	4614.42	180.912	4433.51
39	5.79298	24037	-0.992292	Geocomposite-Textured GM Interface	0	15	545.024	1090.68	4251.37	180.912	4070.46
40	5.79298	23500.8	0.992293	Geocomposite-Textured GM Interface	0	15	539.607	1079.84	4210.91	180.912	4030
41	34.3067	127409	0.992293	Geocomposite-Textured GM Interface	0	15	491.869	984.309	3854.41	180.912	3673.5
42	34.3067	107278	0.992293	Geocomposite-Textured GM Interface	0	15	410.191	820.858	3244.39	180.912	3063.48
43	51.1954	122655	0.992293	Geocomposite-Textured GM Interface	0	15	308.408	617.174	2484.23	180.912	2303.32
44	51.1954	77826.2	0.992293	Geocomposite-Textured GM Interface	0	15	186.523	373.262	1573.95	180.912	1393.03
45	6.72006	6467.83	18.1472	Geocomposite-Textured GM Interface	0	15	127.244	254.635	1119.81	169.502	950.308
46	8.84973	5948.98	18.1472	Geocomposite-Textured GM Interface	0	15	81.4193	162.933	777.577	169.502	608.075
47	4.85668	2022.98	18.1472	Geocomposite-Textured GM Interface	0	15	41.0513	82.1502	476.091	169.502	306.589
48	10.3304	2300.84	1.04667	Geocomposite-Textured GM Interface	0	15	19.5721	39.167	228.697	82.5231	146.174
49	2.48998	143.582	1.04667	Geocomposite-Textured GM Interface	0	15	8.02949	16.0683	59.9676	-19.8908	59.9676
50	0.869334	6.5728	3.32724	Geocomposite-Textured GM Interface	0	15	2.90588	5.81513	21.7023	-47.7418	21.7023

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 2.00116

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	467.052	390.35	0	0	0
2	507.911	360.316	1658.78	392.156	13.3012
3	548.769	330.283	23423.4	5537.57	13.3012
4	589.627	300.249	61337.2	14500.8	13.3012
5	630.486	270.216	115367	27274	13.3011
6	671.344	240.183	185512	43857.2	13.3012
7	712.202	210.149	272712	64472.3	13.3012
8	753.061	180.116	377253	89187	13.3012
9	793.919	150.082	499028	117976	13.3012
10	834.777	120.049	639028	151074	13.3012
11	875.636	90.0157	796981	188416	13.3012
12	876.965	89.0388	802435	189705	13.3012
13	879.49	87.1824	814988	192673	13.3012
14	904.648	87.6181	761944	180133	13.3012
15	946.899	88.3499	676688	159977	13.3012
16	948.215	88.7886	667555	157818	13.3012
17	952.187	89.9761	642591	151916	13.3012
18	954.779	89.9761	638202	150879	13.3012
19	958.344	88.7886	646371	152810	13.3012
20	959.66	88.3499	649392	153524	13.3012
21	1001.91	87.6181	589219	139298	13.3012
22	1043.77	86.8931	532730	125944	13.3012
23	1085.63	86.1681	479351	113324	13.3012
24	1127.49	85.4431	429082	101440	13.3012
25	1133.28	85.3428	422370	99853.4	13.3012
26	1139.07	85.4431	413588	97777	13.3012
27	1180.93	86.1681	352807	83407.8	13.3012
28	1222.79	86.8931	296735	70151.7	13.3012
29	1264.65	87.6181	245372	58008.9	13.3012
30	1306.9	88.3499	198304	46881.4	13.3012
31	1308.22	88.7886	193351	45710.4	13.3012
32	1312.19	89.9761	179905	42531.6	13.3012
33	1314.78	89.9761	177577	41981.3	13.3012
34	1318.34	88.7886	182002	43027.4	13.3012
35	1319.66	88.3499	183640	43414.6	13.3012
36	1361.91	87.6181	152515	36056.4	13.3012
37	1403.77	86.8931	124804	29505.3	13.3013
38	1445.63	86.1681	100204	23689.5	13.3012
39	1487.49	85.4431	78714.3	18609	13.3012
40	1493.28	85.3428	75985.3	17963.8	13.3012
41	1499.07	85.4431	72438.5	17125.3	13.3012
42	1533.38	86.0373	53282.8	12596.7	13.3012
43	1567.69	86.6315	37290.1	8815.83	13.3012
44	1618.88	87.5183	19306.6	4564.32	13.3012
45	1670.08	88.405	8366.94	1978.04	13.3012
46	1676.8	90.6076	5045.84	1192.9	13.3012
47	1685.65	93.5082	2070.24	489.429	13.3012
48	1690.5	95.1	1113.12	263.154	13.3011
49	1700.83	95.2887	867.871	205.175	13.3012
50	1703.32	95.3342	845.16	199.806	13.3012
51	1704.19	95.3848	0	0	0

List Of Coordinates

Water Table

X	Y
0	73.366
1807.73	75.7038
1881.91	71.3276
1946.79	67.5
1984.49	69.7246

Piezoline

X	Y
2.69e-012	89.1657
53.2794	88.2429
99.4967	89.0434
226.556	91.2441
227.88	91.6851
231.464	92.8794
234.601	92.8794
238.679	91.6851
240.002	91.2441
367.062	89.0434
413.279	88.2429
459.497	89.0434
586.556	91.2441
587.88	91.6851
591.957	92.8794
595.094	92.8794
598.679	91.6851
600.002	91.2441
727.062	89.0434
748.551	88.6712
773.279	88.2429
819.497	89.0434
946.556	91.2441
947.88	91.6851
951.957	92.8794
955.094	92.8794
958.679	91.6851
960.002	91.2441
1087.06	89.0434
1133.28	88.2429
1179.5	89.0434
1306.56	91.2441
1307.88	91.6851
1311.96	92.8794
1315.09	92.8794
1318.68	91.6851
1320	91.2441
1447.06	89.0434
1493.28	88.2429
1562.16	89.4359
1669.73	91.2991
1676.47	93.5079
1679.43	94.4781
1690.17	98
1768.81	78

Block Search Polyline

X	Y
53.2794	85.3428
59.0724	85.4431
184.648	87.6181
226.899	88.3499
228.215	88.7886
231.779	89.9761
234.372	89.9761
238.344	88.7886
239.66	88.3499
281.911	87.6181
407.486	85.4431
413.279	85.3428
419.072	85.4431
544.648	87.6181
586.899	88.3499
588.215	88.7886
591.779	89.9761
594.372	89.9761
598.344	88.7886
599.66	88.3499
641.911	87.6181
721.378	86.2417
745.283	85.8277
767.486	85.4431
773.279	85.3428
779.072	85.4431
904.648	87.6181
946.899	88.3499
948.215	88.7886
952.187	89.9761
954.779	89.9761
958.344	88.7886
959.66	88.3499
1001.91	87.6181
1127.49	85.4431
1133.28	85.3428
1139.07	85.4431
1264.65	87.6181
1306.9	88.3499
1308.22	88.7886
1312.19	89.9761
1314.78	89.9761
1318.34	88.7886
1319.66	88.3499
1361.91	87.6181
1487.49	85.4431
1493.28	85.3428
1499.07	85.4431
1567.69	86.6315
1670.08	88.405
1676.8	90.6076
1685.65	93.5082
1690.5	95.1
1704.32	95.3525

External Boundary

X	Y
2.72316e-012	-86.33
1984.49	-86.33
1984.49	39.366
1984.49	57.366
1984.49	69.7246
1946.79	67.5
1881.91	71.3276
1768.81	78
1745.45	85.6583
1731.77	90.1407
1719.51	94.1592
1716.94	95
1708.62	95.1706
1704.74	95.25
1703.98	95.4367
1697.38	97.0585
1172.6	226.062
511.991	388.453
425.63	392.097
411.571	392.691
326.254	388.734
311.15	388.034
285.357	381.585
0	310.246
2.68585e-012	88.1657
2.71e-012	86.3656
2.71427e-012	86.1656
0	57.366
0	39.366

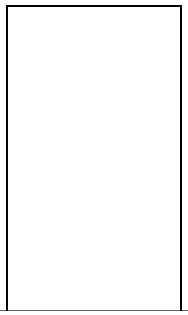
Material Boundary

X	Y
2.68585e-012	88.1657
53.2794	87.2429
99.4967	88.0434
226.556	90.2441
227.88	90.6851
231.464	91.8794
234.601	91.8794
238.679	90.6851
240.002	90.2441
367.062	88.0434
413.279	87.2429
459.497	88.0434
586.556	90.2441
587.88	90.6851
591.957	91.8794
595.094	91.8794
598.679	90.6851
600.002	90.2441
727.062	88.0434
748.551	87.6712
773.279	87.2429
819.497	88.0434
946.556	90.2441
947.88	90.6851
951.957	91.8794
955.094	91.8794
958.679	90.6851
960.002	90.2441
1087.06	88.0434
1133.28	87.2429
1179.5	88.0434
1306.56	90.2441
1307.88	90.6851
1311.96	91.8794
1315.09	91.8794
1318.68	90.6851
1320	90.2441
1447.06	88.0434
1493.28	87.2429
1562.16	88.4359
1669.73	90.2991
1676.47	92.5079
1679.43	93.4781
1690.17	97
1697.38	97.0585

Material Boundary

X	Y
2.71427e-012	86.1656
53.2794	85.2428
59.0724	85.3431
184.648	87.5181
226.899	88.2499
228.215	88.6886
231.779	89.8761
234.372	89.8761
238.344	88.6886
239.66	88.2499
281.911	87.5181
407.486	85.3431
413.279	85.2428
419.072	85.3431
544.648	87.5181
586.899	88.2499
588.215	88.6886
591.779	89.8761
594.372	89.8761
598.344	88.6886
599.66	88.2499
641.911	87.5181
721.378	86.1417
745.283	85.7277
767.486	85.3431
773.279	85.2428
779.072	85.3431
904.648	87.5181
946.899	88.2499
948.215	88.6886
952.187	89.8761
954.779	89.8761
958.344	88.6886
959.66	88.2499
1001.91	87.5181
1127.49	85.3431
1133.28	85.2428
1139.07	85.3431
1264.65	87.5181
1306.9	88.2499
1308.22	88.6886
1312.19	89.8761
1314.78	89.8761
1318.34	88.6886
1319.66	88.2499
1361.91	87.5181
1487.49	85.3431
1493.28	85.2428
1499.07	85.3431
1567.69	86.5315
1670.08	88.305
1676.8	90.5076
1685.65	93.4082
1690.5	95
1704.74	95.25

Material Boundary



X	Y
2.71e-012	86.3656
53.2794	85.4428
59.0724	85.5431
184.648	87.7181
226.899	88.4499
228.215	88.8886
231.779	90.0761
234.372	90.0761
238.344	88.8886
239.66	88.4499
281.911	87.7181
407.486	85.5431
413.279	85.4428
419.072	85.5431
544.648	87.7181
586.899	88.4499
588.215	88.8886
591.779	90.0761
594.372	90.0761
598.344	88.8886
599.66	88.4499
641.911	87.7181
721.378	86.3417
745.283	85.9277
767.486	85.5431
773.279	85.4428
779.072	85.5431
904.648	87.7181
946.899	88.4499
948.215	88.8886
952.187	90.0761
954.779	90.0761
958.344	88.8886
959.66	88.4499
1001.91	87.7181
1127.49	85.5431
1133.28	85.4428
1139.07	85.5431
1264.65	87.7181
1306.9	88.4499
1308.22	88.8886
1312.19	90.0761
1314.78	90.0761
1318.34	88.8886
1319.66	88.4499
1361.91	87.7181
1487.49	85.5431
1493.28	85.4428
1499.07	85.5431
1567.69	86.7315
1670.08	88.505
1676.8	90.7076
1685.65	93.6082
1690.5	95.2
1703.98	95.4367

Material Boundary

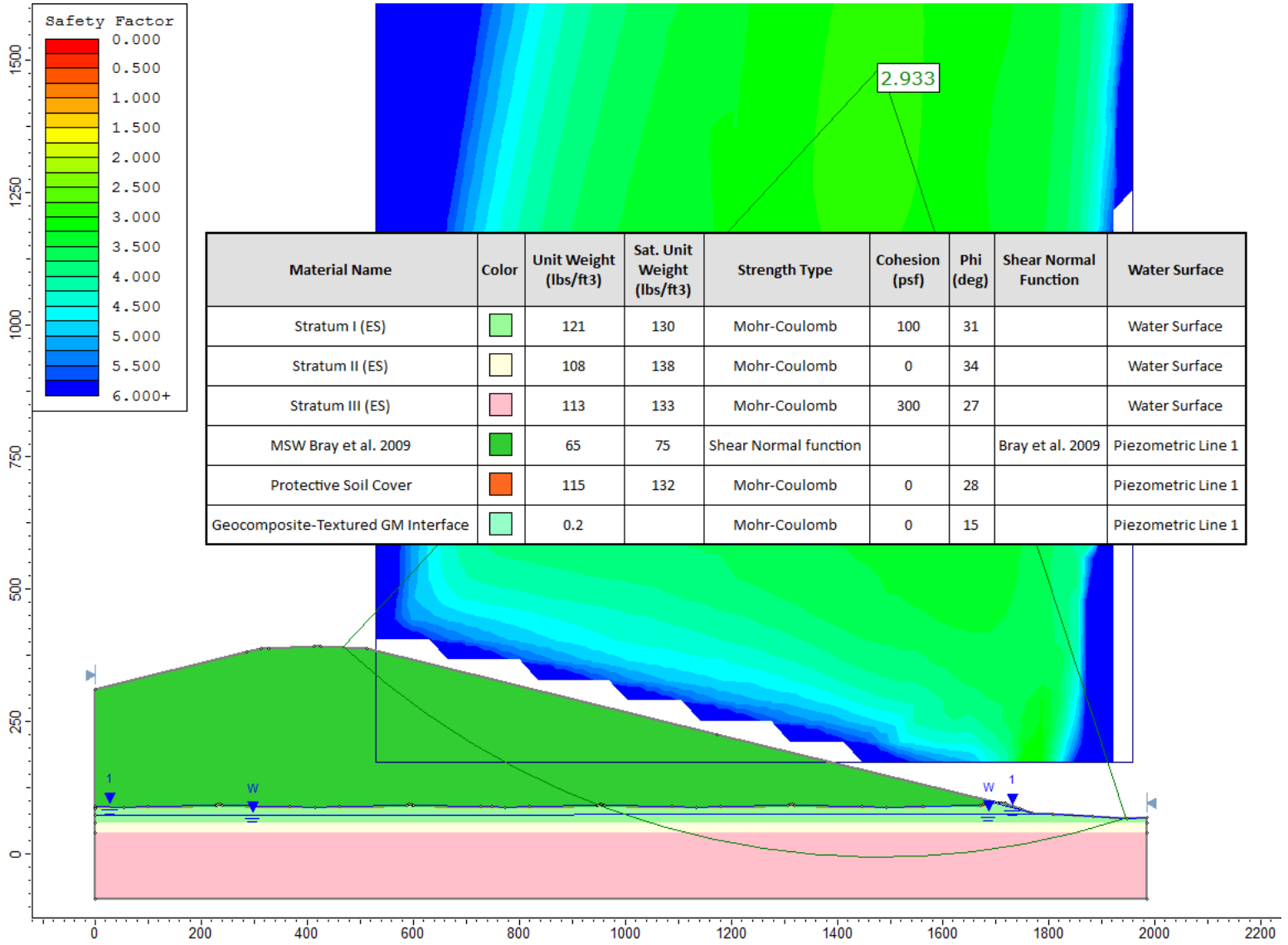
X	Y
0	57.366
1984.49	57.366

Material Boundary

X	Y
0	39.366
1984.49	39.366

APPENDIX III3B-2D-4

SECTION 2 - CIRCULAR FAILURE



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function	Water Surface
Stratum I (ES)		121	130	Mohr-Coulomb	100	31		Water Surface
Stratum II (ES)		108	138	Mohr-Coulomb	0	34		Water Surface
Stratum III (ES)		113	133	Mohr-Coulomb	300	27		Water Surface
MSW Bray et al. 2009		65	75	Shear Normal function			Bray et al. 2009	Piezometric Line 1
Protective Soil Cover		115	132	Mohr-Coulomb	0	28		Piezometric Line 1
Geocomposite-Textured GM Interface		0.2		Mohr-Coulomb	0	15		Piezometric Line 1

FIGURE **III3B-2D-4**

Section 2 - Circular Failure

Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-2D, Final Filled Configuration Stability Analysis

Slide Analysis Information

SLIDE - An Interactive Slope Stability Program

Project Summary

File Name:	Final Configuration_Section 2 - Circular.slim
Slide Modeler Version:	7.011
Project Title:	SLIDE - An Interactive Slope Stability Program
Date Created:	2/28/2017, 3:08:43 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
	Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Advanced Groundwater Method:	None

Random Numbers

Pseudo-random Seed:	10116
Random Number Generation Method:	Park and Miller v.3

Surface Options

Surface Type:	Circular
Search Method:	Grid Search
Radius Increment:	10
Composite Surfaces:	Disabled
Reverse Curvature:	Invalid Surfaces
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis: No
Staged pseudostatic analysis: No

Material Properties

Property	Stratum I (ES)	Stratum II (ES)	Stratum III (ES)	MSW Bray et al. 2009	Protective Soil Cover	Geocomposite-Textured GM Interface
Color						
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Shear Normal function	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113	65	115	
Saturated Unit Weight [lbs/ft3]	130	138	133	75	132	
Cohesion [psf]	100	0	300		0	0
Friction Angle [deg]	31	34	27		28	15
Water Surface	Water Table	Water Table	Water Table	Piezometric Line 1	Piezometric Line 1	Piezometric Line 1
Hu Value	Automatically Calculated	1	1	Automatically Calculated	Automatically Calculated	Automatically Calculated

Shear Normal Functions

Name: Bray et al. 2009

Normal (psf)	Shear (psf)
0	310
600	810
5200	3840
6300	4480
7300	5120
8400	5740
16700	10550

Global Minimums

Method: spencer

FS	2.932690
Center:	1481.284, 1487.204
Radius:	1493.861
Left Slip Surface Endpoint:	467.122, 390.347
Right Slip Surface Endpoint:	1946.212, 67.534
Resisting Moment:	1.22645e+010 lb-ft
Driving Moment:	4.18199e+009 lb-ft
Resisting Horizontal Force:	7.77484e+006 lb
Driving Horizontal Force:	2.6511e+006 lb
Total Slice Area:	196704 ft2
Surface Horizontal Width:	1479.09 ft
Surface Average Height:	132.99 ft

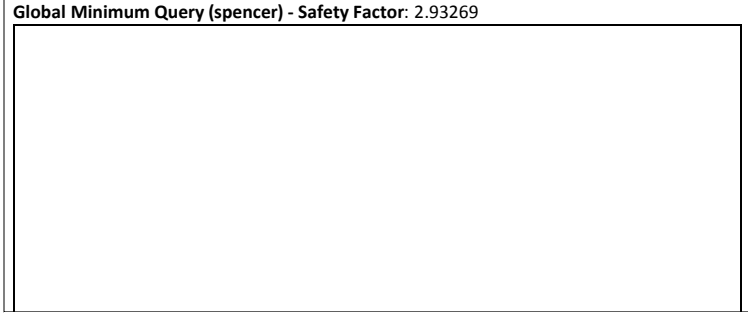
Slice Data

Global Minimum Query (spencer) - Safety Factor: 2.93269

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	32.0637	28601.3	-41.9302	MSW Bray et al. 2009	310	39.8056	275.146	806.919	596.303	-17871.8	596.303
2	32.0637	81671.9	-40.2974	MSW Bray et al. 2009	414.783	33.3727	563.337	1652.09	1878.42	-16090.9	1878.42
3	32.0637	121435	-38.7032	MSW Bray et al. 2009	414.783	33.3727	787.176	2308.54	2875.01	-14406.9	2875.01
4	32.0637	157090	-37.1439	MSW Bray et al. 2009	414.783	33.3727	994.153	2915.54	3796.53	-12813.3	3796.53
5	32.0637	189908	-35.6161	MSW Bray et al. 2009	414.783	33.3727	1190.21	3490.52	4669.44	-11343.9	4669.44
6	32.0637	220052	-34.1169	MSW Bray et al. 2009	814.545	30.1916	1368.42	4013.16	5497.61	-9984.57	5497.61
7	32.0637	247666	-32.6439	MSW Bray et al. 2009	814.545	30.1916	1524.09	4469.68	6282.26	-8701.01	6282.26
8	32.0637	272875	-31.1948	MSW Bray et al. 2009	448	32.6192	1683.31	4936.64	7013.51	-7489.43	7013.51
9	32.0637	295790	-29.7676	MSW Bray et al. 2009	1005.45	29.4072	1822.94	5346.13	7701.22	-6346.52	7701.22
10	32.0637	316509	-28.3605	MSW Bray et al. 2009	1005.45	29.4072	1946.41	5708.21	8343.61	-5269.31	8343.61
11	32.0637	335123	-26.9718	MSW Bray et al. 2009	872.048	30.0931	2063.55	6051.74	8937.93	-4189.21	8937.93
12	32.0637	351708	-25.6	MSW Bray et al. 2009	872.048	30.0931	2171.75	6369.08	9485.53	-3166.46	9485.53
13	32.0637	366336	-24.2438	MSW Bray et al. 2009	872.048	30.0931	2270.81	6659.58	9986.8	-2202.28	9986.8
14	32.0637	379072	-22.9019	MSW Bray et al. 2009	872.048	30.0931	2360.77	6923.4	10442	-1294.77	10442
15	32.0637	389971	-21.5731	MSW Bray et al. 2009	872.048	30.0931	2441.67	7160.66	10851.5	-442.214	10851.5
16	1.48282	18275.4	-20.8815	MSW Bray et al. 2009	872.048	30.0931	2476.15	7261.79	11054.7	28.7348	11025.9
17	2.89988	35935.4	-20.7915	Protective Soil Cover	0	28	2011.7	5899.7	11209.2	113.515	11095.7
18	0.528693	6578.26	-20.7212	Geocomposite-Textured GM Interface	0	15	1028.61	3016.59	11439.2	181.163	11258.1
19	42.1671	545072	-19.8506	Stratum I (ES)	100	31	2433.8	7137.57	11712.5	-476.664	11712.5
20	26.7401	369931	-18.4503	Stratum I (ES)	100	31	2572.13	7543.27	12667.1	279.423	12387.7
21	26.7401	387867	-17.3724	Stratum I (ES)	100	31	2609.98	7654.25	13393.3	820.933	12572.4
22	32.3497	491602	-16.189	Stratum II (ES)	0	34	2932.32	8599.58	14126.7	1377.35	12749.4
23	32.3497	514056	-14.9011	Stratum II (ES)	0	34	2983.33	8749.18	14912.7	1941.56	12971.2
24	30.6624	504394	-13.654	Stratum III (ES)	300	27	2389.17	7006.7	15607.7	2445.08	13162.6
25	30.6624	518896	-12.4467	Stratum III (ES)	300	27	2410.14	7068.18	16174.4	2891.1	13283.3
26	30.6624	531027	-11.2449	Stratum III (ES)	300	27	2426.14	7115.13	16670.4	3294.93	13375.4
27	30.6624	540436	-10.0482	Stratum III (ES)	300	27	2434.99	7141.08	17083.5	3657.13	13426.4
28	30.6624	547157	-8.85592	Stratum III (ES)	300	27	2436.54	7145.62	17413.4	3978.18	13435.3
29	30.6624	551216	-7.66747	Stratum III (ES)	300	27	2430.64	7128.32	17659.8	4258.5	13401.3
30	30.6624	553143	-6.48233	Stratum III (ES)	300	27	2419.99	7097.07	17838.5	4498.47	13340
31	30.6624	549655	-5.29997	Stratum III (ES)	300	27	2385.76	6996.7	17841.4	4698.39	13143
32	30.6624	544035	-4.11987	Stratum III (ES)	300	27	2346.06	6880.26	17773	4858.52	12914.5
33	30.6624	535828	-2.94152	Stratum III (ES)	300	27	2298.05	6739.47	17617.2	4979.06	12638.2
34	30.6624	525043	-1.76442	Stratum III (ES)	300	27	2241.53	6573.7	17373	5060.16	12312.8
35	30.6624	511687	-0.588056	Stratum III (ES)	300	27	2176.26	6382.3	17039.1	5101.92	11937.2
36	30.6624	496101	0.588056	Stratum III (ES)	300	27	2103.99	6170.35	16625.6	5104.4	11521.2
37	30.6624	479294	1.76442	Stratum III (ES)	300	27	2030.47	5954.74	16165.6	5067.58	11098.1
38	30.6624	460056	2.94152	Stratum III (ES)	300	27	1948.4	5714.05	15617.1	4991.43	10625.7
39	30.6624	438240	4.11987	Stratum III (ES)	300	27	1856.64	5444.96	14973.4	4875.84	10097.5
40	30.6624	413837	5.29997	Stratum III (ES)	300	27	1754.87	5146.5	14232.5	4720.66	9511.8
41	30.6624	386833	6.48233	Stratum III (ES)	300	27	1642.73	4817.61	13392	4525.68	8866.32
42	30.6624	362868	7.66747	Stratum III (ES)	300	27	1554.68	4559.38	12650.2	4290.67	8359.51
43	30.6624	335052	8.85592	Stratum III (ES)	300	27	1448.47	4247.9	11763.5	4015.29	7748.18
44	30.6624	284381	10.0482	Stratum III (ES)	300	27	1204.48	3532.36	10043.1	3699.19	6343.86
45	30.6624	229526	11.2449	Stratum III (ES)	300	27	937.163	2748.41	8147.22	3341.95	4805.27
46	30.6624	194388	12.4467	Stratum III (ES)	300	27	798.294	2341.15	6949.05	2943.06	4005.99
47	30.6624	158296	13.654	Stratum III (ES)	300	27	676.781	1984.79	5710.12	2403.53	3306.59
48	32.3497	123951	14.9011	Stratum II (ES)	0	34	579.274	1698.83	4305.18	1786.57	2518.61
49	32.3497	75746.4	16.189	Stratum II (ES)	0	34	355.871	1043.66	2653.17	1105.88	1547.29
50	32.2797	25329.9	17.4841	Stratum I (ES)	100	31	143.28	420.195	908.243	375.349	532.894

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 2.93269



Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	467.122	390.347	0	0	0
2	499.185	361.547	8346.05	1556.35	10.563
3	531.249	334.358	41346.5	7710.19	10.563
4	563.313	308.667	89953.8	16774.4	10.5631
5	595.377	284.379	150270	28022.1	10.5631
6	627.44	261.41	219338	40901.7	10.5631
7	659.504	239.687	294859	54984.6	10.5631
8	691.568	219.147	375002	69929.6	10.5631
9	723.631	199.732	457162	85250.5	10.5631
10	755.695	181.393	539911	100681	10.563
11	787.759	164.085	621879	115967	10.5631
12	819.822	147.768	701520	130818	10.5631
13	851.886	132.405	777566	144999	10.5631
14	883.95	117.966	848917	158304	10.5631
15	916.014	104.42	914622	170557	10.5631
16	948.077	91.7429	973858	181603	10.5631
17	949.56	91.1772	976437	182084	10.5631
18	952.46	90.0761	982942	183297	10.5631
19	952.989	89.8761	984686	183622	10.5631
20	995.156	74.653	1.0603e+006	197723	10.5631
21	1021.9	65.7317	1.10449e+006	205963	10.5631
22	1048.64	57.366	1.1467e+006	213835	10.5631
23	1080.99	47.9742	1.18447e+006	220877	10.563
24	1113.34	39.366	1.21627e+006	226808	10.5631
25	1144	31.9174	1.25923e+006	234818	10.563
26	1174.66	25.1497	1.29475e+006	241442	10.5631
27	1205.32	19.0533	1.32195e+006	246513	10.563
28	1235.98	13.6201	1.34006e+006	249891	10.563
29	1266.65	8.84269	1.3485e+006	251465	10.5631
30	1297.31	4.7147	1.34683e+006	251153	10.563
31	1327.97	1.23074	1.33473e+006	248897	10.563
32	1358.63	-1.61371	1.31228e+006	244712	10.5631
33	1389.3	-3.8223	1.27956e+006	238609	10.563
34	1419.96	-5.39787	1.23681e+006	230638	10.5631
35	1450.62	-6.34242	1.18445e+006	220874	10.5631
36	1481.28	-6.65713	1.12305e+006	209424	10.5631
37	1511.95	-6.34242	1.05327e+006	196411	10.563
38	1542.61	-5.39787	975703	181947	10.5631
39	1573.27	-3.8223	891320	166211	10.563
40	1603.93	-1.61371	801288	149422	10.563
41	1634.6	1.23074	706966	131833	10.563
42	1665.26	4.7147	609910	113735	10.5631
43	1695.92	8.84269	509993	95102.3	10.5631
44	1726.58	13.6201	409355	76335.5	10.563
45	1757.25	19.0533	317835	59269.2	10.5631
46	1787.91	25.1497	239415	44645.6	10.5631
47	1818.57	31.9174	167895	31308.6	10.563
48	1849.23	39.366	104599	19505.3	10.563
49	1881.58	47.9742	48788.5	9097.96	10.5631
50	1913.93	57.366	12351.7	2303.31	10.563
51	1946.21	67.5339	0	0	0

List Of Coordinates

Water Table

X	Y
0	73.366
1807.73	75.7038
1881.91	71.3276
1946.79	67.5
1984.49	69.7246

Piezoline

X	Y
2.69e-012	89.1657
53.2794	88.2429
99.4967	89.0434
226.556	91.2441
227.88	91.6851
231.464	92.8794
234.601	92.8794
238.679	91.6851
240.002	91.2441
367.062	89.0434
413.279	88.2429
459.497	89.0434
586.556	91.2441
587.88	91.6851
591.957	92.8794
595.094	92.8794
598.679	91.6851
600.002	91.2441
727.062	89.0434
748.551	88.6712
773.279	88.2429
819.497	89.0434
946.556	91.2441
947.88	91.6851
951.957	92.8794
955.094	92.8794
958.679	91.6851
960.002	91.2441
1087.06	89.0434
1133.28	88.2429
1179.5	89.0434
1306.56	91.2441
1307.88	91.6851
1311.96	92.8794
1315.09	92.8794
1318.68	91.6851
1320	91.2441
1447.06	89.0434
1493.28	88.2429
1562.16	89.4359
1669.73	91.2991
1676.47	93.5079
1679.43	94.4781
1690.17	98
1768.81	78

External Boundary

X	Y
2.72316e-012	-86.33
1984.49	-86.33
1984.49	39.366
1984.49	57.366
1984.49	69.7246
1946.79	67.5
1881.91	71.3276
1768.81	78
1745.45	85.6583
1731.77	90.1407
1719.51	94.1592
1716.94	95
1708.62	95.1706
1704.74	95.25
1703.98	95.4367
1697.38	97.0585
1172.6	226.062
511.991	388.453
425.63	392.097
411.571	392.691
326.254	388.734
311.15	388.034
285.357	381.585
0	310.246
2.68585e-012	88.1657
2.71e-012	86.3656
2.71427e-012	86.1656
0	57.366
0	39.366

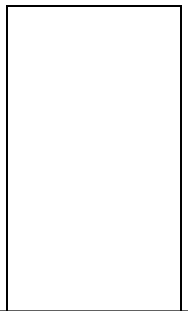
Material Boundary

X	Y
2.68585e-012	88.1657
53.2794	87.2429
99.4967	88.0434
226.556	90.2441
227.88	90.6851
231.464	91.8794
234.601	91.8794
238.679	90.6851
240.002	90.2441
367.062	88.0434
413.279	87.2429
459.497	88.0434
586.556	90.2441
587.88	90.6851
591.957	91.8794
595.094	91.8794
598.679	90.6851
600.002	90.2441
727.062	88.0434
748.551	87.6712
773.279	87.2429
819.497	88.0434
946.556	90.2441
947.88	90.6851
951.957	91.8794
955.094	91.8794
958.679	90.6851
960.002	90.2441
1087.06	88.0434
1133.28	87.2429
1179.5	88.0434
1306.56	90.2441
1307.88	90.6851
1311.96	91.8794
1315.09	91.8794
1318.68	90.6851
1320	90.2441
1447.06	88.0434
1493.28	87.2429
1562.16	88.4359
1669.73	90.2991
1676.47	92.5079
1679.43	93.4781
1690.17	97
1697.38	97.0585

Material Boundary

X	Y
2.71427e-012	86.1656
53.2794	85.2428
59.0724	85.3431
184.648	87.5181
226.899	88.2499
228.215	88.6886
231.779	89.8761
234.372	89.8761
238.344	88.6886
239.66	88.2499
281.911	87.5181
407.486	85.3431
413.279	85.2428
419.072	85.3431
544.648	87.5181
586.899	88.2499
588.215	88.6886
591.779	89.8761
594.372	89.8761
598.344	88.6886
599.66	88.2499
641.911	87.5181
721.378	86.1417
745.283	85.7277
767.486	85.3431
773.279	85.2428
779.072	85.3431
904.648	87.5181
946.899	88.2499
948.215	88.6886
952.187	89.8761
954.779	89.8761
958.344	88.6886
959.66	88.2499
1001.91	87.5181
1127.49	85.3431
1133.28	85.2428
1139.07	85.3431
1264.65	87.5181
1306.9	88.2499
1308.22	88.6886
1312.19	89.8761
1314.78	89.8761
1318.34	88.6886
1319.66	88.2499
1361.91	87.5181
1487.49	85.3431
1493.28	85.2428
1499.07	85.3431
1567.69	86.5315
1670.08	88.305
1676.8	90.5076
1685.65	93.4082
1690.5	95
1704.74	95.25

Material Boundary



X	Y
2.71e-012	86.3656
53.2794	85.4428
59.0724	85.5431
184.648	87.7181
226.899	88.4499
228.215	88.8886
231.779	90.0761
234.372	90.0761
238.344	88.8886
239.66	88.4499
281.911	87.7181
407.486	85.5431
413.279	85.4428
419.072	85.5431
544.648	87.7181
586.899	88.4499
588.215	88.8886
591.779	90.0761
594.372	90.0761
598.344	88.8886
599.66	88.4499
641.911	87.7181
721.378	86.3417
745.283	85.9277
767.486	85.5431
773.279	85.4428
779.072	85.5431
904.648	87.7181
946.899	88.4499
948.215	88.8886
952.187	90.0761
954.779	90.0761
958.344	88.8886
959.66	88.4499
1001.91	87.7181
1127.49	85.5431
1133.28	85.4428
1139.07	85.5431
1264.65	87.7181
1306.9	88.4499
1308.22	88.8886
1312.19	90.0761
1314.78	90.0761
1318.34	88.8886
1319.66	88.4499
1361.91	87.7181
1487.49	85.5431
1493.28	85.4428
1499.07	85.5431
1567.69	86.7315
1670.08	88.505
1676.8	90.7076
1685.65	93.6082
1690.5	95.2
1703.98	95.4367

Material Boundary

X	Y
0	57.366
1984.49	57.366

Material Boundary

X	Y
0	39.366
1984.49	39.366

APPENDIX III3B-2E

FINAL COVER SYSTEM STABILITY

APPENDIX III3B-2E-1

FINAL COVER SYSTEM STABILITY

FINAL COVER SYSTEM STABILITY CALCULATION

Made by: JCW
Checked by: CEI
Reviewed by: JBF

1.0 OBJECTIVE

Evaluate the stability of the final cover liner system.

2.0 GIVEN

The maximum head over the geomembrane is less than the thickness of the geocomposite drainage layer as demonstrated in Appendix III3B-2E-2, Final Cover Drainage Layer Capacity.

Final cover slopes are 4H:1V with a maximum length of 1200 ft.

The failure mechanism will be sliding along one of the liner interfaces. The final cover system consists of (from top to bottom):

24-inch Soil Cover consisting of on-site soils
Double-sided Geocomposite Drainage Layer
40-mil LLDPE textured Geomembrane
Geosynthetic Clay Liner (GCL)

OR

18-inch Soil Cover consisting of on-site soils
Double-sided Geocomposite Drainage Layer
40-mil LLDPE textured Geomembrane
18-inch Clay Liner



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Based on a review of available data at low normal stresses, the following parameters were assigned to the materials.

Table III3B-2E-1: Final Cover Component Interface Unit Weight and Strength Parameters

Soil	Unit Weight (pcf)		Strength Parameters		Reference
	Moist	Saturated	ϕ degrees	c (psf)	
Soil Cover	115	132	28	0	Estimate
Soil Cover / Geocomposite	–	–	28	0	Golder*
Geocomposite/Textured Geomembrane**	–	–	21	0	Golder*
Textured Geomembrane/GCL	–	–	24	0	Golder*
GCL/Clay Liner	–	–	35	0	Golder*

* Based on unpublished data from tests performed in Golder's laboratory, on similar geosynthetic materials. Strength parameters were conservatively assigned to be equal to or a percentage of the peak strength (lower bound) to account for testing material variability (see pages 3 and 4).

**The data indicates a lower-bound angle of 24°, but since the final cover pertains to a long-term condition a conservative angle of 21° is assumed for the calculation.

Based on the shear strength parameters, the critical interface occurs along the geocomposite/ textured geomembrane interface; this interface was assigned a conservative friction angle of 21 degrees.

4.0 METHOD

Create a model representing the sideslope situation and use it in conjunction with limit equilibrium concepts to determine the minimum factor of safety against a sliding block failure along the critical interface.

Infinite Slope Analysis

$$FS = \frac{c + (\gamma b \cos\beta - \gamma_w d \cos\beta)\tan\phi}{\gamma b \sin\beta}$$

Sliding at Geocomposite-Textured Geomembrane Interface

ϕ =	21	interface friction angle
β =	14.0	slope angle (degrees)
c =	0	adhesion (psf)
γ =	115	unit weight of soil (pcf)
b =	2.0	thickness (ft)
d =	0	water depth in cover (ft)
γ_w =	62.4	unit weight of water (pcf)
FS =	**1.54**	

Based on the Corps of Engineers "Design and Constuction of Levees" manual (EM 1110-2-1913) and the "EPA Guilde to Technical Resources for the Design of Land Disposal Facilities", the recommended factor of safety is 1.5 for the veneer slope stabiltiy of the final cover.

5.0 RESULTS

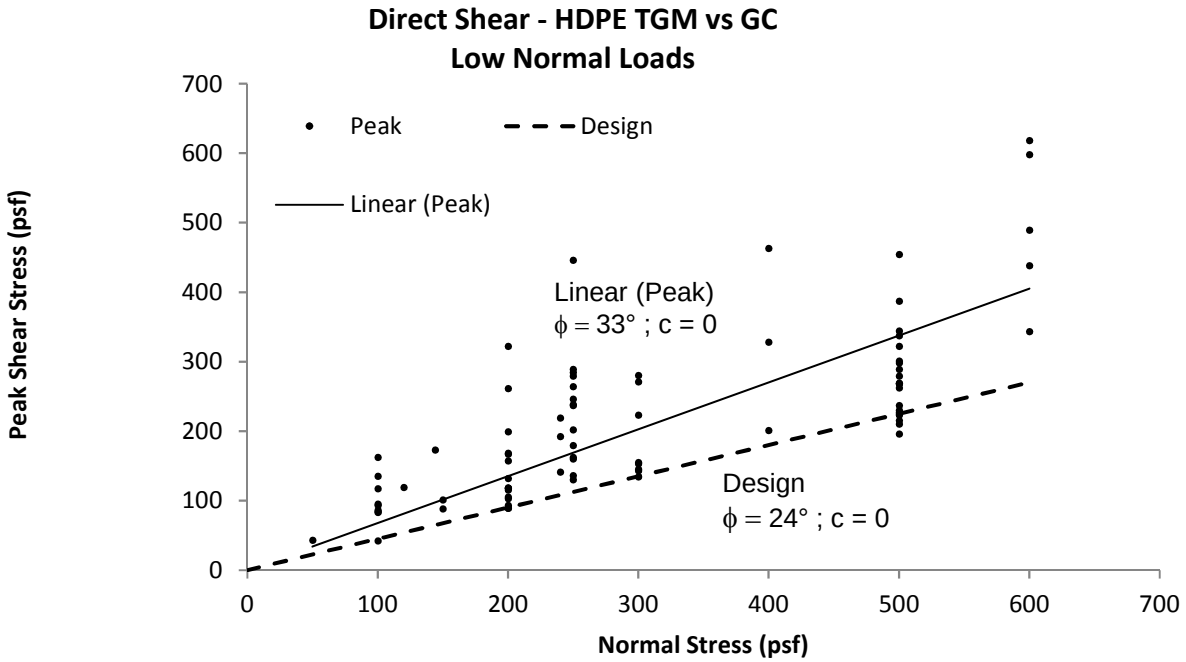
Using the Golder Associates interface friction angle database as a guide, the most critical internal friction angle of the final cover liner system was conservatively assumed to be 21 degrees. The resulting minimum factor of safety was calculated to be 1.54

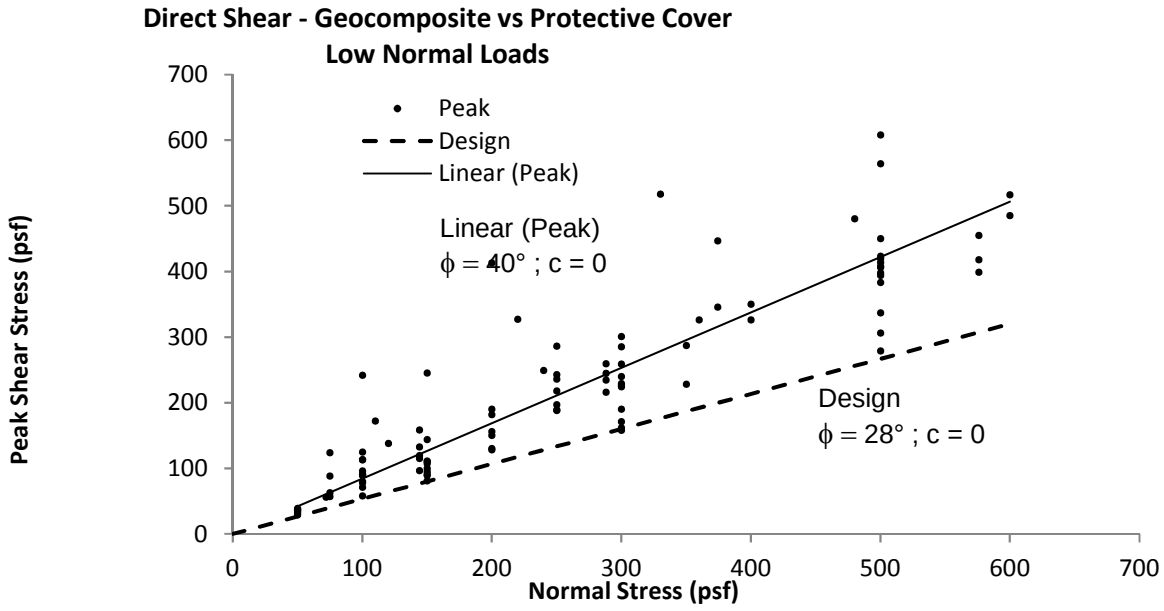
6.0 CONCLUSION

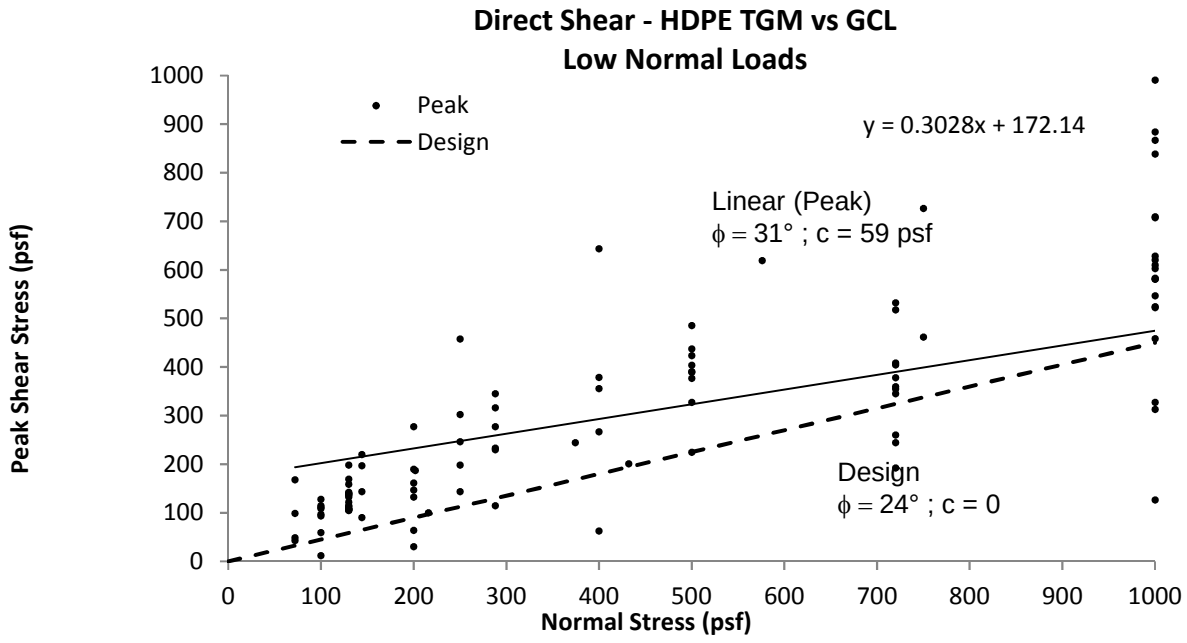
The slope stability analysis indicates that the final cover slope is stable.

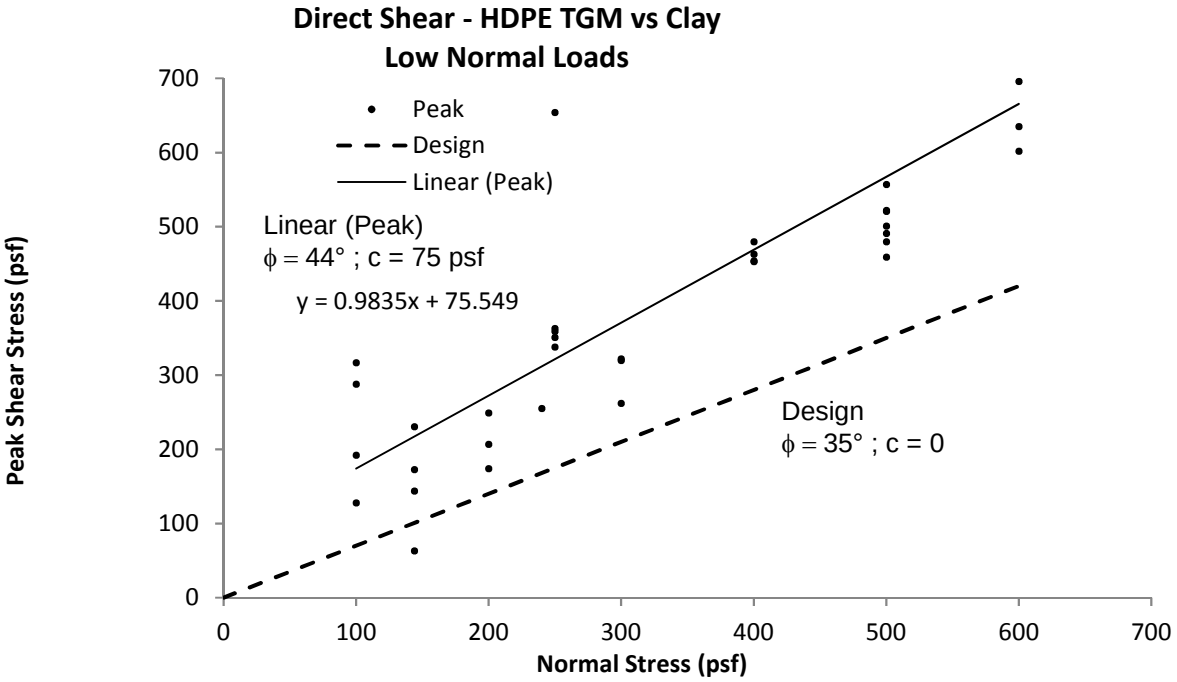
7.0 REFERENCES

Shear-Normal plots from unpublished data from tests performed in Golder's laboratory.






Direct Shear - HDPE TGM vs GCL
Low Normal Loads
Peak
Design
y = 0.3028x + 172.14
Linear (Peak)
ϕ = 31° ; c = 59 psf
Design
ϕ = 24° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
100
200
300
400
500
600
700
800
900
1000


Direct Shear - HDPE TGM vs Clay
Low Normal Loads
Peak
Design
Linear (Peak)
Linear (Peak)
ϕ = 44° ; c = 75 psf
y = 0.9835x + 75.549
Design
ϕ = 35° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
100
200
300
400
500
600
700

APPENDIX III3B-2E-2

FINAL COVER DRAINAGE LAYER CAPACITY

FINAL COVER DRAINAGE LAYER CAPACITY

Made By: VK
Checked by: CEI
Reviewed by: JBF

1.0 OBJECTIVE

I) Determine the required transmissivity of the final cover geocomposite drainage layer on the maximum final cover slope length.

II) Determine the maximum flow length for geocomposite drainage layers with a transmissivity less than the required value determined in I) (i.e. spacing between geocomposite daylight locations.)



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2.0 GIVEN

Maximum length of the 4H:1V slope is approximately (L) = 1200 ft

e permeability of the vegetative cover, K_{veg} = 1.0E-05 cm/s (typical value)

3.0 METHOD

Determine the design transmissivity of geocomposite layer on the final cover sideslope. The design criterion is that the geocomposite should have adequate capacity to transmit all surface water infiltration from the erosion soil layer (i.e. avoid any head build up) in the erosion layer.

$$\theta_{design} = \frac{q_i L}{sin\beta} = \frac{q_i L}{Slope}$$ [Ref. 1]

Where: θ_{design} = design transmissivity (m^2/sec)
qi = impingement rate (m/sec) = conservatively assume saturated hydraulic conductivity of the cover soil and hydraulic gradient of 1 = $1x10^{-5}$ cm/s.
L = horizontal length of slope (m)
β = slope angle (degrees)

Establish a required transmissivity, $\theta_{required}$, by applying reduction factors to the θ_{design}. [Ref. 2]

$\theta_{required} = \theta_{design} \times [RF_{cr} * RF_{cc} * RF_{bc} * RF_{in}]$

Where:
RF_{cr} = Reduction factor for short-term creep
RF_{cc} = Reduction factor for chemical clogging
RF_{bc} = Reduction factor for biological clogging
RF_{in} = Reduction factor for intrusion of geotextile or geomembrane

This required transmissivity will be used as material specification for the transmissivity measured in laboratory during construction.

Test Conditions: $i \geq$ 0.25
Normal Stress ≥ 1,000 psf
Boundary Cond'ns = steel plates
Test Time = 1 hour

Reduction Factor	Description	Value [Ref. 1]
RF_{cr} =	Reduction Factor for creep	1.1
RF_{cc} =	Reduction Factor for chemical clogging of geotextile and/or geonet	1.0
RF_{bc} =	Reduction Factor for biological clogging of geotextile and/or geonet	1.3
RF_{in} =	Reduction Factor for intrusion of geotextile into geonet	1.2
	Π(RF) =	1.7

4.0 CALCULATION

I) Transmissivity for maximum flow length

$$\theta_{required} = \text{2.8E-03 ft}^3\text{/s-ft} = \text{2.6E-04 m}^3\text{/s-m}$$

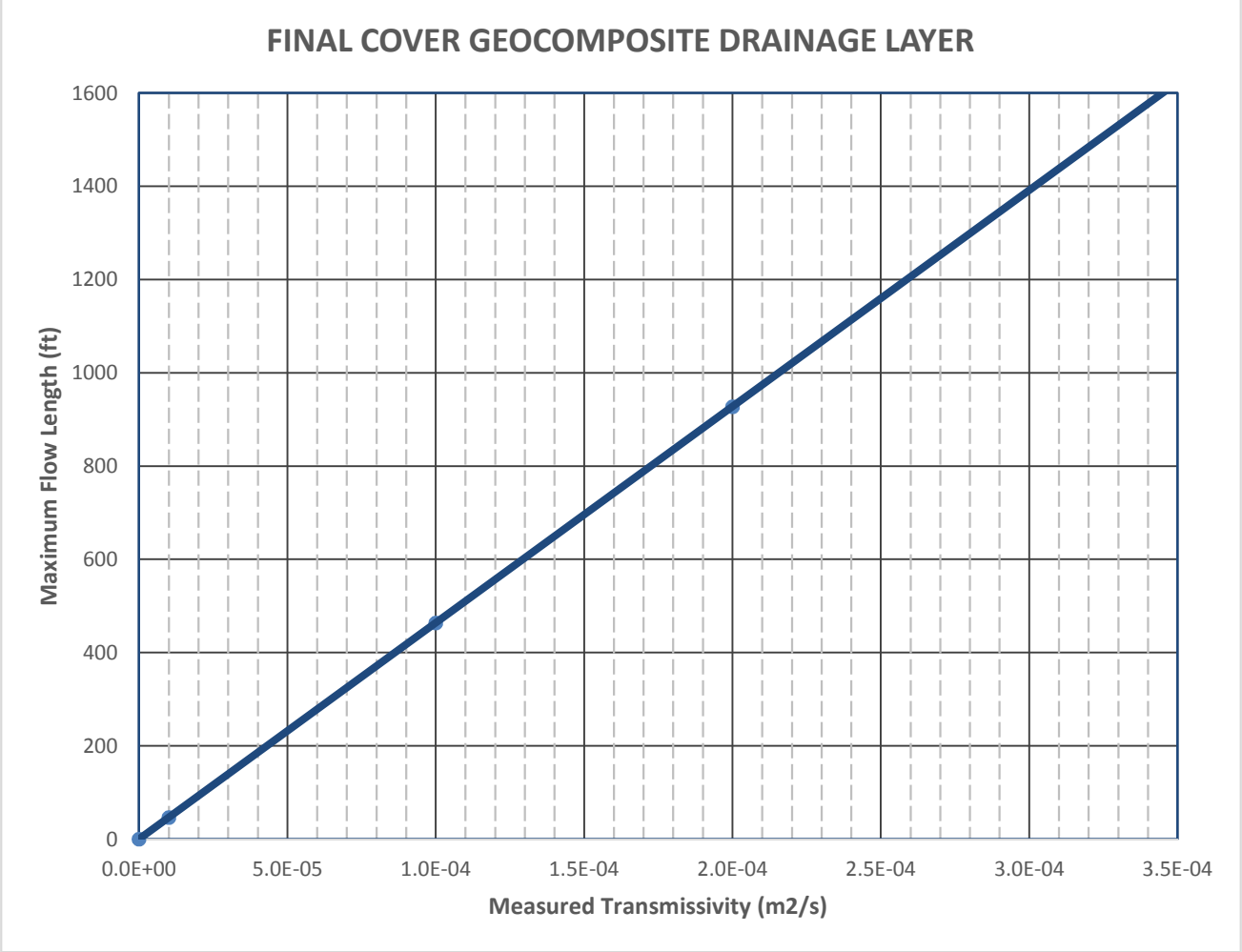
II) Maximum flow length for variable transmissivity

Based on the above equations, the maximum flow length varies linearly with transmissivity. Therefore, if the transmissivity value determined above is not met by the selected geocomposite drainage layer, the maximum flow length must be reduced (i.e., the drainage layer must be "daylighted") as follows (and as shown on the attached chart):

$$L_{max} = [\Theta_{measured}/\Theta_{required}]*1200 \text{ ft}$$

5.0 CONCLUSIONS

The required measured transmissivity of a geocomposite drainage layer to adequately convey surface water infiltration on the maximum slope length on the final cover system is 2.6E-04 m^3/s/m. If the measured transmissivity is less than this value, the geocomposite must be daylighted at certain intervals to provide free drainage and avoid hydraulic head buildup in the cover soil. The maximum allowable continuous geocomposite length must be reduced in direct proportion to the ratio of the actual measured transmissivity and the required measured transmissivity. The geocomposite daylighting detail is presented on Figure III7-3A.



6.0 REFERENCES

1. Giroud, J.P, Zornberg, J.G., and Zhao, A., "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers", Geosynthetics International, Vol. 7, Nos. 4-6, 2000.

2. Robert M. Koerner "Designing with Geosynthetics" Fifth Edition, 2005 Prentice Hall.

APPENDIX III3B-3

OVERLINER

APPENDIX III3B-3A

SETTLEMENT ANALYSIS

SETTLEMENT ANALYSIS

Made by: JCW
Checked by: CEI
Reviewed by: JBF

1.0 OBJECTIVE

Estimate the amount of total settlement and differential settlement under the alternative liner for the development over the vertical expansion of the overliner option. In addition, evaluate the impact of settlement on the leachate collection and control system.

2.0 DESIGN

The overliner design over the existing Pre-Subtitle D Units 1 - 4 is shown on Figures III3-9A through 9D. The overliner will tie into the existing liner system in Unit 5 to the west, and Unit 6 to the east. The overliner's subgrade mimics the previously permitted final cover grades for Units 1 - 4. Longitudinal leachate collection drainage channels are design with a pre-settlement slope of 0.5% and drain into four separate sumps.



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To reduce the overall settlement under the overliner, fill will be placed at least 1 year prior its construction. Prior to overliner installation, additional fill may be placed over the existing grades to the previously permitted final cover grades for Units 1-4 to form a minimum 2.0% lateral slope.

Three critical sections were selected along the leachate flow path for settlement calculations and evaluation of its impact on the leachate collection and control system as shown on Figures III3B-3A-1, III3B-3A-2, and III3B-3A-3.

Line A represents the 2.0% E-W slope at the critical section, with the thickest old waste column (compressible layer), thickest new waste (overburden stress) and greatest base grade change over shortest distance. Points A-1 through A-9 cover the overliner slope from the leachate collection drainage channels to the crest of overliner slope.

Lines B (south to north) and C (north to south) represent the 0.5% N-S slope through the leachage collection drainage channels. The channels represent critical sections due to the requirement to maintain positive drainage grades through the entirety of the sections. Pre-Subtitle D waste is absent along the eastern boundary of the overliner, therefore, all other conditions being similar, the lines along the western boundary were chosen for analysis.

3.0 ANALYSIS METHODOLOGY AND ASSUMPTIONS

Settlement for the overliner system will come from compression of both the underlying old waste and foundations soil layer, which will be loaded by the the grading fill, the new waste and final cover placement.

3.1 Old Waste Settlement

Old waste settlement consists of two components: a) time-dependent secondary compression (or creep) and b) primary settlement caused by the stress increase from the grading fill, the liner system, new waste and final cover.

3.1.1 Secondary Compression

Secondary compression is calculated using the modified secondary compression index ($C_{\alpha\varepsilon}$). The value of $C_{\alpha\varepsilon}$ was conservatively selected from the literature (Ref. 1) based on the characteristics of the waste at Edinburg.

$$S = T \cdot C_{\alpha\varepsilon} \cdot \log\frac{t_2}{t_1}$$

Equation (1)

Where:
S = settlement in feet
T = initial waste thickness in feet
$C_{\alpha\varepsilon}$ = modified secondary compression index
t_1, t_2 = initial and final time, respectively (in days, measured from t_0 = 2018)

To estimate the settlement after the overliner is installed, it is necessary to estimate a timeline. The secondary compression value is calculated for the year 2100 (i.e after an estimated 42-year site life and 30-year post-closure care period). We have assumed that the overliner construction will occur in 2060. Should the liner installation date occur later, the amount of settlement affecting the overliner will be less than estimated. Hence, this assumption is conservative.

Using equation (1) and the assumed timeline above, the secondary compression settlement of old waste can be predicted, as follows (365 days/year):

t_0 : Year = 2018 Day = 0
t_1 : Year = 2060 Day = 15330
t_2 : Year = 2100 Day = 29930

Thus, $\log(t_2/t_1) = 0.3$

And,

$$S = 0.3 * T \cdot C_{\alpha\varepsilon}$$

Equation (2)

3.1.2 Primary Settlement

The primary settlement of old (existing) waste caused by the stress increase from the overliner, new waste and final cover. Since the grading fill will be in place for at least one year and the thickness of waste is not great, the primary settlement due to grading fill will be largerly completed. The primary settlement is calculated using the following equations (Ref. 2):

If $\sigma'_0 + \Delta\sigma > \sigma'_p$ $\quad \Delta H_c = C_{c\varepsilon} \cdot H_0 \cdot \log\frac{(\sigma'_0 + \Delta\sigma)}{\sigma'_p} + C_{r\varepsilon} \cdot H_0 \cdot \log\frac{\sigma'_p}{\sigma'_0}$ **Equation (3)**

If $\sigma'_0 + \Delta\sigma < \sigma'_p$ $\quad \Delta H_c = C_{r\varepsilon} \cdot H_0 \cdot \log\frac{(\sigma'_0 + \Delta\sigma)}{\sigma'_0}$ **Equation (4)**

Where:
ΔH_C = primary settlement
H_0 = initial thickness of the waste layer before settlement
C_{ce} = modified primary compression index (~0.17 - 0.36). C_{ce} = 0.25 selected considering the age of waste. (Consistent with data in Ref. 3)

C_{re} = modified primary recompression index, estimated to be equal to 0.1*C_{ce}, that is = 0.025. (The 0.1 factor is within the range of values in the technical literature, e.g. Refs. 3 and 4.)

$\mathbf{s}_0$ = existing normal stress acting at the mid-level of the waste layer

$\Delta\mathbf{s}$ = increment of normal stress due to vertical expansion (new waste and final cover)

$\mathbf{s}_p$ = maximum past vertical stress acting at the mid-level of the waste layer

3.2 Foundation Soil Settlement

The equations below are used to calculate the settlement due to primary consolidation, S_c, of the subgrade underneath Units 1-4. Strata I and III are modelled as overconsolidated clay soil. Equation 5 is utilized for the entirety of Stratum I and for Stratum III near the north and south ends of the pre-subtitle D area for which the applied maximum overburden vertical stress will be lower than its past preconsolidation stress. Equation 6 is utilized for Stratum III near the center of the pre-Subtitle D area for which the applied maximum overburden vertical stress will be higher than its past preconsolidation stress (See Ref. 5 and 6 for derivations). Stratum II is assumed and modeled as incompressible.

For $\sigma'_0 + \Delta\sigma < \sigma_p$ which applies to the site conditions and proposed design:

$$S_c = C_{r\varepsilon} \cdot H \cdot \log\frac{(\sigma'_0 + \Delta\sigma)}{\sigma'_0} \qquad \textbf{Equation (5)}$$

Where:

$\mathbf{s'}_0$ = Initial average effective vertical stress for the layer of concern

$\Delta\mathbf{s}$ = Vertical stress increase due to new overburden from new waste and final cover

$\mathbf{s'}_p$ = Preconsolidation stress

C_{re} = Modified recompression index

H_0 = Layer thickness

For $\sigma'_0 < \sigma'_p < \sigma'_0 + \Delta\sigma$

$$S_c = C_{r\varepsilon} \cdot H \cdot \log\frac{\sigma'_p}{\sigma'_0} + C_{c\varepsilon} \cdot H \cdot \log\frac{(\sigma'_0 + \Delta\sigma)}{\sigma'_p} \qquad \textbf{Equation (6)}$$

Where: C_{ce} = Modified compression index

3.3 Additional Settlement Considerations

1) For the settlement calculations, it is assumed that the entire block of new waste is instantaneously applied above the overliner. This assumption is conservative, as it will induce greater settlement and potentially greater strain on the liner system.

2) Stresses were determined assuming one-dimensional loading at each analytical point. This assumption overestimates the difference in stress conditions between points and will produce a conservative estimate of differential settlement.

3) For overconsolidated, inorganic clays, settlement due to secondary compression will be minor in comparison to the primary settlement.

4.0 MATERIAL PARAMETERS

4.1 Soil Parameters

Final cover soil thickness:	4	ft (conservative)
Final cover soil Unit Weight:	115	pcf (conservatively assumed)
Protective cover soil thickness:	2	ft
Protective cover soil Unit Weight:	115	pcf (conservatively assumed)
Overliner subgrade thickness:	1	ft (assumed)
Overliner subgrade Unit Weight:	115	pcf
Foundation soil Unit Weight:	125	pcf (obtained from laboratory testing data)
Preconsolidation stress: s_p	22,000	psf (conservatively chosen from Stratum I and II laboratory testing data)
Modified compression index: C_{ce}	0.075	(average obtained from laboratory testing data due to similarity of Stratum I and II data)
Modified recompression index: C_{re}	0.012	(average obtained from laboratory testing data due to similarity of Stratum I and II data)

4.1 Waste Parameters

Unit Weight =	65	pcf
C_{ce} =	0.25	
C_{re} =	0.025	
$C_{\alpha\varepsilon}$ =	0.15	Ref. 1 - for old waste

5.0 CALCULATIONS AND RESULTS

The equations and methods outlined in prior sections were implemented using Excel spreadsheets to perform the settlement calculations. Key and representative analytical points were selected along Lines A, B, and C. The estimated settlement results and liner grade changes due to differential settlement are summarized in Tables 1 and 2, and shown graphically on Figures 1, 2, and 3.

Table 1: Line A Settlement Summary

Elevations and Distance	A-1	A-2	A-3	A-4	A-5	A-6	A-7	A-8	A-9
Proposed Final Contour (ft) =	312.6	312.6	312.6	312.6	312.6	312.6	312.6	312.6	312.6
Proposed Top of the Liner (ft) =	95.0	86.4	95.0	98.1	101.3	100.2	99.1	95.8	86.9
Top of Waste (from 2015 topo) (ft) =	95.0	86.4	95.0	96.6	98.8	98.6	98.3	94.6	86.9
Bottom of Old Waste (ft) =	90.3	86.4	75.0	75.0	75.0	93.0	75.0	75.0	86.9
Hz. Distance from Point A-1 (ft) =	0.0	12.0	45.9	197.5	356.6	411.4	466.6	629.3	665.0
Top of Incompressible Layer (ft) =	-8.0	-8.0	-8.0	-8.3	-8.5	-8.6	-8.7	-8.9	-9.0
Settlement Estimates									
Secondary Compression (ft) =	0.2	0.0	0.9	0.9	1.0	0.2	1.0	0.9	0.0
Primary Settlement (ft) =	2.5	0.0	7.4	7.9	8.4	2.8	8.3	7.3	0.0
Foundation Soil Settlement (ft) =	0.4	0.4	0.2	0.1	0.1	0.3	0.1	0.1	0.3
Total Settlement from liner placement until end of post-closure (ft) =	3.4	0.7	8.8	9.2	9.9	3.7	9.7	8.7	0.7
Liner Slopes		**A-1 →A-2**	**A-2→A-3**	**A-3→A-4**	**A-4→A-5**	**A-5→A-6**	**A-6→A-7**	**A-7→A-8**	**A-8→A-9**
Pre-Settlement slope of overliner =		-71.9%	25.6%	2.0%	2.0%	-2.0%	-2.0%	-2.0%	-25.0%
Post-Settlement slope of overliner =		-49.7%	1.7%	1.8%	1.6%	9.1%	-12.8%	-1.4%	-2.7%

Figure 1: Line A Settlement Summary

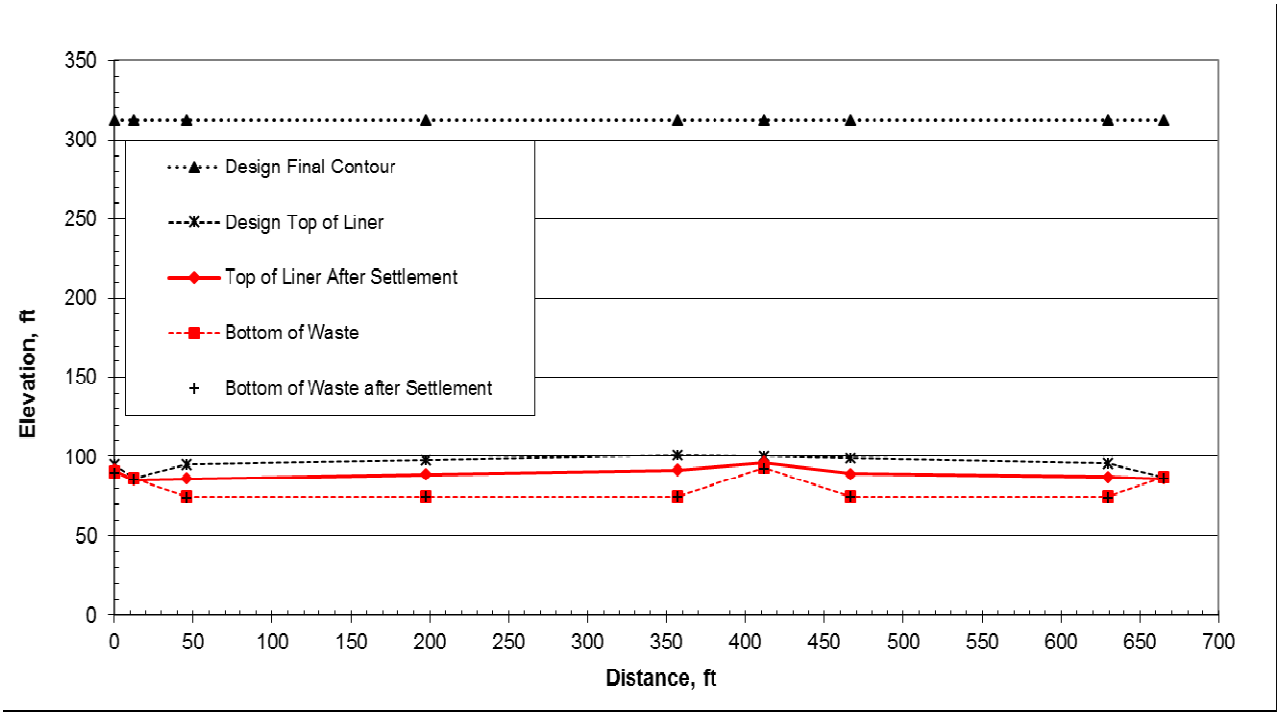


Table 2: Line B Settlement Summary

Elevations and Distance	B-1	B-2	B-3	B-4	B-5	B-6	B-7	B-8
Proposed Final Contour (ft) =	98.8	107.0	108.5	138.8	191.5	263.7	307.6	312.6
Proposed Top of the Liner (ft) =	95.0	84.0	82.0	82.6	83.7	85.1	86.0	86.5
Top of Waste (from 2015 topo) (ft) =	95.0	84.0	82.0	82.6	83.7	85.1	86.0	86.5
Bottom of Old Waste (ft) =	93.0	82.0	82.0	82.6	83.7	85.1	86.0	86.5
Hz. Distance from Point B-1 (ft) =	0.0	33.0	38.9	160.0	371.1	660.0	835.5	935.5
Top of Incompressible Layer (ft) =	4.0	4.1	4.1	2.5	-0.5	-4.6	-7.6	-7.8
Settlement Estimates								
Secondary Compression (ft) =	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Primary Settlement (ft) =	0.6	0.8	0.0	0.0	0.0	0.0	0.0	0.0
Foundation Soil Settlement (ft) =	0.0	0.1	0.1	0.1	0.2	0.3	0.4	0.4
Total Settlement from liner placement until end of post-closure (ft) =	0.7	1.0	0.2	0.3	0.4	0.5	0.7	0.7
Liner Slopes		**B-1→B-2**	**B-2→B-3**	**B-3→B-4**	**B-4→B-5**	**B-5→B-6**	**B-6→B-7**	**B-7→B-8**
Pre-Settlement slope of overliner =		-33.3%	-33.3%	0.5%	0.5%	0.5%	0.5%	0.5%
Post-Settlement slope of overliner =		-34.3%	-18.8%	0.4%	0.4%	0.4%	0.4%	0.5%

Figure 2: Line B Settlement Summary

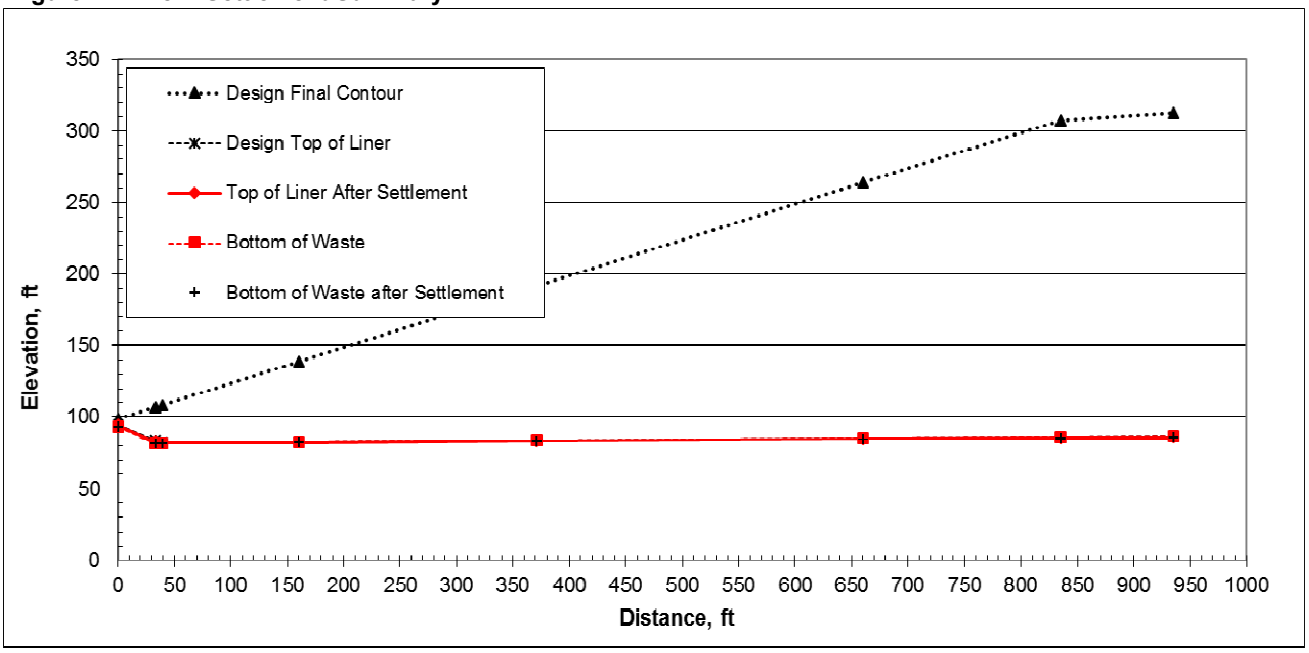
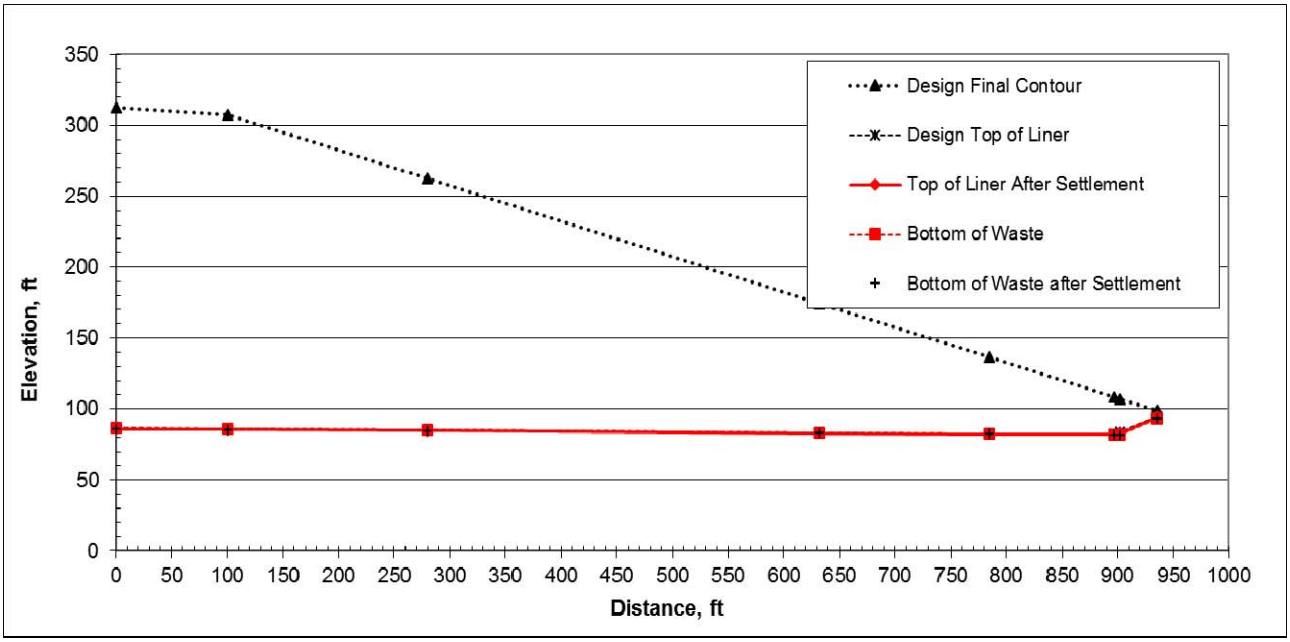


Table 3: Line C Settlement Summary

Elevations and Distance	C-1	C-2	C-3	C-4	C-5	C-6	C-7	C-8
Proposed Final Contour (ft) =	312.6	307.6	262.6	174.5	136.5	108.5	107.0	98.7
Proposed Top of the Liner (ft) =	86.5	86.0	85.1	83.3	82.6	82.0	84.0	95.0
Top of Waste (from 2015 topo) (ft) =	86.5	86.0	85.1	83.3	82.6	82.0	84.0	95.0
Bottom of Old Waste (ft) =	86.5	86.0	85.1	83.3	82.6	82.0	82.0	93.0
Hz. Distance from Point C-1 (ft) =	0.0	100.0	280.0	632.6	784.6	896.6	902.5	935.5
Top of Incompressible Layer (ft) =	-7.8	-7.1	-5.3	-1.7	-0.2	0.0	-0.4	-2.1
Settlement Estimates								
Secondary Compression (ft) =	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Primary Settlement (ft) =	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.6
Foundation Soil Settlement (ft) =	0.4	0.3	0.3	0.2	0.1	0.1	0.1	0.0
Total Settlement from liner placement until end of post-closure (ft) =	0.7	0.7	0.5	0.3	0.2	0.2	1.0	0.7
Liner Slopes		**E-1→E-2**	**E-2→E-3**	**E-3→E-4**	**E-4→E-5**	**E-5→E-6**	**E-6→E-7**	**E-7→E-8**
Pre-Settlement slope of overliner =		-0.5%	-0.5%	-0.5%	-0.5%	-0.5%	33.3%	33.3%
Post-Settlement slope of overliner =		-0.4%	-0.4%	-0.5%	-0.4%	-0.4%	18.8%	34.3%

Figure 3: Line C Settlement Summary



6.0 CONCLUSIONS

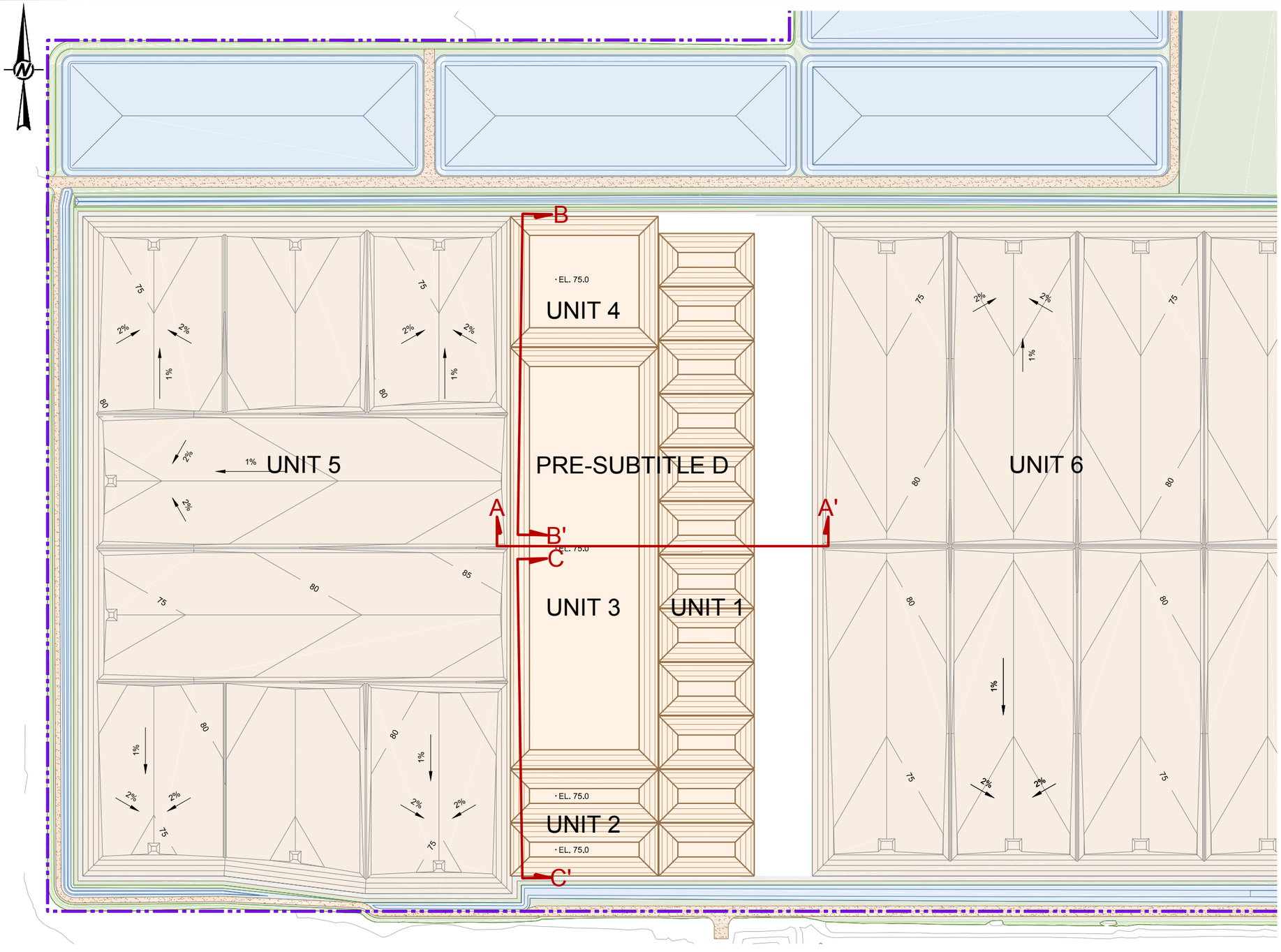
Review of the settlement analysis results show that the maximum settlement of the overliner is estimated to be approximately 9.9 feet across the three sections analyzed. The maximum settlement occuring at points near the toe of the berm separating Units 1 and 3, where the combination of existing MSW under the overliner, and new MSW on top of the overliner is greatest.

Differential settlement occurs at the overliner area, however, the post-settlement liner grade along the leachate flow paths remains at an overall minimum of 1.4% from the center of the overliner area to the leachate collection drainage channels and an overall minimum of 0.4% through the drainage channels.

Therefore, positive drainage will be ensured on the overliner under the conditions analyzed.

7.0 REFERENCES

1. Sharma H. D. and De, A., (2007) "Municipal Solid Waste Landfill Settlement: Postclosure Perspectives". Journal of Geotechnical and Geoenvironmental Engineering, Vol. 133, No. 6, 619-629
2. Xuede Qian, Robert Koerner, and Donald H. Gray, Geotechnical Aspects of Landfill Design and Construction, Prentice Hall, 2001
3. McDougall, John (2008), Geotechnical Characterization, Field Measurement, and Laboratory Testing of Municipal Solid Waste, Proceedings of the 2008 International Symposium on Waste Mechanics, Geotechnical Special Publication 209, ASCE, March 13, 2008.
4. Sharma H. D. and De, A., (2007) "Municipal Solid Waste Landfill Settlement: Postclosure Perspectives". Journal of Geotechnical and Geoenvironmental Engineering, Vol. 133, No. 6, 619-629
5. Braja Das, Principles of Geotechnical Engineering, 4th Edition, PWS Publishing Co., 1998
6. J. Bowles, Foundation Analysis and Design, McGraw-Hill, Inc., 1988



LEGEND

- PERIMETER BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- ROADS

NOTE(S)

1. SUBGRADE ELEVATIONS SHOWN FOR PRE-SUBTITLE D CELLS ARE ESTIMATED BASED ON DIMENSIONS PROVIDED IN TCEQ PERMIT MSW-956B.

ISSUED FOR PERMITTING PURPOSES ONLY

0 150 300
1" = 300' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

SEAL

STATE OF TEXAS
JEFFREY B. FASSETT
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
SETTLEMENT ANALYSIS *PRE–SUBTITLE D UNITS 1 – 4 SUBGRADE LAYOUT*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3B-3A	0	1 of 3	III3B-3A-1

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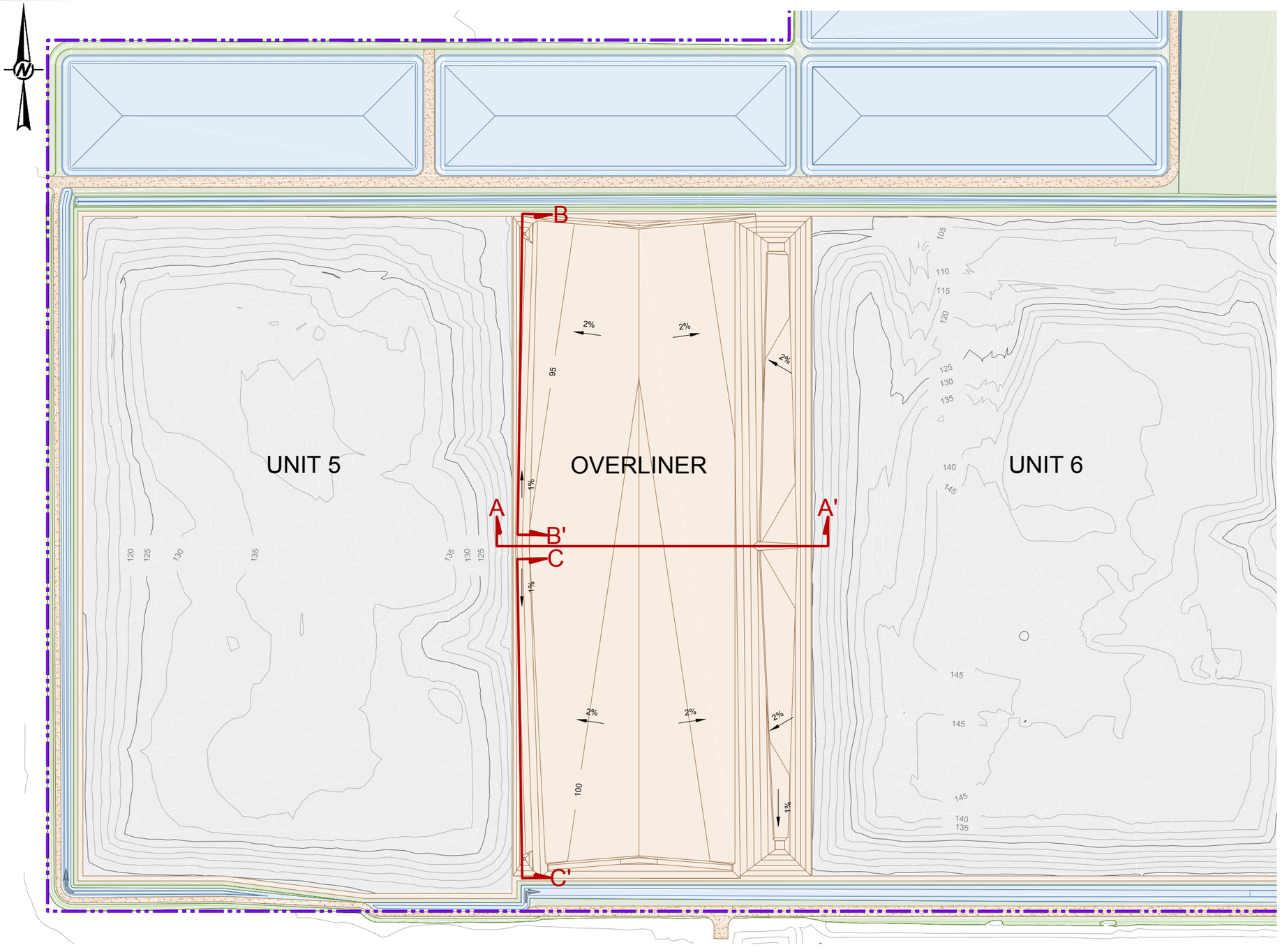

LEGEND

- PERIMETER BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- ROADS
- 1A CELL DESIGNATION

NOTE(S)

1. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
2. SUBGRADE ELEVATIONS SHOWN.
3. TOP OF THE LINER ELEVATIONS IN THE BOTTOM OF THE LEACHATE COLLECTION SUMPS ARE 2 ft LOWER THAN ELEVATION OF THE LOW POINT ON THE LINER.
4. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 70 ft-msl IN OVERLINER EAST.
5. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 79.50 ft-msl IN OVERLINER WEST.

ISSUED FOR PERMITTING PURPOSES ONLY

0 150 300
1" = 300' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
SETTLEMENT ANALYSIS *OVERLINER SUBGRADE LAYOUT*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3B-3A	0	2 of 3	III3B-3A-2

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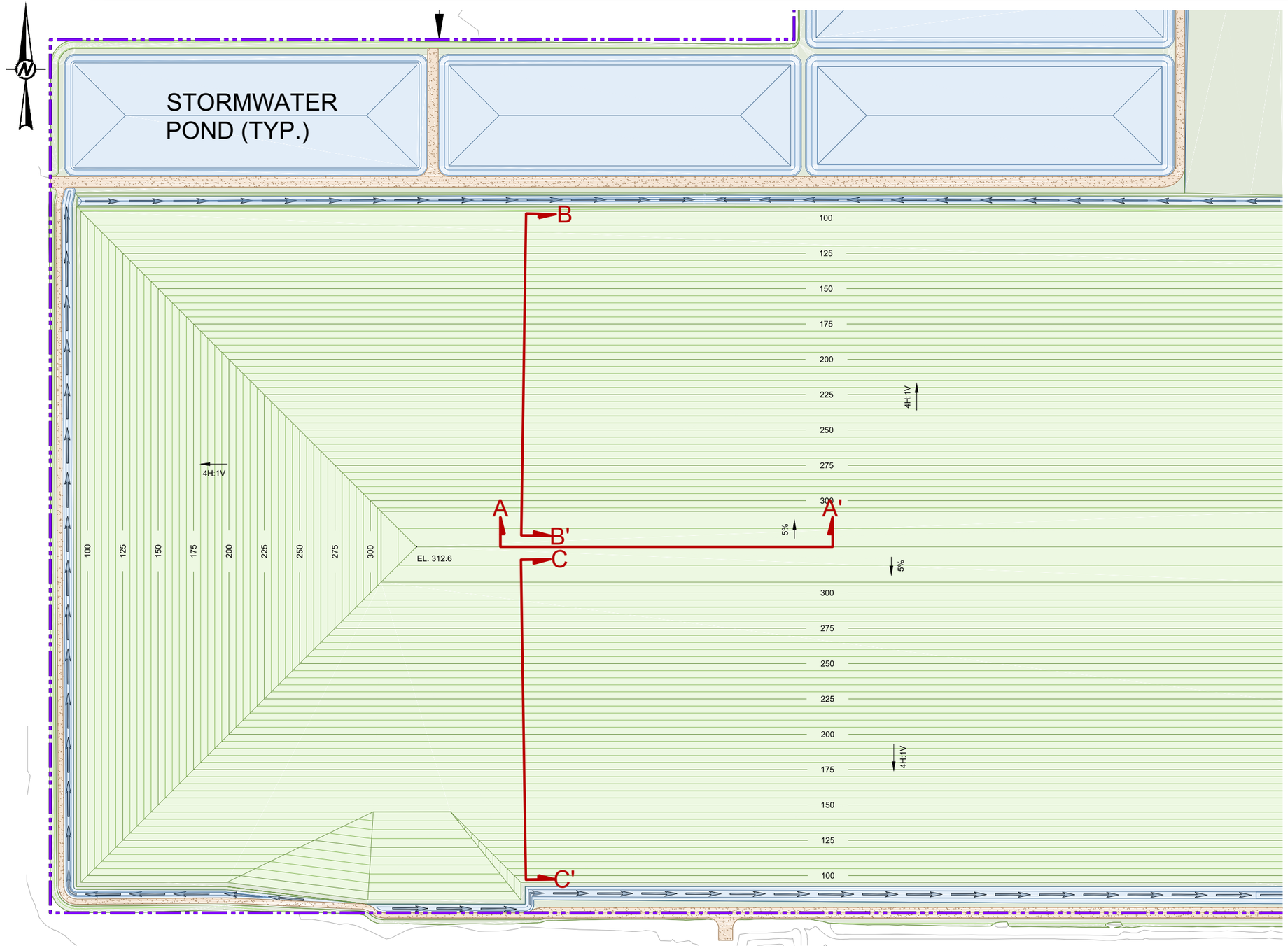

LEGEND

- PERMIT BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- FINAL COVER 25 ft CONTOUR
- FINAL COVER 5 ft CONTOUR

NOTE(S)

1. FINAL COVER ELEVATIONS SHOWN.

ISSUED FOR PERMITTING PURPOSES ONLY

0 150 300
1" = 300' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

SEAL

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
SETTLEMENT ANALYSIS *FINAL CONTOUR MAP*

PROJECT NO.	APPLICATION SECTION	REV.	FIGURE
1401491	III3B-3A	0	3 of 3 III3B-3A-3

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APPENDIX III3B-3B

STRAIN ANALYSIS

STRAIN ANALYSIS

Made by: JBF
Checked by: VK
Reviewed by: MX

1.0 OBJECTIVE

Estimate the tensile strain caused by differential settlement of the overliner.

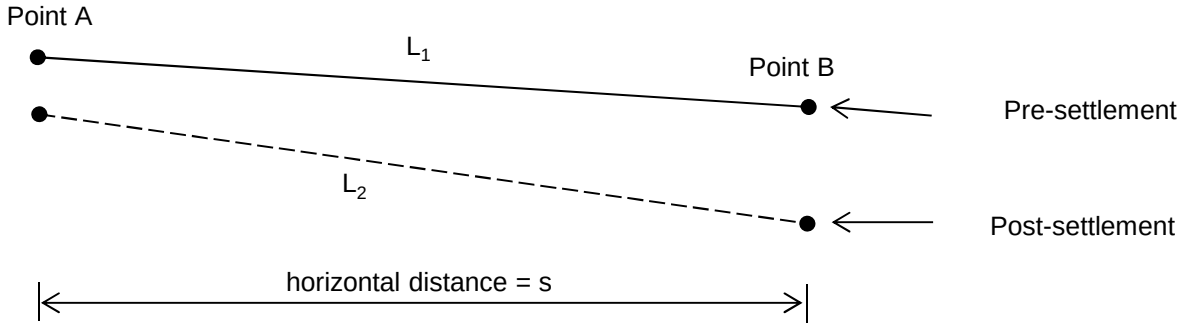
2.0 METHODOLOGY

The proposed overliner system may experience tensile strain because of differential settlement of existing waste and/or from the development of localized depressions.

2.1 Tensile Strain from Differential Settlement

Settlement results from Appendix III3B-3A are used to calculate the induced strain in the liner system along Lines A, B, and C. The locations of the lines are shown on Figure III3B-3B-1.

The tensile strain of a base liner system caused by differential settlement can be estimated by the following equation:



$$\varepsilon = \frac{L_2 - L_1}{L_1}$$

$$L = \sqrt{(Elev.A - Elev.B)^2 + s^2}$$

Where:

e = Tensile strain in liner system between Points A and B
L_1 = Distance between Points A and B, pre-settlement
L_2 = Distance between Points A and B, post-settlement
s = Horizontal distance between Points A and B

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2.2 Tensile Strain from Localized Depression

The tensile strain caused on a liner system by a localized depression (subsidence) can be determined by the method in Koerner (1999), Ref. 1.

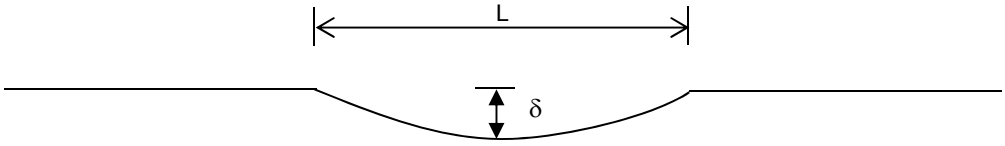


Figure 2: Landfill Liner Subsidence

$$\varepsilon\,(\%) = \left\{\frac{\left[\tan^{-1}\left(\frac{4L\delta}{L^2-4\delta^2}\right)\right]\left[\frac{L^2+4\delta^2}{4\delta}\right]-L}{L}\right\}\times 100 \quad \text{for} \quad \delta < \frac{L}{2}$$

$$\varepsilon\,(\%) = \left\{\frac{\left[\frac{L^2+4\delta^2}{4\delta}\right]\left[\pi-\sin^{-1}\left(\frac{4L\delta}{L^2+4\delta^2}\right)\right]-L}{L}\right\}\times 100 \quad \text{for} \quad \delta \geq \frac{L}{2}$$

Where:

e = Tensile strain in liner system due to localized subsidence

L = Diameter of subsidence area

δ = Center point deflection of the subsidence area

It is noted that the equations above will yield the same strain value for a given ratio of center point deflection to diameter (i.e., δ/L), regardless of the actual magnitudes of each parameter. This fact is used and discussed in the following sections of this analysis.

3.0 CALCULATIONS AND RESULTS

3.1 Tensile Strain from Differential Settlement

The liner strain evaluations due to differential settlement of the underlying waste mass are summarized in Table 1.

Table 1: Liner Integrity Analysis Results

Points	Elevations		Horizontal Distance (s), feet	Pre-settlement Dist. (L_1), feet	Post-settlement Dist. (L_2), feet	Tensile Strain
	Pre-settlement, feet	Post-settlement, feet				
A-1 A-2	95.00 86.36	91.60 85.62	12.02	14.805	13.425	Under Compression
A-2 A-3	86.36 95.05	85.62 86.21	45.93	46.743	45.932	Under Compression
A-3 A-4	95.05 98.11	86.21 88.88	197.46	197.486	197.480	Under Compression
A-4 A-5	98.11 101.33	88.88 91.47	356.64	356.652	356.647	Under Compression
A-5 A-6	101.33 100.22	91.47 96.47	411.36	411.363	411.392	0.01%
A-6 A-7	100.22 99.11	96.47 89.38	466.63	466.629	466.682	0.01%
A-7 A-8	99.11 95.82	89.38 87.16	629.34	629.347	629.342	Under Compression
A-8 A-9	95.82 86.90	87.16 86.21	665.02	665.084	665.025	Under Compression
B-1 B-2	94.99 83.98	94.29 82.96	33.03	34.817	34.920	0.3%
B-2 B-3	83.98 82.03	82.96 81.85	38.90	38.952	38.919	Under Compression
B-3 B-4	82.03 82.63	81.85 82.37	160.00	160.001	160.001	Under Compression
B-4 B-5	82.63 83.69	82.37 83.30	371.11	371.111	371.110	Under Compression
B-5 B-6	83.69 85.13	83.30 84.59	660.00	660.002	660.001	Under Compression
B-6 B-7	85.13 86.01	84.59 85.31	835.47	835.473	835.473	Under Compression
B-7 B-8	86.01 86.51	85.31 85.77	935.48	935.484	935.484	Under Compression
C-1 C-2	86.51 86.01	85.77 85.33	100.00	100.001	100.001	Under Compression
C-2 C-3	86.01 85.11	85.33 84.62	280.00	280.001	280.001	Under Compression
C-3 C-4	85.11 83.35	84.62 83.02	632.56	632.564	632.564	Under Compression
C-4 C-5	83.35 82.59	83.02 82.35	784.58	784.584	784.584	Under Compression
C-5 C-6	82.59 82.03	82.35 81.87	896.58	896.581	896.581	Under Compression
C-6 C-7	82.03 84.00	81.87 82.99	902.51	902.516	902.515	Under Compression
C-7 C-8	86.51 95.00	82.99 94.30	935.53	935.566	935.595	0%
Maximum Tensile Strain due to Differential Settlement =						0.30%

C:\Users\KCrowe\SharePoint\1401491, City of Edinburg Per - Doc\Application\Part III\III3 Waste Management Unit Design\III3B Engineering Analyses\III3B-3 Overliner\III3B-3B\III3B-3B.xlsx

Submitted: July 2017

Golder Associates

3.2 Tensile Strain from Localized Depression

The evaluated equations in Section 2.2 of this analysis in terms of the tensile strain versus normalized deflection (δ/L) are presented in Figure 1 below.

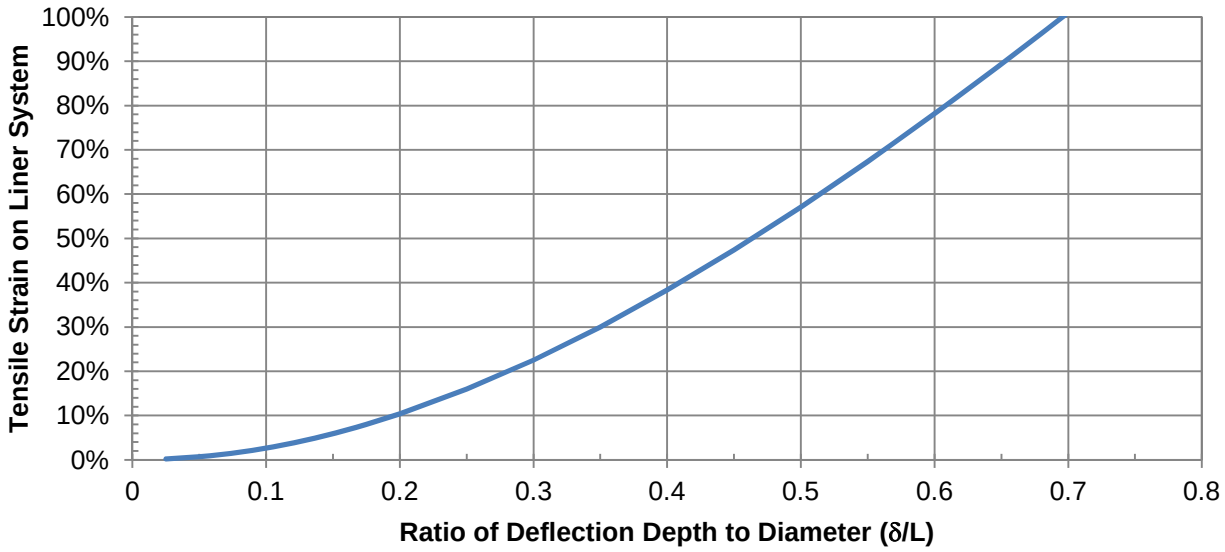


Figure 1: Strain versus Normalized Localized Depression

The critical δ/L values for strains of 5% and 10%, are 0.14 and 0.2, respectively. As discussed in Section 4.0, this strain range comprises the maximum values for different elements of the overliner system.

4.0 DISCUSSION AND CONCLUSIONS

The overliner will consist of geosynthetic clay liner, a geomembrane layer, and a geocomposite drainage layer (geonet layer between two layers of geotextile), of which the geotextile and geonet materials have the minimum allowable tensile strain of ~5% (Refs. 1 and 2). The allowable strains are presented in Table 2.

Table 2: Summary of Allowable Liner Strains

Max. Tensile Strain from Differential Settlement	Max. Tensile Strain from Localized Depression	Liner Component	Allowable Tensile Strain	Tensile Strain less than Allowable?
0.30%	See Discussion Below and Figure 2	Geosynthetic Clay Liner	10%	Yes
		Geomembrane	10%	Yes
		Geotextile	5%	Yes
		Geonet	5%	Yes

The potential strain of the overliner system was analyzed for both the overall differential settlement and localized depressions. Based on conservative assumptions, the maximum liner strain is estimated to be 0.30%, from differential settlement which is less than the allowable strain of the liner system.

The maximum strain that may occur under the more random case of a localized depression was addressed in a parametric basis. Based on this analysis, the ratio of depression depth to diameter must be 0.14 to produce 5% strain, and 0.20 to produce 10% strain. Assuming a 50-foot diameter depression, this corresponds to a depth of 7 feet for a 5% strain and 10 feet for a 20% strain.

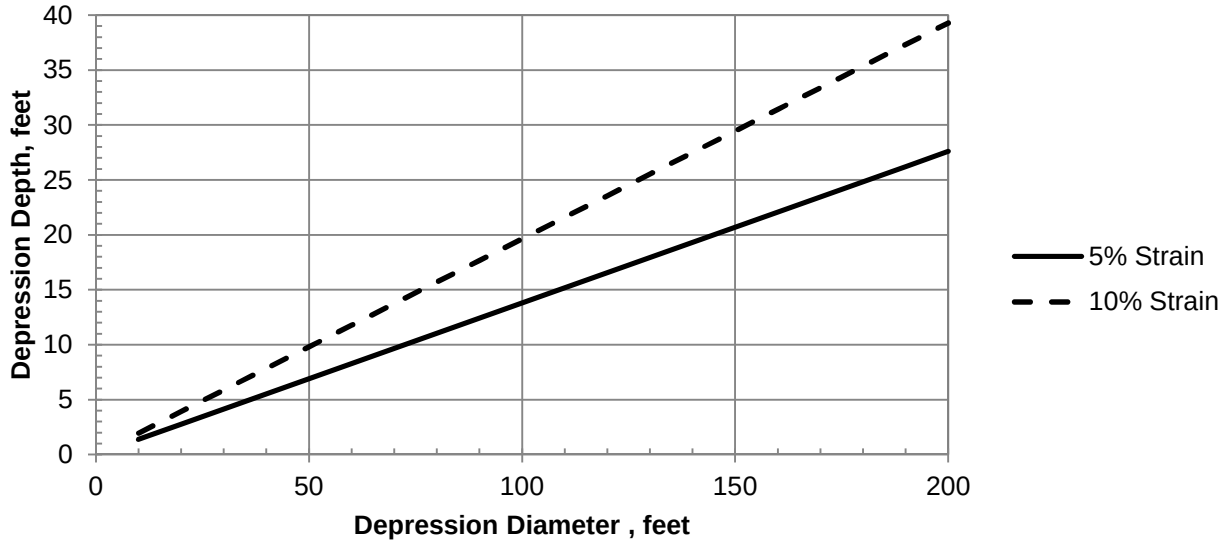
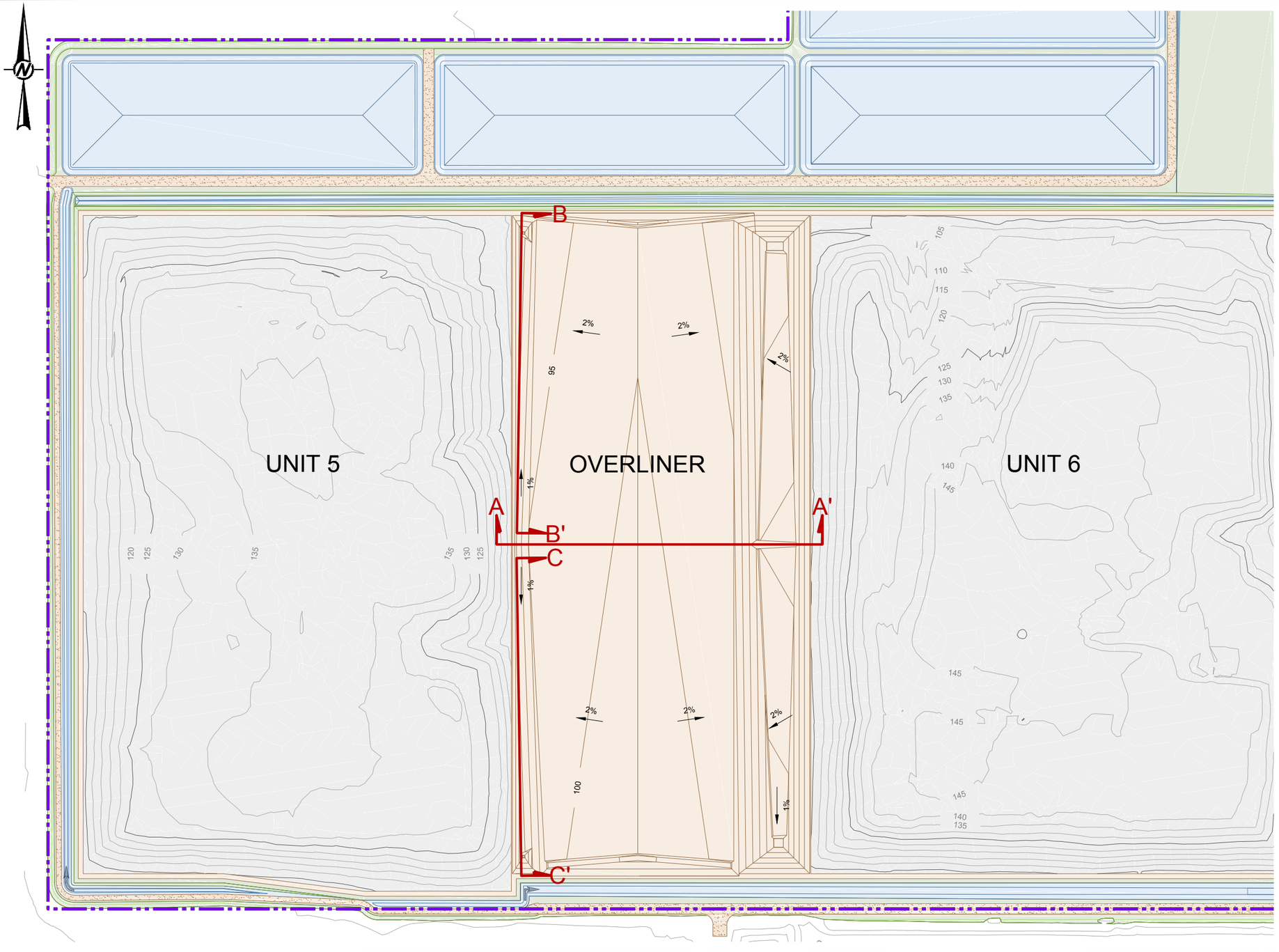


Figure 2: Depression Dimensions as a function of Induced Strain on Liner System

5.0 REFERENCES

1) R.M. Koerner and D.E. Daniel, "Technical Equivalency Assessment of GCLs to CCLs", TR210
2) Robert M. Koerner (2005) Designing with Geosynthetics, Fifth Edition, Pearson/Prentice Hall.



LEGEND

- PERIMETER BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- ROADS
- 1A CELL DESIGNATION

NOTE(S)

1. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
2. SUBGRADE ELEVATIONS SHOWN.
3. TOP OF THE LINER ELEVATIONS IN THE BOTTOM OF THE LEACHATE COLLECTION SUMPS ARE 2 ft LOWER THAN ELEVATION OF THE LOW POINT ON THE LINER.
4. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 70 ft-msl IN OVERLINER EAST.
5. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 79.50 ft-msl IN OVERLINER WEST.

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0 150 300
1" = 300' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

SEAL

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
STRAIN ANALYSIS *OVERLINER SUBGRADE LAYOUT*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3B-3B	0	1 of 1	III3B-3B-1

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APPENDIX III3B-3C

STABILITY ANALYSIS

STABILITY ANALYSIS

Made by: VK
Checked by: CEI
Reviewed by: JBF

1.0 OBJECTIVE

Estimate the factors of safety against sliding and global stability for the final-filled configuration of waste placed above the overliner of the pre-Subtitle D area.

2.0 GIVEN

Based on a review of the design grades, the reasonable worst-case configuration was assumed to consist of a section along the western side of Units 3 and 4, having 4H:1V final cover slopes to a crest and maximum fill elevation of approximately 312.6 ft-msl (Section A-A' shown in Figure III3B-3C-1 and III3B-3C-2). Compared to other sections through the pre-Subtitle D area, the chosen section exhibits thicker existing waste. Additionally, the toe of the future waste along the chosen section is less supported by the perimeter berm.



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One foot of leachate is assumed over the liner interface (conservative because LCRS is designed to maintain < 1 foot of leachate).

The alternative liner for the floor and side walls consists of (from top to bottom):

24 inches of protective cover
Double-sided geocomposite
60-mil textured HDPE geomembrane
Geosynthetic Clay Liner (GCL)

The following parameters were assigned to the materials based on available high load condition data.

Table III3B-2B-1: Alternative Liner Component Interface Unit Weight and Strength Parameters

Soil	Unit Weight (pcf)		Strength Parameters		Reference
	Moist	Saturated	ϕ degrees	c (psf)	
Waste	65	75	Bi-Linear		Ref 1.
Protective Cover	115	132	28	0	Estimate
Protective Cover/Geocomposite	–	–	28	0	Golder*
Geocomposite/Textured Geomembrane	–	–	24	0	Golder*
Textured Geomembrane/GCL	–	–	24	0	Golder*
GCL/Subgrade	–	–	30	0	Golder*

* Based on unpublished data from tests performed in Golder's laboratory, on similar geosynthetic materials presented in this Appendix

Based on the data listed in the above table, the weakest interface in the liner system along the sideslope and floor of the cell is between the geocomposite and textured geomembrane. This interface shear strength was used in the analysis.

As detailed in Part III4, Geology Report the site is underlain by three distinct strata, identified below in order from ground surface down:

Stratum I: sandy clays or clayey sands, with layers of silty clay, silty sand, or clayey silt.

Stratum II: sands/silty sands, fine, poorly graded, and is the uppermost water-bearing unit (uppermost aquifer).

Stratum III: predominantly clay, with some amounts of sandy clay or silty clay, high plasticity, hard, brown, and dry, and is the confining unit underlying the uppermost water-bearing unit (lower confining unit).

Table III3B-3C-2: Soil Unit Weight and Strength Parameters

Soil	Unit Weight (pcf)		Strength Parameters		Analysis Stress State	Reference
	Moist	Saturated	ϕ degrees	c (psf)		
Stratum I	121	130	31	300	Effective	Terzaghi et al. 1996
Stratum II	108	138	36	100	Effective	Golder, NAVFAC
Stratum III	113	133	27	200	Effective	Golder, NAVFAC

3.0 METHOD

Use SLIDE v.7.0 to analyze the final-filled configuration stability, based on limit equilibrium methods following Spencer's method of analyses.

4.0 RESULTS

Global Search Minimum:

Block Slide FS =	2.02
Circular Failure FS =	3.00

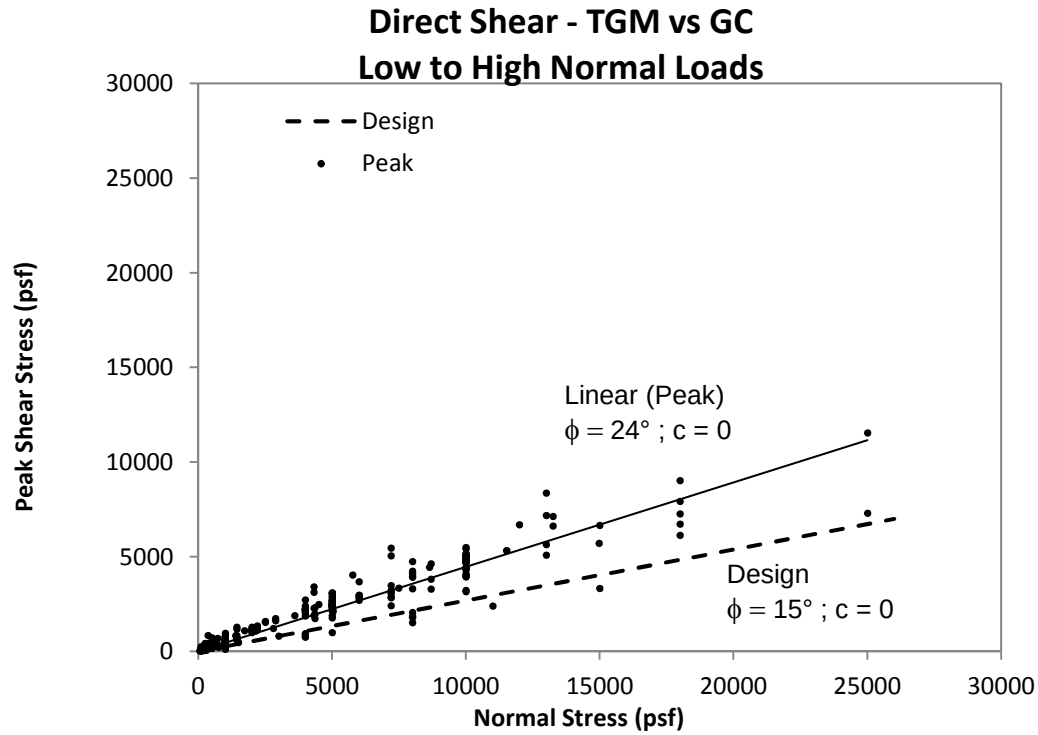
The block failure corresponding to the minimum factor of safety of 2.02 occurs along the interface of the geocomposite and textured geomembrane. The circular failure corresponding to the minimum factor of safety of 3.00 occurs through the waste and overliner system and into the fill beneath the overliner.

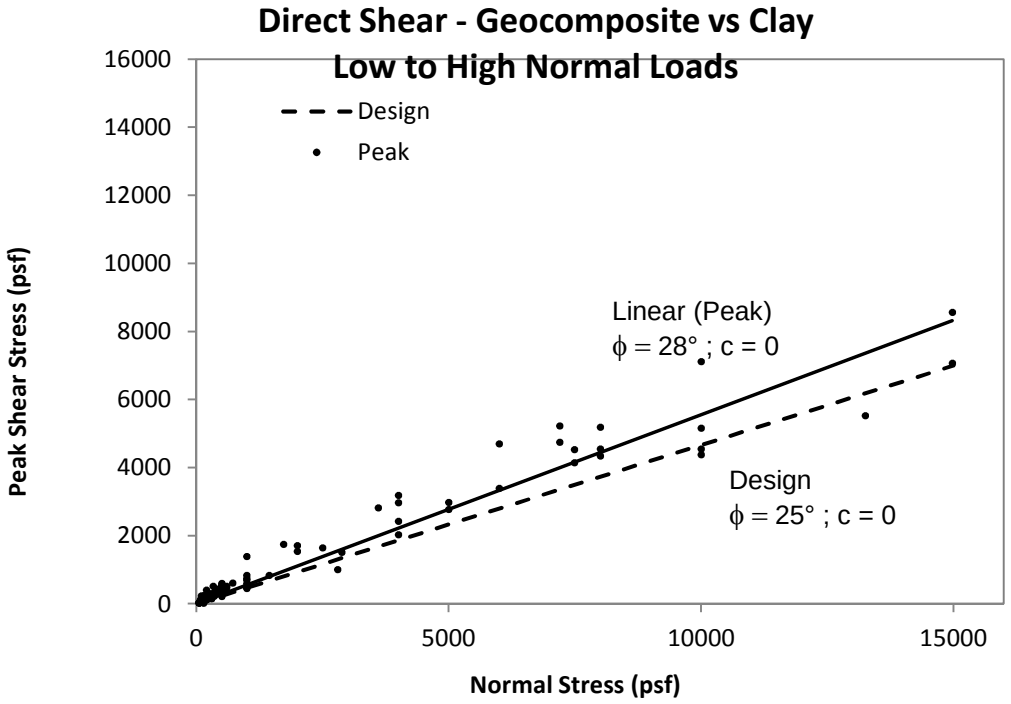
5.0 CONCLUSION

Using strength parameters that are conservatively estimated or based on test results for similar conditions, and the reasonable worst possible case configuration, the analysis indicates that the final-filled configuration above the overliner will be stable.

6.0 REFERENCES

(1) Bray, J.D., D. Zekkos, E. Kavazanjian, Jr., G.A. Athanasopoulos, and F. Riemer. 2009. Shear strength of municipal solid waste. J. Geotech. Geoenviron. Eng. (ASCE) 135(6): 709–22.


Direct Shear - TGM vs GC
Low to High Normal Loads
Design
Peak
Linear (Peak)
ϕ = 24° ; c = 0
Design
ϕ = 15° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
5000
10000
15000
20000
25000
30000


Direct Shear - Geocomposite vs Clay
Low to High Normal Loads
Design
Peak
Linear (Peak)
ϕ = 28° ; c = 0
Design
ϕ = 25° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
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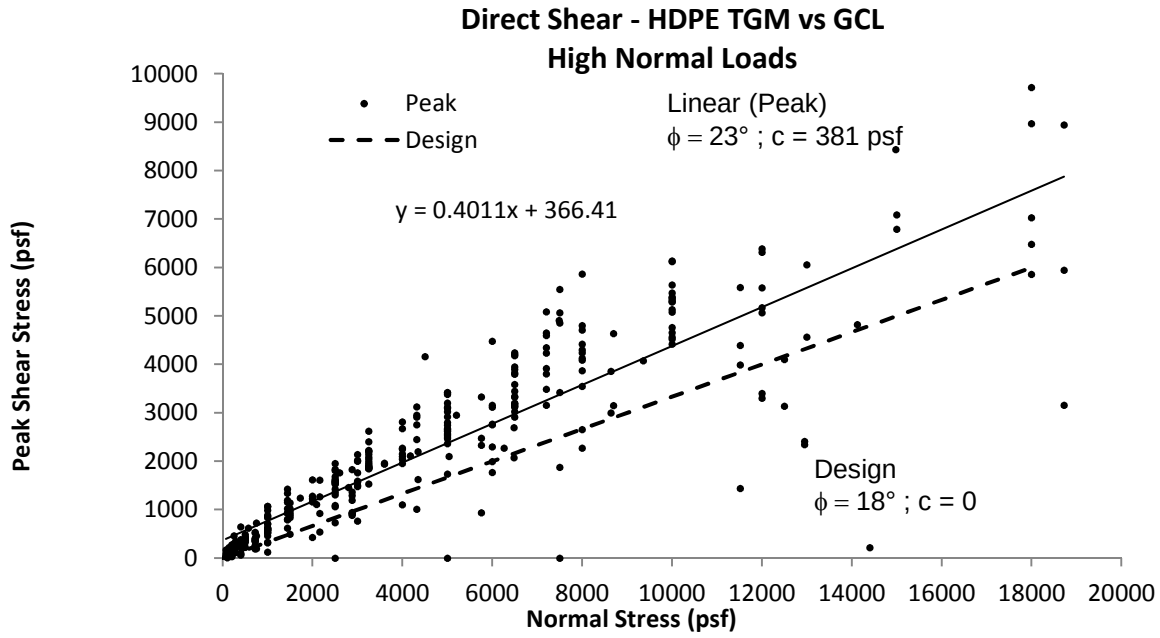
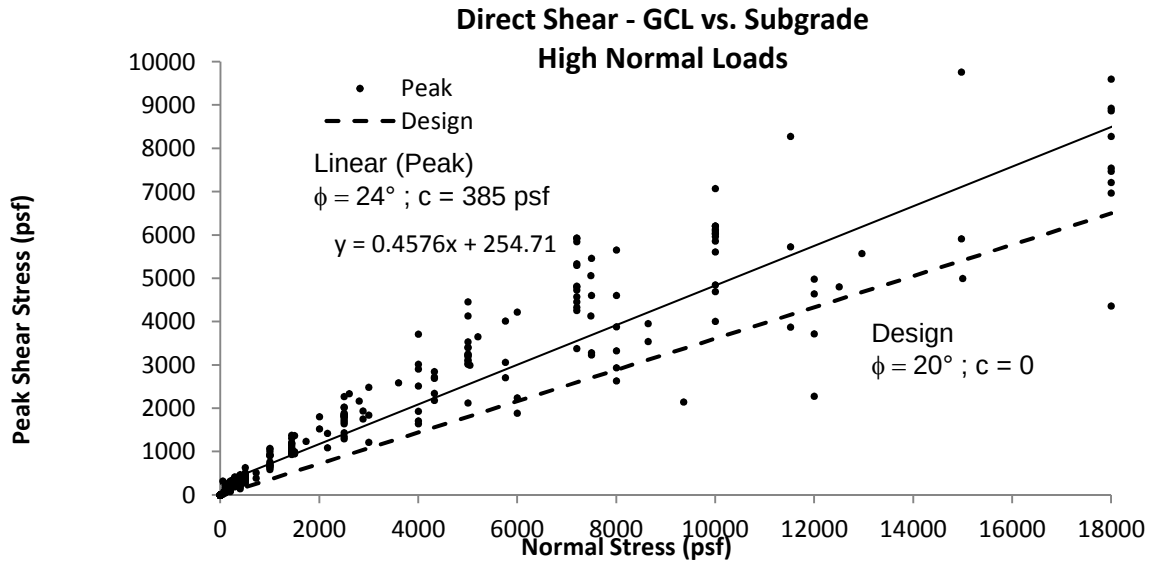
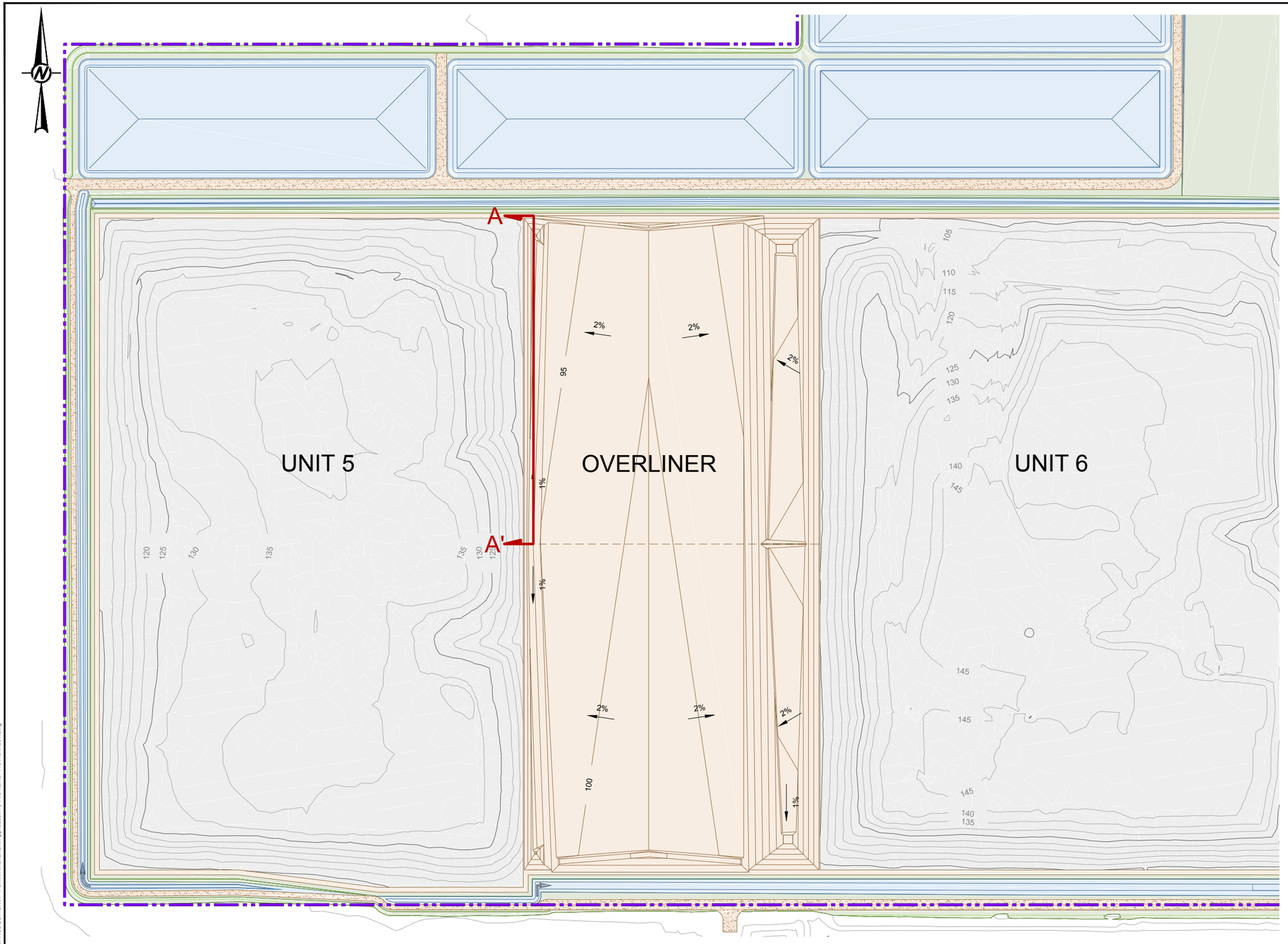
2000
4000
6000
8000
10000
12000
14000
16000
5000
10000
15000


Direct Shear - HDPE TGM vs GCL
High Normal Loads
Peak
Design
Linear (Peak)
ϕ = 23° ; c = 381 psf
y = 0.4011x + 366.41
Design
ϕ = 18° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
20000


Direct Shear - GCL vs. Subgrade
High Normal Loads
Peak
Design
Linear (Peak)
ϕ = 24° ; c = 385 psf
y = 0.4576x + 254.71
Design
ϕ = 20° ; c = 0
Peak Shear Stress (psf)
Normal Stress (psf)
0
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
0
2000
4000
6000
8000
10000
12000
14000
16000
18000



LEGEND

- PERIMETER BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- ROADS
- 1A CELL DESIGNATION

NOTE(S)

1. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
2. SUBGRADE ELEVATIONS SHOWN.
3. TOP OF THE LINER ELEVATIONS IN THE BOTTOM OF THE LEACHATE COLLECTION SUMPS ARE 2 ft LOWER THAN ELEVATION OF THE LOW POINT ON THE LINER.
4. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 70 ft-msl IN OVERLINER EAST.
5. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 79.50 ft-msl IN OVERLINER WEST.

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0 150 300
1" = 300' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

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JEFFREY B. FASSETT
85675
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
STABILITY ANALYSIS *OVERLINER SUBGRADE LAYOUT*

PROJECT NO.	APPLICATION SECTION	REV.	1 of 2	FIGURE
1401491	III3B-3C	0		III3B-3C-1

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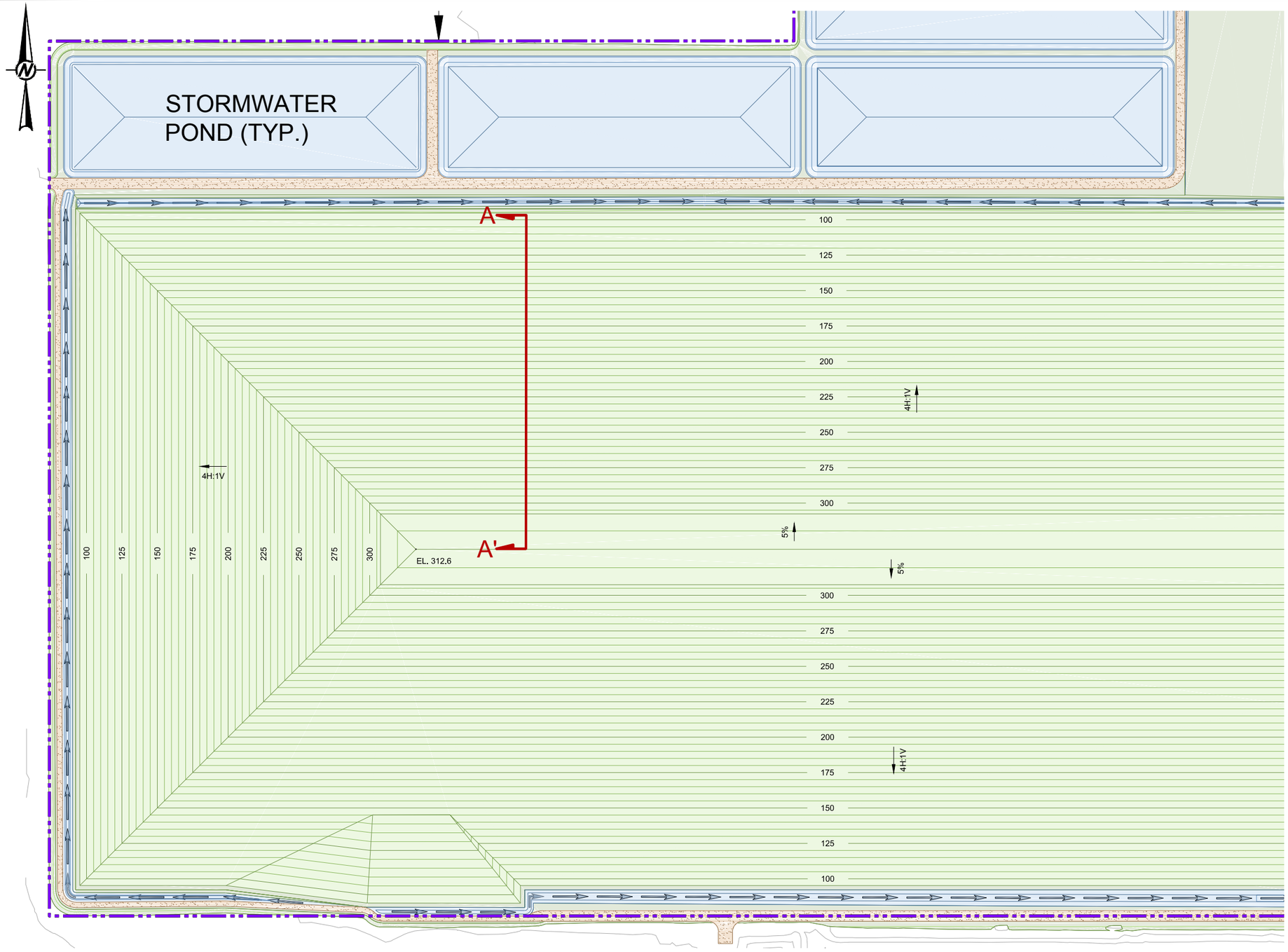

LEGEND

- PERMIT BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- FINAL COVER 25 ft CONTOUR
- FINAL COVER 5 ft CONTOUR

NOTE(S)

1. FINAL COVER ELEVATIONS SHOWN.

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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
STABILITY ANALYSIS *FINAL CONTOUR MAP*

PROJECT NO.	APPLICATION SECTION	REV.	FIGURE
1401491	III3B-3C	0	2 of 2 III3B-3C-2

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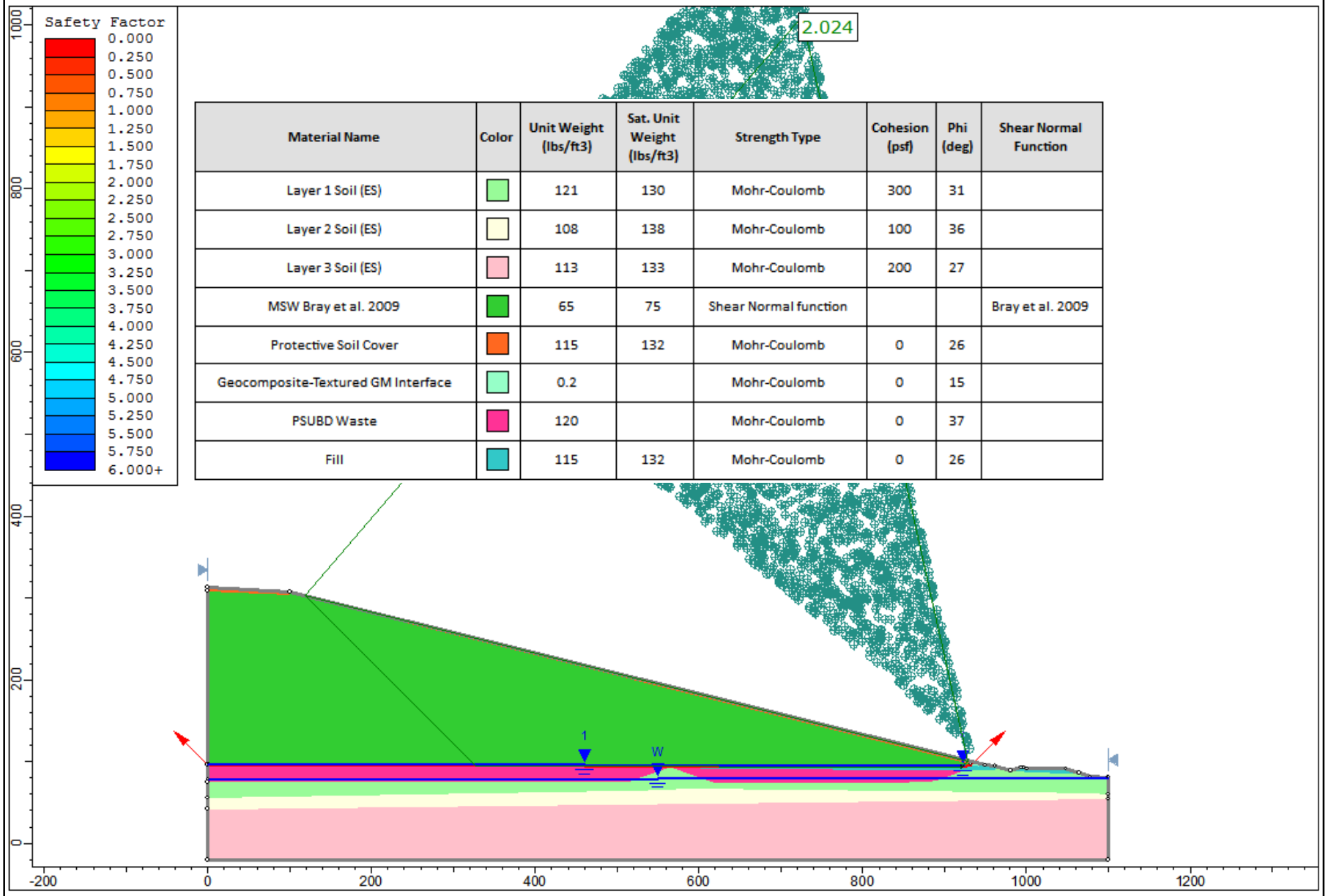
APPENDIX III3B-3C-1

FINAL CONFIGURATION – BLOCK FAILURE



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function
Layer 1 Soil (ES)		121	130	Mohr-Coulomb	300	31	
Layer 2 Soil (ES)		108	138	Mohr-Coulomb	100	36	
Layer 3 Soil (ES)		113	133	Mohr-Coulomb	200	27	
MSW Bray et al. 2009		65	75	Shear Normal function			Bray et al. 2009
Protective Soil Cover		115	132	Mohr-Coulomb	0	26	
Geocomposite-Textured GM Interface		0.2		Mohr-Coulomb	0	15	
PSUBD Waste		120		Mohr-Coulomb	0	37	
Fill		115	132	Mohr-Coulomb	0	26	

FIGURE **III3B-3C-1**

Final Configuration - Block Failure

Edinburg Regional Disposal Facility, Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-3C, Stability Analysis

Slide Analysis Information

Edinburg Regional Disposal Facility

Project Summary

File Name:	Updated 5_20.slmd - Group 1 - Block Failure Along Overliner
Slide Modeler Version:	7.015
Project Title:	Edinburg Regional Disposal Facility
Analysis:	Pre-Subtitle D Overliner Area Slope Stability
Author:	Heath Rolwing
Company:	Golder Associates
Date Created:	5/20/2016, 1:27:44 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
GLE/Morgenstern-Price with interslice force function:	Half Sine Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Use negative pore pressure cutoff:	Yes
Maximum negative pore pressure [psf]:	0
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
Multiple Groups:	Disabled
Pseudo-Random Surfaces:	Enabled
Convex Surfaces Only:	Disabled
Left Projection Angle (Start Angle):	135
Left Projection Angle (End Angle):	135
Right Projection Angle (Start Angle):	45
Right Projection Angle (End Angle):	45
Minimum Elevation:	Not Defined
Minimum Depth:	Not Defined
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Material Properties

Property	Layer 1 Soil (ES)	Layer 2 Soil (ES)	Layer 3 Soil (ES)	MSW Bray et al. 2009	Protective Soil Cover	Geocomposite-Textured GM Interface	PSUBD Waste	Fill
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Shear Normal function	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113	65	115			115
Saturated Unit Weight [lbs/ft3]	130	138	133	75	132			132
Cohesion [psf]	300	100	200		0	0	0	0
Friction Angle [deg]	31	36	27		26	15	37	26
Water Surface	Water Table	Water Table	Water Table	Piezometric Line 1	Water Table	Piezometric Line 1	Water Table	Water Table
Hu Value	Automatically Calculated	1	1	Automatically Calculated	Automatically Calculated	Automatically Calculated	1	1

Shear Normal Functions

Name: Bray et al. 2009

Normal (psf)	Shear (psf)
0	310
600	810
5200	3840
6300	4480
7300	5120
8400	5740
16700	10550

Global Minimums

Method: spencer

FS	2.023580
Axis Location:	725.822, 1010.777
Left Slip Surface Endpoint:	119.047, 302.839
Right Slip Surface Endpoint:	928.108, 100.595
Resisting Moment:	1.54856e+009 lb-ft
Driving Moment:	7.65258e+008 lb-ft
Resisting Horizontal Force:	1.45006e+006 lb
Driving Horizontal Force:	716578 lb
Total Slice Area:	65434.8 ft2
Surface Horizontal Width:	809.06 ft
Surface Average Height:	80.8776 ft

Method: gle/morgenstern-price

FS	1.995280
Axis Location:	707.792, 1064.137
Left Slip Surface Endpoint:	69.413, 309.129
Right Slip Surface Endpoint:	928.771, 100.429
Resisting Moment:	1.85557e+009 lb-ft
Driving Moment:	9.29977e+008 lb-ft
Resisting Horizontal Force:	1.63933e+006 lb
Driving Horizontal Force:	821603 lb
Total Slice Area:	74646.3 ft2
Surface Horizontal Width:	859.358 ft
Surface Average Height:	86.8629 ft

Global Minimum Coordinates

Method: spencer

X	Y
119.047	302.839
327.009	94.8768
920.256	92.7426
928.108	100.595

Method: gle/morgenstern-price

X	Y
69.4129	309.129
283.509	95.0333
921.081	92.7396
928.771	100.429

Valid / Invalid Surfaces

Method: spencer

Number of Valid Surfaces: 4502
Number of Invalid Surfaces: 498

Error Codes:

Error Code -108 reported for 178 surfaces
Error Code -110 reported for 190 surfaces
Error Code -111 reported for 130 surfaces

Method: gle/morgenstern-price

Number of Valid Surfaces: 4414
Number of Invalid Surfaces: 586

Error Codes:

Error Code -108 reported for 85 surfaces
Error Code -110 reported for 190 surfaces
Error Code -111 reported for 311 surfaces

Error Codes

The following errors were encountered during the computation:

-108 = Total driving moment or total driving force < 0.1. This is to limit the calculation of extremely high safety factors if the driving force is very small (0.1 is an arbitrary number).
-110 = The water table or a piezoline does not span the slip region for a given slip surface, when Water Surfaces is specified as the method of pore pressure calculation. If this error occurs, check that the water table or piezoline(s) span the appropriate soil cells.
-111 = safety factor equation did not converge

Slice Data

Global Minimum Query (spencer) - Safety Factor: 2.02358

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	4.66729	939.45	-45	Protective Soil Cover	0	26	34.29	69.3886	142.268	0	142.268
2	18.3442	15587.7	-45	MSW Bray et al. 2009	310	39.8056	347.802	703.805	472.566	0	472.566
3	18.3442	31993.5	-45	MSW Bray et al. 2009	414.783	33.3727	553.436	1119.92	1070.51	0	1070.51
4	18.3442	48399.3	-45	MSW Bray et al. 2009	414.783	33.3727	749.979	1517.64	1674.32	0	1674.32
5	18.3442	64805.1	-45	MSW Bray et al. 2009	414.783	33.3727	946.527	1915.37	2278.12	0	2278.12
6	18.3442	81210.9	-45	MSW Bray et al. 2009	414.783	33.3727	1143.07	2313.09	2881.93	0	2881.93
7	18.3442	97616.7	-45	MSW Bray et al. 2009	414.783	33.3727	1339.62	2710.82	3485.73	0	3485.73
8	18.3442	114023	-45	MSW Bray et al. 2009	414.783	33.3727	1536.16	3108.54	4089.53	0	4089.53

9	18.3442	130428	-45	MSW Bray et al. 2009	414.783	33.3727	1732.71	3506.27	4693.36	0	4693.36
10	18.3442	146834	-45	MSW Bray et al. 2009	814.545	30.1916	1926.4	3898.22	5300.09	0	5300.09
11	18.3442	163240	-45	MSW Bray et al. 2009	814.545	30.1916	2103.51	4256.63	5916.06	0	5916.06
12	18.3442	179646	-45	MSW Bray et al. 2009	448	32.6192	2285.99	4625.89	6527.95	0	6527.95
13	1.00362	10301.8	-45	MSW Bray et al. 2009	448	32.6192	2379.03	4814.15	6853.3	31.1996	6822.1
14	0.504933	5193.32	-45	Geocomposite-Textured GM Interface	0	15	1016.05	2056.06	7751.42	78.0961	7673.32
15	18.539	187850	-0.206116	Geocomposite-Textured GM Interface	0	15	1369.71	2771.71	10438	93.79	10344.2
16	18.539	182347	-0.206116	Geocomposite-Textured GM Interface	0	15	1329.2	2689.75	10132.1	93.7839	10038.3
17	18.539	176843	-0.206116	Geocomposite-Textured GM Interface	0	15	1288.7	2607.79	9826.17	93.7778	9732.39
18	18.539	171340	-0.206116	Geocomposite-Textured GM Interface	0	15	1248.2	2525.83	9520.27	93.7717	9426.5
19	18.539	165836	-0.206116	Geocomposite-Textured GM Interface	0	15	1207.7	2443.87	9214.43	93.7655	9120.67
20	18.539	160333	-0.206116	Geocomposite-Textured GM Interface	0	15	1167.19	2361.91	8908.54	93.7594	8814.78
21	18.539	154829	-0.206116	Geocomposite-Textured GM Interface	0	15	1126.69	2279.95	8602.64	93.7533	8508.89
22	18.539	149326	-0.206116	Geocomposite-Textured GM Interface	0	15	1086.18	2197.98	8296.75	93.7472	8203
23	18.539	143822	-0.206116	Geocomposite-Textured GM Interface	0	15	1045.68	2116.02	7990.85	93.741	7897.11
24	18.539	138319	-0.206116	Geocomposite-Textured GM Interface	0	15	1005.18	2034.06	7684.96	93.7349	7591.22
25	18.539	132815	-0.206116	Geocomposite-Textured GM Interface	0	15	964.676	1952.1	7379.06	93.7288	7285.34
26	18.539	127312	-0.206116	Geocomposite-Textured GM Interface	0	15	924.174	1870.14	7073.17	93.7227	6979.45
27	18.539	121808	-0.206116	Geocomposite-Textured GM Interface	0	15	883.672	1788.18	6767.28	93.7165	6673.56
28	18.539	116305	-0.206116	Geocomposite-Textured GM Interface	0	15	843.169	1706.22	6461.38	93.7104	6367.67
29	18.539	110801	-0.206116	Geocomposite-Textured GM Interface	0	15	802.667	1624.26	6155.49	93.7043	6061.78
30	18.539	105298	-0.206116	Geocomposite-Textured GM Interface	0	15	762.159	1542.29	5849.59	93.6982	5755.89
31	18.539	99794.3	-0.206116	Geocomposite-Textured GM Interface	0	15	721.657	1460.33	5543.75	93.692	5450.06
32	18.539	94290.8	-	Geocomposite-	0	15	681.154	1378.37	5237.84	93.6859	5144.15

			0.206116	Textured GM Interface							
33	18.539	88787.3	-0.206116	Geocomposite-Textured GM Interface	0	15	640.652	1296.41	4931.95	93.6798	4838.27
34	18.539	83283.8	-0.206116	Geocomposite-Textured GM Interface	0	15	600.149	1214.45	4626.06	93.6737	4532.38
35	18.539	77780.3	-0.206116	Geocomposite-Textured GM Interface	0	15	559.647	1132.49	4320.17	93.6675	4226.5
36	18.539	72276.7	-0.206116	Geocomposite-Textured GM Interface	0	15	519.144	1050.53	4014.28	93.6614	3920.62
37	18.539	66773.2	-0.206116	Geocomposite-Textured GM Interface	0	15	478.639	968.565	3708.39	93.6553	3614.73
38	18.539	61269.7	-0.206116	Geocomposite-Textured GM Interface	0	15	438.136	886.604	3402.5	93.6492	3308.85
39	18.539	55766.2	-0.206116	Geocomposite-Textured GM Interface	0	15	397.633	804.642	3096.61	93.643	3002.97
40	18.539	50262.7	-0.206116	Geocomposite-Textured GM Interface	0	15	357.13	722.681	2790.72	93.6369	2697.08
41	18.539	44759.2	-0.206116	Geocomposite-Textured GM Interface	0	15	316.627	640.72	2484.83	93.6308	2391.2
42	18.539	39255.7	-0.206116	Geocomposite-Textured GM Interface	0	15	276.124	558.758	2178.94	93.6247	2085.31
43	18.539	33752.2	-0.206116	Geocomposite-Textured GM Interface	0	15	235.621	476.797	1873.05	93.6185	1779.43
44	18.539	28248.7	-0.206116	Geocomposite-Textured GM Interface	0	15	195.118	394.836	1567.16	93.6124	1473.55
45	18.539	22745.1	-0.206116	Geocomposite-Textured GM Interface	0	15	154.614	312.874	1261.27	93.6063	1167.67
46	18.539	17241.6	-0.206116	Geocomposite-Textured GM Interface	0	15	114.111	230.913	955.377	93.6002	861.777
47	0.498178	387.36	45	Geocomposite-Textured GM Interface	0	15	152.874	309.353	1232.52	77.9981	1154.52
48	0.998242	731.674	45	MSW Bray et al. 2009	414.783	33.3727	980.343	1983.8	2413.16	31.1436	2382.01
49	3.53923	1941.74	45	MSW Bray et al. 2009	414.783	33.3727	851.191	1722.45	1985.25	0	1985.25
50	2.81646	570.132	45	Protective Soil Cover	0	26	104.617	211.701	434.052	0	434.052

Global Minimum Query (gle/morgenstern-price) - Safety Factor: 1.99528

Slice Number	Width [ft]	Weight [lbs]	Angle of Slice Base [degrees]	Base Material	Base Cohesion [psf]	Base Friction Angle [degrees]	Shear Stress [psf]	Shear Strength [psf]	Base Normal Stress [psf]	Pore Pressure [psf]	Effective Normal Stress [psf]
1	3.68421	741.447	-45	Protective Soil Cover	0	26	39.4318	78.6774	161.313	0	161.313
2	18.9912	18779.5	-45	MSW Bray et al. 2009	310	39.8056	399.384	796.883	584.259	0	584.259
3	18.9912	40252.9	-45	MSW Bray et al. 2009	414.783	33.3727	672.701	1342.23	1408	0	1408
4	18.9912	58243.1	-45	MSW Bray et al. 2009	414.783	33.3727	892.618	1781.02	2074.16	0	2074.16

5	18.9912	75826.6	-45	MSW Bray et al. 2009	414.783	33.3727	1101.03	2196.86	2705.46	0	2705.46
6	18.9912	93410.1	-45	MSW Bray et al. 2009	414.783	33.3727	1303.75	2601.35	3319.55	0	3319.55
7	18.9912	110994	-45	MSW Bray et al. 2009	414.783	33.3727	1501.42	2995.76	3918.33	0	3918.33
8	18.9912	128577	-45	MSW Bray et al. 2009	414.783	33.3727	1694.71	3381.41	4503.79	0	4503.79
9	18.9912	146161	-45	MSW Bray et al. 2009	414.783	33.3727	1884.3	3759.71	5078.12	0	5078.12
10	18.9912	163744	-45	MSW Bray et al. 2009	814.545	30.1916	2056.71	4103.7	5653.26	0	5653.26
11	18.9912	181328	-45	MSW Bray et al. 2009	814.545	30.1916	2222.95	4435.42	6223.38	0	6223.38
12	18.9912	198911	-45	MSW Bray et al. 2009	448	32.6192	2399.44	4787.56	6780.58	0	6780.58
13	1.00362	11000.9	-45	MSW Bray et al. 2009	448	32.6192	2484.69	4957.66	7077.51	31.1996	7046.31
14	0.505164	5547.58	-45	Geocomposite-Textured GM Interface	0	15	1063.33	2121.64	7996.16	78.1033	7918.06
15	19.9241	215544	-0.206116	Geocomposite-Textured GM Interface	0	15	1430.91	2855.07	10749.1	93.8042	10655.3
16	19.9241	209187	-0.206116	Geocomposite-Textured GM Interface	0	15	1396.47	2786.34	10492.6	93.7976	10398.8
17	19.9241	202830	-0.206116	Geocomposite-Textured GM Interface	0	15	1361.34	2716.26	10231	93.791	10137.3
18	19.9241	196474	-0.206116	Geocomposite-Textured GM Interface	0	15	1325.5	2644.74	9964.08	93.7844	9870.3
19	19.9241	190117	-0.206116	Geocomposite-Textured GM Interface	0	15	1288.9	2571.72	9691.55	93.7778	9597.77
20	19.9241	183760	-0.206116	Geocomposite-Textured GM Interface	0	15	1251.52	2497.14	9413.25	93.7713	9319.48
21	19.9241	177404	-0.206116	Geocomposite-Textured GM Interface	0	15	1213.36	2420.99	9129.02	93.7647	9035.26
22	19.9241	171047	-0.206116	Geocomposite-Textured GM Interface	0	15	1174.4	2343.26	8838.92	93.7581	8745.16
23	19.9241	164690	-0.206116	Geocomposite-Textured GM Interface	0	15	1134.66	2263.96	8542.95	93.7515	8449.2
24	19.9241	158334	-0.206116	Geocomposite-Textured GM Interface	0	15	1094.14	2183.12	8241.26	93.7449	8147.51
25	19.9241	151977	-0.206116	Geocomposite-Textured GM Interface	0	15	1052.89	2100.81	7934.05	93.7384	7840.31
26	19.9241	145620	-0.206116	Geocomposite-Textured GM Interface	0	15	1010.93	2017.08	7621.56	93.7318	7527.83
27	19.9241	139264	-0.206116	Geocomposite-Textured GM Interface	0	15	968.295	1932.02	7304.11	93.7252	7210.39
28	19.9241	132907	-0.206116	Geocomposite-Textured GM Interface	0	15	925.048	1845.73	6982.09	93.7186	6888.37
29	19.9241	126551	-0.206116	Geocomposite-Textured GM Interface	0	15	881.245	1758.33	6655.86	93.712	6562.14
30	19.9241	120194	-0.206116	Geocomposite-Textured GM Interface	0	15	836.935	1669.92	6325.96	93.7054	6232.25

31	19.9241	113837	-0.206116	Geocomposite-Textured GM Interface	0	15	792.2	1580.66	5992.79	93.6989	5899.1
32	19.9241	107481	-0.206116	Geocomposite-Textured GM Interface	0	15	747.093	1490.66	5656.92	93.6923	5563.23
33	19.9241	101124	-0.206116	Geocomposite-Textured GM Interface	0	15	701.691	1400.07	5318.84	93.6857	5225.16
34	19.9241	94767.3	-0.206116	Geocomposite-Textured GM Interface	0	15	656.068	1309.04	4979.08	93.6791	4885.4
35	19.9241	88410.6	-0.206116	Geocomposite-Textured GM Interface	0	15	610.29	1217.7	4638.18	93.6725	4544.51
36	19.9241	82054	-0.206116	Geocomposite-Textured GM Interface	0	15	564.427	1126.19	4296.66	93.6659	4202.99
37	19.9241	75697.3	-0.206116	Geocomposite-Textured GM Interface	0	15	518.544	1034.64	3955	93.6594	3861.34
38	19.9241	69340.7	-0.206116	Geocomposite-Textured GM Interface	0	15	472.711	943.191	3613.69	93.6528	3520.04
39	19.9241	62984	-0.206116	Geocomposite-Textured GM Interface	0	15	426.983	851.95	3273.17	93.6462	3179.52
40	19.9241	56627.4	-0.206116	Geocomposite-Textured GM Interface	0	15	381.416	761.031	2933.85	93.6396	2840.21
41	19.9241	50270.7	-0.206116	Geocomposite-Textured GM Interface	0	15	336.06	670.533	2596.1	93.633	2502.46
42	19.9241	43914.1	-0.206116	Geocomposite-Textured GM Interface	0	15	290.957	580.541	2260.23	93.6264	2166.61
43	19.9241	37557.5	-0.206116	Geocomposite-Textured GM Interface	0	15	246.146	491.13	1926.55	93.6199	1832.93
44	19.9241	31200.8	-0.206116	Geocomposite-Textured GM Interface	0	15	201.657	402.362	1595.25	93.6133	1501.63
45	19.9241	24844.2	-0.206116	Geocomposite-Textured GM Interface	0	15	157.513	314.283	1266.53	93.6067	1172.92
46	19.9241	18487.5	-0.206116	Geocomposite-Textured GM Interface	0	15	113.731	226.926	940.502	93.6001	846.902
47	0.663035	503.24	45	Geocomposite-Textured GM Interface	0	15	109.147	217.779	885.636	72.8742	812.762
48	0.836398	596.289	45	MSW Bray et al. 2009	414.783	33.3727	660.26	1317.4	1396.41	26.0943	1370.32
49	3.37351	1828.12	45	MSW Bray et al. 2009	414.783	33.3727	583.483	1164.21	1137.75	0	1137.75
50	2.81647	570.138	45	Protective Soil Cover	0	26	65.5953	130.881	268.347	0	268.347

Interslice Data

Global Minimum Query (spencer) - Safety Factor: 2.02358

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	119.047	302.839	0	0	0
2	123.715	298.171	504.246	117.459	13.1126
3	142.059	279.827	2804.22	653.215	13.1126
4	160.403	261.483	12307.4	2866.9	13.1127
5	178.747	243.139	29287.9	6822.33	13.1127
6	197.091	224.795	53745.6	12519.5	13.1126
7	215.436	206.45	85680.6	19958.5	13.1127
8	233.78	188.106	125093	29139.2	13.1127
9	252.124	169.762	171982	40061.6	13.1127
10	270.468	151.418	226349	52725.8	13.1127
11	288.812	133.074	288299	67156.4	13.1127
12	307.157	114.729	358305	83463.7	13.1127
13	325.501	96.3853	436195	101607	13.1126
14	326.504	95.3817	440689	102654	13.1126
15	327.009	94.8768	444091	103447	13.1127
16	345.548	94.8101	419439	97704.3	13.1127
17	364.087	94.7434	395516	92131.7	13.1127
18	382.626	94.6767	372323	86729	13.1127
19	401.165	94.61	349858	81496.1	13.1127
20	419.704	94.5433	328123	76433	13.1127
21	438.243	94.4766	307117	71539.8	13.1126
22	456.782	94.4099	286840	66816.5	13.1126
23	475.321	94.3432	267292	62263	13.1126
24	493.86	94.2765	248473	57879.4	13.1127
25	512.399	94.2098	230383	53665.6	13.1127
26	530.938	94.1431	213023	49621.7	13.1127
27	549.477	94.0765	196392	45747.6	13.1127
28	568.016	94.0098	180490	42043.4	13.1127
29	586.555	93.9431	165317	38509	13.1127
30	605.094	93.8764	150873	35144.5	13.1127
31	623.633	93.8097	137159	31949.8	13.1126
32	642.172	93.743	124173	28924.9	13.1127
33	660.71	93.6763	111917	26070	13.1127
34	679.249	93.6096	100390	23384.8	13.1126
35	697.788	93.5429	89591.8	20869.6	13.1127
36	716.327	93.4762	79523.1	18524.1	13.1126
37	734.866	93.4095	70183.4	16348.6	13.1127
38	753.405	93.3428	61572.9	14342.8	13.1127
39	771.944	93.2761	53691.6	12506.9	13.1126
40	790.483	93.2095	46539.5	10840.9	13.1126
41	809.022	93.1428	40116.5	9344.75	13.1127
42	827.561	93.0761	34422.6	8018.42	13.1127
43	846.1	93.0094	29458	6861.95	13.1127
44	864.639	92.9427	25222.4	5875.32	13.1127
45	883.178	92.876	21716.1	5058.55	13.1127
46	901.717	92.8093	18938.9	4411.62	13.1126
47	920.256	92.7426	16890.8	3934.55	13.1127
48	920.754	93.2408	16200.8	3773.81	13.1126
49	921.752	94.239	12815	2985.12	13.1126
50	925.291	97.7783	2781.47	647.917	13.1127
51	928.108	100.595	0	0	0

Global Minimum Query (gle/morgenstern-price) - Safety Factor: 1.99528

Slice Number	X coordinate [ft]	Y coordinate - Bottom [ft]	Interslice Normal Force [lbs]	Interslice Shear Force [lbs]	Interslice Force Angle [degrees]
1	69.4129	309.129	0	0	0
2	73.0971	305.445	449.041	1.86971	0.238566
3	92.0883	286.454	3960.38	101.38	1.46637
4	111.08	267.463	17925.2	840.868	2.68577
5	130.071	248.472	40364.8	2744.62	3.88986
6	149.062	229.48	70835.8	6286.89	5.07188
7	168.053	210.489	109119	11903.1	6.22542
8	187.044	191.498	155020	19980.2	7.34424
9	206.035	172.507	208370	30853.6	8.42266
10	225.027	153.516	269025	44803.9	9.45536
11	244.018	134.524	337330	62139.2	10.4374
12	263.009	115.533	413304	83069.7	11.3644
13	282	96.542	496509	107644	12.2325
14	283.004	95.5384	501119	109048	12.2767
15	283.509	95.0333	504621	110014	12.2988
16	303.433	94.9616	476883	111298	13.1369
17	323.357	94.8899	449813	111339	13.9026
18	343.281	94.8182	423424	110237	14.5928
19	363.206	94.7466	397729	108099	15.2052
20	383.13	94.6749	372745	105037	15.7375
21	403.054	94.6032	348485	101165	16.188
22	422.978	94.5315	324966	96601.7	16.5555
23	442.902	94.4598	302201	91463.9	16.8389
24	462.826	94.3882	280207	85868.4	17.0375
25	482.75	94.3165	258999	79929	17.1506
26	502.674	94.2448	238591	73756.1	17.178
27	522.599	94.1731	218996	67454.8	17.1198
28	542.523	94.1015	200228	61123.7	16.9759
29	562.447	94.0298	182299	54854.3	16.7467
30	582.371	93.9581	165218	48729.8	16.433
31	602.295	93.8864	148997	42824.1	16.0355
32	622.219	93.8148	133644	37201.7	15.5553
33	642.143	93.7431	119165	31916.8	14.994
34	662.068	93.6714	105566	27013.4	14.3535
35	681.992	93.5997	92851.8	22524.7	13.6358
36	701.916	93.5281	81025.3	18473.5	12.8437
37	721.84	93.4564	70088.1	14872.5	11.9803
38	741.764	93.3847	60040.5	11724.3	11.0493
39	761.688	93.313	50881.5	9021.93	10.0548
40	781.612	93.2414	42609.2	6749.81	9.00154
41	801.536	93.1697	35220.5	4884.07	7.89493
42	821.461	93.098	28711.2	3393.53	6.74082
43	841.385	93.0263	23076.3	2240.55	5.54564
44	861.309	92.9547	18310.4	1381.98	4.31622
45	881.233	92.883	14407.1	770.164	3.05996
46	901.157	92.8113	11359.7	353.922	1.78453
47	921.081	92.7396	9161.19	79.606	0.497858
48	921.744	93.4027	8501.62	67.5061	0.454941
49	922.581	94.2391	6781.45	47.4387	0.400798
50	925.954	97.6126	974.948	3.10339	0.18238
51	928.771	100.429	0	0	0

List Of Coordinates

Water Table

X	Y
0	78
1100	80

Piezoline

X	Y
0	97.558
921.249	94.239
924.275	94.2392

Block Search Polyline

X	Y
0	96.0532
921.258	92.739
932.165	96.363

External Boundary

X	Y
0	-20
1100	-20
1100	54.112
1100	60
1100	80.89
1078.01	81
1064.17	85.614
1048.01	91
1001.09	91
996.495	92.531
993.495	92.531
980.732	88.586
961.489	95
949.489	95.25
100	307.6
0	312.6
0	309.1
0	96.558
0	95.558
0	75
0	55.708
0	42.14

Material Boundary

X	Y
0	95.558
419.51	94.0466
921.249	92.239
932.139	95.838
938.951	95.832
942.242	95
942.242	96
938.951	96.823
932.139	96.838
930.81	96.3987
921.249	93.239
0	96.558

Material Boundary

X	Y
419.51	94.0466
562.177	92.569
563.467	93
565.467	93
566.375	92.697
585.489	92.746
601.308	91.133
926.082	89.871
942.242	95

Material Boundary

X	Y
562.177	92.569
566.375	92.697

Material Boundary

X	Y
0	75
509.467	75
562.177	92.569

Material Boundary

X	Y
566.375	92.697
619.467	75
881.767	75
926.082	89.871

Material Boundary

X	Y
942.242	95
949.489	95.25

Material Boundary

X	Y
926.082	89.871
965.181	90.35
980.732	88.586

Material Boundary

X	Y
980.732	88.586
1002.67	86.332
1052.82	84.218
1064.17	85.614

Material Boundary

X	Y
0	55.708
589.394	65.955
1100	60

Material Boundary

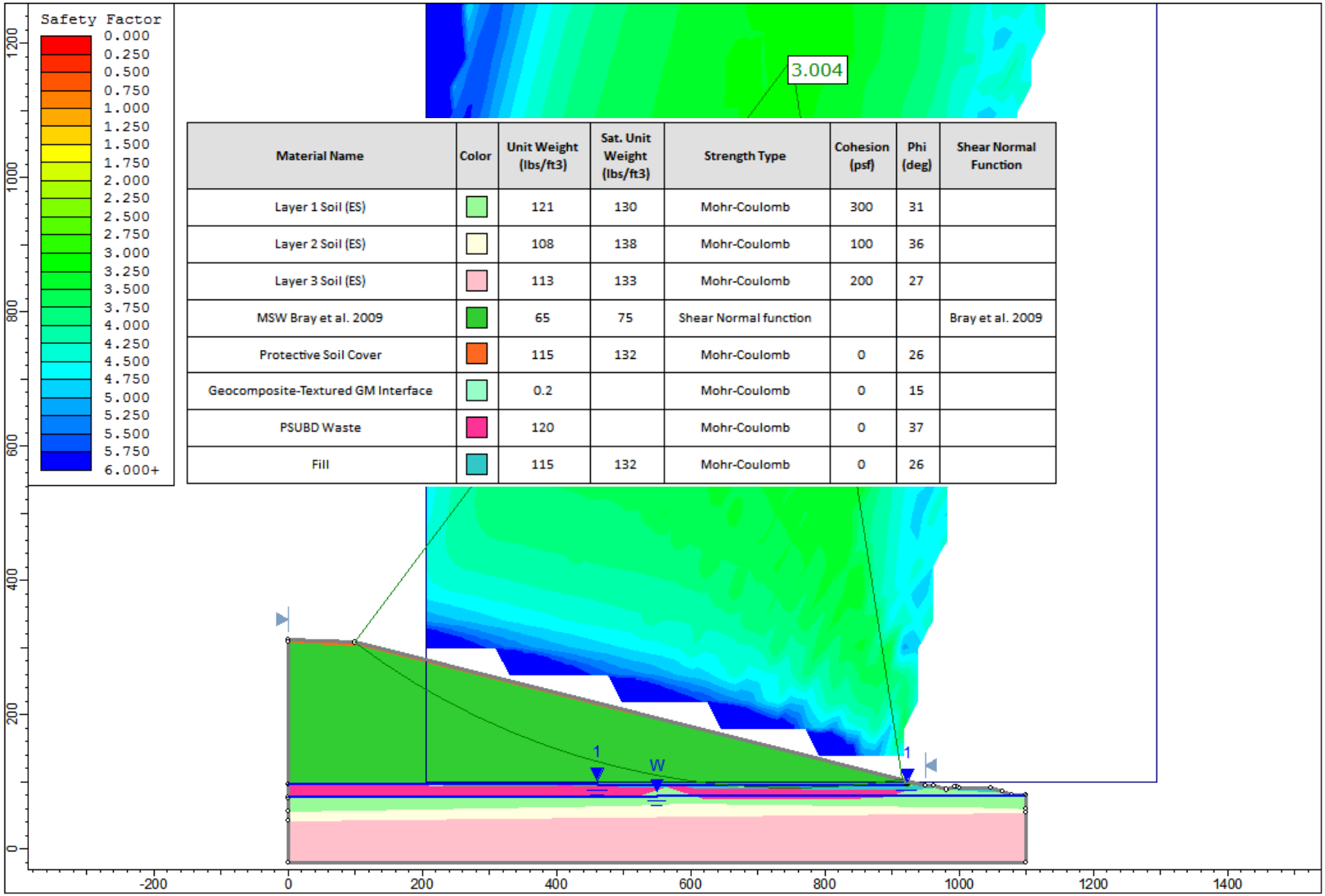
X	Y
0	42.14
1100	54.112

Material Boundary

X	Y
0	309.1
100	304.1
930.81	96.3987

APPENDIX III3B-3C-2

FINAL CONFIGURATION – CIRCULAR FAILURE



Material Name	Color	Unit Weight (lbs/ft3)	Sat. Unit Weight (lbs/ft3)	Strength Type	Cohesion (psf)	Phi (deg)	Shear Normal Function
Layer 1 Soil (ES)		121	130	Mohr-Coulomb	300	31	
Layer 2 Soil (ES)		108	138	Mohr-Coulomb	100	36	
Layer 3 Soil (ES)		113	133	Mohr-Coulomb	200	27	
MSW Bray et al. 2009		65	75	Shear Normal function			Bray et al. 2009
Protective Soil Cover		115	132	Mohr-Coulomb	0	26	
Geocomposite-Textured GM Interface		0.2		Mohr-Coulomb	0	15	
PSUBD Waste		120		Mohr-Coulomb	0	37	
Fill		115	132	Mohr-Coulomb	0	26	

FIGURE **III3B-3C-2**

Final Configuration - Circular Failure

Edinburg Regional Disposal Facility, Permit Amendment Application TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix B-3C-2, Stability Analysis

Slide Analysis Information

Edinburg Regional Disposal Facility

Project Summary

File Name:	Updated 5_20.slmd - Group 1 - Circular Failure Through Old Waste
Last saved with Slide version:	7.011
Project Title:	Edinburg Regional Disposal Facility
Analysis:	Pre-Subtitle D Overliner Area Slope Stability
Author:	Heath Rolwing
Company:	Golder Associates
Date Created:	5/20/2016, 1:27:44 PM

General Settings

Units of Measurement:	Imperial Units
Time Units:	days
Permeability Units:	feet/second
Failure Direction:	Left to Right
Data Output:	Standard
Maximum Material Properties:	20
Maximum Support Properties:	20

Analysis Options

Slices Type:	Vertical
Analysis Methods Used	
GLE/Morgenstern-Price with interslice force function:	Half Sine Spencer
Number of slices:	50
Tolerance:	0.005
Maximum number of iterations:	75
Check malpha < 0.2:	Yes
Create Interslice boundaries at intersections with water tables and piezos:	Yes
Initial trial value of FS:	1
Steffensen Iteration:	Yes

Groundwater Analysis

Groundwater Method:	Water Surfaces
Pore Fluid Unit Weight [lbs/ft3]:	62.4
Use negative pore pressure cutoff:	Yes
Maximum negative pore pressure [psf]:	0
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:	Grid Search
Radius Increment:	10
Composite Surfaces:	Disabled
Reverse Curvature:	Invalid Surfaces
Minimum Elevation:	Not Defined
Minimum Depth [ft]:	4
Minimum Area:	Not Defined
Minimum Weight:	Not Defined

Seismic

Advanced seismic analysis:	No
Staged pseudostatic analysis:	No

Material Properties

Property	Layer 1 Soil (ES)	Layer 2 Soil (ES)	Layer 3 Soil (ES)	MSW Bray et al. 2009	Protective Soil Cover	Geocomposite-Textured GM Interface	PSUBD Waste	Fill
Color								
Strength Type	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Shear Normal function	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb	Mohr-Coulomb
Unsaturated Unit Weight [lbs/ft3]	121	108	113	65	115			115
Saturated Unit Weight [lbs/ft3]	130	138	133	75	132			132
Cohesion [psf]	300	100	200		0	0	0	0
Friction Angle [deg]	31	36	27		26	15	37	26
Water Surface	Water Table	Water Table	Water Table	Piezometric Line 1	Water Table	Piezometric Line 1	Water Table	Water Table
Hu Value	Automatically Calculated	1	1	Automatically Calculated	Automatically Calculated	Automatically Calculated	1	1

Shear Normal Functions

Name: Bray et al. 2009

Normal (psf)	Shear (psf)
0	310
600	810
5200	3840
6300	4480
7300	5120
8400	5740
16700	10550

List Of Coordinates

Water Table

X	Y
0	78
1100	80

Piezoline

X	Y
0	97.558
921.249	94.239
924.275	94.2392

Block Search Polyline

X	Y
565.818	94.095
921.258	92.739
932.165	96.363

External Boundary

X	Y
0	-20
1100	-20
1100	54.112
1100	60
1100	80.89
1078.01	81
1064.17	85.614
1048.01	91
1001.09	91
996.495	92.531
993.495	92.531
980.732	88.586
961.489	95
949.489	95.25
100	307.6
0	312.6
0	309.1
0	96.558
0	95.558
0	75
0	55.708
0	42.14

Material Boundary

X	Y
0	95.558
419.51	94.0466
921.249	92.239
932.139	95.838
938.951	95.832
942.242	95
942.242	96
938.951	96.823
932.139	96.838
930.81	96.3987
921.249	93.239
0	96.558

Material Boundary

X	Y
419.51	94.0466
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565.467	93
566.375	92.697
585.489	92.746
601.308	91.133
926.082	89.871
942.242	95

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566.375	92.697

Material Boundary

X	Y
0	75
509.467	75
562.177	92.569

Material Boundary

X	Y
566.375	92.697
619.467	75
881.767	75
926.082	89.871

Material Boundary

X	Y
942.242	95
949.489	95.25

Material Boundary

X	Y
926.082	89.871
965.181	90.35
980.732	88.586

Material Boundary

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980.732	88.586
1002.67	86.332
1052.82	84.218
1064.17	85.614

Material Boundary

X	Y
0	55.708
589.394	65.955
1100	60

Material Boundary

X	Y
0	42.14
1100	54.112

Material Boundary

X	Y
0	309.1
100	304.1
930.81	96.3987

APPENDIX III3C

ALTERNATIVE LINER CALCULATIONS - POINT OF COMPLIANCE DEMONSTRATION

CITY OF EDINBURG SOLID WASTE MANAGEMENT

PERMIT AMENDMENT APPLICATION

Part III, ATTACHMENT 3, APPENDIX C

POINT OF COMPLIANCE DEMONSTRATION

Edinburg Regional Disposal Facility

Edinburg, Hidalgo County, Texas

TCEQ Permit MSW-956C

Submitted To: City of Edinburg
Department of Solid Waste Management
8601 North Jasman Road
Edinburg, Texas 78542 USA

Submitted By: Golder Associates Inc.
500 Century Plaza Drive, Suite 190
Houston, TX 77073 USA



GOLDER ASSOCIATES INC.
Professional Engineering Firm
Registration Number F-2578

INTENDED FOR PERMITTING PURPOSES ONLY

July 2017

Project No. 1401491

Golder Associates

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GOLDER ASSOCIATES INC.
Professional Engineering Firm
Registration Number F-2578

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EXECUTIVE SUMMARY

In accordance to 30 TAC §330.335, this document will demonstrate that the alternative liner system will provide a level of groundwater protection that is greater than or equal to the level of protection provided by a "composite liner" defined by 30 TAC §330.331(b) by establishing that the maximum contaminant levels, detailed in 30 Texas Administrative Code (TAC) §330.331(a)(1), will not be exceeded in the uppermost aquifer at the point of compliance (POC).

1.0 ALTERNATIVE LINER

The lateral and vertical expansion amendment for a 602.5-acre MSW facility, Edinburg Regional Disposal Facility TCEQ Permit MSW-956C, adds 213.1 acres of waste disposal area including 205.7 acres, Unit 7, located east and north east of Unit 6 and 7.4 acres between Pre-Subtitle D Units 1-4 and Unit 6. Waste disposal areas Units 1-4 and the additional 7.4 acres will be developed as one of two options; an Overliner or Unit 8. The Overliner option includes construction of an alternative liner system over the in-place final cover of Pre-Subtitle D Units 1-4 and the Unit 8 option will relocate the waste within Pre-Subtitle D Units 1–4.

The alternative liner system for the lateral expansion, Units 7 and 8, will be identical to the liner design currently approved under permit TCEQ Permit MSW-956B used in Units 5 and 6, consisting of, from top to bottom:

- 2-foot protective cover soil;
- Double-sided geocomposite drainage layer;
- 60-mil high-density polyethylene (HDPE) geomembrane liner, textured on both sides; and
- Reinforced geosynthetic clay liner (GCL).

For the option of constructing an overliner over the in-place final cover of Pre-Subtitle D Units 1-4, 60-mil linear low-density polyethylene (LLDPE) will be used instead of HDPE because its elastic properties are better suited for potential waste settlement. Prior to placement of an overliner, Units 1–4 will be regraded to their originally permitted final cover grades for the overliner's subgrade.

The alternative liner system differs from the "composite liner" by substituting a GCL in place the minimum 2-foot layer of re-compacted soil with a hydraulic conductivity of no more than $1x10^{-7}$ cm/s. GCLs are geosynthetic materials of low hydraulic conductivity and are manufactured by placing powdered or granulated bentonite on a geotextile or geomembrane substrate. The bentonite layer is characteristically 7 to 10 mm thick (following hydration) and is placed at a unit weight of approximately 0.8 pounds per square foot (lb/ft^2). The GCLs with a geotextile substrate also have an overlying geotextile needle-punched to underlying geotextile for increased structural integrity. Typically, the hydraulic conductivity of the bentonite component of GCLs ranges from less than 1×10^{-9} to 5×10^{-9} cm/sec, which roughly correlates to a hydraulic flux in the 10^{-8} m^3/m^2/sec range.

2.0 HYDRAULIC EVALUATION

2.1 Leakage Rate Estimates

The leakage through composite liners can be estimated using the "Giroud equation", presented in Giroud, 1997. The method requires several assumptions regarding the characteristics of the composite liners. First,

it assumes the permeation through the full area of the geomembrane is insignificant in comparison to rapid leakage through isolated defects or holes. Also a necessary assumption is the extent to which intimate contact has been achieved. A composite liners having intimate contact has been constructed such that the geomembrane component lies flush with the surface of the underlying clay component, with few or no gaps in between. When intimate contact has been achieved, the effective area of leakage is very small, and the total composite liner leakage is minimized. This phenomenon is referred to as "composite action."

The equations used in the analysis are derived both from theoretical models of fluid flow and from empirical analyses of actual composite liners. Flow through a circular defect in a geomembrane is calculated as:

$$Q = C\left[1 + 0.1\left(\frac{h}{t_s}\right)^{0.95}\right] a^{0.1} h^{0.9} k_s^{0.74}$$

where:

Q = rate of leakage through a defect (m^3/sec)

C = Dimensionless constant related to the quality of the intimate contact between the geomembrane and the underlying soil component

h = hydraulic head on the geomembrane (m)

t_s = thickness of the low-permeability soil component (i.e., the CCL or GCL) (m)

a = area of geomembrane defect (m^2)

k_s = hydraulic conductivity of soil component (i.e., CCL or GCL) (m/s)

Using the above equation, leakage rates for the "composite liner" were compared to that of an alternative liner for both "good" and "poor" intimate contact and for circular holes in the geomembrane with an area of 0.1 and 1.0 cm^2. Appendix III3C-1, Leakage Rate Calculations demonstrate for each condition, the geomembrane/GCL combination had calculated leakage rates approximately half that of the geomembrane/compacted clay.

Based on the leakage analysis, substituting a GCL for a compacted clay liner provides a level of groundwater protection that is greater than the level of protection provided by the "composite liner".

3.0 EVALUATION OF IMPACT ON GROUNDWATER QUALITY

The predicted concentrations of selected leachate chemical constituents at the point of compliance for an alternative liner do not exceed the maximum concentration levels (MCLs) listed in Table 1 of 30 TAC §330.331(a)(1) in accordance with 30 TAC §330.335.

Based on the MCLs and leachate concentrations, minimum dilution attenuation factors (DAFs) that must be achieved to meet the regulatory requirements can be calculated. The DAF is defined as the initial

concentration of a contaminant within the leachate, C_o, divided by the concentration at the point of compliance, C_p; therefore, if C_o is input as 1, the contaminant transport model will calculate a value of C_p. The inverse of the C_p is the DAF. The calculated DAF can then be compared with the minimum required DAF to ensure that the alternative liner design meets regulatory requirements.

The Texas Water Commission (TWC) provided recommended leachate concentrations for each contaminant for which MCLs have been established in a document titled ”Alternative Liner Design Handbook, A Performance Standard As Authorized by 30 Texas Administrative Code §330.202, Version 1, August 1993.” Table IIIC3-1, MCL, Input Concentration, and DAF Requirements summarizes these recommended MCLs used to calculate DAF in the absence of leachate chemical composition data.

Leachate samples have been collected from cells within Units 5 and 6 and analyzed between 2005 and 2015. The maximum concentrations from the leachate samples are also listed in Table III3C-1. With the exception of barium, the site specific leachate concentrations are lower than the TWC recommended concentrations.

As shown on Table III3C-1, the DAFs range from 1 to 260 and the maximum DAF using site-specific data is 22. A DAF of 1 or less indicates that no dilution or attenuation is needed; i.e. the concentration of that constituent within the leachate is below the MCL. The highest DAF is 260, for trichloroethylene.

Table III3C-1: MCL, Input Concentration, and DAF Requirements

Constituent	MCL (mg/L) listed in 30 TAC §330.331(a)(1)	Max. Site Specific Leachate Conc. (mg/L)	TWC Input Conc. (mg/L)	Minimum Required DAF	
				Site Specific	TWC
Arsenic	0.05	0.256	5	5	100
Barium	1	22.3	5	22	5
Benzene	0.005	0.0127	0.8140	3	163
Cadmium	0.01	0.0062	1	1	100
Carbon tetrachloride	0.005	<0.001	0.05		10
Chromium (hexavalent)	0.05		5		100
2,4-Dichlorophenoxy acetic acid	0.1		10		100
1,4-Dichlorobenzene	0.075	0.0187	7.5	0.25	100
1,2-Dichloroethane	0.005	0.00121	0.5	0.24	100
1,1-Dichloroethylene	0.007	<0.001	0.7		100
Endrin	0.0002		0.05		250
Fluoride	4				
Lindane	0.004		0.4	0	100
Lead	0.05	0.21	5	4	100
Mercury	0.002	<0.0002	0.2		100
Methoxychlor	0.1				
Nitrate	10				
Selenium	0.01	0.026	1	3	100
Silver	0.05	<0.001	5		100
Toxaphene	0.005		0.5	0	100
1,1,1-Trichloroethane	0.2	<0.001			
Trichloroethylene	0.005	<0.001	1.3		260
2,4,5-Trichlorophenoxy acetic acid	0.01		1	0	100
Vinyl chloride	0.002	0.00498	0.2	2.5	100

The following subsections describe the methodology and input parameters that were used to demonstrate that a suitable DAF will be obtained using an alternative liner design.

3.1 Contaminant Transport Model

MODFLOW and MT3DS software was used to calculate the DAF associated with the transport of leachate from beneath the alternative liner to the point of compliance (POC). MODFLOW and MT3DMS were selected for this analysis because they are well suited to a wide range of flow and transport flow simulations,

have been widely tested and accepted in the groundwater community and by regulatory agencies, and reviewed/tested in a number of legal proceedings over the past 20 years. The model software is MODFLOW 2000 (McDonald and Harbaugh 1988, Harbaugh et al., 1996, 2000, 2005) and MT3DMS (Zheng 2010). The model platform is Groundwater Vistas (ESI 2015). The following section describes the variables required as input to the MODFLOW model.

3.1.1 MODFLOW Variables

3.1.1.1 Point of Compliance

The modeled area, shown on Figure III3C-1, Point of Compliance Demonstrating Relative Concentrations, covers an area of over 5 square miles, including the entire landfill footprint, and is bounded by the point of compliance defined in Part III5, Groundwater Characterization Report.

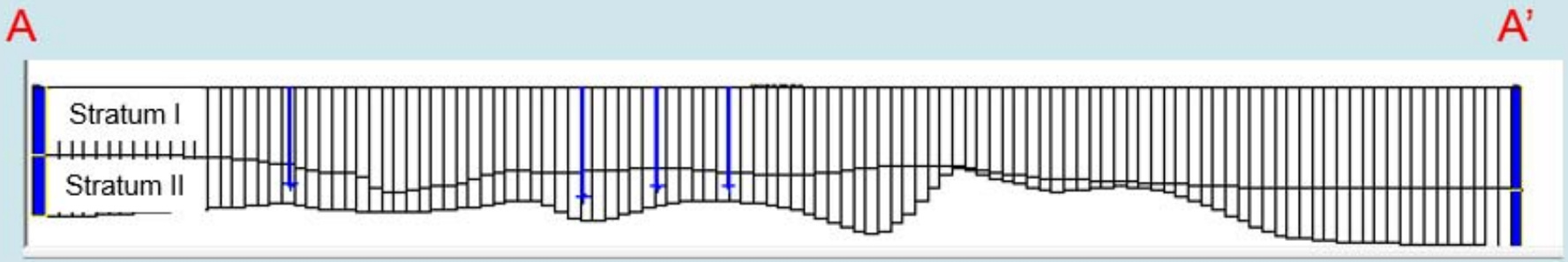
3.1.1.2 Site Stratigraphy

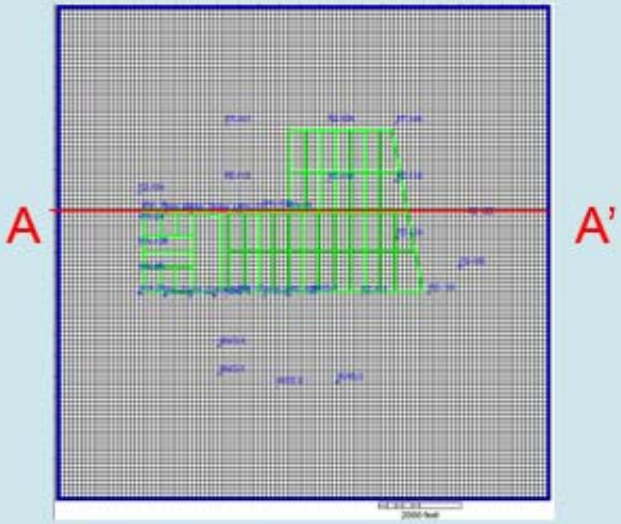
As detailed in Part III4, Geology Report, §4.4 the site is underlain by three distinct strata, identified below in order from ground surface down:

- Stratum I: sandy clays or clayey sands, with layers of silty clay, silty sand, or clayey silt.
- Stratum II: sands/silty sands, fine, poorly graded, and is the uppermost water-bearing unit (uppermost aquifer).
- Stratum III: predominantly clay, with some amounts of sandy clay or silty clay, high plasticity, hard, brown, and dry, and is the confining unit underlying the uppermost water-bearing unit (lower confining unit).

The top of Stratum I and Stratum II surface models were created from boring log elevations and descriptions and were imported into MODFLOW. The model assumed no flow below Stratum II.

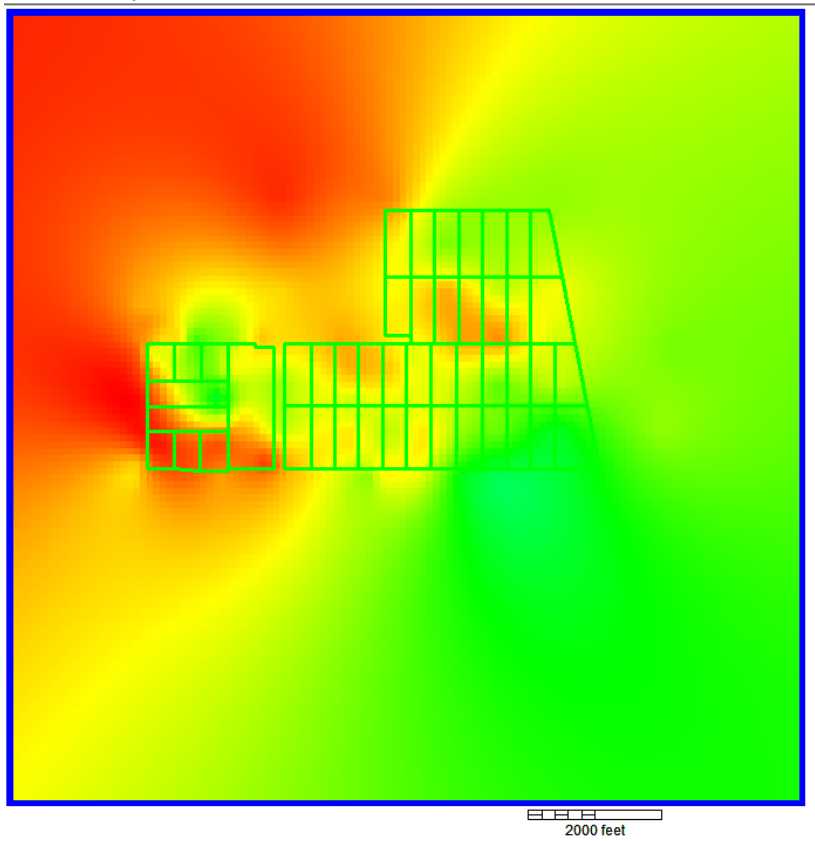
Cross-section Through Model

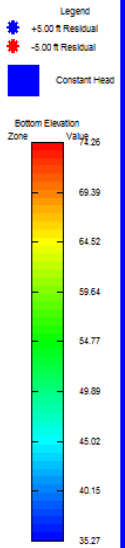




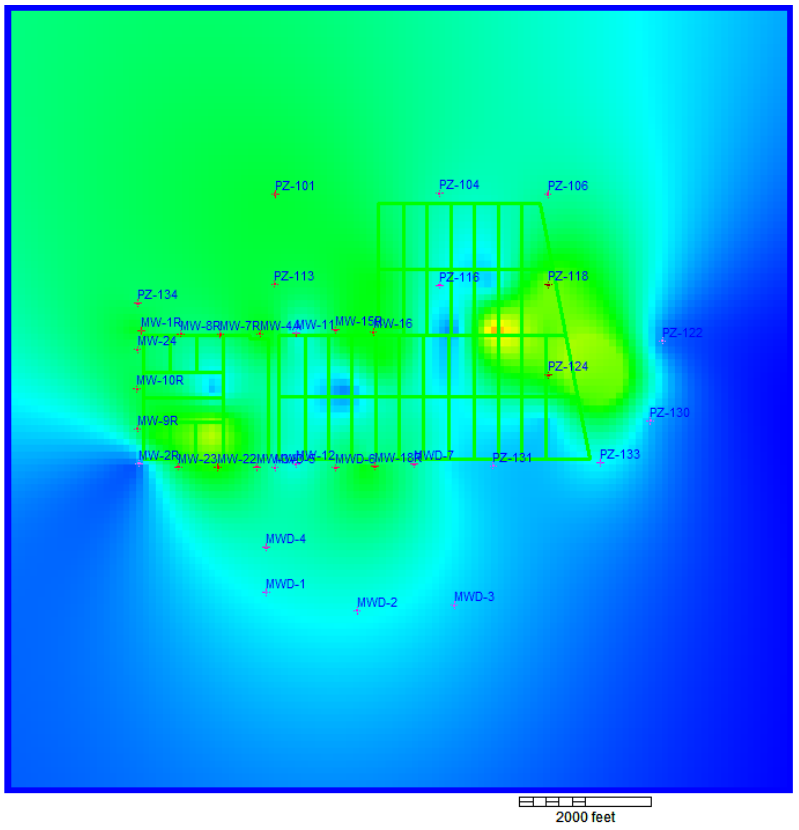
Top and Base Elevations of Stratum II

Top





Base



Input parameters for the geotechnical properties for both Stratum I and Stratum II are summarized in Table III3C-2.

Table III3C-2: Geotechnical Properties

	Permeability (cm/s)		Effective Porosity
	K_x, K_y	K_z	
Stratum I	1.75×10^{-6} (1)	2.18×10^{-7} (1)	0.42
Stratum II	1.65×10^{-4}	1.91×10^{-4}	0.33

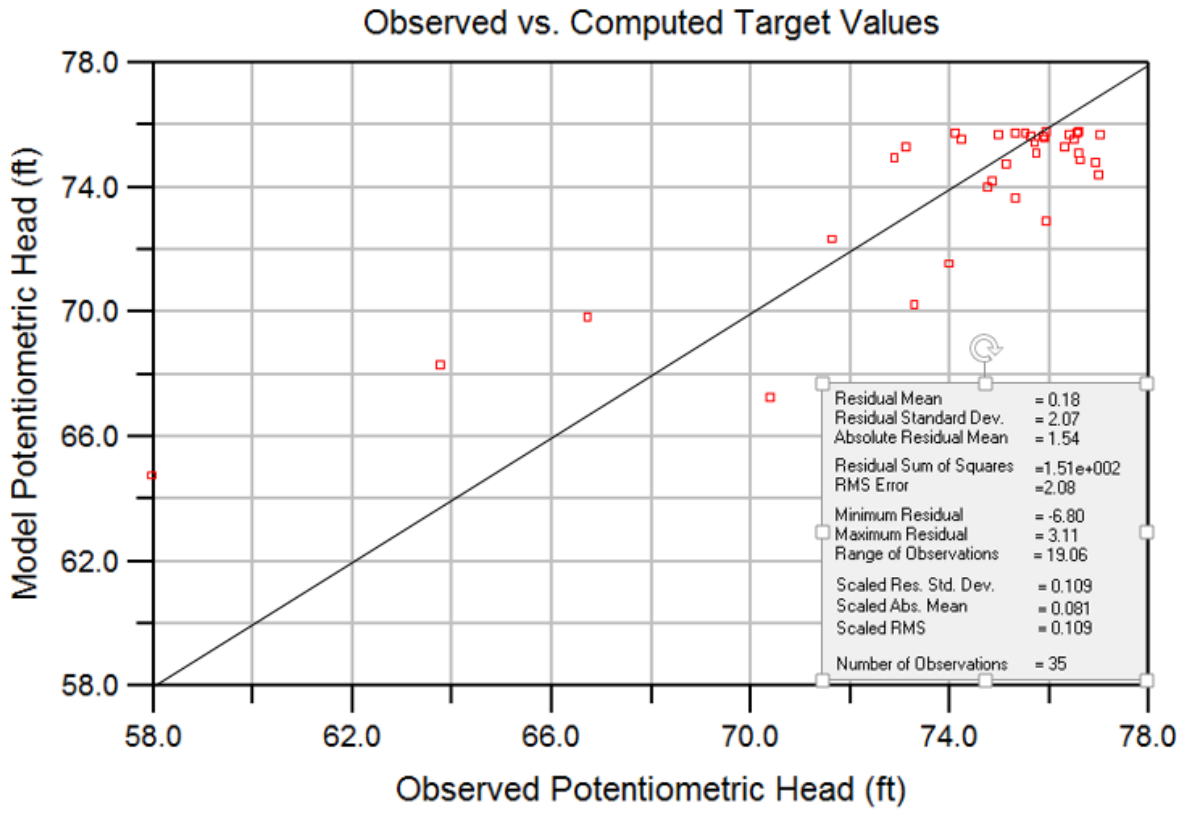
Note: (1) These values are higher than reported in Attachment 4; however, as discussed below, the concentrations increase with increasing permeability and are therefore conservative.

3.1.2 Groundwater Level and Hydraulic Gradients

Based on a review of the January 2015 through February 2016 groundwater elevations, the groundwater levels vary seasonally. Higher water levels were observed during the period of July 2015 to February 2016, so February 2016 data was used as a typical dataset for model calibration. The highest hydraulic gradients, near the northeastern portion of the site, have remained relatively consistent during this period.

Regional infiltration rates are uncertain. To estimate the infiltration rate, the groundwater elevations were held constant along the perimeter of the modeled area and the infiltration rate was adjusted until the predicted groundwater levels and hydraulic gradients approached the observed values in February 2016. Using this approach, the infiltration rate for the area surrounding the landfill was set at 4.5×10^{-6} ft/day.

As shown on the graph below, on average the predicted heads are within 0.18 feet of the measured values.



3.1.3 Leakage Rate

The leakage rate through alternative liner system was estimated using Giroud's equation described in §2.1, using the following assumptions.

- Strict construction quality assurance was/is maintained during installation.
- "Good" installation quality and intimate contact were/are achieved, leading to two defects per acre with a typical defect area of 1 cm^2 (0.0001 m^2).
- 1 foot of head is continuously present over the geomembrane.

As shown on the calculations in Appendix III3C-1, Leakage Rate the alternative geomembrane/GCL composite liner has a calculated leakage rate of approximately 0.05 mm/year. This leakage rate was applied to the facility's entire waste footprint and was assumed to immediately reach the potentiometric surface in Stratum I. Leakage through the liner system is conservatively assumed to remain constant for 100 years.

3.1.4 Initial Contaminant Concentration

A value of 1.0 was input into the model for the initial contaminant concentration within the leachate. This value was utilized to facilitate the computation of the DAF for comparison with the minimum required DAF values, as described in §3.0.

3.1.5 Conservative Assumptions

Conservative estimates of the DAF were derived using the following assumptions:

- No delay or reduction in concentrations in the vadose zone
- Limited dispersion (see discussion below)
- No adsorption, retardation, biodegradation, or decay of contaminants
- Infinite source from entire footprint of landfill
- No capping of landfill
- 100 years of travel time

Dispersion is modeled via the model input dispersivity, which is an empirical parameter supplied to the groundwater transport model that defines the degree to which a contaminant will spread in flowing groundwater. Dispersivity is a scale-dependent parameter that is generally larger as the scale of the contaminant plume increases. A typical rule-of-thumb is that the dispersivity is 10 percent of the length of the contaminant plume (National Research Council, 1990). For this model application, a potential plume of 1,000 ft extent is assumed and the resulting components of dispersivity are calculated as fractions of this plume length:

- Longitudinal dispersivity: 100 ft
- Transverse dispersivity: 10 ft
- Transverse vertical dispersivity: 1 ft
- Longitudinal vertical dispersivity: 1 ft

3.2 Results of MODFLOW Analysis

The model was run to simulate a period of 100 years. The resulting concentrations are shown on Figure III3C-1.

Hydrographs, representing the concentration within each monitoring well, were developed. As expected, the predicted concentrations increase with time since the leachate leakage is assumed to be constant; in reality, the landfill will be closed and leachate levels and leakage will decline.

For the lateral expansion, Unit 7, the maximum predicted concentration after 100 years occurs in MW-118 located approximately 105 ft east of the landfill, with a value of approximately 0.0005, which corresponds to a DAF of 2,000.

For the overliner, the maximum predicted concentration of 0.0001 occurs in MW-4A, which corresponds to a DAF of 10,000. The results for these and other wells near the overliner area are summarized in Table III3C-3.

Table III3C-3. Predicted Concentrations and DAFs Downgradient of the Landfill and Overliner Area

Monitoring Well ID	Predicted Normalized Concentration at 100 years	Predicted DAF at 100 years
MW-118	0.00047	2130
MW-3A	0	∞
MW-22	0	∞
MW-7R	6.3×10^{-5}	15,900
MW-4A	0.0001	10,000
MW-11	3.5×10^{-5}	28,600
MW-105	2.5×10^{-11}	4×10^{10}
MW-118	0.00047	2130

The range of results is well over the minimum DAF requirement of 260.

3.2.1 Sensitivity Analysis

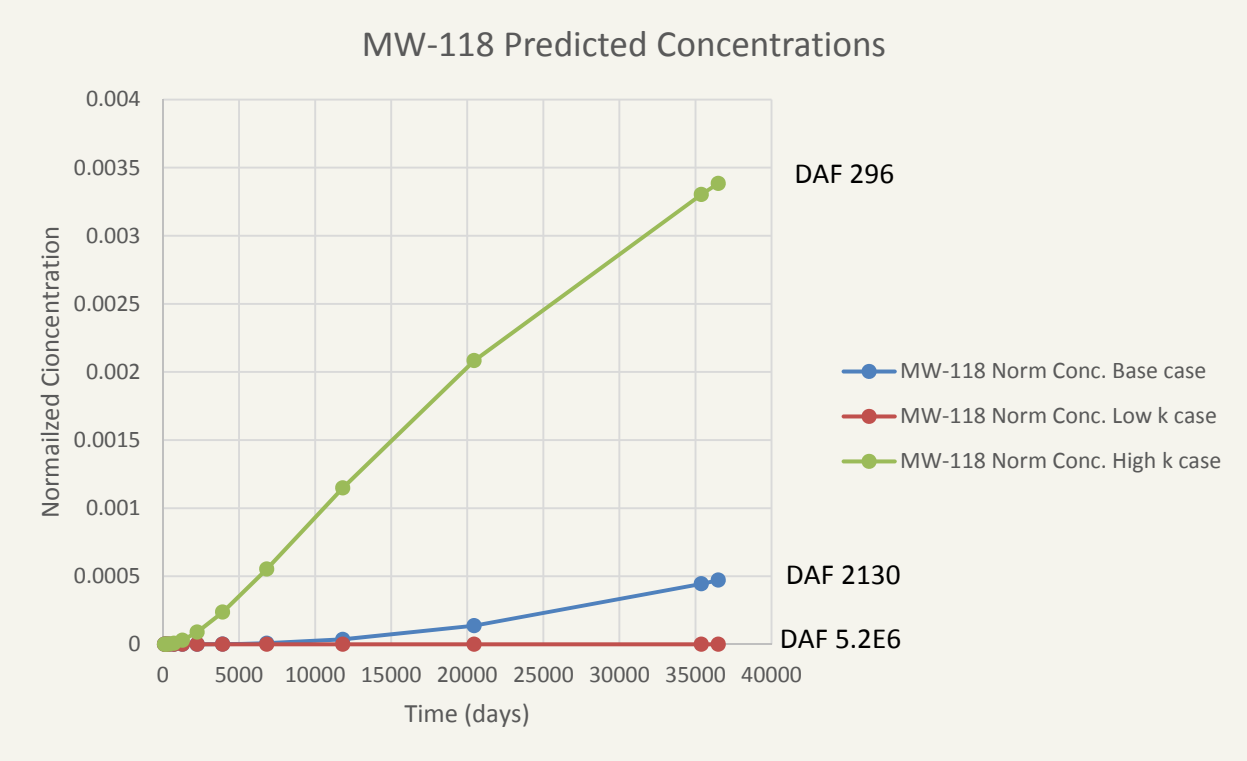
The sensitivity of the predicted results to the observed range of hydraulic properties was tested. The permeability values shown in Table III3C-4 were used.

Table III3C-4: Permeability Values Used in Sensitivity Analysis

	Permeability (cm/s)			
	K_x, K_y		K_z	
	Minimum	Maximum	Minimum	Maximum
Stratum I	5.78×10^{-7}	530×10^{-6}	6.8×10^{-8}	7,47 x 10-7
Stratum II	3.74×10^{-6}	4.40×10^{-3}	1.91×10^{-4}	

The predicted normalized concentrations for the most highly-contaminated observation well, MW-118, are shown in the figure below. Results show that the predicted results are sensitive to the hydraulic conductivities of Stratum I and II, but that even when the maximum measured hydraulic conductivities are applied, in combination, the lowest DAF is 296.

MW-118 Hydrograph



The sensitivity analysis indicates that the DAF remains above 260 after 100 years.

4.0 REFERENCES

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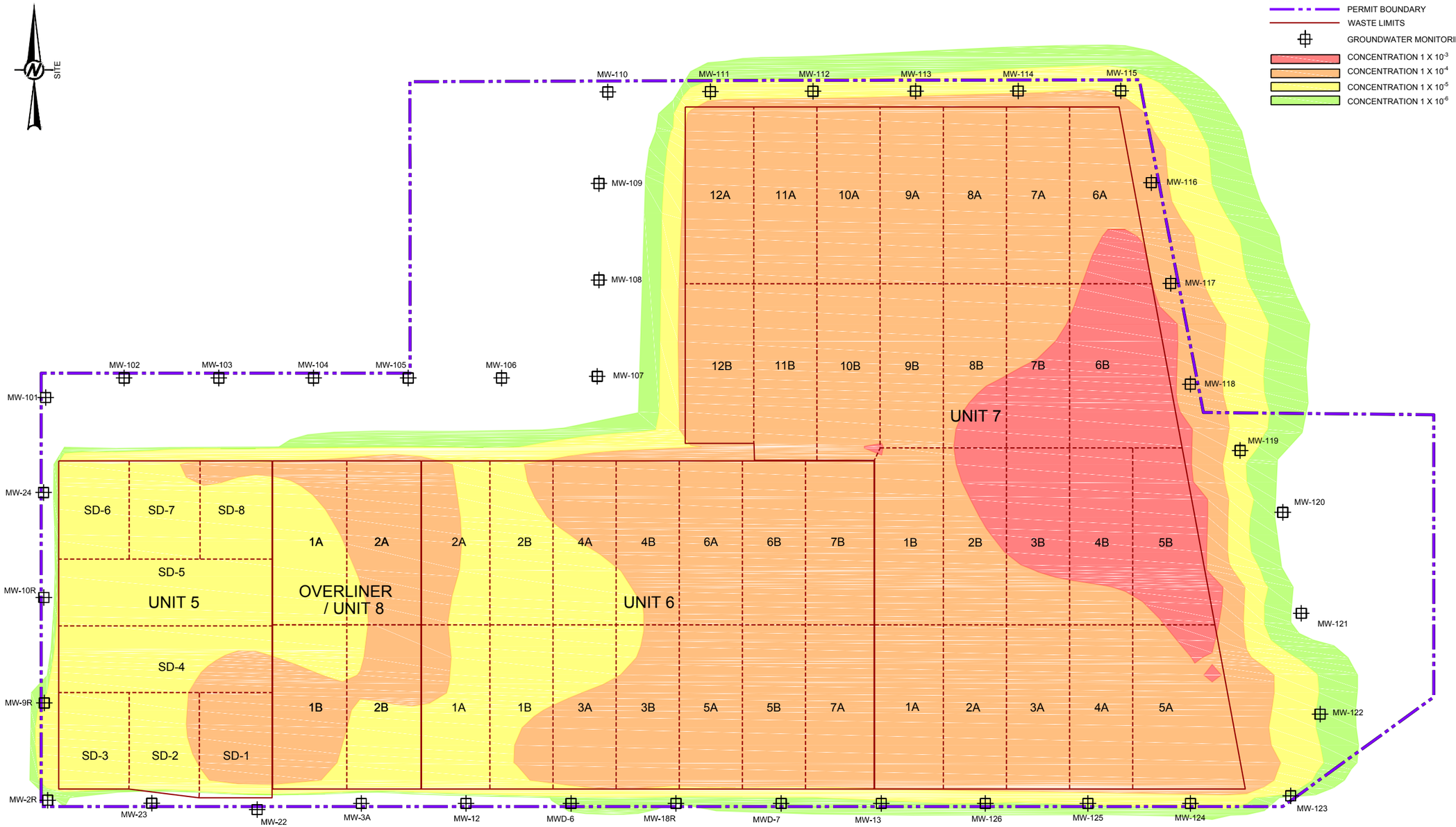
APPENDIX III3C

FIGURES



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0 300 600
1" = 600' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

SEAL

STATE OF TEXAS
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
POINT OF COMPLIANCE DEMONSTRATING RELATIVE CONCENTRATIONS AFTER 100 YEARS

PROJECT NO.	APPLICATION SECTION	REV.	1 of 1	FIGURE
1401491	III3C	0		III3C-1

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APPENDIX III3C-1

LEAKAGE RATE CALCULATIONS

LEAKAGE RATE CALCULATIONS

Made by: JBF
Checked by: VK
Reviewed by: MX

1.0 OBJECTIVE

Evaluate the required transmissivity and drainage capacity of the sideslope geocomposite drainage layer.Compare the leakage rate of a "prescriptive" composite liner system with the leakage rate through the alternate liner system proposed for use in the lateral expansion and in the overliner to be placed over the pre-Subtitle D cells in Units 1 - 4.



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2.0 GIVEN

The prescriptive liner system consists of a 60-mil geomembrane overying a 2-foot thick compacted clay liner (CCL) with a maximum hydraulic conductivity of 1 x 10-7 cm/s. In the alterante liner system the compacted clay liner will be replaced with a geosynthetic clay liner (GCL).

CCL Properties

k =	1E-07	cm/s	or	1E-09 m/s
t =	2	ft		0.61 m
h =	12	inches		0.30 m

(maximum set by regulations)

GCL Properties

k =	5E-09	cm/s	or	5E-11 m/s
t =	7	mm		0.007 m
h =	12	inches		0.30 m

(conservate for geocomposite drainage layer where leachate head is maintained within the 0.5 inch geocomposite layer)

3.0 METHOD

Estimate the leakage rate through each liner system using Giroud Equation. Compare the leakage rate through composite liner systems consisting of a geomembrane/CCL and a geomembrane/GCL.

Leakage through composite geomembrane/GCL liner.

$$Q = C[1+0.1(h/t)^{0.95}]a^{0.1}h^{0.9}k^{0.74}$$ [Ref. 1]

where:

C = 0.21 for good contact
1.15 for poor contact
h = head (m)
t = thickness of low permeability soil component (m)
a = area of hole (m^2)
k = hydraulic conductivity of CCL or GCL (m/s)

4.0 RESULTS

Leakage Rate Per Defect

Intimate Contact		Good		Poor	
Composite Liner System		TCEQ Prescriptive Liner	Alternate Liner	GM/CCL	GM/GCL
Leakage (m^3/sec)	0.1 cm^2 hole	5.24E-09	2.47E-09	2.87E-08	1.35E-08
	1 cm^2 hole	6.60E-09	3.10E-09	3.62E-08	1.70E-08

Comparison

Intimate Contact	$Q_{GM/CCL}/Q_{GM/GCL}$	
	0.1 cm^2 hole	1 cm^2 hole
Good	2.13	2.13
Poor	2.13	2.13

Leakage Rate For POC Modeling

For liner systems installed with good CQA, 1 to 2 holes are expected per acre of geomembrane. Assuming good contact and 2 holes with an area of 1.0 cm^2 are present per acre.

Leakage Rate = 6.21E-09 m^3/s/acre = 0.048 mm/yr

5.0 CONCLUSION

Based on this analysis, the leakage rate through a alternate composite liner system with a GCL will be approximately half that of the prescriptive composite liner system with a CCL.

The leakage rate through the proposed alternate liner in the lateral expansion and the overliner will be approximately 0.05 mm/year.

6.0 REFERENCE

1) Giroud, J.P., “Equations for Calculating the Rate of Liquid Migration Through Composite Liners Due to Geomembrane Defects”, Geosynthetics International, Vol. 4, Nos. 3-4, pp. 335-348, 1997.

APPENDIX III3D

LEACHATE COLLECTION AND REMOVAL SYSTEM CALCULATIONS

APPENDIX III3D-1

HELP MODEL EVALUATION

HELP MODEL EVALUATIONS

Made By: VK
Checked by: CEI
Reviewed by: JBF



GOLDER ASSOCIATES INC.
Professional Engineering Firm
Registration Number F-2578

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1.0 OBJECTIVE

I) Estimate the leachate production rate (impingement rate) for various conditions during the life of the landfill.

II) Determine the minimum design transmissivity (θ_{design}) of the leachate collection system geocomposite drainage layer.

III) Determine the minimum required transmissivity ($\theta_{required}$) of the leachate collection system geocomposite drainage layer, i.e. the transmissivity required during construction quality control and conformance testing.

IV) Estimate the peak and average annual leachate production rates.

2.0 METHOD

I) Use the Hydrologic Evaluation of Landfill Performance (HELP) Model [Ref. 1] with layers simulating the proposed liner, waste, and cover materials, along with climatic data and evapotranspiration parameters consistent with anticipated site conditions, to estimate the peak leachate flow rate (impingement rate) into the geocomposite for:

(i) open condition
(ii) intermediate condition
(iii) final condition prior to final cover placement
(iv) final condition with final cover

II) Determine the transmissivity needed to maintain a hydraulic head less than the thickness of the geocomposite for each condition (θ_{design}) using the following equation [Ref. 2]

$$\theta_{design} = \frac{q_i L}{sin\beta} = \frac{q_i L}{Slope}$$

Where: θ_{design} = design transmissivity (m^2/sec)
q_i = impingement rate (m/sec)
L = horizontal length of slope (m)
β = slope angle (degrees)

III) Establish a required transmissivity, $\theta_{required}$, for each condition, by applying reduction factors to the θ_{design}. [Ref. 3]

$$\theta_{required} = \theta_{design} \times [RF_{cr} * RF_{cc} * RF_{bc} * RF_{in}]$$

Where:
- RF_{cr} = Reduction factor for long-term creep
- RF_{cc} = Reduction factor for chemical clogging
- RF_{bc} = Reduction factor for biological clogging
- RF_{in} = Reduction factor for intrusion of geotextile or geomembrane

3.0 EVALUATION

I) Impingement Rate

Help Model Input

GENERAL:

Climate data synthetically generated using coefficients for Brownsville, TX, and historic temperature and rainfall data for Brownsville, TX.

The slope length of the landfill floor is variable; however, as long as the leachate head is not greater than the thickness of the leachate drainage layer, the impingement rate (i.e. the percolation/leakage into the LCRS) is not affected by the slope length of the cell floor.

Liner System (top to bottom):

24 inches of protective cover soil (k = 1 x 10^{-5} cm/s)
Geocomposite drainage layer (k = 15 cm/s; thickness = 0.2 inches)
60-mil HDPE geomembrane
Geosynthetic Clay Liner (GCL) as barrier soil liner (k = 5.0 x 10^{-9} cm/s)

Cover System (top to bottom):

The slope of the top of final cover is 25% for modeling purposes.
24 inches of cover soil (default material texture No. 0, 1 x 10^{-5} cm/s)
200-mil Geocomposite drainage layer (Assume θ = 4 x 10^{-4} m^2/s; ~k = 7.9 cm/s; 25% slope; 300 ft slope length)
40-mil LLDPE geomembrane
18-inch compacted clay liner (k = 1 x 10^{-5} cm/s)

Alternatively, the facility may use a GCL final cover, which will generate less infiltration and therefore is less critical in terms of leachate generation.

ASSUMPTIONS

Bottom liner and final cover geomembranes are modeled as having 1 pinhole/acre, 1 installation defect/acre, good placement quality

Initial soil and waste moisture contents are calculated by HELP model.

Open Condition (Daily Cover) - Methodology/Assumptions

10 ft of waste with k = 1 x 10^{-3} cm/sec (default material texture No.18)
6 in daily cover soil
Bare ground
Leaf area index = 0
Evaporative zone depth = 12 in (recommended by model)
0% of area allowed to have runoff
5-yr simulation period

Intermediate Cover Condition - Methodology/Assumptions

100 ft of waste with k = 1 x 10^{-3} cm/sec (default material texture No.18)
12 in intermediate cover soil
Bare ground
Leaf area index = 0
Evaporative zone depth = 12 in (recommended by model)
75% of area allowed to have runoff
Surface Slope = 2%
10-yr simulation period

Final - No Cover Condition - Methodology/Assumptions

250 ft of waste with k = 1 x 10^{-3} cm/s (default material texture No.18)
Bare Ground
Leaf area index = 0
Evaporative zone depth = 12 in (recommended by model)
100% of area allowed to have runoff
Surface Slope = 25%
30-yr simulation period (assumed scenario for conservatism)

Final Cover Condition - Methodology/Assumptions

250 ft of waste with k = 1 x 10^{-3} cm/s (default material texture No.18)
Fair grass
Leaf area index = 2
Evaporative zone depth = 24 in
100% of area allowed to have runoff
Surface Slope = 25%
30-yr simulation period

Note that the groundwater inflow to the leachate drainage layer (calculated in Appendix III3D-2) is zero.

HELP Model results for different conditions

Run	Condition Modeled	Peak Daily Values			Ave. Annual Leachate Gen. (cf/ac)
		Head (in)	q_i (in)	Leachate Gen. (cf/ac/day)	
OC	Open	0.071	0.263	956	12,426
IT	Intermediate	0.006	0.001	4	16
FCNC	Final - No cover	0.000	0.001	4	8
FC	Final Cover	0.004	0	1.0E-05	0

II) Design Transmissivity

Using the equation from [Ref. 2] to solve for $\theta_{design.}$

All slopes along the leachate flow path are 2%. Typical cell design in Unit 7 has a maximum flow length of 230 feet. The two exceptions are in Cell 6B and 5A which have the longest flow path of 285 feet and 415 feet respectively. For the overliner, the longest leachate flow path is 315 ft and the slope is at 2%. All these slope lengths are presented in the calculation below.

Condition	q_i		L (ft)	Slope (%)	Θ_{design} (m^2/sec)	Remarks
	in/day	cm/sec				
Open	0.263	7.74E-06	230	2.0	2.71E-04	typ. Cell in Unit 7
	0.263	7.74E-06	285	2.0	3.36E-04	Cell 6B
	0.263	7.74E-06	415	2.0	4.90E-04	Cell 5A
	0.263	7.74E-06	315	2.0	3.72E-04	Overliner
Intermediate	0.001	3.20E-08	230	2.0	1.12E-06	typ. Cell in Unit 7
	0.001	3.20E-08	285	2.0	1.39E-06	Cell 6B
	0.001	3.20E-08	415	2.0	2.03E-06	Cell 5A
	0.001	3.20E-08	315	2.0	1.54E-06	Overliner
Final - no cover	0.001	3.09E-08	230	2.0	1.08E-06	typ. Cell in Unit 7
	0.001	3.09E-08	285	2.0	1.34E-06	Cell 6B
	0.001	3.09E-08	415	2.0	1.95E-06	Cell 5A
	0.001	3.09E-08	315	2.0	1.48E-06	Overliner
Final - no cover	0.000	0.00E+00	230	2.0	0.00E+00	typ. Cell in Unit 7
	0.000	0.00E+00	285	2.0	0.00E+00	Cell 6B
	0.000	0.00E+00	415	2.0	0.00E+00	Cell 5A
	0.000	0.00E+00	315	2.0	0.00E+00	Overliner

III) Required Transmissivity

Apply reduction factors to calculate the required transmissivity.

Each reduction factor is selected to reflect differences between laboratory tested transmissivity values and transmissivity under field conditions [Ref. 3 and 4].

Condition	Θ_{design} (m^2/sec)	RF_{cr}	RF_{cc}	RF_{bc}	R_{in}	$\Theta_{required}$ (m^2/sec)	Remarks
Open	2.71E-04	1.1	1.1	1.1	1.1	**3.97E-04**	typ. Cell in Unit 7
	3.36E-04	1.1	1.1	1.1	1.1	**4.92E-04**	Cell 6B
	4.90E-04	1.1	1.1	1.1	1.1	**7.17E-04**	Cell 5A
	3.72E-04	1.1	1.1	1.1	1.1	**5.44E-04**	Overliner
Intermediate	1.12E-06	1.3	1.7	1.7	1.7	7.17E-06	typ. Cell in Unit 7
	1.39E-06	1.3	1.7	1.7	1.7	8.89E-06	Cell 6B
	2.03E-06	1.3	1.7	1.7	1.7	1.29E-05	Cell 5A
	1.54E-06	1.3	1.7	1.7	1.7	9.82E-06	Overliner
Final - no cover	1.08E-06	2	2	2	2	1.73E-05	typ. Cell in Unit 7
	1.34E-06	2	2	2	2	2.15E-05	Cell 6B
	1.95E-06	2	2	2	2	3.12E-05	Cell 5A
	1.48E-06	2	2	2	2	2.37E-05	Overliner
Final - no cover	0.00E+00	2	2	2	2	0.00E+00	typ. Cell in Unit 7
	0.00E+00	2	2	2	2	0.00E+00	Cell 6B
	0.00E+00	2	2	2	2	0.00E+00	Cell 5A
	0.00E+00	2	2	2	2	0.00E+00	Overliner

4.0 CONCLUSION

I) Based on the HELP model, the impingement rate varies from 0.263 in/day for the open condition to near zero following closure.

II) The critical design transmissivity (θ_{design}) occurs during the open condition when the impingement rate is the greatest.

III) The required transmissivity ($\theta_{required}$) (i.e. the transmissivity required during QC and conformance testing) was determined by applying reduction factors appropriate for each condition. The required transmissivity is dependent on the length of the leachate drainage path and the required value is shown below:

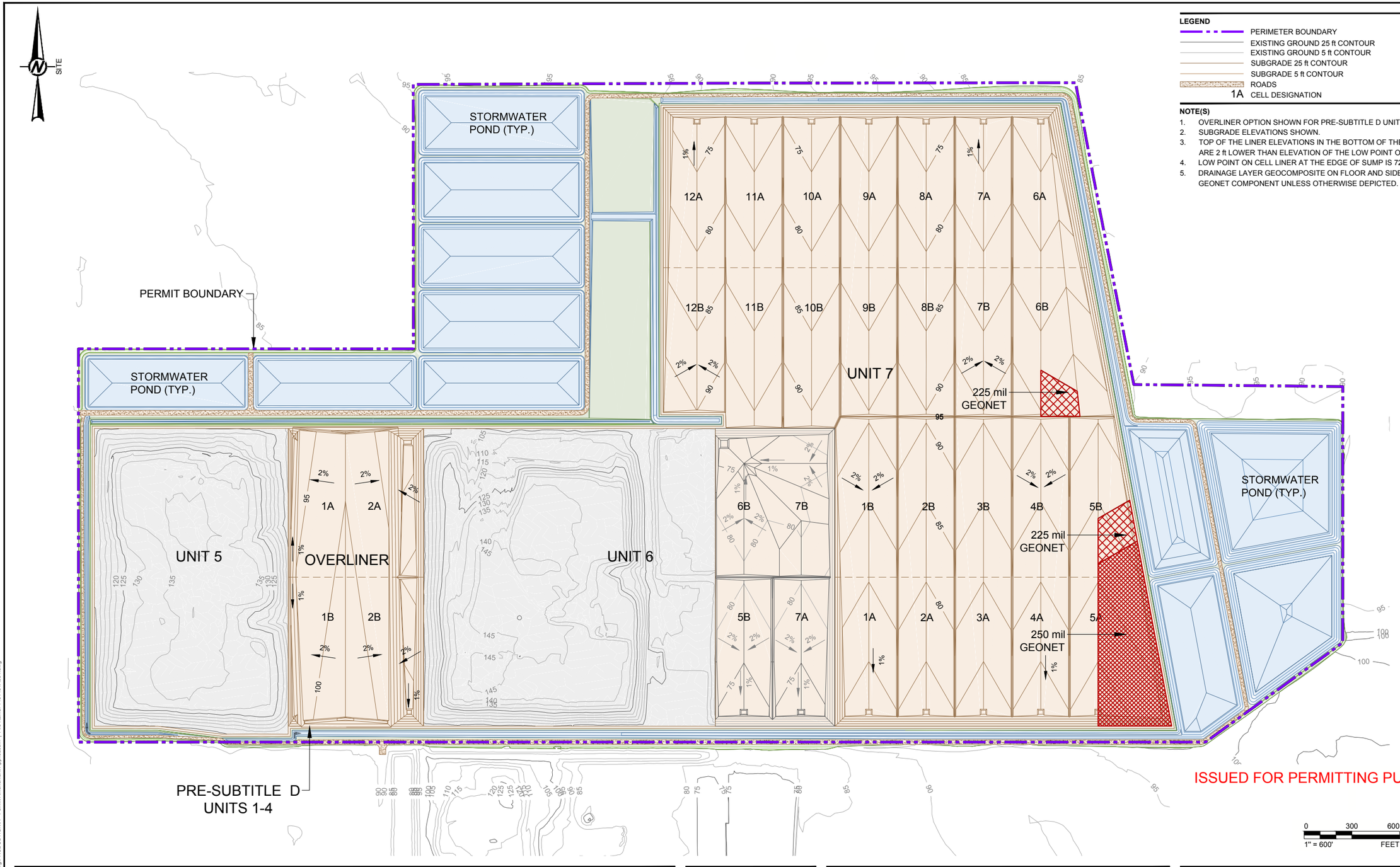
Leachate drainage path flow length L (ft)	Slope (%)	$\Theta_{required}$ (m^2/sec)	Remarks
230	2	**3.97E-04**	typ. Cell in Unit 7
285	2	**4.92E-04**	Cell 6B
415	2	**7.17E-04**	Cell 5A
315	2	**5.44E-04**	Overliner

IV) The maximum peak and average annual leachate production rates occur during the open condition. The values are:

Peak Daily Leachate Production = **956** **cf/ac/day** **7,151** **gal/ac/day**
Average Annual Leachate Production = **12,426** **cf/ac/yr** **255** **gal/ac/day**

5.0 REFERENCES

1. *Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.07* , U.S. EPA and U.S. Army Engineering Waterways Experiment Station, Corps of Engineers, Vicksburg, MS, November 1997.
2. Giroud, J.P., Zornberg, J.G., and Zhao, A., "Hydraulic Design of Geosynthetics and Granular Liquid Collection Layers", Geosynthetics International, Vol. 7, Nos. 4-6, pp. 285-380, 2000.
3 Robert M. Koerner "Designing with Geosynthetics" Fifth Edition, 2005 Prentice Hall
4 Narejo, D. and Allen, S. 2004 "Using the Stepped Isothermal Method for Geonet Creep Evaluation." Proceedings of EuroGeo3, Third European Geosynthetics Conference, Munich, pp. 539-544.



LEGEND

- PERIMETER BOUNDARY
- EXISTING GROUND 25 ft CONTOUR
- EXISTING GROUND 5 ft CONTOUR
- SUBGRADE 25 ft CONTOUR
- SUBGRADE 5 ft CONTOUR
- ROADS
- 1A CELL DESIGNATION

NOTE(S)

1. OVERLINER OPTION SHOWN FOR PRE-SUBTITLE D UNITS 1-4.
2. SUBGRADE ELEVATIONS SHOWN.
3. TOP OF THE LINER ELEVATIONS IN THE BOTTOM OF THE LEACHATE COLLECTION SUMPS ARE 2 ft LOWER THAN ELEVATION OF THE LOW POINT ON THE LINER.
4. LOW POINT ON CELL LINER AT THE EDGE OF SUMP IS 72 ft-msl IN UNIT 7.
5. DRAINAGE LAYER GEOCOMPOSITE ON FLOOR AND SIDESLOPES WILL HAVE A 200 mil GEONET COMPONENT UNLESS OTHERWISE DEPICTED.

ISSUED FOR PERMITTING PURPOSES ONLY

0 300 600
1" = 600' FEET

REV.	YYYY-MM-DD	DESCRIPTION	DESIGNED	PREPARED	REVIEWED	APPROVED
0	2017-07-21	PERMIT AMENDMENT APPLICATION SUBMITTAL	CEI	AA	MX	JBF

SEAL

STATE OF TEXAS
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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
HELP MODEL EVALUATION *SUBGRADE LAYOUT*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3D-1	0	1 of 1	III3D-1-1

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IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B
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 **                                                                         **
 **                                                                         **
 **              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE              **
 **                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
 **                  DEVELOPED BY ENVIRONMENTAL LABORATORY                  **
 **                    USAE WATERWAYS EXPERIMENT STATION                    **
 **             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
 **                                                                         **
 **                                                                         **
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 PRECIPITATION DATA FILE:    C:\Edin\oc.D4
 TEMPERATURE DATA FILE:      C:\edin\oc.D7
 SOLAR RADIATION DATA FILE:  C:\edin\oc.D13
 EVAPOTRANSPIRATION DATA:    C:\edin\oc.D11
 SOIL AND DESIGN DATA FILE:  C:\edin\oc.D10
 OUTPUT DATA FILE:           C:\edin\oc.OUT


 TIME:  10:40     DATE:   7/ 7/2017



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      TITLE:  Edinburg Landfill - Open Condition

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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   0
          THICKNESS                    =      6.00   INCHES
          POROSITY                     =      0.4790 VOL/VOL
          FIELD CAPACITY               =      0.3710 VOL/VOL
          WILTING POINT                =      0.2510 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3081 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC


                                LAYER  2
                                --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =    120.00   INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2866 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


                                LAYER  3
                                --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     24.00   INCHES
          POROSITY                     =      0.4300 VOL/VOL
          FIELD CAPACITY               =      0.3210 VOL/VOL
          WILTING POINT                =      0.2210 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3472 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC


                                LAYER  4
                                --------

                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   =      0.0139 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =   15.0000000000     CM/SEC
          SLOPE                        =      2.00   PERCENT
          DRAINAGE LENGTH              =    230.0    FEET


                                LAYER  5
                                --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  35
          THICKNESS                    =      0.06   INCHES
          POROSITY                     =      0.0000 VOL/VOL
          FIELD CAPACITY               =      0.0000 VOL/VOL
          WILTING POINT                =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
          FML PLACEMENT QUALITY        =  3 - GOOD


                                LAYER  6
                                --------

                TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.24   INCHES
          POROSITY                     =      0.7500 VOL/VOL
          FIELD CAPACITY               =      0.7470 VOL/VOL
          WILTING POINT                =      0.4000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #14 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 230. FEET.

SCS RUNOFF CURVE NUMBER	=	96.40	
FRACTION OF AREA ALLOWING RUNOFF	=	0.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.954	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	6.900	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.968	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	44.758	INCHES
TOTAL INITIAL WATER	=	44.758	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM BROWNSVILLE TEXAS

STATION LATITUDE	=	25.90 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	0
END OF GROWING SEASON (JULIAN DATE)	=	367
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	76.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	75.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.25	1.55	0.50	1.57	2.15	2.70
1.51	2.83	6.24	3.54	1.44	1.16

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
60.30	62.80	68.60	74.90	79.20	82.60
84.10	84.10	81.40	75.30	67.70	62.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS AND STATION LATITUDE = 25.90 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	23.05	83671.500	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	21.921	79573.937	95.10
DRAINAGE COLLECTED FROM LAYER 4	1.1362	4124.344	4.93
PERC./LEAKAGE THROUGH LAYER 6	0.000002	0.008	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0004		
CHANGE IN WATER STORAGE	-0.007	-26.808	-0.03
SOIL WATER AT START OF YEAR	44.758	162472.625	
SOIL WATER AT END OF YEAR	44.751	162445.828	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.020	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	36.09	131006.711	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	29.498	107079.055	81.74
DRAINAGE COLLECTED FROM LAYER 4	6.7928	24657.689	18.82
PERC./LEAKAGE THROUGH LAYER 6	0.000002	0.009	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0025		
CHANGE IN WATER STORAGE	-0.201	-730.115	-0.56
SOIL WATER AT START OF YEAR	44.751	162445.828	

SOIL WATER AT END OF YEAR	44.550	161715.703	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.079	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	24.46	88789.805	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	20.253	73517.461	82.80
DRAINAGE COLLECTED FROM LAYER 4	4.3470	15779.602	17.77
PERC./LEAKAGE THROUGH LAYER 6	0.000002	0.009	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0016		
CHANGE IN WATER STORAGE	-0.140	-507.298	-0.57
SOIL WATER AT START OF YEAR	44.550	161715.703	
SOIL WATER AT END OF YEAR	44.410	161208.406	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.027	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	28.73	104289.922	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	24.971	90646.453	86.92
DRAINAGE COLLECTED FROM LAYER 4	3.0643	11123.566	10.67
PERC./LEAKAGE THROUGH LAYER 6	0.000002	0.008	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0011		
CHANGE IN WATER STORAGE	0.694	2519.858	2.42
SOIL WATER AT START OF YEAR	44.410	161208.406	
SOIL WATER AT END OF YEAR	45.104	163728.266	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.037	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.06	61927.805	100.00
RUNOFF	0.000	0.000	0.00
EVAPOTRANSPIRATION	15.821	57431.410	92.74
DRAINAGE COLLECTED FROM LAYER 4	1.7754	6444.770	10.41
PERC./LEAKAGE THROUGH LAYER 6	0.000002	0.009	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0007		
CHANGE IN WATER STORAGE	-0.537	-1948.405	-3.15
SOIL WATER AT START OF YEAR	45.104	163728.266	
SOIL WATER AT END OF YEAR	44.567	161779.859	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.021	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.72	2.49	0.65	0.05	2.30	3.21
	0.91	1.97	8.61	3.23	0.58	1.15
STD. DEVIATIONS	0.66	1.74	0.36	0.11	1.72	2.82

	0.55	0.93	3.47	2.09	0.27	0.68

RUNOFF

TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

EVAPOTRANSPIRATION

TOTALS	0.801	1.718	1.223	0.347	2.259	2.582
	1.161	1.831	5.414	3.043	1.104	1.010
STD. DEVIATIONS	0.453	1.172	0.697	0.052	1.780	2.026
	0.535	0.919	1.311	1.573	0.588	0.623

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.1734	0.1088	0.1091	0.1232	0.0911	0.0659
	0.3002	0.1471	0.0790	0.9735	0.9286	0.3232
STD. DEVIATIONS	0.0412	0.0191	0.0608	0.1036	0.0547	0.0408
	0.5381	0.2092	0.1020	1.4164	0.9112	0.1771

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0008	0.0005	0.0005	0.0006	0.0004	0.0003
	0.0013	0.0006	0.0004	0.0042	0.0042	0.0014
STD. DEVIATIONS	0.0002	0.0001	0.0003	0.0005	0.0002	0.0002
	0.0023	0.0009	0.0005	0.0062	0.0041	0.0008

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES		CU. FEET	PERCENT
PRECIPITATION	25.88	(7.074)	93937.1	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	22.493	(5.1253)	81649.66	86.919
LATERAL DRAINAGE COLLECTED FROM LAYER 4	3.42314	(2.25176)	12425.994	13.22799
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 5	0.001	(0.001)		
CHANGE IN WATER STORAGE	-0.038	(0.4535)	-138.55	-0.147

PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	3.37	12233.100
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 4	0.26336	955.99854
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00004
AVERAGE HEAD ON TOP OF LAYER 5	0.036	
MAXIMUM HEAD ON TOP OF LAYER 5	0.071	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	2.0 FEET	
SNOW WATER	0.00	0.0000
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4179	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1640	

*** 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 5

LAYER	(INCHES)	(VOL/VOL)
1	1.9093	0.3182
2	34.2653	0.2855
3	8.2103	0.3421
4	0.0026	0.0128
5	0.0000	0.0000
6	0.1800	0.7500
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                 **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                    USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                           **
**                                                                           **
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PRECIPITATION DATA FILE:    C:\Edin\ic.D4
TEMPERATURE DATA FILE:      C:\edin\ic.D7
SOLAR RADIATION DATA FILE:  C:\edin\ic.D13
EVAPOTRANSPIRATION DATA:    C:\edin\ic.D11
SOIL AND DESIGN DATA FILE:  C:\edin\ic.D10
OUTPUT DATA FILE:           C:\edin\ic.OUT


TIME:  10:48     DATE:   7/ 7/2017



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     TITLE:  Edinburg Landfill - Intermed. Condition

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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   0
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4790 VOL/VOL
          FIELD CAPACITY               =      0.3710 VOL/VOL
          WILTING POINT                =      0.2510 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3041 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC


                              LAYER  2
                              --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =   1200.00   INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2920 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


                              LAYER  3
                              --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     24.00   INCHES
          POROSITY                     =      0.4300 VOL/VOL
          FIELD CAPACITY               =      0.3210 VOL/VOL
          WILTING POINT                =      0.2210 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3210 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC


                              LAYER  4
                              --------

                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.    =   15.0000000000     CM/SEC
          SLOPE                        =      2.00   PERCENT
          DRAINAGE LENGTH              =    230.0    FEET


                              LAYER  5
                              --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  35
          THICKNESS                    =      0.06   INCHES
          POROSITY                     =      0.0000 VOL/VOL
          FIELD CAPACITY               =      0.0000 VOL/VOL
          WILTING POINT                =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
          FML PLACEMENT QUALITY        =  3 - GOOD


                              LAYER  6
                              --------

                TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.24   INCHES
          POROSITY                     =      0.7500 VOL/VOL
          FIELD CAPACITY               =      0.7470 VOL/VOL
          WILTING POINT                =      0.4000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #14 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 230. FEET.

SCS RUNOFF CURVE NUMBER	=	96.40	
FRACTION OF AREA ALLOWING RUNOFF	=	75.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.649	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	5.748	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	3.012	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	361.935	INCHES
TOTAL INITIAL WATER	=	361.935	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM BROWNSVILLE TEXAS

STATION LATITUDE	=	25.90 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	0
END OF GROWING SEASON (JULIAN DATE)	=	367
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	76.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	75.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.25	1.55	0.50	1.57	2.15	2.70
1.51	2.83	6.24	3.54	1.44	1.16

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
60.30	62.80	68.60	74.90	79.20	82.60
84.10	84.10	81.40	75.30	67.70	62.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS AND STATION LATITUDE = 25.90 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	23.05	83671.500	100.00
RUNOFF	7.535	27352.215	32.69
EVAPOTRANSPIRATION	15.400	55900.965	66.81
DRAINAGE COLLECTED FROM LAYER 4	0.0043	15.789	0.02
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.111	402.570	0.48
SOIL WATER AT START OF YEAR	361.935	1313822.500	
SOIL WATER AT END OF YEAR	362.045	1314225.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.040	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	36.09	131006.711	100.00
RUNOFF	18.043	65497.090	50.00
EVAPOTRANSPIRATION	18.343	66585.227	50.83
DRAINAGE COLLECTED FROM LAYER 4	0.0053	19.361	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.302	-1095.049	-0.84
SOIL WATER AT START OF YEAR	362.045	1314225.000	

SOIL WATER AT END OF YEAR	361.744	1313130.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.087	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	24.46	88789.805	100.00
RUNOFF	9.925	36029.184	40.58
EVAPOTRANSPIRATION	14.219	51616.516	58.13
DRAINAGE COLLECTED FROM LAYER 4	0.0012	4.357	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.314	1139.803	1.28
SOIL WATER AT START OF YEAR	361.744	1313130.000	
SOIL WATER AT END OF YEAR	362.058	1314269.870	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.058	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	28.73	104289.922	100.00
RUNOFF	10.638	38616.414	37.03
EVAPOTRANSPIRATION	18.079	65625.203	62.93
DRAINAGE COLLECTED FROM LAYER 4	0.0029	10.633	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.010	37.665	0.04
SOIL WATER AT START OF YEAR	362.058	1314269.870	
SOIL WATER AT END OF YEAR	362.068	1314307.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.002	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.06	61927.805	100.00
RUNOFF	5.699	20688.039	33.41
EVAPOTRANSPIRATION	11.286	40968.762	66.16
DRAINAGE COLLECTED FROM LAYER 4	0.0014	5.233	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.073	265.758	0.43
SOIL WATER AT START OF YEAR	362.068	1314307.500	
SOIL WATER AT END OF YEAR	362.141	1314573.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.011	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	34.62	125670.625	100.00
RUNOFF	18.472	67055.102	53.36
EVAPOTRANSPIRATION	16.445	59694.711	47.50
DRAINAGE COLLECTED FROM LAYER 4	0.0022	7.852	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00

AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.299	-1087.073	-0.87
SOIL WATER AT START OF YEAR	362.141	1314573.250	
SOIL WATER AT END OF YEAR	361.842	1313486.120	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.034	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	33.57	121859.055	100.00
RUNOFF	14.503	52645.953	43.20
EVAPOTRANSPIRATION	19.169	69583.133	57.10
DRAINAGE COLLECTED FROM LAYER 4	0.0063	23.008	0.02
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.108	-393.043	-0.32
SOIL WATER AT START OF YEAR	361.842	1313486.120	
SOIL WATER AT END OF YEAR	361.734	1313093.120	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.006	0.00

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	21.97	79751.117	100.00
RUNOFF	9.400	34120.484	42.78
EVAPOTRANSPIRATION	12.476	45286.406	56.78
DRAINAGE COLLECTED FROM LAYER 4	0.0021	7.507	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.093	336.657	0.42
SOIL WATER AT START OF YEAR	361.734	1313093.120	
SOIL WATER AT END OF YEAR	361.826	1313429.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.060	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	23.36	84796.812	100.00
RUNOFF	10.727	38938.613	45.92
EVAPOTRANSPIRATION	12.581	45669.098	53.86
DRAINAGE COLLECTED FROM LAYER 4	0.0009	3.349	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.051	185.776	0.22
SOIL WATER AT START OF YEAR	361.826	1313429.750	
SOIL WATER AT END OF YEAR	361.878	1313615.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.025	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	30.54	110860.195	100.00
RUNOFF	14.112	51225.504	46.21

EVAPOTRANSPIRATION	16.148	58618.109	52.88
DRAINAGE COLLECTED FROM LAYER 4	0.0168	60.904	0.05
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.263	955.578	0.86
SOIL WATER AT START OF YEAR	361.878	1313615.500	
SOIL WATER AT END OF YEAR	362.141	1314571.120	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.099	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 10

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.91	2.12	0.46	1.05	1.43	3.39
	1.48	2.23	8.21	3.56	1.43	1.08
STD. DEVIATIONS	0.52	1.35	0.35	1.52	1.52	2.27
	1.60	1.32	3.12	2.29	1.35	0.54
RUNOFF						
TOTALS	0.085	0.671	0.020	0.553	0.625	1.787
	0.659	0.772	4.529	1.721	0.390	0.094
STD. DEVIATIONS	0.126	0.610	0.031	0.868	0.891	1.417
	1.136	1.018	2.123	1.380	0.630	0.103
EVAPOTRANSPIRATION						
TOTALS	0.818	1.509	0.606	0.642	0.782	1.439
	0.949	1.327	3.411	2.072	1.042	0.818
STD. DEVIATIONS	0.453	0.822	0.433	0.661	0.859	1.165
	0.732	0.657	1.252	1.137	0.570	0.473
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.0001	0.0002	0.0001	0.0000	0.0002	0.0002
	0.0002	0.0010	0.0007	0.0005	0.0009	0.0002
STD. DEVIATIONS	0.0002	0.0002	0.0002	0.0000	0.0004	0.0005
	0.0007	0.0022	0.0010	0.0006	0.0015	0.0006

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

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AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

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DAILY AVERAGE HEAD ON TOP OF LAYER 5

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 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	27.35 (6.303)	99262.4	100.00
RUNOFF	11.905 (4.2587)	43216.86	43.538
EVAPOTRANSPIRATION	15.415 (2.7184)	55954.81	56.371
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.00435 (0.00473)	15.799	0.01592
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000 (0.00000)	0.001	0.00000
AVERAGE HEAD ON TOP OF LAYER 5	0.000 (0.000)		
CHANGE IN WATER STORAGE	0.021 (0.2068)	74.86	0.075

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 10

	(INCHES)	(CU. FT.)
PRECIPITATION	3.51	12741.300
RUNOFF	2.858	10374.4424
DRAINAGE COLLECTED FROM LAYER 4	0.00109	3.94224
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00002

AVERAGE HEAD ON TOP OF LAYER 5 0.000

MAXIMUM HEAD ON TOP OF LAYER 5 0.006

LOCATION OF MAXIMUM HEAD IN LAYER 4
(DISTANCE FROM DRAIN) 0.0 FEET

SNOW WATER 0.00 0.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4102

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.2510

*** 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 10

LAYER	(INCHES)	(VOL/VOL)
1	3.8109	0.3176
2	350.3999	0.2920
3	7.7480	0.3228
4	0.0020	0.0101
5	0.0000	0.0000
6	0.1800	0.7500
SNOW WATER	0.000	

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**                                                                           **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                 **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                    **
**                    USAE WATERWAYS EXPERIMENT STATION                      **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY               **
**                                                                           **
**                                                                           **
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PRECIPITATION DATA FILE:    C:\Edin\fcnc.D4
TEMPERATURE DATA FILE:      C:\edin\fcnc.D7
SOLAR RADIATION DATA FILE:  C:\edin\fcnc.D13
EVAPOTRANSPIRATION DATA:    C:\edin\fcnc.D11
SOIL AND DESIGN DATA FILE:  C:\edin\fcnc.D10
OUTPUT DATA FILE:           C:\edin\fcnc.OUT


TIME:  15:26     DATE:   7/10/2017



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     TITLE:  Edinburg Landfill - Final No Cover Condition

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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   0
          THICKNESS                    =     12.00   INCHES
          POROSITY                     =      0.4790 VOL/VOL
          FIELD CAPACITY               =      0.3710 VOL/VOL
          WILTING POINT                =      0.2510 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3201 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC


                              LAYER  2
                              --------

               TYPE 1 - VERTICAL PERCOLATION LAYER
                   MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =   3000.00   INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2920 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


                              LAYER  3
                              --------

               TYPE 1 - VERTICAL PERCOLATION LAYER
                   MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     24.00   INCHES
          POROSITY                     =      0.4300 VOL/VOL
          FIELD CAPACITY               =      0.3210 VOL/VOL
          WILTING POINT                =      0.2210 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3210 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC


                              LAYER  4
                              --------

               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.    =   15.0000000000     CM/SEC
          SLOPE                        =      2.00   PERCENT
          DRAINAGE LENGTH              =    230.0    FEET


                              LAYER  5
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               TYPE 4 - FLEXIBLE MEMBRANE LINER
                   MATERIAL TEXTURE NUMBER  35
          THICKNESS                    =      0.06   INCHES
          POROSITY                     =      0.0000 VOL/VOL
          FIELD CAPACITY               =      0.0000 VOL/VOL
          WILTING POINT                =      0.0000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.199999996000E-12 CM/SEC
          FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
          FML PLACEMENT QUALITY        =  3 - GOOD


                              LAYER  6
                              --------

               TYPE 3 - BARRIER SOIL LINER
                   MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =      0.24   INCHES
          POROSITY                     =      0.7500 VOL/VOL
          FIELD CAPACITY               =      0.7470 VOL/VOL
          WILTING POINT                =      0.4000 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC
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GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #14 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 25.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	96.60	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.841	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	5.748	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	3.012	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	887.727	INCHES
TOTAL INITIAL WATER	=	887.727	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM BROWNSVILLE TEXAS

STATION LATITUDE	=	25.90 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	0
END OF GROWING SEASON (JULIAN DATE)	=	367
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	76.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	75.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.25	1.55	0.50	1.57	2.15	2.70
1.51	2.83	6.24	3.54	1.44	1.16

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
60.30	62.80	68.60	74.90	79.20	82.60
84.10	84.10	81.40	75.30	67.70	62.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS AND STATION LATITUDE = 25.90 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	23.05	83671.500	100.00
RUNOFF	9.415	34175.984	40.85
EVAPOTRANSPIRATION	13.646	49536.539	59.20
DRAINAGE COLLECTED FROM LAYER 4	0.0040	14.495	0.02
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.015	-55.611	-0.07
SOIL WATER AT START OF YEAR	887.727	3222447.750	
SOIL WATER AT END OF YEAR	887.711	3222392.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.089	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	36.09	131006.711	100.00
RUNOFF	20.796	75490.102	57.62
EVAPOTRANSPIRATION	15.759	57206.094	43.67
DRAINAGE COLLECTED FROM LAYER 4	0.0020	7.217	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.467	-1696.688	-1.30
SOIL WATER AT START OF YEAR	887.711	3222392.250	

SOIL WATER AT END OF YEAR	887.244	3220695.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.009	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	24.46	88789.805	100.00
RUNOFF	11.464	41613.504	46.87
EVAPOTRANSPIRATION	12.587	45692.109	51.46
DRAINAGE COLLECTED FROM LAYER 4	0.0011	4.061	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.408	1480.226	1.67
SOIL WATER AT START OF YEAR	887.244	3220695.500	
SOIL WATER AT END OF YEAR	887.652	3222175.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.098	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	28.73	104289.922	100.00
RUNOFF	12.583	45674.828	43.80
EVAPOTRANSPIRATION	16.167	58685.227	56.27
DRAINAGE COLLECTED FROM LAYER 4	0.0071	25.811	0.02
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.026	-95.934	-0.09
SOIL WATER AT START OF YEAR	887.652	3222175.750	
SOIL WATER AT END OF YEAR	887.625	3222079.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.014	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.06	61927.805	100.00
RUNOFF	6.659	24173.141	39.03
EVAPOTRANSPIRATION	10.778	39123.172	63.18
DRAINAGE COLLECTED FROM LAYER 4	0.0012	4.456	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.378	-1372.993	-2.22
SOIL WATER AT START OF YEAR	887.625	3222079.750	
SOIL WATER AT END OF YEAR	887.247	3220706.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.030	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	34.62	125670.625	100.00
RUNOFF	20.632	74893.031	59.59
EVAPOTRANSPIRATION	13.821	50169.676	39.92
DRAINAGE COLLECTED FROM LAYER 4	0.0025	9.086	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00

AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.165	598.649	0.48
SOIL WATER AT START OF YEAR	887.247	3220706.750	
SOIL WATER AT END OF YEAR	887.412	3221305.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.181	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	33.57	121859.055	100.00
RUNOFF	16.969	61598.516	50.55
EVAPOTRANSPIRATION	16.655	60458.734	49.61
DRAINAGE COLLECTED FROM LAYER 4	0.0044	15.809	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.059	-213.803	-0.18
SOIL WATER AT START OF YEAR	887.412	3221305.500	
SOIL WATER AT END OF YEAR	887.353	3221091.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	-0.0001	-0.197	0.00

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	21.97	79751.117	100.00
RUNOFF	10.752	39029.062	48.94
EVAPOTRANSPIRATION	11.178	40575.152	50.88
DRAINAGE COLLECTED FROM LAYER 4	0.0009	3.117	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.040	143.791	0.18
SOIL WATER AT START OF YEAR	887.353	3221091.750	
SOIL WATER AT END OF YEAR	887.393	3221235.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.005	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	23.36	84796.812	100.00
RUNOFF	12.343	44805.516	52.84
EVAPOTRANSPIRATION	10.986	39878.250	47.03
DRAINAGE COLLECTED FROM LAYER 4	0.0026	9.279	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.029	103.689	0.12
SOIL WATER AT START OF YEAR	887.393	3221235.500	
SOIL WATER AT END OF YEAR	887.421	3221339.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.074	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	30.54	110860.195	100.00
RUNOFF	16.186	58755.094	53.00

EVAPOTRANSPIRATION	14.272	51809.023	46.73
DRAINAGE COLLECTED FROM LAYER 4	0.0039	14.112	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.078	282.043	0.25
SOIL WATER AT START OF YEAR	887.421	3221339.250	
SOIL WATER AT END OF YEAR	887.499	3221621.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.075	0.00

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	22.41	81348.305	100.00
RUNOFF	10.099	36658.184	45.06
EVAPOTRANSPIRATION	12.385	44957.828	55.27
DRAINAGE COLLECTED FROM LAYER 4	0.0022	7.856	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.076	-275.618	-0.34
SOIL WATER AT START OF YEAR	887.499	3221621.250	
SOIL WATER AT END OF YEAR	887.423	3221345.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.058	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	27.81	100950.289	100.00
RUNOFF	14.056	51022.336	50.54
EVAPOTRANSPIRATION	13.851	50278.930	49.81
DRAINAGE COLLECTED FROM LAYER 4	0.0006	2.359	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.097	-353.384	-0.35
SOIL WATER AT START OF YEAR	887.423	3221345.500	
SOIL WATER AT END OF YEAR	887.326	3220992.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.053	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.75	75322.516	100.00
RUNOFF	11.474	41651.895	55.30
EVAPOTRANSPIRATION	9.421	34198.773	45.40
DRAINAGE COLLECTED FROM LAYER 4	0.0008	2.954	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.146	-531.074	-0.71
SOIL WATER AT START OF YEAR	887.326	3220992.250	
SOIL WATER AT END OF YEAR	887.179	3220461.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.033	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	22.55	81856.531	100.00
RUNOFF	11.247	40826.609	49.88
EVAPOTRANSPIRATION	11.283	40957.605	50.04
DRAINAGE COLLECTED FROM LAYER 4	0.0039	14.300	0.02
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.016	57.827	0.07
SOIL WATER AT START OF YEAR	887.179	3220461.250	
SOIL WATER AT END OF YEAR	887.195	3220519.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	0.191	0.00

ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	21.96	79714.820	100.00
RUNOFF	11.197	40645.555	50.99
EVAPOTRANSPIRATION	10.440	37895.809	47.54
DRAINAGE COLLECTED FROM LAYER 4	0.0028	10.251	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.320	1163.177	1.46
SOIL WATER AT START OF YEAR	887.195	3220519.000	
SOIL WATER AT END OF YEAR	887.516	3221682.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.027	0.00

ANNUAL TOTALS FOR YEAR 16

	INCHES	CU. FEET	PERCENT
PRECIPITATION	23.84	86539.203	100.00
RUNOFF	13.207	47941.184	55.40
EVAPOTRANSPIRATION	11.190	40618.668	46.94
DRAINAGE COLLECTED FROM LAYER 4	0.0010	3.461	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.558	-2023.929	-2.34
SOIL WATER AT START OF YEAR	887.516	3221682.250	
SOIL WATER AT END OF YEAR	886.958	3219658.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	-0.0001	-0.183	0.00

ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	27.07	98264.109	100.00
RUNOFF	11.904	43210.840	43.97
EVAPOTRANSPIRATION	14.448	52447.996	53.37
DRAINAGE COLLECTED FROM LAYER 4	0.0018	6.548	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.716	2598.649	2.64
SOIL WATER AT START OF YEAR	886.958	3219658.250	
SOIL WATER AT END OF YEAR	887.674	3222257.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.081	0.00

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ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	28.81	104580.312	100.00
RUNOFF	16.132	58558.262	55.99
EVAPOTRANSPIRATION	12.914	46879.141	44.83
DRAINAGE COLLECTED FROM LAYER 4	0.0011	3.972	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.237	-861.194	-0.82
SOIL WATER AT START OF YEAR	887.674	3222257.000	
SOIL WATER AT END OF YEAR	887.437	3221395.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.134	0.00

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ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	23.14	83998.203	100.00
RUNOFF	11.194	40632.816	48.37
EVAPOTRANSPIRATION	12.208	44316.039	52.76
DRAINAGE COLLECTED FROM LAYER 4	0.0006	2.294	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.263	-952.919	-1.13
SOIL WATER AT START OF YEAR	887.437	3221395.750	
SOIL WATER AT END OF YEAR	887.174	3220442.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.023	0.00

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ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.16	73180.805	100.00
RUNOFF	11.699	42468.230	58.03
EVAPOTRANSPIRATION	8.297	30118.100	41.16
DRAINAGE COLLECTED FROM LAYER 4	0.0002	0.711	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.164	593.774	0.81
SOIL WATER AT START OF YEAR	887.174	3220442.750	
SOIL WATER AT END OF YEAR	887.338	3221036.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.009	0.00

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ANNUAL TOTALS FOR YEAR 21

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.45	74233.523	100.00
RUNOFF	7.204	26150.609	35.23
EVAPOTRANSPIRATION	12.446	45180.555	60.86
DRAINAGE COLLECTED FROM LAYER 4	0.0008	2.843	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.799	2899.524	3.91
SOIL WATER AT START OF YEAR	887.338	3221036.500	
SOIL WATER AT END OF YEAR	888.137	3223936.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00

SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.010	0.00

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ANNUAL TOTALS FOR YEAR 22

	INCHES	CU. FEET	PERCENT
PRECIPITATION	25.25	91657.500	100.00
RUNOFF	13.304	48295.262	52.69
EVAPOTRANSPIRATION	12.389	44971.137	49.06
DRAINAGE COLLECTED FROM LAYER 4	0.0042	15.112	0.02
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.447	-1624.017	-1.77
SOIL WATER AT START OF YEAR	888.137	3223936.000	
SOIL WATER AT END OF YEAR	887.689	3222312.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.005	0.00

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ANNUAL TOTALS FOR YEAR 23

	INCHES	CU. FEET	PERCENT
PRECIPITATION	19.71	71547.297	100.00
RUNOFF	8.257	29973.945	41.89
EVAPOTRANSPIRATION	11.187	40608.207	56.76
DRAINAGE COLLECTED FROM LAYER 4	0.0009	3.274	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.265	962.003	1.34
SOIL WATER AT START OF YEAR	887.689	3222312.000	
SOIL WATER AT END OF YEAR	887.954	3223274.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.131	0.00

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ANNUAL TOTALS FOR YEAR 24

	INCHES	CU. FEET	PERCENT
PRECIPITATION	31.39	113945.695	100.00
RUNOFF	15.943	57874.758	50.79
EVAPOTRANSPIRATION	15.702	56997.621	50.02
DRAINAGE COLLECTED FROM LAYER 4	0.0011	4.070	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.256	-930.764	-0.82
SOIL WATER AT START OF YEAR	887.954	3223274.000	
SOIL WATER AT END OF YEAR	887.698	3222343.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.012	0.00

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ANNUAL TOTALS FOR YEAR 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	25.15	91294.516	100.00
RUNOFF	11.559	41957.484	45.96
EVAPOTRANSPIRATION	14.344	52068.570	57.03
DRAINAGE COLLECTED FROM LAYER 4	0.0057	20.694	0.02
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.758	-2752.410	-3.01

SOIL WATER AT START OF YEAR	887.698	3222343.250	
SOIL WATER AT END OF YEAR	886.940	3219591.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.174	0.00

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ANNUAL TOTALS FOR YEAR 26

	INCHES	CU. FEET	PERCENT
PRECIPITATION	30.61	111114.289	100.00
RUNOFF	14.945	54249.367	48.82
EVAPOTRANSPIRATION	15.024	54537.824	49.08
DRAINAGE COLLECTED FROM LAYER 4	0.0011	3.962	0.00
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.640	2323.253	2.09
SOIL WATER AT START OF YEAR	886.940	3219591.000	
SOIL WATER AT END OF YEAR	887.580	3221914.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.117	0.00

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ANNUAL TOTALS FOR YEAR 27

	INCHES	CU. FEET	PERCENT
PRECIPITATION	21.42	77754.586	100.00
RUNOFF	8.958	32515.934	41.82
EVAPOTRANSPIRATION	12.450	45194.832	58.12
DRAINAGE COLLECTED FROM LAYER 4	0.0018	6.373	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.010	37.443	0.05
SOIL WATER AT START OF YEAR	887.580	3221914.250	
SOIL WATER AT END OF YEAR	887.590	3221951.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.004	0.00

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ANNUAL TOTALS FOR YEAR 28

	INCHES	CU. FEET	PERCENT
PRECIPITATION	24.32	88281.602	100.00
RUNOFF	12.858	46674.871	52.87
EVAPOTRANSPIRATION	11.369	41270.391	46.75
DRAINAGE COLLECTED FROM LAYER 4	0.0012	4.515	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.091	331.893	0.38
SOIL WATER AT START OF YEAR	887.590	3221951.500	
SOIL WATER AT END OF YEAR	887.681	3222283.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.073	0.00

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ANNUAL TOTALS FOR YEAR 29

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.32	139101.578	100.00
RUNOFF	23.755	86229.125	61.99
EVAPOTRANSPIRATION	14.785	53670.879	38.58
DRAINAGE COLLECTED FROM LAYER 4	0.0027	9.857	0.01

PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	-0.223	-808.242	-0.58
SOIL WATER AT START OF YEAR	887.681	3222283.500	
SOIL WATER AT END OF YEAR	887.459	3221475.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.033	0.00

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ANNUAL TOTALS FOR YEAR 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	29.76	108028.828	100.00
RUNOFF	13.472	48904.031	45.27
EVAPOTRANSPIRATION	16.091	58409.801	54.07
DRAINAGE COLLECTED FROM LAYER 4	0.0027	9.662	0.01
PERC./LEAKAGE THROUGH LAYER 6	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 5	0.0000		
CHANGE IN WATER STORAGE	0.194	705.218	0.65
SOIL WATER AT START OF YEAR	887.459	3221475.250	
SOIL WATER AT END OF YEAR	887.653	3222180.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.114	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.01	1.76	0.49	1.23	1.63	2.36
	1.30	2.82	7.16	3.67	1.29	1.24
STD. DEVIATIONS	0.67	1.47	0.43	1.34	1.47	1.83
	1.26	1.85	3.29	2.13	1.31	0.74
RUNOFF						
TOTALS	0.202	0.687	0.041	0.649	0.868	1.312
	0.586	1.414	4.554	1.978	0.425	0.292
STD. DEVIATIONS	0.259	0.800	0.088	0.895	1.021	1.312
	0.915	1.366	2.677	1.491	0.696	0.331
EVAPOTRANSPIRATION						
TOTALS	0.858	0.987	0.656	0.624	0.765	0.921
	0.687	1.354	2.515	1.933	0.850	0.785
STD. DEVIATIONS	0.525	0.618	0.438	0.537	0.610	0.763
	0.411	0.700	0.948	0.770	0.509	0.407
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.0001	0.0001	0.0002	0.0001	0.0002	0.0002
	0.0001	0.0002	0.0004	0.0004	0.0002	0.0001
STD. DEVIATIONS	0.0003	0.0002	0.0004	0.0003	0.0006	0.0005
	0.0001	0.0004	0.0004	0.0006	0.0005	0.0001
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5						
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	25.94 (5.302)	94177.9	100.00
RUNOFF	13.009 (3.9091)	47221.67	50.141
EVAPOTRANSPIRATION	12.936 (2.1213)	46957.09	49.860

LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.00223	(0.00166)	8.084	0.00858
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000	(0.00000)	0.000	0.00000
AVERAGE HEAD ON TOP OF LAYER 5	0.000	(0.000)		
CHANGE IN WATER STORAGE	-0.002	(0.3590)	-8.91	-0.009

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	5.95	21598.500
RUNOFF	5.552	20153.6543
DRAINAGE COLLECTED FROM LAYER 4	0.00105	3.80131
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 5	0.000	
MAXIMUM HEAD ON TOP OF LAYER 5	0.000	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	0.00	0.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4003

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.2510

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 30

LAYER	(INCHES)	(VOL/VOL)
1	3.7671	0.3139
2	876.0000	0.2920
3	7.7040	0.3210
4	0.0020	0.0100
5	0.0000	0.0000
6	0.1800	0.7500
SNOW WATER	0.000	

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**                                                                      **
**                                                                      **
**             HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE             **
**               HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)             **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY               **
**                    USAE WATERWAYS EXPERIMENT STATION                 **
**            FOR USEPA RISK REDUCTION ENGINEERING LABORATORY           **
**                                                                      **
**                                                                      **
**************************************************************************
**************************************************************************



PRECIPITATION DATA FILE:    C:\Edin\fc.D4
TEMPERATURE DATA FILE:      C:\edin\fc.D7
SOLAR RADIATION DATA FILE:  C:\edin\fc.D13
EVAPOTRANSPIRATION DATA:    C:\edin\fc.D11
SOIL AND DESIGN DATA FILE:  C:\edin\fc.D10
OUTPUT DATA FILE:           C:\edin\fc.OUT


TIME:  15:36     DATE:   7/ 7/2017


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

     TITLE:  Edinburg Landfill - Final Condition

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


     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   0
          THICKNESS                    =     24.00   INCHES
          POROSITY                     =      0.4790 VOL/VOL
          FIELD CAPACITY               =      0.3710 VOL/VOL
          WILTING POINT                =      0.2510 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2832 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC


                              LAYER  2
                              --------

              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.    =   7.90000010000     CM/SEC
          SLOPE                        =     25.00   PERCENT
          DRAINAGE LENGTH              =    300.0    FEET


                              LAYER  3
                              --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  36
          THICKNESS                    =      0.04   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.    =  0.399999993000E-12 CM/SEC
          FML PINHOLE DENSITY          =      1.00   HOLES/ACRE
          FML INSTALLATION DEFECTS     =      1.00   HOLES/ACRE
          FML PLACEMENT QUALITY        =  3 - GOOD


                              LAYER  4
                              --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     18.00   INCHES
          POROSITY                     =      0.4750 VOL/VOL
          FIELD CAPACITY               =      0.3780 VOL/VOL
          WILTING POINT                =      0.2650 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.4750 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC


                              LAYER  5
                              --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
          THICKNESS                    =   3000.00   INCHES
          POROSITY                     =      0.6710 VOL/VOL
          FIELD CAPACITY               =      0.2920 VOL/VOL
          WILTING POINT                =      0.0770 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.2920 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


                              LAYER  6
                              --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
          THICKNESS                    =     24.00   INCHES
          POROSITY                     =      0.4300 VOL/VOL
          FIELD CAPACITY               =      0.3210 VOL/VOL
          WILTING POINT                =      0.2210 VOL/VOL
          INITIAL SOIL WATER CONTENT   =      0.3210 VOL/VOL
          EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC
```

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.	=	15.0000000000	CM/SEC
SLOPE	=	2.00	PERCENT
DRAINAGE LENGTH	=	230.0	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	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 9

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.24	INCHES
POROSITY	=	0.7500	VOL/VOL
FIELD CAPACITY	=	0.7400	VOL/VOL
WILTING POINT	=	0.4000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.7500	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.499999997000E-08	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #14 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 25.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	90.30	
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	=	6.798	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	11.496	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	6.024	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	899.236	INCHES
TOTAL INITIAL WATER	=	899.236	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM BROWNSVILLE TEXAS

STATION LATITUDE	=	25.90 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	35
END OF GROWING SEASON (JULIAN DATE)	=	350
EVAPORATIVE ZONE DEPTH	=	24.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	76.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	75.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	76.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
1.25	1.55	0.50	1.57	2.15	2.70
1.51	2.83	6.24	3.54	1.44	1.16

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
60.30	62.80	68.60	74.90	79.20	82.60
84.10	84.10	81.40	75.30	67.70	62.30

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR BROWNSVILLE TEXAS AND STATION LATITUDE = 25.90 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT

PRECIPITATION	23.05	83671.500	100.00
RUNOFF	6.898	25038.826	29.93
EVAPOTRANSPIRATION	16.012	58122.164	69.46
DRAINAGE COLLECTED FROM LAYER 2	0.0014	4.979	0.01
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.139	505.594	0.60
SOIL WATER AT START OF YEAR	899.236	3264226.250	
SOIL WATER AT END OF YEAR	899.375	3264732.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.067	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	36.09	131006.711	100.00
RUNOFF	17.832	64728.738	49.41
EVAPOTRANSPIRATION	18.550	67338.203	51.40
DRAINAGE COLLECTED FROM LAYER 2	0.0013	4.667	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-0.293	-1064.806	-0.81
SOIL WATER AT START OF YEAR	899.375	3264732.000	
SOIL WATER AT END OF YEAR	899.082	3263667.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.084	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	24.46	88789.805	100.00
RUNOFF	9.263	33624.520	37.87
EVAPOTRANSPIRATION	15.280	55465.906	62.47
DRAINAGE COLLECTED FROM LAYER 2	0.0010	3.539	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-0.084	-304.199	-0.34
SOIL WATER AT START OF YEAR	899.082	3263667.000	
SOIL WATER AT END OF YEAR	898.998	3263363.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.037	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	28.73	104289.922	100.00
RUNOFF	10.097	36650.410	35.14
EVAPOTRANSPIRATION	18.187	66020.484	63.30
DRAINAGE COLLECTED FROM LAYER 2	0.0018	6.706	0.01
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		

DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.444	1612.275	1.55
SOIL WATER AT START OF YEAR	898.998	3263363.000	
SOIL WATER AT END OF YEAR	899.442	3264975.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.041	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.06	61927.805	100.00
RUNOFF	5.242	19029.924	30.73
EVAPOTRANSPIRATION	12.558	45584.340	73.61
DRAINAGE COLLECTED FROM LAYER 2	0.0005	1.793	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-0.741	-2688.159	-4.34
SOIL WATER AT START OF YEAR	899.442	3264975.250	
SOIL WATER AT END OF YEAR	898.702	3262287.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.093	0.00

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ANNUAL TOTALS FOR YEAR 6

	INCHES	CU. FEET	PERCENT
PRECIPITATION	34.62	125670.625	100.00
RUNOFF	18.769	68129.992	54.21
EVAPOTRANSPIRATION	15.340	55682.617	44.31
DRAINAGE COLLECTED FROM LAYER 2	0.0010	3.785	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.511	1854.216	1.48
SOIL WATER AT START OF YEAR	898.702	3262287.000	
SOIL WATER AT END OF YEAR	899.212	3264141.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.012	0.00

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ANNUAL TOTALS FOR YEAR 7

	INCHES	CU. FEET	PERCENT
PRECIPITATION	33.57	121859.055	100.00
RUNOFF	13.963	50686.258	41.59
EVAPOTRANSPIRATION	18.286	66379.922	54.47
DRAINAGE COLLECTED FROM LAYER 2	0.0014	5.148	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	1.319	4787.639	3.93
SOIL WATER AT START OF YEAR	899.212	3264141.250	

SOIL WATER AT END OF YEAR	900.531	3268929.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.090	0.00

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ANNUAL TOTALS FOR YEAR 8

	INCHES	CU. FEET	PERCENT
PRECIPITATION	21.97	79751.117	100.00
RUNOFF	9.008	32699.355	41.00
EVAPOTRANSPIRATION	14.706	53382.910	66.94
DRAINAGE COLLECTED FROM LAYER 2	0.0050	18.199	0.02
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-1.749	-6349.398	-7.96
SOIL WATER AT START OF YEAR	900.531	3268929.000	
SOIL WATER AT END OF YEAR	898.782	3262579.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.051	0.00

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ANNUAL TOTALS FOR YEAR 9

	INCHES	CU. FEET	PERCENT
PRECIPITATION	23.36	84796.812	100.00
RUNOFF	10.363	37616.855	44.36
EVAPOTRANSPIRATION	11.672	42367.613	49.96
DRAINAGE COLLECTED FROM LAYER 2	0.0006	2.219	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	1.325	4810.237	5.67
SOIL WATER AT START OF YEAR	898.782	3262579.500	
SOIL WATER AT END OF YEAR	900.107	3267389.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.114	0.00

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ANNUAL TOTALS FOR YEAR 10

	INCHES	CU. FEET	PERCENT
PRECIPITATION	30.54	110860.195	100.00
RUNOFF	13.631	49479.637	44.63
EVAPOTRANSPIRATION	16.441	59679.336	53.83
DRAINAGE COLLECTED FROM LAYER 2	0.0007	2.568	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.468	1698.682	1.53
SOIL WATER AT START OF YEAR	900.107	3267389.750	
SOIL WATER AT END OF YEAR	900.575	3269088.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.023	0.00

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ANNUAL TOTALS FOR YEAR 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	22.41	81348.305	100.00
RUNOFF	8.002	29046.498	35.71
EVAPOTRANSPIRATION	16.013	58126.418	71.45
DRAINAGE COLLECTED FROM LAYER 2	0.0963	349.602	0.43
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.001	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-1.701	-6174.368	-7.59
SOIL WATER AT START OF YEAR	900.575	3269088.500	
SOIL WATER AT END OF YEAR	898.874	3262914.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.157	0.00

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ANNUAL TOTALS FOR YEAR 12

	INCHES	CU. FEET	PERCENT
PRECIPITATION	27.81	100950.289	100.00
RUNOFF	11.441	41530.098	41.14
EVAPOTRANSPIRATION	14.987	54404.074	53.89
DRAINAGE COLLECTED FROM LAYER 2	0.0008	2.906	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	1.381	5013.406	4.97
SOIL WATER AT START OF YEAR	898.874	3262914.000	
SOIL WATER AT END OF YEAR	900.255	3267927.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	-0.0001	-0.195	0.00

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ANNUAL TOTALS FOR YEAR 13

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.75	75322.516	100.00
RUNOFF	9.714	35263.406	46.82
EVAPOTRANSPIRATION	12.129	44029.902	58.46
DRAINAGE COLLECTED FROM LAYER 2	0.0062	22.657	0.03
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-1.100	-3993.576	-5.30
SOIL WATER AT START OF YEAR	900.255	3267927.500	
SOIL WATER AT END OF YEAR	899.155	3263933.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.125	0.00

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ANNUAL TOTALS FOR YEAR 14

	INCHES	CU. FEET	PERCENT
PRECIPITATION	22.55	81856.531	100.00
RUNOFF	8.943	32461.598	39.66

EVAPOTRANSPIRATION	13.214	47965.434	58.60
DRAINAGE COLLECTED FROM LAYER 2	0.0008	2.981	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.393	1426.388	1.74
SOIL WATER AT START OF YEAR	899.155	3263933.750	
SOIL WATER AT END OF YEAR	899.548	3265360.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.131	0.00

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ANNUAL TOTALS FOR YEAR 15

	INCHES	CU. FEET	PERCENT
PRECIPITATION	21.96	79714.820	100.00
RUNOFF	9.111	33072.926	41.49
EVAPOTRANSPIRATION	12.634	45862.176	57.53
DRAINAGE COLLECTED FROM LAYER 2	0.0009	3.195	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.214	776.559	0.97
SOIL WATER AT START OF YEAR	899.548	3265360.250	
SOIL WATER AT END OF YEAR	899.762	3266136.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.041	0.00

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ANNUAL TOTALS FOR YEAR 16

	INCHES	CU. FEET	PERCENT
PRECIPITATION	23.84	86539.203	100.00
RUNOFF	11.191	40624.461	46.94
EVAPOTRANSPIRATION	13.799	50090.582	57.88
DRAINAGE COLLECTED FROM LAYER 2	0.0008	3.049	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-1.151	-4178.798	-4.83
SOIL WATER AT START OF YEAR	899.762	3266136.750	
SOIL WATER AT END OF YEAR	898.611	3261958.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.093	0.00

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ANNUAL TOTALS FOR YEAR 17

	INCHES	CU. FEET	PERCENT
PRECIPITATION	27.07	98264.109	100.00
RUNOFF	9.274	33664.953	34.26
EVAPOTRANSPIRATION	17.015	61764.969	62.86
DRAINAGE COLLECTED FROM LAYER 2	0.0006	2.034	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00

PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.780	2832.171	2.88
SOIL WATER AT START OF YEAR	898.611	3261958.000	
SOIL WATER AT END OF YEAR	899.391	3264790.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.013	0.00

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ANNUAL TOTALS FOR YEAR 18

	INCHES	CU. FEET	PERCENT
PRECIPITATION	28.81	104580.312	100.00
RUNOFF	14.217	51609.211	49.35
EVAPOTRANSPIRATION	14.474	52542.027	50.24
DRAINAGE COLLECTED FROM LAYER 2	0.0002	0.812	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.118	428.049	0.41
SOIL WATER AT START OF YEAR	899.391	3264790.250	
SOIL WATER AT END OF YEAR	899.509	3265218.250	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0001	0.213	0.00

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ANNUAL TOTALS FOR YEAR 19

	INCHES	CU. FEET	PERCENT
PRECIPITATION	23.14	83998.203	100.00
RUNOFF	9.752	35401.113	42.15
EVAPOTRANSPIRATION	13.911	50498.355	60.12
DRAINAGE COLLECTED FROM LAYER 2	0.0006	2.138	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-0.524	-1903.401	-2.27
SOIL WATER AT START OF YEAR	899.509	3265218.250	
SOIL WATER AT END OF YEAR	898.985	3263314.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.002	0.00

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ANNUAL TOTALS FOR YEAR 20

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.16	73180.805	100.00
RUNOFF	10.578	38399.371	52.47
EVAPOTRANSPIRATION	9.866	35814.488	48.94
DRAINAGE COLLECTED FROM LAYER 2	0.0003	1.233	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-0.285	-1034.231	-1.41
SOIL WATER AT START OF YEAR	898.985	3263314.750	
SOIL WATER AT END OF YEAR	898.700	3262280.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00

SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.053	0.00

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ANNUAL TOTALS FOR YEAR 21

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.45	74233.523	100.00
RUNOFF	5.523	20048.219	27.01
EVAPOTRANSPIRATION	13.661	49589.652	66.80
DRAINAGE COLLECTED FROM LAYER 2	0.0007	2.444	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	1.265	4593.111	6.19
SOIL WATER AT START OF YEAR	898.700	3262280.500	
SOIL WATER AT END OF YEAR	899.965	3266873.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.097	0.00

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ANNUAL TOTALS FOR YEAR 22

	INCHES	CU. FEET	PERCENT
PRECIPITATION	25.25	91657.500	100.00
RUNOFF	11.445	41546.559	45.33
EVAPOTRANSPIRATION	14.446	52437.957	57.21
DRAINAGE COLLECTED FROM LAYER 2	0.0007	2.663	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-0.642	-2329.678	-2.54
SOIL WATER AT START OF YEAR	899.965	3266873.750	
SOIL WATER AT END OF YEAR	899.323	3264544.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.001	0.00

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ANNUAL TOTALS FOR YEAR 23

	INCHES	CU. FEET	PERCENT
PRECIPITATION	19.71	71547.297	100.00
RUNOFF	6.167	22387.912	31.29
EVAPOTRANSPIRATION	12.770	46354.750	64.79
DRAINAGE COLLECTED FROM LAYER 2	0.0007	2.633	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.772	2802.039	3.92
SOIL WATER AT START OF YEAR	899.323	3264544.000	
SOIL WATER AT END OF YEAR	900.095	3267346.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.037	0.00

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ANNUAL TOTALS FOR YEAR 24

	INCHES	CU. FEET	PERCENT
PRECIPITATION	31.39	113945.695	100.00
RUNOFF	13.145	47717.664	41.88
EVAPOTRANSPIRATION	19.233	69814.273	61.27
DRAINAGE COLLECTED FROM LAYER 2	0.0876	318.083	0.28
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.001	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.001	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-1.076	-3904.288	-3.43
SOIL WATER AT START OF YEAR	900.095	3267346.000	
SOIL WATER AT END OF YEAR	899.020	3263441.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.034	0.00

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ANNUAL TOTALS FOR YEAR 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	25.15	91294.516	100.00
RUNOFF	8.737	31714.629	34.74
EVAPOTRANSPIRATION	16.955	61546.645	67.42
DRAINAGE COLLECTED FROM LAYER 2	0.0018	6.408	0.01
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-0.544	-1973.192	-2.16
SOIL WATER AT START OF YEAR	899.020	3263441.750	
SOIL WATER AT END OF YEAR	898.476	3261468.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.024	0.00

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ANNUAL TOTALS FOR YEAR 26

	INCHES	CU. FEET	PERCENT
PRECIPITATION	30.61	111114.289	100.00
RUNOFF	12.057	43766.387	39.39
EVAPOTRANSPIRATION	17.187	62389.523	56.15
DRAINAGE COLLECTED FROM LAYER 2	0.0004	1.582	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	1.366	4956.909	4.46
SOIL WATER AT START OF YEAR	898.476	3261468.500	
SOIL WATER AT END OF YEAR	899.842	3266425.500	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.114	0.00

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ANNUAL TOTALS FOR YEAR 27

	INCHES	CU. FEET	PERCENT
PRECIPITATION	21.42	77754.586	100.00
RUNOFF	6.946	25214.857	32.43
EVAPOTRANSPIRATION	15.151	54998.141	70.73

DRAINAGE COLLECTED FROM LAYER 2	0.0008	2.981	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	-0.678	-2461.505	-3.17
SOIL WATER AT START OF YEAR	899.842	3266425.500	
SOIL WATER AT END OF YEAR	899.164	3263964.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.112	0.00

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ANNUAL TOTALS FOR YEAR 28

	INCHES	CU. FEET	PERCENT
PRECIPITATION	24.32	88281.602	100.00
RUNOFF	10.917	39627.258	44.89
EVAPOTRANSPIRATION	13.392	48612.855	55.07
DRAINAGE COLLECTED FROM LAYER 2	0.0009	3.360	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.010	38.108	0.04
SOIL WATER AT START OF YEAR	899.164	3263964.000	
SOIL WATER AT END OF YEAR	899.174	3264002.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.015	0.00

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ANNUAL TOTALS FOR YEAR 29

	INCHES	CU. FEET	PERCENT
PRECIPITATION	38.32	139101.578	100.00
RUNOFF	20.937	76000.961	54.64
EVAPOTRANSPIRATION	17.339	62941.500	45.25
DRAINAGE COLLECTED FROM LAYER 2	0.0006	2.248	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		
CHANGE IN WATER STORAGE	0.043	156.863	0.11
SOIL WATER AT START OF YEAR	899.174	3264002.000	
SOIL WATER AT END OF YEAR	899.217	3264159.000	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.015	0.00

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ANNUAL TOTALS FOR YEAR 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	29.76	108028.828	100.00
RUNOFF	10.519	38183.660	35.35
EVAPOTRANSPIRATION	18.014	65389.035	60.53
DRAINAGE COLLECTED FROM LAYER 2	0.0007	2.416	0.00
PERC./LEAKAGE THROUGH LAYER 4	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 3	0.0000		
DRAINAGE COLLECTED FROM LAYER 7	0.0000	0.000	0.00
PERC./LEAKAGE THROUGH LAYER 9	0.000000	0.000	0.00
AVG. HEAD ON TOP OF LAYER 8	0.0000		

CHANGE IN WATER STORAGE	1.227	4453.751	4.12
SOIL WATER AT START OF YEAR	899.217	3264159.000	
SOIL WATER AT END OF YEAR	900.444	3268612.750	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.031	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.01	1.76	0.49	1.23	1.63	2.36
	1.30	2.82	7.16	3.67	1.29	1.24
STD. DEVIATIONS	0.67	1.47	0.43	1.34	1.47	1.83
	1.26	1.85	3.29	2.13	1.31	0.74
RUNOFF						
TOTALS	0.115	0.537	0.013	0.546	0.718	1.074
	0.467	1.109	3.997	1.691	0.325	0.197
STD. DEVIATIONS	0.217	0.676	0.048	0.791	0.907	1.149
	0.822	1.218	2.493	1.385	0.568	0.267
EVAPOTRANSPIRATION						
TOTALS	0.788	0.966	1.040	1.326	0.882	1.243
	0.874	1.669	2.772	1.830	0.955	0.763
STD. DEVIATIONS	0.260	0.347	0.548	0.958	0.683	0.877
	0.517	0.838	1.030	0.628	0.373	0.280
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0000	0.0017	0.0018	0.0030	0.0000	0.0001
	0.0000	0.0001	0.0002	0.0001	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0092	0.0084	0.0143	0.0001	0.0001
	0.0001	0.0001	0.0003	0.0002	0.0001	0.0001
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 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 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

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3						
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

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	25.94 (5.302)	94177.9	100.00
RUNOFF	10.789 (3.6818)	39165.53	41.587
EVAPOTRANSPIRATION	15.107 (2.3176)	54839.88	58.230
LATERAL DRAINAGE COLLECTED FROM LAYER 2	0.00725 (0.02309)	26.301	0.02793
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00000 (0.00000)	0.000	0.00000
AVERAGE HEAD ON TOP OF LAYER 3	0.000 (0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH	0.00000 (0.00000)	0.000	0.00000

LAYER 9

AVERAGE HEAD ON TOP OF LAYER 8 0.000 (0.000)

CHANGE IN WATER STORAGE 0.040 (0.9145) 146.21 0.155

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	5.95	21598.500
RUNOFF	5.437	19737.9863
DRAINAGE COLLECTED FROM LAYER 2	0.00970	35.22506
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000000	0.00009
AVERAGE HEAD ON TOP OF LAYER 3	0.001	
MAXIMUM HEAD ON TOP OF LAYER 3	0.097	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 7	0.00000	0.00008
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00001
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	
SNOW WATER	0.00	0.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4047

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.2510

*** 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	8.0063	0.3336
2	0.0020	0.0100
3	0.0000	0.0000
4	8.5500	0.4750
5	876.0001	0.2920
6	7.7040	0.3210
7	0.0020	0.0100
8	0.0000	0.0000
9	0.1800	0.7500
SNOW WATER	0.000	

****

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APPENDIX III3D-2

GROUNDWATER INFLOW

GROUNDWATER INFLOW

Made by: JX
Checked by: MX
Reviewed by: JBF

1.0 OBJECTIVE

Estimate the groundwater inflow rate to the leachate collection system in accordance with 30 TAC §330.337(d).



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2.0 GIVEN

(1) The maximum volume of groundwater inflow through a geomembrane is dependent on i) the permeability of the materials surrounding the liner system, ii) the potentiometric conditions of the groundwater, and iii) the geomembrane hole size and spacing.

(2) The maximum unit groundwater flow rate below the liner system can be determined using the following equation:

$$q_0 = ki$$

where:

q_0 = unit groundwater flow rate below liner system

k = permeability of materials surrounding the liner system = 1.65E-04 cm/s
(conservatively use Stratum II permeability, liner actually is located within Statum I)

i = hydraulic gradient = 0.004
(conservatively use Stratum II data that is presented in Part III4, Geology Report)

(3) The liner system will be geosynthetic clay liner overlain with geomembrane. The maximum permeability of the geosynthetic clay liner is:

k_{om} = 5.00E-09 cm/sec

(4) The maximum groundwater head on the liner is about 7 feet. For this analysis, the groundwater head is conservatively assumed to be 10 feet.

h_w = 10 feet

(5) Based on standard geosynthetic installation practice, the geomembrane defect was assumed as a single circular 1 cm^2 hole per acre of geomembrane liner.

A = 1 cm^2

r_0 = 0.01851 ft

3.0 METHOD

Goundwater inflow to the liner system is calculated using the following equation [Ref. 1]:

$$h_w = \left\{ \frac{r_0^2 q_0}{2k_{om}} + \frac{Q}{2\pi k_{om}} \left[\ln\left(\frac{Q}{\pi r_0^2 q_0}\right) - 1 \right] + \frac{1}{4g^2} \left(\frac{Q}{1.88 r_0^2}\right)^4 \right\}^{0.5}$$

where:

h_w = groundwater head on the liner
r_0 = diameter of the geomembrane defect
q_0 = liquid supply i.e. permeation through the Stratum I/II reaching the bottom of the clay liner, which is the unit flow rate of the Stratum I/II interface material.
k_{om} = hydraulic conductivity of the layer upgradient (below) of the geomembrane liner
Q= inflow rate through the geomembrane into the leachate collection system
g= gravitational constant

4.0 CALCULATION

Using equation (1), the unit groundwater inflow rate is:

q_0 =	6.60E-07	cm/s			
Q =	1.82E-08	cf/sec	per acre	(since 1 defect is assumed per acre)	
	0.00	**cf/day**	**per acre**	OR	0.00 inch/year
q_0 =	2.17E-08	ft/sec			
r_0 =	0.01851	ft			
k_{om} =	5.00E-09	cm/sec			
	1.64E-10	ft/sec			
h_w	10.00	ft			

5.0 CONCLUSION

Results of the calculation indicate that the estimated maximum groundwater inflow rate through the liner system is insignificant. This is mainly due to the use of geosynthetic clay liner which has a very low permeability. As a result, there is little engineering value to include this in the HELP model in Appendix III-3E-1 and it will not affect the leachate collection system design.

6.0 REFERENCES

1. Rowe, R. Kerry et al. *Barrier Systems for Waste Disposal Facilities*, 2nd Edition, Spon Press, 2004

APPENDIX III3D-3

DRAINAGE MEDIA SPECIFICATIONS AND PERFORMANCE

APPENDIX III3D-3A

LEACHATE COLLECTION TRENCH HEADER PIPE SIZING

LEACHATE COLLECTION TRENCH HEADER PIPE SIZING

Made by: JX
Checked by: MX
Reviewed by: JBF

1.0 OBJECTIVE

Determine the leachate collection header pipe size required to convey the maximum anticipated leachate generated at the site.

2.0 METHOD

Compare the maximum leachate generation rate to the capacity of the proposed leachate collection header pipe. Use the maximum leachate impingement rate determined by the Hydrologic Evaluation of Landfill Performance (HELP) Model.

3.0 GIVEN

Minimum slope of Header Pipe =	0.6%	(post-settlement)
Approx. Max. Contributing Area =	20.9	acres (Cell 12A)
Maximum Daily Leachate Vol =	956	cf/acre/day; (from HELP Analysis)



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4.0 ASSUMPTIONS

The maximum daily leachate production rate given below represents the peak volume for an open condition: 10 feet of waste covered with 6 inches of daily cover. We will conservatively assume that this condition will exist across the entire cell. In addition, assume that all the flow must enter the pipe ignoring the capacity of the gravel.

5.0 RESULTS

5.1 Maximum Leachate Generation Rate

Peak daily leachate generation rate over largest contributing area =	19,980	cf/day
Converting the peak daily rate to cfs =	0.231	cfs

5.2 Pipe Capacity

Use Manning's Equation to determine the pipe capacity:

For HDPE pipe, Manning's n = 0.011 (Represents long-term conditions)

Pipe OD (in)	HDPE SDR Rating	Wall Thcknss (in)	Pipe ID (in)	Full Flow Capacity (cfs)	Factor of Safety (FS)
6.625	SDR-17	0.390	5.85	0.48	2.1

6.0 CONCLUSION

The capacity of a 6-in SDR 17 HDPE pipe at the minimum slope of 0.6% exceeds the peak leachate generation rate predicted for a conservative estimate of the worst-case conditions. Therefore, a 6-in diameter HDPE pipe will be adequate for use as the leachate collection header pipe.

APPENDIX III3D-3B

LEACHATE COLLECTION TRENCH HEADER PIPE PERFORATIONS

LEACHATE COLLECTION TRENCH HEADER PIPE PERFORATIONS

Made by: JX
Checked by: MX
Reviewed by: JBF

1.0 OBJECTIVE

Evaluate the leachate collection header pipe perforation design based on the HELP model estimate of the maximum anticipated leachate

2.0 GIVEN

The proposed leachate collection header pipes are 6-inch dia. HDPE pipes.
The proposed perforation schedule is 3 rows at 6-inch spacing, staggered.

diameter of perforations=	1/2	inches
Maximum leachate generation rate (q_{max})	956	cf/acre/day
From HELP Analysis.		



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3.0 METHOD

1. The maximum leachate flow rate per foot of pipe can be calculated using the following equation:

$$Q_{req} = q_{max} * L * 1 \quad \text{(Eq. 1)}$$

where:
Q_{req} = maximum leachate flow rate (ft^3/sec)
q_{max} = maximum leachate impingement rate (ft^3/ft^2/sec) based on HELP model results
L = maximum length of accepting areas from both sides of the leachate collection trench
L = 600 ft (from both directions, using maximum length of accepting area in Cell 12A)
1 = unit foot along the leachate header pipe (ft)

2. The inflow capacity per orifice can be calculated from the following equation:

$$Q_b = C * A * v \quad \text{(Eq. 2)}$$

where:
Q_b = inflow capacity per orifice, ft^3/sec;
C = discharge coefficient = 0.62 for sharp edged orifices
A = cross-sectional area of a perforation, ft^2
v = limit leachate entrance velocity, ft/sec = 0.1 ft/sec (Driscoll, 1986)

3. The inflow capacity per foot of the leachate collection pipe can be calcuated as follows:

$$Q_{in} = Q_b * n \quad \text{(Eq. 3)}$$

where:
Q_{in} = inflow capacity per foot of the leachate collection pipe, ft^3/sec;
n = number of orifices per foot of the leachate collection pipe

4.0 CALCULATION

Maximum Leachate Generation Rate

Peak daily leachate impingement rate (q_{max}) =	956	ft^3/acre/day
=	2.54E-07	$ft^3/ft^2/sec$
Max. leachate flow rate per foot of pipe (Eq.1) Q_{req} =	**1.52E-04**	**cfs**

Pipe Perforation Inflow Capacity

Inflow rate per perforation (Eq. 2) Q_b =	8.5E-05	cfs
Total perforations per foot of pipe (for conservative purposes, only the bottom two rows are included) =	4	
Inflow rate per foot of pipe (Eq. 3) Q_{in} =	**3.4E-04**	**cfs**

Factor of Safety = Q_{in}/Q_{req} = **2.2** OK - ignores flow in gravel

5.0 CONCLUSION

The leachate collection pipe perforations have adequate inflow capacity for leachate collection and drainage.

6.0 REFERENCE

1. Driscoll, F.G. (1986) "Groundwater and Wells," Second Edition, Johnson Division, St. Paul, MN, p997.

APPENDIX III3D-3C

HDPE PIPE STRUCTURAL DESIGN

HDPE PIPE STRUCTURAL DESIGN

Made by: JX
Checked by: MX
Reviewed by: JBF

1.0 OBJECTIVE

The maximum vertical pressure will be calculated and evaluate the structural intergity of the leachate collection pipe and sump riser pipe designed to withstand the maximum load. The pipes will be evaluated for 1) wall crushing, 2) wall buckling, and 3) ring deflection.

2.0 GIVEN

The header pipe in the leachate collection trench is 6-inch-diameter HDPE SDR-17 and the riser pipe in the leachate collection sump is 18-inch-diameter HDPE SDR-11. Properties such as wall thickness, pipe stiffness, and modulus of elasticity were taken from manufacturer's pipe specifications.

3.0 MAXIMUM VERTICAL PRESSURE CALCULATIONS

Two most-critical conditions were analyzed to calcuate the maximum design load on the pipe: equipment loading which occurs when the heaviest equipment CAT 836 is placing the first lift of waste, and the overburden load which occurs at the center of the landfill after final cover has been placed.



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3.1 Equipment Loading

Specification per manufacturer's literature for a CAT model 836 landfill compactorare as follows [Ref. 1]:

Operating weight:	F =	113,348	lb
Number of drums:	N=	4	
Load per drum:	Wd ≅	28,337	lb
Width of drums:	w=	4.6	ft
Diameter, drum only:	D=	5.7	ft
Wheel base:	L=	14.9	ft
Width over drums:	W=	14.1	ft

The worst-case scenario for live loading is when one line of drums of the compactor is situated directly on top of the header pipe. For conservative purposes, consider the drum loads as concentrated point loads. The vertical pressure on the buried pipes can be calculated using Boussinesq point load equation [Ref. 1]

$$S_L = W_d\left(\frac{I}{H^2}\right)$$

$$I = \frac{3}{2\pi\left[(R/H)^2 + 1\right]^{5/2}}$$

where:

S_L = vertical stress on the pipe due to equipment load
W_d = drum load
H = total height over pipe (5' waste and 2' soil)
I = influence coefficient:
R = horizontal distance from load application to pipe.

Using the above equations and dimensions given, the following vertical pressure is calcuated:

Equipment Load	R (ft)	I	Vert. Pressure (psi)
Drum 1	0	0.477	1.9
Drum 2	9.5	0.035	0.1
Drum 3	9.3	0.038	0.2
Drum 4	13.3	0.011	0.0
Static Load	**H (ft)**	**Unit Weight (pcf)**	**Vert. Pressure (psi)**
Waste	5	65	2.3
Soil	2	115	1.6
		Total vertical pressure =	**6.1**

3.2 Overburden Load

For the overburden load calculation, it is important to note that the pipe used in the leachate trench does not carry the entire load of the overlying waste. As a load is applied to the pipe, the pipe deflects slightly, transferring the load to the bedding material. This phenomenon is referred to as “soil arching” [Ref. 1]. Research performed by Adams, Muindi, and Selig, documented in “Polyethylene Pipe under High Fill” [Ref. 2] indicates that arching is a significant factor in high fills, and can reduce the vertical load acting on the pipe by 80% as compared to the free-field overburden stress. These findings, which were based on a 95-foot high fill and pipes instrumented with strain and earth pressure gauges, are widely accepted. This calculation has conservatively assumed that no soil arching occurs. For this reason, the pipe vertical load will not be corrected for perforations. The prism load will be used as the design pressure.

Protective and final cover densities were assumed to be 115 lb/cu. ft., with 2 ft. of protective cover and 3.5 ft. of final cover for a total of 5.5 ft. of cover material. The average solid waste density was assumed at 65 lb/cu. ft., and the maximum fill height was determined to be approximately 300 feet for the leachate collection pipes and 55 feet for the upslope risers.

Using the above equations and dimensions given, the following overburden pressure is calcuated:

6-inch SDR 17 Header Pipe	H (ft)	Unit Weight (pcf)	Overburden Pressure (psi)
Waste	300	65	135.4
Final Cover and Protective Soil	5.5	115	4.4
		Total vertical pressure =	**139.8**

18-inch SDR 11 Riser Pipe	H (ft)	Unit Weight (pcf)	Overburden Pressure (psi)
Waste	55	65	24.8
Final Cover and Protective Soil	5.5	115	4.4
		Total vertical pressure =	**29.2**

The overburden load will be used as the desigh stress for the pipe structural analysis, since it is greater than the equipment load.

4.0 STRUCTURAL INTEGRITY CALCULATIONS

The material surrounding the pipes will be clean gravel. A soil modulus value of 3,000 psi is chosen for a high degree of compaction [Ref. 4]. This value is reasonable given that the gravel will be in a trench under high loads and significantly constrained.

4.1 Wall Crushing Analysis

Determine compressive stress on pipe [Ref. 5]:

$$S_A = \frac{(SDR-1)P_D}{2}$$

where:

S_A = actual comporessive stress, psi
SDR = standard dimension ratio of pipe
P_D = external (overburden) design pressure, psi
FS = factor of safety 1500 psi / SA where 1500 psi is the compressive yield strength of Driscopipe

	SDR	P_T	S_A	FS
6-inch SDR 17 Header Pipe	17	139.8	1118	1.3
18-inch SDR 11 Riser Pipe	11	29.2	146	10.3

4.2 Wall Buckling Analysis

Determine maximum load before wall buckling will occur [Ref. 5]:

$$P_c = \frac{2.32(E)}{(SDR)^3}$$

$$P_{cb} = 0.8\left(E' P_c\right)^{0.5}$$

$$FS = \frac{P_{cb}}{P_D}$$

where:

P_c = critical collapse differential pressure
SDR = standard dimension ratio of pipe
E = stress-time dependent tensile modulus of elasticity
35,000 (approximate) [Ref. 6]
E' = soil modulus
3,000 psi

	SDR	Pc	Pcb	FS
6-inch SDR 17 Header Pipe	17	16.5	178	1.3
18-inch SDR 11 Riser Pipe	11	61.0	342	11.7

4.3 Ring Deflection Analysis

Determine maximum pipe deflection using modified Iowa Eqn. [Ref. 5]

$$\frac{dX}{D} = \frac{D_L k P_D}{\left(\frac{EI}{r^3}\right) + (0.061E')}$$

where:

dX/D = delfection (allowable deflection is 7.5%)
D_L = Deflection lag factor [Ref. 4]
k = bedding constant (from Ref. 5, p.15) [Ref. 4]
r = pipe radius (in)
D = pipe diamter (in)
t = pipe wall thickness (in)
I = moment of inertia of pipe wall per unit length (in^4/in)
PS = pipe stiffness in (lb/in/in)

$$I = \frac{t^3}{12} \qquad PS = \frac{6.7EI}{r^3}$$

	D_L	k	D	t	dX/D
6-inch SDR 17 Header Pipe	1	0.1	6	0.390	7.4%
18-inch SDR 11 Riser Pipe	1	0.1	18	1.636	1.5%

5.0 CONCLUSIONS

Review of the results shows that both pipes have satisfactory factors of safety against wall crushing and buckling. The pipe deflection is lower than the allowable deflection value of 7.5% as well. Further contigency is provided for the design since we are using full prism load on the pipe and maximum waste thickness which result in a conservative analyis.

6.0 REFERENCES

[1] Das, B.M. Principles of Geotechnical Engineering, 4th Ed., PWS Publishing Co., Boston, MA, 1998.

[2] Gipson, Allen H. Jr., and Deschamps, Jean-Guy, “Soil Box Able to Test 700-foot Heap Leach Heights,” 1996.

[3] Adams, Muindi, and Selig, "Polyethylene Pipe Under High Fill" TRB 1231, Washington, D.C., 1989 Analysis, Design and Behavior of Underground Culverts

[4] Xued Quian, Robert M. Koerner and Donald Gray = Geotechnical Aspects of Landfill Design and Construction "Prentice Hall, New Jersey, 2002

[5] Chevron Phillips Chemical Company LP, “Performance Pipe Engineering Manual”, March 2003.

[6] National Engineering Handbook, Part 636 Structural Engineering, Chapter 52, 210-VI-NEH, June 2005

APPENDIX III3D-4

LEACHATE COLLECTION SUMP CAPACITY

LEACHATE COLLECTION SUMP CAPACITY

Made by: JX
Checked by: MX
Reviewed by: JBF

1.0 OBJECTIVE

Calculate the volume and capacity of a typical leachate collection sump and, with this quantity, estimate the sump cycle time.

2.0 GIVEN

The typical sump dimensions for the lateral expansion sumps are provided below. Because sumps for the overliner option are larger in size, their capacities are not evaluated for the purpose of this calculation.

Sump base dimensions:	30' wide X 24' long X 2' deep
Sideslopes in sump:	3 :1 (horizontal:vertical)
Sump gravel porosity:	0.3



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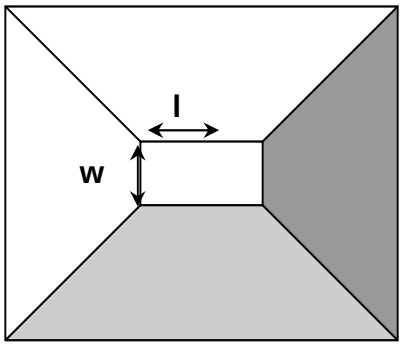
3.0 CALCULATIONS

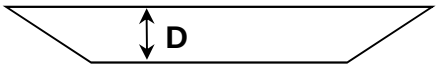
3.1 Total Sump Volume & Sump Capacity

$V = 1/3\ (A_1+A_2+(A1A2)^{1/2})\ D$ where

A_1 = area at base of sump
A_2 = area at top of sump
D = depth of sump



Plan View



Profile View

Sump Capacity=Gravel Porosity * Total Sump Volume

Base Sump Dimensions			Total Vol.	Sump Capacity	
Length (l)	Width (w)	Depth (D)	(ft^3)	(ft^3)	gallons
30	24	2	2,184	655	4,900

3.2 Time to Fill Sump, Worst-case Conditions

The maximum leachate generation rate was computed by the HELP model to be 956 ft^3/acre/day.

q_{max} =	956	ft^3/acre/day
	7151	gal/acre/day
Maximum contributing area =	20.9	acres (Cell 12A)
Maximum flow into sump =	149,453	gal/day
=	103.8	gpm

Assuming 3 inches of leachate remains at the base of the sump, the remaining void volume in the sump is:

=	598	ft^3
=	4,473	gal

The time it takes to fill the sump when 3 inches of leachate remains at the sump base and worst-case conditions exist is:

=	43.1	minutes
=	0.7	hr

3.3 Time to Fill Sump, Typical Conditions

The maximum average annual leachate generation rate was computed by the HELP model to be 12,494 ft^3/acre.

assume q_{ave} =	12,494	ft^3/acre/yr
	34.23	ft^3/acre/day
=	0.02	gal/acre/min
Maximum contributing area =	20.9	acre
Typical flow into sump =	0.5	gpm

Assuming 3 inches of leachate remains at base of sump, the time to fill the sump during typical conditions is:

=	9,003	min
=	150.1	hr

4.0 CONCLUSION

Each sump will have a capacity of approximately 4,900 gallons. Under worst-case conditions, leachate will reach the crest of the sump approximately 0.7 hours after pumping. Under typical conditions, leachate will reach the crest of the sump approximately 150 hours after pumping. Therefore, the propose pump design will provide adequate time for pump recycling.

APPENDIX III3E

BALLAST AND DEWATERING SYSTEM CALCULATIONS

APPENDIX III3E-1

SUFFICIENT BALLAST CALCULATIONS

SUFFICIENT BALLAST CALCULATIONS

Made by: CEI
Checked by: MX
Reviewed by: JBF

1.0 OBJECTIVE

Provide ballast calculations in accordance with Appendix III3F, Liner Quality Control Plan (LQCP).

2.0 APPROACH

The factor of safety against hydrostatic uplift is defined as the sum of the resisting forces provided by the ballast (weight) of overlying materials including protective soil cover, waste, and final cover, divided by the hydrostatic uplift forces acting at the base of the geomembrane liner. As described in the LQCP, a factor of safety of 1.5 is required when waste is being used as the ballast material.



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3.0 EXAMPLE BALLAST CALCULATIONS

Provided below are example calculations demonstrating the factor of safety in the final fill condition and the waste thickness required to achieve a factor of safety of 1.5.

Final-Filled Condition		**Ballast Offset (lb)**			**Hydrostatic Force (lb)**	
Slope of Alternative Liner at Evaluation Point	3 H:1V	*Final Cover*	*Waste*	*Protective Cover*	*Alternate Liner*	*Ground-water*
Top Elevation (ft-msl)		120.0	116.5	74.0	72.0	75.8
Thickness (ft)		3.5	42.5	2.0	-	3.8
Unit Weight (pcf)		115.0	44.0	105.0	-	62.4
Hydrostatic Offset Factor	**9.4**	2234.3			237.1	

Waste Thickness Required		**Ballast Offset (lb)**		**Hydrostatic Force (lb)**	
Slope of Alternative Liner at Evaluation Point	3 H:1V	*Waste*	*Protective Cover*	*Alternate Liner*	*Ground-water*
Top Elevation (ft-msl)		79.9	74.0	72.0	76.5
Thickness (ft)		**5.9**	2.0	-	4.5
Unit Weight (pcf)		44.0	105.0	-	62.4
Hydrostatic Offset Factor	**1.5**	421.2		280.8	

4.0 CALCULATIONS AND RESULTS

Final filled condition and waste thickness required ballast calculations for each evaluation point within the lateral expansion area of Unit 7 as depicted in Figure III3E-1-1 is summarized in the tables below. The final cover, protective cover, and alternate liner elevations are the same for each ballast evaluation point. In addition, the final cover and protective cover thickness as well as associated unit weight is assumed to be the same as the sample calculation provided above.

Final-Filled Condition	Factor of Safety	Component Elevations				
		Final Cover	*Waste*	*Protective Cover*	*Alternate Liner*	*Ground-water*
Point 1	**8.5**	120.0	116.5	74.0	72.0	76.2
Point 2	**8.7**	120.0	116.5	74.0	72.0	76.1
Point 3	**9.4**	120.0	116.5	74.0	72.0	75.8
Point 4	**9.2**	120.0	116.5	74.0	72.0	75.9
Point 5	**8.5**	120.0	116.5	74.0	72.0	76.2
Point 6	**NA**	120.0	116.5	74.0	72.0	70.2
Point 7	**NA**	120.0	116.5	74.0	72.0	71.8
Point 8	**19.9**	120.0	116.5	74.0	72.0	73.8
Point 9	**10.9**	120.0	116.5	74.0	72.0	75.3
Point 10	**9.2**	120.0	116.5	74.0	72.0	75.9
Point 11	**8.3**	120.0	116.5	74.0	72.0	76.3
Point 12	**8.0**	120.0	116.5	74.0	72.0	76.5

NA: Groundwater elevation is below liner elevation.

Waste Thickness Required	Waste Thickness	*Factor of Safety*	Component Elevations			
			Waste	*Protective Cover*	*Alternate Liner*	*Ground-water*
Point 1	**5.2**	1.5	79.2	74.0	72.0	76.2
Point 2	**4.9**	1.5	78.9	74.0	72.0	76.1
Point 3	**4.2**	1.5	78.2	74.0	72.0	75.8
Point 4	**4.4**	1.5	78.4	74.0	72.0	75.9
Point 5	**5.2**	1.5	79.2	74.0	72.0	76.2
Point 6	**0.0**	1.5	74.0	74.0	72.0	70.2
Point 7	**0.0**	1.5	74.0	74.0	72.0	71.8
Point 8	**0.0**	1.5	74.0	74.0	72.0	73.8
Point 9	**3.0**	1.5	77.0	74.0	72.0	75.3
Point 10	**4.4**	1.5	78.4	74.0	72.0	75.9
Point 11	**5.4**	1.5	79.4	74.0	72.0	76.3
Point 12	**5.9**	1.5	79.9	74.0	72.0	76.5

5.0 CONCLUSION

A ballast calculation was performed at each evaluation point depicted on Figure III3E-1-1 within the lateral expansion area of Unit 7. The evaluation point number 12 selected within Cell 12 where the difference between the seasonal high groundwater surface and the design basegrade is the greatest is the worst-case scenario. The final filled condition has a factor of satety of 8.0 and 5.9 ft was waste is required to acheive a factor of safety of 1.5. Review of the results indicate that long-term vallast is adequate for the proposed design.



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PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
SUFFICIENT BALLAST EVALUATION *SUBGRADE LAYOUT*

PROJECT NO.	APPLICATION SECTION	REV.	FIGURE
1401491	III3E-1	0	1 of 2 III3E-1-1

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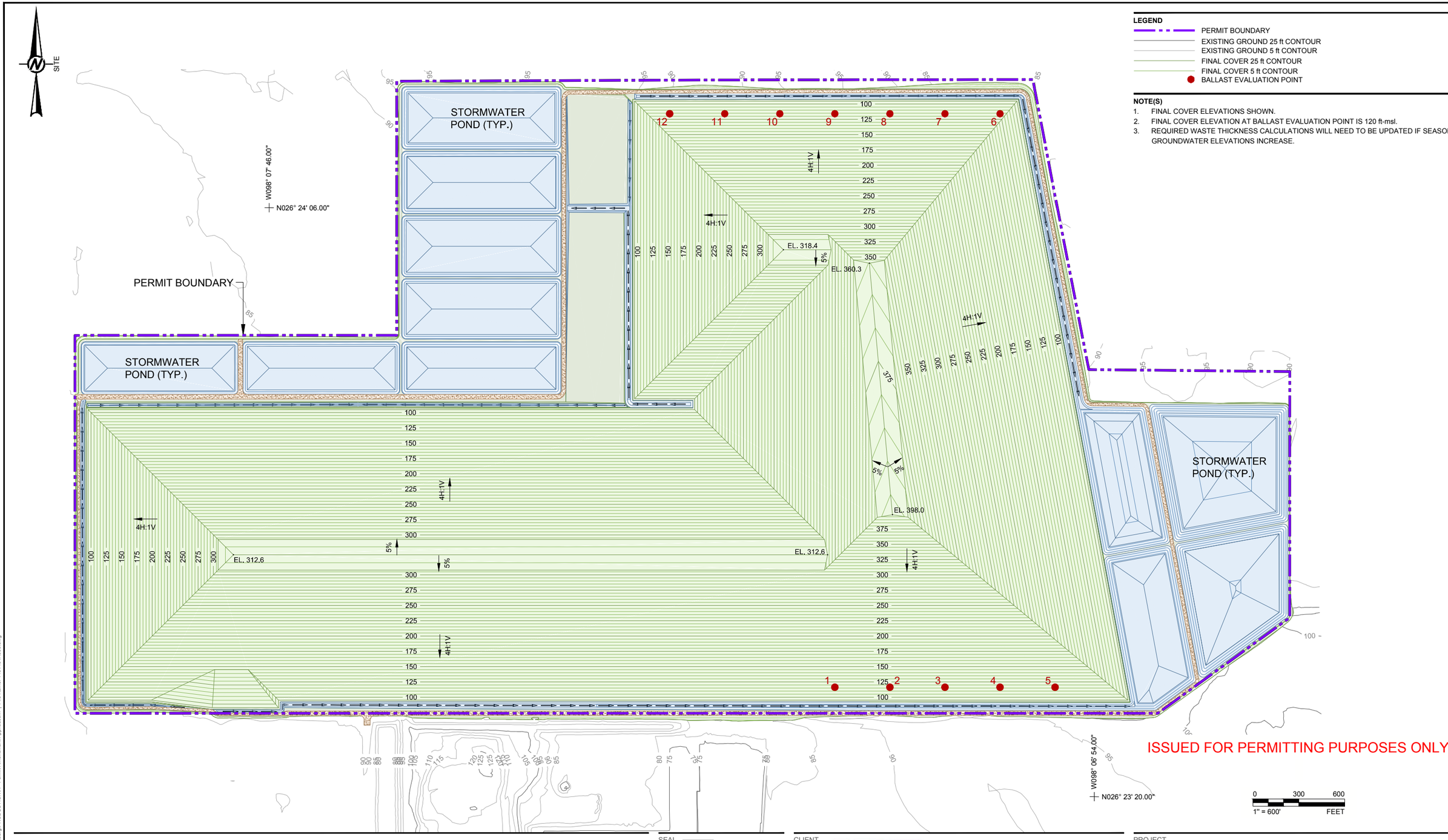

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PROJECT

EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE

SUFFICIENT BALLAST EVALUATION *FINAL CONTOUR MAP*

PROJECT NO.	APPLICATION SECTION	REV.		FIGURE
1401491	III3E-1	0	2 of 2	III3E-1-2

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APPENDIX III3E-2

DEWATERING SYSTEM CALCULATIONS

APPENDIX III3E-2A

UNDERDRAIN SEEPAGE CALCULATION

UNDERDRAIN SEEPAGE CALCULATION

Made by: JX
Checked by: MX
Reviewed by: JBF

1.0 OBJECTIVE

Use finite element analyses to model seepage and estimate the potential seepage flow under the Edinburg Regional Disposal Facility expansion area liner system. Design the underdrain system to limit build-up of water pressure under the most critical seepage conditions.



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2.0 DISCUSSION

2.1 Site Conditions

The subsurface stratigraphy of the site includes three units, Stratum I, II, and III. These units are comprised of: sandy clays/clayey sands (Stratum I); silty fine sand and sand (Stratum II); and high plasticity, hard, dry clay (Stratum III). Based upon an evaluation of the soil boring and groundwater data from site investigations, Stratum II is the uppermost water bearing layer. Stratum I in general acts as a confining layer for Stratum II. Stratum I is underlain by Stratum II at an approximate elevation of 65 ft msl (mean sea level) in the northern cells and 55 ft msl in the southern cells. Stratum II is underlain by Stratum III at an approximate elevation of 45 ft msl in the northern cells and 35 ft msl in the southern cells. Cell excavation in the expansion area will be within Stratum I.

Seasonal high groundwater elevations, based on historical groundwater measurements, are shown on Figures IIIF-3A and III3F-3B.

The cell liner system for the facility includes a geosynthetic clay liner (GCL), a geomembrane liner and 2 feet of protective cover soil.

2.3 Underdrain Design

In cell areas where the subgrade elevation will be lower than the seasonal high groundwater elevation, an underdrain system will be installed. The proposed underdrain design includes a toe drain (consisting of a perforated pipe in a gravel filled trench), a geocomposite drainage layer on the cell sideslope, and a sump at the end of the cell (underneath the leachate sump). The underdrain is design to reduce the hydrostatic uplifting forces on the liner system.

3.0 METHOD

Use SEEP/W, a 2-Dimensional finite element analysis program, to estimate flow into the underdrain based on a generalized subsurface stratigraphy. For conservative purposes, the worst-case scenario is used to calculate the anticipated flow and design the underdrain capacity.

4.0 INPUT PARAMETERS

4.1 Soil Parameters

Permeability parameters were determined by measuring the hydraulic conductivity of the soils with a flexible wall permeameter (ASTM Test Method D5084). The horizontal hydraulic conductivity of Stratum II was based on field slug test data. Details on Edinburg Regional Disposal Facility soil stratum properties are available in the Geology Report in Part III4, Geology Report.

Stratum Number	Horizontal Permeability K_x (cm/s)	Horizontal Permeability K_x (ft/s)	Vertical Permeability K_y (cm/s)	Vertical Permeability K_y (ft/s)	K_y/K_x Ratio
I	1.75E-06	5.74E-08	2.18E-07	7.15E-09	0.125
II	1.65E-04	5.41E-06	1.91E-04	6.27E-06	1.158
III	1.63E-07	5.35E-09	8.84E-09	2.90E-10	0.054

Due to the pockets of sand found in Stratum I, the models were conservatively designed such that the material properties of Stratum I actually reflect permeability of Stratum II. This would result in a greater flow into the underdrain, which in turn will produce a conservative underdrain design.

4.2 Critical Cross Sections

The critical cross-section will occur along portions of the Edinburg Regional Disposal Facility Unit 7 that have the highest seasonal groundwater level underlying the liner system (geosynthetic clay liner, geomembrane liner, and 2 feet of protective cover soil). Three cross-sections were selected to represent the most critical conditions. All cross-sections were modeled assuming Stratum II layer is a consistent 20 ft thickness. Two cross-sections are on the north side of the expansion, one in Cell 12A and the other in Cells 10A and 11A. On the south side of the expansion, a cross-section was selected in Cell 1. The cross-sections align with the groundwater flow directions. Locations of the cross-sections are shown on Figures III3F-3A and III3F-3B.

4.3 Boundary Conditions

4.3.1 Sideslope Underdrain and Liner System

A geocomposite underdrain layer will be placed along the sideslope to intercept, collect, and transmit groundwater to the toe of the slope. The sideslope underdrain was modeled as a seepage face; i.e. a free draining surface with no positive pore pressures. The liner system was modeled as an impenetrable boundary.

4.3.2 Total Head

Total head boundaries were set to represent hydrostatic groundwater conditions below existing grade.

For North Cross-Section 1, the highest seasonal groundwater elevations ranged from 78 ft msl at the western boundary of Cell 12A to 76 ft msl at the northern boundary of Cell 12A.

For North Cross-Section 2, the highest seasonal groundwater elevation ranged from 77.5 ft msl at the western boundary of Cell11A to 75.5 ft msl at the northern boundary of Cell 10A.

For the South Cross-Section, the highest seasonal groundwater elevation ranged from 76.5 ft msl at the southern boundary of the expansion area to 75 ft msl at the northern point of Cell 1.

4.3.3 Toe Drain

The toe drain was designed to be 2 feet wide by 2 feet deep and modeled as a sink (a node assigned zero pressure). A sink models a condition in which all water seeping into it is removed before creating a pressure condition.

5.0 RESULTS

SEEP/W output figure, showing analysis configurations, boundary conditions, phreatic surface, total head contours, etc., are attached. As discussed above, three cross-sections were modeled in the SEEP/W analyses, two for the generalized north cell orientation and one for the generalized south cell oritentation. Section 5.1 presents the groundwater flows and Section 5.2 addresses the pore water pressure head on the liner.

5.1 Groundwater Flow Summary

Steady-state flow rate of groundwater into each toe-drain was calculated.

North cross-section 1, west toe drain =	1.15E-06	ft^3/sec/ft
North cross-section 1, north toe drain =	1.42E-05	ft^3/sec/ft
North cross-section 2, toe drain =	2.47E-05	ft^3/sec/ft
South cross-section, toe drain =	1.60E-05	ft^3/sec/ft
Maximum flow rate into the toe drain=	2.47E-05	ft^3/sec/ft

Evaluation of the sideslope underdrain geocomposite calculation is presented in Appendix III3E-2C.

5.2 Pore Water Pressure on The Liner

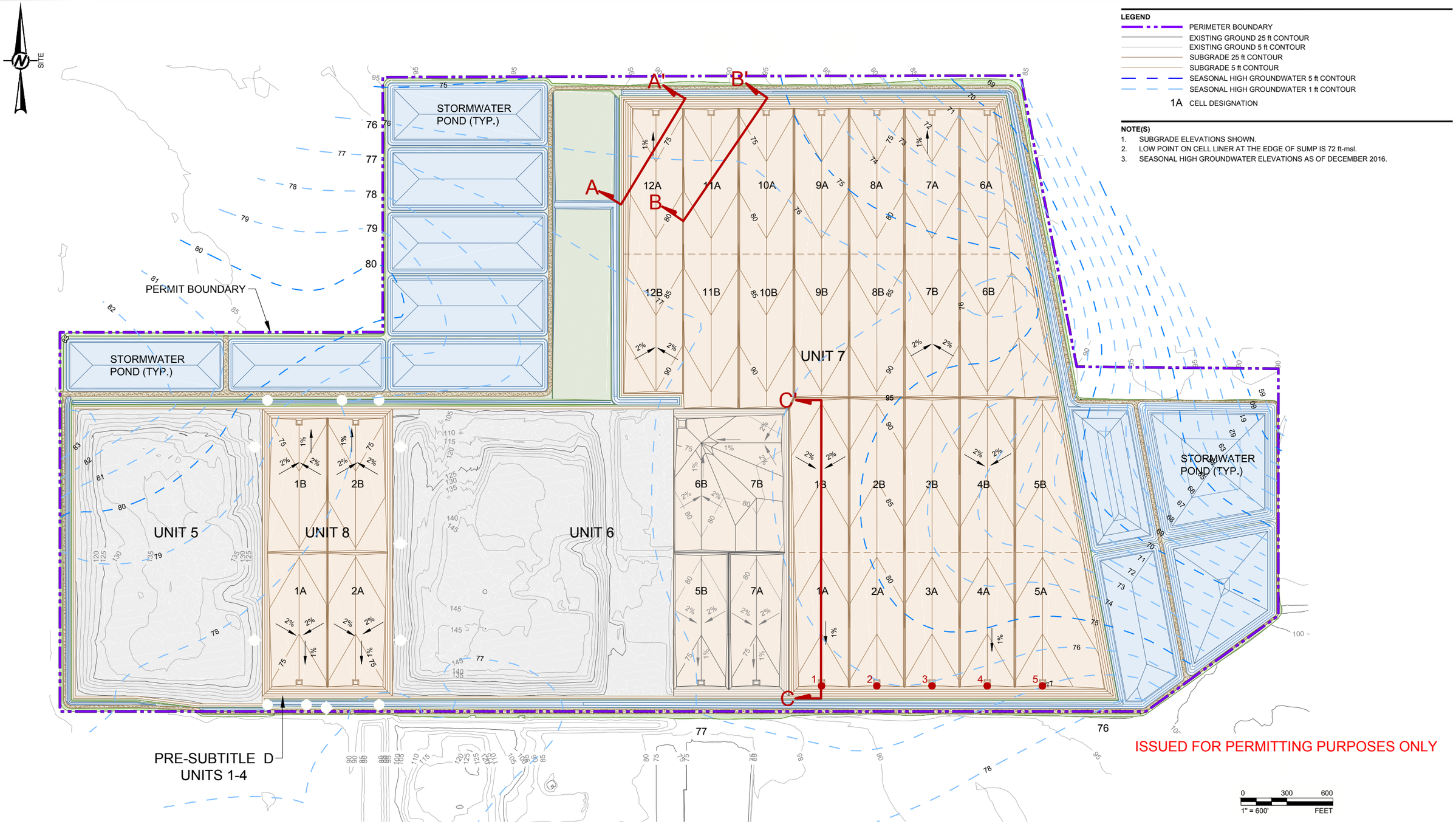
The analysis shows that the toe drains draw down the phreatic surface to below the liner elevations in the north cross-section 2 and south cross-section. In north cross-section 1, i.e. where the seasonal high groundwater elevation is the highest, the maximum pressure head exerted on the liner (GCL, geomembrane, and 2 feet protective cover soil) is 1.5 feet The factor of safety against hydrostatic uplift is calculated as follows:

Maximum Pore Water Pressure =	93.6 psf (1.5 feet of water head at 62.4 pcf)
Ballast Pressure =	210 psf (2 feet of protective cover at 105 pcf)
Factor of Safety =	2.2 >1.2 OKAY

Since the factor of safety is above 1.2, the liner will exert enough pressure to offset the hydostatic uplift from groundwater.

6.0 CONCLUSION

Based on the landfill's cross-sectional geometry, seasonal high groundwater table, subsurface soil properties and conservative assumptions listed above, the analysis shows that the maximum anticipated steady-state flow of groundwater flow to the proposed underdrain system is 2.47E-05 ft^3/sec/ft. The maximum calculated steady-state flow of groundwater into the toe drain will not exceed the capacity of the underdrain collection pipe, as shown in the underdrain pipe sizing calculation in Appendix III-3E-2B. Additionally, the maximum pore water pressure head along the liner system is 1.5 feet; therefore, the hydrostatic pressure exerted on the liner by the groundwater can be offset over the short-term by the 2-ft thick protective cover soil with a factor of safety greater than 1.2. Long term ballast will be achieved with a combination of soil and overlying waste with a factor of safety greater than 1.5 as shown in Appendix III-3E-1.



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PROJECT

EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE

UNDERDRAIN SEEPAGE *SUBGRADE LAYOUT AND SEASONAL HIGH GROUNDWATER MAP*

PROJECT NO.	APPLICATION SECTION	REV.	FIGURE
1401491	III3E-2A	0	1 of 1 III3E-2A-1

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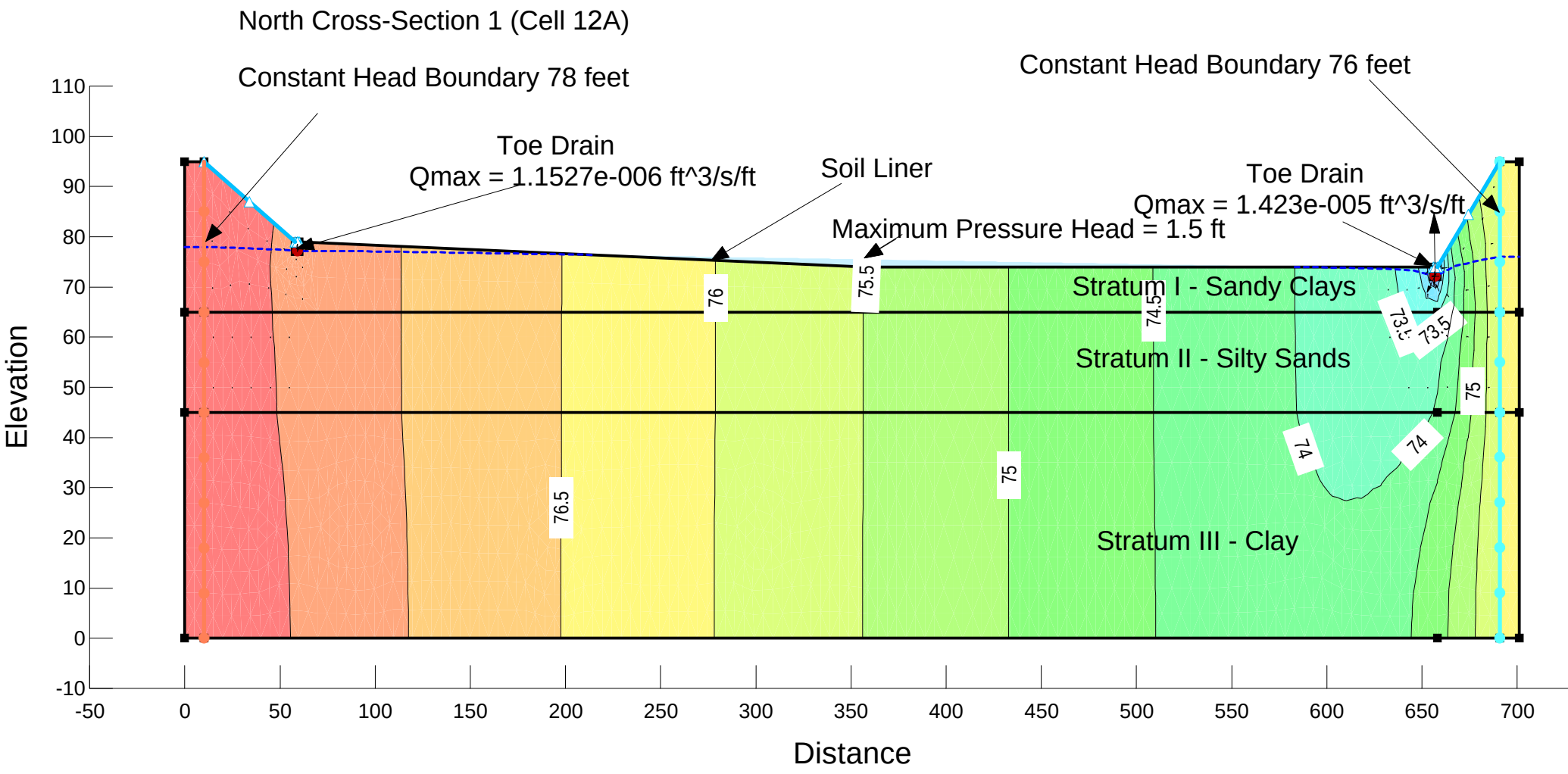

Figure III3E-2A-1

Edinburg Regional Disposal Facility, Permit Amendment Applications TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix E-2, Underdrain Seepage

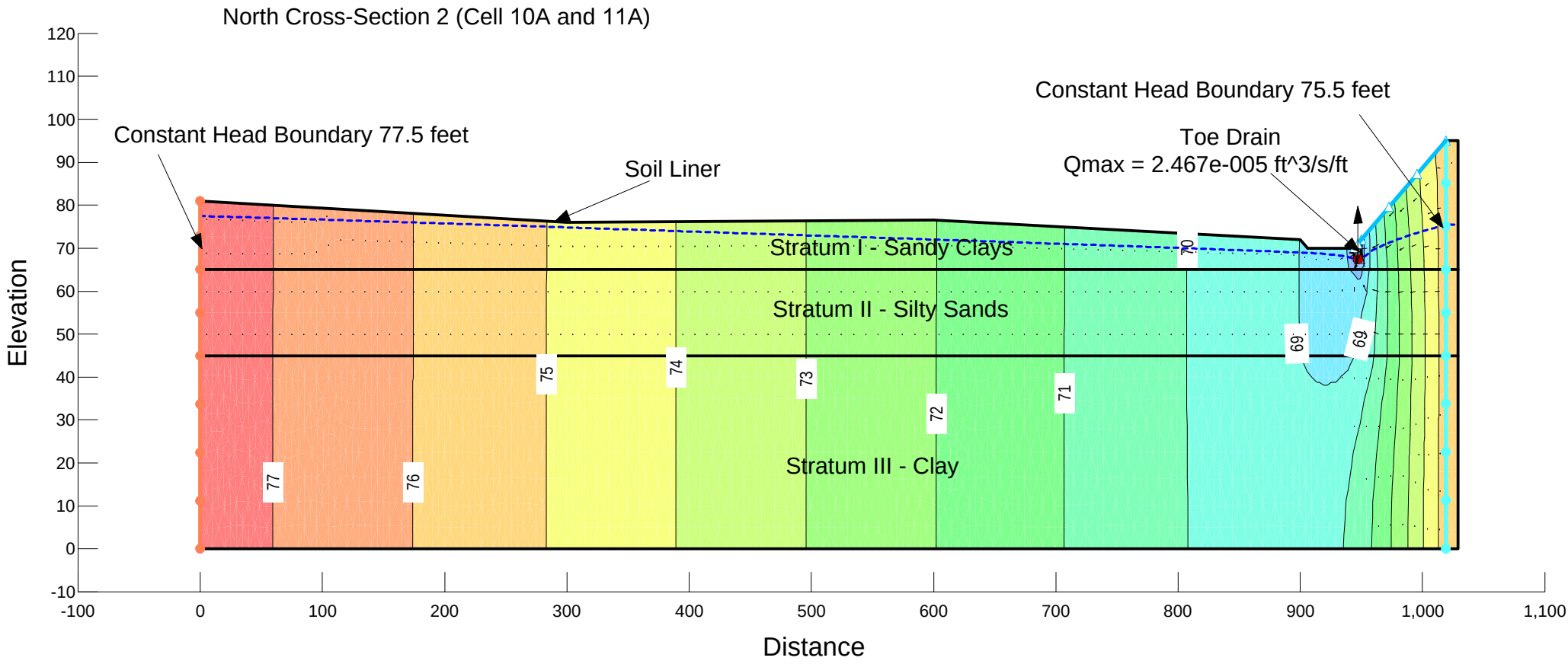

Figure III3E-2A-2

Edinburg Regional Disposal Facility, Permit Amendment Applications TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix E-2, Underdrain Seepage

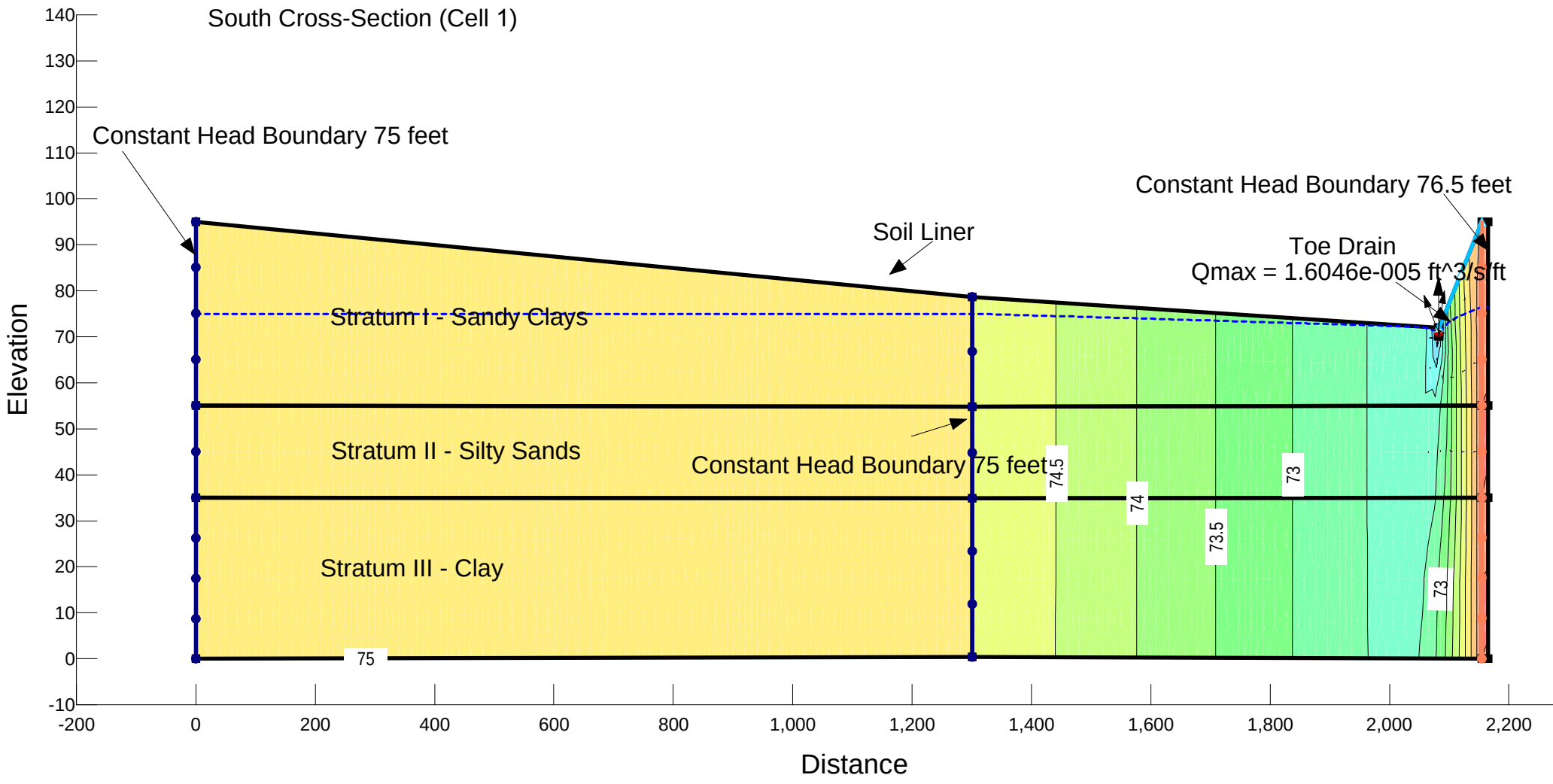

Figure III3E-2A-3

Edinburg Regional Disposal Facility, Permit Amendment Applications TCEQ Permit MSW-956C, Part III, Attachment 3, Appendix E-2, Underdrain Seepage

APPENDIX III3E-2B

UNDERDRAIN PIPE SIZING CALCULATION

UNDERDRAIN PIPE SIZING CALCULATION

Made by: JX
Checked by: MX
Reviewed by: JBF

1.0 OBJECTIVE

Determine the pipe size required to convey the maximum anticipated groundwater flow into the underdrain toe drain.



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2.0 METHOD

Compare the maximum groundwater flow rate to the capacity of the proposed toe drain pipe. Use the maximum groundwater flow rate determined from underdrain seepage calculations (Appendix III3E-2A).

3.0 GIVEN

Minimum slope of Header Pipe =	0.6%	(conservative estimated post-settlement)
Approx. Max. Pipe Length =	700.0	ft
Maximum Daily Groundwater Volume per Unit Width =	2.47E-05	$ft^3/sec/ft$ (maximum flow into toe drain and along excavated slope from Appendix III3F-3A)

4.0 ASSUMPTIONS

Assume that all the flow must flow through the pipe ignoring the capacity of the gravel.

Use 4-inch ADS N-12 corrugated HDPE pipes.

5.0 RESULTS

5.1 Maximum Groundwater Flow Rate

Maximum Flow Into Underdrain = Approx. Max. Length of Pipe * Maximum Groundwater Vol. per Unit Width

Maximum Groundwater Flow into Underdrain = 1.73E-02 ft^3/sec

5.2 Pipe Capacity

Use Manning's Equation to determine the pipe capacity:

For HDPE pipe, Manning's n = 0.012 (Represents long-term conditions)

Pipe OD (in)	HDPE SDR Rating	Wall Thcknss (in)	Pipe ID (in)	Full Flow Capacity (cfs)	Factor of Safety (FS)
4.5	SDR-17	0.265	3.97	0.16	9.1

6.0 CONCLUSION

The capacity of a 4-inch ADS N-12 HDPE (or equal) pipe at a minimum slope of 0.6% exceeds the maximum groundwater flow rate predicted for a conservative estimate of the worst-case conditions. Therefore, the designed underdrain will have adequate capacity to convey the groundwater flow.

APPENDIX III3E-2C

UNDERDRAIN GEOCOMPOSITE CALCULATION

UNDERDRAIN GEOCOMPOSITE CALCULATION

Made By: VK
Checked by: CEI
Reviewed by: JBF

1.0 OBJECTIVE

I) Determine the required transmissivity of the underdrain drainage layer (double-sided geocomposite) for the maximum groundwater flow on the sideslope.

II) Based on published data, determine the geosynthetic drainage layer type that will meet the required transmissivity.



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2.0 GIVEN

Maximum groundwater flow along entire sideslope = 2.47E-05 ft^3/sec per unit width
(maximum total flow along slope - see Appendix III-3E-2A; same as impingement rate x max. slope length)

Sideslope gradient, $i_{sideslope}$ = 0.33

3.0 METHOD

Determine the design transmissivity of underdrain geocomposite layer. The design criterion is that the geocomposite should have adequate capacity to transmit all groundwater flow (i.e. avoid any build up of hydrostatic pressure below the liner) on the sideslopes.

$$\theta_{design} = \frac{q_i L}{sin\beta} = \frac{q_i L}{Slope}$$ [Ref. 1]

Where: θ_{design} = design transmissivity (m^2/sec)
q_i = impingement rate (m/sec)
L = horizontal length of slope (m)
β = slope angle (degrees)

Establish a required transmissivity, $\theta_{required}$, by applying reduction factors to the θ_{design}. [Ref. 2]

$$\theta_{required} = \theta_{design} \times [RF_{cr} * RF_{cc} * RF_{bc} * RF_{in}]$$

Where: RF_{cr} = Reduction factor for short-term creep
RF_{cc} = Reduction factor for chemical clogging
RF_{bc} = Reduction factor for biological clogging
RF_{in} = Reduction factor for intrusion of geotextile or geomembrane

This required transmissivity will be used as material specification for' the transmissivity measured in laboratory during construction.

Test Conditions: $i \geq$ 0.33

Normal Stress ≥ 1,000 psf

Boundary Cond'ns = steel plates

Test Time = 1 hour

Reduction Factor	Description	Value [Ref. 2 &3]
RF_{cr} =	Reduction Factor for creep	1.2
RF_{cc} =	Reduction Factor for chemical clogging of geotextile and/or geonet	1.1
RF_{bc} =	Reduction Factor for biological clogging of geotextile and/or geonet	1.0
RF_{in} =	Reduction Factor for intrusion of geotextile into geonet	1.2
	Π(RF) =	1.6

4.0 CALCULATION

I) Transmissivity for maximum flow:

$$\theta_{required} = \textbf{1.2E-04 ft}^3\textbf{/s-ft} = \textbf{1.2E-05 m}^3\textbf{/s-m}$$

II) An industry standard 200-mil double-sided geocompsite has a typical laboratory-measured transmissivity of approximately 1.0E-04 m^2/sec, therefore a typical 200-mil double-sided is expected to be acceptable. Nevertheless, conformance testing will be performed to demonstrate the material can meet the specification.

5.0 CONCLUSION

The underdrain geocomposite drainage layer is required to have adequate flow capacity to prevent the development of hydrostatic pressure below the liner on the sideslopes. The required transmissivity of the underdrain geocomposite layer on the sideslopes is 1.2E-05 m^2/sec (i.e. required minimum laboratory testing result).

6.0 REFERENCES

1. Giroud, J.P, Zornberg, J.G., and Zhao, A., "Hydraulic Design of Geosynthetic and Granular Liquid Collection Layers", Geosynthetics International, Vol. 7, Nos. 4-6, 2000.
2. Robert M. Koerner "Designing with Geosynthetics" Fifth Edition, 2005 Prentice Hall
3. Narejo, D. and Allen, S. 2004 "Using the Stepped Isothermal Method for Geonet Creep Evaluation." Proceedings of EuroGeo3, Third European Geosynthetics Conference, Munich, pp. 539-544.

APPENDIX III3F

LINER QUALITY CONTROL PLAN

CITY OF EDINBURG SOLID WASTE MANAGEMENT

PERMIT AMENDMENT APPLICATION

Part III, Attachment 3, Appendix F

LINER QUALITY CONTROL PLAN

Edinburg Regional Disposal Facility

Edinburg, Hidalgo County, Texas

TCEQ Permit MSW-956C

Submitted To: City of Edinburg
Department of Solid Waste Management
8601 North Jasman Road
Edinburg, Texas 78542 USA

Submitted By: Golder Associates Inc.
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July 2017

Project No. 1401491

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1.0 PURPOSE

1.1 Purpose

30 TAC §330.339(a)

This Liner Quality Control Plan (LQCP), is prepared under the direction of a licensed professional engineer, and it is the basis for the type and rate of quality control testing performance and reported in the geosynthetic liner evaluation report (GLER) as required in §30 TAC §330.341. The plan provides operating personnel adequate procedural guidance for assuring continuous compliance with groundwater protection requirements. The plan specifies construction methods employing good engineering practices for installation and testing of components of the alternative liner including geosynthetic clay liner (GCL), geomembrane (GM), leachate collection and removal system (LCRS), and protective cover soil. In addition, dewatering plans are included.

1.2 Liner Quality Control Testing Procedures

30 TAC §330.339(a)(2)

The liner quality control testing procedures, including sampling frequency, are provided in this LQCP. All field sampling and testing, both during construction and after completion, shall be performed by a person acting in compliance with the provisions of the Texas Engineering Practice Act and other applicable state laws and regulations. The professional of record who signs the GLER or his representative should be on site during all liner construction. Quality control of construction and quality assurance of sampling and testing procedures should follow the latest technical guidelines of the TCEQ.

2.0 GEOSYNTHETIC CLAY LINER

This section presents general procedures, quality control testing requirements, and installation procedures for geosynthetic clay liner (GCL) construction. The GCL approved for use at the site consists of sodium bentonite encapsulated between two geotextile layers, needle-punched or stitched-bonded together.

2.1 Pre-Installation Material Evaluation

2.1.1 Manufacturer's Quality Control Certificates

Prior to the installation of the GCL, the manufacturer or installer shall provide the POR with quality control certificates signed by a responsible party employed by the manufacturer. Each quality control certificate shall include roll identification numbers, testing procedures, and results of quality control tests. The quality control tests shall be performed in accordance with project-specific testing methods and subject to the minimum testing frequency shown in Table III3F-1. The owner may require more frequent testing at his discretion.

The quality control testing may be performed in the manufacturing plant. The POR shall review the test results prior to accepting the GCL to ensure that the certified minimum properties meet the values presented in Table III3F-1.

2.1.2 Conformance Testing

In addition to the manufacturer's quality control certificates, samples of rolls of GCL will be obtained for conformance testing. The samples shall be tested by an independent third party laboratory in accordance with Table III3F-2. The POR shall review the test results to ensure that they meet the values presented in Table III3F-1.

The POR shall compare measured shear strength values to those used in the stability analyses included in Appendix III3B-2B, III3B-2C, and III3B-2D. If the measured interface shear strength is less than the values used in the analyses, the stability of the liner system shall be reassessed and revised calculations shall be included in the Geosynthetic Liner Evaluation Report (GLER).

In order to prevent premature hydration, the GCL rolls shall be shipped in plastic wrapping that shall remain intact until material installation. Upon delivery of the GCL, storage and handling procedures shall be documented. The rolls will be stacked, stored, and handled in accordance with ASTM D5888 or manufacturer's recommendations.

Table III3F-1: GCL QC Submittal Frequency & Material Specifications

Bentonite					
Property	**Qualifier**	**Unit**	**Value**	**Test Method(1)**	**Frequency**
Fluid Loss	max.	ml	18	ASTM D5891	1 per 50 tons or every truck or railcar
Free Swell	min.	ml	24	ASTM D5890	
Geotextile					
Property	**Qualifier**	**Unit**	**Value**	**Test Method(1)**	**Frequency**
Mass per Unit Area	—	g/cc	—	ASTM D5261	1 per 200,000 ft^2
Tensile Properties:	—	lb	—	ASTM D4632	
GCL Product					
Property	**Qualifier**	**Unit**	**Value**	**Test Method(1)**	**Frequency**
Bentonite Mass	min.	lb/ft^2	0.8	ASTM D5993	1 per 40,000 ft^2
Bentonite Moisture Content	—	%	—	ASTM D5993	
Grab Tensile Strength	—	lb	—	ASTM D6768	1 per 200,000 ft^2
Hydraulic Flux	max.	m^3/m^2-s	1×10^{-8}	ASTM D5887	1 per week for each production line(2)

Notes:
1. Updated methods may be implemented based on a review by the POR.
2. Report last 20 test values, ending on production date of supplied GCL.
3. For those properties that do not indicate a value, the GCL material must meet the manufacturer's minimum specification.

Table III3F-2: GCL Conformance Test Schedule

TEST	**METHOD(1)**	**FREQUENCY**
Bentonite Mass/Unit Area	ASTM D5993	Not less than 1 test per 100,000 ft^2
Hydraulic Flux	ASTM D5887	
Direct Shear(2)(3)	ASTM D6243	1 test per GCL/adjoining material

Notes:
1. Updated methods may be implemented based on a review by the POR.
2. Direct shear testing shall be performed on the GCL/geomembrane/geocomposite sandwich. Soak interface and apply normal stresses of 1000, 5000, and 18,000 psf for at least 1 hour prior to shearing at a displacement rate of 0.04 in/min.
3. The testing results shall be compared to the values used in the stability analyses included in the Appendix III3B-3B. If the measured interface shear strength is less than the values used in the analyses, the stability of the liner system shall be reassessed and revised calculations shall be included in the GLER.
4. Test results from materials used during one construction event may be used in subsequent events provided the materials used are the same and approved by the POR.

2.2 Installation Procedures

2.2.1 GCL Subgrade Preparation

Surfaces to be lined should be smooth and free of all rocks greater than 0.75-inch diameter (or as recommended by the manufacturer, if less than 0.75 inches), sharp/angular objects, sticks, roots, or debris

of any kind. The surface should provide a firm, unyielding foundation for the GCL with no sudden, sharp, or abrupt changes or break in grade. The subgrade surface shall be prepared by rolling with a smooth-drum roller to minimize the roughness and press down protruding soil or rock particles prior to GCL deployment. Loose rocks and/or dry soil particles that could damage the GCL shall be removed. Excessive voids or dimples shall be filled with soil.

Standing water or excessive moisture on the subgrade will not be allowed. The subgrade shall be maintained in a smooth, uniform, and drained condition.

2.2.2 Anchor Trench Construction

The anchor trench shall be constructed according to the project plans and specifications, and the excavation and backfilling operations shall be documented. If the anchor trench is excavated in a clay material susceptible to desiccation, the amount of anchor trench open at any time should be minimized. The inside edge of the trench shall be rounded so as to avoid stresses from sharp bends in the GCL. The GCL will not be placed into the anchor trench on top of any rocks greater than 0.75-inch diameter, sharp/angular objects, sticks, roots, or debris of any kind. The anchor trench shall be adequately drained to prevent ponding or hydration of the GCL while the trench is open. The anchor trench shall be backfilled and compacted according to the project plans and specifications; however, backfilling shall be performed, at a minimum, with ordinary compaction as deemed suitable by the POR.

2.2.3 GCL Deployment

Equipment used to deploy GCL must not cause excessive rutting of the subgrade. Deployed GCL panels should contain no folds or excessive slack. Installation personnel must not smoke or wear damaging shoes on GCL. GCL should not be placed during excessive winds. In general, only low ground pressure rubber-tired support equipment approved by the POR may be allowed on the GCL. If the POR observes any potential damage done to the liner by the support equipment, use of the equipment will cease and the damage will be repaired. Generators, gasoline or solvent cans, tools, or supplies must not be stored directly on the GCL.

Panels should be overlapped and seamed, as recommended by the manufacturer. End-to-end seams on sideslopes should be kept to a minimum. If end-to-end seams on sideslopes are necessary (i.e., if the GCL roll lengths are insufficient to cover the entire slope length), a minimum overlap of 5 feet will be required and may be placed only in the lower half of the slope and must be staggered.

GCL deployment shall be limited to the amount that can be covered with the overlying geomembrane liner the same day. GCL deployment shall not be undertaken during precipitation or when there is an impending threat of precipitation.

Following deployment, the CQA monitor shall visually examine the entire surface of the GCL for even bentonite distribution, thin spots, or other panel defects. All defects will be recorded and repaired in accordance with this LQCP. The QA/QC representative shall also verify the following:

- Proper overlap during deployment
- Seams between GCL panels are constructed per manufacturer's recommendations
- Defects are patched and overlapped properly
- The bentonite has not become excessively hydrated

Excessively hydrated GCL shall be removed and replaced with new material. Geomembrane shall not be placed on hydrated GCL.

GCL panels shall be given an identification code, mapped, and logged to record relevant installation information.

2.2.4 GCL Repairs

Torn or otherwise damaged geosynthetic facing must be patched with the same type of geosynthetic. The geosynthetic patch must extend at least 12 inches beyond the damaged area and must be heat bonded, or otherwise attached to the main GCL to avoid shifting during placement of overlying geosynthetics. If the GCL damage includes loss of bentonite, the patch must consist of full GCL extending at least 12 inches beyond the damaged area. Lapping procedures must be the same as specified for original laps of GCL panels.

2.2.5 GCL Protection

The overlying geosynthetics and soil layers shall be deployed in such a manner as to ensure that the GCL is not damaged. Textured geomembranes shall not be dragged across previously installed GCL. A smooth rubsheet shall be placed between the GCL and textured geomembrane to prevent damage. The rubsheet will be removed when the geomembrane is in position. Other methods may be employed at the POR's discretion.

To avoid local bentonite displacement, and the possible impact on the hydraulic performance of a GCL, the protective cover soil of suitable thickness should be placed over the geomembrane and geocomposite overlying the GCL as soon as practicable following completion of the geomembrane and leachate collection system construction.

3.0 GEOMEMBRANE LINER

This section presents general procedures, quality control testing requirements, and construction specifications for geomembrane liner construction. The alternative liner design includes the use of a 60-mil high-density polyethylene (HDPE) geomembrane liner with an exception for the overliner option which

includes the use of a 60-mil linear low-density polyethylene (LLDPE) because its elastic properties are better suited for potential waste settlement.

3.1 Pre-installation Material Evaluation

3.1.1 Manufacturer's Quality Control Certificates

Prior to the installation of any geomembrane, the manufacturer or installer shall provide the POR with quality control certificates signed by a responsible party employed by the manufacturer. Each quality control certificate shall include roll identification numbers, testing procedures, and results of quality control tests. The quality control tests shall be performed in the manufacturing plant using the test methods and frequencies listed in the most recent version of the Geosynthetic Research Institute (GRI) test method GM13 for HDPE geomembrane and GM17 for LLDPE geomembrane. The owner may require more frequent testing at his/her discretion.

The POR shall review the test results prior to accepting the geomembrane to assure that the certified minimum properties meet the minimum values for textured geomembranes, as determined by the most recent GRI test method GM13 or GM17. The current versions of the GRI test methods are included in Appendix III3F-1.

The rolls delivered to the site shall be inventoried, recording the manufacturer's name and product identification, and the roll thickness, number, and dimensions. Manufacturer's certificates should be cross-referenced to rolls delivered on-site.

Resumes of the installer's supervisor(s) or Master Seamer(s) shall be obtained to verify that adequate seaming experience will be utilized on the project. The installer's supervisor or Master Seamer shall have had experience totaling a minimum of 2,000,000 square feet of geomembrane installation.

Upon delivery of geosynthetic materials, storage and handling procedures shall also be documented. Rolls of geosynthetic materials shall be handled and stored in such a way as not to damage the material. As a general rule, rolls of geosynthetic materials should not be stacked more than four rolls high.

3.1.2 Conformance Testing

In addition to the manufacturer's quality control certificates, samples of the geomembrane will be obtained either at the manufacturing facility or upon delivery to the site for conformance testing. The test samples shall be obtained for conformance testing in accordance with the testing schedule shown in Table III3F-3.

The POR shall review the test results to ensure that they meet the values presented in Table III3F-3.

TABLE III3F-3: Geomembrane Conformance Test Schedule

TEST	METHOD(1)	FREQUENCY
Thickness (laboratory measurement)	ASTM D5994 (Textured)	Not less than 1 test per 100,000 ft^2 with not less than 1 per resin lot
Density	ASTM D1505 or D792	
Carbon black content	ASTM D4218	
Carbon black dispersion	ASTM D5596	
Tensile properties	ASTM D6693, Type IV	

Notes:
1. Updated ASTM or GRI methods may be implemented based on a review by the POR.

3.2 Installation Procedures

3.2.1 Geomembrane Deployment

The geomembrane shall be installed in direct and uniform contact with the GCL. The geomembrane shall not be placed during inclement weather, such as high winds or rain.

Geomembrane seaming should generally not take place when ambient temperatures are below 32 degrees Fahrenheit (°F), unless preheating is used. For extrusion welding, preheating will be required if the temperature is below 32°F. For fusion welding, preheating may be waived if the installer demonstrates that quality welds may be obtained without preheating. Seaming shall not be permitted at ambient temperatures above 104°F, unless the installer can demonstrate that seam quality is not compromised.

In general, only low ground pressure rubber-tired support equipment approved by the POR may be allowed on the geomembrane. If the POR observes any potential damage done to the liner by the support equipment, use of the equipment will cease and the damage will be repaired. Personnel working on the geomembrane shall not smoke, wear damaging shoes, or engage in any other activity likely to damage the geomembrane. Only those sections that are to be placed and seamed in one day should be unrolled. Panels left unseamed should be anchored with sandbags or other suitable weights. In general, seams should be oriented parallel to the line of maximum slope (i.e., oriented up and down, not across the slope). In corners and odd-shaped geometric locations, the number of field seams should be minimized.

Panels should be overlapped, as recommended by the manufacturer, as appropriate for the type of seam welding to be performed; however, overlapping shall be no less than 2 inches. Field seaming shall only be performed by the method(s) approved by the manufacturer, either by extrusion welding or double-tracked fusion welding. No seaming shall take place without the installer's supervisor or Master Seamer and CQA monitor being present. Fishmouths, or wrinkles at the seam overlap, shall be cut along the ridge of the wrinkle to achieve a flat overlap. The cut shall be seamed and/or patched. Seams shall extend to the outside edge of panels placed in the anchor trench.

Panel layout and field seams shall be given an identification code, mapped, and logged to record relevant installation information. Inspection and testing records shall be logged as well as repair and retest data. Section 7.0 includes a thorough list of items to be documented during geomembrane construction and testing.

3.3 Installation Monitoring and Testing

3.3.1 Trial Seams

Each day prior to commencing field seaming, trial seams shall be made on pieces of geomembrane material to verify that conditions are adequate for production seaming. Trial seams shall be made at the beginning of each seaming period and shift (generally, at least twice each day) for each combination of production seaming machine and operator to be used that day. The trial test seam shall be at least 3 feet long by 1 foot wide (after seaming) with the seam centered lengthwise. Four 1-inch wide specimens shall be die-cut from the trial seam sample. Two specimens shall be tested in the field for shear and two for peel (test both inner and outer welds for dual track fusion welding) and shall be compared to the minimum seam strength requirements specified in the most current version of the Geosynthetic Research Institute, GRI Test Method GM19. The current versions of the GRI test methods are included in Appendix III3F-1.

If any of the trial seam specimens fail, the entire trial seam operation shall be repeated. If an additional specimen fails during the second trial seam, the seaming machine and seamer shall not be used for seaming until the deficiencies are corrected and two consecutive successful trial seams are achieved. Additional trial seams shall be performed if frequent field seaming problems are experienced or if power to the seaming machines is interrupted sufficiently long to require rewarming.

3.3.2 Non-Destructive Testing

Continuous, non-destructive testing shall be performed on all seams by the installer. All leaks must be isolated and repaired by following the procedures described in this LQCP.

Air Pressure Testing – ASTM D5820. The ends of the air channel of the dual-track fusion weld must be sealed and pressured to approximately 30 pounds per square inch (psi), if possible. The air pump must then be shut off and the air pressure observed after 2 minutes. A loss of less than 3 psi is acceptable if it is determined that the air channel is not blocked between the sealed ends. A loss greater or equal to 3 psi indicates the presence of a seam leak that must then be isolated and repaired by following the procedures described in this LQCP. The POR or his/her qualified representative must observe and record all pressure gauge readings.

Vacuum-Box Testing – ASTM D5641. Apply a vacuum of approximately 4 to 8 psi to all extrusion welded seams that can be tested in this manner. The seam must be observed for leaks for at least 10 seconds while subjected to this vacuum. The POR or his/her qualified representative must observe 100% of this testing.

Other Testing. Other non-destructive testing must have prior written approval from the TCEQ.

3.3.3 Destructive Seam Testing

Destructive samples shall be taken at a minimum frequency of one test location, selected randomly, within each 500 linear feet of seam length, inclusive of both primary longitudinal and cross seams, cap strips, and repairs 20 square feet or larger. Each test sample should be of sufficient length and 12 inches wide with the seam located in the middle. Test specimens, approximately 1 inch wide, shall be cut from both ends of the sample for field testing (peel and shear). The remaining sample should be cut into three parts (one for quality assurance laboratory testing, one for installer quality control laboratory testing, and one for archive storage to be maintained at a location selected by the owner).

The field tests shall be conducted on a certified calibrated tensiometer capable of maintaining a constant extension rate of 2 inches per minute. If one of the field test specimens from the ends of the destructive sample fails, then the seam will be considered to have failed, and repairs shall be initiated as described below. If both specimens pass, then a sample for laboratory testing will be sent to the quality assurance laboratory for testing in both peel and shear. Seam strengths for HDPE geomembranes shall meet the minimum values specified in the most current version of the Geosynthetic Research Institute, GRI Test Method GM19 “Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes”.

Destructive test results for both field and laboratory tests shall include qualitative data, including the location of the failure and locus-of-break code, as described in ASTM D6392. Peel tests on double-tracked fusion welds shall be performed on both inside and outside tracks of the weld. Seam break classifications for extrusion and fusion welds are shown on Figures III3F-1 and III3F-2, respectively.

At a minimum, a destructive test must be done for each welding machine used for seaming or repairs. A sufficient amount of the seam must be removed to conduct field testing, independent laboratory testing, and archiving of enough material to retest the seam when necessary. Destructive seam testing locations shall be cap-stripped and the cap completely seamed by extrusion welding to the geomembrane. Capped sections shall be non-destructively tested. Additional destructive test samples may be taken if deemed necessary by the POR or his/her qualified representative.

Weld Acceptance Criteria: For HDPE seams, the minimum passing criteria for destructive seam testing are described in the Geosynthetic Institute, GRI Test Method GM19. The POR must use the most current version of GM19 when evaluating welded seams.

Seam Failure Delineation: When a sample fails a destructive test, the installer shall trace the welding path to an intermediate location at least 10 feet in each direction, or a distance determined by the POR, from the point of the failed test and take 1-inch wide specimens for an additional set of field tests. If these additional samples pass the tests, then two laboratory destructive samples shall be taken adjacent to the intermediate locations or at locations determined by the POR or his/her representative. If these laboratory samples pass the tests, then the seam shall be repaired between these locations. If either sample fails, then the process shall be repeated to establish a zone where the seam should be repaired. All acceptable repaired seams shall be bounded by two locations from which samples passing laboratory destructive tests have been taken.

Seam Failure Repairs: Any portion of the geomembrane exhibiting a flaw or failing a destructive or non-destructive test shall be repaired. Repair methods may include spot welding (extrusion) for minor flaws and punctures; patches for larger holes and tears; capping for large lengths of failed seams or panel damage; and extrusion welding of outer flap to repair an inadequate fusion seam (less than 100-feet cumulative length) that has an exposed edge.

For any repair method, the following provisions shall be satisfied:

- Surfaces of the geomembrane that are to be repaired using extrusion methods shall be ground no more than one hour prior to the repair.
- All surfaces shall be clean and dry at the time of repair.
- Patches or caps shall extend at least 6 inches beyond the edge of the defect, and all corners of patches shall be rounded with a radius of approximately 3 inches.
- All repairs shall be non-destructively tested, as previously described.
- All seaming equipment, personnel, and operation procedures used in repair work shall meet the same requirements as for new seaming operations.

The POR or his/her qualified representative shall observe all non-destructive testing of repairs and shall record the number of each repair, type, date, and test outcome. Repairs that pass the non-destructive tests shall be taken as an indication of an adequate repair. Repairs more than 150 feet long shall also be required to have a destructive test performed. Repairs that fail the initial retest shall be redone and retested until a passing test results. All work and testing of repairs shall be fully documented in a repair log.

When placing overlying material on the geomembrane, effort must be made to minimize wrinkle development. If possible, cover should be placed during the coolest weather available. Small wrinkles should be isolated and covered as quickly as possible to prevent their growth. In no case shall the geomembrane be allowed to fold over on itself.

4.0 LEACHATE COLLECTION SYSTEM

4.1 Leachate Collection System and Drainage Materials

The leachate collection trenches and sumps shall be constructed in conjunction with liner construction. All GCL and geomembrane testing shall be completed prior to installing the leachate collection system on the area under evaluation. The locations of the trenches and sumps and design details are shown on the Figures III3-2A, III3-2B, III3-6A, III3-6B, and III3-8. The installation of the leachate collection system and protective cover system will have continuous inspection by the POR or his/her qualified representative(s). Quality assurance monitoring shall consist of measuring the dimensions of the excavated trenches and sumps, and documenting that the pipe, geotextile filters, bedding materials and drainage layers have been placed in accordance with the design details. All data and observations regarding construction of the leachate collection system shall be documented in the Geosynthetic Liner Evaluation Report (GLER).

Materials selected for use in the leachate collection system and drainage layers shall be verified by the POR to comply with this section of the LQCP.

4.1.1 Double-sided Geocomposite Drainage Layer

Geosynthetic drainage material shall conform to the material and performance properties specified in Table III3F-4. Manufacturers' certificates of material and performance characteristics shall be obtained and documented at the minimum frequency shown on Table III3F-4, with not less than one per resin lot. Geosynthetic drainage material conformance testing will consist of transmissivity testing on each material type using the test set-up described in Table III3F-4.

The drainage layer for the leachate collection system will consist of a geosynthetic drainage layer over both the floor and sideslopes of the landfill cells. The geosynthetic drainage layer shall consist of a geonet with a nonwoven geotextile heat-bonded to both sides. The geosynthetic drainage layer shall be anchored in an anchor trench at the crest of the sideslopes.

Geotextile panels placed in the leachate collection system shall be overlapped and either heat-bonded or field sewn. Only low ground pressure rubber-tired support equipment approved by the POR may be allowed on the geotextile. Personnel working on the geotextile shall not smoke, wear damaging shoes, or engage in any activity that damages the geotextile, or underlying geosynthetics.

TABLE III3F-4: Geosynthetic Drainage Layer Specifications(1)

GEOCOMPOSITE					
Property	**Qualifier**	**Unit**	**Value**	**Test Method**	**Frequency**
Transmissivity	Min.	m^2/sec	See note 1	ASTM D4716(2)	200,000 sf
Ply Adhesion	Min.	lb/in	0.5	ASTM D7005	200,000 sf
GEONET CORE					
Property	**Qualifier**	**Unit**	**Value**	**Test Method**	**Frequency**
Thickness	Min.	mils	See note 1	ASTM D5199	200,000 sf
Density (black resin)	Min.	g/cm^3	0.940	ASTM D1505	200,000 sf
Carbon Black Content	Range	%	2 to 3	ASTM D4218	200,000 sf
GEOTEXTILE					
Property	**Qualifier**	**Unit**	**Value**	**Test Method**	**Frequency**
Mass per Unit Area	MARV	oz/yd^2	6	ASTM D5261	200,000 sf
AOS		US Sieve (mm)	70 (0.210)	ASTM D4751	540,000 sf

Notes:
(1) See Appendix III3D-3D-1 for design calculations for the geocomposite. These calculations shall be referenced to determine the suitability of the alternate materials.
(2) The transmissivity shall be measured at a minimum gradient of 0.1 under a minimum normal pressure of 10,000 psf with a minimum seating period of 100 hour.

4.1.2 Filter Geotextile

The leachate drainage aggregate that is placed in the collection trenches and sumps shall be wrapped in a geotextile filter fabric. The geotextile shall have the minimum properties listed in Table III3F-5.

Table III3F-5: Nonwoven Filter Geotextile Specifications

Property	Qualifier	Unit	Value	Test Method	Frequency
Mass per Unit Area	MARV	oz/yd^2	7.5	ASTM D5261	100,000 sf
AOS		US Sieve (mm)	80 (0.15)	ASTM D4751	550,000 sf
Puncture Resistance		lb	550	ASTM D6241	550,000 sf
Grab Tensile Strength		lb	205	ASTM D4632	100,000 sf

4.1.3 Leachate Pipe

The leachate piping includes perforated collection trench pipes and solid sideslope riser pipes. The leachate piping shall conform to ASTM D3350 with a minimum cell classification value of 345464C. The pipe shall have the minimum SDR rating and perforation schedule shown on the plans and specifications.

4.1.4 Drainage Material

Granular drainage materials, to be used in the underdrains, along the leachate collection lines, and in the sumps. At least one set of pre-construction tests shall be conducted for each drainage medium from each proposed source. Pre-construction tests shall include a complete grain-size analysis, including minus No. 200 Sieve (ASTM D422) and calcium carbonate content (ASTM D3042 modified to use hydrochloric acid with a pH of 5 or the J&L method). The grain-size analysis will be used to determine if the material is compatible with the perforations in the leachate collection pipes and if the material is expected to achieve a minimum permeability of 1×10^{-2} cm/sec. The measured calcium carbonate content must not exceed 15 percent.

Granular drainage materials selected for use shall be tested at regular intervals for conformance during construction. Minimum testing frequency shall include one grain-size analysis for every 3,000 cubic yards, or portion thereof, for each material being used.

4.2 Protective Cover Material

Protective cover materials shall be free of deleterious materials that could puncture the synthetic lining system. The protective cover material shall be selected and placed so as not to harm the geomembrane or other geosynthetic layers. The installation of the leachate collection system and protective cover system will have continuous inspection by the POR or his/her qualified representative(s).

Visual observations shall be made to verify that no deleterious materials are present in the protective cover that could damage the lining and leachate collection systems or impede their performance as designed.

Alternate protective cover material, such as shredded tire chips, may only be used when overlying a protective layer of sufficient puncture resistance to prevent penetration of steel belting fragments or other deleterious materials through the geosynthetic drainage layers or geomembrane. Prior to use of an alternate protective cover material, written approval will be obtained from the TCEQ.

Protective cover does not require compaction control; however, it should be stable for construction and disposal traffic. Care shall be exercised in placement so as not to shift, wrinkle, or damage the underlying geosynthetic layers, and the placement methods shall be documented. Protective cover placement should be conducted at the coolest part of the day to minimize the development of wrinkles in the geosynthetic materials.

The protective cover shall be placed such that the top surface, while spreading, is at least 2 feet above the geosynthetic layers at all times unless low ground pressure dozers are used (i.e., track pressure less than 5 psi). A greater thickness shall be maintained to support loaded hauling trucks and trailers and for turning areas. Drivers shall proceed with caution when on the overlying soil and prevent spinning of tires, quick stops, or sharp turns.

The final thickness of the protective cover shall be a minimum 24 inches above a geosynthetic drainage layer. The required thickness of protective cover shall be verified by survey methods on an established grid system with not less than one verification point per 5,000 square feet of surface area.

5.0 DEWATERING SYSTEM

Waste management unit excavations extend below the seasonal high water table resulting in upward or inward hydrostatic forces on the alternative liner. Measures will be taken to protect the liner and leachate collection system during construction below the seasonal high groundwater table. During construction of the alternative liner, groundwater will be controlled by installing an active dewatering system which includes an underdrain composed of toe drains, a geocomposite along the sideslopes, and an underdrain sump.

5.1 Foundation Evaluation

Prior to excavating any waste management unit below the seasonal high water table, a preliminary foundation evaluation considering stability, settlement, and constructability shall be performed. This evaluation has been performed and is provided in Appendix III3B, Waste Management Unit Design Analyses.

5.2 Excavation

Excavations below the water table can result in the excessive influx of groundwater and excavated bottom or slope instability. Since soil is typically excavated gradually for use as daily cover, groundwater influx can be controlled by allowing the seepage to drain away from the cell excavation area, thus temporarily lowering

the groundwater level. If this approach is not effective or practical, other means, such as well-points may be used to lower the surrounding groundwater table.

5.3 Underdrain Construction

Once excavated to design subgrade, an underdrain shall be installed. The underdrain consists of a double-sided geocomposite installed along the excavated sideslope and toe drains. Toe drains are 2-foot wide by 2-foot deep trenches installed along the toe of excavation with a 4-inch ADS N-12 corrugated HDPE (or equal) perforated pipe surrounded by drainage material, wrapped with filter geotextile. The toe drains will direct groundwater to an underdrain sump located directly beneath the leachate collection sump. Pumps sized to accommodate the designed groundwater flows from the underdrain system will be installed within a riser pipe with controls to allow automatic operation. The underdrain sump riser pipe shall exit the cell in such a manner so as not to penetrate the alternative liner within the planned limits of the waste disposal. Underdrain material specifcations shall be that of materials used in the leachate collection system.

5.4 Alternative Liner Stability During Construction

30 TAC §330.337(f)(1)

The dewatering system will prevent excessive pressure head from developing beneath the alternative liner during construction because the double-sided geocomposite and toe drains have been designed to accommodate the maximum anticipated inflow of groundwater as presented in Appendix III3E-2, Dewatering System Calculations. During construction activities, the POR shall evaluate the groundwater level and confirm the underdrain design.

The POR shall observe the liner subgrade, liner, and leachate collection system materials for the presence of groundwater seepage during construction to verify the subgrade is suitable for liner system construction. The entire subgrade shall be observed during excavation, and the occurrence of the following shall be noted:

- Groundwater seepage within the subgrade.
- Softening of the subgrade surface resulting from groundwater seepage.
- Softness or sheen in the secondary features resulting from groundwater seepage.

In each GLER, observations and subgrade evaluations performed by the POR will be presented to verify that the subgrade soils are suitable for liner system construction.

5.5 Alternative Liner Stability During Filling and Operation

30 TAC §330.337(c) After the waste management unit is constructed and approved to receive waste, landfill operators shall ensure the stability of the alternative liner by maintaining continuous operation

of the dewatering system. The underdrain will be in operation until sufficient ballast is in place to offset hydrostatic uplift.

6.0 BALLAST REQUIREMENTS

To offset hydrostatic uplift, the weight of the alternative liner and the waste placed above it will provide the ballast (weight) to protect the liner system from uplift forces from groundwater. The ballast counteracting the hydrostatic forces include the soil materials from the leachate collection system components, the protective cover, waste above the liner and leachate collection system, and the soil materials from the final cover. The weight of the geosynthetic components of the leachate collection system and any geosynthetic components of the final cover is considered negligible.

6.1 Seasonal High Groundwater Table

30 TAC §330.337(i)

To evaluate the ballast required to offset hydrostatic uplift, groundwater levels within the waste management unit must be assessed. Groundwater level data are presented in Appendix III3F-2. Using groundwater level data provided in III4E, Historic Groundwater Levels. Figures III3F-3A and III3F-3B present the seasonal high groundwater contours elevations.

For each new increment of liner construction, the POR shall reevaluate the seasonal high groundwater table for the construction area as part of the Geosynthetic Liner Evaluation Report (GLER) submittal. The seasonal high water table shall be adjusted upward, if necessary, as additional groundwater elevation data become available.

6.2 Ballast Thickness Calculations

The required ballast thickness will be calculated using the following procedures:

1. Determine the hydrostatic uplift pressure, *P*, acting on the alternative liner from the assumed seasonal high groundwater table, and the resistance provided by the ballast:

   Determine the maximum hydrostatic uplift pressure, *P*, acting on the geomembrane component of the alternative liner using the unit weight of water, γ_w, times the vertical distance from the base of the alternative liner to the seasonal high water table, H_{wt}.

   $$P = \gamma_w H_{wt}$$

   The resisting pressure, R_N, provided by the ballast is equal to the normal component of the sum of the unit weights of each ballast component, γ_i, times their respective vertical thickness, T_i, as shown in the following equation:

   $$R_N = \Sigma(\gamma_i T_i)\cos^2 \beta$$

Where β is the angle between the slope of alternative liner and horizontal.

2. The equations for *R* and *P* are solved for equilibrium to find the thickness of ballast required to counteract the calculated water pressure.

   The safety factors indicated in the regulations, either 1.2 or 1.5 depending on the type and configuration of ballast used, are incorporated into the above referenced equations by multiplying by the appropriate factor. If only soil ballast is used, a factor of 1.2 is used in the equation, and if some combination of soil layers and waste is used as ballast, a factor of 1.5 is used.

$$1.2P = R \qquad or \qquad 1.5P = R$$

   When the equations for *R* and *P* are input, the required waste thickness, and/or required ballast thickness, is then determined. The equations can be solved for any location within or near an excavation where the piezometric profile is known or can be estimated.

The example ballast calculation are presented in Appendix III3E-1.

In each GLER, waste for ballast calculations will be provided to determine the minimum amount of waste needed, if any, to offset the hydrostatic uplift from the seasonal high water table.

6.3 Ballast Verification

30 TAC §330.337(f)(2)

When the operator determines that adequate ballast is in place, the amount of ballast must be verified to be sufficient to offset hydrostatic uplift on the alternative liner by a factor of 1.5 per Appendix III3E-1, Example Ballast Calculations. The measures and tests used to verify that any ballast including waste are sufficient to meet the established ballast criteria include surveyed elevations to determine component thickness and density to determine component weight. In addition, the seasonal high water table shall be adjusted upward, if necessary, as additional groundwater elevation data become available.

7.0 MARKING AND IDENTIFYING EVALUATED AREAS

In accordance with 30 TAC §330.143(b)(1) and (6), markers shall be placed so that all areas for which the GLER have been submitted and approved by the TCEQ are readily identifiable. Such markers are to provide site workers with immediate knowledge of the extent of approved disposal areas and shall be placed in accordance with the Site Operating Plan.

Markers shall be metal, wooden, or recycled posts and shall extend at least 6 feet above ground level. Markers shall not be obscured by vegetation and shall be placed so that they are not destroyed during operations. Sufficient intermediate markers shall be installed to show the required boundary. Lost markers shall be promptly replaced. Limits of the evaluated area shall be referenced to the site grid system. Markers shall not be placed inside the evaluated area. Markers shall be color coded in accordance with 30 TAC §330.143(b)(1). GLER markers shall be red in color.

8.0 DOCUMENTATION AND REPORTING

8.1 Geosynthentic Liner Evaluation Report

30 TAC §330.341

A Geosynthetic Liner Evaluation Report (GLER) includes documentation of cell construction including geosynthetic clay liner installation, geomembrane installation, and leachate collection system installation including protective cover soil. Prior to the disposal of solid waste in any cell, or on any area, excavation, or unprotected surface, a GLER shall be submitted to the TCEQ.

Each GLER shall be submitted in triplicate (including all attachments) to the executive director and shall be prepared in accordance with the methods and procedures contained in this LQCP. If the executive director provides no response, either written or verbal, within 14 days of receipt, the owner or operator may continue facility construction or operation.

If the executive director determines that a report is incomplete or that the test data provided are insufficient to support the evaluation conclusions, additional test data or other information may be required, and use of the cell or disposal area will not be allowed until such additional data are received, reviewed, and accepted. Each report must be signed and, where applicable, sealed by the POR performing the evaluation and counter-signed by the facility operator or an authorized representative.

The construction documentation provided in the GLER will contain a narrative describing the work conducted and testing programs required by the LQCP, "as-built" or record drawings, and appendices of field and laboratory data. The GLER will contain or discuss the information included in Table III3F-7 at a minimum.

Table III3F-7: GLER Content

Geosynthetic Clay Liner	Roll shipment and receipt information
	Manufacturer's quality control certificates and results
	Storage and handling information
	Conformance test sampling and test results
	Subgrade acceptance
	Anchor trench preparation and backfilling
	Panel deployment, identification, and placement
	Equipment placed or operated on GCL
	100 percent visual inspection for defects, damage, etc.
	Seaming methods
	Repairs, including patch size and shape
Geomembrane Liner	Roll shipment and receipt information
	Manufacturer's quality control certificates and results

	Storage and handling information
	Conformance test sampling and test results
	Seamer's names and resumes of experience and qualifications
	Subgrade acceptance
	Anchor trench preparation and backfilling
	Panel deployment, identification, and placement
	Seam preparation, orientation, and identification
	Equipment placed or operated on geomembrane
	100 percent visual inspection for defects, damage, etc.
	Trial seam tests for each combination of seaming equipment and personnel
	Seaming methods, times, temperature, and equipment shutdowns and startups
	Continuous 100 percent non-destructive seam testing, methods, criteria, and results
	Destructive testing methods, criteria, and results
	Repairs, including preparation and procedures, failure delineation, patch size and shape, and retesting
	Material properties and placement of drainage materials and protective cover
Record Drawings	Phase layout plan
	Location of the subject cell with GLER markers
	Previous filled and active areas
	As-built GCL panel layout drawings, showing locations of patches and repairs
	As-built geomembrane panel layout drawings showing location of destructive test samples, patches, and repairs
	As-built drawings showing elevations of protective cover to confirm its thickness
Ballast Evaluation	Waste for ballast calculations will be provided to determine the minimum amount of waste needed, if any, to offset the hydrostatic uplift from the seasonal high water table.

8.2 Interim Status Report

An Interim Status Report (ISR) should be provided to the TCEQ for portions of a liner system that remain uncovered with waste for more than six months from the date that the protective cover was applied, and the area shall be reevaluated by a POR.

8.3 Ballast Evaluation Report

30 TAC §330.337(j)

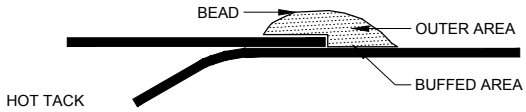
A Ballast Evaluation Report (BER) must be submitted to the TCEQ when the ballast verification demonstrates that further ballasting or dewatering is no longer necessary. If the TCEQ provides no response within 14 days of the date of receipt, dewatering or further ballasting operations may be discontinued. The BER shall include a statement verifying the alternative liner did not undergo uplift during construction, certification that ballast met the criteria established in this LQCP, and signed and sealed by an independent licensed professional engineer performing the evaluation and signature of the facility

operator or his authorized representative. The following information will be included, as applicable, with the BER.

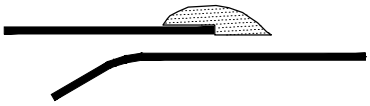
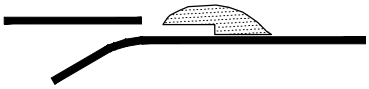
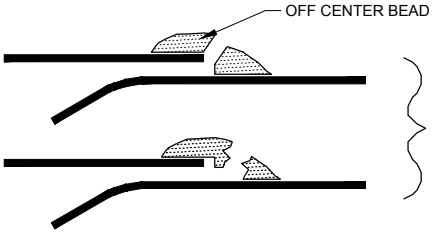
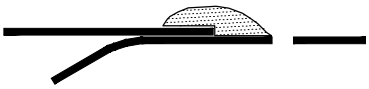
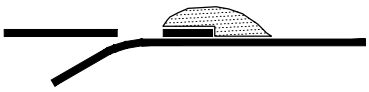
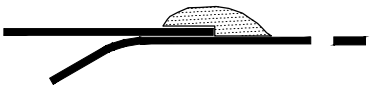
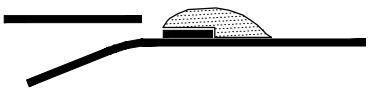
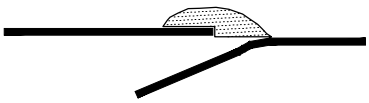
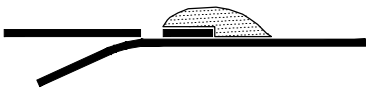
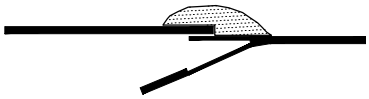
- A summary of in-place density measurements will be presented verifying that the weight of the leachate collection system, protective cover, ballast (if any), and cover required as ballast complied with the calculations.
- The top of protective cover will be surveyed after installation to assure that the liner and leachate collection system did not undergo uplift prior to waste placement.
- Water level measurements obtained from appropriate site piezometer and monitor wells near each excavation area will be presented verifying that the groundwater levels do not exceed the design seasonal high water table. If the observed water levels exceed the design seasonal high water level, the ballast calculations will be adjusted accordingly.
- A TCEQ Waste-as-Ballast Placement Record form completed by the landfill manager or designated representative will be presented confirming that the waste material in the first 5 feet of waste was free of brush and large bulky items, daily operations of the pressure relief/underdrain system (if required) were completed, and a wheeled trash compactor having a minimum weight of 40,000 pounds was used to place waste.

APPENDIX III3F

FIGURES



UNTESTED SPECIMEN
EXTRUSION WELD WITH LEISTER HEAT SEAM

TYPES OF BREAK	LOCUS-OF-BREAK CODE	BREAK DESCRIPTION
	AD1	FAILURE IN ADHESION. SPECIMENS MAY ALSO DELAMINATE UNDER THE BEAD AND BREAK THROUGH THE THIN EXTRUDED MATERIAL IN THE OUTER AREA.
	AD2	FAILURE IN ADHESION
	AD-WLD	BREAKS THOUGH THE FILLET. BREAKS THOUGH THE FILLET RANGE FROM BREAKS STARTING AT THE EDGE OF THE TOP SHEET TO BREAKS THOUGH THE FILLET AFTER SOME ADHESION FAILURE BETWEEN THE FILLET AND THE BOTTOM SHEET.
	SE1	BREAK AT SEAM EDGE IN THE BOTTOM SHEET. SPECIMENS MAY BREAK ANYWHERE FROM THE BEAD/OUTER AREA EDGE TO THE OUTER AREA/BUFF AREA. (APPLICABLE TO SHEAR ONLY).
	SE2	BREAK AT SEAM EDGE IN THE TOP SHEET. SPECIMENS MAY BREAK ANYWHERE FROM THE BEAD/OUTER AREA EDGE TO THE OUTER AREA/BUFF AREA. (APPLICABLE TO SHEAR ONLY).
	SE3	BREAK AT SEAM EDGE IN THE BOTTOM SHEET. (APPLICABLE TO PEEL ONLY).
	BRK1	BREAK IN THE BOTTOM SHEETING. A "B" IN PARENTHESIS FOLLOWING THE CODE MEANS THE SPECIMEN BREAK IN THE BUFFED AREA. (APPLICABLE TO SHEAR ONLY).
	BRK2	BREAK IN THE TOP SHEETING. A "B" IN PARENTHESIS FOLLOWING THE CODE MEANS THE SPECIMEN BREAK IN THE BUFFED AREA. (APPLICABLE TO SHEAR ONLY).
	AD-BRK	BREAK IN THE BOTTOM SHEETING AFTER SOME ADHESION FAILURE BETWEEN THE FILLET AND THE BOTTOM SHEET. (APPLICABLE TO PEEL ONLY).
	HT	BREAK AT THE EDGE OF THE HOT TACK FOR SPECIMENS WHICH COULD NOT BE DELAMINATED IN THE HOT TACK.
	SIP	SEPARATION IN THE PLANE OF THE SHEET.

CLIENT
CITY OF EDINBURG SOLID WASTE MANAGEMENT

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-07-21
DESIGNED	CEI
PREPARED	AA
REVIEWED	MX
APPROVED	JBF

PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

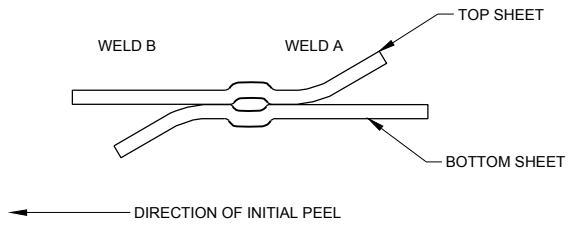
TITLE
EXTRUSION WELD SEAM BREAK CLASSIFICATION

PROJECT NO.	APPLICATION SECTION	REV.	FIGURE
1401491	III3F	0	III3F-1

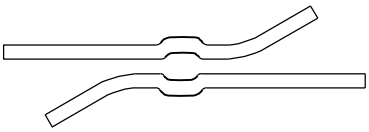
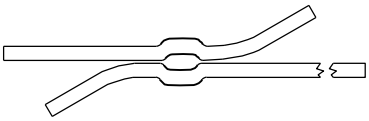
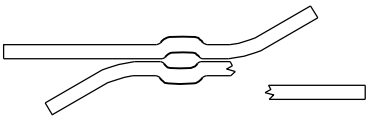
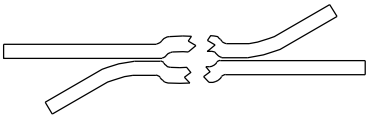
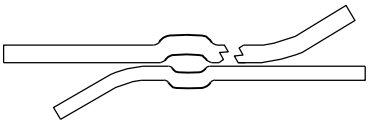
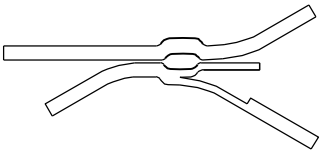
IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

0 1in

Path: \\houston\drafting_2014\1401491 - city of edinburg\PRODUCTION\A - Permit Amendment Application\ | File Name: 1401491A067.dwg



SCHEMATIC OF UNTESTED SPECIMEN

TYPES OF FAILURE	LOCUS-OF-BREAK CODE	BREAK
	AD	ADHESION FAILURE
	BRK	BREAK IN SHEETING. BREAK CAN BE IN EITHER TOP OR BOTTOM SHEET.
	SE1	BREAK AT OUTER EDGE OF SEAM. BREAK CAN BE IN EITHER TOP OR BOTTOM SHEET.
	SE2	BREAK AT INNER EDGE OF SEAM THROUGH BOTH SHEETS.
	AD-BRK	BREAK IN FIRST SEAM AFTER SOME ADHESION FAILURE BREAK CAN BE IN EITHER THE TOP OF BOTTOM SHEET
	SIP	SEPARATION IN THE PLANE OF THE SHEET. BREAK CAN BE IN EITHER TOP OF BOTTOM SHEET.

ISSUED FOR PERMITTING PURPOSES ONLY

CLIENT
CITY OF EDINBURG SOLID WASTE MANAGEMENT

CONSULTANT
Golder Associates

YYYY-MM-DD	2017-07-21
DESIGNED	CEI
PREPARED	AA
REVIEWED	MX
APPROVED	JBF

PROJECT
EDINBURG REGIONAL DISPOSAL FACILITY
PERMIT AMENDMENT APPLICATION TCEQ PERMIT MSW-956C
EDINBURG, HIDALGO COUNTY, TEXAS

TITLE
FUSION WELD SEAM BREAK CLASSIFICATION

PROJECT NO.	APPLICATION SECTION	REV.	FIGURE
1401491	III3F	0	III3F-2

IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI A

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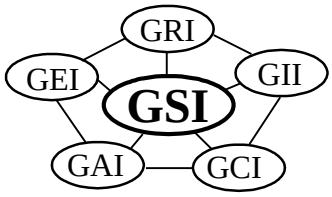
APPENDIX III3F-1

GEOSYNTHETIC RESEARCH INSTITUTE (GRI) TEST METHODS

GM13

Geosynthetic Institute
475 Kedron Avenue
Folsom, PA 19033-1208 USA
TEL (610) 522-8440
FAX (610) 522-8441



Revision 13: November 4, 2015
Revision schedule on pg. 11

GRI Test Method GM13*

Standard Specification for

"Test Methods, Test Properties and Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers high density polyethylene (HDPE) geomembranes with a formulated sheet density of 0.940 g/ml, or higher, in the thickness range of 0.75 mm (30 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, physical, mechanical and chemical properties that must be met, or exceeded by the geomembrane being manufactured. In a few cases a range is specified.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

1.4 This standard specification is intended to ensure good quality and performance of HDPE geomembranes in general applications, but is possibly not adequate for the complete specification in a specific situation. Additional tests, or more restrictive

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

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All rights reserved

values for test indicated, may be necessary under conditions of a particular application.

Note 2: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

D 792 Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004 Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
D 1603 Test Method for Carbon Black in Olefin Plastics
D 3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5397 Procedure to Perform a Single Point Notched Constant Tensile Load – (SP-NCTL) Test: Appendix
D 5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
D 5885 Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
D 5994 Test Method for Measuring the Core Thickness of Textured Geomembranes
D 6370 Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent UV Condensation Apparatus
D 7466 Test Method for Measuring the Asperity Height of Textured Geomembranes

2.2 GRI Standards

GM10 Specification for the Stress Crack Resistance of Geomembrane Sheet

2.3 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.
ref. EPA/600/R-93/182

Formulation, n - The mixture of a unique combination of ingredients identified by type, properties and quantity. For HDPE polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

4. Material Classification and Formulation

4.1 This specification covers high density polyethylene geomembranes with a formulated sheet density of 0.940 g/ml, or higher. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.932 g/ml or higher, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be a similar HDPE as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth HDPE geomembranes and Table 2 is for single and double sided textured HDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is soft.

Note 3: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of 23°C ± 2°C. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of 21°C ± 2°C. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of 23°C ± 2°C should be utilized for testing purposes.

Note 4: There are several tests often included in other HDPE specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693)
- Wide Width Tensile
- Water Vapor Transmission
- Water Absorption
- Ozone Resistance
- Modulus of Elasticity
- Hydrostatic Resistance
- Tensile Impact
- Field Seam Strength
- Multi-Axial Burst
- Various Toxicity Tests

Note 5: There are several tests which are included in this standard (that are not customarily required in other HDPE specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time
- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet (see Note 6)
- Trouser Tear (see Note 7)

Note 6: The minimum average value of asperity height does not represent an expected value of interface shear strength. Shear strength associated with geomembranes is both site-specific and product-specific and should be determined by direct shear testing using ASTM D5321/ASTM D6243 as prescribed. This testing should be included in the particular site's CQA conformance testing protocol for the geosynthetic materials involved, or formally waived by the Design Engineer, with concurrence from the Owner prior to the deployment of the geosynthetic materials.

Note 7: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Puncture Resistance
- Stress Crack Resistance
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The properties of the HDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent and is certified accordingly, it must be followed in like manner.

Note 8: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from agglomerated texturing material and such defects that would affect the specified properties of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

ENGLISH UNITS

Table 1(a) – High Density Polyethylene (HDPE) Geomembrane -Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness (min. ave.)	D5199	nom.	Nom.	Nom.	Nom.	Nom.	Nom.	Nom.	Per roll
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density mg/l (min.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,000 lb
Tensile Properties *(1)* (min. ave.)	D 6693								20,000 lb
• yield strength	Type IV	63 lb/in.	84 lb/in.	105 lb/in.	126 lb/in.	168 lb/in.	210 lb/in.	252 lb/in.	
• break strength		114 lb/in.	152 lb/in.	190 lb/in.	228 lb/in.	304 lb/in.	380 lb/in.	456 lb/in.	
• yield elongation		12%	12%	12%	12%	12%	12%	12%	
• break elongation		700%	700%	700%	700%	700%	700%	700%	
Tear Resistance (min. ave.)	D 1004	21 lb	28 lb	35 lb	42 lb	56 lb	70 lb	84 lb	45,000 lb
Puncture Resistance (min. ave.)	D 4833	54 lb	72 lb	90 lb	108 lb	144 lb	180 lb	216 lb	45,000 lb
Stress Crack Resistance *(2)*	D5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI-GM10
Carbon Black Content (range)	D 4218 *(3)*	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	20,000 lb
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(5)*									200,000 lb
(a) Standard OIT	D 3895	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	100 min.	
— or —									
(b) High Pressure OIT	D 5885	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	400 min.	
Oven Aging at 85°C *(5), (6)*	D 5721								
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	55%	55%	55%	55%	55%	55%	55%	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	80%	80%	80%	80%	80%	80%	80%	
UV Resistance *(7)*	D 7238								
(a) Standard OIT (min. ave.)	D 3895	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	N.R. *(8)*	per each formulation
— or —									
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 5885	50%	50%	50%	50%	50%	50%	50%	

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 in.

(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (METRIC) UNITS

Table 1(b) – High Density Polyethylene (HPDE) Geomembrane - Smooth

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness - mils (min. ave.) • lowest individual of 10 values	D5199	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	nom. (mil) -10%	per roll
Density (min.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg
Tensile Properties *(1)* (min. ave.) • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	 11 kN/m 20 kN/m 12% 700%	 15 kN/m 27 kN/m 12% 700%	 18 kN/m 33 kN/m 12% 700%	 22 kN/m 40 kN/m 12% 700%	 29 kN/m 53 kN/m 12% 700%	 37 kN/m 67 kN/m 12% 700%	 44 kN/m 80 kN/m 12% 700%	9,000 kg
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	240 N	320 N	400 N	480 N	640 N	800 N	960 N	20,000 kg
Stress Crack Resistance *(2)*	D 5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI GM-10
Carbon Black Content - %	D 4218 *(3)*	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	2.0-3.0%	9,000 kg
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(5)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	90,000 kg
Oven Aging at 85°C *(5), (6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 3895 D 5885	 N. R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	 N.R. *(8)* 50%	per each formulation

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm

(2) The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

ENGLISH UNITS

Table 2(a) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.)	D 7466	16 mil	16 mil	16 mil	16 mil	16 mil	16 mil	16 mil	every 2nd roll *(1)*
Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	200,000 lb
Tensile Properties (min. ave.) *(2)* • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	 63 lb/in. 45 lb/in. 12% 100%	 84 lb/in. 60 lb/in. 12% 100%	 105 lb/in. 75 lb/in. 12% 100%	 126 lb/in. 90 lb/in. 12% 100%	 168 lb/in. 120 lb/in. 12% 100%	 210 lb/in. 150 lb/in. 12% 100%	 252 lb/in. 180 lb/in. 12% 100%	20,000 lb
Tear Resistance (min. ave.)	D 1004	21 lb	28 lb	35 lb	42 lb	56 lb	70 lb	84 lb	45,000 lb
Puncture Resistance (min. ave.)	D 4833	45 lb	60 lb	75 lb	90 lb	120 lb	150 lb	180 lb	45,000 lb
Stress Crack Resistance *(3)*	D 5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI GM10
Carbon Black Content (range)	D 4218 *(4)*	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	20,000 lb
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	45,000 lb
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	200,000 lb
Oven Aging at 85°C *(6), (7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	D 7238 D 3895 D 5885	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	per each formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 1.3 inches
Break elongation is calculated using a gage length of 2.0 inches

(3) P-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (METRIC UNITS)

Table 2(b) – High Density Polyethylene (HDPE) Geomembrane - Textured

Properties	Test Method	Test Value							Testing Frequency (minimum)
		0.75 mm	1.00 mm	1.25 mm	1.50 mm	2.00 mm	2.50 mm	3.00 mm	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.)	D 7466	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	0.40 mm	every 2nd roll *(1)*
Density (min. ave.)	D 1505/D 792	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	0.940 g/cc	90,000 kg
Tensile Properties (min. ave.) *(2)* • yield strength • break strength • yield elongation • break elongation	D 6693 Type IV	 11 kN/m 8 kN/m 12% 100%	 15 kN/m 10 kN/m 12% 100%	 18 kN/m 13 kN/m 12% 100%	 22 kN/m 16 kN/m 12% 100%	 29 kN/m 21 kN/m 12% 100%	 37 kN/m 26 kN/m 12% 100%	 44 kN/m 32 kN/m 12% 100%	9,000 kg
Tear Resistance (min. ave.)	D 1004	93 N	125 N	156 N	187 N	249 N	311 N	374 N	20,000 kg
Puncture Resistance (min. ave.)	D 4833	200N	267 N	333 N	400 N	534 N	667 N	800 N	20,000 kg
Stress Crack Resistance *(3)*	D 5397 (App.)	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	500 hr.	per GRI GM10
Carbon Black Content (range)	D 4218 *(4)*	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	2.0-3.0 %	9,000 kg
Carbon Black Dispersion	D 5596	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	note *(5)*	20,000 kg
Oxidative Induction Time (OIT) (min. ave.) *(6)* (a) Standard OIT — or — (b) High Pressure OIT	 D 3895 D 5885	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	 100 min. 400 min.	90,000 kg
Oven Aging at 85°C *(6), (7)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	 55% 80%	per each formulation
UV Resistance *(8)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(10)*	D 7238 D 3895 D 5885	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	 N.R. *(9)* 50%	per each formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
Yield elongation is calculated using a gage length of 33 mm
Break elongation is calculated using a gage length of 50 mm

(3) The SP-NCTL test is not appropriate for testing geomembranes with textured or irregular rough surfaces. Test should be conducted on smooth edges of textured rolls or on smooth sheets made from the same formulation as being used for the textured sheet materials.
The yield stress used to calculate the applied load for the SP-NCTL test should be the manufacturer's mean value via MQC testing.

(4) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(5) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
9 in Categories 1 or 2 and 1 in Category 3

(6) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(7) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(8) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(9) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(10) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Adoption and Revision Schedule
for
HDPE Specification per GRI-GM13

"Test Methods, Test Properties, Testing Frequency for
High Density Polyethylene (HDPE) Smooth and Textured Geomembranes"

Adopted:	June 17, 1997
Revision 1:	November 20, 1998; changed CB dispersion from allowing 2 views to be in Category 3 to requiring all 10 views to be in Category 1 or 2. Also reduced UV percent retained from 60% to 50%.
Revision 2:	April 29, 1999: added to Note 5 after the listing of Carbon Black Dispersion the following: "(In the viewing and subsequent quantitative interpretation of ASTM D5596 only near spherical agglomerates shall be included in the assessment)" and to Note (4) in the property tables.
Revision 3:	June 28, 2000: added a new Section 5.2 that the numeric table values are neither MARV or MaxARV. They are to be interpreted per the the designated test method.
Revision 4:	December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".
Revision 5:	May 15, 2003: Increased minimum acceptable stress crack resistance time from 200 hrs to 300 hrs.
Revision 6:	June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 2.
Revision 7:	February 20, 2006: Added Note 6 on Asperity Height clarification with respect to shear strength.
Revision 8:	Removed recommended warranty from specification.
Revision 9:	June 1, 2009: Replaced GRI-GM12 test for asperity height of textured geomembranes with ASTM D 7466.
Revision 10	April 11, 2011: Added alternative carbon black content test methods
Revision 11	December 13, 2012: Replaced GRI-GM11 with the equivalent ASTM D 7238.
Revision 12	November 14, 2014: Increased minimum acceptable stress crack resistance time from 300 to 500 hours. Also, increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).
Revision 13	November 4, 2015: Removed Footnote (1) on asperity height from tables.

GM17

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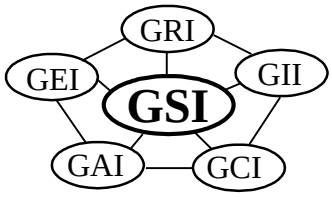

Revision 12: November 4, 2015
Revision schedule on pg. 11

GRI Test Method GM17*

Standard Specification for

"Test Methods, Test Properties and Testing Frequency for
Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes"

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification covers linear low density polyethylene (LLDPE) geomembranes with a formulated sheet density of 0.939 g/ml, or lower, in the thickness range of 0.50 mm (20 mils) to 3.0 mm (120 mils). Both smooth and textured geomembrane surfaces are included.

1.2 This specification sets forth a set of minimum, maximum, or range of physical, mechanical and endurance properties that must be met, or exceeded by the geomembrane being manufactured.

1.3 In the context of quality systems and management, this specification represents manufacturing quality control (MQC).

Note 1: Manufacturing quality control represents those actions taken by a manufacturer to ensure that the product represents the stated objective and properties set forth in this specification.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 2-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

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1.4 This standard specification is intended to ensure good uniform quality LLDPE geomembranes for use in general applications.

Note 2: Additional tests, or more restrictive values for the tests indicated, may be necessary under conditions of a particular application. In this situation, interactions with the manufacturers are required.

Note 3: For information on installation techniques, users of this standard are referred to the geosynthetics literature, which is abundant on the subject.

2. Referenced Documents

2.1 ASTM Standards

D 792 Specific Gravity (Relative Density) and Density of Plastics by Displacement
D 1004 Test Method for Initial Tear Resistance of Plastics Film and Sheeting
D 1238 Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer
D 1505 Test Method for Density of Plastics by the Density-Gradient Technique
D 1603 Test Method for Carbon Black in Olefin Plastics
D 3895 Test Method for Oxidative Induction Time of Polyolefins by Thermal Analysis
D 4218 Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique
D 4833 Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D 5199 Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes
D 5323 Practice for Determination of 2% Secant Modulus for Polyethylene Geomembranes
D 5596 Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
D 5617 Test Method for Multi-Axial Tension Test for Geosynthetics
D 5721 Practice for Air-Oven Aging of Polyolefin Geomembranes
D 5885 Test method for Oxidative Induction Time of Polyolefin Geosynthetics by High Pressure Differential Scanning Calorimetry
D 5994 Test Method for Measuring the Core Thickness of Textured Geomembranes
D 6370 Standard Test Method for Rubber-Compositional Analysis by Thermogravimetry (TGA)
D 6693 Test Method for Determining Tensile Properties of Nonreinforced Polyethylene and Nonreinforced Flexible Polypropylene Geomembranes
D 7238 Test Method for Effect of Exposure of Unreinforced Polyolefin Geomembrane Using Fluorescent Condensation Device

D 7466 Test Method for Measuring the Asperity Height of Textured Geomembranes

2.2 U. S. Environmental Protection Agency Technical Guidance Document "Quality Control Assurance and Quality Control for Waste Containment Facilities," EPA/600/R-93/182, September 1993, 305 pgs.

3. Definitions

Manufacturing Quality Control (MQC) - A planned system of inspections that is used to directly monitor and control the manufacture of a material which is factory originated. MQC is normally performed by the manufacturer of geosynthetic materials and is necessary to ensure minimum (or maximum) specified values in the manufactured product. MQC refers to measures taken by the manufacturer to determine compliance with the requirements for materials and workmanship as stated in certification documents and contract specifications.
ref. EPA/600/R-93/182

Manufacturing Quality Assurance (MQA) - A planned system of activities that provides assurance that the materials were constructed as specified in the certification documents and contract specifications. MQA includes manufacturing facility inspections, verifications, audits and evaluation of the raw materials (resins and additives) and geosynthetic products to assess the quality of the manufactured materials. MQA refers to measures taken by the MQA organization to determine if the manufacturer is in compliance with the product certification and contract specifications for the project.
ref. EPA/600/R-93/182

Linear Low Density Polyethylene (LLDPE), n – A ethylene/α-olefin copolymer having a linear molecular structure. The comonomers used to produce the resin can include 1-butene, 1-hexene, 1-octene or 4-methyl-1-pentene. LLDPE resins have a natural density in the range of 0.915 to 0.926 g/ml (ref. Pate, T. J. Chapter 29 in Handbook of Plastic Materials and Technology, I.I. Rubin Ed., Wiley, 1990).

Formulation, n - The mixture of a unique combination of ingredients identified by type, properties and quantity. For linear low density polyethylene geomembranes, a formulation is defined as the exact percentages and types of resin(s), additives and carbon black.

4. Material Classification and Formulation

4.1 This specification covers linear low density polyethylene geomembranes with a formulated sheet density of 0.939 g/ml, or lower. Density can be measured by ASTM D1505 or ASTM D792. If the latter, Method B is recommended.

4.2 The polyethylene resin from which the geomembrane is made will generally be in the density range of 0.926 g/ml or lower, and have a melt index value per ASTM D1238 of less than 1.0 g/10 min. This refers to the natural, i.e., nonformulated, resin.

4.3 The resin shall be virgin material with no more than 10% rework. If rework is used, it must be of the same formulation (or other approved formulation) as the parent material.

4.4 No post consumer resin (PCR) of any type shall be added to the formulation.

5. Physical, Mechanical and Chemical Property Requirements

5.1 The geomembrane shall conform to the test property requirements prescribed in Tables 1 and 2. Table 1 is for smooth LLDPE geomembranes and Table 2 is for single and double sided textured LLDPE geomembranes. Each of the tables are given in English and SI (metric) units. The conversion from English to SI (metric) is "soft". It is to be understood that the tables refer to the latest revision of the referenced test methods and practices.

Note 4: The tensile strength properties in this specification were originally based on ASTM D 638 which uses a laboratory testing temperature of 23°C ± 2°C. Since ASTM Committee D35 on Geosynthetics adopted ASTM D 6693 (in place of D 638), this GRI Specification followed accordingly. The difference is that D 6693 uses a testing temperature of 21°C ± 2°C. The numeric values of strength and elongation were not changed in this specification. If a dispute arises in this regard, the original temperature of 23°C ± 2°C should be utilized for testing purposes.

Note 5: There are several tests sometimes included in other LLDPE geomembrane specifications which are omitted from this standard because they are outdated, irrelevant or generate information that is not necessary to evaluate on a routine MQC basis. The following tests have been purposely omitted:

- Volatile Loss
- Dimensional Stability
- Coeff. of Linear Expansion
- Resistance to Soil Burial
- Low Temperature Impact
- ESCR Test (D 1693 and D 5397)
- Wide Width Tensile
- Water Vapor Transmission
- Solvent Vapor Transmission
- Water Absorption
- Ozone Resistance
- Hydrostatic Resistance
- Tensile Impact
- Small Scale Burst
- Various Toxicity Tests
- Field Seam Strength

Note 6: There are several tests which are included in this standard (that are not customarily required in other LLDPE geomembrane specifications) because they are relevant and important in the context of current manufacturing processes. The following tests have been purposely added:

- Oxidative Induction Time

- Oven Aging
- Ultraviolet Resistance
- Asperity Height of Textured Sheet

Note 7: There are other tests in this standard, focused on a particular property, which are updated to current standards. The following are in this category:

- Thickness of Textured Sheet
- Tensile Properties, incl. 2% Secant Modulus
- Puncture Resistance
- Axi-Symmetric Break Resistance Strain
- Carbon Black Dispersion (In the viewing and subsequent quantitative interpretation of ASTM D 5596 only near spherical agglomerates shall be included in the assessment).

Note 8: The minimum average value of asperity height does not represent an expected value of interface shear strength. Shear strength associated with geomembranes is both site-specific and product-specific and should be determined by direct shear testing using ASTM D5321/ASTM D6243 as prescribed. This testing should be included in the particular site's CQA conformance testing protocol for the geosynthetic materials involved, or formally waived by the Design Engineer, with concurrence from the Owner prior to the deployment of the geosynthetic materials.

5.2 The values listed in the tables of this specification are to be interpreted according to the designated test method. In this respect they are neither minimum average roll values (MARV) nor maximum average roll values (MaxARV).

5.3 The various properties of the LLDPE geomembrane shall be tested at the minimum frequencies shown in Tables 1 and 2. If the specific manufacturer's quality control guide is more stringent, it must be followed in like manner.

Note 9: This specification is focused on manufacturing quality control (MQC). Conformance testing and manufacturing quality assurance (MQA) testing are at the discretion of the purchaser and/or quality assurance engineer, respectively. Communication and interaction with the manufacturer is strongly suggested.

6. Workmanship and Appearance

6.1 Smooth geomembrane shall have good appearance qualities. It shall be free from such defects that would affect the specified properties and hydraulic integrity of the geomembrane.

6.2 Textured geomembrane shall generally have uniform texturing appearance. It shall be free from such defects that would affect the specified properties and hydraulic integrity of the geomembrane.

6.3 General manufacturing procedures shall be performed in accordance with the manufacturer's internal quality control guide and/or documents.

7. MQC Sampling

7.1 Sampling shall be in accordance with the specific test methods listed in Tables 1 and 2. If no sampling protocol is stipulated in the particular test method, then test specimens shall be taken evenly spaced across the entire roll width.

7.2 The number of tests shall be in accordance with the appropriate test methods listed in Tables 1 and 2.

7.3 The average of the test results should be calculated per the particular standard cited and compared to the minimum value listed in these tables, hence the values listed are the minimum average values and are designated as "min. ave."

8. MQC Retest and Rejection

8.1 If the results of any test do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the manufacturing protocol as set forth in the manufacturer's quality manual.

9. Packaging and Marketing

9.1 The geomembrane shall be rolled onto a substantial core or core segments and held firm by dedicated straps/slings, or other suitable means. The rolls must be adequate for safe transportation to the point of delivery, unless otherwise specified in the contract or order.

9.2 Marking of the geomembrane rolls shall be done in accordance with the manufacturers accepted procedure as set forth in their quality manual.

10. Certification

10.1 Upon request of the purchaser in the contract or order, a manufacturer's certification that the material was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

English Units

Table 1(a) – Linear Low Density Polyethylene (LLDPE) Geomembrane (SMOOTH)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness - mils (min. ave.)	D5199	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	per roll
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	200,00 lb
Tensile Properties *(1)* (min. ave.)	D 6693									20,000 lb
• break strength - lb/in.	Type IV	76	114	152	190	228	304	380	456	
• break elongation - %		800	800	800	800	800	800	800	800	
2% Modulus – lb/in. (max.)	D 5323	1200	1800	2400	3000	3600	4800	6000	7200	per formulation
Tear Resistance - lb (min. ave.)	D 1004	11	16	22	27	33	44	55	66	45,000 lb
Puncture Resistance - lb (min. ave.)	D 4833	28	42	56	70	84	112	140	168	45,000 lb
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content - %	D 4218 *(2)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	45,000 lb
Carbon Black Dispersion	D 5596	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	45,000 lb
Oxidative Induction Time (OIT) *(4)*										
(a) Standard OIT (min. ave.)	D 3895	100	100	100	100	100	100	100	100	200,000 lb
— or —										
(b) High Pressure OIT (min. ave.)	D 5885	400	400	400	400	400	400	400	400	
Oven Aging at 85°C *(5)*	D 5721									
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	35	35	35	35	35	35	35	35	per formulation
— or —										
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	60	60	60	60	60	60	60	60	
UV Resistance *(6)*	D 7238									
(a) Standard OIT (min. ave.)	D 3895	N. R. *(7)*	N.R. *(7)*	N.R. *(7)*	N.R. *(7)*	N.R. *(7)*	N.R. *(7)*	N.R. *(7)*	N.R. *(7)*	per formulation
— or —										
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(8)*	D 5885	35	35	35	35	35	35	35	35	

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 2.0 in. at 2.0 in./min.

(2) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(3) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(4) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(5) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(6) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(7) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(8) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (Metric) Units

Table 1(b) – Linear Low Density Polyethylene (LLDPE) Geomembrane (SMOOTH)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.50 mm	2.00 mm	2.5 mm	3.0 mm	
Thickness - mm (min. ave.)	D5199	nom.	nom.	nom.	nom.	nom.	nom.	nom.	nom.	per roll
• lowest individual of 10 values		-10%	-10%	-10%	-10%	-10%	-10%	-10%	-10%	
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	90,000 kg
Tensile Properties *(1)* (min. ave.)	D 6693									9,000 kg
• break strength – N/mm	Type IV	13	20	27	33	40	53	66	80	
• break elongation - %		800	800	800	800	800	800	800	800	
2% Modulus – N/mm (max.)	D 5323	210	315	420	520	630	840	1050	1260	per formulation
Tear Resistance - N (min. ave.)	D 1004	50	70	100	120	150	200	250	300	20,000 kg
Puncture Resistance - N (min. ave.)	D 4833	120	190	250	310	370	500	620	750	20,000 kg
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 kg
Carbon Black Dispersion	D 5596	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	note *(3)*	20,000 kg
Oxidative Induction Time (OIT) *(4)*										90,000 kg
(c) Standard OIT (min. ave.)	D 3895	100	100	100	100	100	100	100	100	
— or —										
(d) High Pressure OIT (min. ave.)	D 5885	400	400	400	400	400	400	400	400	
Oven Aging at 85°C *(5)*	D 5721									
(a) Standard OIT (min. ave.) - % retained after 90 days	D 3895	35	35	35	35	35	35	35	35	per formulation
— or —										
(b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5885	60	60	60	60	60	60	60	60	
UV Resistance *(6)*	D 7238									
(a) Standard OIT (min. ave.)	D 3895	N. R. *(7)*	N.R. *(7)*	N.R. *(7)*	N.R. *(7)*	N.R. *(7)*	N.R. *(7)*	N.R. *(7)*	N.R. *(7)*	per formulation
— or —										
(b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(8)*	D 5885	35	35	35	35	35	35	35	35	

(1) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 50 mm at 50 mm/min.

(2) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(3) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(4) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(5) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(6) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(7) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(8) UV resistance is based on percent retained value regardless of the original HP-OIT value.

English Units

Table 2(a) – Linear Low Density Polyethylene (LLDPE) Geomembrane (TEXTURED)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mils (min. ave.)	D 7466	16	16	16	16	16	16	16	16	Every 2nd roll *(1)*
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	200,000 lb
Tensile Properties *(2)* (min. ave.) • break strength – lb/in. • break elongation - %	D 6693 Type IV	 30 250	 45 250	 60 250	 75 250	 90 250	 120 250	 150 250	 180 250	20,000 lb
2% Modulus – lb/in. (max.)	D 5323	1200	1800	2400	3000	3600	4800	6000	7200	per formulation
Tear Resistance – lb (min. ave.)	D 1004	11	16	22	27	33	44	55	66	45,000 lb
Puncture Resistance – lb (min. ave.)	D 4833	22	33	44	55	66	88	110	132	45,000 lb
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	45,000 lb
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	45,000 lb
Oxidative Induction Time (OIT) *(5)* (e) Standard OIT (min. ave.) — or — (f) High Pressure OIT (min. ave.)	 D 3895 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	200,000 lb
Oven Aging at 85°C *(6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	per formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 3895 D 5885	 N. R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	per formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 2.0 in. at 2.0 in./min.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

SI (Metric) Units

Table 2(b) – Linear Low Density Polyethylene (LLDPE) Geomembrane (TEXTURED)

Properties	Test Method	Test Value								Testing Frequency (minimum)
		0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.50 mm	2.00 mm	2.5 mm	3.0 mm	
Thickness mils (min. ave.) • lowest individual for 8 out of 10 values • lowest individual for any of the 10 values	D 5994	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	nom. (-5%) -10% -15%	per roll
Asperity Height mm (min. ave.)	D 7466	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	Every 2nd roll *(1)*
Density g/ml (max.)	D 1505/D 792	0.939	0.939	0.939	0.939	0.939	0.939	0.939	0.939	90,000 kg
Tensile Properties *(2)* (min. ave.) • break strength – N/mm • break elongation - %	D 6693 Type IV	 5 250	 9 250	 11 250	 13 250	 16 250	 21 250	 26 250	 31 250	9,000 kg
2% Modulus – N/mm (max.)	D 5323	210	315	420	520	630	840	1050	1260	per formulation
Tear Resistance – N (min. ave.)	D 1004	50	70	100	120	150	200	250	300	20,000 kg
Puncture Resistance – N (min. ave.)	D 4833	100	150	200	250	300	400	500	600	20,000 kg
Axi-Symmetric Break Resistance Strain - % (min.)	D 5617	30	30	30	30	30	30	30	30	per formulation
Carbon Black Content - %	D 4218 *(3)*	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	2.0-3.0	20,000 kg
Carbon Black Dispersion	D 5596	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	note *(4)*	20,000 kg
Oxidative Induction Time (OIT) *(5)* (g) Standard OIT (min. ave.) — or — (h) High Pressure OIT (min. ave.)	 D 3895 D 5885	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	 100 400	90,000 kg
Oven Aging at 85°C *(6)* (a) Standard OIT (min. ave.) - % retained after 90 days — or — (b) High Pressure OIT (min. ave.) - % retained after 90 days	D 5721 D 3895 D 5885	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	 35 60	per formulation
UV Resistance *(7)* (a) Standard OIT (min. ave.) — or — (b) High Pressure OIT (min. ave.) - % retained after 1600 hrs *(9)*	D 7238 D 3895 D 5885	 N. R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	 N.R. *(8)* 35	per formulation

(1) Alternate the measurement side for double sided textured sheet

(2) Machine direction (MD) and cross machine direction (XMD) average values should be on the basis of 5 test specimens each direction.
- Break elongation is calculated using a gage length of 50 mm at 50 mm/min.

(3) Other methods such as D 1603 (tube furnace) or D 6370 (TGA) are acceptable if an appropriate correlation to D 4218 (muffle furnace) can be established.

(4) Carbon black dispersion (only near spherical agglomerates) for 10 different views:
- 9 in Categories 1 or 2 and 1 in Category 3

(5) The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.

(6) It is also recommended to evaluate samples at 30 and 60 days to compare with the 90 day response.

(7) The condition of the test should be 20 hr. UV cycle at 75°C followed by 4 hr. condensation at 60°C.

(8) Not recommended since the high temperature of the Std-OIT test produces an unrealistic result for some of the antioxidants in the UV exposed samples.

(9) UV resistance is based on percent retained value regardless of the original HP-OIT value.

Adoption and Revision Schedule
for
GRI Test Method GM17

"Test Methods, Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes"

Adopted: April 3, 2000

Revision 1: June 28, 2000: added a new Section 5.2 that the numeric tables values are neither MARV nor MaxARV. They are to be interpreted per the designated test method. Also, corrected typographical error of textured sheet thickness test method designation from D5199 to D5994.

Revision 2: December 13, 2000: added one Category 3 is allowed for carbon black dispersion. Also, unified terminology to "strength" and "elongation".

Revision 3: June 23, 2003: Adopted ASTM D 6693, in place of ASTM D 638, for tensile strength testing. Also, added Note 4.

Revision 4: February 20, 2006: Added Note 9 on Asperity Height clarification with respect to shear strength.

Revision 5: Removed recommended warranty from specification.

Revision 6: June 1, 2009: Replaced GRI-GM12 test method for asperity height of textured geomembranes with ASTM D 7466.

Revision 7: April 11, 2011: Added alternative carbon black test methods.

Revision 8: October 3, 2011: Expanded types of comonomers in the definition of LLDPE.

Revision 9: December 14, 2012: Replaced GRI-GM12 with the equivalent ASTM D7238.

Revision 10: November 14, 2014: Increased asperity height of textured sheet from 10 to 16 mils (0.25 to 0.40 mm).

Revision 11: April 13, 2015: Unit conversion error was corrected for 0.75 mm (30 mil) thickness for the property of 2% modulus. The test value was changed from 370 N/mm to 315 N/mm in the SI (Metric) units tables to agree with the English units tables.

Revision 12: November 4, 2015: Removed Footnote (1) on asperity height from tables.

GM19

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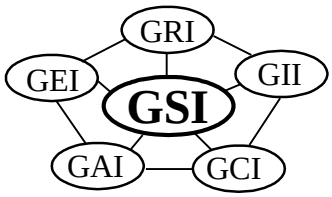

Original: February 28, 2002
Revision 8: February 12, 2015
Revision schedule is on pg. 13

GRI Test Method GM19*

Standard Specification for

Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes

This specification was developed by the Geosynthetic Research Institute (GRI), with the cooperation of the member organizations for general use by the public. It is completely optional in this regard and can be superseded by other existing or new specifications on the subject matter in whole or in part. Neither GRI, the Geosynthetic Institute, nor any of its related institutes, warrant or indemnifies any materials produced according to this specification either at this time or in the future.

1. Scope

1.1 This specification addresses the required seam strength and related properties of thermally bonded polyolefin geomembranes; in particular, high density polyethylene (HDPE), linear low density polyethylene both nonreinforced (LLDPE) and scrim reinforced (LLDPE-R) and flexible polypropylene both nonreinforced (fPP) and scrim reinforced (fPP-R).

1.2 Numeric values of seam strength and related properties are specified in both shear and peel modes.

Note 1: This specification does not address the test method details or specific testing procedures. It refers to the relevant ASTM test methods where applicable.

1.3 The thermal bonding methods focused upon are hot wedge (single and dual track) and extrusion fillet.

*This GRI standard is developed by the Geosynthetic Research Institute through consultation and review by the member organizations. This specification will be reviewed at least every 5-years, or on an as-required basis. In this regard it is subject to change at any time. The most recent revision date is the effective version.

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Note 2: Other acceptable, but less frequently used, methods of seaming are hot air and ultrasonic methods. They are inferred as being a subcategory of hot wedge seaming.

1.4 This specification does not suggest a specific distance between destructive seam samples to be taken in the field, i.e., the sampling interval. A separate GRI Standard Practice is focused on this issue, see GRI-GM29.

1.5 This specification is only applicable to laboratory testing.

1.6 This specification does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

2. Referenced Documents

2.1 ASTM Standards

D6392 Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods

D7747 Standard Test Method for Determining Integrity of Seams Produced Using Thermo-Fusion Methods for Reinforced Geomembranes by the Strip Tensile Method

2.2 EPA Standards

EPA 600/2.88/052 (NTIS PB-89-129670)
Lining of Waste Containment and Other Containment Facilities

2.3 GRI Standards

GM13 Test Properties and Testing Frequency for High Density Polyethylene (HDPE) Smooth and Textured Geomembranes

GM14 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using the Method of Attributes

GM17 Test Properties and Testing Frequency for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes

GM18 Test Properties and Testing Frequency for Flexible Polypropylene (fPP and fPP-R) Geomembranes

GM20 Selecting Variable Intervals for Taking Geomembrane Destructive Seam Samples Using Control Charts

GM25 Test Property and Testing Frequency for Scrim Reinforced Linear Low Density Polyethylene Geomembranes

GM29 Practice for Field Integrity Evaluation of Geomembrane Seams (and Sheet) Using Destructive and Nondestructive Testing

3. Definition

3.1 Geomembrane, n – An essentially impermeable geosynthetic composed of one or more synthetic sheets used for the purpose of liquid, gas or solid containment.

3.2 Hot Wedge Seaming – A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a hot metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Seams of this type can be made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual hot wedge seams or double-track seams.

3.3 Hot Air Seaming – This seaming technique introduces high-temperature air or gas between two geomembrane surfaces to facilitate localized surface melting. Pressure is applied to the top or bottom geomembrane, forcing together the two surfaces to form a continuous bond.

3.4 Ultrasonic Seaming - A thermal technique which melts the two opposing geomembrane surfaces to be seamed by running a ultrasonically vibrated metal wedge or knife between them. Pressure is applied to the top or bottom geomembrane, or both, to form a continuous bond. Some seams of this type are made with dual bond tracks separated by a nonbonded gap. These seams are referred to as dual-track seams or double-track seams.

3.5 Extrusion Fillet Seaming – This seaming technique involves extruding molten resin at the edge of an overlapped geomembrane on another to form a continuous bond. A depreciated method called “extrusion flat” seaming extrudes the molten resin between the two overlapped sheets. In all types of extrusion seaming the surfaces upon which the molten resin is applied must be suitably prepared, usually by a slight grinding or buffing.

4. Significance and Use

4.1 The various methods of field fabrication of seams in polyolefin geomembranes are covered in existing ASTM standards mentioned in the referenced document section. What is not covered in those documents is the numeric values of strength and related properties that the completed seam must meet, or exceed. This specification provides this information insofar as minimum, or maximum, property values are concerned when the field fabricated seams are sampled and laboratory tested in shear and peel. A separate GRI standard, GRI-GM29 (DRAFT), provides guidance as to the spacing that destructive samples should be taken in typical field installation projects.

5. Sample and Specimen Preparation

5.1 The spacing for taking field seam samples for destructive testing is provided in GRI-GM29 (DRAFT), a standard-of-practice. The process describes a progression from the most restrictive interval of 1 per 500 feet (1 per 150 m) to the complete use and reliance of the electrical leak location survey (ELLS) method. Intermediate between these extremes are variations depending upon the installers experience and performance.

5.2 The size of field seam samples is to be according to the referenced test method, e.g., ASTM D6392 or site-specific CQA plan.

5.3 The individual test specimens taken from the field seam samples are to be tested according to the referenced test method, i.e., ASTM D6392 for HDPE, LLDPE and fPP, and ASTM D751 (modified to a 150 mm + seam width gage length) for fPP-R. The specimens are to be conditioned prior to testing according to these same test methods and evaluated accordingly.

6. Assessment of Seam Test Results

6.1 HDPE seams – For HDPE seams (both smooth and textured), the strength of four out of five 1.0 inch (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values. In addition, five out five specimens should meet the shear percent elongation, calculated as follows, and exceed the values given in Tables 1(a) and 1(b):

$$E = \frac{L}{L_o}(100) \quad (1)$$

where

E = elongation (%)
L = extension at end of test (in. or mm)
L_o = original average length (usually 1.0 in. or 25 mm)

Note 3: The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

For HDPE seams (both smooth and textured), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 1(a) and 1(b). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 1(a) and 1(b) for all five out of five specimens. The value shall be based on

the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_o}(100) \qquad (2)$$

where

S = separation (%)
A = average area of separation, or incursion (in^2 or mm^2)
A_0 = original bonding area (in^2 or mm^2)

Note 4: The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%
Extrusion Fillet: AD1, AD2
Exception: AD-WLD (unless strength is achieved)

Note 5: Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

6.2 LLDPE seams – For LLDPE seams (smooth, textured and scrim reinforced), the strength of four out of five 1.0 in. (25 mm) wide strip specimens in shear should meet or exceed the values given in Tables 2(a) through 2(d). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are 4.0 in. (100 mm) wide grab tests. In addition, the shear percent elongation, calculated as follows, should exceed the values given in Tables 2(a) through 2(d). All five out of five should meet the shear elongation requirement.

$$E = \frac{L}{L_o}(100) \qquad (1)$$

where
E = elongation (%)
L = extension at end of test (in. or mm)
L_o = original average length (usually 1.0 in. or 25 mm)

Note 3 (Repeated): The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

Shear elongation is not relevant to scrim reinforced geomembranes and as such is listed as "not applicable" in Tables 2 (c) and (d).

For LLDPE seams (smooth, textured and scrim reinforced), the strength of four out of five 1.0 in. (25 mm) wide strip specimens tested in peel should meet or exceed the values given in Tables 2(a) through 2(d). The fifth must meet or exceed 80% of the given values.

In addition, the peel separation (or incursion) should not exceed the values given in Tables 2(a) through 2(d). All five out of five specimens shall meet the peel separation value. The value shall be based on the proportion of area of separated bond to the area of the original bonding as follows:

$$S = \frac{A}{A_o}(100) \qquad (2)$$

where

S = separation (%)
A = average depth of separation, or incursion ($in.^2$ or mm^2)
A_0 = original bonding distance ($in.^2$ or mm^2)

Note 4 (Repeated): The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%
Extrusion Fillet: AD1, AD2
Exception: AD-WLD (unless strength is achieved)

Note 5 (Repeated): Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

6.3 fPP Seams – For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in shear should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are 4.0 in. (100 mm) wide grab tests. In addition, the shear percent elongation on the unreinforced specimens, calculated as follows, should exceed the values given in Tables 3(a) and 3(b). All five out of five specimens should meet the shear elongation requirement.

$$E = \frac{L}{L_o}(100) \quad (1)$$

where
E = elongation (%)
L = extension at end of test (in. or mm)
L_o = original gauge length (usually 1.0 in. or 25 mm)

Note 3 (Repeated): The assumed gage length is considered to be the unseamed sheet material on either side of the welded area. It generally will be 1.0 in. (25 mm) from the edge of the seam to the grip face.

Shear elongation is not relevant to scrim reinforced geomembranes and as such is listed as "not applicable" in Tables 3(a) and 3(b).

For fPP seams (both nonreinforced and scrim reinforced), the strength of four out of five specimens in peel should meet or exceed the values given in Tables 3(a) and 3(b). The fifth must meet or exceed 80% of the given values. Note that the unreinforced specimens are 1.0 in. (25 mm) wide strips and the scrim reinforced specimens are grab tests. In addition, the peel percent separation (or incursion) should not exceed the values given in Tables 3(a) and 3(b). All five out of five specimens should meet the peel separation value. The values should be based on the proportion of area of separated bond to the area of the original bonding as follows.

$$S = \frac{A}{A_o}(100) \quad (2)$$

where

S = separation in (%)
A = average depth of separation, or incursion ($in.^2$ or mm^2)
A_o = original bonding distance ($in.^2$ or mm^2)

Note 4 (Repeated): The area of peel separation can occur in a number of nonuniform patterns across the seam width. The estimated dimensions of this separated area is visual and must be done with care and concern. The area must not include squeeze-out which is part of the welding process.

Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D6392 (in this regard, SIP is an acceptable break code);

Hot Wedge: AD and AD-Brk > 25%
Extrusion Fillet: AD1, AD2
Exception: AD-WLD (unless strength is achieved)

Note 5 (Repeated): Separation-in-plane (SIP) is a locus-of-break where the failure surface propagates within one of the seamed sheets during destructive testing (usually in the peel mode). It is not merely a surface skin effect producing a few ductile fibrils (sometimes called ductile drawdown). SIP is acceptable if the required strength, shear elongation and peel separation criteria are met.

In this regard, five out of five specimens shall result in acceptable break patterns.

7. Retest and Rejection

7.1 If the results of the testing of a sample do not conform to the requirements of this specification, retesting to determine conformance or rejection should be done in accordance with the construction quality control or construction quality assurance plan for the particular site under construction.

8. Certification

8.1 Upon request of the construction quality assurance officer or certification engineer, an installer's certification that the geomembrane was installed and tested in accordance with this specification, together with a report of the test results, shall be furnished at the completion of the installation.

Table 1(a) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** High Density Polyethylene (HDPE) Geomembranes **(English Units)**

Geomembrane Nominal Thickness	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams[1]							
shear strength[2], lb/in.	57	80	100	120	160	200	240
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], lb/in.	45	60	76	91	121	151	181
peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength[2], lb/in.	57	80	100	120	160	200	240
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], lb/in.	39	52	65	78	104	130	156
peel separation, %	25	25	25	25	25	25	25

Notes for Tables 1(a) and 1(b):

1. Also for hot air and ultrasonic seaming methods
2. Value listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 1(b) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** High Density Polyethylene (HDPE) Geomembranes **(S.I. Units)**

Geomembrane Nominal Thickness	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot Wedge Seams[1]							
shear strength[2], N/25 mm.	250	350	438	525	701	876	1050
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], N/25 mm	197	263	333	398	530	661	793
peel separation, %	25	25	25	25	25	25	25
Extrusion Fillet Seams							
shear strength[2], N/25 mm	250	350	438	525	701	876	1050
shear elongation at break[3], %	50	50	50	50	50	50	50
peel strength[2], N/25 mm	170	225	285	340	455	570	680
peel separation, %	25	25	25	25	25	25	25

Table 2(a) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** Linear Low Density Polyethylene (LLDPE) Geomembranes (English Units)

Geomembrane Nominal Thickness	20 mils	30 mils	40 mils	50 mils	60 mils	80 mils	100 mils	120 mils
Hot Wedge Seams[1]								
shear strength[2], lb/in.	30	45	60	75	90	120	150	180
shear elongation[3], %	50	50	50	50	50	50	50	50
peel strength[2], lb/in.	25	38	50	63	75	100	125	150
peel separation, %	25	25	25	25	25	25	25	25
Extrusion Fillet Seams								
shear strength[2], lb/in.	30	45	60	75	90	120	150	180
shear elongation[3], %	50	50	50	50	50	50	50	50
peel strength[2], lb/in.	22	34	44	57	66	88	114	136
peel separation, %	25	25	25	25	25	25	25	25

Notes for Tables 2(a) and 2(b):
1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing

Table 2(b) – Seam Strength and Related Properties of Thermally Bonded **Smooth and Textured** Linear Low Density Polyethylene (LLDPE) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	0.50 mm	0.75 mm	1.0 mm	1.25 mm	1.5 mm	2.0 mm	2.5 mm	3.0 mm
Hot Wedge Seams[1]								
shear strength[2], N/25 mm	131	197	263	328	394	525	657	788
shear elongation[3], %	50	50	50	50	50	50	50	50
peel strength[2], N/25 mm	109	166	219	276	328	438	547	657
peel separation, %	25	25	25	25	25	25	25	25
Extrusion Fillet Seams								
shear strength[2], N/25 mm	131	197	263	328	394	525	657	788
shear elongation[3], %	50	50	50	50	50	50	50	50
peel strength[2], N/25 mm	95	150	190	250	290	385	500	595
peel separation, %	25	25	25	25	25	25	25	25

Table 2(c) – Seam Strength and Related Properties of Thermally Bonded **Scrim Reinforced** Linear Low Density Polyethylene (LLDPE-R) Geomembranes (English Units)

Geomembrane Nominal Thickness	36 mil[4]	45 mil[4]
Hot Wedge Seams[1]		
shear strength[2], lb	200	200
shear elongation[3], %	n/a	n/a
peel strength[2], lb	20	20
peel separation, %	n/a	n/a
Extrusion Fillet Seams		
shear strength[2], lb	200	200
shear elongation[3], %	n/a	n/a
peel strength[2], lb	20	20
peel separation, %	n/a	n/a

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

Table 2(d) – Seam Strength and Related Properties of Thermally Bonded **Scrim Reinforced** Linear Low Density Polyethylene (LLDPE-R) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	36 mil[4]	45 mil[4]
Hot Wedge Seams[1]		
shear strength[2], N	890	890
shear elongation[3], %	n/a	n/a
peel strength[2], N	90	90
peel separation, %	n/a	n/a
Extrusion Fillet Seams		
shear strength[2], N	890	890
shear elongation[3], %	n/a	n/a
peel strength[2], N	90	90
peel separation, %	n/a	n/a

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

Table 3(a) – Seam Strength and Related Properties of Thermally Bonded **Nonreinforced and Scrim Reinforced** Flexible Polypropylene (fPP) Geomembranes (English Units)

Geomembrane Nominal Thickness	30 mil-NR	40 mil-NR	36 mil-R[4]	45 mil-R[4]
Hot Wedge Seams[1]				
shear strength[2], lb/in. (NR); lb (R)	25	30	200	200
shear elongation[3], %	50	50	n/a	n/a
peel strength[2], lb/in. (NR); lb (R)	20	25	20	20
peel separation, %	25	25	n/a	n/a
Extrusion Fillet Seams				
shear strength[2], lb/in. (NR); lb (R)	25	30	200	200
shear elongation[3], %	50	50	n/a	n/a
peel strength[2], lb/in. (NR); lb (R)	20	25	20	20
peel separation, %	25	25	n/a	n/a

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

Table 3(b) – Seam Strength and Related Properties of Thermally Bonded **Nonreinforced and Scrim Reinforced** Flexible Polypropylene (fPP) Geomembranes (S.I. Units)

Geomembrane Nominal Thickness	0.75 mm-NR	1.0 mm-NR	0.91 mm-R[4]	1.14 mm-R[4]
Hot Wedge Seams[1]				
shear strength[2], N/25 mm (NR); N (R)	110	130	890	890
shear elongation[3], %	50	50	n/a	n/a
peel strength[2], N/25 mm (NR); N (R)	85	110	90	90
peel separation, %	25	25	n/a	n/a
Extrusion Fillet Seams				
shear strength[2], N/25 mm (NR); N (R)	110	130	890	890
shear elongation[3], %	50	50	n/a	n/a
peel strength[2], N/25 mm (NR); N (R)	85	110	90	90
peel separation, %	25	25	n/a	n/a

1. Also for hot air and ultrasonic seaming methods
2. Values listed for shear and peel strengths are for 4 out of 5 test specimens; the 5th specimen can be as low as 80% of the listed values
3. Elongation measurements should be omitted for field testing
4. Values are based on grab tensile strength and elongation per D7747 for laboratory tested specimens

Adoption and Revision Schedule
for
Seam Specification per GRI-GM19

"Seam Strength and Related Properties of Thermally Bonded Polyolefin Geomembranes"

Adopted: February 18, 2002

Revision 1: May 15, 2003; Increased selected shear and peel test requirements, per the following:

Material	Test	Seam Type	Current GM19	Proposed GM19	Difference
HDPE	Shear	Hot Wedge	95% yield	95% yield	no change
		Extrusion	95% yield	95% yield	no change
	Peel	Hot Wedge	62% yield	72% yield	16% increase
		Extrusion	62% yield	62% yield	no change
LLDPE	Shear	Hot Wedge	1300 psi break	1500 psi break	15% increase
		Extrusion	1300 psi break	1500 psi break	15% increase
	Peel	Hot Wedge	1100 psi break	1250 psi break	14% increase
		Extrusion	1100 psi break	1100 psi break	no change

Revision 2: January 28, 2005; added Note 6 (in three locations) stating that incursion is measured on an area basis and not depth as in ASTM D6392.

Revision 3: June 4, 2010; Removed Note 6 on peel incursion since ASTM D6392 (2008) now uses area of incursion whereas previously they used linear length of incursion. Thus ASTM is now in agreement with GM19 in this regard.

Revision 4: November 15, 2010; Added Note 6 (in three locations) stating what separation-in-plane (SIP) is, and is not, and that it is acceptable if the required strength, shear elongation and peel separation criteria are met.

Revision 5: July 12, 2011; AD1 and AD2 breaks are now unacceptable even if strength is achieved.

Revision 6: October 3, 2011; Added LLDPE-R to the various geomembrane types, in particular, Tables 2(c) and 2(d) and made editorial changes.

Revision 7: November 3, 2013; clarified issues of 4 out of 5 passing strength and 5 out of 5 passing locus-of-break, shear elongation and peel separation.

Revision 8: February 12, 2015; upgraded standards and terminology

APPENDIX III3F-2

GROUNDWATER LEVEL DATA

Groundwater Level Monitoring Data
December 2014 - March 2016
Groundwater Elevation (ft)

Well/ Piezometer Descripton	Dec-14	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Seasonal High
MW-1R	71.8	-	72.95	73.14	79.24	81.73	82.62	78.97	77.49	76.65	76.43	77.64	77.17	76.73	76.55	76.08	82.62
MW-2R	69.17	-	70.26	70.41	72.69	74.63	76.01	75.06	74.66	74.51	74.41	75.63	75.4	75.12	74.96	74.61	76.01
MW-3A	70.43	-	71.1	71.38	72	73.84	74.91	76.03	75.75	75.64	75.51	76.34	76.11	75.93	75.87	75.47	76.34
MW-4A	70.2	-	71.77	72.09	73.82	76.34	76.66	77.21	76.51	76.02	75.85	76.84	76.69	76.47	76.31	75.86	77.21
MW-7R	72.15	-	73.12	73.72	75.59	78.27	79.47	78.02	76.78	76.15	76.02	77.3	76.95	76.7	76.49	76.01	79.47
MW-8R	72.95	-	75.23	75.23	79.07	81.65	82.51	79.63	77.94	77	76.8	78.41	77.81	77.28	77.02	76.46	82.51
MW-9R	69.31	-	70.52	70.71	72.74	75.89	76.19	75.26	74.96	74.77	74.66	75.77	75.65	75.3	75.31	74.92	76.19
MW-10R	69.77	-	71.31	71.59	72.57	79.16	76.02	76.13	75.72	75.5	75.4	76.55	76.41	75.96	75.92	75.51	79.16
MW-11	70.63	-	71.88	72.37	73.33	75.25	77.19	77.39	76.88	76.45	76.3	77.05	76.82	77.73	76.59	76.16	77.73
MW-12	70.72	-	71.61	71.68	72.21	73.55	75.46	75.99	75.76	75.86	75.77	76.5	76.19	76.02	75.89	75.4	76.5
MW-15R	74.19	-	72.98	73.42	74.01	74.97	77.62	77.2	76.75	76.74	76.59	77.3	77.1	76.97	76.91	76.48	77.62
MW-16	72.51	-	73.42	73.88	73.89	75.27	76.81	77.17	77.07	77.05	77.03	76.81	77.08	77.05	76.98	76.51	77.17
MW-18R	71.64	-	72.21	72.21	73.73	73.6	74.57	75.66	75.61	75.95	76.07	76.54	76.17	75.79	75.73	75.28	76.54
MW-22	69.91	-	70.71	71.05	71.81	74.27	74.91	75.71	75.36	75.18	75.06	75.72	75.7	75.58	75.51	75.16	75.72
MW-23	69.15	-	70.33	70.52	71.97	74.07	75.04	75.1	74.62	74.56	74.46	75.22	75.29	75.11	74.09	74.69	75.29
MW-24	71.29	-	72.67	72.9	75.58	79.36	83.89	77.45	77.32	77.32	76.36	77.64	77.19	75.68	76.57	76.08	83.89
MWD-1	-	-	-	69.29	70.18	71.91	74.34	74.29	73.16	72.93	72.79	73.7	73.46	73.33	73.12	72.57	74.34
MWD-2	-	-	-	72.15	73	74.49	75.56	75.26	73.74	73.06	72.81	73.62	73.62	73.34	72.88	72.04	75.56
MWD-3	-	-	-	72.23	74.98	77.19	80.21	76.44	74.89	74.26	74	75.13	75.02	74.98	74.85	74.37	80.21
MWD-4	-	-	-	70.73	72.24	74.88	76.27	76.68	75.61	75.18	74.91	75.48	74.96	74.48	74.23	73.68	76.68
MWD-5	-	-	-	71.31	71.89	73.46	74.99	75.93	75.54	75.5	75.42	76.25	75.92	75.78	75.63	75.13	76.25
MWD-6	71.16	-	71.86	75.99	72.28	73.34	74.26	75.54	75.63	75.95	75.99	76.39	76.02	75.78	75.7	75.29	76.39
MWD-7	71.96	-	72.02	72.03	73.41	75.27	76.9	76.09	75.31	75.24	75.13	75.97	75.7	75.25	75.13	74.5	76.9
PZ-101	68.61	69.79	70.58	71.23	71.77	-	74.13	74.65	74.39	74.24	74.07	74.49	74.63	74.74	74.75	74.63	74.75
PZ-104	66.98	67.36	67.95	68.42	69.63	-	74.18	75.41	75.13	74.56	74.14	74.34	74.27	74.08	73.97	73.75	75.41
PZ-106	58.98	59.24	59.55	59.77	60.3	-	68	65.75	64.25	63.39	63.05	64.17	63.9	63.79	63.75	63.4	68
PZ-113	70.37	71.03	72.15	72.49	75.49	78.4	80.79	78.07	76.71	75.96	75.75	76.75	76.74	76.7	76.61	76.25	80.79
PZ-116	69.7	70.22	70.8	71.21	72.45	-	76.2	76.98	76.84	76.36	76.03	76.27	76.28	76.07	75.94	75.57	76.98
PZ-118	62.03	62.24	62.59	62.82	63.51	76.54	66.59	66.68	66.52	68.34	66.04	66.4	66.47	66.71	66.71	66.54	76.54
PZ-122	-	56.26	56.55	56.44	57.01	-	-	57.34	-	56.68	56.64	57.19	57.5	57.87	57.96	58.1	58.1
PZ-124	67.41	67.68	67.72	67.77	68.11	-	70.6	71.54	71.28	71.45	71.16	71.88	71.73	71.76	71.63	71.36	71.88
PZ-130	-	66.36	66.74	67.09	67.29	-	68.44	68.74	68.65	69.16	69.11	69.84	69.84	70.3	70.39	70.14	70.39
PZ-131	70.4	68.2	71.44	71.49	72.34	86.47*	75.59	76.48	75.77	75.36	75.1	75.7	75.51	75.41	75.31	74.81	76.48
PZ-133	78.34	68.8	68.91	69.06	69.44	-	71.54	72.36	72.54	72.74	72.71	73.1	73.1	73.28	73.28	73.18	78.34
PZ-134	71.98	72.49	73.02	73.11	80.68	82.66	83.04	78.96	77.31	76.66	76.45	77.39	76.91	76.58	76.4	75.98	83.04

* Data not reasonable, ignored.