REPORT

CELL 2 LANDFILL LINER SYSTEM CONSTRUCTION PERMIT APPLICATION DOCUMENTS

INTERNATIONAL PAPER
RIEGELWOOD MILL
RIEGELWOOD, NORTH CAROLINA

Prepared for

International Paper
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July 2010

URS

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1.0 INTRODUCTION

International Paper (IP) operates an Industrial Solid Waste Landfill adjacent to its Kraft pulp and paper mill in Riegelwood, North Carolina. Process residuals, including dewatered wastewater treatment solids, boiler ash, and other solids are managed in the industrial process landfill (NCDENR Facility Permit No.:24-02). The landfill facility is located adjacent to the mill in Columbus County (34°21'06"N x 78°12'21"W).

1.1 Background

IP-Riegelwood submitted a Lateral Expansion Permit Application to NCDENR in February 2002, proposing to construct their North Bay landfill site in 2 similarly sized cells of approximately 13.5 acres each. Cell 1 was 13.6 acres in size, had a design capacity of 711,700 cubic yards (cyds), and was expected to last 4.1 years. Cell 1 construction was completed in September 2003, and active use of the cell began in early 2005. Figure 1-1 shows the North Bay landfill cells. The February 2002 Lateral Expansion Permit Application showed future cell development and facility closure information for conceptual purposes, and was not approved for construction in the NCDENR December 2002 Permit to Construct.

As IP-Riegelwood began to schedule Cell 2 construction they learned that Holtrachem Corporation (now owned by Honeywell Corporation) had discharged Polychlorinated biphenyls (PCB's) near the northwest corner of Cell 2 during their use of the mill's wastewater treatment system. While PCB-impacted sediment removal work was being planned, permitted and executed, IP-Riegelwood extended their landfill via an expansion to the south side of Cell 1. This extension was completed in 2008 and 2009 to extend Cell's 1 fillable life. Honeywell completed removal of the PCB-impacted sediments in January 2009, allowing IP-Riegelwood to resume their Cell 2 landfill expansion planning work.

1.2 Purpose

URS was retained by IP to update the Cell 2 development plans following Honeywell's sediment removal activities. Because of the extensive excavation work completed by Honeywell, IP met with NCDENR in September 2008 to explain the impact of Honeywell's work on their property and schedule for Cell 2 construction. IP submitted a subgrade restoration plan which NCDENR Division of Waste Management approved January 13, 2009. IP-Riegelwood began the subgrade restoration work in October 2009, and is herein submitting complete Construction Permit Application plans for the remaining Cell 2 landfill features. Updated Construction Specifications and a Quality Assurance Manual are included as part of this package.

The various NCDENR approvals for the activities that have taken place for Cell 1 and 2 are provided in Appendix A. Cell 2 is designed using the same principles as were used for the Cell 1 design. The intent of this submittal is not to repeat already approved design concepts and supporting calculations, but rather to present modifications to the Cell 1 concepts that will be used to construct Cell 2, and to provide the supporting calculations. Modifications are presented in the following sections.

Figure 1-1. Riegelwood North Bay Landfill Cells – 2004 Aerial Photograph

2.0 DESIGN MODIFICATIONS

Modifications to the February 2002 Lateral Landfill Expansion Permit application plans for Cell 1 and 2 are detailed in the following report sections. Modifications were made to account for IP infrastructure and to simplify Cell 2 construction. These modifications are reflected on the attached plans and are described below.

2.1 Cell 2 Footprint Configuration

The configuration of Cell 2 was adjusted slightly from the 2002 layout due to several design modifications. The waste footprint was reduced and the northwest perimeter berm top elevation was lowered. These modifications are described below.

2.1.1 Waste Footprint

The waste footprint for Cell 2 was reduced as shown on attached Existing Conditions, Sheet 3. The northeast corner of the cell was moved southward to avoid the oxygen tank and underground piping in that area. The footprint was changed slightly on the west side as a result of lowering the perimeter berm surface elevation.

2.1.2 Perimeter Berm Lowering

The 2002 Permit Application drawings had the north perimeter berm transitioning from elevation +47 to +37 on the northwest side of Cell 2. As part of the operational evaluation, URS shifted this perimeter berm surface transition to the southwest to allow for addition of an access ramp for trucks. The revised perimeter berm and access ramp are shown on the attached Subgrade Grading Plan, Sheet 5. This modification leads to a reduction in the originally permitted air space capacity. Table 2-1 summarizes the landfill acreage and capacity as originally permitted, and after incorporating design modifications presented herein.

Table 2-1

Summary of Originally Permitted Landfill Acreage and Capacity

	(1) 2002 Permit to Construct	(1) 2009 Cell 1 Vertical Expansion Permit to Construct	(1) Cell 2 Permit to Construct
Description	**Gross Vol. (cyds)**	**Gross Vol. (cyds)**	**Gross Vol (cyds)**
Cell 1	749,000	749,000	905,007
Cell 1 Extension	0	158,170	158,170
Cell 2	1,870,000	1,870,000	1,173,921
Cumulative	**2,619,000**	**2,777,170**	**2,237,098**

Notes: (1) Gross Volume includes final cover + residual volume.

2.1.3 Cell Floor

Cell 2 floor elevations have been modified as a result of revisions to the waste footprint discussed above. Cell floor slopes (2% parallel to leachate flow direction and 0.5% beneath leachate collection and removal pipes) have been maintained and replicate those already approved in landfill Cell 1. The Feb. 2002 permit plans showed the cell floor elevation ranging between elevation 15 and 26. The attached Underdrain Layout and Piping, Sheet 4, shows the cell floor elevation ranging between elevation 16 and 23.

2.2 Underdrain System

Cell 2's underdrain system was designed to replicate the Cell 1 underdrain system since it's already operating effectively. In addition to adjusting the underdrain pipe layout to account for adjustments to the cell footprint, URS has increased the separation distance between the underdrain pipe invert and liner from 4.0 feet minimum in the approved 2002 Permit Drawings, to between 4.4-6.0 feet for Cell 2. The Cell 1 underdrain manhole will be decommissioned, with the piping extended into the Cell 2 system. A new manhole will be constructed outside the northeast corner of Cell 2 that will receive the combined Cell 1 and 2 underdrain system water. This new manhole will contain a duplex pumping system to increase reliability and facilitate maintenance. This system was designed to maintain the ability to gravity drain the entire underdrain system to the river should water quality permit and the need arise.

After the construction of the subgrade restoration project URS became aware that the subgrade and underdrain piping was installed 0.53 feet lower than what was permitted. The new monument at Cell 2 was established using a previous monument that had settled six inches. According to the plans the approved liner surface would be six inches above the subgrade. URS and IP decided to discuss this matter with the state to determine if six inches of soil needed to be installed or the liner surface could be lowered. The state was not opposed of lowering the liner surface since the air space capacity increase is significantly less than 10% change from the original permitted capacity.

2.3 Liner System Modifications

IP-Riegelwood intends to duplicate the double-liner system approved for installation beneath Cell 1 for use beneath Cell 2. IP-Riegelwood also requests continuation of the Cell 1 Action Leakage Rate (ALR) of 500 gal/acre/day for use with Cell 2 as well. This ALR has never been triggered. IP Riegelwood's electronic data acquisition system shows 16,876.5 gallons of water were pumped from the secondary system between March 2, 2005 and May 22, 2009. Using 13.89 acres as Cell 1's lined area, and time interval of 1544 days, the calculated average flow rate to the secondary collection system is 0.79 gal/acre/day. The flow rate into the secondary collection system is therefore very small.

2.4 Leachate Collection System Enhancements

IP-Riegelwood is hereby requesting modification of the leachate collection system for Cell 2 as follows:

2.4.1 Leachate Collection Sump

The filter media configuration in the leachate sump area is being modified. The new design prescribes a berm of #57 stone, 15 feet in height, over the leachate sump area, as shown on attached Leachate Management Details, Sheet 14. This modification will increase the drainage surface area for the sump, increases storage capacity for large storm events, and should serve to enhance filtering effectiveness.

Appendix B provides calculations demonstrating filtering compatibility of Gooseneck borrow material, used as the Protective Cover in Cell 1 with the North Carolina Department of Transportation Table 1005-1 No. 78 and No. 57 aggregates, along with ½-inch diameter hole size proposed for the leachate collection and removal pipes. The protective cover soil will be extended over all No. 78 filtering aggregate over the leachate collection pipes for Cell 2 in order to improve the filtering efficiency of the collection system.

2.4.2 Leachate Collection Side Riser Pipes

The Cell 2 leachate collection system was designed to replicate the as-built conditions of the Cell 1 leachate collection system since Cell 1 already operates effectively. Although the Cell 1 permit drawings show a 24" diameter leachate collection side riser pipe, the as-built drawings show that 18" diameter pipes were actually used. URS modified the Cell 2 plans to show an 18" diameter leachate collection side riser pipe. URS confirmed with the pump manufacturer that the pump specified for this project will fit inside an 18" HDPE pipe. The pump will be able to successfully navigate through the elbow to reach the horizontal section of the riser pipe.

3.0 PUMP SELECTION

Both the leachate collection and removal system and the underdrain pump systems are designed as duplex pumping systems. The Cell 1 and Cell 2 leachate and groundwater pumping and conveyance systems were modeled using the SewerGEMS Version 8 computer program to confirm pump selection. These systems share the existing forcemain which currently conveys leachate and groundwater from the Cell 1 systems to the clarifier. Model output is provided in Appendix C. The system was modeled for six different operating scenarios:

- All pumps at all three locations on simultaneously;
- One pump at each of the 3 locations on simultaneously;
- One proposed leachate and underdrain pump on simultaneously;
- One proposed leachate pump on only;
- One proposed underdrain pump on only; and
- One existing leachate pump on only.

Performance curves for the pumps selected using these modeling results, along with the plotted range in discharge rates, are provided in Appendix C. The modeling effort was completed after flow rates were field-measured at the forcemain discharge for the existing Cell 1 primary leachate pumps and the underdrain pump.

3.1 Underdrain System

In order to size the Cell 2 underdrain pumps URS modeled the groundwater collection system. We calibrated the model using field-measured discharge rates from Cell 1, combined with IP-Riegelwood's electronic data acquisition records for the Cell 1 underdrain pump run time. Appendix D includes calculations that estimate the increase in groundwater flow from Cell 2 is approximately 6 to 7 gal/min. The modeled Cell 1 collection system flow rate was approximately 19 gal/min, compared with a field measured average flow rate of 12 gal/min URS field measured the discharge rate for the Cell 1 underdrain system pump at 60 gpm. Therefore, if a pump capable of producing 60 gpm is installed in Cell 2 it would be sufficient to handle the expected long-term flow rate. The pump calculations are provided in Appendix C. Stormwater generated within Cell 2 prior to liner installation was not considered in sizing the underdrain system pumps.

3.2 Leachate System

The Cell 2 leachate collection and removal system was designed to replicate the Cell 1 leachate collection and removal system since Cell 1's system has been operating efficiently. The leachate from the secondary collection system in Cell 1 is pumped into the primary leachate collection sump. URS designed the Cell 2 secondary leachate collection system to replicate Cell 1. Therefore when URS used the existing discharge rate for the primary leachate pump the flow from the secondary collection system was accounted for.

The existing Primary Leachate pumps in Cell 1 are rated at 75 gpm. Field measurements confirmed discharge rates of 85 gpm for Primary leachate pump P-1, and 50 gpm for P-2. P-2's lower pumping rate was reasonable based on an observed 90° bend in the discharge hose. Based on existing Cell 1 system performance, and the nearly identical size of Cells 1 and 2, the pumps proposed for Cell 2 are each rated for 85 gpm. The pump calculations are provided in Appendix C.

4.0 STABILITY ANALYSIS

While preparing the Cell 2 Liner System Permit drawings URS modified the final contour drawings to account for the adjusted Cell 2 footprint, and included the Cell 1 Extension. The resulting net residual capacity and lined landfill areas were provided in Table 2-1. Final landfill slopes (4H:1V) and the peak elevation are similar to those shown on the 2002 Permit Drawings. The Final Cover Grading Plan (Sheet 8) shows the proposed final cover contours. Stormwater control features are also provided, and supported by calculations in Appendix F. The Operational Plan (Sheet 9) shows Cell 1 final contours just prior to transitioning into Cell 2. The operating plan contemplates a 3H:1V active filling face as the steepest safe operating slope.

The following stability calculations were performed to confirm the adequacy of these design slopes for Cell 2:

- Final Cover Veneer Stability; and
- Active Operating Slope Stability.

The outcome of these calculations is described below.

4.1 Final Cover Stability

URS has proposed a final cover cross-section that includes a geomembrane overlain by a geocomposite drainage layer. Veneer Stability calculations were performed to determine the minimum interface friction angle to maintain stability using these final cover components. In order to achieve a static stability safety factor of 1.5 or greater, an interface friction angle of at least 21 degrees is required (see Appendix E). To achieve a seismic stability safety factor greater than 1.0, the minimum interface friction angle for the cover components must be greater than 21 degrees.

4.2 Operational Slope Stability

Since intermediate operating landfill slopes are specified at 3H:1V, these slopes represent the critical condition from a slope stability perspective. These analyses considered both static and seismic conditions. Piezometric (water table) conditions considered the underdrain system performance, effectiveness of the leachate collection system at the landfill base, and the prospect for perched leachate levels within the landfilled residuals.

4.2.1 Static Analysis

Table 4-1 below summarizes results of the various stability analysis trials. Undrained analyses (total stress strength parameters) were used for the stability evaluation. Soil, landfilled residuals, and geosynthetic interface strength parameters used for the analysis are provided in Appendix E.

Table 4-1

Intermediate Slope Stability Analysis Result Summary
IP-Riegelwood Landfill Cell 2

Trial	Description	Safety Factor
Trial 1	Int. Slope 3:1 – high water - static	1.5
Trial 2	Int. Slope 3:1 – low water - static	1.7
Trial 3	Int. Slope 3:1 – high water- seismic	1.2
Trial 4	Int. Slope 3:1 – low water - seismic	1.4

Computer models were prepared for analysis using the selected cross-section. The stability analyses were conducted using the computer program PCSTABL6. This program calculates safety factors for assigned material properties, sliding surface geometry, and groundwater conditions. For these analyses randomly shaped (Modified Janbu method) sliding surfaces were evaluated to determine the most critical condition (lowest safety factor). The landfill slope was modeled using a two-dimensional analysis. The outputs for the different trials are provided in Appendix E. A safety factor of 1.5 for static conditions and 1.0 for seismic analyses of the intermediate landfill slope was considered acceptable.

4.2.2 Seismic Analysis

The IP-Riegelwood landfill lies inside a seismic impact zone ($a_{max} \geq 0.10$ g according to USGS (Frankel, et. al.)). The peak bedrock acceleration for the project site was obtained from the 2008 USGS' Earthquake Hazards Program custom mapping and analysis tools - Latitude Longitude interpolation mapping feature. This USGS interpolation program reports that a Peak Ground Acceleration (PGA) of 0.125g would have a 2% probability of being exceeded in a 50 year time span. This PGA also has a 90% probability of not being exceeded in 250 years, which corresponds to an earthquake return period of once in 2400 years.

Normal practice interprets the PGA as the horizontal acceleration at a hypothetical bedrock outcrop at a project site (EPA/600/R-95/051). The PGA is normally attenuated as the shear wave propagates through soil overlying the bedrock according to a relationship presented by Seed and Idriss (1982) and Idriss (1990). The amount of amplification/attenuation was estimated using empirical relationships suggested by Idriss (1990), described in EPA/600/R-95/051. This procedure relates the level of motion in bedrock to motion at the surface of a soil deposit based on the soil type through which the seismic motion propagates.

The Idriss (1990) relationship suggests the 0.125 g rock accelerations would attenuate/amplify to 0.125g by the time it reached the natural ground surface beneath the landfill.

Procedures recommended by Bray et al. (1995) suggest motion would then attenuate as it passes from the landfill bottom into, and through, the landfilled residuals. The amount of attenuation is estimated at 50%, resulting in an estimated ground motion of 0.07g within the landfill mass.

Results of the seismic analyses, summarized in Table 4-1, suggest the operational slopes should remain stable under both static and seismic conditions.

5.0 FINAL COVER AND STORMWATER MANAGEMENT

The new design for the final cover shows the high point at elevation 132 (see attached Final Cover Grading Plan, Sheet 8). The Feb. 2002 permit plans show a high point of 136. Final cover slopes have been adjusted to be compatible with the slight change in the waste footprint and lowering of the perimeter berm surface elevation.

The Final Cover Grading Plan presents a conceptual design and we expect a more detailed and specific closure plan will be submitted as the site nears final capacity. This will allow for IP to take advantage of current technology and methods that are being practiced at that time.

5.1 Drainage Channels and Swales

Along with modifications to the final cover, URS has included stormwater management details for the final cover, including perimeter drainage channels, runoff diversion swales, and downdrain pipe systems. The calculations were based on a 25 year 24 hour storm event. The calculations are provided in Appendix F. The drainage features were designed at a depth of 2 feet or more, and should therefore provide more then 0.5 feet of freeboard. The maximum allowable velocity for the type of vegetation that will line the drainage features is 5.0 ft/sec. The maximum calculated velocity is 4.69 ft/sec., therefore grass vegetation would be adequate.

There will be three down pipes strategically located on the final cover. The drawing in Appendix F outlines the drainage areas and shows the discharge flow for each area. The required down pipe size is shown on the Final Cover Grading Plan, Sheet 8. The down pipe calculations are provided in Appendix F. The down pipe calculations indicated a discharge velocity of greater then 5 ft/sec, therefore an energy dissipator surrounded by Class B rip rap will be installed at the end of the down pipes to minimize the impact to the surrounding area.

APPENDIX A

NCDENR Approval

APPENDIX B

Aggregate Selection

APPENDIX C

Pump Selection

APPENDIX D

Underdrain System

APPENDIX E

Stability Analysis

APPENDIX F

Drainage Features

APPENDIX G

Specifications

APPENDIX H

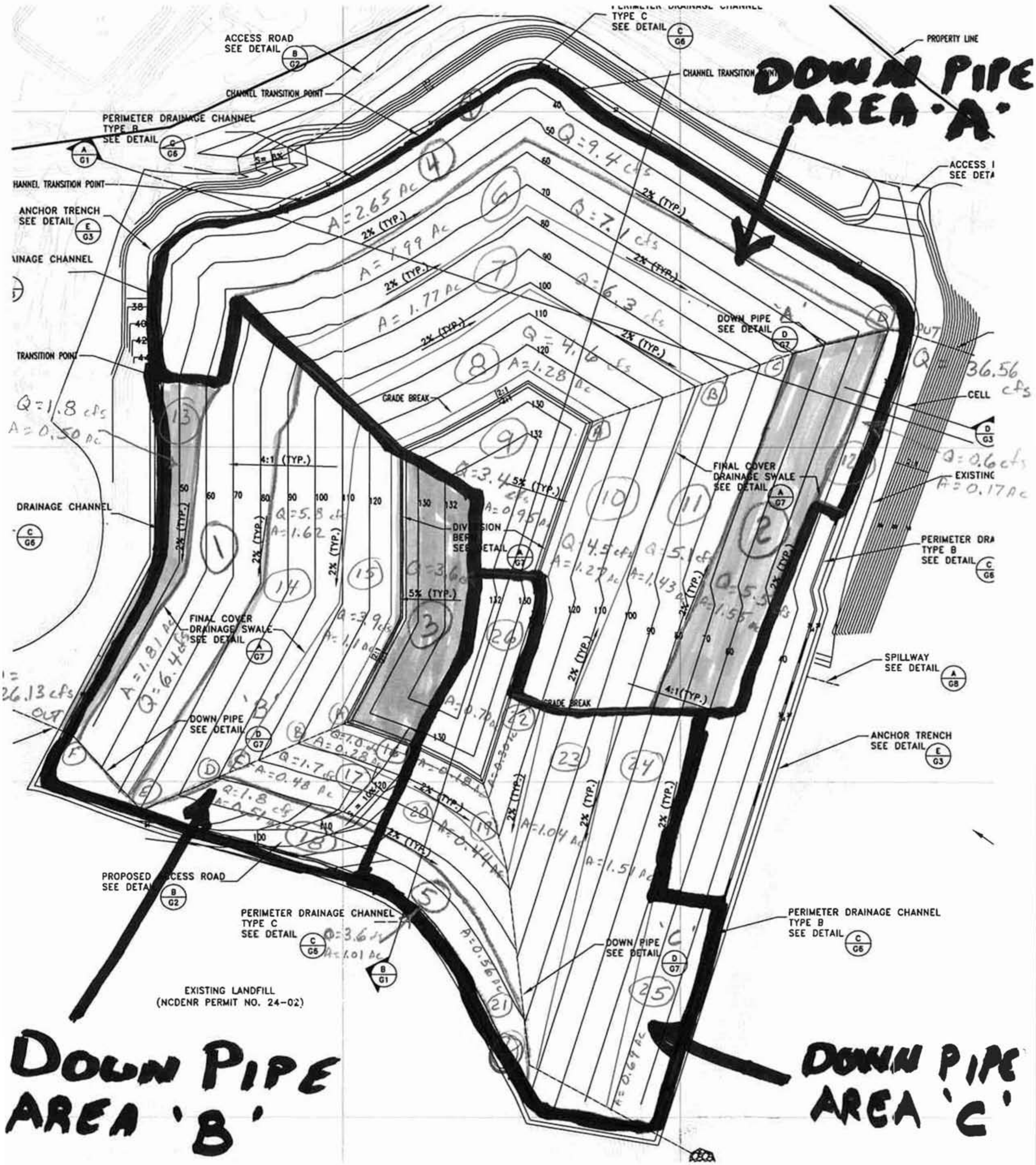
Drawings

Sheet 1	Title/Cover Sheet
Sheet 2	Site Plan
Sheet 3	Existing Conditions
Sheet 4	Underdrain Layout and Piping
Sheet 5	Base Grades Grading Plan
Sheet 6	Protective Cover
Sheet 7	Leachate Management Plan
Sheet 8	Final Cover Grading Plan
Sheet 9	Operational Plan
Sheet 10	Cross Sections
Sheet 11	Underdrain Details
Sheet 12	Liner and Perimeter Berm Details
Sheet 13	Leachate Management Details
Sheet 14	Leachate Management Details
Sheet 15	Final Cover Details
Sheet 16	Drainage Channel Details
Sheet 17	Spillway Detail
Sheet 18	Erosion & Sediment Control Details
Sheet 19	Underdrain & Leachate Forcemain Details
Sheet 20	Subgrade Control Points
Sheet 21	Protective Cover Control Points

APPENDIX F

Drainage Features

DRAINAGE ANALYSIS


DOWN PIPE AREA 'A'
DOWN PIPE AREA 'B'
DOWN PIPE AREA 'C'
PERIMETER DRAINAGE CHANNEL TYPE C SEE DETAIL
ACCESS ROAD SEE DETAIL
PROPERTY LINE
CHANNEL TRANSITION POINT
PERIMETER DRAINAGE CHANNEL TYPE B SEE DETAIL
ANCHOR TRENCH SEE DETAIL
FINAL COVER DRAINAGE SWALE SEE DETAIL
DIVERSION BERM SEE DETAIL
DOWN PIPE SEE DETAIL
GRADE BREAK
SPILLWAY SEE DETAIL
PROPOSED ACCESS ROAD SEE DETAIL
EXISTING LANDFILL (NCDENR PERMIT NO. 24-02)
Q=9.4 cfs
Q=7.1 cfs
Q=6.3 cfs
Q=4.6 cfs
A=2.65 Ac
A=1.99 Ac
A=1.77 Ac
A=1.28 Ac
Q=36.56 cfs
Q=1.8 cfs
A=0.50 Ac
Q=0.6 cfs
A=0.17 Ac
Q=5.8 cfs
A=1.62
Q=3.4 cfs
A=0.95 Ac
Q=4.5 cfs
A=1.27 Ac
Q=5.1 cfs
A=1.43 Ac
Q=5.5 cfs
A=1.55 Ac
A=1.81 Ac
Q=6.4 cfs
26.13 cfs
Q=3.9 cfs
A=1.1 Ac
Q=3.6 cfs
A=1.01 Ac
A=1.04 Ac
A=1.51 Ac
A=0.56 Ac
A=0.69 Ac
2% (TYP.)
4:1 (TYP.)
5% (TYP.)

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design#1		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t): 1.81 acres

Q_p = 6.4 cfs

Runoff Coefficient				
Runoff Coefficient, C	CA = sum(Area x "C") C = Total CA / Total DA	**CA =** **C =**	**0.634** **0.350**	
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse				
Time of Concentration				
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c =**	**0.05**	**hrs.**
Overland Flow	See Worksheet Tc	**T_t =**	**SF =**	**0.052**
Shallow Concentrated Flow	See Worksheet Tc	**T_t =**	**SCF =**	**0.000**
Channel Flow	See Worksheet Tc	**T_t =**	**CF =**	**0.000**
Duration				
Duration, D	D = T_c	**D =**	**5.00**	**min.**
Frequency				
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F =**	**25**	**year design storm**
Intensity				
Intensity, I		**I =**	**10.16**	**in./hr.**
Discharge				
Discharge, Q_p	Q_p = C*I*A	**Q_p =**	**6.4**	**cfs**

(2)

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

North Carolina 34.351754 N 78.205299 W 9 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3
G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2004
Extracted: Thu May 7 2009

Confidence Limits | Seasonality | Location Maps | Other Info. | GIS data | Maps | Docs

Precipitation Intensity Estimates (in/hr)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	(
1	5.83	4.66	3.88	2.66	1.66	0.98	0.70	0.42	0.25	0.14	0.08	0.05	0.03	0.02	0.02	0.01	0.01	0
2	6.92	5.53	4.64	3.20	2.01	1.19	0.85	0.52	0.30	0.17	0.10	0.06	0.04	0.03	0.02	0.02	0.01	0
5	8.09	6.48	5.46	3.88	2.49	1.52	1.08	0.66	0.39	0.22	0.13	0.07	0.05	0.04	0.02	0.02	0.02	0
10	9.01	7.20	6.07	4.40	2.87	1.78	1.28	0.78	0.46	0.27	0.15	0.08	0.06	0.04	0.03	0.02	0.02	0
25	10.16	8.10	6.84	5.07	3.37	2.16	1.58	0.97	0.57	0.34	0.19	0.10	0.07	0.05	0.03	0.03	0.02	0
50	11.04	8.78	7.42	5.59	3.78	2.48	1.83	1.13	0.67	0.40	0.22	0.12	0.08	0.06	0.04	0.03	0.02	0
100	11.92	9.47	7.98	6.11	4.21	2.83	2.11	1.30	0.78	0.47	0.26	0.14	0.09	0.07	0.04	0.03	0.03	0
200	12.79	10.13	8.52	6.64	4.65	3.20	2.42	1.50	0.91	0.54	0.30	0.16	0.10	0.07	0.05	0.03	0.03	0
500	13.93	11.02	9.24	7.35	5.28	3.75	2.88	1.79	1.10	0.66	0.37	0.19	0.12	0.09	0.05	0.04	0.03	0
1000	14.86	11.69	9.79	7.92	5.78	4.21	3.28	2.05	1.26	0.77	0.42	0.21	0.13	0.10	0.06	0.04	0.03	0

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.
Please refer to NOAA Atlas 14 Document for more information. NOTE: Formatting forces estimates near zero to appear as zero.

* Upper bound of the 90% confidence interval
Precipitation Intensity Estimates (in/hr)

ARI** (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	(
1	6.32	5.05	4.21	2.88	1.80	1.07	0.77	0.47	0.28	0.16	0.09	0.05	0.03	0.03	0.02	0.01	0.01	0
2	7.50	6.00	5.03	3.47	2.18	1.30	0.94	0.57	0.34	0.19	0.11	0.06	0.04	0.03	0.02	0.02	0.01	0
5	8.77	7.02	5.92	4.21	2.70	1.66	1.19	0.73	0.43	0.25	0.14	0.08	0.05	0.04	0.03	0.02	0.02	0
10	9.74	7.79	6.57	4.76	3.10	1.95	1.41	0.86	0.52	0.30	0.17	0.09	0.06	0.05	0.03	0.02	0.02	0
25	10.97	8.74	7.38	5.47	3.64	2.36	1.73	1.06	0.64	0.37	0.21	0.11	0.07	0.06	0.04	0.03	0.02	0
50	11.90	9.49	8.00	6.03	4.08	2.71	2.01	1.24	0.75	0.44	0.25	0.13	0.08	0.06	0.04	0.03	0.02	0
100	12.86	10.22	8.61	6.59	4.54	3.08	2.31	1.43	0.87	0.52	0.29	0.15	0.10	0.07	0.04	0.03	0.03	0
200	13.80	10.94	9.20	7.16	5.02	3.49	2.65	1.64	1.00	0.60	0.34	0.17	0.11	0.08	0.05	0.04	0.03	0
500	15.06	11.92	10.00	7.95	5.71	4.09	3.15	1.96	1.21	0.74	0.41	0.21	0.13	0.09	0.06	0.04	0.03	0
1000	16.09	12.67	10.60	8.58	6.27	4.61	3.60	2.25	1.39	0.86	0.47	0.24	0.14	0.11	0.06	0.05	0.04	0

* The **upper** bound of the confidence interval at 90% confidence level is the value which 5% of the simulated quantile values for a given frequency are **greater** than.
** These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.

Please refer to NOAA Atlas 14 Document for more information. NOTE: Formatting prevents estimates near zero to appear as zero.

* Lower bound of the 90% confidence interval
Precipitation Intensity Estimates (in/hr)

ARI** (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	(

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design#1		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2):	**4.1**	**in.**

Total T_c =	**0.05**	**hrs.**

Sheet Flow						
Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	100					ft
Input Surface Slope, S	0.250					ft/ft
Sheet Flow Time	0.052	0.000	0.000	0.000	0.000	hrs.
Sheet Flow Time =	$\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$			**Total SF =**	**0.052**	**hrs.**

Shallow Concentrated Flow						
Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	8					ft
Water Course Slope, S	0.250					ft/ft
Average Velocity, V	8.07	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$ Shallow Concentrated Flow Time = L/(3600*V)				**Total SCF =**	**0.000**	

Channel Flow						
Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
R = A/P	$V = (1.49*R^{2/3}*S^{1/2}) / n$ Channel Flow Time = L/(3600*V)			**Total CF =**	**0.000**	**hrs.**

4

POINT PRECIPITATION FREQUENCY ESTIMATES FROM NOAA ATLAS 14

North Carolina 34.351754 N 78.205299 W 9 feet

from "Precipitation-Frequency Atlas of the United States" NOAA Atlas 14, Volume 2, Version 3
G.M. Bonnin, D. Martin, B. Lin, T. Parzybok, M.Yekta, and D. Riley
NOAA, National Weather Service, Silver Spring, Maryland, 2004
Extracted: Thu May 7 2009

Confidence Limits | Seasonality | Location Maps | Other Info. | GIS data | Maps | Docs

Precipitation Frequency Estimates (inches)

ARI* (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	(
1	0.49	0.78	0.97	1.33	1.66	1.96	2.09	2.54	2.98	3.42	4.00	4.50	5.22	5.91	7.96	9.90	12.40	1
2	0.58	0.92	1.16	1.60	2.01	2.38	2.55	3.09	3.63	4.14	4.83	5.42	6.29	7.08	9.47	11.75	14.65	1
5	0.67	1.08	1.37	1.94	2.49	3.03	3.25	3.96	4.67	5.36	6.19	6.87	7.91	8.76	11.54	14.10	17.36	2
10	0.75	1.20	1.52	2.20	2.87	3.56	3.86	4.70	5.58	6.43	7.38	8.10	9.26	10.16	13.25	16.00	19.55	2
25	0.85	1.35	1.71	2.53	3.37	4.32	4.74	5.79	6.93	8.07	9.17	9.93	11.22	12.20	15.68	18.64	22.56	2
50	0.92	1.46	1.85	2.79	3.78	4.96	5.50	6.74	8.11	9.52	10.75	11.51	12.87	13.91	17.68	20.75	24.95	2
100	0.99	1.58	2.00	3.06	4.21	5.66	6.34	7.80	9.44	11.17	12.52	13.25	14.67	15.74	19.79	22.92	27.38	3
200	1.07	1.69	2.13	3.32	4.65	6.40	7.27	8.97	10.93	13.04	14.52	15.17	16.61	17.71	22.03	25.16	29.88	3
500	1.16	1.84	2.31	3.68	5.28	7.50	8.66	10.74	13.21	15.91	17.56	18.09	19.45	20.57	25.19	28.25	33.27	3
1000	1.24	1.95	2.45	3.96	5.78	8.43	9.86	12.28	15.21	18.45	20.20	20.60	21.82	22.93	27.77	30.68	35.93	3

* These precipitation frequency estimates are based on a partial duration series. ARI is the Average Recurrence Interval.
Please refer to NOAA Atlas 14 Document for more information. NOTE: Formatting forces estimates near zero to appear as zero.

* Upper bound of the 90% confidence interval Precipitation Frequency Estimates (inches)

ARI** (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	(
1	0.53	0.84	1.05	1.44	1.80	2.14	2.31	2.81	3.33	3.79	4.41	4.94	5.69	6.40	8.55	10.58	13.19	1
2	0.62	1.00	1.26	1.74	2.18	2.61	2.81	3.42	4.05	4.61	5.34	5.96	6.86	7.67	10.19	12.57	15.59	1
5	0.73	1.17	1.48	2.10	2.70	3.31	3.58	4.37	5.21	5.95	6.84	7.54	8.61	9.49	12.40	15.07	18.46	2
10	0.81	1.30	1.64	2.38	3.10	3.89	4.24	5.17	6.21	7.12	8.14	8.89	10.08	11.02	14.22	17.10	20.79	2
25	0.91	1.46	1.85	2.73	3.64	4.72	5.20	6.36	7.68	8.92	10.12	10.90	12.22	13.22	16.84	19.93	24.02	2
50	0.99	1.58	2.00	3.01	4.08	5.42	6.03	7.40	8.98	10.53	11.88	12.65	14.03	15.10	19.02	22.22	26.59	3
100	1.07	1.70	2.15	3.30	4.54	6.17	6.94	8.54	10.44	12.36	13.88	14.60	16.02	17.12	21.37	24.60	29.25	3
200	1.15	1.82	2.30	3.58	5.02	6.98	7.94	9.82	12.08	14.45	16.15	16.78	18.20	19.34	23.88	27.09	32.04	3
500	1.25	1.99	2.50	3.98	5.71	8.18	9.47	11.76	14.60	17.74	19.64	20.14	21.47	22.62	27.52	30.62	35.88	3
1000	1.34	2.11	2.65	4.29	6.27	9.22	10.80	13.47	16.79	20.68	22.73	23.10	24.25	25.40	30.54	33.44	38.97	4

* The **upper** bound of the confidence interval at 90% confidence level is the value which 5% of the simulated quantile values for a given frequency are **greater** than.
** These precipitation frequency estimates are based on a partial duration series. **ARI** is the Average Recurrence Interval.

Please refer to NOAA Atlas 14 Document for more information. NOTE: Formatting prevents estimates near zero to appear as zero.

* Lower bound of the 90% confidence interval Precipitation Frequency Estimates (inches)

ARI** (years)	5 min	10 min	15 min	30 min	60 min	120 min	3 hr	6 hr	12 hr	24 hr	48 hr	4 day	7 day	10 day	20 day	30 day	45 day	(

TABLE 5-2
VALUES OF RUNOFF COEFFICIENT (C) FOR RATIONAL FORMULA

Land Use	C	Land Use	C
Business:		Lawns:	
Downtown areas	0.70-0.95	Sandy soil, flat, 2%	0.05-0.10
Neighborhood areas	0.50-0.70	Sandy soil, average, 2-7%	0.10-0.15
		Sandy soil, steep, 7%	0.15-0.20
		Heavy soil, flat, 2%	0.13-0.17
		Heavy soil, average, 2-7%	0.18-0.22
		Heavy soil, steep, 7%	0.25-0.35
Residential:		Agricultural land:	
Single-family areas	0.30-0.50	Bare packed soil	
Multi units, detached	0.40-0.60	* Smooth	0.30-0.60
Multi units, attached	0.60-0.75	* Rough	0.20-0.50
Suburban	0.25-0.40	Cultivated rows	
		* Heavy soil, no crop	0.30-0.60
		* Heavy soil, with crop	0.20-0.50
		* Sandy soil, no crop	0.20-0.40
		* Sandy soil, with crop	0.10-0.25
		Pasture	
		* Heavy soil	0.15-0.45
		* Sandy soil	0.05-0.25
		Woodlands	0.05-0.25
Industrial:		Streets:	
Light areas	0.50-0.80	Asphaltic	0.70-0.95
Heavy areas	0.60-0.90	Concrete	0.80-0.95
		Brick	0.70-0.85
Parks, cemeteries	0.10-0.25	Unimproved areas	0.10 0.30
Playgrounds	0.20-0.35	Drives and walks	0.75-0.85
Railroad yard areas	0.20-0.40	Roofs	0.75-0.95

Note: The designer must use judgement to select the appropriate "C" value within the range. Generally, larger areas with permeable soils, flat slopes and dense vegetation should have the lowest C values. Smaller areas with dense soils, moderate to steep slopes, and sparse vegetation should be assigned the highest C values.

Source: American Society of Civil Engineers

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**1.810**	**0.35**	0.634
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
Totals	1.81		0.63

Manning's n for Sheet Flow	
Surface Description	n
Smooth surfaces (concrete, asphalt, gravel, or bare soil)	0.011
Fallow (no residue)	0.050
Cultivated soils:	
- Residue cover <= 20%	0.060
- Residue cover > 20%	0.170
Grass types:	
- Short grass prairie	0.150
- Dense grass[1]	0.240
- Bermuda grass	0.410
Range (natural)	0.130
Woods:[2]	
- Light underbrush	0.400
- Dense underbrush	0.800

Note: [1] Includes species such as weeping lovegrass, bluegrass, buffalo grass, blue grama grass, and native grass mixtures.

[2] When selecting n, consider cover to a height of about 0.1 ft. This is the only part of the plant cover that will obstruct sheet flow.

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design#1		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Q_p = 6.4 cfs **V = 4.57 ft/sec**

Channel Characteristics				
Depth of Flow, d_F		**d_F =**	**0.09**	**ft**
Min. Freeboard, FB		**FB =**	**0.50**	**ft**
Depth of Channel, d_C	$d_c = d_F + FB$	**d_C =**	**0.59**	**ft**
Side Slopes, m	2H:1V or Flatter minimum	**m =**	**4**	**H:1V**
Manning's n	Use Table to find Roughness Coefficient, n	**n =**	**0.020**	**earth lined-sand**
Channel Design				
Channel Bottom Width , b		**b =**	**0.00**	**ft**
Wetted Area, A	$A = m*d_F^2 + d_F*b$	**A =**	**1.40**	**ft^2**
Wetted Perimeter, P	$P = 2*d_F*(m^2 + 1)^{0.5} + b$	**P =**	**4.88**	**ft**
Slope. S	S = change in elevation/distance for change	**S =**	**0.020**	**ft/ft**
Channel Top Width, w	$w = 2*(m*d_c) + b$	**w =**	**4.73**	**ft**
Discharge				
Discharge, Q	$Q = (1.486/n)*A*R^{2/3}*S^{1/2}$	**Q =**	**6.4**	**cfs**
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	**V =**	**4.57**	**ft/sec**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Drainage Channel#2		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t): 1.55 acres

Q_p = 5.5 cfs

Runoff Coefficient				
Runoff Coefficient, C	CA = sum(Area x "C")	**CA =**	**0.543**	
	Total CA / Total DA	**C =**	**0.350**	
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse				
Time of Concentration				
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c =**	**0.05**	**hrs.**
Overland Flow	See Worksheet Tc	**T_t =**	**SF =**	**0.052**
Shallow Concentrated Flow	See Worksheet Tc	**T_t =**	**SCF =**	**0.000**
Channel Flow	See Worksheet Tc	**T_t =**	**CF =**	**0.000**
Duration				
Duration, D	$D = T_c$	**D =**	**5.00**	**min.**
Frequency				
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F =**	**25**	**year design storm**
Intensity				
Intensity, I		**I =**	**10.16**	**in./hr.**
Discharge				
Discharge, Q_p	Q_p = C*I*A	**Q_p =**	**5.5**	**cfs**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Drainage Channel#2		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	aa	**Date:**	8-Nov-44

Input 2 Yr 24-hr Rainfall Depth (P_2):	**4.1**	**in.**

Total T_c =	**0.05**	**hrs.**

Sheet Flow						
Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	100					ft
Input Surface Slope, S	0.250					ft/ft
Sheet Flow Time	0.052	0.000	0.000	0.000	0.000	hrs.
Sheet Flow Time =	$\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$			**Total SF =**	**0.052**	**hrs.**

Shallow Concentrated Flow						
Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	13					ft
Water Course Slope, S	0.250					ft/ft
Average Velocity, V	8.07	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$ Shallow Concentrated Flow Time = L/(3600*V)				**Total SCF =**	**0.000**	

Channel Flow						
Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
R = A/P	$V = (1.49*R^{2/3}*S^{1/2}) / n$ Channel Flow Time = L/(3600*V)			**Total CF =**	**0.000**	**hrs.**

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**1.550**	**0.35**	0.543
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0

Totals	1.55		0.54

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Drainage Channel#2		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Q_p = 5.5 cfs

V = 4.40 ft/sec

Channel Characteristics				
Depth of Flow, d_F		**d_F =**	**0.06**	**ft**
Min. Freeboard, FB		**FB =**	**0.50**	**ft**
Depth of Channel, d_C	$d_c = d_F + FB$	**d_C =**	**0.56**	**ft**
Side Slopes, m	2H:1V or Flatter minimum	**m =**	**4**	**H:1V**
Manning's n	Use Table to find Roughness Coefficient, n	**n =**	**0.020**	**earth lined-sandy soils**
Channel Design				
Channel Bottom Width , b		**b =**	**0.00**	**ft**
Wetted Area, A	$A = m^*d_F^2 + d_F^*b$	**A =**	**1.25**	**ft^2**
Wetted Perimeter, P	$P = 2^*d_F^*(m^2 + 1)^{0.5} + b$	**P =**	**4.61**	**ft**
Slope. S	S = change in elevation/distance for change	**S =**	**0.020**	**ft/ft**
Channel Top Width, w	$w = 2^*(m^*d_c) + b$	**w =**	**4.47**	**ft**
Discharge				
Discharge, Q	$Q = (1.486/n)^*A^*R^{2/3*}S^{1/2}$	**Q =**	**5.5**	**cfs**
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	**V =**	**4.40**	**ft/sec**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #3		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t): 1.02 acres

Q_p = 3.6 cfs

Runoff Coefficient				
Runoff Coefficient, C	CA = sum(Area x "C")	**CA =**	**0.357**	
	C = Total CA / Total DA	**C =**	**0.350**	
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse				
Time of Concentration				
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c =**	**0.10**	**hrs.**
Overland Flow	See Worksheet Tc	**T_t =**	**SF =**	**0.100**
Shallow Concentrated Flow	See Worksheet Tc	**T_t =**	**SCF =**	**0.001**
Channel Flow	See Worksheet Tc	**T_t =**	**CF =**	**0.000**
Duration				
Duration, D	$D = T_c$	**D =**	**7.00**	**min.**
Frequency				
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F =**	**25**	**year design storm**
Intensity				
Intensity, I		**I =**	**10.16**	**in./hr.**
Discharge				
Discharge, Q_p	Q_p = C*I*A	**Q_p =**	**3.6**	**cfs**

Project Name:	IP Riegelwood Liner System
Project No.:	31826746
File Name:	Final Cover Channel Design #3
Design Engineer:	Lenore Gaier — **Date:** 7-May-09
Checked By:	Meme Diaz — **Date:** 4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2): 4.1 in.

Total T_c = 0.10 hrs.

Sheet Flow

Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	100					ft
Input Surface Slope, S	0.050					ft/ft
Sheet Flow Time	0.100	0.000	0.000	0.000	0.000	hrs.
Sheet Flow Time = $\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$				**Total SF =**	**0.100**	**hrs.**

Shallow Concentrated Flow

Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	18					ft
Water Course Slope, S	0.050					ft/ft
Average Velocity, V	3.61	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0.001	0.000	0.000	0.000	0.000	hrs.
Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$ Shallow Concentrated Flow Time = L/(3600*V)				**Total SCF =**	**0.001**	

Channel Flow

Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
R = A/P $V = (1.49*R^{2/3}*S^{1/2}) / n$ Channel Flow Time = L/(3600*V)				**Total CF =**	**0.000**	**hrs.**

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**1.020**	**0.35**	0.357
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
Totals	1.02		0.36

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #3		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Q_p = 3.6 cfs **V = 1.60 ft/sec**

Channel Characteristics				
Depth of Flow, d_F		d_F =	-0.16	ft
Min. Freeboard, FB		FB =	0.50	ft
Depth of Channel, d_C	$d_c = d_F + FB$	d_C =	0.34	ft
Side Slopes, m	2H:1V or Flatter minimum	m =	20	H:1V
Manning's n	Use Table to find Roughness Coefficient, n	n =	0.020	earth lined-sandy soils
Channel Design				
Channel Bottom Width , b		b =	0.00	ft
Wetted Area, A	$A = m*d_F^2 + d_F*b$	A =	2.25	ft^2
Wetted Perimeter, P	$P = 2*d_F*(m^2 + 1)^{0.5} + b$	P =	13.44	ft
Slope. S	S = change in elevation/distance for change	S =	0.005	ft/ft
Channel Top Width, w	$w = 2*(m*d_c) + b$	w =	13.43	ft
Discharge				
Discharge, Q	$Q = (1.486/n)*A*R^{2/3}*S^{1/2}$	Q =	3.6	cfs
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	V =	1.60	ft/sec

Project Name:	IP Reigelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #4a		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t):	**2.65 acres**

Q_p =	**9.4**	**cfs**

Runoff Coefficient		
Runoff Coefficient, C	CA = sum(Area x "C") C = Total CA / Total DA	**CA = 0.928** **C = 0.350**
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse		
Time of Concentration		
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c = 0.05 hrs.**
Overland Flow	See Worksheet Tc	**T_t = SF = 0.052**
Shallow Concentrated Flow	See Worksheet Tc	**T_t = SCF = 0.001**
Channel Flow	See Worksheet Tc	**T_t = CF = 0.000**
Duration		
Duration, D	D = T_c	**D = 5.00 min.**
Frequency		
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F = 25 year design storm**
Intensity		
Intensity, I		**I = 10.16 in./hr.**
Discharge		
Discharge, Q_p	Q_p = C*I*A	**Q_p = 9.4 cfs**

Project Name:	IP Reigelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #4a		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2):	**4.1**	**in.**

Total T_c =	**0.05**	**hrs.**

Sheet Flow

Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	100					ft
Input Surface Slope, S	0.250					ft/ft
Sheet Flow Time	0.052	0.000	0.000	0.000	0.000	hrs.

Sheet Flow Time = $\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$ **Total SF = 0.052 hrs.**

Shallow Concentrated Flow

Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	17					ft
Water Course Slope, S	0.250					ft/ft
Average Velocity, V	8.07	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0.001	0.000	0.000	0.000	0.000	hrs.

Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$
Shallow Concentrated Flow Time = L/(3600*V)

Total SCF = 0.001

Channel Flow

Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.

R = A/P $V = (1.49*R^{2/3}*S^{1/2}) / n$ Channel Flow Time = L/(3600*V)

Total CF = 0.000 hrs.

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**2.650**	**0.35**	0.928
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
Totals	2.65		0.93

Project Name:	IP Reigelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #4a		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Q_p = 9.4 cfs

V = 2.95 ft/sec

Channel Characteristics				
Depth of Flow, d_F		**d_F =**	**0.18**	**ft**
Min. Freeboard, FB		**FB =**	**0.50**	**ft**
Depth of Channel, d_C	$d_c = d_F + FB$	**d_C =**	**0.68**	**ft**
Side Slopes, m	2H:1V or Flatter minimum	**m =**	**4**	**H:1V**
Manning's n	Use Table to find Roughness Coefficient, n	**n =**	**0.020**	**earth lined-sandy soils**
Channel Design				
Channel Bottom Width , b		**b =**	**2.00**	**ft**
Wetted Area, A	$A = m^*d_F^2 + d_F^*b$	**A =**	**3.19**	**ft^2**
Wetted Perimeter, P	$P = 2^*d_F^*(m^2 + 1)^{0.5} + b$	**P =**	**7.58**	**ft**
Slope. S	S = change in elevation/distance for change	**S =**	**0.005**	**ft/ft**
Channel Top Width, w	$w = 2^*(m^*d_c) + b$	**w =**	**7.42**	**ft**
Discharge				
Discharge, Q	$Q = (1.486/n)^*A^*R^{2/3}*S^{1/2}$	**Q =**	**9.4**	**cfs**
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	**V =**	**2.95**	**ft/sec**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #5		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t):	**1.01 acres**
Q_p =	**3.6 cfs**

Runoff Coefficient				
Runoff Coefficient, C	CA = sum(Area x "C") C = Total CA / Total DA	**CA =** **C =**	**0.354** **0.350**	
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse				
Time of Concentration				
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c =**	**0.05**	**hrs.**
Overland Flow	See Worksheet Tc	**T_t =**	**SF =**	**0.046**
Shallow Concentrated Flow	See Worksheet Tc	**T_t =**	**SCF =**	**0.000**
Channel Flow	See Worksheet Tc	**T_t =**	**CF =**	**0.000**
Duration				
Duration, D	D = T_c	**D =**	**5.00**	**min.**
Frequency				
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F =**	**25**	**year design storm**
Intensity				
Intensity, I		**I =**	**10.16**	**in./hr.**
Discharge				
Discharge, Q_p	Q_p = C*I*A	**Q_p =**	**3.6**	**cfs**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #5		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2): **4.1 in.**

Total T_c = 0.05 hrs.

Sheet Flow						
Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	85					ft
Input Surface Slope, S	0.250					ft/ft
Sheet Flow Time	0.046	0.000	0.000	0.000	0.000	hrs.
Sheet Flow Time =	$\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$			**Total SF =**	**0.046**	**hrs.**
Shallow Concentrated Flow						
Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	0					ft
Water Course Slope, S	0.250					ft/ft
Average Velocity, V	8.07	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0	0.000	0.000	0.000	0.000	hrs.
Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$ Shallow Concentrated Flow Time = L/(3600*V)				**Total SCF =**	**0.000**	
Channel Flow						
Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
R = A/P $V = (1.49*R^{2/3}*S^{1/2}) / n$ Channel Flow Time = L/(3600*V)				**Total CF =**	**0.000**	**hrs.**

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**1.010**	**0.35**	0.354
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0

Totals	1.01		0.35

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #5		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Q_p = 3.6 cfs **V = 2.28 ft/sec**

Channel Characteristics				
Depth of Flow, d_F		d_F =	-0.07	ft
Min. Freeboard, FB		FB =	0.50	ft
Depth of Channel, d_C	$d_c = d_F + FB$	d_C =	0.43	ft
Side Slopes, m	2H:1V or Flatter minimum	m =	4	H:1V
Manning's n	Use Table to find Roughness Coefficient, n	n =	0.020	earth lined-sandy soils
Channel Design				
Channel Bottom Width , b		b =	2.00	ft
Wetted Area, A	$A = m*d_F^2 + d_F*b$	A =	1.58	ft^2
Wetted Perimeter, P	$P = 2*d_F*(m^2 + 1)^{0.5} + b$	P =	5.51	ft
Slope. S	S = change in elevation/distance for change	S =	0.005	ft/ft
Channel Top Width, w	$w = 2*(m*d_c) + b$	w =	5.41	ft
Discharge				
Discharge, Q	$Q = (1.486/n)*A*R^{2/3}*S^{1/2}$	Q =	3.6	cfs
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	V =	2.28	ft/sec

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #6		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t): 1.99 acres

Q_p = 7.1 cfs

Runoff Coefficient		
Runoff Coefficient, C	CA = sum(Area x "C") C = Total CA / Total DA	**CA = 0.697** **C = 0.350**
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse		
Time of Concentration		
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c = 0.05 hrs.**
Overland Flow	See Worksheet Tc	**T_t = SF = 0.052**
Shallow Concentrated Flow	See Worksheet Tc	**T_t = SCF = 0.000**
Channel Flow	See Worksheet Tc	**T_t = CF = 0.000**
Duration		
Duration, D	D = T_c	**D = 5.00 min.**
Frequency		
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F = 25 year design storm**
Intensity		
Intensity, I		**I = 10.16 in./hr.**
Discharge		
Discharge, Q_p	Q_p = C*I*A	**Q_p = 7.1 cfs**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #6		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2): **4.1 in.**

Total T_c = 0.05 hrs.

Sheet Flow						
Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	100					ft
Input Surface Slope, S	0.250					ft/ft
Sheet Flow Time	0.052	0.000	0.000	0.000	0.000	hrs.
Sheet Flow Time =	$\frac{[0.007(n^*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$			**Total SF =**	**0.052**	**hrs.**

Shallow Concentrated Flow						
Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	9					ft
Water Course Slope, S	0.250					ft/ft
Average Velocity, V	8.07	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
Paved: $V = 20.3282^*S^{1/2}$ Unpaved: $V = 16.1345^*S^{1/2}$ Shallow Concentrated Flow Time = L/(3600*V)				**Total SCF =**	**0.000**	

Channel Flow						
Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
R = A/P	$V = (1.49^*R^{2/3*}S^{1/2}) / n$ Channel Flow Time = L/(3600*V)			**Total CF =**	**0.000**	**hrs.**

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**1.990**	**0.35**	0.697
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0

Totals	1.99		0.70

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #6		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Q_p = 7.1 cfs

V = 4.69 ft/sec

Channel Characteristics				
Depth of Flow, d_F		**d_F =**	**0.12**	**ft**
Min. Freeboard, FB		**FB =**	**0.50**	**ft**
Depth of Channel, d_C	$d_c = d_F + FB$	**d_C =**	**0.62**	**ft**
Side Slopes, m	2H:1V or Flatter minimum	**m =**	**4**	**H:1V**
Manning's n	Use Table to find Roughness Coefficient, n	**n =**	**0.020**	**earth lined-sandy soils**
Channel Design				
Channel Bottom Width , b		**b =**	**0.00**	**ft**
Wetted Area, A	$A = m*d_F^2 + d_F*b$	**A =**	**1.51**	**ft^2**
Wetted Perimeter, P	$P = 2*d_F*(m^2 + 1)^{0.5} + b$	**P =**	**5.07**	**ft**
Slope. S	S = change in elevation/distance for change	**S =**	**0.020**	**ft/ft**
Channel Top Width, w	$w = 2*(m*d_c) + b$	**w =**	**4.92**	**ft**
Discharge				
Discharge, Q	$Q = (1.486/n)*A*R^{2/3}*S^{1/2}$	**Q =**	**7.1**	**cfs**
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	**V =**	**4.69**	**ft/sec**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #7		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t): **1.77 acres**	**Q_p = 6.3 cfs**

Runoff Coefficient				
Runoff Coefficient, C	CA = sum(Area x "C") C = Total CA / Total DA	**CA =** **C =**	**0.620** **0.350**	
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse				
Time of Concentration				
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c =**	**0.05**	**hrs.**
Overland Flow	See Worksheet Tc	**T_t =**	**SF =**	**0.052**
Shallow Concentrated Flow	See Worksheet Tc	**T_t =**	**SCF =**	**0.000**
Channel Flow	See Worksheet Tc	**T_t =**	**CF =**	**0.000**
Duration				
Duration, D	D = T_c	**D =**	**5.00**	**min.**
Frequency				
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F =**	**25**	**year design storm**
Intensity				
Intensity, I		**I =**	**10.16**	**in./hr.**
Discharge				
Discharge, Q_p	Q_p = C*I*A	**Q_p =**	**6.3**	**cfs**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #7		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2):	**4.1**	**in.**

Total T_c =	**0.05**	**hrs.**

Sheet Flow

Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	100					ft
Input Surface Slope, S	0.250					ft/ft
Sheet Flow Time	0.052	0.000	0.000	0.000	0.000	hrs.
Sheet Flow Time =	$\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$			**Total SF =**	**0.052**	**hrs.**

Shallow Concentrated Flow

Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	9					ft
Water Course Slope, S	0.250					ft/ft
Average Velocity, V	8.07	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$ Shallow Concentrated Flow Time = L/(3600*V)				**Total SCF =**	**0.000**	

Channel Flow

Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
R = A/P $V = (1.49*R^{2/3}*S^{1/2}) / n$ Channel Flow Time = L/(3600*V)				**Total CF =**	**0.000**	**hrs.**

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**1.770**	**0.35**	0.620
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0

Totals	1.77		0.62

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #7		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Q_p = 6.3 cfs

V = 4.55 ft/sec

Channel Characteristics				
Depth of Flow, d_F		d_F =	0.09	ft
Min. Freeboard, FB		FB =	0.50	ft
Depth of Channel, d_C	$d_c = d_F + FB$	d_C =	0.59	ft
Side Slopes, m	2H:1V or Flatter minimum	m =	4	H:1V
Manning's n	Use Table to find Roughness Coefficient, n	n =	0.020	earth lined-sandy soils
Channel Design				
Channel Bottom Width , b		b =	0.00	ft
Wetted Area, A	$A = m*d_F^2 + d_F*b$	A =	1.38	ft^2
Wetted Perimeter, P	$P = 2*d_F*(m^2 + 1)^{0.5} + b$	P =	4.85	ft
Slope. S	S = change in elevation/distance for change	S =	0.020	ft/ft
Channel Top Width, w	$w = 2*(m*d_c) + b$	w =	4.70	ft
Discharge				
Discharge, Q	$Q = (1.486/n)*A*R^{2/3}*S^{1/2}$	Q =	6.3	cfs
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	V =	4.55	ft/sec

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #8		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t): 1.28 acres

Q_p = 4.6 cfs

Runoff Coefficient				
Runoff Coefficient, C	CA = sum(Area x "C") C = Total CA / Total DA	**CA =** **C =**	**0.448** **0.350**	
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse				
Time of Concentration				
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c =**	**0.05**	**hrs.**
Overland Flow	See Worksheet Tc	**T_t =**	**SF =**	**0.052**
Shallow Concentrated Flow	See Worksheet Tc	**T_t =**	**SCF =**	**0.001**
Channel Flow	See Worksheet Tc	**T_t =**	**CF =**	**0.000**
Duration				
Duration, D	D = T_c	**D =**	**5.00**	**min.**
Frequency				
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F =**	**25**	**year design storm**
Intensity				
Intensity, I		**I =**	**10.16**	**in./hr.**
Discharge				
Discharge, Q_p	Q_p = C*I*A	**Q_p =**	**4.6**	**cfs**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #8		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2):	**4.1**	**in.**

Total T_c =	**0.05**	**hrs.**

Sheet Flow

Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	100					ft
Input Surface Slope, S	0.250					ft/ft
Sheet Flow Time	0.052	0.000	0.000	0.000	0.000	hrs.

Sheet Flow Time = $\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$ **Total SF = 0.052 hrs.**

Shallow Concentrated Flow

Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	29					ft
Water Course Slope, S	0.250					ft/ft
Average Velocity, V	8.07	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0.001	0.000	0.000	0.000	0.000	hrs.

Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$
Shallow Concentrated Flow Time = L/(3600*V) **Total SCF = 0.001**

Channel Flow

Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.

R = A/P $V = (1.49*R^{2/3}*S^{1/2}) / n$ Channel Flow Time = L/(3600*V) **Total CF = 0.000 hrs.**

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**1.280**	**0.35**	0.448
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0

Totals	1.28		0.45

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #8		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	

Q_p = 4.6 cfs

V = 4.21 ft/sec

Channel Characteristics				
Depth of Flow, d_F		**d_F =**	**0.02**	**ft**
Min. Freeboard, FB		**FB =**	**0.50**	**ft**
Depth of Channel, d_C	$d_c = d_F + FB$	**d_C =**	**0.52**	**ft**
Side Slopes, m	2H:1V or Flatter minimum	**m =**	**4**	**H:1V**
Manning's n	Use Table to find Roughness Coefficient, n	**n =**	**0.020**	**earth lined-sandy soils**
Channel Design				
Channel Bottom Width , b		**b =**	**0.00**	**ft**
Wetted Area, A	$A = m*d_F^2 + d_F*b$	**A =**	**1.09**	**ft^2**
Wetted Perimeter, P	$P = 2*d_F*(m^2 + 1)^{0.5} + b$	**P =**	**4.31**	**ft**
Slope. S	S = change in elevation/distance for change	**S =**	**0.020**	**ft/ft**
Channel Top Width, w	$w = 2*(m*d_c) + b$	**w =**	**4.18**	**ft**
Discharge				
Discharge, Q	$Q = (1.486/n)*A*R^{2/3}*S^{1/2}$	**Q =**	**4.6**	**cfs**
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	**V =**	**4.21**	**ft/sec**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #9		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t):	**0.95 acres**	**Q_p =**	**3.4 cfs**

Runoff Coefficient				
Runoff Coefficient, C	CA = sum(Area x "C") C = Total CA / Total DA	**CA =** **C =**	**0.333** **0.350**	
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse				
Time of Concentration				
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c =**	**0.10**	**hrs.**
Overland Flow	See Worksheet Tc	**T_t =**	**SF =**	**0.100**
Shallow Concentrated Flow	See Worksheet Tc	**T_t =**	**SCF =**	**0.001**
Channel Flow	See Worksheet Tc	**T_t =**	**CF =**	**0.000**
Duration				
Duration, D	D = T_c	**D =**	**7.00**	**min.**
Frequency				
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F =**	**25**	**year design storm**
Intensity				
Intensity, I		**I =**	**10.16**	**in./hr.**
Discharge				
Discharge, Q_p	Q_p = C*I*A	**Q_p =**	**3.4**	**cfs**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #9		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2): **4.1** **in.**

Total T_c = 0.10 hrs.

Sheet Flow						
Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	100					ft
Input Surface Slope, S	0.050					ft/ft
Sheet Flow Time	0.100	0.000	0.000	0.000	0.000	hrs.
Sheet Flow Time =	$\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$			**Total SF =**	**0.100**	**hrs.**

Shallow Concentrated Flow						
Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	18					ft
Water Course Slope, S	0.050					ft/ft
Average Velocity, V	3.61	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0.001	0.000	0.000	0.000	0.000	hrs.
Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$ Shallow Concentrated Flow Time = L/(3600*V)				**Total SCF =**	**0.001**	

Channel Flow						
Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
R = A/P $V = (1.49*R^{2/3}*S^{1/2}) / n$ Channel Flow Time = L/(3600*V)				**Total CF =**	**0.000**	**hrs.**

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Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**0.950**	**0.35**	0.333
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
Totals	0.95		0.33

Project Name:	IP Riegelwood Liner System
Project No.:	31826746
File Name:	Final Cover Channel Design #9
Design Engineer:	Lenore Gaier — **Date:** 7-May-09
Checked By:	Meme Diaz — **Date:** 4-Jun-09

Q_p = 3.4 cfs

V = 1.57 ft/sec

Channel Characteristics				
Depth of Flow, d_F		**d_F =**	**-0.17**	**ft**
Min. Freeboard, FB		**FB =**	**0.50**	**ft**
Depth of Channel, d_C	$d_c = d_F + FB$	**d_C =**	**0.33**	**ft**
Side Slopes, m	2H:1V or Flatter minimum	**m =**	**20**	**H:1V**
Manning's n	Use Table to find Roughness Coefficient, n	**n =**	**0.020**	**earth lined-sandy soils**
Channel Design				
Channel Bottom Width , b		**b =**	**0.00**	**ft**
Wetted Area, A	$A = m*d_F^2 + d_F*b$	**A =**	**2.16**	**ft^2**
Wetted Perimeter, P	$P = 2*d_F*(m^2 + 1)^{0.5} + b$	**P =**	**13.16**	**ft**
Slope. S	S = change in elevation/distance for change	**S =**	**0.005**	**ft/ft**
Channel Top Width, w	$w = 2*(m*d_c) + b$	**w =**	**13.14**	**ft**
Discharge				
Discharge, Q	$Q = (1.486/n)*A*R^{2/3}*S^{1/2}$	**Q =**	**3.4**	**cfs**
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	**V =**	**1.57**	**ft/sec**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #10		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t):	**1.27 acres**
Q_p =	**4.5 cfs**

Runoff Coefficient		
Runoff Coefficient, C	CA = sum(Area x "C") C = Total CA / Total DA	**CA = 0.445** **C = 0.350**
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse		
Time of Concentration		
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c = 0.05 hrs.**
Overland Flow	See Worksheet Tc	**T_t = SF = 0.052**
Shallow Concentrated Flow	See Worksheet Tc	**T_t = SCF = 0.001**
Channel Flow	See Worksheet Tc	**T_t = CF = 0.000**
Duration		
Duration, D	$D = T_c$	**D = 5.00 min.**
Frequency		
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F = 25 year design storm**
Intensity		
Intensity, I		**I = 10.16 in./hr.**
Discharge		
Discharge, Q_p	Q_p = C*I*A	**Q_p = 4.5 cfs**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #10		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2): **4.1** **in.**

Total T_c = 0.05 hrs.

Sheet Flow						
Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	100					ft
Input Surface Slope, S	0.250					ft/ft
Sheet Flow Time	0.052	0.000	0.000	0.000	0.000	hrs.
Sheet Flow Time =	$\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$			**Total SF =**	**0.052**	**hrs.**

Shallow Concentrated Flow						
Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	31					ft
Water Course Slope, S	0.250					ft/ft
Average Velocity, V	8.07	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0.001	0.000	0.000	0.000	0.000	hrs.
Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$ Shallow Concentrated Flow Time = L/(3600*V)				**Total SCF =**	**0.001**	

Channel Flow						
Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
R = A/P	$V = (1.49*R^{2/3}*S^{1/2}) / n$		Channel Flow Time = L/(3600*V)	**Total CF =**	**0.000**	**hrs.**

(43)

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**1.270**	**0.35**	0.445
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
Totals	1.27		0.44

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #10		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Q_p = 4.5 cfs **V = 4.19 ft/sec**

Channel Characteristics				
Depth of Flow, d_F		**d_F =**	**0.02**	**ft**
Min. Freeboard, FB		**FB =**	**0.50**	**ft**
Depth of Channel, d_C	$d_c = d_F + FB$	**d_C =**	**0.52**	**ft**
Side Slopes, m	2H:1V or Flatter minimum	**m =**	**4**	**H:1V**
Manning's n	Use Table to find Roughness Coefficient, n	**n =**	**0.020**	**earth lined-sandy soils**
Channel Design				
Channel Bottom Width , b		**b =**	**0.00**	**ft**
Wetted Area, A	$A = m*d_F^2 + d_F*b$	**A =**	**1.07**	**ft^2**
Wetted Perimeter, P	$P = 2*d_F*(m^2 + 1)^{0.5} + b$	**P =**	**4.27**	**ft**
Slope. S	S = change in elevation/distance for change	**S =**	**0.020**	**ft/ft**
Channel Top Width, w	$w = 2*(m*d_c) + b$	**w =**	**4.15**	**ft**
Discharge				
Discharge, Q	$Q = (1.486/n)*A*R^{2/3}*S^{1/2}$	**Q =**	**4.5**	**cfs**
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	**V =**	**4.19**	**ft/sec**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #11		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t): 1.43 acres

Q_p = 5.1 cfs

Runoff Coefficient		
Runoff Coefficient, C	CA = sum(Area x "C") C = Total CA / Total DA	**CA = 0.501** **C = 0.350**
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse		
Time of Concentration		
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c = 0.05 hrs.**
Overland Flow	See Worksheet Tc	**T_t = SF = 0.052**
Shallow Concentrated Flow	See Worksheet Tc	**T_t = SCF = 0.000**
Channel Flow	See Worksheet Tc	**T_t = CF = 0.000**
Duration		
Duration, D	D = T_c	**D = 5.00 min.**
Frequency		
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F = 25 year design storm**
Intensity		
Intensity, I		**I = 10.16 in./hr.**
Discharge		
Discharge, Q_p	Q_p = C*I*A	**Q_p = 5.1 cfs**

Project Name:	IP Riegelwood Liner System
Project No.:	31826746
File Name:	Final Cover Channel Design #11
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2): **4.1** **in.**

Total T_c = 0.05 hrs.

Sheet Flow						
Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	100					ft
Input Surface Slope, S	0.250					ft/ft
Sheet Flow Time	0.052	0.000	0.000	0.000	0.000	hrs.
Sheet Flow Time =	$\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$			**Total SF =**	**0.052**	**hrs.**

Shallow Concentrated Flow						
Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	13					ft
Water Course Slope, S	0.250					ft/ft
Average Velocity, V	8.07	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$ Shallow Concentrated Flow Time = L/(3600*V)				**Total SCF =**	**0.000**	

Channel Flow						
Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
R = A/P	$V = (1.49*R^{2/3}*S^{1/2}) / n$	Channel Flow Time = L/(3600*V)		**Total CF =**	**0.000**	**hrs.**

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**1.430**	**0.35**	0.501
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0

Totals	1.43		0.50

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #11		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Q_p = 5.1 cfs

V = 4.32 ft/sec

	Channel Characteristics			
Depth of Flow, d_F		**d_F =**	**0.04**	**ft**
Min. Freeboard, FB		**FB =**	**0.50**	**ft**
Depth of Channel, d_C	$d_c = d_F + FB$	**d_C =**	**0.54**	**ft**
Side Slopes, m	2H:1V or Flatter minimum	**m =**	**4**	**H:1V**
Manning's n	Use Table to find Roughness Coefficient, n	**n =**	**0.020**	**earth lined-sandy soils**
	Channel Design			
Channel Bottom Width , b		**b =**	**0.00**	**ft**
Wetted Area, A	$A = m*d_F^2 + d_F*b$	**A =**	**1.18**	**ft^2**
Wetted Perimeter, P	$P = 2*d_F*(m^2 + 1)^{0.5} + b$	**P =**	**4.48**	**ft**
Slope. S	S = change in elevation/distance for change	**S =**	**0.020**	**ft/ft**
Channel Top Width, w	$w = 2*(m*d_c) + b$	**w =**	**4.35**	**ft**
	Discharge			
Discharge, Q	$Q = (1.486/n)*A*R^{2/3}*S^{1/2}$	**Q =**	**5.1**	**cfs**
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
	Velocity			
Velocity, V	V = Q / A	**V =**	**4.32**	**ft/sec**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #12		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Total DA (A_t):	**0.17 acres**	**Q_p =**	**0.6 cfs**

Runoff Coefficient		
Runoff Coefficient, C	CA = sum(Area x "C") C = Total CA / Total DA	**CA = 0.060** **C = 0.350**
Use Table 5-2 to determine Values of Runoff Coefficient (C) for Rational Formula based on Landuse		
Time of Concentration		
Time of Concentration, T_c	T_c = Calculated from TR-55 (use Worksheet Tc)	**T_c = 0.02 hrs.**
Overland Flow	See Worksheet Tc	**T_t = SF = 0.022**
Shallow Concentrated Flow	See Worksheet Tc	**T_t = SCF = 0.000**
Channel Flow	See Worksheet Tc	**T_t = CF = 0.000**
Duration		
Duration, D	$D = T_c$	**D = 5.00 min.**
Frequency		
Frequency, F	2 year: On-site Storm Drain 5 year: Local Street / Minor System 10 year: Collector Street / Major System 50 year: Culverts Under I-264	**F = 25 year design storm**
Intensity		
Intensity, I		**I = 10.16 in./hr.**
Discharge		
Discharge, Q_p	$Q_p = C*I*A$	**Q_p = 0.6 cfs**

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #12		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Input 2 Yr 24-hr Rainfall Depth (P_2): **4.1** **in.**

Total T_c = 0.02 hrs.

Sheet Flow						
Segment ID	1	2	3	4	5	Units
Input Surface Type (see SF n-table)	grass					
Input Manning's n (see SF n-table)	0.150					
Input Sheet Flow Length (≤ 100 ft), L	34					ft
Input Surface Slope, S	0.250					ft/ft
Sheet Flow Time	0.022	0.000	0.000	0.000	0.000	hrs.
Sheet Flow Time =	$\frac{[0.007(n*L)^{0.8}]}{(P_2)^{0.5}S^{0.4}}$			**Total SF =**	**0.022**	**hrs.**

Shallow Concentrated Flow						
Segment ID	1	2	3	4	5	Units
Surface Description	Unpaved					
Flow Length, L	0					ft
Water Course Slope, S	0.250					ft/ft
Average Velocity, V	8.07	0.00	0.00	0.00	0.00	ft/s
Shallow Concentrated Flow Time	0	0.000	0.000	0.000	0.000	hrs.
Paved: $V = 20.3282*S^{1/2}$ Unpaved: $V = 16.1345*S^{1/2}$ Shallow Concentrated Flow Time = L/(3600*V)				**Total SCF =**	**0.000**	

Channel Flow						
Segment ID	1	2	3	4	5	Units
Flow Area, A						ft^2
Wetted Perimeter, P						ft
Channel Slope, S						ft/ft
Channel Manning's n						
Channel Flow Length, L						ft
Hydraulic Radius, R						ft
Velocity, V						ft/s
Channel Flow Time	0.000	0.000	0.000	0.000	0.000	hrs.
R = A/P	$V = (1.49*R^{2/3}*S^{1/2}) / n$ Channel Flow Time = L/(3600*V)			**Total CF =**	**0.000**	**hrs.**

Landuse	Area (acres)	C value	CA
Disturbed	**0.000**	**0.5**	0.000
Undisturbed	**0.170**	**0.35**	0.060
Road	**0.000**	**0.8**	0.000
			0.000
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0
			0

Totals	0.17		0.06

Project Name:	IP Riegelwood Liner System		
Project No.:	31826746		
File Name:	Final Cover Channel Design #12		
Design Engineer:	Lenore Gaier	**Date:**	7-May-09
Checked By:	Meme Diaz	**Date:**	4-Jun-09

Q_p = 0.6 cfs

V = 1.36 ft/sec

Channel Characteristics				
Depth of Flow, d_F		**d_F =**	**-0.33**	**ft**
Min. Freeboard, FB		**FB =**	**0.50**	**ft**
Depth of Channel, d_C	$d_c = d_F + FB$	**d_C =**	**0.17**	**ft**
Side Slopes, m	2H:1V or Flatter minimum	**m =**	**4**	**H:1V**
Manning's n	Use Table to find Roughness Coefficient, n	**n =**	**0.020**	**earth lined-sandy soils**
Channel Design				
Channel Bottom Width , b		**b =**	**2.00**	**ft**
Wetted Area, A	$A = m*d_F^2 + d_F*b$	**A =**	**0.44**	**ft^2**
Wetted Perimeter, P	$P = 2*d_F*(m^2 + 1)^{0.5} + b$	**P =**	**3.37**	**ft**
Slope. S	S = change in elevation/distance for change	**S =**	**0.005**	**ft/ft**
Channel Top Width, w	$w = 2*(m*d_c) + b$	**w =**	**3.33**	**ft**
Discharge				
Discharge, Q	$Q = (1.486/n)*A*R^{2/3}*S^{1/2}$	**Q =**	**0.6**	**cfs**
Set Q = Q_p by changing d_C. If need more capacity but can't increase depth of channel, increase b.				
Velocity				
Velocity, V	V = Q / A	**V =**	**1.36**	**ft/sec**

URS CALCULATION SHEET	PROJECT IP-Riegelwood Cell 2 Liner System				JOB NO. 31826746	
	SUBJECT Final Cover Drainage Swale Calculations				SHEET NO. 1	
	ORIGINATED B Lenore Gaie	DATE 5/12/2009	CHECKED BY Meme Diaz	DATE 6/4/2009	CALC. NO.	REV. NO.

Velocity

Determine if grass vegetation is adequate lining for the channel

After calculating all the different drainage areas within the final cover
case 6 was the worse case. (See attached map)
Case 6: Q=7.1 cfs and V=4.69 f/s and S=2%

Using Table 5 to determine the maximum permissible velocity
Grass cover consist of Tall Fescue, Lespedeza and Red Top therefore Vmax=5 f/s

V=4<5=Vmax grass lining will be adaquate

Shear Force

Calculate the shear stress exerted by the flowing water on the channel lining

t=∂ x d x S
∂=62.4 lbs/ft3 = unit weight of water
d=0.4 ft = maximum depth
S=2% = slope
t=0.5 lb/ft2

Table 5-4 Permissible Shear Stresses
tp=0.60 lb/ft2 (for class D vegetation)

t=0.51<0.60=tp grass lining will be adaquate

Table 5-2. Classification of Vegetal Covers as to Degree of Retardance.**

Retardance Class	Cover	Condition
A	Weeping lovegrass	Excellent stand, tall, average 0.76 m (2.5 ft)
	Yellow bluestem Ischaemum	Excellent stand, tall, average 0.91 m (3.0 ft)
B	Kudzu	Very dense growth, uncut
	Bermuda grass	Good stand, tall, average 0.30 m (1.0 ft)
	Native grass mixture (Little bluestem, bluestem, blue gamma, and other long and short midwest grasses)	Good stand, unmowed
	Weeping lovegrass	Good stand, tall, average 0.61 m (2.0 ft)
	Lespedeza sericea	Good stand, not woody, tall, average 0.48 m (1.6 ft)
	Alfalfa	Good stand, uncut, average 0.28 m (0.91 ft)
	Weeping lovegrass	Good stand, unmowed, average 0.33 m (1.1 ft)
	Kudzu	Dense growth, uncut
	Blue gamma	Good stand, uncut, average 0.33 m (1.1 ft)
C	Crabgrass	Fair stand, uncut, avg. 0.25 to 1.20 m (0.8 to 4.0 ft)
	Bermuda grass	Good stand, mowed, average 0.15 m (0.5 ft)
	Common lespedeza	Good stand, uncut, average 0.28 m (0.91 ft)
	Grass-legume mixture– summer (orchard grass, redtop Italian ryegrass, and common lespedeza)	Good stand, uncut, average 0.15 to 0.20 m (0.5 to 1.5 ft)
	Centipedegrass	Very dense cover, average 0.15 m (0.5 ft)
	Kentucky bluegrass	Good stand, headed, avg. 0.15 to 0.30 m (0.5 to 1.0 ft)
D	Bermuda grass	Good stand, cut to 0.06 m (0.2 ft)
	Common lespedeza	Excellent stand, uncut, average 0.11 m (0.4 ft)
	Buffalo grass	Good stand, uncut, avg. .08 to 0.15 m (0.3 to 0.5 ft)
	Grass-legume mixture-- fall, spring (orchard grass, redtop, Italian ryegrass, and common lespedeza)	Good stand, uncut, 0.10 to 0.13 m (0.3 to 0.4 ft)
	Lespedeza sericea	After cutting to 0.05 m (0.2 ft) height, very good stand before cutting
E	Bermuda grass	Good stand, cut to average 0.04 m (0.1 ft)
	Bermuda grass	Burned stubble

Note: Covers classified have been tested in experimental channels. Covers were green and generally uniform.

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Table 5-4. Permissible Shear Stresses for Lining Materials.**

Lining Category	Lining Type	Permissible Unit Shear Stress	
		Pa	lb/ft^2
Temporary*	Woven Paper Net	7.2	0.15
	Jute Net	21.6	0.45
	Fiberglass Roving:		
	Single	28.7	0.60
	Double	40.7	0.85
	Straw with Net	69.5	1.45
	Curled Wood Mat	74.3	1.55
	Synthetic Mat	95.7	2.00
Vegetative	Class A	177.2	3.70
	Class B	100.6	2.10
	Class C	47.9	1.00
	Class D	28.7	0.60
	Class E	16.8	0.35
Gravel Riprap	25 mm (1 in)	15.7	0.33
	50 mm (2 in)	31.4	0.67
Rock Riprap	150 mm (6 in)	95.7	2.00
	300 mm (12 in)	191.5	4.00
Bare Soil	Non-cohesive	see chart 23	
	Cohesive	see chart 24	

*Some "temporary linings become permanent when buried.
**Reproduced from HEC-15[34]

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erosiveness of the soil in which the vegetation is growing and the slope of the channel. In this table the channel's soil is divided into two categories defined by the RUSLE's K-value found in Module 2, "erosion resistant" ($K < 0.37$) and "easily eroded" ($K > 0.37$). The values given in Table 5 are for good vegetative stands. If the stand of vegetation used provides less than full coverage, the values in Table 5 should be decreased accordingly.

Table 5. Maximum permissible velocities for vegetation lined channels. (Modified from Ree, 1949 and PA-DER, 1990).

	Maximum Permissible Velocities					
	Erosion Resistant Soils			Easily Eroded Soils		
	K < 0.37			K > 0.37		
	(percent slope)			(percent slope)		
	0-5	5-10	Over 10	0-5	5-10	Over 10
Cover	fps	fps	fps	fps	fps	fps
Bermuda Grass	8	7	6	6	5	4
Buffalo Grass Kentucky Bluegrass						
Smooth Bromegrass	7	6	5	5	4	3
Blue Grama Tall Fescue						
Grass Mixture	5	4	NR[a]	4	3	NR
Reed Canarygrass	5	4	NR	4	3	NR
Lespedeza Weeping Lovegrass Red Top						
Kudzu	3.5	NR	NR	2.5	NR	NR
Alfalfa Red Fescue Crabgrass						
Annuals for Temporary Protection	3.5	NR	NR	2.5	NR	NR
Sudangrass	3.5	NR	NR	2.5	NR	NR

[a]Not Recommeded.

Maximum Allowable Shear Stress or Tractive Force, τ_{all}

Maximum allowable tractive force is a measure of the shear stress exerted by the flowing water on the channel lining. If the actual shear stress, in lbs/ft^2, exceeds the maximum allowable shear stress or tractive force, the flowing water will erode the channel, usually at its deepest depth. Maximum allowable tractive forces for non-cohesive soils smaller than 6.35 mm (sands and gravels) are given in Figure 4. Allowable tractive forces for a wide variety of channel linings are shown in Table 6. The dimensions for the North Carolina rock classification are given in Table 7. Suggested products for use in controlling erosion on side slopes are given in Table 8.

URS

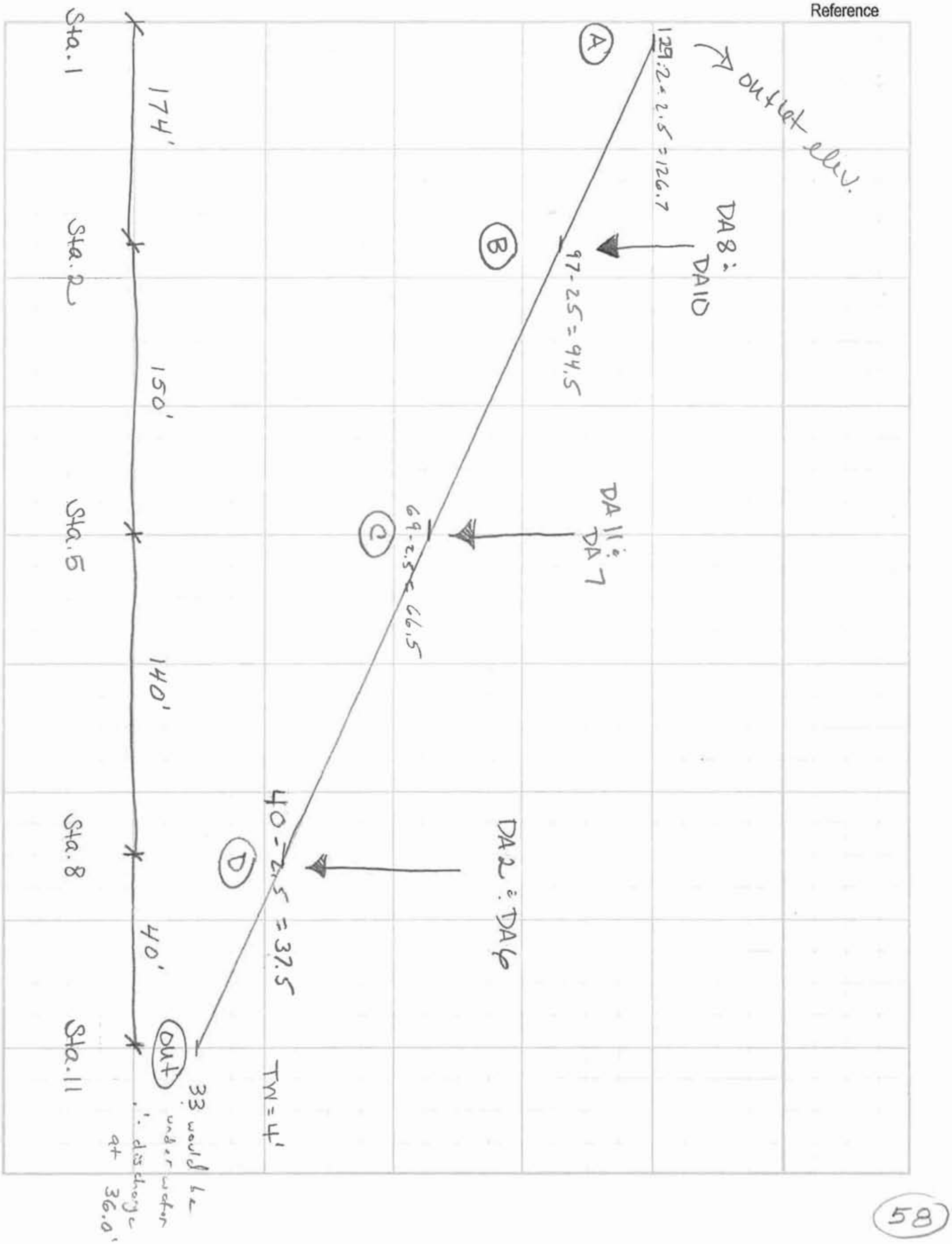
Page ____ of ____

Job Ringwood | Project No. 31826746 | Sheet ____ of ____

Description Down Pipe Sizing | Computed by ________ | Date 6/8/09

A' - NE corner Cell 2 Final Cover | Checked by RKL | Date 6/15/09

Reference



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IP-Riegelwood.xls

INLET COMPUTATION SHEET

English Units

SHEET 1 OF

PROJECT NO. 31826746 COUNTY: Riegelwood Cell 2 Landfill DESIGNED BY: MAD CHECKED BY: LG & MD

LOCATION			ROADWAY			RUNOFF						TOTAL	INLET			
STR NO.	SHT NO.	STA	INLET ELEV	GRADE	CROSS SLOPE	DRAINAGE AREA	RUNOFF COEFF	TIME OF CONC	RAINFALL INTEN	DISCHRG FROM DA	DISCHRG CARYOVR	Q10 DISCHRG	SPREAD	INTRCEPT	BYPASS	REMARKS
1		9	130.20 / 128.70	-	-	0.95	0.35	5.0	10.2	3.38		3.38				OPEN END
2	0	A	129.20 / 126.70	-	-	0.95	0.35	5.0	10.2	3.39		3.39				TEE
	0	8	98.00 / 96.50	-	-	1.27	0.35	5.0	10.2	4.53		4.53				OPEN END
	0	10	98.00 / 96.50	-	-	1.28	0.35	5.0	10.2	4.57		4.57				OPEN END
		B	97.00 / 94.50			3.50	0.35	5.0	10.2	12.50		12.50				TEE
	0	11	70.00 / 68.50	-	-	1.43	0.35	5.0	10.2	5.11		5.11				OPEN END
	0	7	71.00 / 68.50	-	-	1.77	0.35	5.0	10.2	6.32		6.32				OPEN END
	0	C	69.00 / 66.50	-	-	6.70	0.35	5.0	10.2	23.92		23.92				TEE
	0	2	41.00 / 39.50	-	-	1.55	0.35	5.0	10.2	5.53		5.53				OPEN END
	0	6	41.00 / 39.50	-	-	1.99	0.35	5.0	10.2	7.10		7.10				OPEN END
	0	D	40.00 / 37.50	-	-	10.24	0.35	5.0	10.2	36.56		36.56				TEE

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PROJECT NO. 31826746
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STORM DRAIN DESIGN COMPUTATION

English Units

SHEET OF

COUNTY: Riegelwood Cell 2 Landfill   DESIGNED BY: MAD   CHECKED BY: LG & MD

				RUNOFF		PIPE DESIGN													
STR STR	SHT	STA		D.A. ACRE	SUM CA	PROPOSED LENGTH	INLET TIME	FLOW TIME	DESIGN TIME	INT (I)	DISCH Q10	ELEV INL	ELEV OUTL	SLOPE ft/ft	DIA in	CAP cfs	VEL fps	REMARKS
1	0	From	9	0.95	0.33	10.0	1.8	1.8	5.0	10.16	3.4	128.70	126.70	0.200	18	13.0	1.91	OPEN END
2		To	A												**CSP**			Depth= 1.50
2	0	From	A	0.95	0.33	174.0	1.8	1.8	5.0	10.16	3.4	126.70	94.50	0.185	30	43.0	0.69	TEE
0		To	B															Depth= 2.50
0	0	From	8	1.27	0.44	10.0	1.8	6.1	5.0	10.16	4.5	96.50	94.50	0.200	18	13.0	2.56	OPEN END
0		To	B												**CSP**			Depth= 1.50
0	0	From	10	1.28	0.45	10.0	1.8	6.1	5.0	10.16	4.6	96.50	94.50	0.200	18	13.0	2.58	OPEN END
0		To	B												**CSP**			Depth= 1.50
0	0	From	B	3.50	1.23	150.0	1.8	6.1	5.0	10.16	12.4	94.50	66.50	0.187	30	43.0	2.54	TEE
0		To	C															Depth= 2.50
0	0	From	11	1.43	0.50	10.0	1.8	7.1	5.0	10.16	5.1	68.50	66.50	0.200	18	13.0	2.88	OPEN END
0		To	C												**CSP**			Depth= 1.50
0	0	From	7	1.77	0.62	10.0	1.8	7.2	5.0	10.16	6.3	68.50	66.50	0.200	18	13.0	3.56	OPEN END
0		To	C												**CSP**			Depth= 2.50
0	0	From	C	6.70	2.35	140.0	1.8	7.2	5.0	10.16	23.8	66.50	37.50	0.207	30	43.0	4.85	TEE
0		To	D															Depth= 2.50
0	0	From	2	1.55	0.54	10.0	1.8	7.7	5.0	10.16	5.5	39.50	37.50	0.200	18	13.0	3.12	OPEN END
0		To	D												**CSP**			Depth= 1.50
0	0	From	6	1.99	0.70	10.0	1.8	7.7	5.0	10.16	7.1	39.50	37.50	0.200	18	13.0	4.00	OPEN END
0		To	D												**CSP**			Depth= 1.50
0	0	From	D	10.24	3.58	40.0	1.8	7.7	5.0	10.16	36.4	37.50	36.00	0.038	30	43.0	7.42	TEE
0		To	OUT															Depth= 2.50

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PROJECT NO. 31826746
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HYDRAULIC GRADE LINE

English Units

COUNTY: Riegelwood Cell 2 Landfill

DESIGNED BY: MAD

SHEET OF

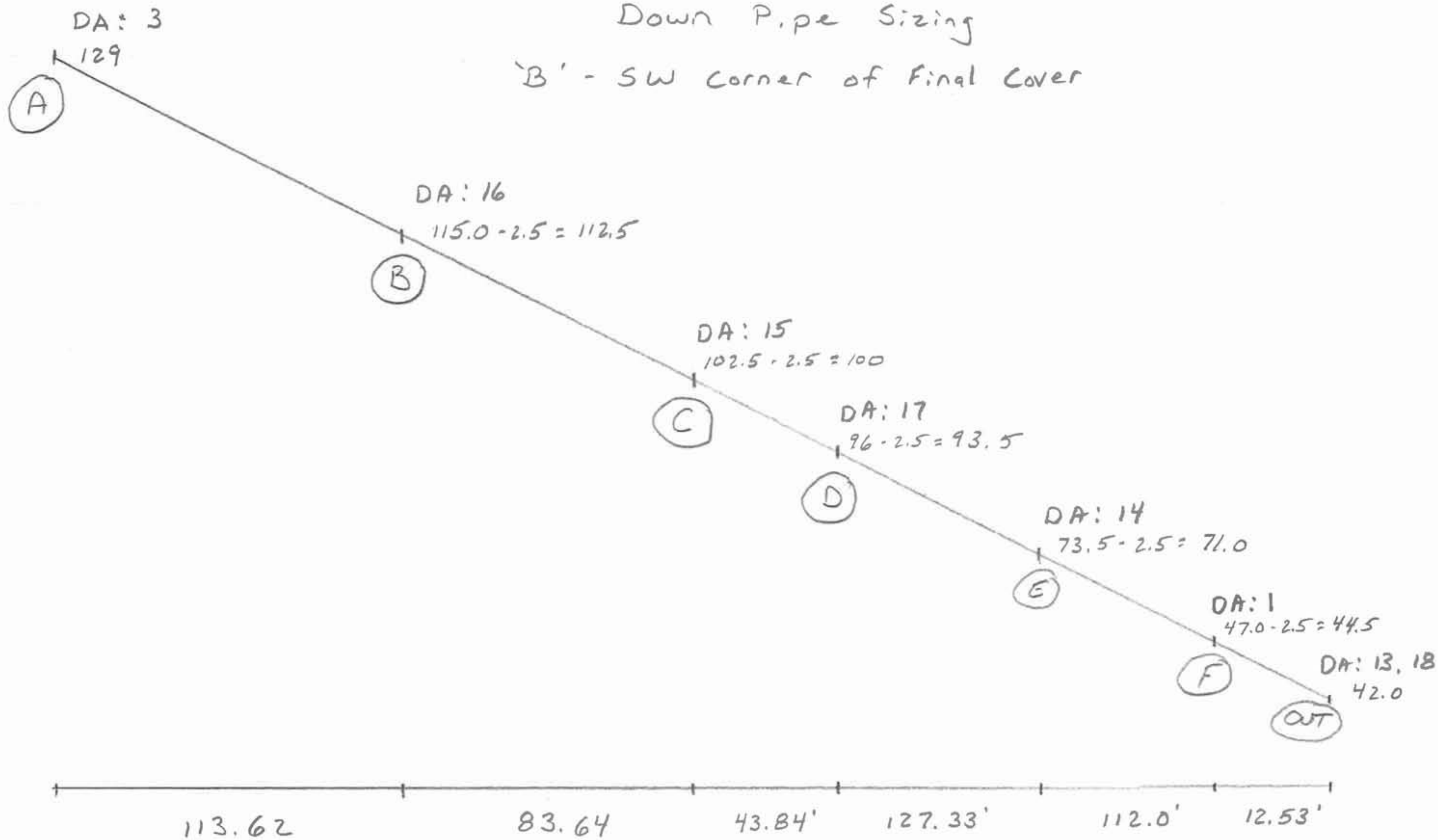
CHECKED BY: LG & MD

STR STR	SHT	STATION	OUTLET W.S. ELEV	Do (in)	Qo	Lo	HEAD LOSSES Hf	Hc	He	Hb	Ht	INLET W.S. ELEV	RIM ELEV	POTENTIAL WATER SURFACE DEPTH BELOW RIM
1	0	From 9	128.70	18	3.38	10.0	0.01	0.01	0.03	0.03	0.08	129.90	130.20	OK - Open End Pipe
2		To A					n=0.024							d=1.20
2	0	From A	96.50	30	3.38	174.0	0.02	0.00	0.02	0.00	0.12	128.70	129.20	0.50
0		To B												
0	0	From 8	96.50	18	4.52	10.0	0.02	0.03	0.00	0.00	0.06	97.70	98.00	OK - Open End Pipe
0		To B					n=0.024							d=1.20
0	0	From 10	95.70	18	4.55	10.0	0.02	0.03	0.05	0.05	0.15	97.70	98.00	OK - Open End Pipe
0		To B					n=0.024							d=1.20
0	0	From B	68.50	30	12.45	150.0	0.18	0.02	0.04	0.00	0.45	96.50	97.00	0.50
0		To C												
0	0	From 11	68.50	18	5.09	10.0	0.03	0.03	0.05	0.05	0.16	69.70	70.00	OK - Open End Pipe
0		To C					n=0.024							d=1.20
0	0	From 7	67.70	18	6.29	10.0	0.05	0.05	0.06	0.06	0.22	69.70	71.00	OK - Open End Pipe
0		To C					n=0.024							d=1.20
0	0	From C	39.50	30	23.83	140.0	0.63	0.09	0.07	0.00	1.17	68.50	69.00	0.50
0		To D												
0	0	From 2	39.50	18	5.51	10.0	0.04	0.04	0.18	0.17	0.43	40.70	41.00	OK - Open End Pipe
0		To D					n=0.024							d=1.20
0	0	From 6	38.70	18	7.08	10.0	0.06	0.06	0.08	0.07	0.27	40.70	41.00	OK - Open End Pipe
0		To D					n=0.024							d=1.20
0	0	From D	38.00	30	36.41	45.0	0.47	0.21	0.09	0.02	1.49	39.50	40.00	0.50
0		To OUT												

IP - Riegelwood Cell 2 Landfill 31826746

Down Pipe Sizing

'B' - SW Corner of Final Cover



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INLET COMPUTATION SHEET

English Units

SHEET 1 OF

PROJECT NO. 31826746 COUNTY: Riegelwood Cell 2 Landfill DESIGNED BY: MAD CHECKED BY: LG & MD

LOCATION		ROADWAY			RUNOFF						TOTAL	INLET			
SHT NO.	STA	INLET ELEV	GRADE	CROSS SLOPE	DRAINAGE AREA	RUNOFF COEFF	TIME OF CONC	RAINFALL INTEN	DISCHRG FROM DA	DISCHRG CARYOVR	Q10 DISCHRG	SPREAD	INTRCEPT	BYPASS	REMARKS
	3	130.70 / 129.20	-	-	1.02	0.35	5.0	10.2	3.63		3.63				OPEN END
0	A	131.50 / 129.00	-	-	1.02	0.35	5.0	10.2	3.64		3.64				TEE
0	16	114.20 / 112.70	-	-	0.28	0.35	5.0	10.2	1.00		1.00				OPEN END
0	B	115.00 / 112.50	-	-	1.30	0.35	5.0	10.2	4.64		4.64				TEE
	15	101.70 / 100.20			1.10	0.35	5.0	10.2	3.93		3.93				OPEN END
0	C	102.50 / 100.00	-	-	2.40	0.35	5.0	10.2	8.57		8.57				TEE
0	17	96.20 / 93.70	-	-	0.48	0.35	5.0	10.2	1.71		1.71				OPEN END
0	D	96.00 / 93.50	-	-	2.88	0.35	5.0	10.2	10.28		10.28				TEE
0	14	72.70 / 71.20	-	-	1.62	0.35	5.0	10.2	5.78		5.78				OPEN END
0	E	73.50 / 71.00	-	-	4.50	0.35	5.0	10.2	16.07		16.07				TEE
0	1	46.20 / 44.70	-	-	1.81	0.35	5.0	10.2	6.46		6.46				OPEN END
0	F	47.00 / 44.50	-	-	6.31	0.35	5.0	10.2	22.53		22.53				TEE
0	13	43.70 / 42.20	-	-	0.50	0.35	5.0	10.2	1.79		1.79				OPEN END
0	18	43.70 / 42.20	-	-	0.51	0.35	5.0	10.2	1.82		1.82				OPEN END
0	Outlet	44.50 / 42.00	-	-	7.32	0.35	5.0	10.2	26.13		26.13				TEE

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MORRISVILLE, NORTH CAROLINA

6/16/2009

IP-Riegelwood.xls
PROJECT NO. 31826746
0

STORM DRAIN DESIGN COMPUTATION

English Units

SHEET OF

COUNTY: Riegelwood Cell 2 Landfill

DESIGNED BY: MAD

CHECKED BY: LG & MD

STR STR	SHT	STA		RUNOFF D.A. ACRE	RUNOFF SUM CA	PIPE DESIGN PROPOSED LENGTH	INLET TIME	FLOW TIME	DESIGN TIME	INT (I)	DISCH Q10	ELEV INL	ELEV OUTL	SLOPE ft/ft	DIA in	CAP cfs	VEL fps	REMARKS
1	0	From	3	1.02	0.36	10.0	1.8	1.8	5.0	10.16	3.6	129.20	129.00	0.020	18	12.8	2.05	OPEN END
2		To	A															Depth= 1.50
2	0	From	A	1.02	0.36	113.6	1.8	1.8	5.0	10.16	3.6	129.00	112.50	0.145	30	43.0	0.74	TEE
0		To	B															Depth= 2.50
0	0	From	16	0.28	0.10	10.0	1.8	4.4	5.0	10.16	1.0	112.70	112.50	0.020	18	12.8	0.56	OPEN END
0		To	B															Depth= 1.50
0	0	From	B	1.30	0.46	83.6	1.8	4.7	5.0	10.16	4.6	112.50	100.00	0.149	30	43.0	0.94	TEE
0		To	C															Depth= 2.50
0	0	From	15	1.10	0.39	10.0	1.8	4.7	5.0	10.16	3.9	100.20	100.00	0.020	18	12.8	2.21	OPEN END
0		To	C															Depth= 1.50
0	0	From	C	2.40	0.84	43.8	1.8	4.8	5.0	10.16	8.5	100.00	93.50	0.148	30	43.0	1.74	TEE
0		To	D															Depth= 2.50
0	0	From	17	0.48	0.17	10.0	1.8	5.2	5.0	10.16	1.7	93.70	93.50	0.020	18	12.8	0.97	OPEN END
0		To	D															Depth= 2.50
0	0	From	D	2.88	1.01	127.3	1.8	5.2	5.0	10.16	10.2	93.50	71.00	0.177	30	43.0	2.09	TEE
0		To	E															Depth= 2.50
0	0	From	14	1.62	0.57	10.0	1.8	6.2	5.0	10.16	5.8	71.20	71.00	0.020	18	12.8	3.26	OPEN END
0		To	E															Depth= 1.50
0	0	From	E	4.50	1.58	112.0	1.8	6.3	5.0	10.16	16.0	71.00	44.50	0.237	30	43.0	3.26	TEE
0		To	F															Depth= 2.50
0	0	From	1	1.81	0.63	10.0	1.8	6.3	5.0	10.16	6.4	44.70	44.50	0.020	18	12.8	3.64	OPEN END
0		To	F															Depth= 1.50
0	0	From	F	6.31	2.21	12.5	1.8	6.8	5.0	10.16	22.4	44.50	42.00	0.200	30	43.0	4.57	TEE
0		To	Outlet															Depth= 2.50
0	0	From	13	0.50	0.18	10.0	1.8	6.9	5.0	10.16	1.8	42.20	42.00	0.020	18	12.8	1.01	OPEN END
0		To	Outlet															Depth= 1.50
0	0	From	18	0.51	0.18	10.0	1.8	7.0	5.0	10.16	1.8	42.20	42.00	0.020	18	12.8	1.03	OPEN END
0		To	Outlet															Depth= 1.50
0	0	From	Outlet	7.32	2.56	10.0	1.8	7.0	5.0	10.16	26.0	42.00	41.00	0.100	30	43.0	5.30	TEE
0		To	OUT															Depth= 2.50

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URS Corporation - North Carolina
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6/16/2009

IP-Riegelwood.xls
PROJECT NO. 31826746
0

HYDRAULIC GRADE LINE

English Units

COUNTY: Riegelwood Cell 2 Landfill

DESIGNED BY: MAD

SHEET OF

CHECKED BY: LG & MD

STR STR	SHT	STATION		OUTLET W.S. ELEV	Do (in)	Qo	Lo	HEAD LOSSES Hf	Hc	He	Hb	Ht	INLET W.S. ELEV	RIM ELEV	POTENTIAL WATER SURFACE DEPTH BELOW RIM
1	0	From	3	131.00	18	3.63	10.0	0.02	0.02	0.03	0.03	0.10	131.10	130.70	OK - Open End Pipe
2		To	A												d=1.90
2	0	From	A	114.50	30	3.63	113.6	0.01	0.00	0.02	0.00	0.13	131.00	131.50	0.50
0		To	B												
0	0	From	16	114.50	18	1.00	10.0	0.00	0.00	0.00	0.00	0.01	114.51	114.20	OK - Open End Pipe
0		To	B												d=1.81
0	0	From	B	102.00	30	4.62	83.6	0.01	0.00	0.00	0.00	0.03	114.50	115.00	0.50
0		To	C												
0	0	From	15	102.00	18	3.91	10.0	0.02	0.02	0.01	0.01	0.05	102.05	101.70	OK - Open End Pipe
0		To	C												d=1.85
0	0	From	C	95.50	30	8.53	43.8	0.03	0.01	0.03	0.04	0.15	102.00	102.50	0.50
0		To	D												
0	0	From	17	95.50	18	1.71	10.0	0.00	0.00	0.02	0.02	0.05	95.55	96.20	OK - Open End Pipe
0		To	D												d=1.85
0	0	From	D	73.00	30	10.24	127.3	0.11	0.02	0.01	0.00	0.18	95.50	96.00	0.50
0		To	E												
0	0	From	14	73.00	18	5.76	10.0	0.04	0.04	0.03	0.03	0.15	73.15	72.70	OK - Open End Pipe
0		To	E												d=1.95
0	0	From	E	46.50	30	16.00	112.0	0.23	0.04	0.06	0.08	0.55	73.00	73.50	0.50
0		To	F												
0	0	From	1	46.50	18	6.44	45.0	0.22	0.05	0.08	0.08	0.44	46.94	46.20	OK - Open End Pipe
0		To	F												d=2.24
0	0	From	F	44.00	30	22.44	12.5	0.05	0.08	0.07	0.00	0.64	46.50	47.00	0.50
0		To	Outlet												
0	0	From	13	44.00	18	1.78	10.0	0.00	0.00	0.16	0.15	0.32	44.32	43.70	OK - Open End Pipe
0		To	Outlet												d=2.12
0	0	From	18	44.00	18	1.81	10.0	0.00	0.00	0.01	0.01	0.02	44.02	43.70	OK - Open End Pipe
0		To	Outlet												d=1.82
0	0	From	Outlet	43.00	30	26.03	45.0	0.24	0.11	0.01	0.00	0.70	44.00	44.50	0.50
0		To	OUT												

P:\Jobs4_Projects\International Paper\IP - Riegelwood\Cell 2 Landfill\Liner Construction Drawings\5.0 Cost Estimate & Bid Form & Calculations\Drainage Calculations\Down Pipe Sizing1.XLS

Riprap Energy Dissipator Design

Project Name:	IP-Riegelwood Cell 2 Liner System		
Project No.:	31826746		
File Name:	HEC-14 Riprap Energy Dissipator Design		
Design Engineer:	Lenore Gaier	**Date:**	11-Jun-09
Checked By:	Meme Diaz	**Date:**	11-Jun-09

HEC-14 Method[1]

Calculations reflect the suggested and minimum suggested basin dimensions. Calculated dimensions may not be utilized in order to adhere to other design considerations.

Pipe Diameter		**D = 2.5 ft.**
10-Year Storm Pipe Flow		**Q = 36.6 cfs**
Constant	K_u = 1.0 for English Units	**K_u = 1.0**
		$\frac{K_u * Q}{D^{2.5}}$ = 3.70
Tail Water		**TW = 0 ft.**
		$\frac{TW}{D}$ = 0
	From HEC-14 Figure 3.4	**$\frac{y_o}{D}$ = 0.64**
Outlet (Brink) Depth	$y_o = \frac{y_o}{D} * D$	**y_o = 1.60 ft.**
	From HEC-14 Table B.2	**$\frac{A}{D^2}$ = 0.53**
Area of Flow	$A = \frac{A}{D\^2} * D^2$	**A = 3.32 ft^2**
Culvert Outlet Velocity	$v_o = \frac{Q}{A}$	**v_o = 11.02 ft/sec**
Equivalent Depth	$y_e = (A/2)^{0.5}$	**y_e = 1.29 ft.**
Froude Number	$Fr = \frac{v_o}{[32.2 * y_e]^{0.5}}$	**Fr = 1.71**
Select a trial D_{50} and obtain h_s/y_e. Ensure $h_s/D_{50} \geq 2$ and $D_{50}/y_e \geq 0.1$		
		h_s/D_{50} = 1.4 **D_{50}/y_e = 0.5**
Riprap Mean Diameter	Class B Stone	**D_{50} = 0.67 ft.** ✓
Acceleration Due to Gravity		**g = 32.2 ft/sec**
		$\frac{TW}{y_e}$ = 0
Tailwater Parameter	C_o = 1.4 when $TW/y_e < 0.75$ = 4.0 * (TW/y_e) - 1.0 when $0.75 < TW/y_e < 1.0$ = 2.4 when $TW/y_e > 1.0$	**C_o = 1.4**

Riprap Energy Dissipator Design

Project Name:	IP-Riegelwood Cell 2 Liner System
Project No.:	31826746
File Name:	HEC-14 Riprap Energy Dissipator Design
Design Engineer:	Lenore Gaier — **Date:** 11-Jun-09
Checked By:	Meme Diaz — **Date:** 11-Jun-09

	$\frac{h_s}{y_e} = 0.86 * (D_{50}/y_e)^{-0.55} * [v_o/(g*y_e)^{0.5}] - C_c$	$\frac{h_s}{y_e}$ = **0.71**
Depth of Scour	$h_s = \frac{h_s}{y_e} * h_s$	h_s = **0.92 ft.**

Basin Size		
Length of Dissipator Pool	$L_s = 10 * h_s$	L_s = **9.2 ft.**
Minimum Length of Dissipator Pool	$L_{s\,min} = 3 * D$	$L_{s\,min}$ = **7.5 ft.**
Length of Apron	$L_A = 5 * h_s$	L_A = **4.6 ft.**
Minimum Length of Apron	$L_{A\,min} = D$	$L_{A\,min}$ = **2.5 ft.**
Total Length of Basin	$L_B = 15 * h_s$	L_B = **13.8 ft.**
Minimimum Total Length of Basin	$L_{B\,min} = 4 * D$	$L_{B\,min}$ = **10.0 ft.**
Width of Basin	$W_B = D + 2*(L_B/3)$	W_B = **11.7 ft.**

Basin Exit Depth		
	$\frac{Q^2}{g} = 41.5 = \frac{A_c^3}{T_c} = 34.0 = \frac{[y_c * (W_B + z*y_c)]^3}{(W_B + 2*z*y_c)} = 13.9$ ft.	
Critical Flow Basin Exit Depth		y_c = **0.08 ft.**
Basin Side Slope		z = **33 ft/ft**
Area of Exit Flow		A_c = **8.8 ft^2**
Top Width of Exit Flow		T_c = **20.3 ft.**
Exit Velocity	$V_c = \frac{Q}{A_c}$	V_c = **4.14 ft/sec**

[1] Hydraulic Engineering Circular No. 14, Third Edition - Hydraulic Design of Energy Dissipators for Culverts and Channels

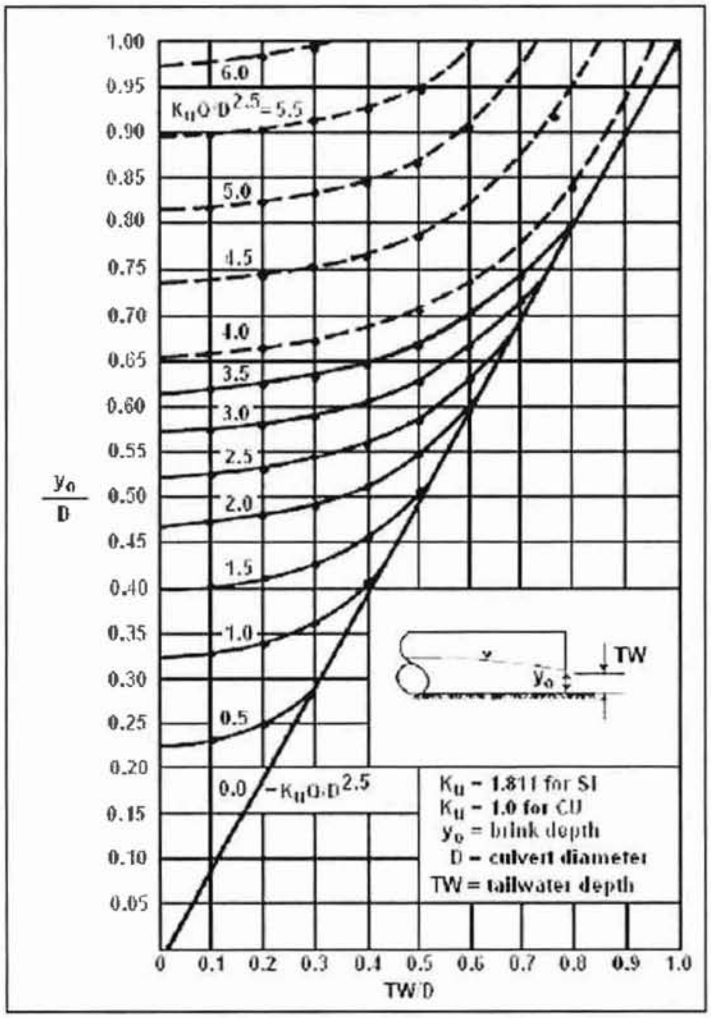


Figure 3.4. Dimensionless Rating Curves for the Outlets of Circular Culverts on Horizontal and Mild Slopes (Simons, 1970)

Table B.2. Uniform Flow in Circular Sections Flowing Partly Full

y/D	A/D^2	R/D	$\frac{(\alpha Qn)}{(D^{8/3} S^{1/2})}$	$\frac{(\alpha Qn)}{(y^{8/3} S^{1/2})}$	y/D	A/D^2	R/D	$\frac{(\alpha Qn)}{(D^{8/3} S^{1/2})}$	$\frac{(\alpha Qn)}{(y^{8/3} S^{1/2})}$
0.01	0.0013	0.0066	0.00007	15.04	0.51	0.4027	0.2531	0.239	1.442
0.02	0.0037	0.0132	0.00031	10.57	0.52	0.4127	0.2562	0.247	0.415
0.03	0.0069	0.0197	0.00074	8.56	0.53	0.4227	0.2592	0.255	1.388
0.04	0.0105	0.0262	0.00138	7.38	0.54	0.4327	0.2621	0.263	1.362
0.05	0.0147	0.0325	0.00222	6.55	0.55	0.4426	0.2649	0.271	1.336
0.06	0.0192	0.0389	0.00328	5.95	0.56	0.4526	0.2676	0.279	1.311
0.07	0.0294	0.0451	0.00455	5.47	0.57	0.1626	0.2703	0.287	1.286
0.08	0.0350	0.0513	0.00604	5.09	0.58	0.4724	0.2728	0.295	1.262
0.09	0.0378	0.0575	0.00775	4.76	0.59	0.4822	0.2753	0.303	1.238
0.10	0.0409	0.0635	0.0097	4.49	0.60	0.4920	0.2776	0.311	1.215
0.11	0.0470	0.0695	0.0118	4.25	0.61	0.5018	0.2799	0.319	1.192
0.12	0.0534	0.0755	0.0142	4.04	0.62	0.5115	0.2821	0.327	1.170
0.13	0.0600	0.0813	0.0167	3.86	0.63	0.5212	0.2842	0.335	1.148
0.14	0.0668	0.0871	0.0195	3.69	0.64	0.5308	0.2862	0.343	1.126
0.15	0.0739	0.0929	0.0225	3.54	0.65	0.5405	0.2988	0.350	1.105
0.16	0.0811	0.0985	0.0257	3.41	0.66	0.5499	0.2900	0.358	1.084
0.17	0.0885	0.1042	0.0291	3.28	0.67	0.5594	0.2917	0.366	1.064
0.18	0.0961	0.1097	0.0327	3.17	0.68	0.5687	0.2933	0.373	1.044
0.19	0.0139	0.1152	0.0365	3.06	0.69	0.5780	0.2948	0.380	1.024
0.20	0.1118	0.1206	0.0406	2.96	0.70	0.5872	0.2962	0.388	1.004
0.21	0.1199	0.1259	0.0448	2.87	0.71	0.5964	0.2975	0.395	0.985
0.22	0.1281	0.1312	0.0492	2.79	0.72	0.6054	0.2987	0.402	0.965
0.23	0.1365	0.1364	0.0537	2.71	0.73	0.6143	0.2998	0.409	0.947
0.24	0.1449	0.1416	0.0585	2.63	0.74	0.6231	0.3008	0.416	0.928
0.25	0.1535	0.1466	0.0634	2.56	0.75	0.6319	0.3042	0.422	0.910
0.26	0.1623	0.1516	0.0686	2.49	0.76	0.6405	0.3043	0.429	0.891
0.27	0.1711	0.1566	0.0739	2.42	0.77	0.6489	0.3043	0.435	0.873
0.28	0.1800	0.1614	0.0793	2.36	0.78	0.6573	0.3041	0.441	0.856
0.29	0.1890	0.1662	0.0849	2.30	0.79	0.6655	0.3039	0.447	0.838
0.30	0.1982	0.1709	0.0907	2.25	0.80	0.6736	0.3042	0.453	0.821
0.31	0.2074	0.1756	0.0966	2.20	0.81	0.6815	0.3043	0.458	0.804
0.32	0.2167	0.1802	0.1027	2.14	0.82	0.6893	0.3043	0.463	0.787
0.33	0.2260	0.1847	0.1089	2.09	0.83	0.6969	0.3041	0.468	0.770
0.34	0.2355	0.1891	0.1153	2.05	0.84	0.7043	0.3038	0.473	0.753
0.35	0.2450	0.1936	0.1218	2.00	0.85	0.7115	0.3033	0.453	0.736
0.36	0.2546	0.1978	0.1284	1.958	0.86	0.7186	0.3026	0.458	0.720
0.37	0.2642	0.2020	0.1351	1.915	0.87	0.7254	0.3018	0.485	0.703
0.38	0.2739	0.2062	0.1420	1.875	0.88	0.7320	0.3007	0.488	0.687
0.39	0.2836	0.2102	0.1490	1.835	0.89	0.7384	0.2995	0.491	0.670
0.40	0.2934	0.2142	0.1561	1.797	0.90	0.7445	0.2980	0.494	0.654
0.41	0.3032	0.2182	0.1633	1.760	0.91	0.7504	0.2963	0.496	0.637
0.42	0.3130	0.2220	0.1705	1.724	0.92	0.7560	0.2944	0.497	0.621
0.43	0.3229	0.2258	0.1779	1.689	0.93	0.7612	0.2921	0.498	0.604
0.44	0.3328	0.2295	0.1854	1.655	0.94	0.7662	0.2895	0.498	0.588
0.45	0.3428	0.2331	0.1929	1.622	0.95	0.7707	0.2865	0.498	0.571
0.46	0.3527	0.2366	0.201	1.590	0.96	0.7749	0.2829	0.496	0.553
0.47	0.3627	0.2401	0.208	1.559	0.97	0.7785	0.2787	0.494	0.535
0.48	0.3727	0.2435	0.216	1.530	0.98	0.7817	0.2735	0.489	0.517
0.49	0.3827	0.2468	0.224	1.500	0.99	0.7841	0.2666	0.483	0.498
0.50	0.3927	0.2500	0.232	1.471	1.00	0.7854	0.2500	0.463	0.463

y = depth of flow, m (ft)
D = diameter of pipe, m (ft)
A = area of flow, m^2 (ft^2)
R= hydraulic radius, m (ft)
Source: USBR (1974)

Q = discharge by Manning's Equation, m^3/s (ft^3/s)
n = Manning's coefficient
S = channel bottom and water surface slope
α = units conversion = 1.49 for SI, 1 for CU

SECTION 1042
RIPRAP MATERIALS

1042-1 PLAIN RIPRAP

Stone for plain riprap consists of field stone or rough unhewn quarry stone. The stone shall be sound, tough, dense, resistant to the action of air and water, and suitable in all other respects for the purpose intended. Where broken concrete from demolished structures or pavement is available, it may be used in place of stone provided that such use meets with the approval of the Engineer. However, the use of broken concrete that contains reinforcing steel will not be permitted.

All stone shall meet the approval of the Engineer. While no specific gradation is required, there should be equal distribution of the various sizes of the stone within the

required size range. The size of an individual stone particle will be determined by measuring its long dimension.

Stone or broken concrete for riprap shall meet the requirements of Table 1042-1 for the class and size distribution.

TABLE 1042-1
ACCEPTANCE CRITERIA FOR RIPRAP AND STONE FOR EROSION CONTROL

	REQUIRED STONE SIZES - INCHES		
CLASS	MINIMUM	MIDRANGE	MAXIMUM
A	2	4	6
B	5	8	12
1	5	10	17
2	9	14	23r

No more than 5.0% of the material furnished can be less than the minimum size specified nor no more than 10.0% of the material can exceed the maximum size specified.

1042-2 TESTING

Test riprap materials in accordance with the requirements of this section and Sections 1005-4(E) Resistance to Abrasion, and 1005-4(F) Soundness. Satisfactory resistance to abrasion will be considered to be a percentage of wear of not greater than 55 percent. Satisfactory soundness will be considered to be a loss in weight of not greater than 15 percent when subjected to 5 alterations of the soundness test.

APPENDIX E

Stability Analysis

URS CALCULATION SHEET	PROJECT IP-Riegelwood Cell 2 Liner System				JOB NO. 31826746	
	SUBJECT Final Cover Veneer Stability Calculation				SHEET NO. 1 of 2	
	ORIGINATED BY Lenore Gaier	DATE 5/19/2009	CHECKED BY Rich Lowe	DATE 6/1/2009	CALC. NO.	REV. NO.

Determine the minimum interface friction angle for the components of the final cover

Reference: Matasovic, N. (1991), "Selection of Method for Seismic Slope Stability Analysis," Proc. 2nd International Conference on Recent Advances in Geotechnical Earthquake Engineering and Soil Dynamics, St. Louis, Vol. 2 pp. 1057-1062.

Treat the final cover as an infinite slope and use the following equation

$$FS = \frac{c/(\partial * z * \cos^2\beta) + \tan\Phi[1-u/(\partial * z)] - k_s * \tan\beta * \tan\Phi}{k_s + \tan\beta}$$

where:

FS = Factory of Safety; FS (static) = 1.5, FS (dynamic) = 1.0
ks = Seismic Coefficient (= 0 for Static Stability) (Dynamic see attached map)
∂ = Unit Weight of Slope Material(s)
c = Cohesion
Φ = Interface Friction Angle of Assumed Failure Surface (degrees)
u = Pore Pressure (above geomembrane)
$u = \partial_w(z-d_w)$ (for pore pressure)
∂_w = Unit Weight of Water (62.4 psf)
z = Depth to Failure Surface
d_w = Depth to Seepage Surface (= z if slope is Dry)
β = Slope Angle of Cover

Given:

FS =	To be calculated	
ks =	0	Static Conditions
	0.125	Dynamic Conditions
∂ =	120	psf
c =	0	
Φ =	will vary	degrees
u =	0	
z =	2	ft
β =	14	degrees

See drawing for cover cross-section dimensions/slope

URS CALCULATION SHEET	PROJECT IP-Riegelwood Cell 2 Liner System			JOB NO. 31826746	
	SUBJECT Final Cover Veneer Stability Calculation			SHEET NO. 2 of 2	
	ORIGINATED BY Lenore Gaier	DATE 5/19/2009	CHECKED BY Rich Lowe	DATE 6/1/2009	CALC. NO.	REV. NO.

Calculate Static FS against sliding:

Interface Friction Angle	Resisting Force	Driving Force	FS	Comment
18	0.32	0.25	1.30	No Good
19	0.34	0.25	1.38	No Good
20	0.36	0.25	1.46	No Good
21	0.38	0.25	1.54	GOOD

Calculate Dynamic FS against sliding:

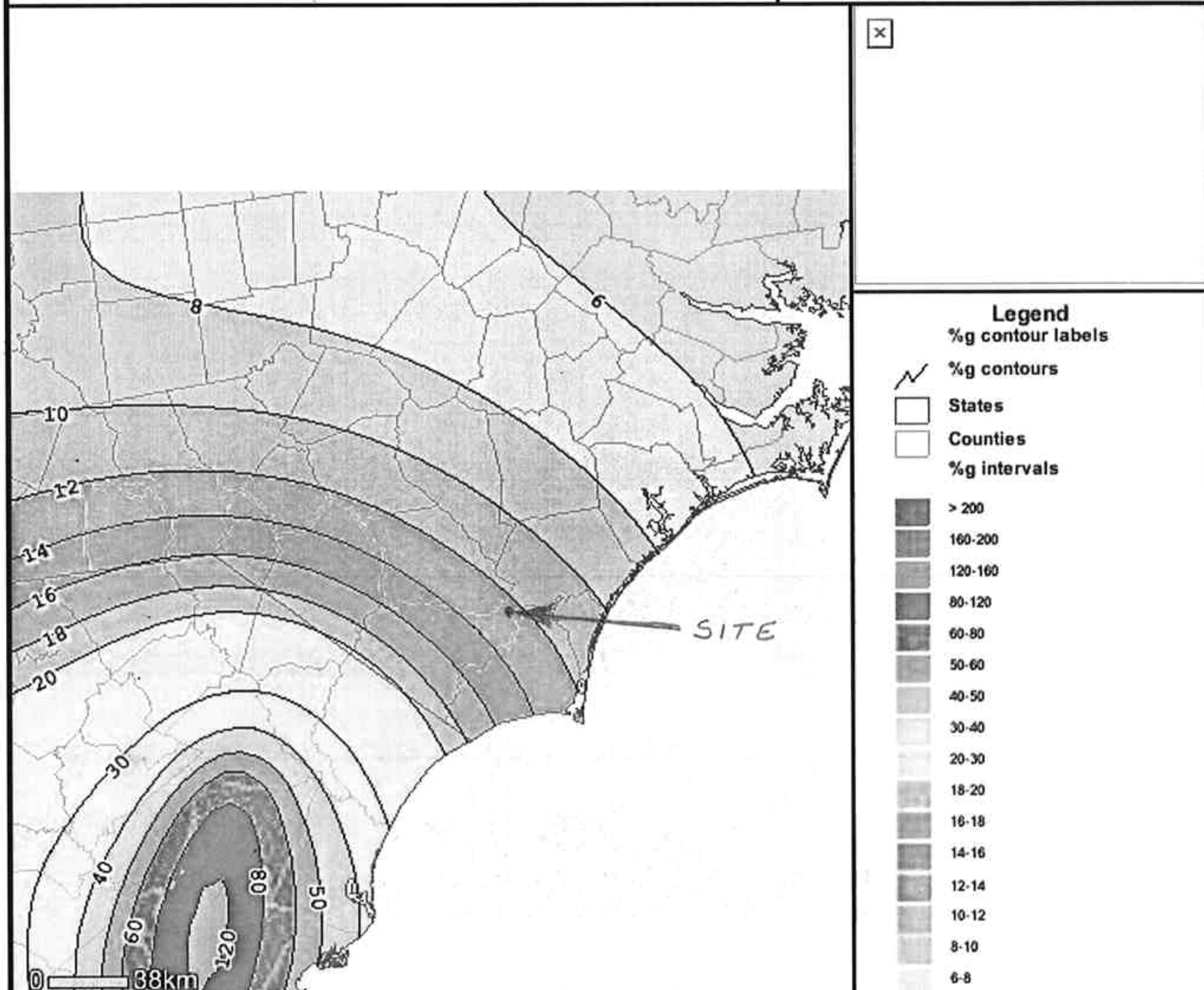
Interface Friction Angle	Resisting Force	Driving Force	FS	Comment
18	0.31	0.37	0.84	No Good
19	0.33	0.37	0.89	No Good
20	0.35	0.37	0.94	No Good
21	0.37	0.37	0.99	GOOD
22	0.39	0.37	1.05	GOOD

RL

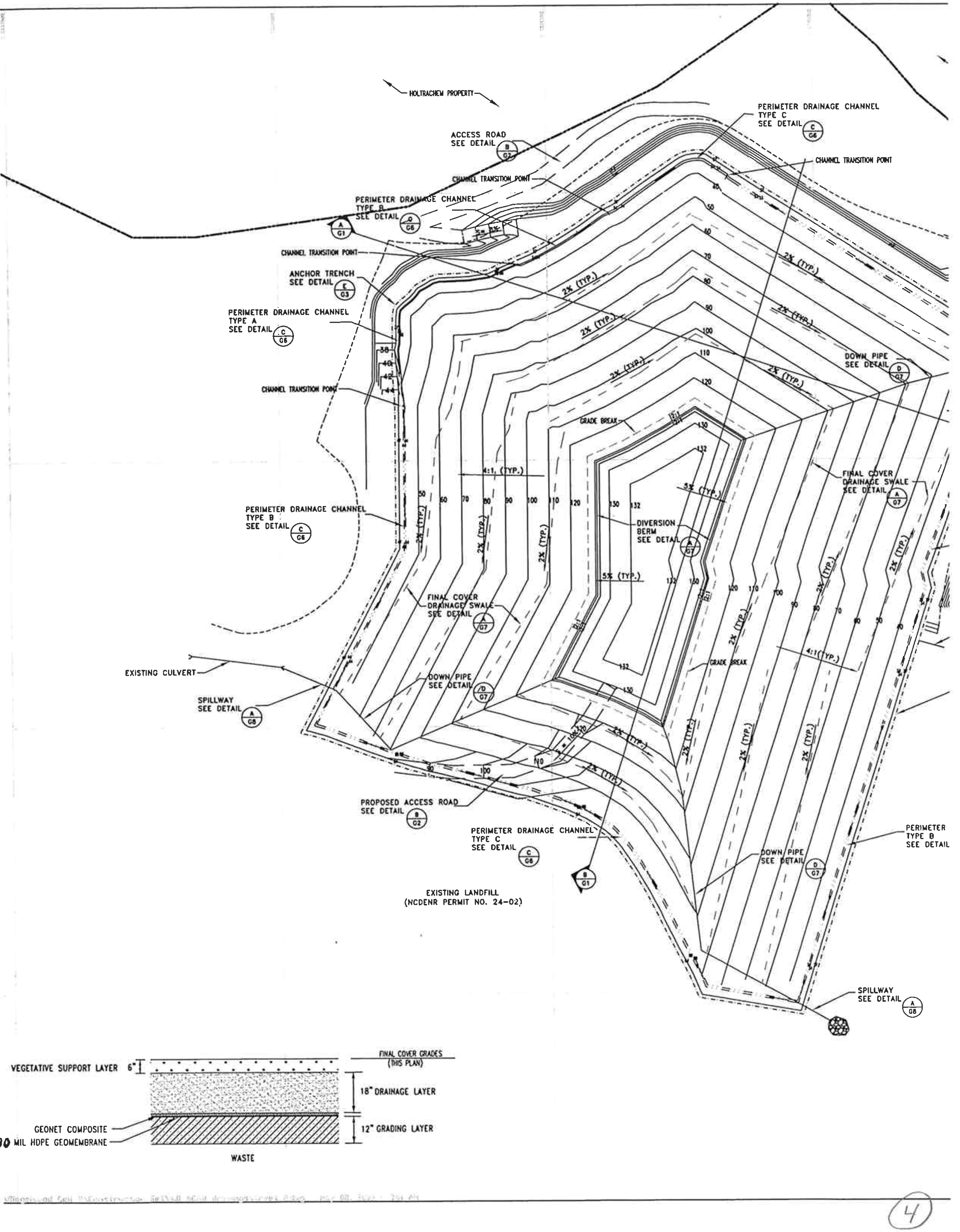
Therefore all the interface friction angles for the final cover must have a angle greater than 21 degrees.

The interface friction angle test results table outlines the friction angle between the different interfaces used in Cell 1. All the highlighted numbers are for 150 psf load, the best representation for a final cover. All the interface friction angles in the table are greater than 21 degrees. Therefore if similar material is used to construct the final cover the interface friction angles will meet the specification requirements.

USGS Seismic Hazard Maps



Peak Horizontal Acceleration with 2% Probability of Exceednace in 50 Years (Preliminary)

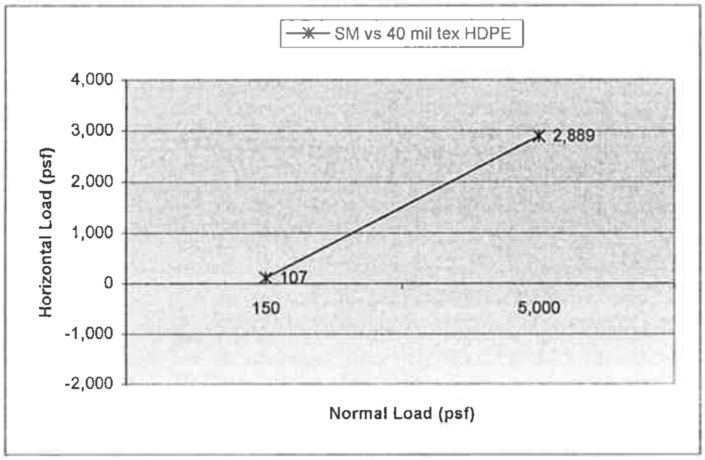

HOLTRACHEM PROPERTY
PERIMETER DRAINAGE CHANNEL TYPE C SEE DETAIL C G6
ACCESS ROAD SEE DETAIL B G2
CHANNEL TRANSITION POINT
PERIMETER DRAINAGE CHANNEL TYPE B SEE DETAIL D G6
A G1
ANCHOR TRENCH SEE DETAIL E G3
PERIMETER DRAINAGE CHANNEL TYPE A SEE DETAIL C G6
DOWN PIPE SEE DETAIL D G7
GRADE BREAK
4:1 (TYP.)
2% (TYP.)
5% (TYP.)
FINAL COVER DRAINAGE SWALE SEE DETAIL A G7
PERIMETER DRAINAGE CHANNEL TYPE B SEE DETAIL C G6
DIVERSION BERM SEE DETAIL A G7
EXISTING CULVERT
SPILLWAY SEE DETAIL A G8
PROPOSED ACCESS ROAD SEE DETAIL B G2
PERIMETER DRAINAGE CHANNEL TYPE C SEE DETAIL C G6
B G1
EXISTING LANDFILL (NCDENR PERMIT NO. 24-02)
PERIMETER TYPE B SEE DETAIL
FINAL COVER GRADES (THIS PLAN)
VEGETATIVE SUPPORT LAYER 6"
18" DRAINAGE LAYER
GEONET COMPOSITE
12" GRADING LAYER
MIL HDPE GEOMEMBRANE
WASTE

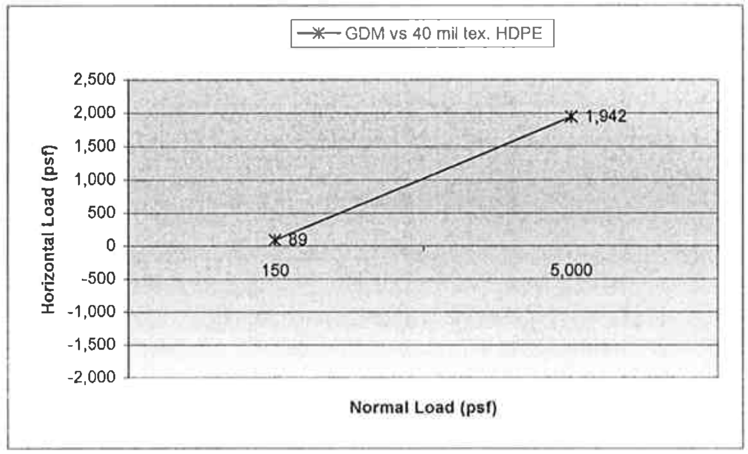
INTERNATIONAL PAPER RELIABILITY ENGINEERING CALCULATION SHEET	PROJECT Riegelwood mill landfill 2003				TECH. JOB NO.	
	SUBJECT Interface Friction Test Results Summary				SHEET NO.	
	ORIGINATED B Rich Lowe	DATE 4/7/2005	CHECKED BY	DATE	CALC. NO.	REV. NO.

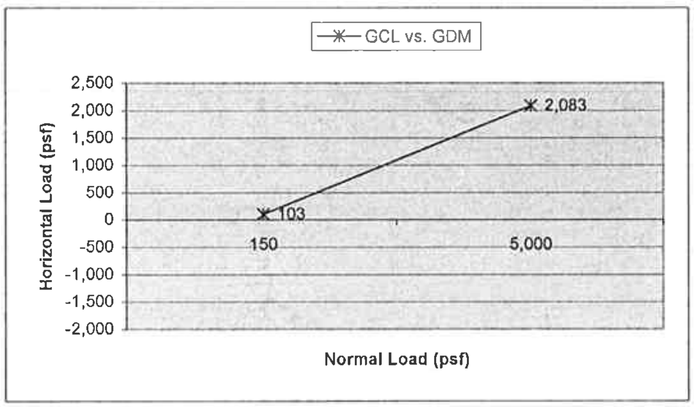
Interface Friction Test Results

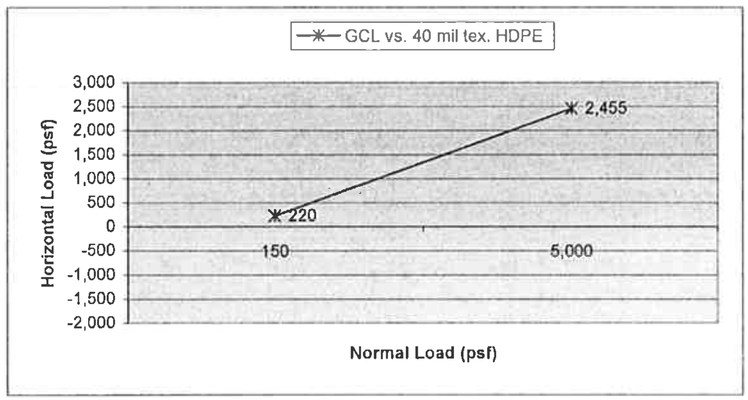
normal load Interface	150 psf load (95 psf min req. result)	5,000 psf load (2,000 min. req. result)	calculated cohesion psf	 friction angle
south pond soil vs. SM vs 40 mil tex HDPE	107	2,889	21.0	29.84
Geonet Drainage media GDM vs 40 mil tex. HDPE	89	1,942	31.7	30.68 20.91
GCL vs. GDM	103	2,083	41.8	22.21
GCL vs. 40 mil tex. HDPE	220	2,455	150.9	24.74
south pond soil SM vs GDM	104	3,232	7.3	34.73 32.82
gooseneck borrow SM vs. GDM	135	2,895	49.6	41.99 29.64
gooseneck borrow SM vs. 40 mil tex. HDPE	153	3,029	64.1	45.57 30.67

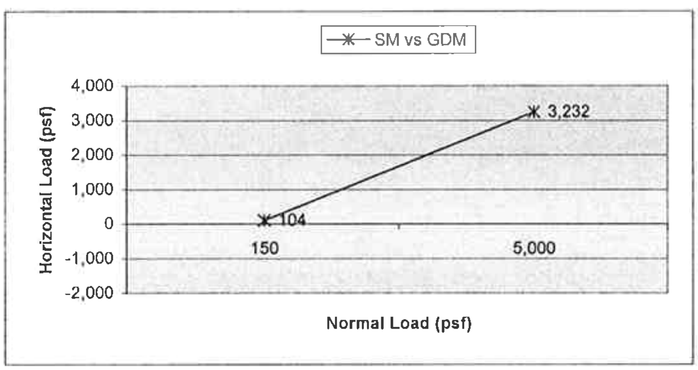
Data obtained from Cell 1 as-built report

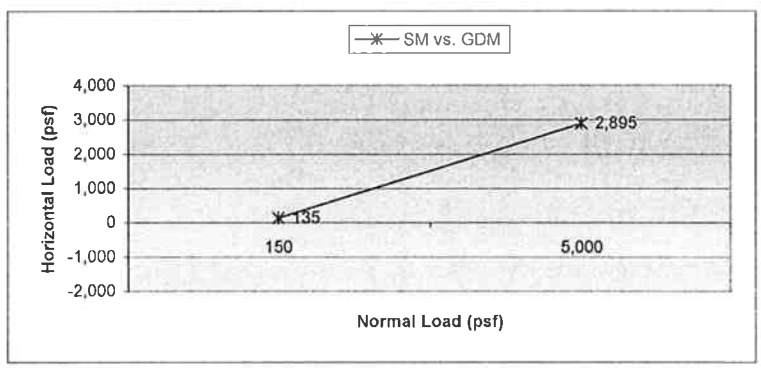

SM vs 40 mil tex HDPE
Horizontal Load (psf)
4,000
3,000
2,000
1,000
0
-1,000
-2,000
107
2,889
150
5,000
Normal Load (psf)

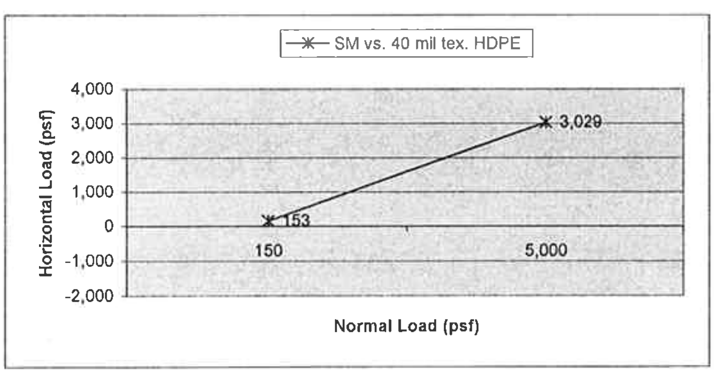

GDM vs 40 mil tex. HDPE
Horizontal Load (psf)
2,500
2,000
1,500
1,000
500
0
-500
-1,000
-1,500
-2,000
89
1,942
150
5,000
Normal Load (psf)


GCL vs. GDM
Horizontal Load (psf)
2,500
2,000
1,500
1,000
500
0
-500
-1,000
-1,500
-2,000
103
2,083
150
5,000
Normal Load (psf)


GCL vs. 40 mil tex. HDPE
Horizontal Load (psf)
3,000
2,500
2,000
1,500
1,000
500
0
-500
-1,000
-1,500
-2,000
220
2,455
150
5,000
Normal Load (psf)


SM vs GDM
Horizontal Load (psf)
4,000
3,000
2,000
1,000
0
-1,000
-2,000
104
3,232
150
5,000
Normal Load (psf)


SM vs. GDM
Horizontal Load (psf)
4,000
3,000
2,000
1,000
0
-1,000
-2,000
135
2,895
150
5,000
Normal Load (psf)


SM vs. 40 mil tex. HDPE
Horizontal Load (psf)
4,000
3,000
2,000
1,000
0
-1,000
-2,000
153
3,029
150
5,000
Normal Load (psf)

2. Carbon black dispersion required all 10 views in categories 1, 2 or 3 (no category 4 views).

The manufacturer's conformance tests showed all rolls tested met or exceeded the Project Specifications. The Manufacturer's Quality Control Certificates were obtained for all rolls of geomembrane delivered to the site. Lists were also obtained including resin batch/lot numbers for each roll. Each certificate was reviewed for conformance with the geomembrane and resin properties outlined in the project specification. Manufacturer's quality control certificates for each roll are presented in **Appendix 7.2**.

7.3 Interface Friction Tests (All)

The contractor was also required to perform interface friction tests on the geosynthetics and the site soil. Interface friction tests for all materials are summarized in **Table7.2**.

Table 7.2: Interface Friction (ASTM D 5321) Test Summary

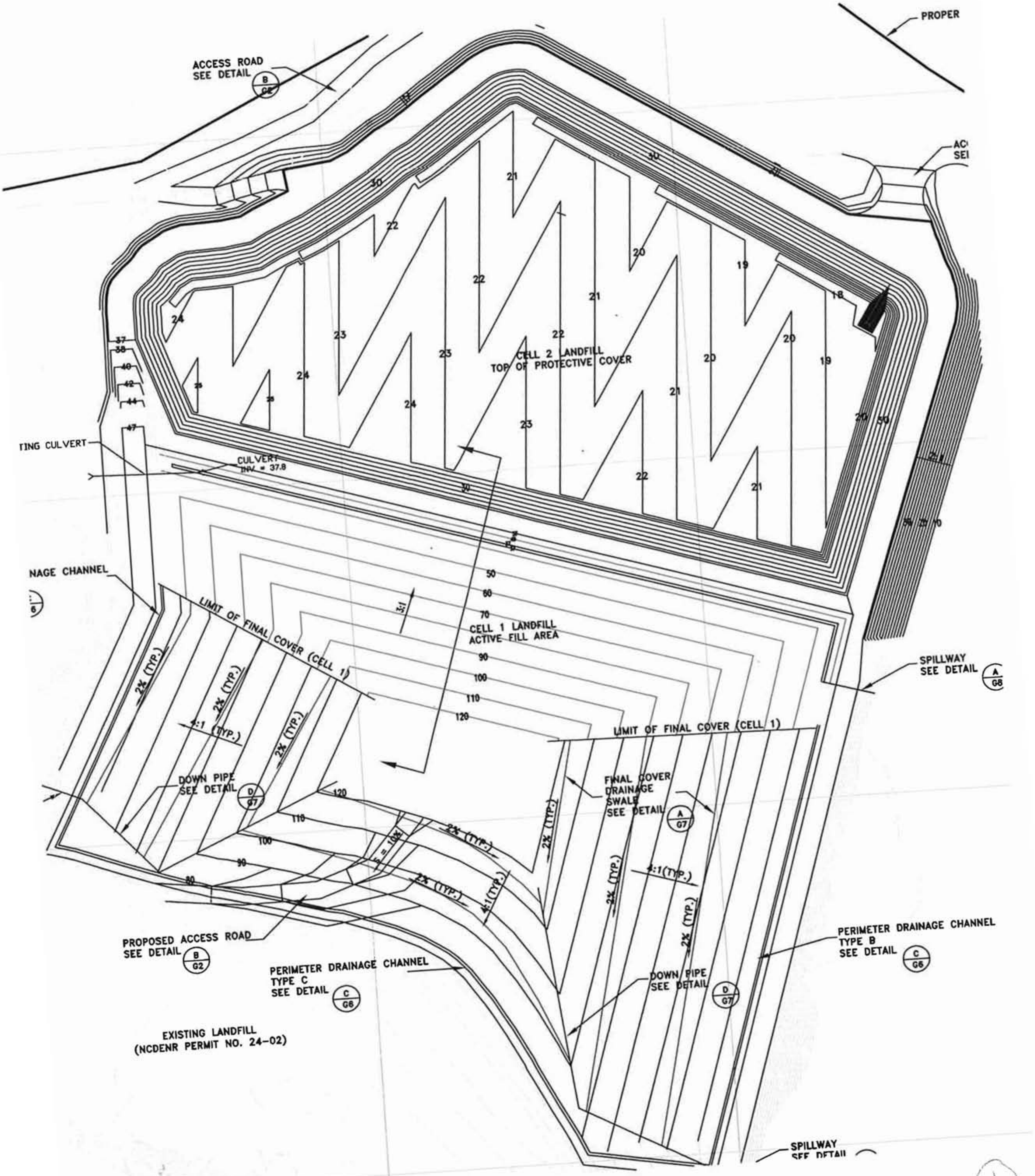
Interface	150 psf Load (95 psf min req. Result)	5,000 psf Load (2,000 min. req. Result)
South Ponds Soil vs. 40 mil Geomembrane	107	2,889
Geonet Drainage Media vs. 40-mil Geomembrane	89	1,942
GCL vs. Geonet Drainage Media	103	2,083
GCL vs. 40-mil Geomembrane	220	2,455
South Ponds Soil vs. Geonet Drainage Media	104	3,232
Gooseneck Soil vs. Geocomposite	135	2,895
Gooseneck Soil vs. 40-mil Geomembrane	153	3,029

The shear strength values for the geonet drainage media against the geomembrane were below the required values. However, the friction angles represented by those results (30.6° and 21.2°) were higher than the value of 20° used in the stability analysis to give a factor of safety of 1.5. Therefore, the geomembrane was accepted for use with the geocomposite.

7.4 Geomembrane Conformance Testing

In addition to the tests performed by the manufacturer, CQA tests were required for the same properties at a frequency of one test every 200,000 square feet, or one test per lot. CQA

OPERATIONAL SLOPE STABILITY ANALYSIS



ACCESS ROAD
SEE DETAIL
B
G2
PROPER
CELL 2 LANDFILL
TOP OF PROTECTIVE COVER
TING CULVERT
CULVERT
INV = 37.8
NAGE CHANNEL
LIMIT OF FINAL COVER (CELL 1)
CELL 1 LANDFILL
ACTIVE FILL AREA
3:1
4:1 (TYP.)
2% (TYP.)
SPILLWAY
SEE DETAIL
A
G8
LIMIT OF FINAL COVER (CELL 1)
DOWN PIPE
SEE DETAIL
D
G7
FINAL COVER
DRAINAGE
SWALE
SEE DETAIL
A
G7
PROPOSED ACCESS ROAD
SEE DETAIL
B
G2
PERIMETER DRAINAGE CHANNEL
TYPE C
SEE DETAIL
C
G6
PERIMETER DRAINAGE CHANNEL
TYPE B
SEE DETAIL
C
G6
DOWN PIPE
SEE DETAIL
D
G7
EXISTING LANDFILL
(NCDENR PERMIT NO. 24-02)
SPILLWAY

1

URS CALCULATION SHEET	PROJECT IP-Riegelwood Cell 2 Liner Design/Permit Plans				JOB NO.	
	SUBJECT Slope Stability Analysis - Undrained Analysis				SHEET NO. 2	
	ORIGINATED B Rich Lowe	DATE 5/27/2009	CHECKED BY	DATE	CALC. NO.	REV. NO.

	Landfilled Materials	Ben Use Primary	Protective Cover	Geosynth	Nat Sand	Pee Dee
Moist Den (pcf)	60	60	120	60	120	125
Sat Den (pcf)	63	63	125	60	125	130
cohesion (psf)	430	430	0	31.7	0	720
friction Φ (deg)	8	8	34	21	32	5
source	(1)	(2)	(3)	(4)	(5)	(6)

(1) Low average of 2001 Virginia Geotechnical Tests for Joyce Engr

(2) Low average of 2001 Virginia Geotechnical Tests for Joyce Engr

(3) 1991 RMT Borrow direct shear test results quoted by S&ME in 1993

(4) 2003 Cell 1 Interface friction testing (GDM/HDPET interface) GNRA

(5) Upper existing embankment sand properties from S&ME 1993

(6) Undrained strength test results on Pee Dee from S&ME 1993

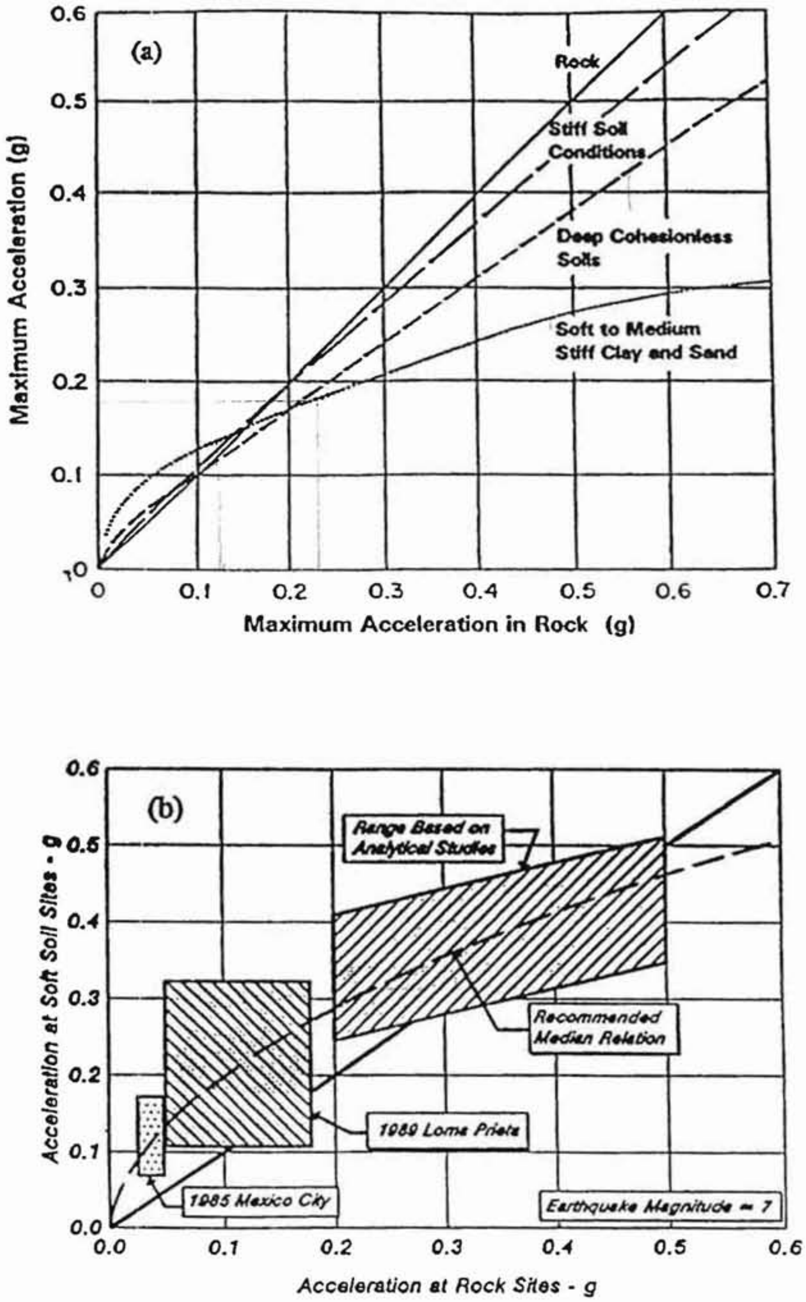
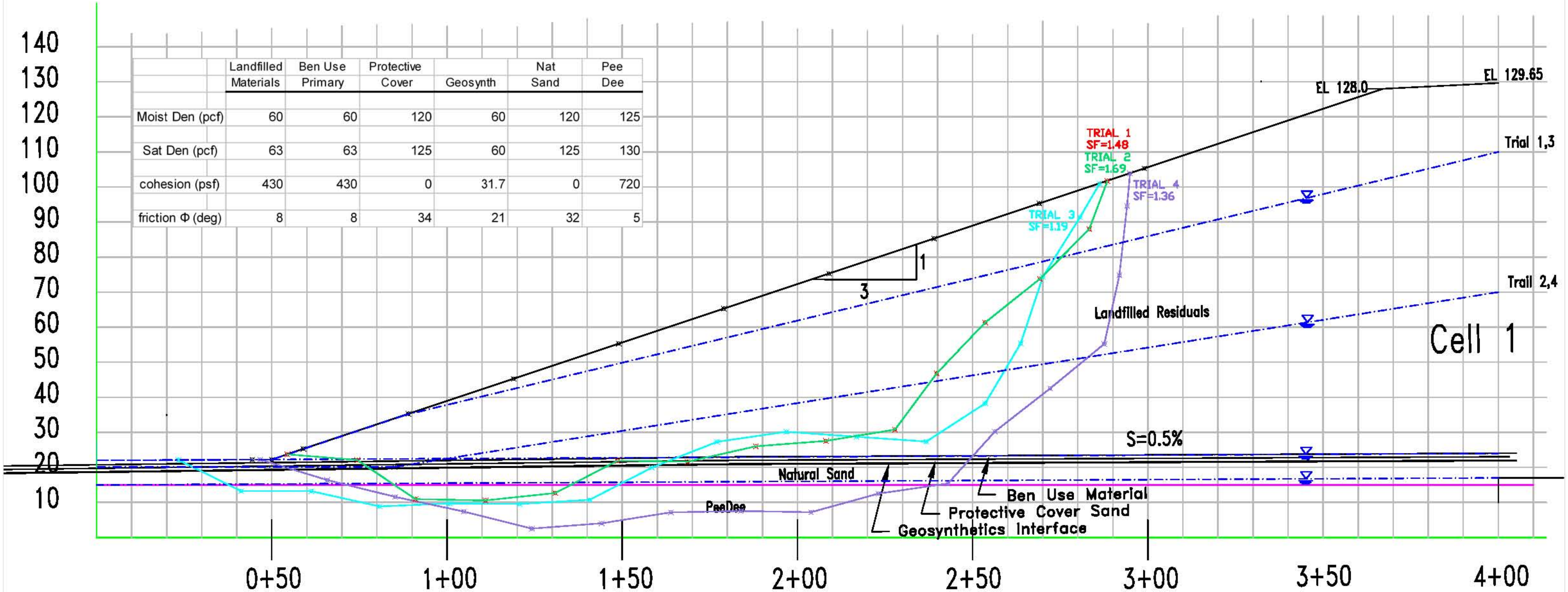


Figure 4.4 Relationship Between Maximum Acceleration on Rock and Other Local Site Conditions: (a) Seed and Idriss (1982); (b) Idriss (1990).

(3)

IP RIEGELWOOD
INTERMEDIATE SLOPE
CROSS-SECTION



	Landfilled Materials	Ben Use Primary	Protective Cover	Geosynth	Nat Sand	Pee Dee
Moist Den (pcf)	60	60	120	60	120	125
Sat Den (pcf)	63	63	125	60	125	130
cohesion (psf)	430	430	0	31.7	0	720
friction Φ (deg)	8	8	34	21	32	5

NOT TO SCALE

Trail 1

** PCSTABL6 **

by
Purdue University

modified by
Peter J. Bosscher
University of Wisconsin-Madison

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

PROBLEM DESCRIPTION Intermediate Cover 3:1 Trial 1

BOUNDARY COORDINATES

3 Top Boundaries
8 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	22.00	50.00	22.25	2
2	50.00	22.25	367.25	128.00	1
3	367.25	128.00	400.00	128.20	1
4	50.00	22.25	400.00	24.00	2
5	0.00	21.00	400.00	23.00	3
6	0.00	20.10	400.00	22.10	4
7	0.00	20.00	400.00	22.00	5
8	0.00	15.00	400.00	15.00	6

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	60.0	63.0	430.0	8.0	0.00	0.0	1
2	60.0	63.0	430.0	8.0	0.00	0.0	1
3	120.0	125.0	0.0	34.0	0.00	0.0	2
4	60.0	60.0	31.7	21.0	0.00	0.0	2
5	120.0	125.0	0.0	32.0	0.00	0.0	3
6	125.0	130.0	720.0	5.0	0.00	0.0	3

3 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	22.00
2	50.00	22.25
3	88.25	35.00
4	400.00	110.00

Piezometric Surface No. 2 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	22.00
2	400.00	24.00

Piezometric Surface No. 3 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	15.00
2	400.00	17.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Irregular Surfaces, Has Been Specified.

100 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 10 Points Equally Spaced Along The Ground Surface Between X = 0.00 ft.
and X = 70.00 ft.

Each Surface Terminates Between X = 100.00 ft.
and X = 300.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 0.00 ft.

20.00 ft. Line Segments Define Each Trial Failure Surface.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	54.44	23.73
2	74.38	22.10
3	90.99	10.96
4	110.99	10.59
5	130.88	12.70
6	148.63	21.90
7	168.63	21.62
8	188.14	26.02
9	208.08	27.55
10	227.82	30.79
11	239.75	46.84
12	253.55	61.32
13	269.19	73.79
14	283.27	87.98
15	288.46	101.74

*** 1.478 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	41.25	13.23
3	61.25	13.21
4	80.77	8.87
5	100.76	9.72
6	120.75	9.57
7	140.72	10.74
8	158.48	19.95
9	177.07	27.31
10	196.87	30.16
11	216.82	28.74
12	236.77	27.36
13	253.56	38.24
14	263.74	55.45

15	270.06	74.42
16	280.65	91.39
17	286.25	101.00

*** 1.508 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	46.67	22.23
2	65.80	16.41
3	85.21	11.58
4	104.77	7.41
5	124.17	2.54
6	144.11	4.05
7	163.87	7.18
8	183.86	7.57
9	203.86	7.21
10	223.14	12.54
11	242.93	15.39
12	256.33	30.24
13	272.11	42.53
14	287.56	55.23
15	291.86	74.77
16	294.07	94.64
17	294.90	103.88

*** 1.613 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	42.93	18.10
3	62.33	13.25
4	82.31	14.07
5	102.31	14.15
6	122.24	12.50
7	142.10	10.12
8	161.89	13.01
9	181.21	18.19
10	200.74	22.51
11	219.84	28.43
12	234.58	41.95
13	248.49	56.32
14	261.35	71.64
15	273.75	87.33
16	277.18	97.98

*** 1.628 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	28.92
2	89.95	30.28
3	109.86	32.22
4	129.79	30.61
5	149.22	25.84
6	168.78	21.70
7	187.47	28.82
8	204.82	38.77
9	219.60	52.25
10	225.62	71.32
11	230.73	82.49

*** 1.656 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	42.11	15.23
3	57.26	2.17
4	77.26	2.11
5	94.97	11.41
6	114.91	9.95
7	134.44	5.61
8	153.72	0.33
9	173.66	1.87
10	193.56	3.89
11	213.07	8.31
12	224.50	24.72
13	235.02	41.73
14	244.32	59.43
15	252.76	77.57
16	269.26	88.87
17	272.82	96.52

*** 1.671 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	37.74	8.24
3	56.42	1.10
4	76.32	3.07
5	92.98	14.14
6	109.84	24.90
7	129.44	28.86
8	149.42	27.98
9	169.29	30.25
10	188.34	24.15
11	207.73	29.06
12	219.95	44.89
13	236.67	55.87
14	248.57	71.94
15	262.54	86.25
16	271.25	96.00

*** 1.696 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.11	22.16
2	47.90	11.29
3	65.45	1.69
4	85.38	0.02
5	104.63	5.42
6	124.18	1.21
7	143.63	5.88
8	157.16	20.61
9	175.02	29.61
10	189.16	43.75
11	204.77	56.25
12	219.79	69.46
13	222.98	79.91

*** 1.840 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	62.22	26.32
2	76.42	12.24
3	96.42	12.13
4	116.37	10.71
5	136.05	14.31
6	155.18	20.11
7	174.56	25.08
8	193.26	32.17
9	205.81	47.74
10	216.84	64.42
11	225.70	80.82

*** 1.845 ***

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.89	22.19
2	53.03	8.05
3	72.35	2.88
4	92.25	4.89
5	111.82	0.75
6	131.67	3.18
7	149.71	11.80
8	164.36	25.42
9	182.63	33.55
10	194.92	49.33
11	204.85	66.69
12	206.99	74.58

*** 1.858 ***

```
                 Y            A     X     I     S            F     T

                 0.00     50.00    100.00    150.00    200.00    250.00

X       0.00 +--**-----+---------+---------+---------+---------+
             -   .
             - . .
             - ..2
             ... 8
             -.724
       50.00 ..8.*
             6..2 1
             8..3. 5
             679.1.
             8.24..
             .017..5W
A     100.00 ..24.....
             031..75...
             ..2.......
             83.4.......
             .6.1 .5....
             -32.........
X     150.00 6.0.157.....
             - .42..... ..
             -3..107. ....
             6 .  28. ... .
             - 3.4 50......
             -6.  19 .80....
I     200.00 +3   42    ....
             -  .. 1 5.98.0.0
             - 6   2 .75 .98..
             -  3 61  ..  .5.8
             -    2  4  7.   5.
             -  3     1  6. .
S     250.00 +      .2  41 7 6.
             -     3   .   4  ..
             -          2   1 76.
             -        3       4 64
             -                 1 2
             -          3   3   313
      300.00 +
             -
             -
             -
             -
             -
F     350.00 +
             -
             -                         *
             -
             -
             -
T     400.00 +  ***                 W   *
```

Trail 2

** PCSTABL6 **

by
Purdue University

modified by
Peter J. Bosscher
University of Wisconsin-Madison

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

PROBLEM DESCRIPTION   Intermediate Cover 3:1 Trial 2

BOUNDARY COORDINATES

3 Top   Boundaries
8 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	22.00	50.00	22.25	2
2	50.00	22.25	367.25	128.00	1
3	367.25	128.00	400.00	128.20	1
4	50.00	22.25	400.00	24.00	2
5	0.00	21.00	400.00	23.00	3
6	0.00	20.10	400.00	22.10	4
7	0.00	20.00	400.00	22.00	5
8	0.00	15.00	400.00	15.00	6

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	60.0	63.0	430.0	8.0	0.00	0.0	1
2	60.0	63.0	430.0	8.0	0.00	0.0	1
3	120.0	125.0	0.0	34.0	0.00	0.0	2
4	60.0	60.0	31.7	21.0	0.00	0.0	2
5	120.0	125.0	0.0	32.0	0.00	0.0	3
6	125.0	130.0	720.0	5.0	0.00	0.0	3

3 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	20.10
2	85.00	20.10
3	400.00	70.00

Piezometric Surface No. 2 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	22.00
2	400.00	24.00

Piezometric Surface No. 3 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	15.00
2	400.00	17.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Irregular Surfaces, Has Been Specified.

100 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 10 Points Equally Spaced Along The Ground Surface Between X = 0.00 ft. and X = 70.00 ft.

Each Surface Terminates Between X = 100.00 ft. and X = 300.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 0.00 ft.

20.00 ft. Line Segments Define Each Trial Failure Surface.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	54.44	23.73
2	74.38	22.10
3	90.99	10.96
4	110.99	10.59
5	130.88	12.70
6	148.63	21.90
7	168.63	21.62
8	188.14	26.02
9	208.08	27.55
10	227.82	30.79
11	239.75	46.84
12	253.55	61.32
13	269.19	73.79
14	283.27	87.98
15	288.46	101.74

*** 1.689 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	41.25	13.23
3	61.25	13.21
4	80.77	8.87
5	100.76	9.72
6	120.75	9.57
7	140.72	10.74
8	158.48	19.95
9	177.07	27.31
10	196.87	30.16
11	216.82	28.74
12	236.77	27.36
13	253.56	38.24
14	263.74	55.45

15	270.06	74.42
16	280.65	91.39
17	286.25	101.00

*** 1.752 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	42.93	18.10
3	62.33	13.25
4	82.31	14.07
5	102.31	14.15
6	122.24	12.50
7	142.10	10.12
8	161.89	13.01
9	181.21	18.19
10	200.74	22.51
11	219.84	28.43
12	234.58	41.95
13	248.49	56.32
14	261.35	71.64
15	273.75	87.33
16	277.18	97.98

*** 1.778 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	46.67	22.23
2	65.80	16.41
3	85.21	11.58
4	104.77	7.41
5	124.17	2.54
6	144.11	4.05
7	163.87	7.18
8	183.86	7.57
9	203.86	7.21
10	223.14	12.54
11	242.93	15.39
12	256.33	30.24
13	272.11	42.53
14	287.56	55.23
15	291.86	74.77
16	294.07	94.64
17	294.90	103.88

*** 1.784 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	42.11	15.23
3	57.26	2.17
4	77.26	2.11
5	94.97	11.41
6	114.91	9.95
7	134.44	5.61
8	153.72	0.33
9	173.66	1.87
10	193.56	3.89
11	213.07	8.31
12	224.50	24.72
13	235.02	41.73
14	244.32	59.43
15	252.76	77.57
16	269.26	88.87
17	272.82	96.52

*** 1.799 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.11	22.16
2	47.90	11.29
3	65.45	1.69
4	85.38	0.02
5	104.63	5.42
6	124.18	1.21
7	143.63	5.88
8	157.16	20.61
9	175.02	29.61
10	189.16	43.75
11	204.77	56.25
12	219.79	69.46
13	222.98	79.91

*** 1.982 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	37.74	8.24
3	56.42	1.10
4	76.32	3.07
5	92.98	14.14
6	109.84	24.90
7	129.44	28.86
8	149.42	27.98
9	169.29	30.25
10	188.34	24.15
11	207.73	29.06
12	219.95	44.89
13	236.67	55.87
14	248.57	71.94
15	262.54	86.25
16	271.25	96.00

*** 1.995 ***

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.89	22.19
2	53.03	8.05
3	72.35	2.88
4	92.25	4.89
5	111.82	0.75
6	131.67	3.18
7	149.71	11.80
8	164.36	25.42
9	182.63	33.55
10	194.92	49.33
11	204.85	66.69
12	206.99	74.58

*** 2.008 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	62.22	26.32
2	76.42	12.24
3	96.42	12.13
4	116.37	10.71
5	136.05	14.31
6	155.18	20.11
7	174.56	25.08
8	193.26	32.17
9	205.81	47.74
10	216.84	64.42
11	225.70	80.82

*** 2.028 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	28.92
2	89.95	30.28
3	109.86	32.22
4	129.79	30.61
5	149.22	25.84
6	168.78	21.70
7	187.47	28.82
8	204.82	38.77
9	219.60	52.25
10	225.62	71.32
11	230.73	82.49

*** 2.063 ***

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           Y            A     X     I     S            F     T

           0.00     50.00    100.00    150.00    200.00    250.00

X      0.00 +--**-----+---------+---------+---------+---------+
            -   .
            - . .
            - ..2
            ... 6
            -.723
      50.00 ..6.*
            5..2 1
            6..4. 0
            579.1.
            6.23W.
            .817..0
A    100.00 ..23.....
            841..70...
            ..2.......
            64.3.......
            .5.1 .7....
            -42.........
X    150.00 5.8.107.....
            - .32..... ..
            -4..187. ....
            5 .  26. ... .
            - 4.3 08......
            -5.  19 .68....
I    200.00 +4   32    ....
            -  .. 1 0.96.8.8
            - 5   2 .70 .96..
            -  4 51  ..  .0.6
            -    2  3  7.   0.
            -  4     1  5. .
S    250.00 +      .2  31 7 5.
            -     4   .   3  ..
            -          2   1 75.
            -        4       3 53
            -                  1 2
            -          4   4   414
     300.00 +
            -
            -
            -
            -
            -
F    350.00 +
            -
            -                         *
            -
            -
            -
T    400.00 +  ***         W           *
```

Trail 3

** PCSTABL6 **

by
Purdue University

modified by
Peter J. Bosscher
University of Wisconsin-Madison

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

PROBLEM DESCRIPTION Intermed. Cover Trial 1 Seis g=.07

BOUNDARY COORDINATES

3 Top Boundaries
8 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	22.00	50.00	22.25	2
2	50.00	22.25	367.25	128.00	1
3	367.25	128.00	400.00	128.20	1
4	50.00	22.25	400.00	24.00	2
5	0.00	21.00	400.00	23.00	3
6	0.00	20.10	400.00	22.10	4
7	0.00	20.00	400.00	22.00	5
8	0.00	15.00	400.00	15.00	6

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	60.0	63.0	430.0	8.0	0.00	0.0	1
2	60.0	63.0	430.0	8.0	0.00	0.0	1
3	120.0	125.0	0.0	34.0	0.00	0.0	2
4	60.0	60.0	31.7	21.0	0.00	0.0	2
5	120.0	125.0	0.0	32.0	0.00	0.0	3
6	125.0	130.0	720.0	5.0	0.00	0.0	3

3 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 4 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	22.00
2	50.00	22.25
3	88.25	35.00
4	400.00	110.00

Piezometric Surface No. 2 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	22.00
2	400.00	24.00

Piezometric Surface No. 3 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	15.00
2	400.00	17.00

A Horizontal Earthquake Loading Coefficient
Of0.070 Has Been Assigned

A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned

Cavitation Pressure = 0.0 psf

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Irregular Surfaces, Has Been Specified.

100 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 10 Points Equally Spaced Along The Ground Surface Between X = 0.00 ft. and X = 70.00 ft.

Each Surface Terminates Between X = 100.00 ft. and X = 300.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 0.00 ft.

20.00 ft. Line Segments Define Each Trial Failure Surface.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	41.25	13.23
3	61.25	13.21
4	80.77	8.87
5	100.76	9.72
6	120.75	9.57
7	140.72	10.74
8	158.48	19.95
9	177.07	27.31
10	196.87	30.16
11	216.82	28.74
12	236.77	27.36
13	253.56	38.24
14	263.74	55.45
15	270.06	74.42
16	280.65	91.39
17	286.25	101.00

*** 1.191 ***

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	54.44	23.73
2	74.38	22.10
3	90.99	10.96
4	110.99	10.59
5	130.88	12.70
6	148.63	21.90
7	168.63	21.62
8	188.14	26.02
9	208.08	27.55
10	227.82	30.79
11	239.75	46.84
12	253.55	61.32

13	269.19	73.79
14	283.27	87.98
15	288.46	101.74

*** 1.196 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	46.67	22.23
2	65.80	16.41
3	85.21	11.58
4	104.77	7.41
5	124.17	2.54
6	144.11	4.05
7	163.87	7.18
8	183.86	7.57
9	203.86	7.21
10	223.14	12.54
11	242.93	15.39
12	256.33	30.24
13	272.11	42.53
14	287.56	55.23
15	291.86	74.77
16	294.07	94.64
17	294.90	103.88

*** 1.230 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	42.11	15.23
3	57.26	2.17
4	77.26	2.11
5	94.97	11.41
6	114.91	9.95
7	134.44	5.61
8	153.72	0.33
9	173.66	1.87
10	193.56	3.89
11	213.07	8.31
12	224.50	24.72
13	235.02	41.73
14	244.32	59.43
15	252.76	77.57
16	269.26	88.87
17	272.82	96.52

*** 1.283 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	42.93	18.10
3	62.33	13.25
4	82.31	14.07
5	102.31	14.15
6	122.24	12.50
7	142.10	10.12
8	161.89	13.01
9	181.21	18.19
10	200.74	22.51
11	219.84	28.43
12	234.58	41.95
13	248.49	56.32
14	261.35	71.64
15	273.75	87.33
16	277.18	97.98

*** 1.293 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	37.74	8.24
3	56.42	1.10
4	76.32	3.07
5	92.98	14.14
6	109.84	24.90
7	129.44	28.86
8	149.42	27.98
9	169.29	30.25
10	188.34	24.15
11	207.73	29.06
12	219.95	44.89
13	236.67	55.87
14	248.57	71.94
15	262.54	86.25
16	271.25	96.00

*** 1.339 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	70.00	28.92
2	89.95	30.28
3	109.86	32.22
4	129.79	30.61
5	149.22	25.84
6	168.78	21.70
7	187.47	28.82
8	204.82	38.77
9	219.60	52.25
10	225.62	71.32
11	230.73	82.49

*** 1.343 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.11	22.16
2	47.90	11.29
3	65.45	1.69
4	85.38	0.02
5	104.63	5.42
6	124.18	1.21
7	143.63	5.88
8	157.16	20.61
9	175.02	29.61
10	189.16	43.75
11	204.77	56.25
12	219.79	69.46
13	222.98	79.91

*** 1.409 ***

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.89	22.19
2	53.03	8.05
3	72.35	2.88
4	92.25	4.89
5	111.82	0.75
6	131.67	3.18
7	149.71	11.80
8	164.36	25.42
9	182.63	33.55
10	194.92	49.33
11	204.85	66.69
12	206.99	74.58

*** 1.427 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	62.22	26.32
2	76.42	12.24
3	96.42	12.13
4	116.37	10.71
5	136.05	14.31
6	155.18	20.11
7	174.56	25.08
8	193.26	32.17
9	205.81	47.74
10	216.84	64.42
11	225.70	80.82

*** 1.482 ***

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                Y           A     X     I     S          F     T

               0.00     50.00    100.00    150.00    200.00    250.00

X       0.00 +--**-----+---------+---------+---------+---------+
             -   .
             - . .
             - ..1
             ... 8
             -.615
       50.00 ..8.*
             4..1 2
             8..3. 7
             460.2.
             8.15..
             .926..7W
A     100.00 ..15.....
             932..67...
             ..1.......
             83.5.......
             .4.2 .6....
             -31.........
X     150.00 4.9.276.....
             - .51..... ..
             -3..296. ....
             4 .  18. ... .
             - 3.5 79......
             -4.  20 .89....
I     200.00 +3   51    ....
             -  .. 2 7.08.9.9
             - 4   1 .67 .08..
             -  3 42  ..  .7.8
             -    1  4  6.   7.
             -  3     2  4. .
S     250.00 +       .1  52 6 4.
             -     3    .   5  ..
             -          1   1 64.
             -        3       5 45
             -                  1 1
             -          3   3   323
      300.00 +
             -
             -
             -
             -
             -
F     350.00 +
             -
             -                         *
             -
             -
             -
T     400.00 +  ***                W   *
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Trail 4

** PCSTABL6 **

by
Purdue University

modified by
Peter J. Bosscher
University of Wisconsin-Madison

--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

PROBLEM DESCRIPTION   Intermediate Cover Trial 2 Seis g=.07

BOUNDARY COORDINATES

3 Top   Boundaries
8 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	0.00	22.00	50.00	22.25	2
2	50.00	22.25	367.25	128.00	1
3	367.25	128.00	400.00	128.20	1
4	50.00	22.25	400.00	24.00	2
5	0.00	21.00	400.00	23.00	3
6	0.00	20.10	400.00	22.10	4
7	0.00	20.00	400.00	22.00	5
8	0.00	15.00	400.00	15.00	6

ISOTROPIC SOIL PARAMETERS

6 Type(s) of Soil

Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Pore Pressure Param.	Pressure Constant (psf)	Piez. Surface No.
1	60.0	63.0	430.0	8.0	0.00	0.0	1
2	60.0	63.0	430.0	8.0	0.00	0.0	1
3	120.0	125.0	0.0	34.0	0.00	0.0	2
4	60.0	60.0	31.7	21.0	0.00	0.0	2
5	120.0	125.0	0.0	32.0	0.00	0.0	3
6	125.0	130.0	720.0	5.0	0.00	0.0	3

3 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 3 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	20.10
2	85.00	20.10
3	400.00	70.00

Piezometric Surface No. 2 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	22.00
2	400.00	24.00

Piezometric Surface No. 3 Specified by 2 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	0.00	15.00
2	400.00	17.00

A Horizontal Earthquake Loading Coefficient
Of0.070 Has Been Assigned

A Vertical Earthquake Loading Coefficient
Of0.000 Has Been Assigned

Cavitation Pressure = 0.0 psf

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Irregular Surfaces, Has Been Specified.

100 Trial Surfaces Have Been Generated.

10 Surfaces Initiate From Each Of 10 Points Equally Spaced Along The Ground Surface Between X = 0.00 ft.
and X = 70.00 ft.

Each Surface Terminates Between X = 100.00 ft.
and X = 300.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation At Which A Surface Extends Is Y = 0.00 ft.

20.00 ft. Line Segments Define Each Trial Failure Surface.

Following Are Displayed The Ten Most Critical Of The Trial Failure Surfaces Examined. They Are Ordered - Most Critical First.

* * Safety Factors Are Calculated By The Modified Janbu Method * *

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	46.67	22.23
2	65.80	16.41
3	85.21	11.58
4	104.77	7.41
5	124.17	2.54
6	144.11	4.05
7	163.87	7.18
8	183.86	7.57
9	203.86	7.21
10	223.14	12.54
11	242.93	15.39
12	256.33	30.24
13	272.11	42.53
14	287.56	55.23
15	291.86	74.77
16	294.07	94.64
17	294.90	103.88

*** 1.361 ***

Failure Surface Specified By 15 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	54.44	23.73
2	74.38	22.10
3	90.99	10.96
4	110.99	10.59
5	130.88	12.70
6	148.63	21.90
7	168.63	21.62
8	188.14	26.02
9	208.08	27.55
10	227.82	30.79
11	239.75	46.84
12	253.55	61.32

13	269.19	73.79
14	283.27	87.98
15	288.46	101.74

*** 1.366 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	42.11	15.23
3	57.26	2.17
4	77.26	2.11
5	94.97	11.41
6	114.91	9.95
7	134.44	5.61
8	153.72	0.33
9	173.66	1.87
10	193.56	3.89
11	213.07	8.31
12	224.50	24.72
13	235.02	41.73
14	244.32	59.43
15	252.76	77.57
16	269.26	88.87
17	272.82	96.52

*** 1.377 ***

Failure Surface Specified By 17 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	41.25	13.23
3	61.25	13.21
4	80.77	8.87
5	100.76	9.72
6	120.75	9.57
7	140.72	10.74
8	158.48	19.95
9	177.07	27.31
10	196.87	30.16
11	216.82	28.74
12	236.77	27.36
13	253.56	38.24
14	263.74	55.45
15	270.06	74.42
16	280.65	91.39
17	286.25	101.00

*** 1.384 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	42.93	18.10
3	62.33	13.25
4	82.31	14.07
5	102.31	14.15
6	122.24	12.50
7	142.10	10.12
8	161.89	13.01
9	181.21	18.19
10	200.74	22.51
11	219.84	28.43
12	234.58	41.95
13	248.49	56.32
14	261.35	71.64
15	273.75	87.33
16	277.18	97.98

*** 1.412 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.11	22.16
2	47.90	11.29
3	65.45	1.69
4	85.38	0.02
5	104.63	5.42
6	124.18	1.21
7	143.63	5.88
8	157.16	20.61
9	175.02	29.61
10	189.16	43.75
11	204.77	56.25
12	219.79	69.46
13	222.98	79.91

*** 1.513 ***

Failure Surface Specified By 12 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	38.89	22.19
2	53.03	8.05
3	72.35	2.88
4	92.25	4.89
5	111.82	0.75
6	131.67	3.18
7	149.71	11.80
8	164.36	25.42
9	182.63	33.55
10	194.92	49.33
11	204.85	66.69
12	206.99	74.58

*** 1.537 ***

Failure Surface Specified By 16 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	23.33	22.12
2	37.74	8.24
3	56.42	1.10
4	76.32	3.07
5	92.98	14.14
6	109.84	24.90
7	129.44	28.86
8	149.42	27.98
9	169.29	30.25
10	188.34	24.15
11	207.73	29.06
12	219.95	44.89
13	236.67	55.87
14	248.57	71.94
15	262.54	86.25
16	271.25	96.00

*** 1.573 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	62.22	26.32
2	76.42	12.24
3	96.42	12.13
4	116.37	10.71
5	136.05	14.31
6	155.18	20.11
7	174.56	25.08
8	193.26	32.17
9	205.81	47.74
10	216.84	64.42
11	225.70	80.82

*** 1.625 ***

Failure Surface Specified By 13 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	31.11	22.16
2	45.31	8.07
3	64.94	4.23
4	84.57	0.38
5	104.18	4.33
6	123.51	9.46
7	143.42	11.27
8	163.29	13.57
9	179.09	25.82
10	194.90	38.08
11	210.63	50.44
12	222.91	66.22
13	224.16	80.30

*** 1.635 ***

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                 Y          A      X      I      S            F      T

                 0.00      50.00    100.00    150.00    200.00    250.00

X       0.00 +--**-----+---------+---------+---------+---------+
             -   .
             - . .
             - ..3
             ... 6
             -.835
       50.00 ..6.*
             3..4 2
             60.1. .
             379.2.
             6.15W.
             .728...
A     100.00 ..45.....
             712..8....
             ..3.......
             6105.......
             .3.2 .8....
             -14.........
X     150.00 3.7.2.8.....
             - .54..... ..
             -1.0278. ....
             3 .  46. ... .
             - 1.5 .7......
             -3.  29 067....
I     200.00 +1   54     ....
             -  .. 2 ..96.7.7
             - 3   4 .8. .96..
             -  1 32  ..  0..6
             -    4  3  8.    ..
             -  1     2  3. .
S     250.00 +       .4  52 8 3.
             -     1    .   5  ..
             -          4   2 83.
             -        1       5 35
             -                 2 4
             -          1   1   121
      300.00 +
             -
             -
             -
             -
             -
F     350.00 +
             -
             -                         *
             -
             -
             -
T     400.00 +  ***        W           *
```

56

APPENDIX D

Underdrain System

URS CALCULATION SHEET	PROJECT: IP-Riegelwood North Bay Landfill Cell 2				JOB NO. 31826716	
	SUBJECT: Groundwater collection system flow volumes				SHEET NO. 1	
	ORIGINATED BY: Rich Lowe	DATE: 6/3/2009	CHECKED BY: CJK	DATE: 5/29/2009	CALC. NO.	REV. NO. 1

Purpose: Estimate the volume and flow rate for groundwater collected in the landfill Cell 2 groundwater collection system for pump/pipe sizing

Method: Water collected in the underdrain system will originate from:
1. Groundwater seepage from the site perimeter
2. Rainwater falling in the landfill footprint prior to liner installation.

Since the primary function of the underdrain is to provide for long-term groundwater separation from the landfill liner, rainwater control is only a temporary construction concern.

Groundwater collection pipe spacing will duplicate that for Cell 1 in approved construction permit 24-02.

Seepage from around landfill Cell 2 perimeter is estimated as follows:

Seepage Source	GPM	Reference
1. Through east landfill dike and C/B slurry wall.	1.75	see pg 2
2. From northeast of landfill cell.	3.46	see pg 2
3. From northwest of landfill cell.	1.44	see pg 3
Cumulative Groundwater Seepage Volume =	**6.65**	gallons/minute

Check methodology against 5-12-09 measured Cell 1 underdrain pump rate

Seepage Source	GPM	Reference
1. Through east dike and C/B slurry wall	1.64	see pg 4
2. From beneath old landfill on south side	15.60	see pg 4
3. From west side of cell near clarifier	2.61	see pg 5
4. From beneath future cell 2 on north side	-0.49	see pg 5
Cumulative Cell 1 Underdrain Seepage Volume Est=	**19.36**	gallons/minute

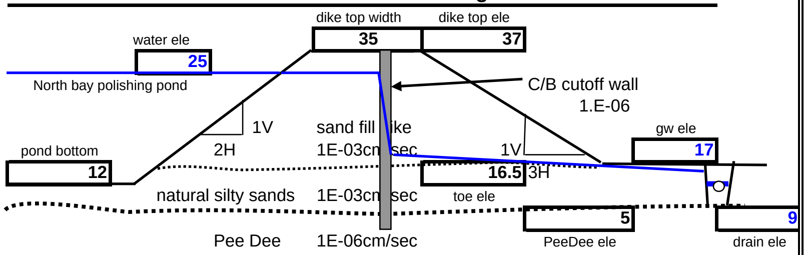
Cell 1 Underdrain pumping records showed following on 5-12-09
Pump ran 47.4 minutes in 4 hours (1:37 to 5:37) @ 60 gpm measured flow rate
This yields an average system flow rate of 11.85 gpm

Therefore, applying same techniques to Cell 2 underdrain, expected flow rate of 3 to 6 gpm expected after liner installation (no direct precip).
Total combined underdrain flow rate likely to rise from 12 gpm to 15-20 gpm.

URS CALCULATION SHEET	PROJECT IP-Riegelwood North Bay Landfill Cell 2			JOB NO. 31826716	
	SUBJECT Groundwater collection system flow volumes			SHEET NO. 2	
	ORIGINATED BY Rich Lowe	DATE 6/3/2009	CHECKED BY CJK	DATE 5/29/2009	CALC. NO.	REV. NO. 1

Purpose: Estimate seepage through/beneath Cell 2 East dike, with an installed cutoff wal collected in groundwater collection and control system to size pumps.

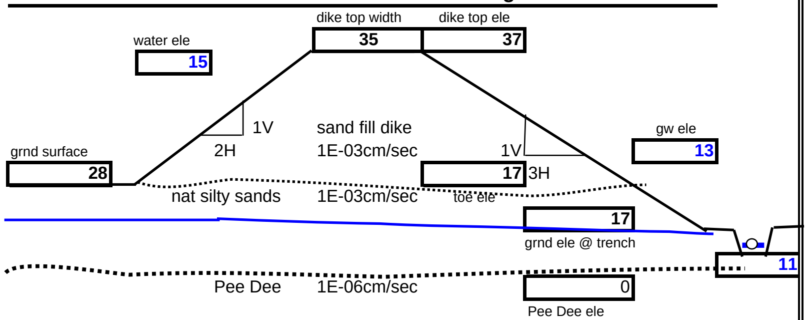
East Cell 2 Dike Cross-Section - Length = 370 feet



layer	k cm/sec	Gradient head loss	Gradient horizontal L	Area sq. ft/L. F.	q gpd/L. F.	Q gpd
sand dike/slurry wall	1.E-06	16	1	8.5	2.9	1,067
nat si sand	1.E-06	16	1	11.5	3.9	1,444
Pee Dee	1.E-06	16	166.5	5	0.0	4
						2,514

1.75 gpm

Northeast Cell 2 Dike Cross-Section - Length = 600 feet

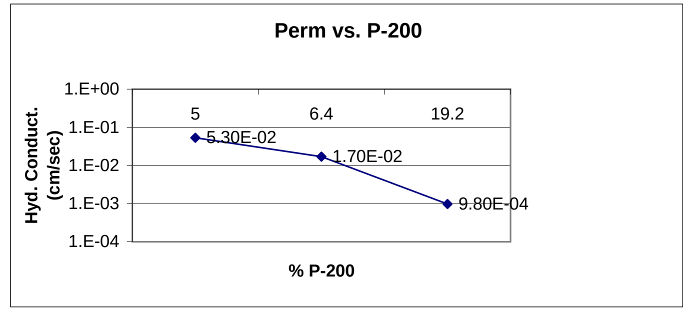


layer	k cm/sec	Gradient head loss	Gradient horizontal L	Area sq. ft/L. F.	q gpd/L. F.	Q gpd
sand dike fill	1.E-03	0				
nat si sand	1.E-03	4	133	13	8.3	4,974
Pee Dee	1.E-06	4	133	5	0.0	2
						4,976

3.46 gpm

All test data from Cell 1 As-Built Rept.

Sample	p-200	k (cm/sec)
SF-7	5	5.30E-02
PC-1	6.4	1.70E-02
stockpile	19.2	9.80E-04
CB wall		1.00E-06



Shallow, naturally occurring silty sand soils are known as the Penholoway aquifer
Penholoway aquifer average horizontal hydraulic conductivity = 4.65E-05 ft/sec (1E-03 cm/sec)

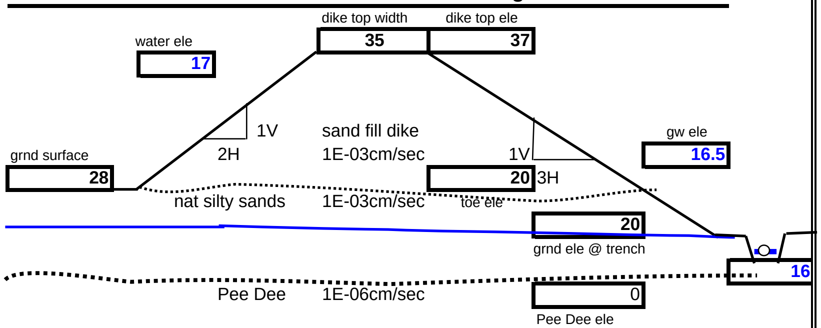
Peedee formation average horiz. Hydraulic conductivity = 3.4E-08 ft/sec (1E-06 cm/sec)
information from December 2004 Water Quality Monitoring Plan prepared by GN Richardson

Upgradient groundwater elevation estimated from following information:
Limited recharge area remaining between landfill perimeter and Cape Fear River bank

URS CALCULATION SHEET	PROJECT: IP-Riegelwood North Bay Landfill Cell 2			JOB NO.: 31826716	
	SUBJECT: Groundwater collection system flow volumes			SHEET NO.: 3	
	ORIGINATED BY: Rich Lowe	DATE: 6/3/2009	CHECKED BY: CJK	DATE: 5/29/2009	CALC. NO.:	REV. NO.: 1

Purpose: Estimate seepage through Cell 2 Northwest dike,
collected in groundwater collection and control system to size pumps

Northwest Cell 2 Dike Cross-Section - Length = 737 feet

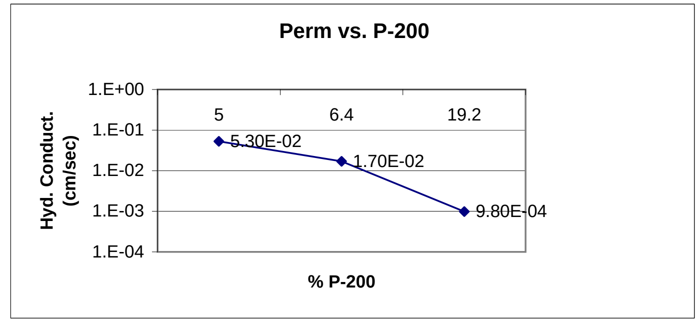


layer	k cm/sec	Gradient head loss	Gradient horizontal L	Area sq. ft/L. F.	q gpd/L. F.	Q gpd
sand dike fill	1.E-03	0				0
nat si sand	1.E-03	1	124	16.5	2.8	2,079
Pee Dee	1.E-06	1	124	5	0.0	1
						2,080

1.44 gpm

All test data from Cell 1 As-Built Rept.

Sample	p-200	k (cm/sec)
SF-7	5	5.30E-02
PC-1	6.4	1.70E-02
stockpile	19.2	9.80E-04
CB wall		1.00E-06



Shallow, naturally occurring silty sand soils are known as the Penholoway aquifer
Penholoway aquifer average horizontal hydraulic conductivity = 4.65E-05 ft/sec (1E-03 cm/sec)

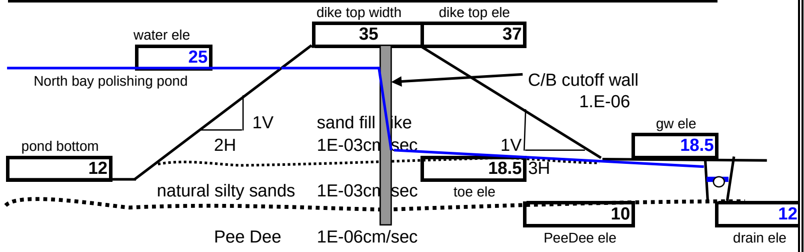
Peedee formation average horiz. Hydraulic conductivity = 3.4E-08 ft/sec (1E-06 cm/sec)
information from December 2004 Water Quality Monitoring Plan prepared by GN Richardson

Upgradient groundwater elevation estimated from following information:
Limited recharge area remaining between landfill perimeter and Cape Fear River bank

URS CALCULATION SHEET	PROJECT: IP-Riegelwood North Bay Landfill Cell 2			JOB NO. 31826716	
	SUBJECT: Groundwater collection system flow volumes			SHEET NO. 4	
	ORIGINATED BY: Rich Lowe	DATE: 6/3/2009	CHECKED BY: CJK	DATE: 5/29/2009	CALC. NO.	REV. NO. 1

Purpose: Calibrate seepage estimates through/beneath Cell 1 East dike, with an installec collected in groundwater collection with actual 5-12-09 pumping rate records.

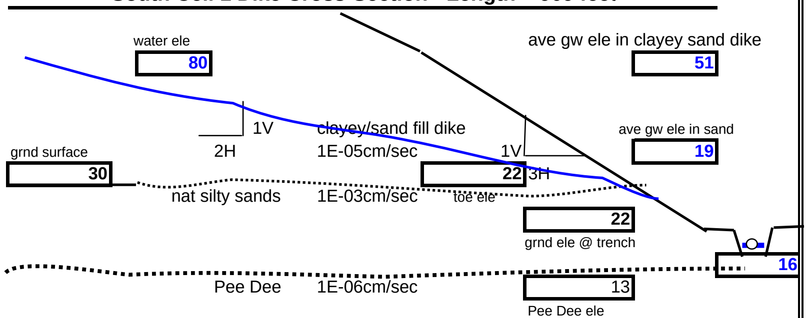
East Cell 1 Dike Cross-Section - Length = 570 feet



layer	k cm/sec	Gradient head loss	Gradient horizontal L	Area sq. ft/L. F.	q gpd/L. F.	Q gpd
sand dike/slurry wall	1.E-06	13	1	6.5	1.8	1,021
nat si sand	1.E-06	13	1	8.5	2.3	1,335
Pee Dee	1.E-06	13	160.5	5	0.0	5
						2,362

1.64 gpm

South Cell 1 Dike Cross-Section - Length = 909 feet

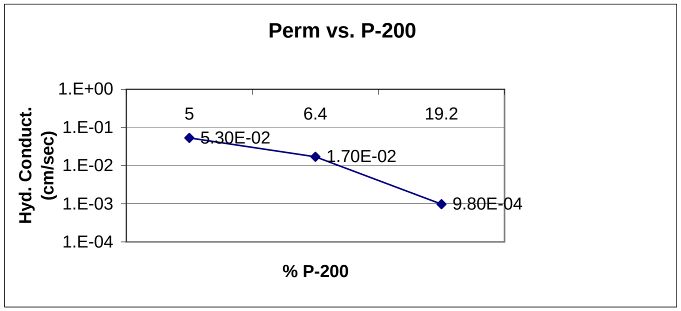


layer	k cm/sec	Gradient head loss	Gradient horizontal L	Area sq. ft/L. F.	q gpd/L. F.	Q gpd
sand dike fill	1.E-05	58	250	29	1.4	1,297
nat si sand	1.E-03	64	350	6	23.3	21,146
Pee Dee	1.E-06	64	350	5	0.0	18
						22,460

15.60 gpm

All test data from Cell 1 As-Built Rept.

Sample	p-200	k (cm/sec)
SF-7	5	5.30E-02
PC-1	6.4	1.70E-02
stockpile	19.2	9.80E-04
CB wall		1.00E-06



Shallow, naturally occurring silty sand soils are known as the Penholoway aquifer
Penholoway aquifer average horizontal hydraulic conductivity = 4.65E-05 ft/sec (1E-03 cm/sec)

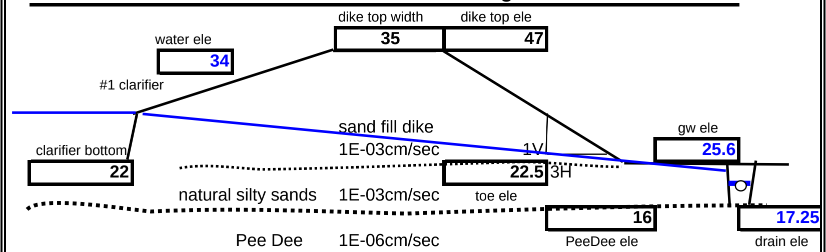
Peedee formation average horiz. Hydraulic conductivity = 3.4E-08 ft/sec (1E-06 cm/sec)
information from December 2004 Water Quality Monitoring Plan prepared by GN Richardson

Clayey sand dike fill hydraulic conductivity of south Cell 1 dike based on visual recollections of author from 2002 construction observation. Source: Wright Chemical beneath power lines. No testing was performed on the material.

URS CALCULATION SHEET	PROJECT: IP-Riegelwood North Bay Landfill Cell 2			JOB NO.: 31826716	
	SUBJECT: Groundwater collection system flow volumes			SHEET NO.: 5	
	ORIGINATED BY: Rich Lowe	DATE: 6/3/2009	CHECKED BY: CJK	DATE: 5/29/2009	CALC. NO.:	REV. NO.: 1

Purpose: Calibrate seepage estimates through/beneath Cell 1 East dike, with an installec collected in groundwater collection with actual 5-12-09 pumping rate records.

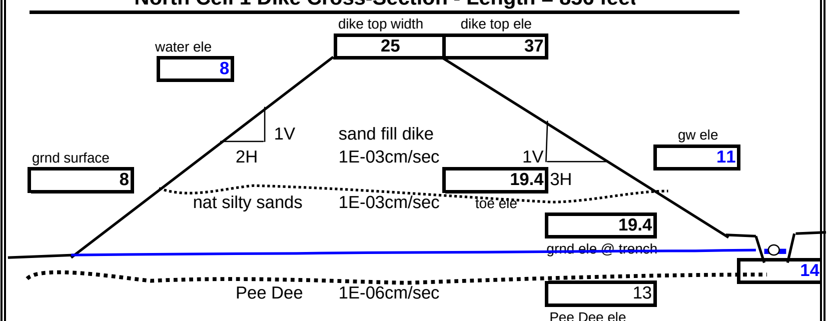
West Cell 1 Dike Cross-Section - Length = 326 feet



layer	k cm/sec	Gradient head loss	Gradient horizontal L	Area sq. ft/L. F.	q gpd/L. F.	Q gpd
sand dike fill	1.E-03					0
nat si sand	1.E-03	16.75	162	5.25	11.5	3,752
Pee Dee	1.E-06	16.75	162	5	0.0	4
						3,756

2.61 gpm

North Cell 1 Dike Cross-Section - Length = 856 feet

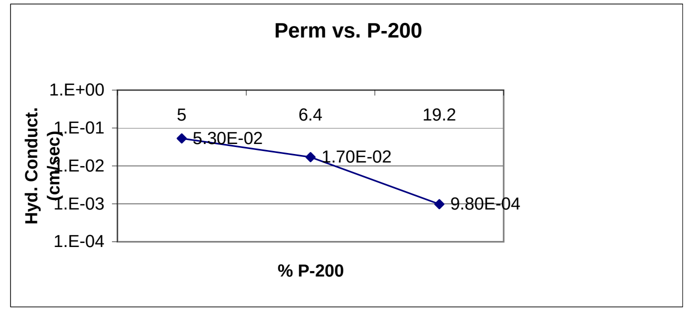


layer	k cm/sec	Gradient head loss	Gradient horizontal L	Area sq. ft/L. F.	q gpd/L. F.	Q gpd
sand dike fill	1.E-03		155.8			
nat si sand	1.E-03	-6	155.8	1	-0.8	-699
Pee Dee	1.E-06	-6	155.8	5	0.0	-3
						-702

-0.49 gpm

All test data from Cell 1 As-Built Rept.

Sample	p-200	k (cm/sec)
SF-7	5	5.30E-02
PC-1	6.4	1.70E-02
stockpile	19.2	9.80E-04
CB wall		1.00E-06



Shallow, naturally occurring silty sand soils are known as the Penholoway aquifer
Penholoway aquifer average horizontal hydraulic conductivity = 4.65E-05 ft/sec (1E-03 cm/sec)

Peedee formation average horiz. Hydraulic conductivity = 3.4E-08 ft/sec (1E-06 cm/sec)
information from December 2004 Water Quality Monitoring Plan prepared by GN Richardson

APPENDIX C

Pump Selection

IP Riegelwood Landfill Leachate/Underdrain Pump and Force Main Model
Prepared by: Ben Latino
Software: Bentley SewerGEMS V8
File: Riegelwood 2.swg

Assumptions:

Hazen C-value of 130 for all pipe
Existing leachate pump in cell 1 - GunnCo Sidesloper Model P2K-75.2 (see attached curve)
Proposed leachate pump in cell 2 - GunnCo Sidesloper Model P2K-85 (see attached curve)
Proposed underdrain pump in cell 2 - GunnCo Sidelsoper P3K Sump Pump (see attached curve)
Underdrain wetwell and piping based on Sheet 11 of 19, Liner System Drawings, 4/23/09
Underdrain wetwell piping changed from 2" HDPE to 2" Cast Iron
Cell 2 leachate pump and piping based on Sheet 14 of 19, Liner System Drawings, 4/23/09
Cell 1 leachate pump and piping based on provided elevations by LG, Pump el. 15.0', Pump off el. 16.0', Lead on el. 17.0', Lag on el. 18.5'
Cell 1 and 2 "wet wells" assumed to be 16' long by 10' wide by 4' deep above the pumps for purpose for providing an input into the model, i.e., sufficient collection of leachate to turn on all pumps.
Cell 1 hose length assumed to be identical to Cell 2.
Piping lengths based on Sheet 18 of 19, Liner System Drawings, 4/23/09

Analysis:

See attached model schematic.
Pumps and force main analyzed for the following scenarios:

1. All pumps at all three locations on simultaneously
2. One pump at each of the three locations on simultaneously
3. One existing leachate pump on only
4. One proposed leachate pump on only
5. One proposed underdrain pump on only
6. One proposed leachate and underdrain pump on simultaneously.

Results from SewerGEMS flex tables

1. All pumps at all three locations on simultaneously

Id	Label	Pumps	Elevation (ft)	Downstream Head (ft)	Pump Flow (gpm)	Pump Head (ft)	Upstream Head (ft)
20	Ex. P-1	<Collection: 1 it	15	60.9	64.22	42.9	19
21	Ex. P-2	<Collection: 1 it	15	60.9	64.31	42.8	19
22	Leach P-1	<Collection: 1 it	12.5	74.1	91.57	59.6	16.5
23	Leach P-2	<Collection: 1 it	12.5	74.1	91.67	59.5	16.5
24	Under P-1	<Collection: 1 it	0.2	61.9	29.29	57.6	5
25	Under P-2	<Collection: 1 it	0.2	61.9	29.74	57.5	5

Id	Label	Start-node Id	Stop-node Id	Diameter (in)	Material	Minor Loss Coefficient	Flow (gpm)	Hydraulic Grade (ft)	Maximum Flow (gpm)	Maximum Velocity (ft/s)	Velocity (ft/s)	User Defined Length (ft)
26	PP-2	20: Ex. P-1	16: PJ-1	3	Rubber Hose	4.77	64.63	61.4	98.77	4.48	2.93	72
27	PP-3	21: Ex. P-2	16: PJ-1	3	Rubber Hose	4.77	64.68	61.4	79.69	3.62	2.94	72
29	PP-4	22: Leach P-1	28: PJ-3	3	Rubber Hose	4.77	91.17	75.2	120.44	5.47	4.14	72
30	PP-5	23: Leach P-2	28: PJ-3	3	Rubber Hose	4.77	91.29	75.1	91.29	4.14	4.14	72
32	PP-6	16: PJ-1	31: PJ-4	6	HDPE	4.62	126.09	60.3	160.92	1.83	1.43	786.3
34	PP-8	28: PJ-3	31: PJ-4	3	HDPE	2.02	180.94	66.9	180.94	8.21	8.21	159
36	PP-9	24: Under P-1	35: PJ-5	2	Cast Iron	3.97	29.67	62.3	73.53	7.51	3.03	26
37	PP-10	25: Under P-2	35: PJ-5	2	Cast Iron	3.97	30.18	62.2	51.39	5.25	3.08	26
39	PP-11	31: PJ-4	38: PJ-6	6	HDPE	0.35	308.09	59.6	308.09	3.5	3.5	6.3
41	PP-13	35: PJ-5	38: PJ-6	2	HDPE	0.74	50.24	60.7	101.4	10.36	5.13	39
55	PP-16	38: PJ-6	19: OF-1	6	HDPE	1.00	359.06	47.8	360.72	4.09	4.07	2,161.80

Id	Label	Elevation (ft)	Pressure (feet H2O)	HGL (ft)	Maximum Hydraulic Grade (ft)	Total Outflow (gpm)
16	PJ-1	34.4	26.5	60.9	61.2	126.09
28	PJ-3	36	38.1	74.1	75.1	180.94
31	PJ-4	26.2	33.4	59.6	59.9	308.09
35	PJ-5	26	35.9	61.9	62.5	50.24
38	PJ-6	26.2	33.3	59.5	59.8	359.06

2. One pump at each of the three locations on simultaneously

Id	Label	Pumps	Elevation (ft)	Downstream Head (ft)	Pump Flow (gpm)	Pump Head (ft)	Upstream Head (ft)
20	Ex. P-1	<Collection: 1 it	15	48.2	82.17	33.9	17
21	Ex. P-2	<Collection: 1 it	15	48.2	0	0	17
22	Leach P-1	<Collection: 1 it	12.5	53.9	108.31	44.5	13.8
23	Leach P-2	<Collection: 1 it	12.5	53.9	0	0	13.8
24	Under P-1	<Collection: 1 it	0.2	50.8	55.31	52.9	2.1
25	Under P-2	<Collection: 1 it	0.2	50.8	0	0	2.1

Id	Label	Start-node Id	Stop-node Id	Diameter (in)	Material	Minor Loss Coefficient	Flow (gpm)	Hydraulic Grade (ft)	Maximum Flow (gpm)	Maximum Velocity (ft/s)	Velocity (ft/s)	User Defined Length (ft)
26	PP-2	20: Ex. P-1	16: PJ-1	3	Rubber Hose	4.77	82.54	49.6	98.77	4.48	3.75	72
27	PP-3	21: Ex. P-2	16: PJ-1	3	Rubber Hose	4.77	0	48.2	79.69	3.62	0	72
29	PP-4	22: Leach P-1	28: PJ-3	3	Rubber Hose	4.77	107.89	56.2	120.44	5.47	4.9	72
30	PP-5	23: Leach P-2	28: PJ-3	3	Rubber Hose	4.77	0	53.9	91.29	4.14	0	72
32	PP-6	16: PJ-1	31: PJ-4	6	HDPE	4.62	82.54	47.9	160.92	1.83	0.94	786.3
34	PP-8	28: PJ-3	31: PJ-4	3	HDPE	2.02	107.89	50.8	180.94	8.21	4.9	159
36	PP-9	24: Under P-1	35: PJ-5	2	Cast Iron	3.97	55.59	53.1	73.53	7.51	5.68	26
37	PP-10	25: Under P-2	35: PJ-5	2	Cast Iron	3.97	0	50.8	51.39	5.25	0	26
39	PP-11	31: PJ-4	38: PJ-6	6	HDPE	0.35	190.46	47.6	308.09	3.5	2.16	6.3
41	PP-13	35: PJ-5	38: PJ-6	2	HDPE	0.74	55.59	49.2	101.4	10.36	5.68	39
55	PP-16	38: PJ-6	19: OF-1	6	HDPE	1	246.09	41.6	360.72	4.09	2.79	2,161.80

Id	Label	Elevation (ft)	Pressure (feet H2O)	HGL (ft)	Maximum Hydraulic Grade (ft)	Total Outflow (gpm)
16	PJ-1	34.4	13.8	48.2	61.2	82.54
28	PJ-3	36	17.9	53.9	75.1	107.89
31	PJ-4	26.2	21.4	47.6	59.9	190.46
35	PJ-5	26	24.8	50.8	62.5	55.59
38	PJ-6	26.2	21.3	47.5	59.8	246.09

3. One existing leachate pump on only

Id	Label	Pumps	Elevation (ft)	Downstream Head (ft)	Pump Flow (gpm)	Pump Head (ft)	Upstream Head (ft)
20	Ex. P-1	<Collection: 1 it	15	38.6	98.85	25.6	16.7
21	Ex. P-2	<Collection: 1 it	15	38.6	0	0	16.7
22	Leach P-1	<Collection: 1 it	12.5	37.7	0	0	14.4
23	Leach P-2	<Collection: 1 it	12.5	37.7	0	0	14.4
24	Under P-1	<Collection: 1 it	0.2	37.7	0	0	1.4
25	Under P-2	<Collection: 1 it	0.2	37.7	0	0	1.4

Id	Label	Start-node Id	Stop-node Id	Diameter (in)	Material	Minor Loss Coefficient	Flow (gpm)	Hydraulic Grade (ft)	Maximum Flow (gpm)	Maximum Velocity (ft/s)	Velocity (ft/s)	User Defined Length (ft)
26	PP-2	20: Ex. P-1	16: PJ-1	3	Rubber Hose	4.77	98.44	40.5	98.77	4.48	4.47	72
27	PP-3	21: Ex. P-2	16: PJ-1	3	Rubber Hose	4.77	0	38.6	79.69	3.62	0	72
29	PP-4	22: Leach P-1	28: PJ-3	3	Rubber Hose	4.77	0	37.7	120.44	5.47	0	72
30	PP-5	23: Leach P-2	28: PJ-3	3	Rubber Hose	4.77	0	37.7	91.29	4.14	0	72
32	PP-6	16: PJ-1	31: PJ-4	6	HDPE	4.62	98.44	38.2	160.92	1.83	1.12	786.3
34	PP-8	28: PJ-3	31: PJ-4	3	HDPE	2.02	0	37.7	180.94	8.21	0	159
36	PP-9	24: Under P-1	35: PJ-5	2	Cast Iron	3.97	0	37.7	73.53	7.51	0	26
37	PP-10	25: Under P-2	35: PJ-5	2	Cast Iron	3.97	0	37.7	51.39	5.25	0	26
39	PP-11	31: PJ-4	38: PJ-6	6	HDPE	0.35	98.44	37.7	308.09	3.5	1.12	6.3
41	PP-13	35: PJ-5	38: PJ-6	2	HDPE	0.74	0	37.7	101.4	10.36	0	39
55	PP-16	38: PJ-6	19: OF-1	6	HDPE	1	98.44	36.6	360.72	4.09	1.12	2,161.80

Id	Label	Elevation (ft)	Pressure (feet H2O)	HGL (ft)	Maximum Hydraulic Grade (ft)	Total Outflow (gpm)
16	PJ-1	34.4	4.2	38.6	61.2	98.44
28	PJ-3	36	1.7	37.7	75.1	0
31	PJ-4	26.2	11.5	37.7	59.9	98.44
35	PJ-5	26	11.7	37.7	62.5	0
38	PJ-6	26.2	11.5	37.7	59.8	98.44

4. One proposed leachate pump on only

Id	Label	Pumps	Elevation (ft)	Downstream Head (ft)	Pump Flow (gpm)	Pump Head (ft)	Upstream Head (ft)
20	Ex. P-1	<Collection: 1 it	15	40.9	0	0	16.9
21	Ex. P-2	<Collection: 1 it	15	40.9	0	0	16.9
22	Leach P-1	<Collection: 1 it	12.5	47.9	114.76	38.7	14
23	Leach P-2	<Collection: 1 it	12.5	47.9	0	0	14
24	Under P-1	<Collection: 1 it	0.2	41.1	0	0	1.2
25	Under P-2	<Collection: 1 it	0.2	41.1	0	0	1.2

Id	Label	Start-node Id	Stop-node Id	Diameter (in)	Material	Minor Loss Coefficient	Flow (gpm)	Hydraulic Grade (ft)	Maximum Flow (gpm)	Maximum Velocity (ft/s)	Velocity (ft/s)	User Defined Length (ft)
26	PP-2	20: Ex. P-1	16: PJ-1	3	Rubber Hose	4.77	0	40.9	98.77	4.48	0	72
27	PP-3	21: Ex. P-2	16: PJ-1	3	Rubber Hose	4.77	0	40.9	79.69	3.62	0	72
29	PP-4	22: Leach P-1	28: PJ-3	3	Rubber Hose	4.77	114.34	50.4	120.44	5.47	5.19	72
30	PP-5	23: Leach P-2	28: PJ-3	3	Rubber Hose	4.77	0	47.9	91.29	4.14	0	72
32	PP-6	16: PJ-1	31: PJ-4	6	HDPE	4.62	0	40.9	160.92	1.83	0	786.3
34	PP-8	28: PJ-3	31: PJ-4	3	HDPE	2.02	114.34	44.4	180.94	8.21	5.19	159
36	PP-9	24: Under P-1	35: PJ-5	2	Cast Iron	3.97	0	41.1	73.53	7.51	0	26
37	PP-10	25: Under P-2	35: PJ-5	2	Cast Iron	3.97	0	41.1	51.39	5.25	0	26
39	PP-11	31: PJ-4	38: PJ-6	6	HDPE	0.35	111.3	40.9	308.09	3.5	1.26	6.3
41	PP-13	35: PJ-5	38: PJ-6	2	HDPE	0.74	0	41	101.4	10.36	0	39
55	PP-16	38: PJ-6	19: OF-1	6	HDPE	1	158.54	38.2	360.72	4.09	1.8	2,161.80

Id	Label	Elevation (ft)	Pressure (feet H2O)	HGL (ft)	Maximum Hydraulic Grade (ft)	Total Outflow (gpm)
16	PJ-1	34.4	6.5	40.9	61.2	0
28	PJ-3	36	11.9	47.9	75.1	114.34
31	PJ-4	26.2	14.7	40.9	59.9	111.3
35	PJ-5	26	15.1	41.1	62.5	0
38	PJ-6	26.2	14.6	40.8	59.8	158.54

5. One proposed underdrain pump on only

Id	Label	Pumps	Elevation (ft)	Downstream Head (ft)	Pump Flow (gpm)	Pump Head (ft)	Upstream Head (ft)
20	Ex. P-1	<Collection: 1 it	15	(N/A)	(N/A)	(N/A)	(N/A)
21	Ex. P-2	<Collection: 1 it	15	(N/A)	(N/A)	(N/A)	(N/A)
22	Leach P-1	<Collection: 1 it	12.5	36.8	0	0	14.5
23	Leach P-2	<Collection: 1 it	12.5	36.8	0	0	14.5
24	Under P-1	<Collection: 1 it	0.2	42.4	73.73	48.6	1.2
25	Under P-2	<Collection: 1 it	0.2	42.4	0	0	1.2

Id	Label	Start-node Id	Stop-node Id	Diameter (in)	Material	Minor Loss Coefficient	Flow (gpm)	Hydraulic Grade (ft)	Maximum Flow (gpm)	Maximum Velocity (ft/s)	Velocity (ft/s)	User Defined Length (ft)
26	PP-2	20: Ex. P-1	16: PJ-1	3	Rubber Hose	4.77	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	72
27	PP-3	21: Ex. P-2	16: PJ-1	3	Rubber Hose	4.77	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	72
29	PP-4	22: Leach P-1	28: PJ-3	3	Rubber Hose	4.77	0	36.8	119.41	5.42	0	72
30	PP-5	23: Leach P-2	28: PJ-3	3	Rubber Hose	4.77	0	36.8	97.46	4.42	0	72
32	PP-6	16: PJ-1	31: PJ-4	6	HDPE	4.62	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	786.3
34	PP-8	28: PJ-3	31: PJ-4	3	HDPE	2.02	0	36.8	194.71	8.84	0	159
36	PP-9	24: Under P-1	35: PJ-5	2	Cast Iron	3.97	74.13	46.3	88.11	9	7.57	26
37	PP-10	25: Under P-2	35: PJ-5	2	Cast Iron	3.97	0	42.4	57.07	5.83	0	26
39	PP-11	31: PJ-4	38: PJ-6	6	HDPE	0.35	0	36.8	194.71	2.21	0	6.3
41	PP-13	35: PJ-5	38: PJ-6	2	HDPE	0.74	74.13	39.6	115.38	11.78	7.57	39
55	PP-16	38: PJ-6	19: OF-1	6	HDPE	1	74.29	36.1	285.64	3.24	0.84	2,161.80

Id	Label	Elevation (ft)	Pressure (feet H2O)	HGL (ft)	Maximum Hydraulic Grade (ft)	Total Outflow (gpm)
16	PJ-1	34.4	(N/A)	(N/A)	(N/A)	(N/A)
28	PJ-3	36	0.8	36.8	68.4	0
31	PJ-4	26.2	10.6	36.8	51.2	0
35	PJ-5	26	16.4	42.4	58.5	74.13
38	PJ-6	26.2	10.6	36.8	51.2	74.29

6. One proposed leachate and underdrain pump on simultaneously

Id	Label	Pumps	Elevation (ft)	Downstream Head (ft)	Pump Flow (gpm)	Pump Head (ft)	Upstream Head (ft)
20	Ex. P-1	<Collection: 1 it	15	(N/A)	(N/A)	(N/A)	(N/A)
21	Ex. P-2	<Collection: 1 it	15	(N/A)	(N/A)	(N/A)	(N/A)
22	Leach P-1	<Collection: 1 it	12.5	49.2	113	40.3	13.7
23	Leach P-2	<Collection: 1 it	12.5	49.2	0	0	13.7
24	Under P-1	<Collection: 1 it	0.2	46.8	66.57	50.4	2.5
25	Under P-2	<Collection: 1 it	0.2	46.8	0	0	2.5

Id	Label	Start-node Id	Stop-node Id	Diameter (in)	Material	Minor Loss Coefficient	Flow (gpm)	Hydraulic Grade (ft)	Maximum Flow (gpm)	Maximum Velocity (ft/s)	Velocity (ft/s)	User Defined Length (ft)
26	PP-2	20: Ex. P-1	16: PJ-1	3	Rubber Hose	4.77	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	72
27	PP-3	21: Ex. P-2	16: PJ-1	3	Rubber Hose	4.77	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	72
29	PP-4	22: Leach P-1	28: PJ-3	3	Rubber Hose	4.77	112.6	51.7	119.41	5.42	5.11	72
30	PP-5	23: Leach P-2	28: PJ-3	3	Rubber Hose	4.77	0	49.2	97.46	4.42	0	72
32	PP-6	16: PJ-1	31: PJ-4	6	HDPE	4.62	(N/A)	(N/A)	(N/A)	(N/A)	(N/A)	786.3
34	PP-8	28: PJ-3	31: PJ-4	3	HDPE	2.02	112.6	45.8	194.71	8.84	5.11	159
36	PP-9	24: Under P-1	35: PJ-5	2	Cast Iron	3.97	66.96	50.1	88.11	9	6.84	26
37	PP-10	25: Under P-2	35: PJ-5	2	Cast Iron	3.97	0	46.8	57.07	5.83	0	26
39	PP-11	31: PJ-4	38: PJ-6	6	HDPE	0.35	112.6	42.2	194.71	2.21	1.28	6.3
41	PP-13	35: PJ-5	38: PJ-6	2	HDPE	0.74	66.96	44.5	115.38	11.78	6.84	39
55	PP-16	38: PJ-6	19: OF-1	6	HDPE	1	179.66	38.9	285.64	3.24	2.04	2,161.80

Id	Label	Elevation (ft)	Pressure (feet H2O)	HGL (ft)	Maximum Hydraulic Grade (ft)	Total Outflow (gpm)
16	PJ-1	34.4	(N/A)	(N/A)	(N/A)	(N/A)
28	PJ-3	36	13.2	49.2	68.4	112.6
31	PJ-4	26.2	16	42.2	51.2	112.6
35	PJ-5	26	20.8	46.8	58.5	66.96
38	PJ-6	26.2	16	42.2	51.2	179.66

URS

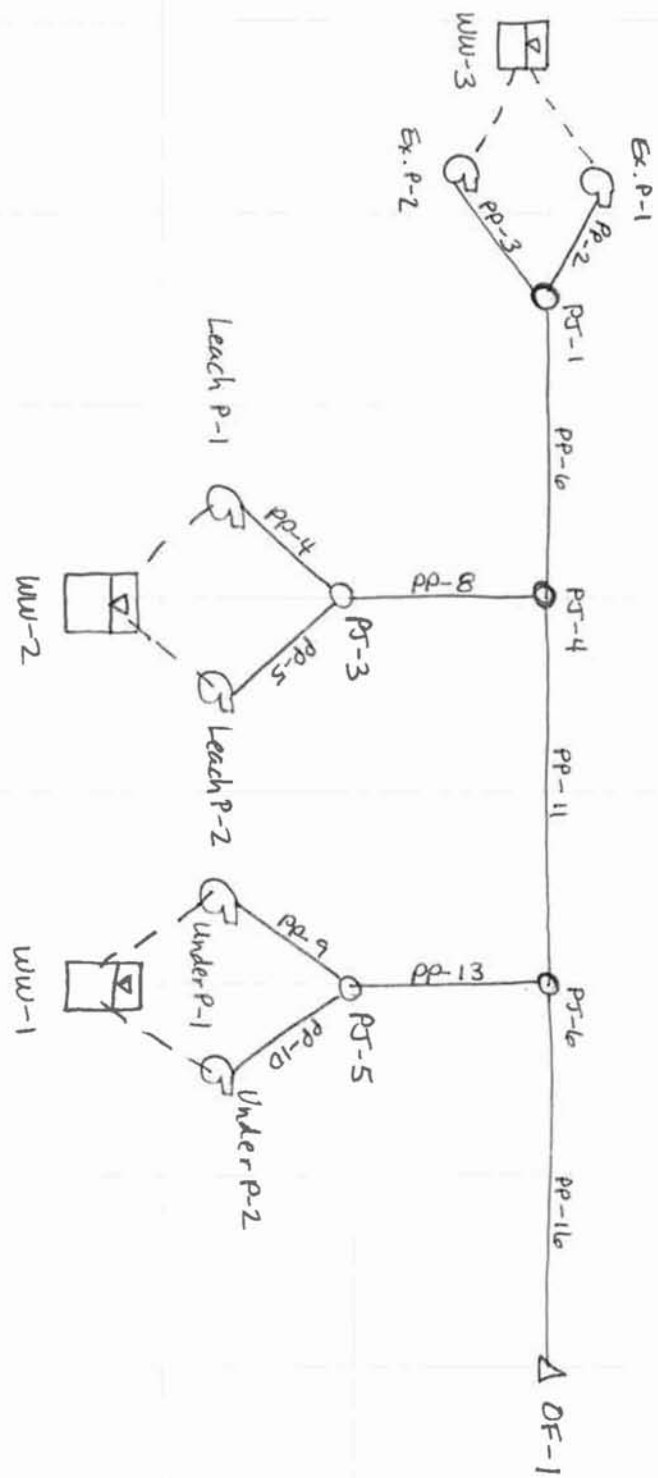
Page ____ of ____

Job: IP Riegelwood | Project No. ____ | Sheet 5 of 8

Description: Underdrain/Leachate Pump Model Schematic | Computed by ____ | Date ____

Checked by ____ | Date ____

Reference



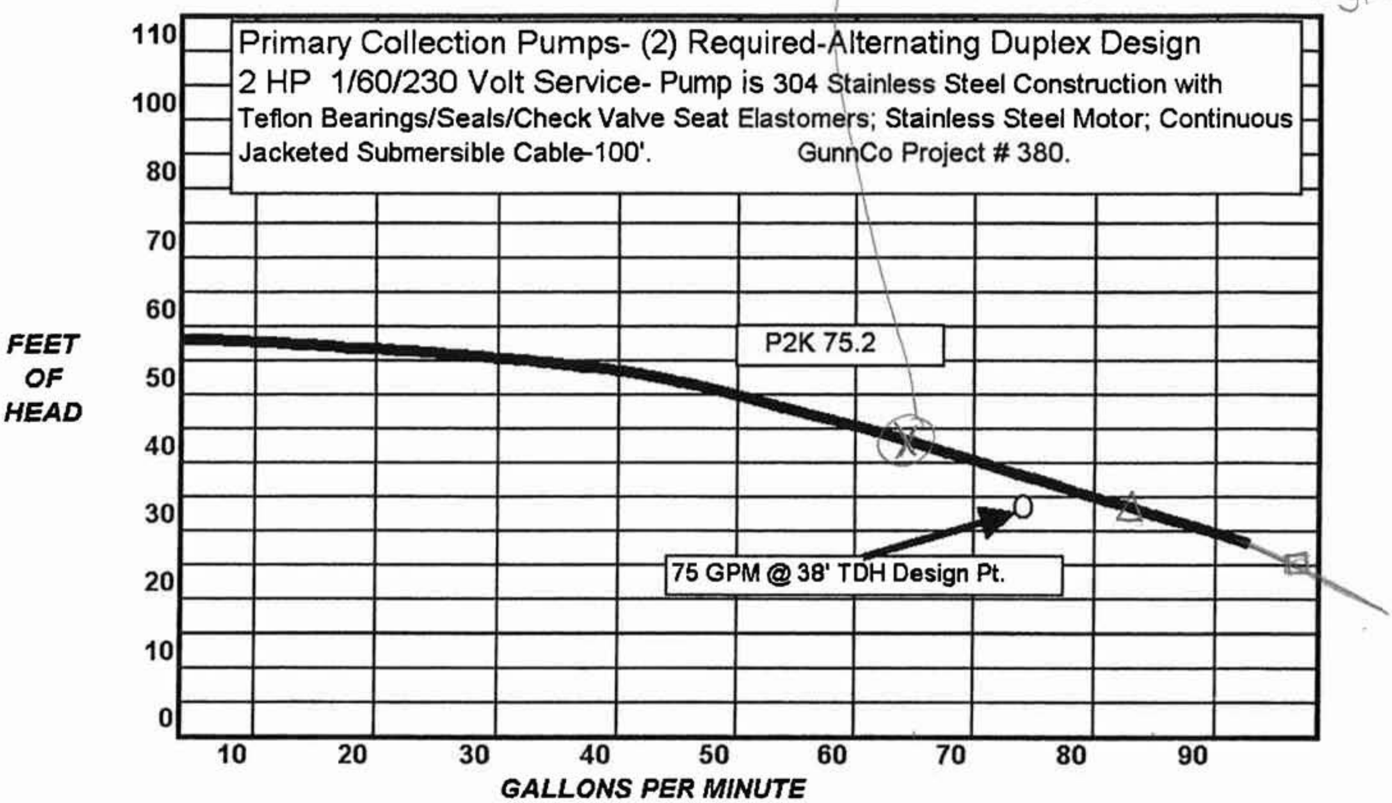
Existing LEACHATE

GunnCo Sidesloper™ Pump

75 GALLONS PER MINUTE NOMINAL FLOW PUMP **P2K-75.2**

MULTI-STAGE TURBINE SIDE SLOPE EXTRACTION PUMP 1.03

(NOTE: ON PARALLEL CURVE Q = 128 gpm



PUMP	MODEL	H.P.	"L"
P2K	75-1	1.0	36"
P2K	75-2	1.5	36"
P2K	75-3	2.0	36"
P2K	75-4	3.0	42"
P2K	75-5	3.0	42"

All pumps include wheeled carrier and are designed for application in 18" SDR 11 to 17 HDPE pipe.

Pumps may be ordered for use in 24" or other custom pipe sizes.

Pump construction is 304 stainless steel with bearings and seals of Teflon material.

X – ALL PUMPS ON

△ – ONE PUMP EACH ON

□ – ONLY EXISTING ON

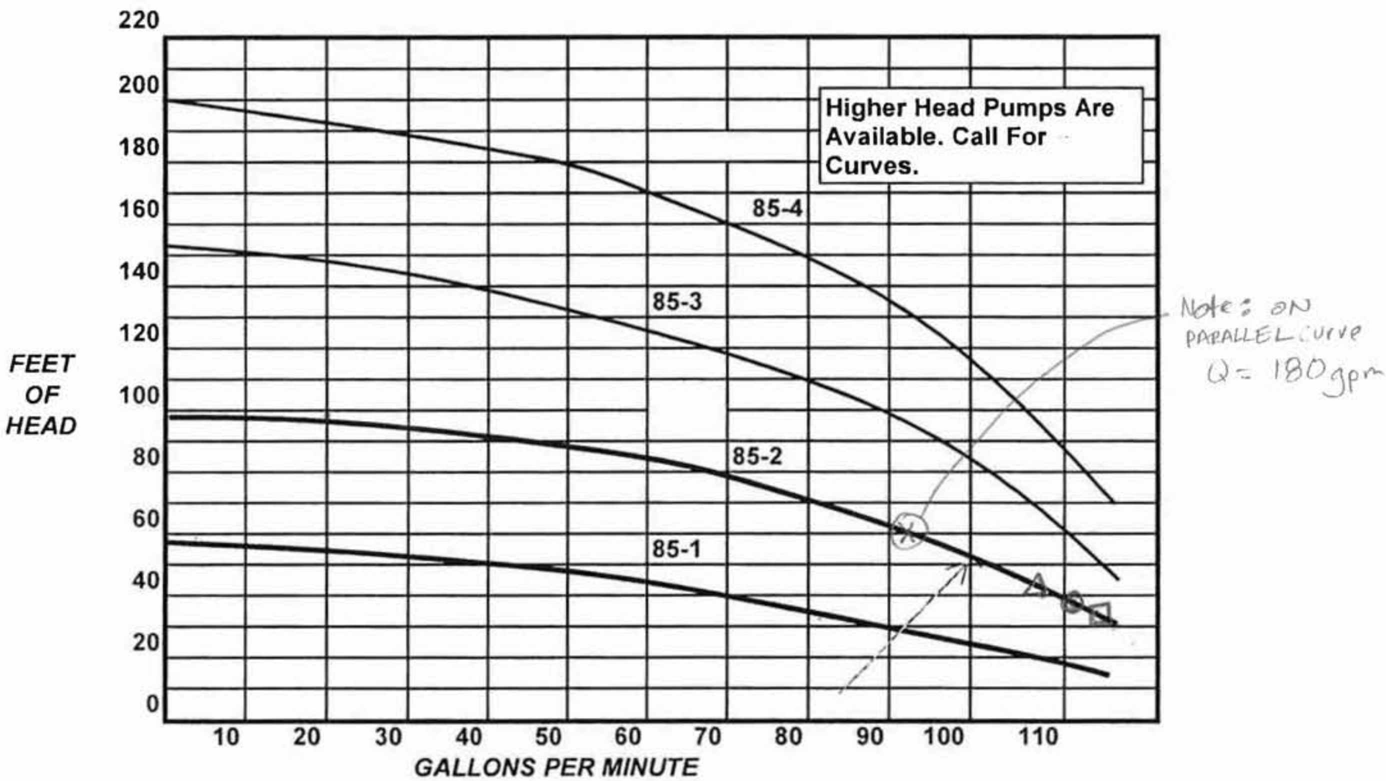
85 —

Proposed Primary
LEACHATE PUMP

GunnCo............***Sidesloper***™ *Pump*

85 GALLONS PER MINUTE NOMINAL FLOW PUMP *P2K-85*

MULTI-STAGE TURBINE SIDE SLOPE EXTRACTION PUMP



PUMP	MODEL	H.P.	* "L"
P2K	85-1	1.5	36"
P2K	85-2	3.0	46"
P2K	85-3	5.0	55"
P2K	85-4	5.0	55"

* "L" Represents maximum length Consult GunnCo for actual "L" dimension.

All pumps include wheeled carrier and are designed for application in 24" SDR 11 to 22 HDPE pipe.

Pumps may be ordered for use in 18" or other custom pipe sizes.

Pump construction is 304 stainless steel with bearings and seals of Teflon material.
Motor construction 304 S/S
Carrier construction 304 S/S

X - ALL PUMPS ON

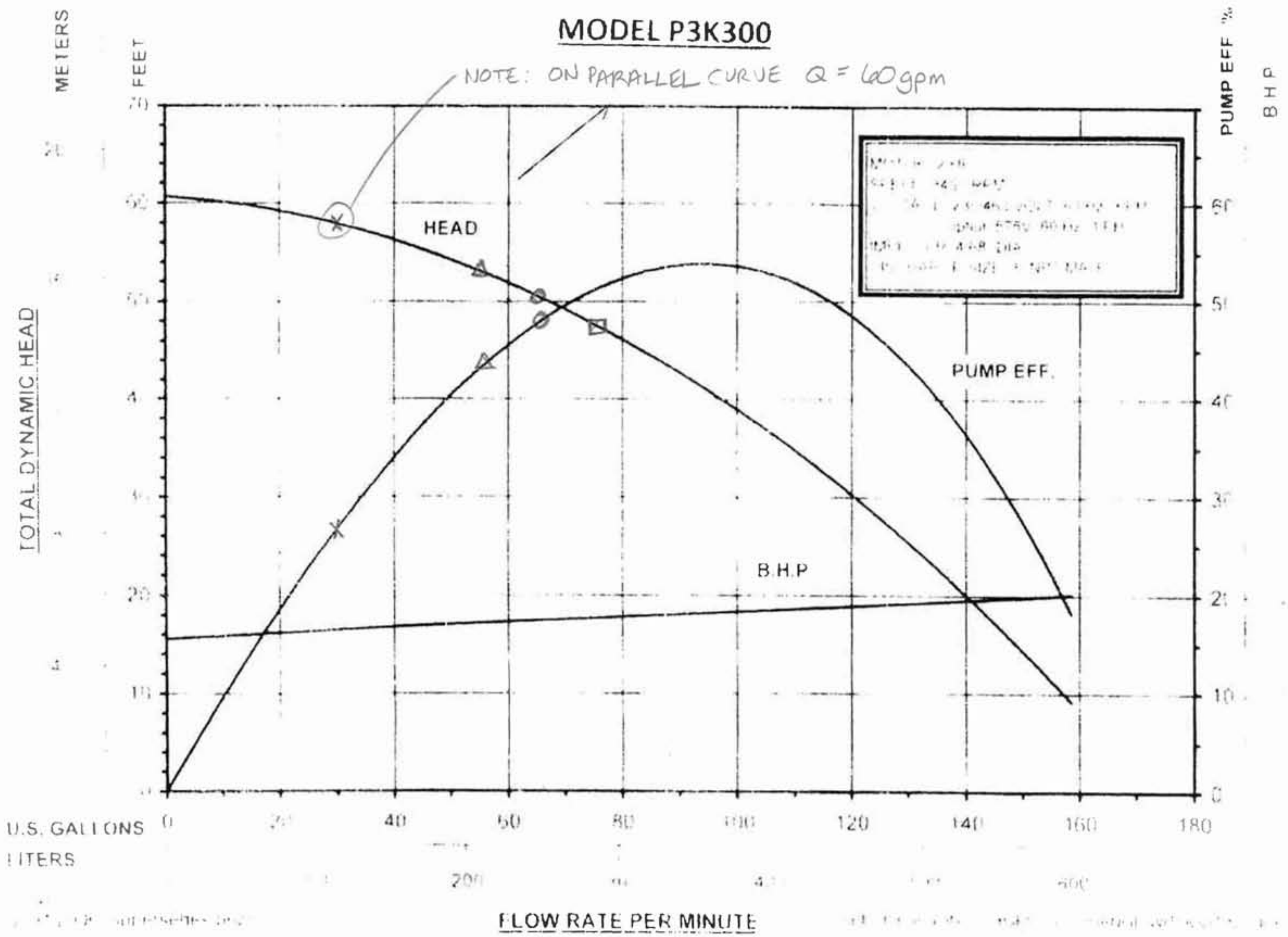
Δ - ONE PUMP EACH ON

O - ONE PUMP LEACHATE/UNDERDRAIN ONLY

□ - ONLY LEACHATE

PROPOSED UNDERDRAIN SUBMERSIBLE PUMP

X - ALL PUMPS ON
Δ - ONE PUMP EACH ON
O - ONE PUMP LEACHATE/UNDER ONLY
□ - ONLY UNDERDRAIN



APPENDIX B

Aggregate Selection

URS CALCULATION SHEET	PROJECT IP-Riegelwood Cell 2 Liner System				JOB NO. 31826746	
	SUBJECT Filter Media Calculations				SHEET NO. 1 of 5	
	ORIGINATED B Lenore Gaie	DATE 5/14/2009	CHECKED BY Rich Lowe	DATE 6/1/2009	CALC. NO.	REV. NO.

Case 1

2' Sand Blanket
Protective Cover — B

Filter Media — F

Determine the aggregate size of the filter media

1 $D_{15F} / D_{15B} > 4$

where: $D_{15B} = 0.17 - 0.075$ (from sand blanket curve)

$D_{15F} = 4 * 0.17 = 0.68$
$D_{15F} = 4 * 0.075 = 0.30$

Therefore D_{15F} lower limit = 0.68

2 $D_{15F} / D_{85B} \leq 9$

where: $D_{85B} = 0.73 - 0.53$ (from sand blanket curve)

$D_{15F} = 9 * 0.73 = 6.57$
$D_{15F} = 9 * 0.53 = 4.77$

Therefore D_{15F} upper limit = 6.57

3 $D_{50F} / D_{50B} < 25$

where: $D_{50B} = 0.39 - 0.28$ (from sand blanket curve)

$D_{50F} = 25 * 0.39 = 9.75$
$D_{50F} = 25 * 0.28 = 7.0$

Therefore D_{50F} limits = 9.75 - 7.0

4 $D_{15F} / D_{15B} < 20$

where: $D_{15B} = 0.17 - 0.075$ (from sand blanket curve)

$D_{15F} = 20 * 0.17 = 3.4$
$D_{15F} = 20 * 0.075 = 1.5$

Therefore D_{15F} upper limit = 3.4
(since 3.4 is less than 6.57 no need to plot as upper limit)

5 Coefficient of Uniformity

$Cu = D_{60}/D_{10}$ where: $D_{60} = 0.42$ and $D_{10} = 0.14$ (from sand blanket curve)

$Cu = .42/.14 = 4.2$

Since $Cu = 4.2 > 4$ therefore $D_{15F}/D_{15B} = 40$

$D_{15F} = 40 * 0.17 = 6.8$
$D_{15F} = 40 * 0.0.075 = 3.0$

Therefore D_{15F} upper limit = 6.8
(since 6.8 is greater than 6.57 it's the new upper limit)

URS CALCULATION SHEET	PROJECT IP-Riegelwood Cell 2 Liner System				JOB NO. 31826746	
	SUBJECT Filter Media Calculations				SHEET NO. 2 of 5	
	ORIGINATED BY Lenore Gaier	DATE 5/14/2009	CHECKED BY Rich Lowe	DATE 6/1/2009	CALC. NO.	REV. NO.

Case 1 (cont)

2' Sand Blanket Protective Cover	B
Filter Media	F

6 Plot the limits

D_{15F} lower limit = 0.68

D_{15F} upper limit = 6.8

D_{50F} limits = 9.75 - 7.0

According to Table 1005-1 #78 stone falls within the calculated limits of the filter media.
Therefore #78 stone can be used as the filter media. RLL

Case 2

Filter Media B

#57 Stone F

Determine if #57 Stone is adequate as filter material below the filter media.

1 $D_{15F} / D_{15B} > 4$

where: $D_{15B} = 4 - 2.5$ (from #78 stone curve)

$D_{15F} = 4 * 4 = 16$
$D_{15F} = 4 * 2.5 = 10$

Therefore D_{15F} lower limit = 16

2 $D_{15F} / D_{85B} \leq 9$

where: $D_{85B} = 11 - 7.8$ (from #78 stone curve)

$D_{15F} = 9 * 11 = 99$
$D_{15F} = 9 * 7.8 = 70.2$

Therefore D_{15F} upper limit = 99

3 $D_{50F} / D_{50B} < 25$

where: $D_{50B} = 7.9 - 4.8$ (from #78 stone curve)

$D_{50F} = 25 * 7.9 = 197.5$
$D_{50F} = 25 * 4.8 = 120$

Therefore D_{50F} limits = 197.5 - 120

4 $D_{15F} / D_{15B} < 20$

where: $D_{15B} = 4 - 2.5$ (from #78 stone curve)

$D_{15F} = 20 * 4 = 80$
$D_{15F} = 20 * 2.5 = 50$

Therefore D_{15F} upper limit = 50
(The new upper limit for D_{15F} is 50 not 99)

5 Coefficient of Uniformity
$Cu = D_{60}/D_{10}$ where: $D_{60} = 8.2$ and $D_{10} = 3.5$ (from #78 stone curve)
$Cu = 8.2/3.5 = 2.34$

Since Cu = 2.34 its not < 1.5 and not > 4 then no further calculations for D_{15F} needs to be done

URS CALCULATION SHEET	PROJECT IP-Riegelwood Cell 2 Liner System				JOB NO. 31826746	
	SUBJECT Filter Media Calculations				SHEET NO. 4 of 5	
	ORIGINATED B Lenore Gaier	DATE 5/14/2009	CHECKED BY Rich Lowe	DATE 6/1/2009	CALC. NO.	REV. NO.

Case 2 (cont)

Filter Media	B
#57 Stone	F

6 Plot the limits

D_{15F} lower limit = 16 D_{50F} limits = 197.5 - 120

D_{15F} upper limit = 50

According to Table 1005-1 #57 stone falls within the calculated limits.
Therefore #57 stone can be used as the filter media. ✓ RKL

Case 3

# 57 Stone	B
HDPE perforated pipe	F

Determine if drain pipe perforations are adequately sized

1 D_{85F} / hole diameter > 1.0 to 1.2

where: D_{85B} = 26 - 20 (from #57 stone curve)

hole diameter = 1/2" = 12.7 mm

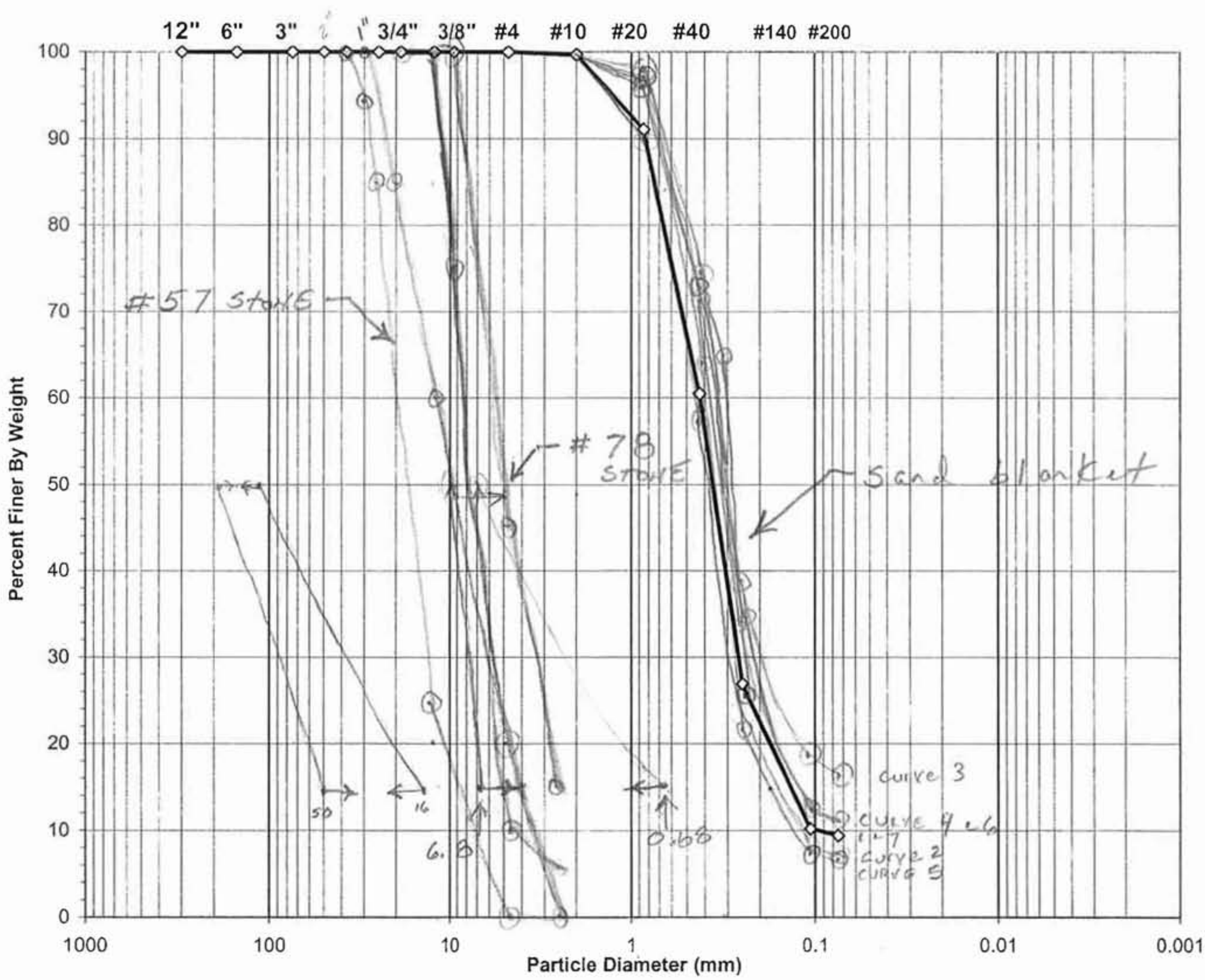
20 / 12.7 = 1.6 > 1.2

Therefore hole diameter of 1/2" is adaquate ✓ RKL

SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

Client	G.N. RICHARDSON & ASSOC.	Boring No.	8/25/03
Client Reference	I.P. RIEGELWOOD	Depth (ft)	CELL 1
Project No.	2003-511-10	Sample No.	PC8
Lab ID	2003-511-10-02	Soil Color	**TAN**

USCS	*SIEVE ANALYSIS*		*HYDROMETER*
	gravel	sand	silt and clay



USCS Symbol	***sp-sm, ASSUMED***	**D60 =**	**0.4**	**CC =**	**1.7**
USCS Classification	***POORLY GRADED SAND WITH SILT***	**D30 =**	**0.3**	**CU =**	**4.3**
		D10 =	**0.1**		

Tested By ES Date 09/13/03 Checked By DAJ Date 9-17-03

 DCN: CT-S3C DATE 6-25-98 REVISION: 2 *C:\2003 Projects\2003-511 GNR\[2003-511-10-02 Sieve.XLS]Sheet1*

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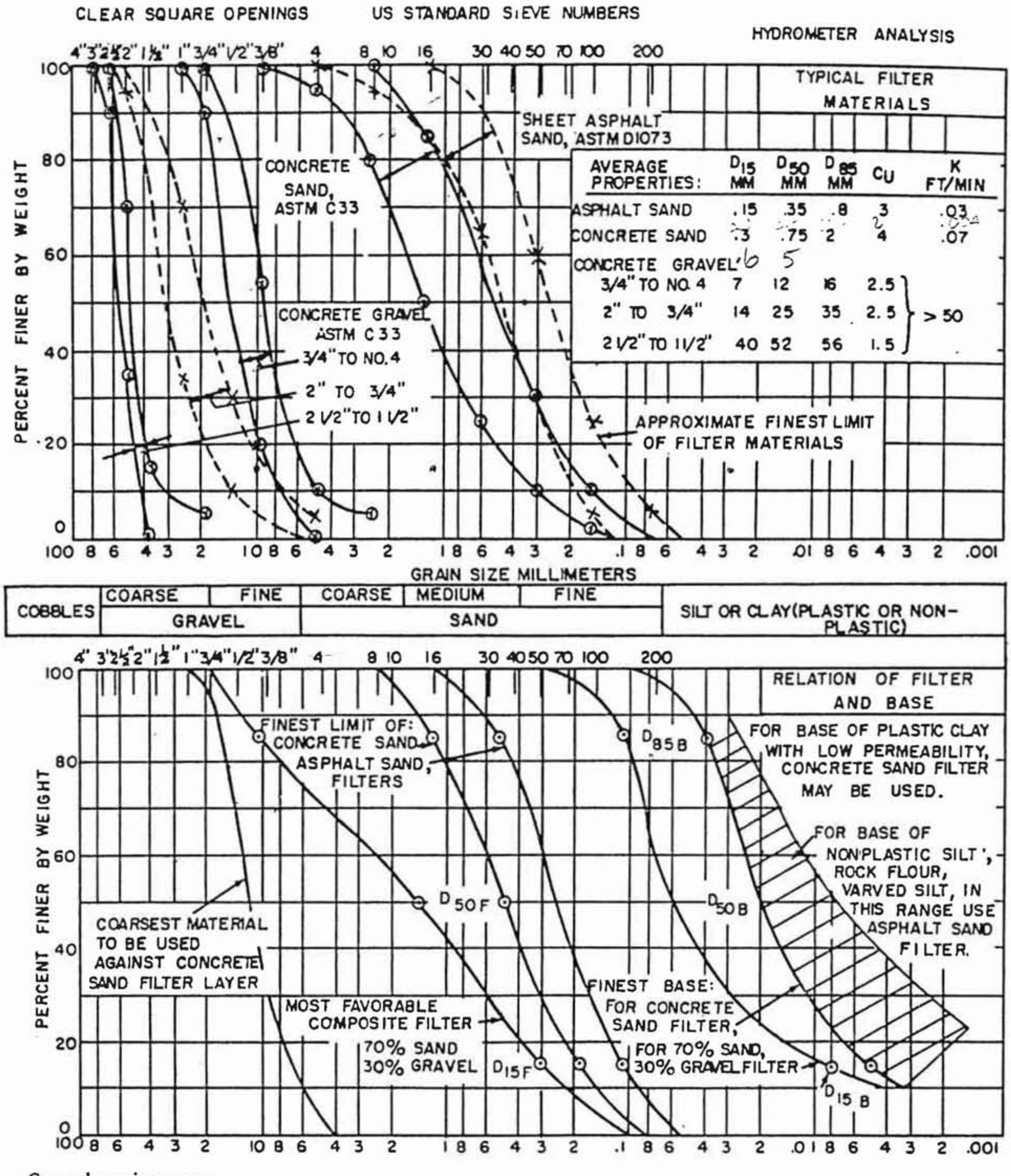
TABLE 1005-1
AGGREGATE GRADATION, COARSE AGGREGATE

STD SIZE #	2"	1 1/2"	1"	3/4"	1/2"	3/8"	#4	#8	#10	#16	#30	#40	#50	#80	#100	#200	REMARKS
	PERCENTAGE OF TOTAL BY WEIGHT OF PASSING																
4	100	90-100	20-55	0-15		0-5										0-* 0.6	Asphalt Plant Mix Pavement
467M	100	95-100		35-70		0-30	0-5									0-* 0.6	Asphalt Plant Mix Pavement
5		100	90-100	20-55	0-10	0-5										0-* 0.6	AST Mat coat, Sediment Control Stone
57		100	95-100		25-60		0-10	0-5								0-* 0.6	Str. Conc., Shoulder Drain, Sediment Control Stone
57M		100	95-100		25-45		0-10	0-5								0-* 0.6	P. C. Concrete Pavement
6M			100	90-100	20-55	0-20	0-8									*	AST
67			100	90-100		20-55	0-10	0-5								0-* 0.6	Str. Conc., Asphalt Plant Mix Pavement.
78M				100	98-100	75-100	20-45	0-15								0-* 0.6	Asphalt Plant Mix Pavement, AST Weep Hole Drains, Str. Concrete
14M						100	35-70	5-20		0-8						*	* AST
ABC		100	75-97		55-80		35-55		25-45			14-30				4-12**	Aggregate. Stabilization Aggregate/Base Course Asphalt Plant Mix Pavement
ABC(M)		100	75-100		45-79		20-40		0-25							0-12**	Maintenance Stabilization



General requirements:

1. To avoid head loss in filter: $\frac{D_{15\,F}}{D_{15\,B}} > 4$, and permeability of filter must be large enough to suffice for the particular drainage system.
2. To avoid movement of particles from base: $\frac{D_{15\,F}}{D_{85\,B}} < 5$, $\frac{D_{50\,F}}{D_{50\,B}} < 25$, $\frac{D_{15\,F}}{D_{15\,B}} < 20$
   For very uniform base material ($C_u < 1.5$): $D_{15\,F}/D_{85\,D}$ may be increased to 6
   For broadly graded base material ($C_u > 4$): $D_{15\,F}/D_{15\,B}$ may be increased to 40
3. To avoid movement of filter in drain pipe perforations or joints:
   $D_{85\,F}$/slot width > (1.2 to 1.4) $D_{85\,F}$/hole diameter > (1.0 to 1.2)
4. To avoid segregation filter should contain no sizes larger than 3".
5. To avoid internal movement of fines, filter should have no more than 5% passing No. 200 sieve.

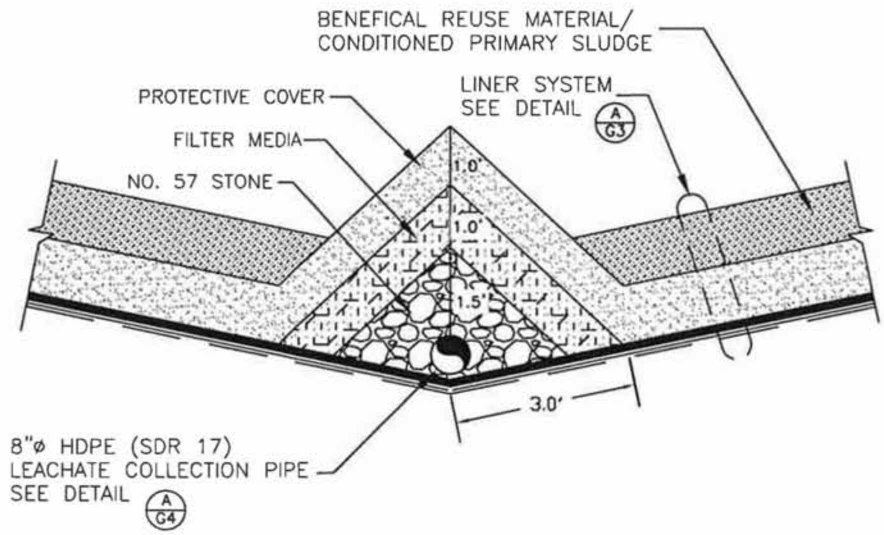
These are not good guidelines see "Sherard et al June 84 ASCE Geotech journal"

this is also conservative

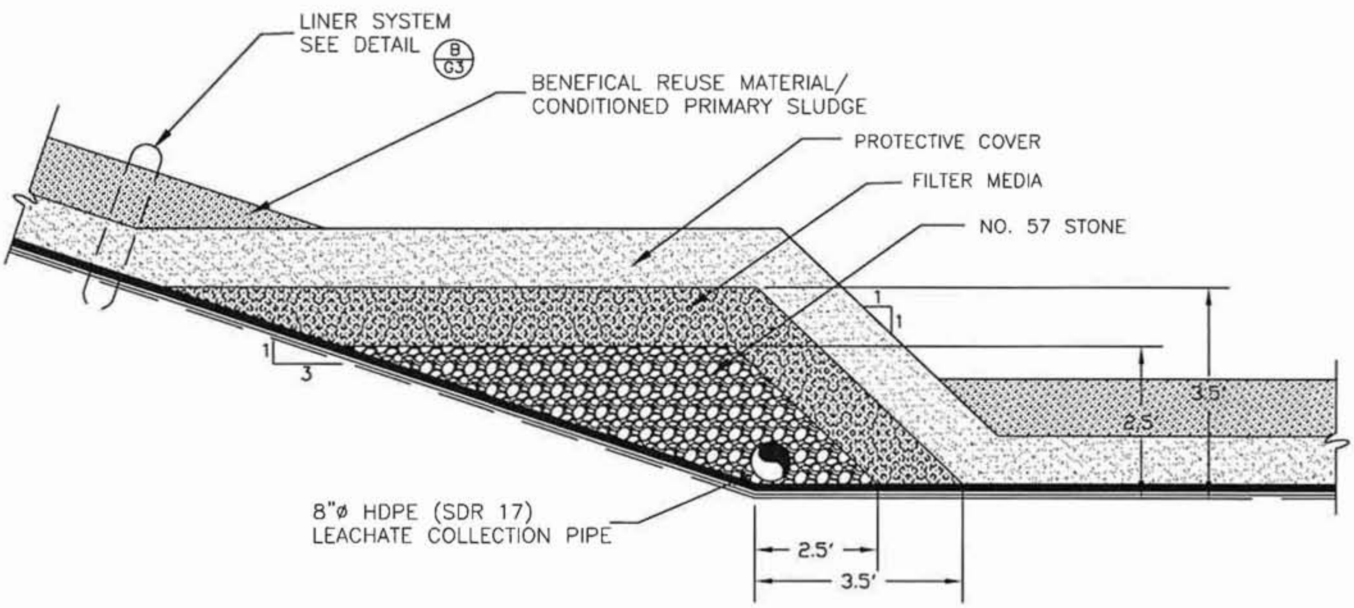
FIGURE 8-8
Design Criteria for Protective Filters

$\frac{D_{15F}}{D_{85B}} \leq 9$ ok in general

From: Design Manual, Soil Mechanics, Foundations, + Earth Structures, NAVFAC DM-7, 1971



TYPE 2 – IN VALLEY



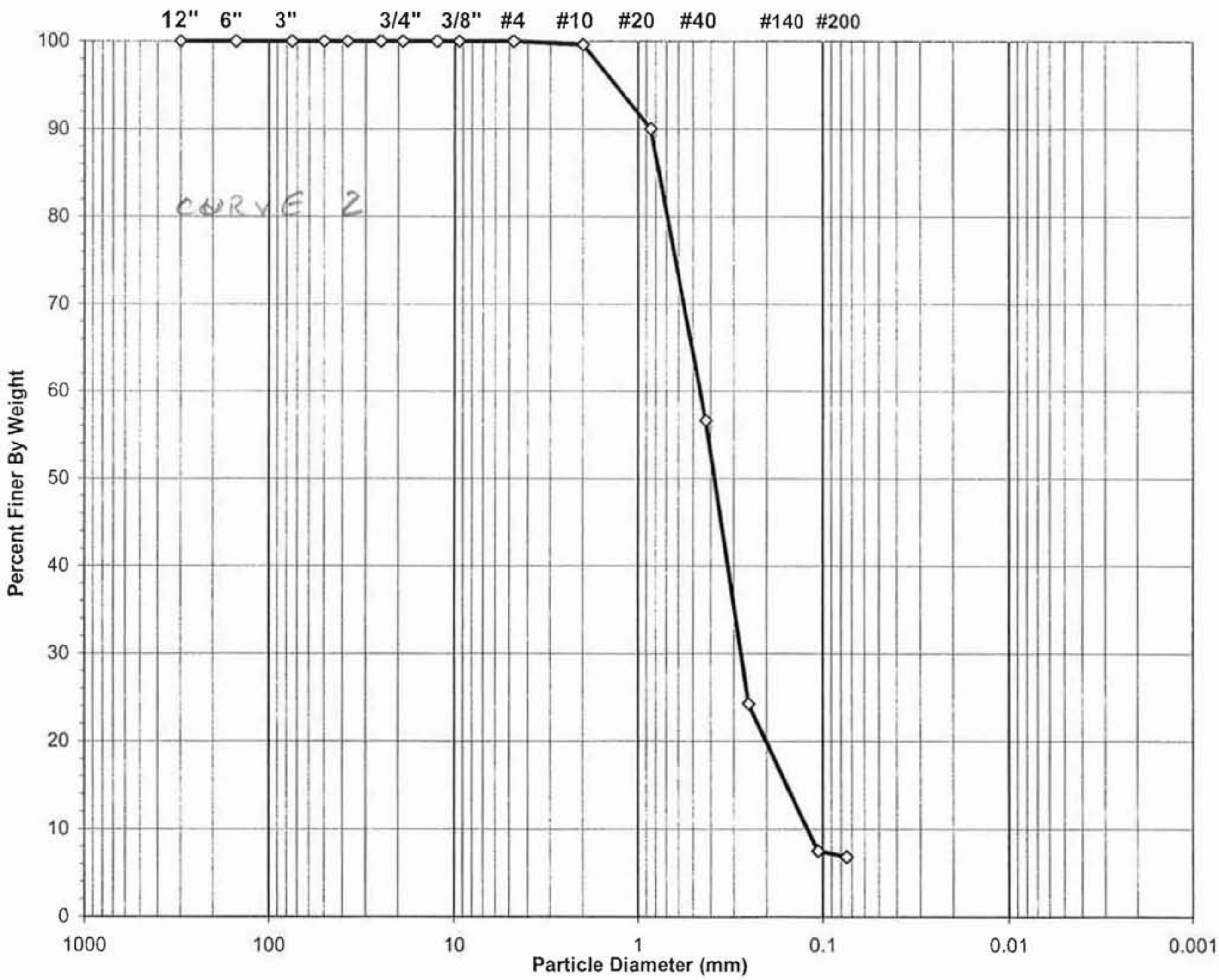
TYPE 1 – ALONG TOE

geotechnics
INTEGRITY IN TESTING

SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

Client	G.N. RICHARDSON & ASSOC.	Boring No.	8/24/03
Client Reference	I.P. RIEGELWOOD	Depth (ft)	CELL 1
Project No.	2003-511-10	Sample No.	PC7
Lab ID	2003-511-10-01	Soil Color	**BROWN**

USCS	*SIEVE ANALYSIS*		*HYDROMETER*
	gravel	sand	silt and clay



USCS Symbol	***sp-sm, ASSUMED***	**D60 =**	**0.5**	**CC =**	**1.4**
USCS Classification	***POORLY GRADED SAND WITH SILT***	**D30 =**	**0.3**	**CU =**	**3.8**
		D10 =	**0.1**		

Tested By ES Date 09/13/03 Checked By DAJ Date 9-17-03

DCN: CT-S3C DATE 6-25-98 REVISION: 2
C:\2003 Projects\2003-511 GNR\[2003-511-10-01 Sieve.XLS]Sheet1

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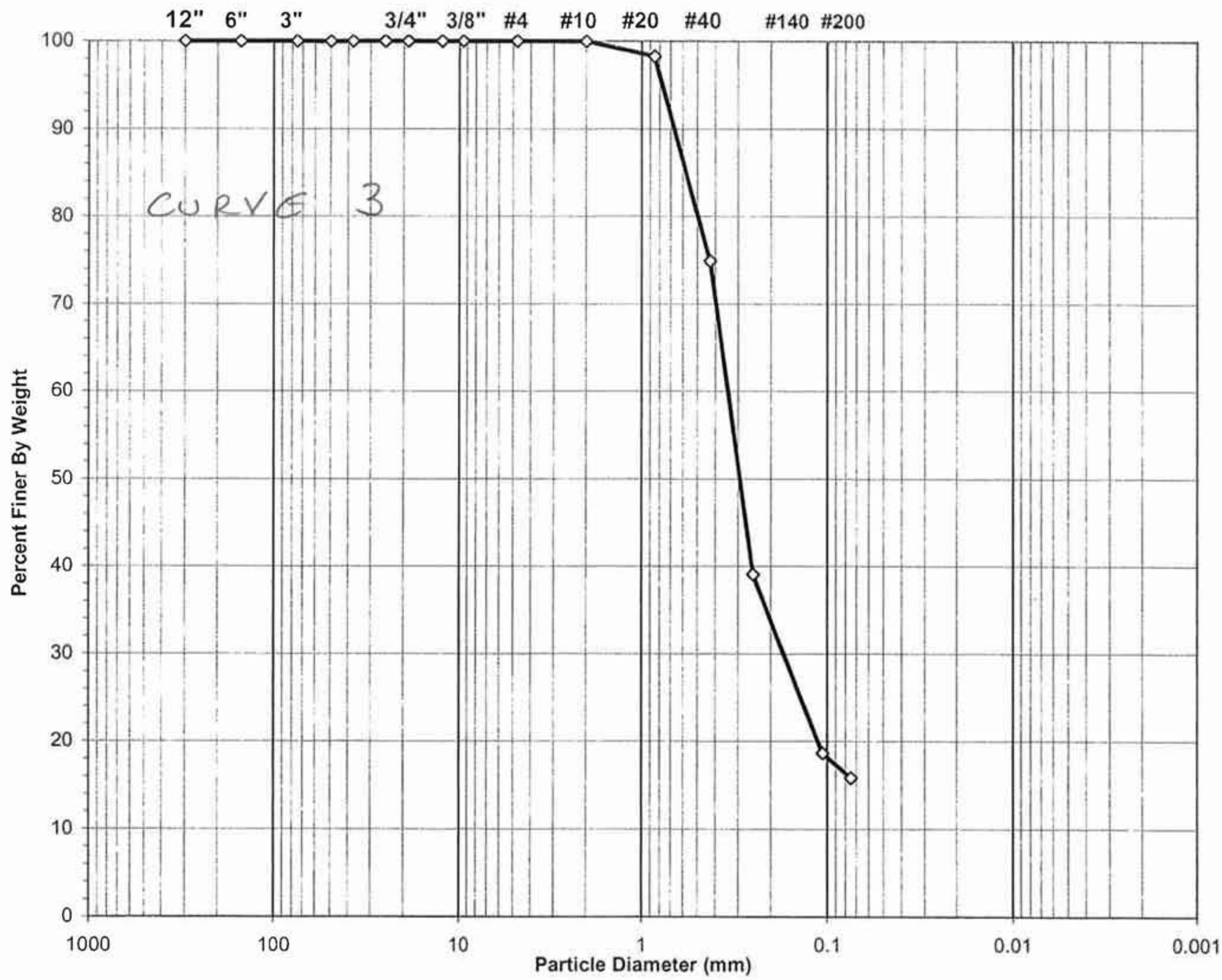
SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

Client	G.N. RICHARDSON & ASSOC.	Boring No.	NA
Client Reference	I.P. RIEGELWOOD	Depth (ft)	NA
Project No.	2003-511-11	Sample No.	PC6
Lab ID	2003-511-11-01	Soil Color	**BROWN**

	SIEVE ANALYSIS		*HYDROMETER*
USCS	gravel	sand	silt and clay



USCS Symbol ***sm, ASSUMED***

USCS Classification ***SILTY SAND***

Tested By DJK Date 09/08/03 Checked By DAJ Date 9-9-03

 DCN: CT-S3C DATE 6-25-98 REVISION: 2 *C:\2003 Projects\2003-511 GNR\[2003-511-11-01 Sieve.XLS]Sheet1*

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geotechnics

SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

Client	G.N. RICHARDSON & ASSOC.	Boring No.	CELL 1
Client Reference	I.P. RIEGELWOOD	Depth (ft)	8/12/03
Project No.	2003-511-09	Sample No.	PC-5
Lab ID	2003-511-09-02	Soil Color	**LIGHT BROWN**

USCS Symbol ***sp-sm, ASSUMED***

USCS Classification ***POORLY GRADED SAND WITH SILT***

Tested By DJK Date 08/20/03 Checked By DAJ Date 8-21-03

 DCN: CT-S3C DATE 6-25-98 REVISION: 2 *C:\2003 Projects\2003-511 GNR\[2003-511-09-02 Sieve.XLS]Sheet1*

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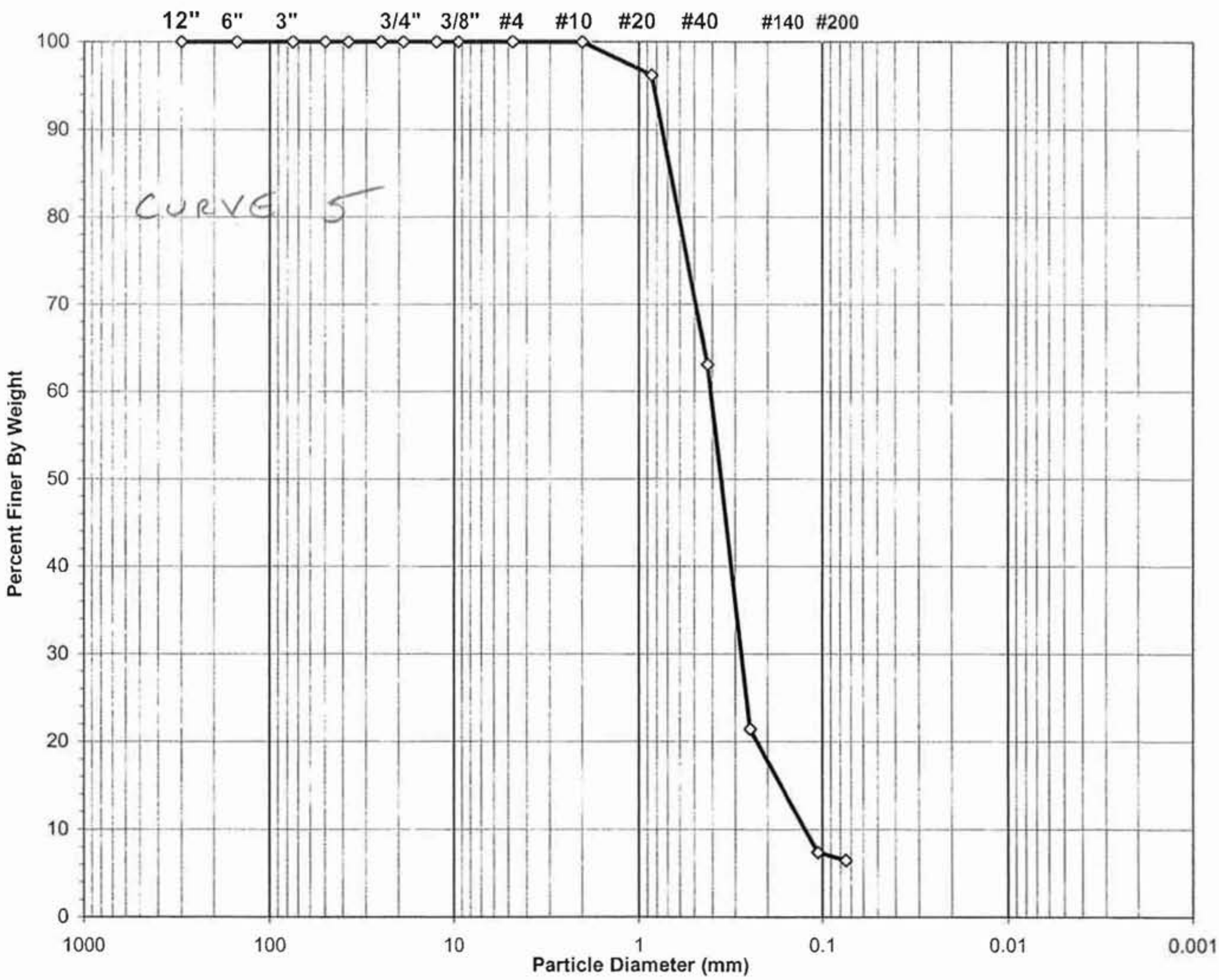
SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

Client	G.N. RICHARDSON & ASSOC.	Boring No.	CELL 1
Client Reference	I.P. RIEGELWOOD	Depth (ft)	8/6/03
Project No.	2003-511-09	Sample No.	PC-4
Lab ID	2003-511-09-01	Soil Color	**DARK BROWN**

USCS	*SIEVE ANALYSIS*		*HYDROMETER*
	gravel	sand	silt and clay



USCS Symbol	***sp-sm, ASSUMED***	**D60 =**	**0.4**	**CC =**	**1.5**
USCS Classification	***POORLY GRADED SAND WITH SILT***	**D30 =**	**0.3**	**CU =**	**3.3**
		D10 =	**0.1**		

Tested By DJK Date 08/20/03 Checked By DAJ Date 8-21-03

 DCN: CT-S3C DATE 6-25-98 REVISION: 2 *C:\2003 Projects\2003-511 GNR\[2003-511-09-01 Sieve.XLS]Sheet1*

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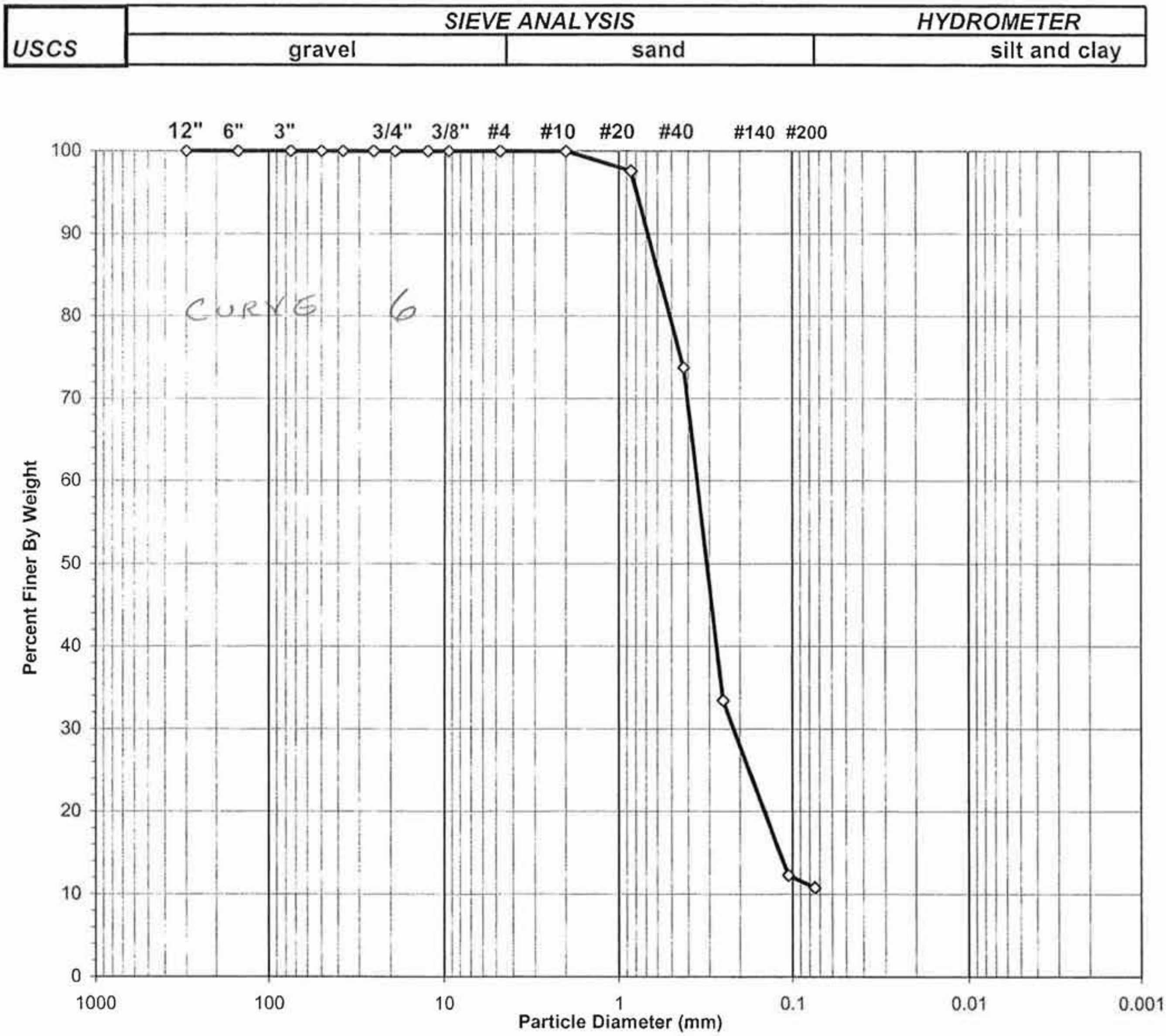
SIEVE ANALYSIS
ASTM D 422-63 (SOP-S3)

Client	G.N. RICHARDSON & ASSOC.	Boring No.	CELL 1
Client Reference	I.P. RIEGELWOOD	Depth (ft)	7/30/03
Project No.	2003-511-08	Sample No.	PC-3
Lab ID	2003-511-08-01	Soil Color	**BROWN**



USCS Symbol ***sp-sm, ASSUMED***

USCS Classification ***POORLY GRADED SAND WITH SILT***

Tested By DJK Date 08/05/03 Checked By DAJ Date 8-5-03

 DCN: CT-S3C DATE 6-25-98 REVISION: 2 *C:\2003 Projects\2003-511 GNR\[2003-511-08-01 Sieve.XLS]Sheet1*

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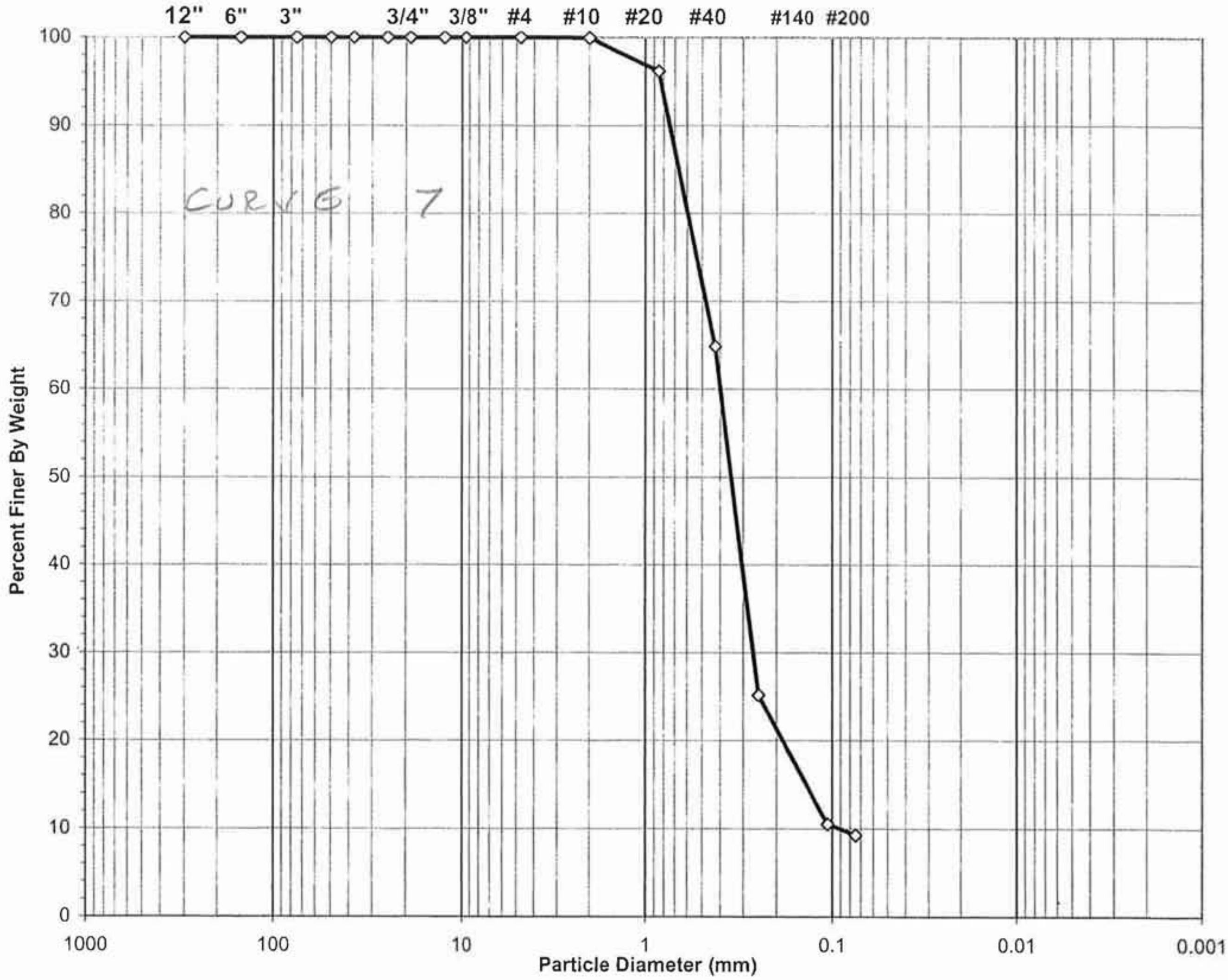
geotechnics

SIEVE ANALYSIS

ASTM D 422-63 (SOP-S3)

Client	G.N. RICHARDSON & ASSOC.	Boring No.	PC-2
Client Reference	I.P. RIEGELWOOD	Depth (ft)	7/23/03
Project No.	2003-511-07	Sample No.	IP-CELL 1
Lab ID	2003-511-07-01	Soil Color	**GRAYISH-BROWN**

	SIEVE ANALYSIS		*HYDROMETER*
USCS	gravel	sand	silt and clay



USCS Symbol	***sp-sm, ASSUMED***	**D60 =**	**0.4**	**CC =**	**1.9**
USCS Classification	***POORLY GRADED SAND WITH SILT***	**D30 =**	**0.3**	**CU =**	**4.3**
		D10 =	**0.1**		

Tested By DJK Date 07/29/03 Checked By DAJ Date 7-29-03

DCN: CT-S3C DATE 6-25-98 REVISION: 2

C:\2003 Projects\2003-511 GNR\[2003-511-07-01 Sieve.XLS]Sheet1

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Technical Specifications
International Paper Industrial Landfill
Cell 2
Riegelwood, North Carolina

Prepared for:

International Paper

805 John L. Riegelwood Road

Riegelwood, North Carolina

July 2010

URS Corporation

1600 Perimeter Park Drive Suite 400

Morrisville, NC 27560

URS

INTERNATIONAL PAPER INDUSTRIAL LANDFILL
CELL 2
RIEGELWOOD, NORTH CAROLINA

TECHNICAL SPECIFICATIONS

TABLE OF CONTENTS

SECTION 02110
SITE PREPARATION

Site Preparation: Site Preparation includes clearing, grubbing, and stripping operations which precede the proposed construction.

A. DESCRIPTION

1. General:

   a. The Contractor shall furnish all labor, material, and equipment to complete Site Preparation in accordance with the Contract Drawings and these Specifications.

   b. Principal items of work include:

      1. Notifying all authorities owning utility lines running to or on the property. Protect and maintain all utility lines to remain and cap those that are not required in accordance with instructions of the Utility Companies, and all other authorities having jurisdiction.

      2. Clearing the site within the clearing limits, including removal of grass, brush, shrubs, trees, loose debris, and other encumbrances except for trees to remain.

      3. Boxing and protecting all areas to be preserved.

      4. Removing all topsoil from designated areas and stockpiling on site where directed by the Engineer for future use.

      5. Disposing from the site all debris resulting from work under this Section.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Excavation	02222
Embankment	02223

B. MATERIALS

Not Used

C. SUBMITTALS

Not Used

D. CONSTRUCTION

1. Clearing of the Site:

   a. Clearing limits, as shown on the Contract Drawings, shall be established by the Contractor's Surveyor. Once established, the clearing limits shall be inspected and approved by the Engineer prior to clearing the affected areas.

b. Before removal of topsoil, and start of excavation and grading operations, the areas within the clearing limits shown on the Contract Drawings shall be cleared and grubbed.

c. Clearing shall consist of cutting, removal, and satisfactory disposal of all trees, fallen timber, brush, bushes, rubbish, fencing, and other perishable and objectionable material within the clearing limits.

Should it become necessary to remove a tree, bush, brush, or other plants adjacent to the area to be excavated, the Contractor shall do so only after permission has been granted by the Engineer.

d. Excavation resulting from the removal of trees, roots, and the like shall be filled with suitable material, as approved by the Engineer, and thoroughly compacted per the requirements contained in Section 02223, Embankment, of these Specifications.

e. In temporary construction easement locations, only those trees and shrubs shall be removed which are in actual interference with excavation or grading work under this Contract, and removal shall be subject to approval by the Engineer. However, the Engineer reserves the right to order additional trees and shrubs removed at no additional cost to the Owner, if such, in his opinion, they are too close to the work to be maintained or have become damaged due to the Contractor's operations.

2. Stripping and Stockpiling Existing Topsoil:

a. Existing topsoil on the site within areas designated on the Contract Drawings shall be stripped to whatever depth it may occur, and reused to surface outboard slopes.

b. The topsoil shall be free of stones, roots, brush, rubbish, or other unsuitable materials before stockpiling.

c. Care shall be taken not to contaminate the stockpiled topsoil with any unsuitable materials.

3. Grubbing:

a. Grubbing shall consist of the removal and disposal of all stumps, roots, logs, sticks, and other perishable materials to a depth of at least 6 inches below ground surfaces.

b. Large stumps located in areas to be excavated may be removed during grading operations, subject to the approval of the Engineer.

4. Disposal of Cleared and Grubbed Material:

All trees, stumps, roots, bushes, and refuse shall be disposed of by burning (Only if allowed by the Owner and local zoning) or shall be removed from the site and disposed of by the Contractor. The Contractor shall receive written authorization from the Owner prior to burning. Any material other than plant growth shall not be burned. On-site and off-site disposal areas are subject to approval by the Engineer. Ashes and residue from burning operations shall be removed from the site and disposed of by the Contractor. The Contractor shall also obtain all of the required permits for his burning operations, as applicable.

END OF SECTION

SECTION 02140
DEWATERING

Dewatering: Dewatering refers to controlling and disposing of surface and shallow ground water as is necessary for proper excavation, compaction, and other operations requiring dry conditions.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete Dewatering in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Excavation	02222
Embankment	02223

B. MATERIALS

Not Used.

C. SUBMITTALS

Procedures for Dewatering proposed by the Contractor shall be submitted to the Engineer for review prior to any Dewatering operations.

D. CONSTRUCTION

1. The Contractor shall do all Dewatering as required for the completion of the work. All surface or ground water removed by Dewatering operations shall be disposed of in accordance with all applicable regulations.
2. The Dewatering system shall be of sufficient size and capacity as required to control ground water or seepage to permit proper excavation operations, embankment construction and reconstruction, sub grade preparation, and to allow concrete to be placed in a dry condition. The system shall include a sump system or other equipment, appurtenances, and other related earthwork necessary for the required control of surface water. The Contractor shall drawdown ground water to at least 3 feet below the bottom of excavations at all times in order to maintain a dry and undisturbed condition.
3. The Contractor shall take all the steps that he considers necessary to familiarize himself with the surface and subsurface site conditions, and shall obtain the data that is required to analyze the water and soil environment at the site and to assure that the materials used for the Dewatering systems will not erode, deteriorate, or clog to the extent that the Dewatering systems will not perform properly during the period of Dewatering.

4. The Contractor shall control, by acceptable means, all water regardless of source. Water shall be controlled and its disposal provided for at each berm, structure, etc. when necessary. The entire periphery of the excavation area shall be ditched and diked to prevent surface water from entering the excavation where applicable. The Contractor shall be fully responsible for disposal of the water and shall provide all necessary means at no additional expense to the Owner. The Contractor shall be solely responsible for proper design, installation, proper operation, maintenance, and any failure of any component of the system.

5. The Contractor shall be responsible for and shall repair without cost to the Owner, any damage to work in place and the excavation, including damage to the bottom due to heave and including removal of material and pumping out of the excavated area. The Contractor shall be responsible for damages to any other area or structure caused by his failure to maintain and operate the Dewatering system proposed and installed by the Contractor.

END OF SECTION

SECTION 02222
EXCAVATION

Excavation: Excavation includes excavating, sealing, hauling, scraping, undercutting, removal of accumulated surface water or ground water, stockpiling, and all necessary and incidental items as required for bringing the landfill and related structures to the specified lines and grades.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment required to complete Excavation of the landfill containment area and related structures in accordance with the Contract Drawings and these Specifications, except as noted below:

a. Clearing and grubbing and removal of topsoil is addressed in Section 02110, Site Preparation, of these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Site Preparation	02110
Dewatering	02140
Embankment	02223
Erosion and Sedimentation Control	02270
Roadway Work	02500
CQA Manual	Attached

3. Quality Assurance:

Quality Assurance during Excavation will be provided by the Owner as described in the accompanying Project CQA Manual.

4. Definitions:

a. Excavation: shall consist of the removal and satisfactory disposal and/or stockpiling of materials located within the limits of construction including widening cuts and shaping of slopes necessary for the preparation of roadbeds, landfill slope areas, cutting of any ditches, channels, waterways, entrances, and other work incidental thereto.

b. Borrow: shall consist of approved material required for the construction of embankments/fills or for other portions of the work.

c. Unsuitable Material: is any in-place or excavated material which contains undesirable materials, or is in a state which is not appropriate; in the opinion of the CQA Engineer, for the intended use or support of planned structures, embankment, or excavation. This may include but not be limited to organic material, waste/refuse, soft, or wet material not meeting required specifications, etc.

d. Unsuitable Materials Excavation (Overexcavation): shall consist of the removal and satisfactory disposal of all unsuitable material located within the limits of construction. Where excavation to the finished grade section shown results in a subgrade or slopes of unsuitable material, the Contractor shall overexcavate such material to below the grade shown on the Contract Drawings or as directed by the Engineer and CQA Engineer.

B. MATERIALS

Excavation shall include the removal of all soil, weathered rock, boulders, conduits, pipe, and all other obstacles encountered and shown on the Contract Drawings or specified herein.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer before approval is given to proceed:

1. Descriptive information on Excavation equipment to be used.

D. CONSTRUCTION

1. The Contractor shall conduct Excavation activities in such a manner that erosion of disturbed areas and off site sedimentation is absolutely minimized as outlined in Section 02270, Erosion and Sedimentation Control, of these Specifications.
2. The Contractor shall excavate to the lines and grades shown on the Contract Drawings and stockpile all suitable excavated materials. As the excavation is made, the materials will be examined and identified to the CQA Engineer.

   The Contractor will perform all surveys necessary to establish and verify lines and grades for all Excavation, including pipe excavations, soil overexcavation, and anchor trenches.
3. Stockpiling:

   The Contractor shall stockpile the materials in appropriate stockpiles as approved by the CQA Engineer. The Contractor shall use equipment and methods as necessary to maintain the moisture content of soils stockpiled (excluding topsoil) at or near their optimum moisture content.

   Stockpiles shall be properly sloped and the surfaces sealed by the Contractor at the end of each working day, or during the day in the event of heavy rain, to the satisfaction of the Engineer.
4. The Contractor shall protect all existing facilities and structures including, but not limited to, existing utilities, monitoring wells, signs, grade stakes, etc. during the grading and stockpiling operations.
5. All excavations shall be made in the dry and in such a manner and to such widths as will give ample room for properly constructing and inspecting the structures and/or piping they are to contain and for such sheeting, timbering, pumping, and drainage as may be required.
6. The Contractor shall be responsible for Dewatering as described in Section 02140, Dewatering, of these Specifications, when necessary.

7. Excavation slopes shall be flat enough to avoid sloughs and slides that will cause disturbance of the subgrade or damage of adjacent areas. Slides and overbreaks which occur due to negligence, carelessness, or improper construction techniques on the part of the Contractor shall be removed and disposed of by the Contractor as directed by the Engineer at no additional cost to the Owner.

8. The intersection of slopes with natural ground surfaces, including the beginning and ending of cut slopes, shall be uniformly rounded. All protruding roots and other vegetation shall be removed from slopes.

9. The bottom of all excavations for structures and pipes shall be examined by the CQA Engineer for bearing value and the presence of unsuitable material. If, in the opinion of the CQA Engineer, additional Excavation is required due to the low bearing value of the subgrade material, or if the in-place materials are soft, yielding, pumping and wet, the Contractor shall remove such material to the required width and depth and replace it with thoroughly compacted structural fill, or material directed by the CQA Engineer. No payment will be made for subgrade disturbance caused by inadequate Dewatering or improper construction methods.

10. Any areas excavated below design subgrade elevations by the Contractor, unless directed by the CQA Engineer, shall be brought back to design elevations at no cost to the Owner. The Contractor shall place and compact such material in accordance with Section 02223, Embankment, of these Specifications.

11. The Contractor shall dispose of excess or unsuitable excavation materials on-site at location(s) approved by the Owner.

12. The Contractor shall properly level-off bottoms of all excavations. Proof-rolling shall be conducted with appropriate equipment.

13. Upon reaching subgrade elevations shown in excavation areas, the Contractor shall scarify sub grade soils to a minimum depth of 6" and obtain the CQA Engineer's approval of quality. If unsuitable materials are encountered at the subgrade elevation, perform additional excavations as approved by the CQA Engineer to remove unsuitable materials.

14. <u>Overexcavation and Backfill</u>:

    Where subgrade materials are determined to be unsuitable, such materials shall be removed by the Contractor to the lengths, widths and depths approved by the CQA Engineer and backfilled with suitable material in accordance with Section 02223, Embankment, of these Specifications unless further excavation or earthwork is required. No additional payment will be made for such excavation and backfill 1 foot or less than the finished subgrade. Unsuitable material excavation greater than 1 foot beneath the finished subgrade shall be made on a unit price basis for excavation and backfill, only as approved by the Engineer and CQA Engineer prior to the work. Unit price for overexcavation and backfill greater than 1 foot in depth shall include disposal of unsuitable materials.

15. All cuts shall be brought to the grade and cross section shown on the Contract Drawings, or established by the Engineer, prior to final inspection.

16. The Contractor shall protect finished lines and grades of completed excavation against excessive erosion, damage from trafficking, or other causes and shall repair any damage at no additional cost to the Owner.

17. Trench Excavation:

   a. All pipe Excavation and trenching shall be done in strict accordance with these Specifications, all applicable parts of the OSHA Regulations, 29 CFR 1926, Subpart P, International Paper's Excavating and Trenching Procedures, and other applicable regulations. In the event of any conflicts in this information, safe working conditions as established by the appropriate OSHA guidelines shall govern.

   b. The minimum trench widths shall be as indicated on the Contract Drawings. Enlargements of the trench shall be made as needed to give ample space for operations at pipe joints. The width of the trench shall be limited to the maximum dimensions shown on the Contract Drawings, except where a wider trench is needed for the installation of and work within sheeting and bracing.

   c. Except where otherwise specified, excavation slopes shall be flat enough to avoid slides which will cause disturbance of the subgrade, damage to adjacent areas, or endanger the lives or safety of persons in the vicinity.

   d. Hand excavation shall be employed wherever, in the opinion of the Engineer, it is necessary for the protection of existing utilities, poles, trees, pavements, obstructions, or structures.

   e. No greater length of trench in any location shall be left open, in advance of pipe laying, than shall be authorized or directed by the Engineer and, in general, such length shall be limited to approximately one hundred (100) feet.

   f. Pipe Bedding: All pipe bedding shall be as shown on the Contract Drawings, unless otherwise specified herein.

18. Sheeting and Bracing:

   a. The Contractor shall furnish, place, and maintain such sheeting and bracing which may be required to support sides of Excavation or to protect pipes and structures from possible damage and to provide safe working conditions in accordance with current OSHA requirements. If the Engineer is of the opinion that at any point sufficient or proper supports have not been provided, he may order additional supports put in at the sole expense of the Contractor. The Contractor shall be responsible for the adequacy of all sheeting and bracing used and for all damage resulting from sheeting and bracing failure or from placing, maintaining, and removing it.

   b. The Contractor shall exercise caution in the installation and removal of sheeting to insure that excessive or unusual loadings are not transmitted to any new or existing structure. The Contractor shall promptly repair at his expense any and all damage that can be reasonably attributed to sheeting installation or removal.

   c. All sheeting and bracing shall be removed upon completion of the work.

19. If grading operations are suspended for any reason whatsoever, partially completed cut and fill slopes shall be brought to the required slope and the work of seeding and mulching or other required erosion and sedimentation control operations shall be performed at the Contractor's sole expense.

END OF SECTION

SECTION 02223
EMBANKMENT

Embankment: Embankment is the on-site compacted fill that provides the foundation and the berms for the containment area, the subgrade for some access roadways and structures, and backfill around structures and piping.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete Embankment including borrowing, hauling, screening, discing, drying, compaction, control of surface and subsurface water, final grading, sealing, and all necessary and incidental items as detailed or required to complete the Embankment, all in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications

WORK	SECTION
Dewatering t	02140
Excavation	02222
Erosion and Sedimentation Control	02270
Roadway Work	02500
CQA Manual	Attached

3 Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these Specifications.

ASTM D 698	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft3).
ASTM D 1556	Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.
ASTMD 2167	Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method.
ASTM D 2216	Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass
ASTM D 2488	Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).
ASTM D 2922	Standard Test Methods for Density of Soil and SoilAggregate in Place by Nuclear Methods (Shallow Depth).
ASTM D 2937	Standard Test Method for Density of Soil in Place by the Drive Cylinder Method.
ASTM D 3017	Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth).
ASTM D 4643	Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method.

ASTM D 4959	Standard Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating Method

4. Quality Assurance:

   Quality Assurance during placement of Embankment will be provided by the Owner as described in the accompanying Project CQA Manual.

5. Definitions:

   a. Embankment: Shall include construction of all site earthwork including roadways, subgrade, perimeter berm embankments, including preparation of the areas upon which materials are to be placed. Embankment may also be referred to as structural and/or controlled fill. All Embankment materials will be borrow unless otherwise noted on Contract Drawings or specified by the Engineer.

   b. Prepared Subgrade: The ground surface after clearing, grubbing, stripping, excavation, scarification, and/or compaction, and/or proof rolling to the satisfaction of the CQA Engineer.

   c. Well-Graded: A mixture of particle sizes that has no specific concentration or lack thereof of one or more sizes. Well-graded does not define any numerical value that must be placed on the coefficient of uniformity, coefficient of curvature, or other specific grain size distribution parameters. Well-graded is used to define a material type that, when compacted, produces a strong and relatively incompressible soil mass free from detrimental voids.

   d. Unclassified Fill: The nature of materials to be used is not identified or described herein but must be approved by the Engineer prior to use.

B. MATERIALS

1. Embankment materials shall consist of clean well-graded natural soil classified as SM, SP, SC, ML, MH, CL-ML, CL or CH (ASTM D 2488) containing no topsoil or other deleterious material. Other material classifications may be approved by the Engineer.
2. Stones or rock fragments shall not exceed one half the maximum lift thickness as compacted in any dimension.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer before approval is given to proceed:

1. Descriptive information on compaction equipment to be used for construction of Embankment and appurtenant structures.

D. CONSTRUCTION

1. The Contractor shall conduct Embankment activities in such a manner that erosion of disturbed areas and off-site sedimentation is absolutely minimized as outlined in Section 02270, Erosion and Sedimentation Control, of these Specifications.
2. All placement and compaction of Embankment shall be performed only when the CQA Engineer is informed by the Contractor of intent to perform such work.
3. Embankment shall be placed and compacted to the lines and grades shown on the Contract Drawings. Placement of Embankment outside the construction limits shall occur only as directed and approved by the Engineer.

The Contractor will perform all surveys necessary to establish and verify lines and grades for all Embankment.

4. The Contractor shall protect all existing facilities including, but not limited to, utilities and monitoring wells.

5. Subgrade Preparation:

   a. The CQA Engineer shall inspect the exposed subgrade prior to placement of Embankment to assure that all rocks, topsoil, vegetation, roots, debris, or other deleterious materials have been removed.

   b. Prior to placement of Embankment, the exposed subgrade shall be proofrolled using a static smooth-drum roller, loaded tandem axle dump truck, or other suitable equipment in the presence of the CQA Engineer. Any soft or unsuitable materials revealed before or during the in-place compaction shall be removed as directed by the CQA Engineer and replaced with suitable Embankment.

6. Surfaces on which Embankment is to be placed, shall be scarified or stepped in a manner which will permit bonding of the Embankment with the existing surface.

7. The Contractor shall be responsible for preparing the materials for the Embankment, including but not limited to, in-place drying or wetting of the soil necessary to achieve the compaction criteria of these Specifications.

8. The Contractor shall be responsible for Dewatering as described in Section 02140, Dewatering, of these Specifications, when necessary.

9. Embankment materials shall be placed in a manner permitting drainage and in continuous, approximately horizontal layers.

10. Compaction Requirements:

    a. The Contractor shall compact Embankment in accordance with the requirements shown in Table 1 of this section. If Embankment does not meet the specified requirements, the Contractor shall rework the material, as may be necessary and continue compaction to achieve these requirements, or remove and replace the material to achieve the specified requirements, at Contractor's expense.

    b. Each lift shall be compacted prior to placement of succeeding lifts. In confined areas, mechanical equipment, suitable for small areas and capable of achieving the density requirements, shall be required.

    c. Lift compaction shall be performed with an appropriately heavy, properly ballasted, penetrating-foot or smooth-drum vibratory compactor depending on soil type. Compaction equipment shall be subject to approval by the CQA Engineer.

11. Embankment that becomes excessively eroded, soft, or otherwise unsuitable shall be removed or repaired by the Contractor as directed by the CQA Engineer, at no cost to the Owner.

12. The exposed surface of Embankment shall be rolled with a smooth-drum roller at the end of each work day to protect from adverse weather conditions.

13. Where Embankment is to be placed and compacted on slopes that are steeper than 3: 1, the subgrade shall be benched to a minimum depth of 6 inches and the Embankment shall be placed in horizontal lifts.

14. Backfilling for Structures and Piping:

a. All structures, including manholes and pipes shall be backfilled with Embankment as shown in the Contract Drawings and as described in these Specifications.

b. Where sheeting is used, the Contractor shall take all reasonable measures to prevent loss of support beneath and adjacent to pipes and existing structures when sheeting is removed. If significant volumes of soil cannot be prevented from clinging to the extracted sheets, the voids shall be continuously backfilled as rapidly as possible. The Contractor shall thereafter limit the depth below sub grade that sheeting will be driven in similar soil conditions or employ other appropriate means to prevent loss of support.

c. When backfilling around structures, do not backfill until concrete has sufficiently cured (as determined by the CQA Engineer) and is properly supported. Place backfill in a manner to avoid displacement or damage of structures.

TABLE 1: REQUIRED EMBANKMENT PROPERTIES

ITEM	Required % Standard Proctor (ASTM D698)[2]	Required Moisture Content (ASTM D 3017)[3]	Maximum Lift Thickness (Compacted) (inches)
Embankment	95	± 4% of Optimum Moisture Content	8
Embankment Beneath Structures and Roads[1]	98		8
Backfill Around Structures	95		8
Backfill in Pipe Trenches	95		6
Unclassified Fill	N/A	N/A	N/A

Notes:

1. Embankment beneath structures shall be considered to include a zone 10 feet out from the foundation of the structure extending down to the natural ground on a 45° slope. Embankment beneath roads shall be considered to include all embankment placed within 2 vertical feet of the final wearing surface and shall also include shoulders.
2. Determine field density using ASTM D 2922, ASTM D 1556, ASTM D 2167, or ASTMD 2937.
3. Optionally use ASTM D 2216, ASTM D 4643, or ASTM D 4959.

END OF SECTION

SECTION 02240
GEOTEXTILES

Geotextiles: For the proposed construction, a Type GT -S (Separator/Filter) Geotextile is specified. The Type GT -S Geotextile will be placed in the underdrain collection system, leachate collection system as a component of the Geonet Composite, between soil subgrade and aggregate in access roads, and in some erosion control and drainage applications.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of Geotextiles including all necessary and incidental items as detailed or required for the Contractor to complete the installation in accordance with the Contract Drawings and these Specifications, except as noted below:

   a. Geotextiles used as a Silt Fence is covered under Section 02270, Erosion and Sedimentation Control, of these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Erosion and Sedimentation Control	02270
Roadway Work	02500
Geonet Composite	02712
CQA Manual	Attached

3. Reference Standards:

   The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the American Association of State Highway and Transportation Officials (AASHTO) are hereby made a part of these specifications.

ASTM D 3786	Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method.
ASTM D 4355	Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).
ASTM D 4491	Standard Test Methods for Water Permeability of Geotextiles by Permittivity.
ASTM D 4533	Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
ASTM D 4751	Standard Test Method for Determining Apparent Opening Size of a Geotextile.
ASTM D 4833	Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.

ASTM D 5261	Standard Test Method for Measuring Mass per Unit Area of Geotextiles.
AASHTO M 288	Standard Specification for Geotextiles.

4. Quality Assurance:

   Quality Assurance during installation of Geotextiles will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. General:

   The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

   Labels on each roll of Geotextile shall identify the length, width, lot and roll numbers, and name of Manufacturer.

2. The Type GT -S Geotextile shall be a woven, nonwoven spunbonded, or nonwoven needlepunched synthetic fabric consisting of polyester or polypropylene manufactured in a manner approved by the Engineer. Note that Type GT-S Geotextile used as a component of the Geonet Composite shall be a nonwoven fabric.
3. All Geotextiles shall conform to the properties listed in Table 1 of this section.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit one copy of a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for each type of Geotextile attesting that the Geotextiles meet the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample (4" x 6") of each Geotextile to be used. The samples shall be labeled with the product name and be accompanied by the Manufacturer's specifications.
2. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.
3. Quality Control Certificates: For Geotextiles delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of each type of Geotextile supplied. Each certificate shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 2 of this section.
4. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

   All Geotextiles shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

Geotextiles that are rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of Geotextiles supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Installation of Geotextiles:

a. The surface receiving the Geotextiles shall be prepared to a relatively smooth condition, free of obstructions, excessive depressions, debris, and very soft or loose pockets of soil. This surface shall be approved by the CQA Engineer prior to Geotextile placement.

b. Geotextiles shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, Geotextiles shall be rejected by the CQA Engineer if they have defects, rips, holes, flaws, evidence of deterioration, or other damage.

c. The Geotextiles shall be placed smooth and free of excessive wrinkles.

d. On slopes, Geotextiles shall be anchored at the top and unrolled down the slope. In the presence of wind, all Geotextiles shall be weighted with sandbags or other material as approved by the CQA Engineer. Geotextiles uplifted by wind may be reused upon approval by the CQA Engineer.

4. Seams:

a. All Geotextile seams shall be sewn. On slopes greater than 10 percent, all seams shall be oriented parallel to (in the direction of) the slope unless otherwise approved by the Engineer.

b. Seams to be sewn shall be sewn using a Type 401 stitch. One or two rows of stitching may be used. Each row of stitching shall consist of 4 to 7 stitches per inch. The minimum distance from the geotextile edge to the stitch line nearest to that edge (seam allowance) shall be 1.5 inches if a Type SSa (prayer or flat) seam is used. The minimum seam allowance for all other seam types shall be 1.0 inches. All seams must be approved by the CQA Engineer.

c. Alternately, the Contractor may overlap or heat bond adjacent panels with methods approved by the Engineer.

5 Repair Procedures:

a. Any Geotextile that is torn or punctured shall be repaired or replaced, as directed by the CQA Engineer, by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of the same type of Geotextile placed over the failed areas and shall overlap the existing Geotextile a minimum of 6 inches from any point of the rupture. Patches shall be spot sewn so as not to shift during cover placement.

b. Slopes Less Than or Equal to 10 Percent: Damaged areas of a size exceeding 10 percent of the roll width shall be removed and replaced across the entire roll width with new material. Damaged areas of a size less than 10 percent of the roll width may be patched.

c. Slopes Greater Than 10 Percent: Geotextile panels which require repair shall be removed and replaced with new material. Replacement material shall be sewn as previously described in this specification.

6. Cover Placement:

Placement of cover over Geotextiles shall be performed in a manner as to ensure that the Geotextiles are not damaged. Cover material shall be placed such that excess tensile stress is not mobilized in the Geotextile.

TABLE 1: REQUIRED GEOTEXTILE PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUEI
			TYPE GT-S
Geotextile Construction (NW = Nonwoven) (W = Woven)	----------	----------	NW[2] or W[3] NW (See Note 5)
Mass per Unit Area (Unit Weight)	ASTM D 5261	oz/yd^2	N/A 6 (See Note 5)
Ultraviolet Resistance (500 hrs)	ASTM D 4355	%	70
Strength Class4	AASHTO M 288	Class	2
Grab Tensile Strength	ASTM D 4632	lbs	160 (NW) 250 (W)
Grab Tensile Elongation	ASTM D 4632	%	≥ 50 (NW) < 50 (W)
Puncture Resistance	ASTM D 4833	lbs	55 (NW) 90 (W)
Trapezoidal Tear Strength	ASTMD4533	lbs	55 (NW) 90 (W)
Burst Strength	ASTM D 3786	psi	200 (NW) 400 (W)
Apparent Opening Size (AOS)	ASTMD 4751	U.S. Sieve	70+
Permittivity	ASTMD 4491	sec^{-1}	1.0

Notes:

1. Minimum Average Roll Value (MARV).
2. Nonwoven geotextiles that have been heat calendared are not acceptable, unless approved by the Engineer in advance.
3. Woven geotextiles formed exclusively with slit film fibers are not acceptable.
4. AASHTO M 288 criteria includes the above listed requirements for: Grab Tensile Strength, Grab Tensile Elongation, Puncture Resistance, Trapezoidal Tear Strength, and Burst Strength.
5. Required for Geonet Composite.

TABLE 2: REQUIRED MANUFACTURER'S QUALITY CONTROL TEST DATA

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Mass per Unit Area (Unit Weight)	ASTM D 5261	200,000 ft^2
Ultraviolet Resistance (500 hrs)	ASTM D 4355	Periodic
Grab Tensile Strength	ASTMD4632	200,000 ft^2
Grab Tensile Elongation	ASTMD 4632	200,000 ft^2
Burst Strength (Diaphragm Methods)	ASTMD 3786	200,000 ft^2
Apparent Opening Size (AOS)	ASTMD 4751	Periodic
Permittivity	ASTMD 4491	Periodic
Puncture Resistance	ASTM D 4833	200,000 ft^2
Trapezoidal Tear Strength	ASTM D 4533	200,000 ft^2

END OF SECTION

SECTION 02256
PROTECTIVE COVER

Protective Cover: The Protective Cover consists of clean sandy fill material. The Protective Cover protects the leachate collection layer and Geomembrane from damage due to the placement of waste.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of the Protective Cover, including borrowing, hauling, screening, removal of surface water and removal of all previously placed material that is unsuitable due to weather conditions, final grading and sealing, and all necessary and incidental items as detailed or required to complete the Protective Cover, all in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Geotextiles	02240
HDPE Pipe	02614
Drainage Aggregate	02710
Geonet Composite	02712
HDPE Geomembrane	02775
Geosynthetic Clay Liner	02777
CQA Manual	Attached

3. Reference Standards:

   The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these Specifications.

ASTM D 698	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-Ibf/ft3).
ASTM D 2488	Standard Practice for Description and Identification of Soils (Visual-Manual Procedure)

4. Quality Assurance:

   Quality Assurance during placement of Protective Cover will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. Soil that meets all of the following requirements shall be classified as select soil fill for use in construction of the Protective Cover. Soil suitable for use as Protective Cover is available at a borrow source provided by the Owner (location to be designated during bidding). The Contractor is responsible for all excavation and hauling activities to bring this material to the project site. Optionally, the Contractor may provide Protective Cover material from an alternate source if deemed in his best interest. In this case, the Contractor shall provide access to the site for material sampling by the CQA Engineer.

a. Soil shall be classified according to the Unified Soil Classification System (USCS) as SW, SP, SM, SM-SC, or SC (ASTM D 2488). Other material classifications may be approved by the Engineer.

b. Select soil fill materials shall be reasonably free of gypsum, ferrous, and/or calcareous concretions and nodules, refuse, roots, or other deleterious substances.

c. The soil cover shall be uniform, smooth, and free of debris, plant materials, and other foreign material. The maximum rock size shall be 3 inches in diameter. The material should contain no sharp edges.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Before approval is given to proceed, the Contractor shall submit descriptive information on equipment to be used in construction of the Protective Cover.

2. Survey Results:

   After completion of a segment of Protective Cover, survey results shall be submitted for review prior to Protective Cover acceptance.

D. CONSTRUCTION

1. The Protective Cover is placed directly over geosynthetics and/or piping; thus, extreme caution shall be exercised by the Contractor to prevent damage to these materials.

2. All placement and compaction of Protective Cover shall be performed only when the CQA Engineer is informed by the Contractor of intent to perform such work.

3. Protective Cover shall be placed over geosynthetics only after areas have been released by the Geosynthetics Installer and the CQA Engineer. Protective Cover shall be placed as specified below:

   a. Protective Cover shall be placed and spread using low ground pressure (6 psi ground pressure or less) tracked equipment on the landfill side slopes. Low ground pressure equipment is not required for placement or spreading of Protective Cover on the landfill base. The CQA Engineer shall approve the equipment used to place Protective Cover.

   b. Tracked equipment used to place and compact Protective Cover shall operate on at least 1 foot of Protective Cover overlying geosynthetics and/or piping. Sharp turning of tracked equipment on the Protective Cover will not be permitted.

   c. On side slopes, place Protective Cover from the bottom up unless otherwise approved by the Engineer. No material shall be dumped down a slope.

   d. Protective Cover shall be placed and compacted to the lines and grades shown on the Contract Drawings with the exception that a 0.15 foot overbuild at Contractor’s expense is allowed. The Contractor will perform all surveys necessary to establish and verify lines and grades for all Protective Cover.

   e. The Protective Cover shall be compacted by tracking the final lift with conventional tracked equipment.

4. The Protective Cover shall be spread in a manner that minimizes development of wrinkles in the underlying geosynthetics. Any portion of the underlying geosynthetics

that develops excessive wrinkles or crimp shall be repaired by the Geosynthetics Installer at no expense to the Owner.

a.. Protective Cover shall be placed before noon or at other times when the ambient air temperature is not more than 75°F to minimize wrinkling of underlying geosynthetics unless otherwise approved by the Engineer.

b. If during spreading, excessive wrinkles develop, the Contractor shall adjust placement and spreading methods, or cease until the underlying geosynthetics cool and wrinkles decrease in size.

c. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and spreading methods or underlying geosynthetics that become crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

5. Stockpiling of Protective Cover within the limits of the containment area shall be subject to advance approval by the Engineer. Any hauling equipment (dump trucks, etc.) operating within the containment area limits shall have a minimum of 3 feet of separation between the vehicle wheels and the Geomembrane.

6. Protective Cover shall not be placed over the gravel columns or over the coarse aggregate in the sump area without protective Type GT -S geotextile or other approved means.

   The Contractor shall minimize equipment operations directly over coarse aggregate.

7. The CQA Engineer may require removal of Protective Cover and/or other underlying layers at the Contractor's sole expense to allow examination of the underlying geosynthetics and/or piping. Any damage to underlying layers or excessive wrinkling or crimping during placement or compaction of the Protective Cover shall be repaired in accordance with the applicable section of these Specifications at the Contractor's sole expense.

8. <u>Surveying:</u>

   After completion of a segment of Protective Cover, the Protective Cover shall be surveyed on 100 foot centers and at slope breaks (including all tops and toes of slope, points of grade change, etc.) to ensure:

   a. The specified thickness has been achieved.

   b. The top of the Protective Cover slopes at grades specified on the Contract Drawings; and

   c. Protective Cover placed more than 0.15 feet beyond the limits of the lines and grades as shown on the Contract Drawings will not be accepted and must be removed at the Contractor's expense if required by the Engineer.

   This work shall be performed at the Contractor's cost by a surveyor registered in the State of North Carolina.

END OF SECTION

SECTION 02270
EROSION AND SEDIMENTATION CONTROL

Erosion and Sedimentation Control: Erosion and Sedimentation Control is a system of construction practices and engineered structures which act to minimize surface water induced erosion of disturbed areas and resulting sedimentation off-site.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of and maintain Erosion and Sedimentation Control facilities and other construction in accordance with the Contract Drawings and these Specifications.

All Erosion and Sedimentation Control work shall be in accordance with the latest edition of the North Carolina Erosion and Sediment Control Planning and Design Manual.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Geotextiles	02240
Rip Rap	02271
Rolled Erosion Control Products	02275
Storm Water Systems	02720
Revegetation	02930
Concrete Work	02775
Geosynthetic Clay Liner	02777
CQA Manual	Attached

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these specifications.

ASTM D 3786	Test Method for Hydraulic Bursting Strength of Knitted Goods and Nonwoven Fabrics: Diaphragm Bursting Strength Tester Method
ASTM D 4355	Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).
ASTM D 4491	Standard Test Methods for Water Permeability of Geotextiles by Permittivity
ASTM D 4533	Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
ASTM D 4751	Standard Test Method for Determining Apparent Opening Size of a Geotextile.

ASTM D 4833 Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.

B. MATERIALS

1. Permanent Ditches. Swales. and Drainage Channels:

   Permanent ditches, swales, and drainage channels shall be constructed as shown on the Contract Drawings.

2. Silt Fence:

   Silt fences shall be constructed as shown on the Contract Drawings and as needed, based on the Contractor's discretion and Engineer's approval. The silt fence is a permeable barrier erected within and downgradient of small disturbed areas to capture sediment from sheet flow. It is made of filter fabric buried at the bottom, stretched, and supported by posts and wire mesh backing. Silt fence shall conform to the following properties:

   a. Posts: Posts shall be 3 feet long "U" or "T"-type steel or wood posts.

   b. Filter Fabric: Filter fabric shall be a woven geotextile made specifically for sediment control. Filter fabric shall conform to the properties listed in Table 1 of this section.

3. Geotextiles:

   Geotextiles shall conform to the requirements of Section 02240, Geotextiles, of these Specifications.

4. Filter Berms:

   Filter berms shall be constructed as shown on the Contract Drawings.

5. Rip Rap:

   Rip Rap shall conform to the requirements of Section 02271, Rip Rap, of these Specifications.

6. Rolled Erosion Control Products (RECPs):

   Rolled Erosion Control Products (RECPs) shall conform to the requirements of Section 02275, Rolled Erosion Control Products, of these Specifications.

7. Other Work:

   In addition to the erosion control measures shown on the Contract Drawings, the Contractor shall provide adequate means to prevent any sediment from entering any storm drains, drop inlets, ditches, streams, or bodies of water downstream of any area disturbed by construction. Excavation materials shall be placed upstream of any trench or other excavation to prevent sedimentation of off-site areas. In areas where a natural buffer area exists between the work area and the closest stream or water course, this area shall not be disturbed. All paved areas shall be scraped and swept as necessary to prevent the accumulation of dirt and debris. Work associated with this provision shall be considered incidental to the project and no separate payment will be made.

8. Temporary and Permanent Ground Cover:

The Contractor shall provide temporary or permanent ground cover adequate to restrain erosion on erodible slopes or other areas within 15 working days or 30 calendar days (whichever is shorter) following completion of any phase of grading.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. Submit a certification and summary of all required test results, prior to installation, that all Erosion and Sedimentation Control materials manufactured for the project have been produced in accordance with these Specifications.

Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

D. CONSTRUCTION

1. Establishment of Erosion Control Devices:

   a. All erosion control structures will be constructed according to the Contract Drawings and these Specifications.

   b. Due to the nature of the work required by this Contract, it is anticipated that the location and nature of the erosion control devices may need to be adjusted on several occasions to reflect the current phase of construction.

   c. Erosion control devices shall be established prior to the work in a given area. Where such practice is not feasible, the erosion control device(s) shall be established immediately following completion of the clearing operation.

   d. The construction schedule adopted by the Contractor will impact the placement and need for specific devices required for the control of erosion. The Contractor shall develop and implement such additional techniques as may be required to minimize erosion and off-site sedimentation.

   e. The location and extent of erosion control devices shall be revised at each phase of construction that results in a change in either the quantity or direction of surface runoff from construction areas. All deviations from the control provisions shown on the Contract Drawings shall have the prior approval of the Engineer.

2. Maintenance of Erosion Control Devices:

   a. The Contractor shall furnish the labor, material, and equipment required for maintenance of all erosion control devices. Maintenance shall be scheduled as required for a particular device to maintain the removal efficiency and intent of the device.

   b. All erosion control devices shall be inspected immediately after each significant rainfall event, and appropriate maintenance conducted.

   c. Maintenance shall include, but not be limited to:

      (1) The removal and satisfactory disposal of trapped sediments from basins or silt barriers;
      (2) Replacement of filter fabrics used for silt fences upon loss of specified efficiency; and

(3) Replacement of any other components which are damaged or cannot serve the intended use.

d. Sediments removed from erosion control devices shall be disposed of in locations that will not result in off-site sedimentation as approved by the Engineer.

e. All erosion control structures shall be maintained to the satisfaction of the Engineer until the site has been stabilized.

3. Finish Grading:

All disturbed areas shall be uniformly graded to the lines, grades, and elevations shown on the Contract Drawings. Finished surfaces shall be reasonably smooth, compacted, and free from irregular surface changes. Unless otherwise specified, the degree of finish shall be that ordinarily obtainable from either blade or scraper operations. Areas shall be finished to a smoothness suitable for application of topsoil.

4. Seeding:

Seeding shall conform to the requirements of Section 02930, Revegetation, of these Specifications.

5. Cleanup:

a. The Contractor shall remove from the site all subsoil excavated from his work and all other debris including, but not limited to, branches, paper, and rubbish in all landscape areas, and remove temporary barricades as the work proceeds.

b. All areas shall be kept in a neat, orderly condition at all times. Prior to final acceptance, the Contractor shall clean up the entire landscaped area to the satisfaction of the Engineer.

TABLE 1: REQUIRED SILT FENCE FILTER FABRIC PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE[1]
Grab Tensile Strength[2]	ASTM D 4632	lbs	100 x 100
Grab Elongation	ASTM D 4632	%	15 (Max.)
Trapezoidal Tear Strength[2]	ASTM D 4533	lbs	50 x 50
Burst Strength	ASTMD 3786	psi	265
Puncture Resistance	ASTM D 4833	lbs	55
Ultraviolet Resistance (500 hrs)	ASTM D 4355	%	80
Apparent Opening Size (AOS)	ASTMD 4751	U. S. Sieve	20 (Max.)/40 (Min.)
Permittivity	ASTMD 4491	sec^{-1}	0.20

Notes:

1. Minimum Average Roll Value (MARV).
2. Values for machine and cross machine direction (MD x XD), respectively.

END OF SECTION

SECTION 02271
RIP RAP

Rip Rap: This section includes all rip rap aprons and channel protection.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of Rip Rap for protection of against erosion as indicated, including all necessary and incidental items, in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Geotextiles	02240
Erosion and Sedimentation Control	02270
Storm Water System	02720

3. Reference Standards:

   The latest revision of the following standards of the North Carolina Department of Transportation (NCDOT) is hereby made a part of these Specifications.

   NCDOT Road and Bridge Specifications

B. MATERIALS

1. Rip Rap: Rip Rap shall be of the size indicated on the Contract Drawings and shall conform to NCDOT Section 1042, Stone for Rip Rap.
2. Geotextiles: Geotextiles shall conform to the requirements outlined in Section 02240, Geotextiles, of these Specifications.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. Submit a certification and summary of all required test results prior to installation, that all Rip Rap has been produced in accordance with these Specifications.
2. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

D. CONSTRUCTION

1. Surface Preparation:

   a. Trim and dress all areas to conform to the Contract Drawings as indicated with tolerance of 2 inches from theoretical slope lines and grades.

   b. Bring areas that are below allowable minimum tolerance limit to grade by filling with compacted Embankment material similar to adjacent material.

   c. Geotextiles shall be placed as shown on the Contract Drawings and in accordance with Section 02240, Geotextiles, of these Specifications.

d. Do not place any stone material on the prepared surface prior to inspection and approval to proceed from the Engineer.

2. Placing Rip Rap:

Rip Rap shall be placed in accordance with NCDOT Section 1042, Rip Rap.

END OF SECTION

SECTION 02275
ROLLED EROSION CONTROL PRODUCTS

Rolled Erosion Control Products: Rolled Erosion Control Products (RECPs) include erosion control blankets (ECB), and turf reinforcement matting (TRM) placed in channels and on slopes.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of all RECPs in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Erosion and Sedimentation Control	02270
Revegetation	02930

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these specifications.

ASTM D 1777	Standard Test Method for Thickness of Textile Materials.
ASTM D 4355	Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).
ASTM D 4595	Standard Test Method for Tensile Properties of Geotextiles by the Wide-Width Strip Method.
ASTM D 5035	Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method).
ASTM D 5261	Standard Test Method for Measuring Mass per Unit Area of Geotextiles.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

Labels on each RECP shall identify the length, width, product name, and name of Manufacturer.

2. Erosion Control Blanket (ECB) (Double Net):

ECB (double net) shall consist of a machine-produced mat of curled wood excelsior. At least 80 percent of the individual excelsior fibers shall be 6 inches or more in length. The excelsior fibers shall be evenly distributed over the entire blanket. The top and bottom sides of the blanket shall be covered with a photodegradable extruded plastic or woven biodegradable mesh. The mesh shall be attached to the curled wood excelsior with degradable thread. ECB (double net) shall also conform to the properties listed in Table 1 of this section. ECB (double net) shall be CURLEX II, as manufactured by American Excelsior Company, or approved equal.

3. Turf Reinforcement Matting (TRM):

TRM shall consist of a machine-produced mat of mechanically or melt-bonded polymer nettings, monofilaments, or fibers entangled to form a strong, dimensionally stable, three dimensional permanent vegetation reinforcement structure. The mat shall be crush-resistant, pliable, water-permeable, and highly resistant to chemical and environmental degradation. TRM shall also conform to the properties listed in Table 1 of this section. TRM shall be LANDLOK TRM 435, as manufactured by Synthetic Industries, or approved equal.

4. Anchors:

Anchors for RECPs shall consist of machine made staples of No. 8 gage new steel wire formed into a "U" shape. The size when formed shall be not less that 8 inches in length with a throat of not less than 1 inch in width. Longer anchors may be required for loose soils. Other anchors, such as metal pins or plastic pegs, may also be used if approved in advance by the Engineer.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit one copy of a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for each RECP attesting that each RECP meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of each RECP to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

2. Shipping, Handling, and Storage Instructions The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

3. Furnish copies of delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

D. CONSTRUCTION

1. Shipping. Handling. and Storage:

All RECPs shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Installation - General:

a. Placing of RECPs shall be done immediately following seeding. Seeding shall be performed in accordance with Section 02930, Revegetation, of these Specifications.

b. RECPs shall be placed to the lines and grades shown on the Contract Drawings. The earth surface shall be smooth and free from stones, clods, or debris which will prevent the contact of the RECP with the soil. Care shall be taken to preserve the required line, grade, and cross section of the area.

c. RECPs shall be unrolled in the direction of the flow of water and shall be applied without stretching so that it will lie smoothly but loosely on the soil surface.

d. At the time of installation, RECPs shall be rejected, if they have defects, rips, holes, flaws, evidence of deterioration, or other damage.

e. The Engineer may require adjustments in the installation requirements to fit individual conditions.

3. Installation - Channels:

RECPs installed in channels shall be unrolled parallel to the direction of water flow. The first roll shall be centered longitudinally in the channel and anchored with staples. Subsequent rolls shall be installed outward to the edges of the channel and be lapped to allow installation of a common row of anchors. RECP ends shall be overlapped with the upstream ends on top ("shingled"). Refer to the Contract Drawings for installation details.

4. Installation - Slopes:

RECPs installed on slopes shall be oriented in vertical strips and anchored. Subsequent rolls shall be installed outward to the edge(s) of the original roll and be lapped to allow installation of a common row of anchors. RECP ends shall be shingled. Refer to the Contract Drawings for installation details.

5. Maintenance:

Maintenance of RECPs shall be in accordance with Section 02270, Erosion and Sedimentation Control, of these Specifications.

TABLE 1: REQUIRED ROLLED EROSION CONTROL PRODUCT PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE[1]
Erosion Control Blanket (ECB) (Double Net)			
Mass per Unit Area (Unit Weight)	ASTM D 5261	lbs/yd^2	0.975 ± 10%
Aperture Size - Mesh	Measured	inches	1.0 x 1.0 (max.)
Maximum Permissible Shear Stress (Un-Vegetated)	-----	lb/ft^2	1.65
Turf Reinforcement Matting (TRM)			
Mass per Unit Area (Unit Weight)	ASTM D 5261	oz/yd^2	8
Thickness	ASTM D 1777	inches	0.35
Tensile Strength2	ASTM D 5035	lbs/ft	145 x 110
Tensile Elongation	ASTM D 5035	%	50 (max.)
Porosity	Calculated	%	90
Resiliency	ASTM D 1777	%	80
UV Stability	ASTM D 4355	%	80
Maximum Permissible Velocity (Long-Term Vegetated)	-----	ft/sec	8
Maximum Permissible Shear Stress (Long-Term Vegetated)	-----	lb/ft^2	3

Notes:

1. Minimum Average Roll Value (MARV).
2. Values for machine and cross machine direction (MD x XD), respectively.

END OF SECTION

SECTION 02500
ROADWAY WORK

Roadway Work: Roadway Work refers to the construction of gravel road surfaces.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment required to complete construction of all Roadway Work including gravel roads in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Excavation	02222
Embankment	02223
Geotextiles	02240

3. Reference Standards:

   The latest revision of the following standards of the North Carolina Department of Transportation (NCDOT) is hereby made a part of these Specifications:

   NCDOT Road and Bridge Specifications

B. MATERIALS

1. Geotextiles:

   Geotextiles shall conform to the requirements outlined in Section 02240, Geotextiles, of these Specifications.

2. Aggregate Base Course (ABC):

   All work, including materials, associated with ABC shall be in accordance with NCDOT Section 1005, General Requirements for Aggregrate.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. Submit a certification and summary of all required test results, prior to installation, that all materials for Roadway Work have been produced in accordance with these Specifications.

2. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

D. CONSTRUCTION

1. General:

   All Roadway Work including the replacement of portions of the existing roads shall be to the limits, grades, thicknesses, and types as shown on the Contract Drawings. Patches for pipe crossings and areas damaged during the construction work shall be asphalt or gravel, depending upon the material encountered, unless otherwise indicated.

2. Earthwork:

   The earthwork for all Roadway Work shall be completed in accordance with Section 02222, Excavation, and Section 02223, Embankment, of these Specifications and as shown on the Contract Drawings.

3. Geotextiles:

   Geotextiles shall be placed as shown on the Contract Drawings and in accordance with Section 02240, Geotextiles, of these Specifications. If overlapped seams are used, overlaps shall be a minimum of 12 inches.

4. Aggregate Base Course:

   ABC shall be constructed in accordance with NCDOT Section 1005, General Requirements for Aggregrate, except that mixing, moisture addition, and compaction testing may be omitted.

END OF SECTION

SECTION 02600
SIDESLOPE PUMPS

Sideslope pumps: Sideslope pumps are used for removal and conveyance and control of leachate from the landfill.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation, start-up services specified and also including placement of the equipment into satisfactory and acceptable operation. The Sideslope pumps shall also be in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
HDPE Sumps	02606
HDPE Pipe	02614
Electrical	16000

3. Quality Assurance:

   Quality Assurance during placement of Sideslope pumps will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. General:

   a. Pump shall be constructed of stainless steel including housing, impellers, bowls, check valve disc, shaft, coupling, and strainer. Bearings and seal rings shall be constructed of Teflon material.

   b. Primary pumps shall provide a flow of 100 gpm at a discharge pressure of 40-50 feet of head.

   c. Secondary pump shall provide a flow of 25 gpm at a discharge pressure of 40-50 feet of head.

2. Motor:

   a. The motor shall be 3.0 hp non-overloading and suitable for operation on three phase 460 volt power.

   b. Motor shall be permanently lubricated and constructed of stainless steel wetted parts with stainless steel clad or corrosion resistant end housings.

   c. Power cable shall be heavy duty submersible type, jacketed, continuous length, and sized per U.S. NEC standards. A strain relief/riser exit fitting shall be provided. The cable shall be equal to the riser pump length plus 20’ minimum.

3. Carrier:

   a. Pump and motor shall be mounted in a wheeled carrier constructed of stainless steel with non-corrosive and self lubricating wheels. An inlet strainer and level sensor clamp shall be provided. The level sensor may be installed without disassembly or removal of the pump.

b. The pump assembly shall be designed for use in an 18” SDR 26 HDPE riser pipe with maximum pump riser length of approximately 80’. The carrier shall allow the pump to travel to and from the riser sump area over welding beads and allow for stable operation of the pump. Wheels shall have a minimum diameter of 6” and shall be constructed of a self lubricating non-metallic material.

c. Carrier supplied must be in compliance with US patents laws.

d. The carrier shall be equipped with a welded stainless steel ring with a suitable ¼ stainless retrieval cable equal to the total riser pump length. The cable shall be provided with stainless steel U-bolt type clamps, snap hook, and anchor. The cable shall be removable from the pump carrier without removal of cable U-bolt clips.

4. Controls:

a. The control panel shall provide automatic pump operation and protection and level indication. Panel shall be rated NEMA 4X stainless steel. Enclosure size shall be 24” x 30” (minimum) and shall include an outer door viewing window which allows view of all indicators and pump operator switch. Door shall open and close using a three point latch system with exterior handle and no clips or latches shall be required or installed. The handle shall be equipped with a lock hasp for use with customers pad lock. Panel shall be capable of operating a single pump with a 3 hp motor (primary system) or 0.5 hp motor (secondary system) operating on three phase, 460 volt service.

b. The panel shall be equipped with a properly sized main thermal magnetic permanent trip (Square D type FAL or equal) circuit breaker inner door interlocked operator handle, motor breaker and control circuit breaker. Breakers shall be selected for the required trip characteristics of the components protected and shall be back-plate mounted with dead front door cut outs for access to each breaker.

c. The motor starter shall be a heavy duty NEMA rated Square D 8536 or equal with properly selected thermal overloads with alarm auxiliary contacts.

d. An indicating controller with digital level read out in inches to 1/10th of an inch shall be provided. Range shall be 0-138.6” and display shall be with ½ “ high LCD digits. Controller shall be adjustable for pump and alarm set and reset points using only the selector knob and form mounted potentiometers using a screwdriver. No punch and scroll techniques shall be required to check or adjust settings shall be required. Control unit shall have plug in type terminals for all input and output connections to allow simple replacement if required. Display shall flash during a high level condition. An auxiliary start relay shall be incorporated into the control design to minimize wear to motor starter contactor.

e. Interior door accessible operator controls and indicators shall be include level indicator, breaker switches, run light, overload light, voltage fault light, H-O-A switch, elapsed run time meter, flow meter display, and disconnect operator handle.

f. The unit shall include a primary power TVSS lightning arrestor (UL 1449 listed/40,000 amps/phase and phase indicating LED's, control circuit surge suppressor (UL 1449 listed) with operational indicating led, and an instrument signal surge suppressor. The level system shall be intrinsically safe using a dual barrier fused ISB. A plug in type adjustable voltage monitor with operational LED shall be provided to protect against voltage fault conditions. A properly sized circuit breaker for voltage/phase monitor shall be provided on the back-plate.

g. A condensate heater with adjustable thermostat shall be provided.

h. Terminal strip shall be provided for connection of level sensor and flow meter which shall be mounted for easy access. All components shall be labeled and all wires shall be numbered. Schematic drawing shall include wire and terminal numbers for each component.

i. A transformer shall be provided where required or specified with a minimum rating of 100VA. Transformer shall be fused and shall operate from main breaker circuit. All control circuits shall be equipped with a properly sized fuse in addition to the control circuit breaker.

j. An overload reset shall be provided. Reset shall be a through the door push button with spring return.

k. A top mounted red high level alarm light shall be provided in addition to the flashing level indicator display feature. Alarm light shall be a strobe type.

5. Instrumentation:

a. A submersible pressure transducer of stainless steel construction compatible with control panel and with a static accurate of no more than 1% of range shall be provided. Range shall be 0-5 psi and the unit shall provide a 4-20 mA signal and be equipped with an integral surge suppressor.

b. The transducer shall be equipped with a shielded cable suitable for the application and of continuous length with a heavy outer jacket. A strain relief/riser exit fitting shall be provided. Cable shall be equal to pump power cable length.

c. The transducer shall be equipped with a desiccant type disposable drier tube for shipment and a permanent below breather located in the control panel for operation.

C. SUBMITTALS

1. Operations and Maintenance Manuals shall be provided and shall be provided and shall include troubleshooting guide, system controls operator instructions, pump assembly and service guide, pump operating characteristics, electrical as-built schematic, bill of materials of electrical control panel, warranty statement, contact statement, and additional information as necessary for normal operation and maintenance of the system.

2. Submittal shall include pump performance data, assembly drawings, electrical schematics, key components cut sheets, fittings installation details, warranty statement, and list any revisions or exceptions to all specifications.

3. Manufacturer's installation and start-up instructions.

D. CONSTRUCTION

1. Installation:

   a. Pumps shall be properly installed by the contractor based upon the contract documents and manufacturers instructions.

   b. An accurate as-built sketch shall be recorded of the riser pipe fabrication and dimensions at the time of installation of the pumps.

   c. A record of the total lengths of materials “as installed” used in each riser pipe shall be recorded and provided to at the manufacturer at the time of start-up along with a copy of the original as-built sketch.

   d. Control panels shall be installed to meet local codes and all electrical routing between the control panel and equipment shall allow for recovery and installation necessary for service and prevent moisture or fumes from entering control panel from the riser pipes.

   e. Flow meter sensor fitting shall be installed per manufacturers instructions and shall ensure that the sensor tee fitting remains full at all time for proper recording of flow totals.

   f. All piping outside the riser pipe, pipe supports, required pipe fittings, check valves, and isolation valves shall be supplied and installed by the contractor.

   g. All collection piping and the riser pipe should be free of shavings, debris, sand, silt or mud at the time of pump installation.

   h. Contractor shall ensure there is sufficient liquid in the risers at the time of start-up and testing.

2. Start-up:

   a. After installation the manufacturer shall provide system start-up services including the following services:

      (1) Inspect installation and adjust or set all necessary adjustments for proper service.

      (2) Test and record pump control operating characteristics including flow rates, amperage, and level readings and cycles at start and completion of testing.

      (3) Confirm that the installation is correct and advise contractor of any revisions necessary for proper maintenance or operation.

      (4) A final start-up report shall be furnished which shall include the as-built.

END OF SECTION

SECTION 02602
SUBMERSIBLE PUMPS

Submersible pumps: Subermersible pumps are used for removal and conveyance and control of groundwater from the underdrain manhole.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation, start-up services specified and also including placement of the equipment into satisfactory and acceptable operation. The submersible pumps shall also be in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Precast Concrete Structures	02608
HDPE Pipe	02614
Electrical	16000

3. Quality Assurance:

   Quality Assurance during placement of subermersible pumps will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. General:

   a. Pump shall be constructed of stainless steel wetted parts including casing, stator housing, impellers, seal and bearing housings, fasteners, seal springs, and discharge fittings. O'Rings shall be Viton material. Upper mechanical seal to be carbon/ceramic. Lower seal to be silicon carbide/silicon carbide.

   b. Impeller shall be multivane, semi-open and capable of passing ¼" solids, sand.

   c. Pump shall provide a flow of 60 gpm at a discharge pressure of 50 feet of head.

   d. Pumps shall be free standing with built in strainer.

2. Motor:

   a. The motor shall be 2.0 hp and suitable for operation on three phase 480 volt power.

   b. Motor shall have a fixed stator operating on a permanently lubricated anti-friction bearings with duel mechanical seals. Seals shall operate in an oil bath and motor shall be air filled type. Motor to have built in thermal protection.

   c. Power cable shall be heavy duty submersible type, jacketed, continuous length, and sized per U.S. NEC standards. The cable shall be equal to the depth of the manhole plus 20' minimum.

3. Carrier:

a. A stainless steel lifting cable shall be provided with each pump. Cable shall be ¼" stainless steel, 7 x 19 strand construction, rated a minimum breaking strength of 6,400 pounds and shall be equipped with necessary clips with a removable link connector at the pump and a snap hook at the upper end with a properly sized eye bolt to serve as and anchor for the snap hook. Cable length shall be 40 feet and shall be adjusted to the required well depth to minimize slack and facilitate lifting.

4. Controls:

a. Panel shall be rated NEMA 4X stainless steel. Panel shall be capable of operating 2x pumps with 2 hp motor using 3 phase, 460 volt service.

b. The controller shall be an Intrinsically Safe Duplexer (ISD) built for intrinsically safe pump control operation. The controller's intrinsically safe float switch inputs shall be designed to allow safe handling of float switches by lift station personnel. The ISD Controller is to be labeled UL913, as an Intrinsically Safe device.

c. The controller is to be designed to simplify control panel construction by incorporating four intrinsically safe relays, an alternator, a lag pump delay timer, two HOA switches, a push-to-test switch, and a lead/lag/auto select switch into the unit.

d. The ISD controller must have the following features:

(1) Level indicators

(2) HOA switches

(3) Power-on indicator

(4) Push-to-test switch

(5) Lead/lag/auto switch

(6) Output indicators

(7) High-level alarm indicator

(8) Float out-of-sequence indicator

(9) Internal alternator

(10) Lag pump time delay.

e. The Push-to-Test push-button (which internally closes the Off and the Lead float inputs), allows the operator to test the automatic pump call function of the unit, as well as the related pump control circuitry.

f. The Float Switch out-of-sequence logic float switches not opening or closing as they should. This logic also compensates for float switch failure conditions, and allows for continued pump operation. The float out-of-sequence indicator is to be turned off by either a return to normal float sequencing, or by resetting the control power.

g. The controller must provide a delay for the lead pump immediately following a power interruption.

h. The panel shall be equipped with a properly sized main breaker, motor protector switch/motor starter with 120V coil, main TVSS surge suppressor.

i. A terminal shall be provided for use with float switches.

5. Instrumentation:

a. Four wet well floats with a NO wired switch shall be provided.

b. Floats shall be self weighted type and provided with 35 feet of cable.

c. Floats shall be polypropylene casing with PVC type STO cable with hermetically sealed switch.

C. SUBMITTALS

1. Operations and Maintenance Manuals shall be provided and shall be provided and shall include troubleshooting guide, system controls operator instructions, pump assembly and service guide, pump operating characteristics, electrical as-built schematic, bill of materials of electrical control panel, warranty statement, contact statement, and additional information as necessary for normal operation and maintenance of the system.

2. Submittal shall include pump performance data, assembly drawings, electrical schematics, key components cut sheets, fittings installation details, warranty statement, and list any revisions or exceptions to all specifications.

3. Manufacturer's installation and start-up instructions.

D. CONSTRUCTION

1. Installation:

a. Pumps shall be properly installed by the contractor based upon the contract documents and manufacturers instructions.

b. Control panels shall be installed to meet local codes and all electrical routing between the control panel and equipment shall allow for recovery and installation necessary for service and prevent moisture or fumes from entering control panel.

c. Flow meter sensor fitting shall be installed per manufacturers instructions and shall ensure that the sensor tee fitting remains full at all time for proper recording of flow totals.

d. All piping, pipe supports, required pipe fittings, check valves, and isolation valves shall be supplied and installed by the contractor.

e. All wires and terminals shall be labeled on each end. Wires shall be color coded where applicable to connecting components.

2. Start-up:

a. After installation the manufacturer shall provide system start-up services including the following services:

(1) Inspect installation and adjust or set all necessary adjustments for proper service.

(2) Test and record pump control operating characteristics including flow rates, amperage, and level readings and cycles at start and completion of testing.

(3) Confirm that the installation is correct and advise contractor of any revisions necessary for proper maintenance or operation.

(4) A final start-up report shall be furnished which shall include the as-built.

END OF SECTION

SECTION 02608
PRECAST CONCRETE STRUCTURES

Precast Concrete Structures: Precast Concrete Structures are used in the underdrain management system.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of Precast Concrete Structures in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Excavation	02222
Embankment	02223
Submersible Pumps	02602
HDPE Pipe	02614
Valves	02640
Concrete Work	03310
CQA Manual	Attached

3. Reference Standards:

   The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these Specifications.

ASTM A 615	Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement.
ASTM C 443	Standard Specification for Joints for Circular Concrete Sewer and Culvert Pipe, Using Rubber Gaskets.
ASTM C 478	Standard Specification for Precast Reinforced Concrete Manhole Sections.
ASTM C 497	Standard Test Methods for Concrete Pipe, Manhole Sections, or Tile.
ASTM C 789	Standard Specification for Precast Reinforced Concrete Box Sections for Culverts, Storm Drains, and Sewers.
ASTM C 850	Standard Specification for Precast Reinforced Concrete Box Sections for Culvers, Storm Drains, and Sewers with Less Than 2 feet of Cover Subjected to Highway Loadings.
ASTM C 990	Standard Specification for Joints for Concrete Pipe, Manholes, and Precast Box Sections Using Preformed Flexible Joint Sealants.

4. Quality Assurance:

   Quality Assurance during placement of Precast Concrete Structures will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. Precast Concrete Manholes: All precast concrete manholes shall be constructed from non-shrink, 4,000 psi compressive strength concrete in conformance with ASTM C 478 and as detailed on the Contract Drawings.
2. Precast Concrete Boxes: All precast concrete boxes shall be constructed from non-shrink, 4,000 psi compressive strength concrete in conformance with ASTM C 789 or ASTM C 850, as applicable, and as detailed on the Contract Drawings.
3. Joints: All joints shall be sealed with preformed plastic gaskets in conformance with ASTM C 990 or rubber gaskets in conformance with ASTM C 443.
4. Steps: All steps shall be constructed of 0.5 inch reinforcing rod completely encased in corrosion-resistant rubber or plastic. The upper surfaces of each step shall have a traction tread of self cleaning rubber cleats and guide lugs on both sides to prevent slippage.
5. Frames and Covers: Frames and covers, where shown on the Contract Drawings, shall consist of ¼" Aluminum frames and covers (Bilco, or equal) equipped with handles and shall be of the opening size as indicated on the Contract Drawings. Markings on the covers shall indicate the intended use of the structure and shall be acceptable to the Owner.
6. Markings: All Precast Concrete Structures shall include markings clearly identifying the date of manufacture, the name of the manufacturer, and any other pertinent information
7. Epoxy Coating: Where indicated on the Contract Drawings, an epoxy coating shall be applied. Epoxy coating shall be by Sherwin-Williams, or approved equal. Follow the Manufacturer's recommendations in applying the epoxy coating.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. The Contractor shall submit shop drawings for Precast Concrete Structures for approval at least 4 weeks prior to construction. Shop drawings shall show complete design, installation, and construction information in such detail as to enable the Engineer to determine the adequacy of the proposed units for the intended purpose. Details of steel reinforcement size and placement shall be included. The shop drawings shall include a schedule which will list the size and type of precast structure at each location where the precast structures are to be used.
2. Submit a certification and summary of all required test results, prior to installation, that all Precast Concrete Structures have been produced in accordance with these Specifications.

D. CONSTRUCTION

1. The Precast Concrete Structures shall be installed at the locations and to the elevations indicated on the Contract Drawings. The Contractor shall give the CQA Engineer sufficient notice so he may observe the field location and installation activities.

2. The Precast Concrete Structures will be bedded and backfilled as indicated on the Contract Drawings.

3. Precast Concrete Structures which are damaged or become damaged will be rejected or shall be repaired in a manner approved by the Engineer at the Contractor's sole expense.

END OF SECTION

SECTION 02614
HIGH DENSITY POLYETHYLENE (HDPE) PIPE

High Density Polyethylene (HDPE) Pipe: HDPE Pipe is used in the collection and transmission of groundwater and leachate from the landfill.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of HDPE Pipe in accordance with the Contract Drawings and these Specifications. The Contractor shall also clean and test pipelines where required.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Excavation	02222
Embankment	02223
Protective Cover	02256
HDPE Sumps	02606
Precast Concrete Structures	02608
Drainage Aggregate	02710
Concrete Work	03310
CQA Manual	Attached

3. Reference Standards:

   The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these specifications.

ASTM D 638	Standard Test Method for Tensile Properties of Plastics.
ASTM D 790	Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials.
ASTM D 1238	Standard Test Method for Flow Rates of Thermoplastics by Extrusion Plastometer.
ASTM D 1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique.
ASTM D 1603	Standard Test Method for Carbon Black in Olefin Plastics.
ASTM D 2837	Standard Test Method for Obtaining Hydrostatic Design Basis for Thermoplastic Pipe Materials.
ASTM D 3035	Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Controlled Outside Diameter.
ASTM D 3261	Standard Specification for Butt Heat Fusion Polyethylene (PE) Plastic Fittings for Polyethylene (PE) Plastic Pipe and Tubing.
ASTM D 3350	Standard Specification for Polyethylene Plastics Pipe and Fitting Materials.
ASTM F 412	Standard Terminology Relating to Plastic Piping Systems.

ASTM F 714	Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter.
ASTM F 1417	Standard Test Method for Installation Acceptance of Plastic Gravity Sewer Lines Using Low-Pressure Air.
ASTM F 1473	Standard Test Method for Notch Tensile Test to Measure the Resistance to Slow Crack Growth of Polyethylene Pipes and Resins.
ASTM F 2164	Standard Practice for Field Leak Testing of Polyethylene (PE) Pressure Piping Systems Using Hydrostatic Pressure.

4. Quality Control:

   The Contractor will perform pressure testing of HDPE Pipe as described in this section.

5. Quality Assurance:

   Quality Assurance during placement of HDPE Pipe will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. All HDPE Pipe shall be manufactured from new materials meeting the physical requirements shown in Table 1 of this section.
2. All HDPE Pipe shall have smooth interior walls and the SDR and diameter of the pipe shall be as shown on the Contract Drawings.
3. All HDPE Pipe having an outside diameter 3.5 inches and larger shall meet the requirements of ASTM F 714. All HDPE Pipe having an outside diameter less than 3.5 inches shall meet the requirements of ASTM D 3035.
4. Visible defects, such as cracks, creases, crazing, non-uniformly pigmented areas, or undispersed raw materials shall not be acceptable and will result in rejection of the pipe by the CQA Engineer.
5. Pipe Perforations: The perforations of the perforated HDPE Pipe shall be as shown on the Contract Drawings.
6. All HDPE Pipe fittings shall be in accordance with ASTM D 3261 and shall be manufactured by the Manufacturer of the HDPE Pipe supplied for the project and shall be pressure rated to match the system piping. The fittings shall be manufactured from the same materials as the pipe itself. The butt fusion outlets of fittings shall be machined to the same SDR as the system piping to which they are to be fused.
7. Materials used as anchorage for pipe c1eanouts shall be provided and installed under this section. Concrete shall be in accordance with Section 03310, Concrete Work, of these Specifications.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Submit a certification and summary of all required test results, prior to installation, confirming all HDPE Pipe manufactured for the project has been produced in accordance with these Specifications.

2. Submit a copy of the HDPE Pipe Manufacturer's recommendations for shipping, handling, and storage of pipe.

3. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

4. Survey Results:

5. After placement of HDPE Pipe, survey results shall be submitted for review prior to acceptance.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

   All HDPE Pipe shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. HDPE Pipe Installation:

   a. The Contractor shall install HDPE Pipe to the lines and grades shown on the Contract Drawings. Line and grade of piping shall be maintained with laser or approved equivalent. The Contractor shall give the CQA Engineer sufficient notice so that he may observe field location and installation activities.

   b. Excavation for underdrain and leachate discharge lines shall be backfilled as directed by the Engineer as shown on the Contract Drawings. Sand backfill or approved soil backfill compacted to at least 95 percent of the Standard Proctor dry density (ASTM D 698) shall be used.

      Sharp stones or other potentially damaging material shall be removed from the base of the trench prior to placement of the piping. A leveling course, as required, shall consist of sand or other approved material.

   c. Pipe Connections: Joining of HDPE Pipe shall be as follows:

      (1) General pipe sections shall be butt-fusion welded according to the Manufacturer's recommendations and shall be performed by a Manufacturer's authorized, trained fusion technician.

      (2) Pipe ends to be butt-fusion welded shall be clean and dry at the time of welding. No welding shall occur during precipitation or excessive moisture.

      (3) The Contractor shall grind burrs or other potentially damaging areas in the welds prior to placement of the pipe.

      (4) Specified bolted pipe connections shall be made as specified on the Contract Drawings using stainless steel hardware and neoprene gaskets.

      (5) Polyethylene stub ends and flanges must be at the ambient temperature of the surrounding soil at the time they are bolted tight to prevent relaxation of the flange bolts and loosening of the joint due to thermal contraction of the polyethylene.

      (6) Properly executed electrofusion fittings may be used.

   d. Perforated HDPE Pipe shall be placed during construction as shown on the Contract Drawings.

3. Cleaning:

All HDPE Pipe shall be cleaned of any accumulation of silt, debris, or foreign matter of any kind and shall be kept clear of such accumulation until final acceptance of the work.

4. Pressure Testing:

a. Only sections of solid piping where factory or field joints have been performed require pressure testing except as noted below.

(1) Any section of pipe showing visual signs of damage or that is of questionable quality may be required to be pressure tested as directed by the CQA Engineer.

(2) Cleanout risers within the containment areas do not require pressure testing.

b. All underdrain and leachate discharge piping shall be pressure tested by the Contractor prior to approval by the CQA Engineer.

c. Pressure testing shall be conducted by the Contractor in a manner approved by the Engineer. Such testing shall be observed by the CQA Engineer.

d. The underdrain and leachate discharge lines shall be tested as follows:

(1) All gravity piping shall be tested using low-pressure air in accordance with ASTM F 1417.

(2) All force main piping shall be tested using hydrostatic pressure in accordance with ASTM F 2164.

The pressures used in testing must not exceed the working pressure of the lowest rated component in the system (i.e. valves, meters, flanges, unions, etc.). The Manufacturer's recommendation for pressure testing may also be acceptable as an alternative if approved in advance by the Engineer.

Pressure testing of short sections of underdrain discharge line or leachate discharge line to be placed in confined or inaccessible areas may be pressure tested by the Contractor prior to installation when approved by the Engineer. Temporary fittings, etc. required to plug section ends shall be provided by the Contractor at no expense to the Owner.

Any underdrain and/or leachate discharge line that does not meet the pressure test criteria shall be repaired and retested at the Contractor's expense. No underdrain and/or leachate discharge line shall be approved until successful pressure testing is completed.

5. Surveying:

All HDPE Pipe shall be surveyed on 100 foot centers and at bends to ensure the proper location and grade of the piping.

This work shall be performed at the Contractor's cost by a surveyor registered in the State of North Carolina.

TABLE 1: REQUIRED HDPE PIPE PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE[1]
Material Designation	ASTM D 412	----------	PE 3408
Cell Classification	ASTM D 3350	----------	345464 C
Density	ASTM D 1505	g/cm^3	0.955
Melt Flow Index	ASTM D 1238	g/1 0 min	0.1
Flexural Modulus	ASTM D 790	psi	130,000
Tensile Strength (*j*4 Yield	ASTMD 638	psi	3,200
SCG (PENT)	ASTMF 1473	hrs.	> 100
Hydrostatic Design Basis at 73˚ F	ASTM D 2837	psi	1,600
UV Stabilizer	ASTM D 1603	% Carbon Black	2 - 3%

Notes:

1. Nominal Values.

END OF SECTION

SECTION 02621
TRI-PLANAR GEONET COMPOSITE

Tri-Planar Geonet Composite (TGC): The Tri-Planar Geonet Composite consists of a layer of Geonet with a non-woven Geotextile bonded to each surface. The purpose of the TGC is to rapidly transmit flow to collection pipes. Thus, it is important that this layer remain hydraulically connected and clog-free.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of TGC, including all necessary and incidental items, in accordance with the Contract Drawings and these Specifications.

2 Related Work:

   Related Contract Work is described in the following sections of the Specifications:

Work	Section
Geotextiles	02240
Protective Cover	02256
HDPE Pipe	02614
Drainage Aggregate	02710
Geonet Composite	02712
HDPE Geomembrane	02775
Geosynthetic Clay Liner	02777
CQA Manual	Attached

3. Reference Standards:

   The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the Geosynthetic Research Institute (GRI) are hereby made a part of these specifications.

ASTM D 792	Standard Test Methods for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
ASTM D 1238	Standard Test Method for Melt Flow Rates of Thermoplastics by Extrusion Plastometer.
ASTM D 1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique.
ASTM D 3786	Standard Test Method for Bursting Strength of Textile Fabrics-Diaphragm Bursting Strength Tester Method.
ASTM D 4218	Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds by the Muffle-Furnace Technique.
ASTM D 4355	Standard Test Method for Deterioration of Geotextile by Exposure to Light, Moisture and Heat in a Xenon Arc Type

	Apparatus
ASTM D 4491	Standard Test Method for Water Permeability of Geotextiles by Permittivity.
ASTM D 4533	Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
ASTM D 4716	Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products.
ASTM D 4751	Standard Test Method for Determining Apparent Opening Size of a Geotextile.
ASTM D 4833	Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
ASTM D 5035	Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method).
ASTM D 5199	Standard Test Method for Measuring the Nominal Thickness of Geosynthetics.
ASTM D 5261	Standard Test Method for Measuring the Mass Per Unit Area of Geotextiles.
ASTM D 7005	Determination the Bond Strength (Ply-Adhesion) of Geocomposites.
ASTM D 7179	Standard Test Method for Determining Geonet Breaking Force.

4. Quality Assurance:

Quality Assurance during installation of TGC will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1 General:

The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

Labels on each roll of TGC shall identify the length, width, lot and roll numbers, and name of Manufacturer.

2. The Geocomposite shall be manufactured by extruding two crossing strands to form a bi-planar drainage net structure with a non-woven Geotextile bonded to one or both sides.

3. The Geonet shall contain UV inhibitors to prevent ultraviolet light degradation.

4. Physical properties of the TGC shall be as shown in Table 1 of this section.

5. Resin:

a. Resin shall be new first quality, compounded polyethylene resin.

b. Natural resin (without carbon black) shall meet the following additional minimum requirements shown in Table 2.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit one copy of a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the TGC attesting that the TGC meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample (4" x 6") of the TGC to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.
2. Shipping. Handling. and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.
3. Quality Control Certificates: For TGC delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of TGC. Each certification shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 3 of this section.
4. Furnish copies of delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

D. CONSTRUCTION

1. Shipping. Handling. and Storage:

   All TGC shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing COA Material Control Tests:

   TGC that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and quality assurance testing of TGC supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Installation:

   a. TGC shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, the TGC shall be rejected, if it has defects, rips, holes, flaws, evidence of deterioration, or other damage.

   b. The TGC shall be installed in the direction of the slope and in the intended direction of flow unless otherwise specified by the Engineer.

   c. The TGC shall be placed only on Geomembrane that has been approved by the Geomembrane Installer and accepted by the CQA Engineer.

   d. The TGC shall be placed smooth and free of excessive wrinkles.

   e. In the presence of wind, all geocomposites shall be weighted down with sandbags or the equivalent. Such sandbags shall be used during placement and remain until replaced with cover material.

f. Seams and Overlaps:

(1) Each component of the geocomposite will be secured or seamed to the like component at overlaps.

(2) Adjacent edges of the Geonet along the length of the geocomposite roll shall be placed with edges of each Geonet butted against each other.

(3) The overlaps shall be joined by tying the Geonet structure with cable ties. These ties shall be spaced every 5 feet along the roll length.

(4) Adjoining geocomposite rolls (end to end) acroos the roll width should be shingled down in the direction of the slope, with the Geonet portion of the top overlapping the Geonet portion of the bottom geocomposite a minimum of 12 inches across the roll width.

4. Repair:

Any TGC that is torn, crushed, or punctured shall be repaired or replaced by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of the same type of material, placed over the failed area and shall overlap the existing material a minimum of 12 inches from any point of the rupture. The patch shall be connected to the Geonet using polyethylene ties at 6 inch spacing.

5. Cover Placement:

Placement of materials over TGC shall be performed in a manner as to ensure that TGC and the underlying geosynthetics are not damaged; minimal slippage of TGC on the underlying geosynthetics occurs; no excess tensile stresses occur in the TGC; and that no portion of the TGC develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or TGC that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

TABLE 1: REQUIRED TRI-PLANAR GEONET COMPOSITE PROPERTIES

TESTED PROPERTY	TEST METHOD	FREQUENCY	MINIMUM AVERAGE ROLL VALUE
Geocomposite			
Roll Size	12.5 ft x 200 ft (3.8 m x 61 m)		
Peel Adhesion, lb/in (g/in)	ASTM D 7005	1/50,000 ft^2	1.0 (454)
Transmissivity[a], m^2/sec	ASTM D 4716	1/540,000 ft^2	2.0×10^{-3}
Geonet Core			
Thickness, mil(mm)	ASTM D 5199	1/50,000 ft^2	300 (7.6)
Density, g/cm^3	ASTM D 792	1/50,000 ft^2	0.94 – 0.96
Melt Flow Index, g/10min	ASTM D 1238	1/50,000 ft^2	1.0
Carbon Black Content (%)	ASTM D 4218	1/50,000 ft^2	2.0 – 3.0
Tensile Strength - MD[b], lb/in (kN/m)	ASTM D 7179	1/50,000 ft^2	500 (7.6)
Tensile Strength - WD[b], lb/in (kN/m)	ASTM D 7179	1/50,000 ft^2	500 (7.6)
Creep Reduction Factor	GRI-GC8	once per formulation	1 .2[c]
Geotextile			
UV Resistance, %	ASTM D 4355 (after 500 hours)	once per formulation	70
Grab Tensile, lb (N)	ASTM D 4632	1/90,000 ft^2	160 (712)
Grab Elongation, %	ASTM D 4632	1/90,000 ft^2	50
Tear Strength, lb (N)	ASTM D 4533	1/90,000 ft^2	60 (267)
Puncture Strength, lb (N)	ASTM D 4833	1/90,000 ft^2	85 (378)
Mullen Burst, psi (kPa)	ASTM D 3786	1/90,000 ft^2	330 (2274)
AOS, US Sieve (mm)	ASTM D 4751	1/540,000 ft^2	70 (0.212)
Permittivity, sec^{-1}	ASTM D 4491	1/540,000 ft^2	1.1
Flow Rate, gpm/ft^2 (lpm/m^2)	ASTM D 4491	1/540,000 ft^2	85 (3462)

NOTES:

(a) This is an index transmissivity value measured at stress = 15,000 psf; gradient = 0.1. Testing boundary conditions as follows: steel plate/Ottawa sand/geocomposite/60 mil HDPE geomembrane/steel plate.

(b) Creep reduction factors is determined under 15,000 psf load and 40 °C temperature, extrapolated to 30 years of design life.

(c) MD = Machine Direction, WD = Width Direction.

TABLE 2: REQUIRED RESIN PROPERTIES

Property	Test Method	Value
Density (g/cm3)	ASTM D 792	>0.94
Melt Flow Index (g/10 min)	ASTM D 1238	$\leq$ 1.0

TABLE 3: REQUIRED MANUFACTURER'S QUALITY CONTROL TEST DATA

Manufacturing Quality Control Test Frequencies			
Characteristics	**Test Method**	**Units**	**FREQUENCY**
			Bi-Planar
Resin			
Polymer Density Melt Flow Index	ASTM D 1505 ASTM D 1238	g/cm^3 g/10 min	Once Per Lot Once Per Lot
Geonet Test			
Carbon Black Tensile Strength, MD Density	ASTM D 4218 ASTM D 7179 ASTM D 792	% lb/ ft g/cm^3	1/50,000 ft^2 1/50,000 ft^2 1/50,000 ft^2
Geotextile Tests			
Mass per Unit Area Grab Tensile Puncture AOS, US Sieve Water Flow Rate UV Resistance	ASTM D 5261 ASTM D 4632 ASTM D 4833 ASTM D 4751 ASTM D 4491 ASTM D 4355 (after 500 hours)	oz/yd^2 lb lb mm gpm/ft^2 % retained	1/90,000 ft^2 1/90,000 ft^2 1/90,000 ft^2 1/540,000 ft^2 1/540,000 ft^2 Once per resin formulation
Geocomposite Tests			
Ply Adhesion Transmissivity	ASTM D7005 ASTM D 4716	lb/in m^2/sec	1/50,000 ft^2 1/540,000 ft^2

END OF SECTION

SECTION 02640
VALVES

Valves: Gate, swing check, plug, and air release valves are to be installed in the leachate management system of the landfill.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of all valves including all fittings, appurtenances, and transition pieces required for a complete and operable installation in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Precast Concrete Structures	02608
HDPE Pipe	02614
Concrete Work	03310
CQA Manual	Attached

3. Reference Standards:

   The latest revision of the following standards of the American National Standard Institute (ANSI) is hereby made a part of these specifications.

   ANSI B 16.1 Pipe Flanges and Flanged Fittings.

4. Quality Assurance:

   Quality Assurance during installation of Valves will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. Valve Materials and Construction:

   a. All valves shall be constructed of new, first quality materials which have strength, wearing, and corrosion resistance characteristics entirely suitable for the types of service for which the individual valves are designated.

   b. All valve body castings shall be clean, sound, and without defects of any kind. No plugging, welding, or repairing of defects will be allowed.

   c. Valves shall have flanged ends for exposed service and mechanical joint, or butt fused (for Polyethylene valves) ends for buried service, unless otherwise shown on the Contract Drawings or specified herein. Flanged ends shall be flat-faced, 125 lb. American Standard unless otherwise shown or specified in accordance with ANSI B16.1. All bolt heads and nuts shall be hexagonal of American Standard size. The Contractor shall be responsible for coordinating connecting piping.

2. Ball Valves:

Ball valves shall be constructed of Polyethylene body material compatible with the pipe materials to permit butt fusion or electrofusion welding, and polypropylene ball and stem adapter, or similar materials. Flowserve Nordstrom valves compatible with adjacent pipe are recommended or approved alternate materials.

3. Gate Valves:

Gate valves shall be rated to 150 psi at 70°F. Body shall be PVC. The valve shaft shall be cast iron or stainless steel and be of blow out proof design. Seals shall be Teflon. Gate valves shall have flanged (ANSI) ends. Gate valves shall be as manufactured by ITT Engineered Valves, or equal.

4. Swing Check Valves:

Swing Check Valves shall be constructed of solid cast iron or stainless steel with Teflon seats and seals. Valves intended for chemical service shall be constructed of materials suitable for the intended service. Valves shall have an external lever and weight. Check valves shall have flanged (ANSI) ends. Valves shall be capable of top entry to facilitate cleaning and repair without removal from the line. Valves shall incorporate a single disc design. Check valves shall be as manufactured by Crane, ITT, M&H, or equal.

5. Plug Valves:

Plug valves shall be of the non-lubricated, tapered type. Valve body shall be semi-steel with flanged end connection drilled to ANSI 125 lb. Standard Valves shall be furnished with a drip-tight shutoff plug mounted in stainless steel or Teflon over phenolic bearings, and shall have a resilient facing bonded to the sealing surface. Plug valves shall be as manufactured by Crane, ITT, M&H, or equal.

6. Air Release Valves:

Air release valves (leachate pump station) shall operate by sealing a BUNA-N rubber outlet seat with a peripheral float as the liquid enters the valve chamber to raise the float. The valve shall satisfactorily withstand hydrostatic pressures of 300 psi. The valve shall be constructed of cast iron body and top flange with stainless steel or bronze and brass trim. The peripheral guided float shall be stainless steel. Air release valves shall be as manufactured by Crispin, or equal.

Air release valves (leachate forcemain) are to be supplied by the Owner and installed by the Contractor.

7. Valve Operators:

The valve operator shall be designed to unseat, open or close, and seat the valve under the most adverse operating condition to which the valve will be subjected. All gearing shall be totally enclosed, sealed, and permanently lubricated. Extended operators shall be constructed of 3 16 stainless steel.

8. Valve Boxes:

Valve boxes shall be constructed of reinforced concrete or cast iron, have cast iron lids, and shall generally be as shown on the Contract Drawings. Valve boxes shall be of the appropriate size depending on the particular valve installed. Valve boxes shall be approved by the Engineer prior to installation. Precast concrete valve boxes shall be in accordance with Section 02608, Precast Concrete Structures, of these Specifications.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Submit a certification and summary of all required test results, prior to installation, that all valves manufactured for the project have been produced in accordance with these Specifications.
2. Submit Shop Drawings for all valves and accessories prior to installation. Submittals shall include all layout dimensions, size and materials of construction for all components, information on support and anchoring where necessary, pneumatic and hydraulic characteristics, and complete descriptive information to demonstrate full compliance with the Contract Documents.
3. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.
4. Operation and maintenance manuals and installation instructions shall be submitted for all valves and accessories. The Manufacturer(s) shall delete all information which does not apply to the equipment being furnished.

D. CONSTRUCTION

1. Before installation, all valves shall be lubricated, manually opened and closed to check their operation, and the interior of the valves shall be thoroughly cleaned.
2. Install all valves where shown on the Contract Drawings in accordance with the Manufacturer's instructions.
3. Install all valves so that operating handwheels or wrenches may be conveniently turned but without interfering with access, and as approved by the Engineer.
4. Unless otherwise approved, install all valves plumb and level. Valves shall be installed free from distortion and strain caused by misaligned piping, equipment or other causes. Concrete valve footings shall be provided for each unsupported valve where recommended by the Manufacturer or as directed by the Engineer.
5. Valve boxes shall be set plumb, and centered with the bodies directly over the valves so that traffic loads are not transmitted to the valve. Earth fill shall be carefully tamped around each valve box to a distance of 4 feet on all sides of the box, or to the undisturbed trench face, if less than 4 feet.

END OF SECTION

SECTION 02710
DRAINAGE AGGREGATE

Drainage Aggregate: Drainage Aggregate includes aggregate which is placed around underdrain and leachate collection pipes (gravel columns) and in the sumps for the purpose of groundwater and leachate collection and removal.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete the installation of Drainage Aggregate in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Geotextiles	02240
HDPE Pipe	02614
Geonet Composite	02712
HDPE Geomembrane	02775
CQA Manual	Attached

3. Reference Standards:

   The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the North Carolina Department of Transportation (NCDOT) are hereby made a part of these specifications.

ASTM C 136	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
ASTM D 2434	Standard Test Method for Permeability of Granular Soils (Constant Head).
ASTM D 3042	Standard Test Method for Insoluble Residue in Carbonate Aggregates.
NCDOT	Road and Bridge Specifications.

4. Quality Assurance:

   Quality Assurance during placement of Drainage Aggregate will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. No. 78 Stone:

   a. A granular material (NCDOT No.78 or alternate gradation if approved by the Engineer) from a non-carbonate source ($\leq$ 15% carbonate content by ASTM D 3042) shall be used as a filter media over No. 57 stone as shown on the Contract Drawings and shall be approved by the CQA Engineer at least four weeks prior to construction.

b. The collection media shall consist of sub-angular or smooth particles and shall be sound, durable, and free from seams, cracks, or other structural defects. The material shall be free of shale, clay, friable materials, and debris.

c. The collection media shall meet the following gradation criteria and have a coefficient of permeability of 1 x 10^{-1} cm/sec. (ASTM D 2434) or greater.

Sieve Size	**Percent Passing**
3/4 Inch	100
1/2 Inch	98 – 100
3/8 Inch	75 - 100
No. 4	20 - 45
No. 8	0 - 15
No. 200	≤ 0.6

The Engineer may approve an alternate gradation if the material meets permeability criteria.

2. No. 57 Stone:

a. Coarse aggregate (NCDOT No. 57 or alternate gradation if approved by the Engineer) from a non-carbonate source (≤ 15% carbonate content by ASTM D 3042) shall be placed around the collection pipes and within the sumps and as the gravel roadways as where shown on the Contract Drawings and shall be approved by the CQA Engineer at least four weeks prior to construction.

b. Coarse aggregate shall consist of rounded or sub-angular or smooth particles and shall be sound, durable, and free from seams, cracks, or other structural defects. The material shall be free of shale, clay, friable materials, and debris. Coarse aggregate consisting of long, thin, angular particles may be rejected in the sole discretion of the Engineer.

c. Coarse aggregate shall meet the following gradation criteria.

Sieve Size	**Percent Passing**
1 1/2 Inch	100
1 Inch	95 - 100
1/2 Inch	25 – 60
No.4	0 – 10
No.8	0 - 5
No. 200	≤ 0.6

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Before approval is given to proceed, the Contractor shall submit descriptive information on equipment to be used for placement of the Drainage Aggregate.
2. The Contractor shall submit at least two bulk samples each of the underdrain and leachate collection media and coarse aggregate from each material source for approval at least four weeks prior to beginning construction of the underdrain collection system. Along with the bulk samples, the Contractor shall also submit a certification from each material source that the materials proposed meet the specified gradation requirements.

D. CONSTRUCTION

1. Failing CQA Material Control Tests:

   Drainage Aggregate that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of Drainage Aggregate supplied as replacement for rejected material shall be performed by the CQA Engineer at the Contractor's cost.
2. The Drainage Aggregate is placed directly over geosynthetics and piping; thus, extreme caution shall be exercised by the Contractor to prevent damage to these materials.

   Test areas to evaluate potential damage due to equipment operations may be required by the Engineer to assess equipment to be used by the Contractor at the Contractor's sole expense. Test area parameters shall be determined by the Engineer and Contractor in advance of construction of the leachate collection system.
3. Placement of Drainage Aggregate within the containment area shall be conducted only when the CQA Engineer is informed by the Contractor of intent to perform such work.
4. The Contractor shall exercise care in maintaining a true line and grade for all piping during placement and spreading of Drainage Aggregate.
5. Drainage Aggregate shall be placed over geosynthetics only after areas have been released by the Geosynthetics Installer and the CQA Engineer. Drainage Aggregate shall be placed as specified below:
   a. Drainage Aggregate shall be placed and spread with low ground pressure equipment (6 psi ground pressure or less) as approved by the CQA Engineer to reduce potential damage to the underlying geosynthetics. The surface of geosynthetics shall be off-limits to construction traffic.
   b. Low ground pressure equipment used to spread Drainage Aggregate shall operate on at least 1 foot of material overlying geosynthetics and/or piping. Sharp turning of tracked equipment on the Drainage Aggregate will not be permitted.
   c. On side slopes, place Drainage Aggregate from the bottom up unless otherwise approved by the Engineer. No material shall be dumped down a slope.
   d. Drainage Aggregate shall not be placed over standing water or ice.

e. Drainage Aggregate shall not be compacted within the limits of the containment area.

f. Drainage Aggregate shall be placed to the lines and grades as shown on the Contract Drawings. Drainage Aggregate placed beyond these limits shall be removed at the Contractor's sole expense if required by the Engineer.

6. The Drainage Aggregate shall be spread in a manner that minimizes development of wrinkles in the underlying geosynthetics. Any portion of the underlying geosynthetics that develops excessive wrinkles or crimp shall be repaired by the Geosynthetics Installer at no expense to the Owner.

   a. Drainage Aggregate shall be placed before noon or at other times when the ambient air temperature is not more than 75"F to minimize wrinkling of underlying geosynthetics unless otherwise approved by the Engineer.

   b. If during spreading, excessive wrinkles develop, the Contractor shall adjust placement and spreading methods, or cease until the underlying geosynthetics cool and wrinkles decrease in size.

   c. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and spreading methods or underlying geosynthetics that become crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

7. Stockpiling of Drainage Aggregate within the limits of the containment area shall be subject to advance approval by the Engineer. Any hauling equipment (dump trucks, etc.) operating within the containment area shall have a minimum of 3 feet of separation between the vehicle wheels and the Geomembrane.

   The Contractor shall minimize equipment operations directly over coarse aggregate.

8. The CQA Engineer may require removal of Drainage Aggregate and/or other underlying layers at the Contractor's sole expense to allow examination of the underlying geosynthetics and/or piping. Any damage to the underlying layers or excessive wrinkling or crimping during placement of Drainage Aggregate shall be repaired in accordance with the applicable section of these Specifications at the Contractor's sole expense.

END OF SECTION

SECTION 02712
GEONET COMPOSITE

Geonet Composite (GC): The Geonet Composite consists of a layer of Geonet with a Type GT -S Geotextile bonded to each surface. The purpose of the GC is to rapidly transmit flow to collection pipes. Thus, it is important that this layer remain hydraulically connected and clog-free.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of GC, including all necessary and incidental items, in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Geotextiles	02240
Protective Cover	02256
HDPE Pipe	02614
Drainage Aggregate	02710
HDPE Geomembrane	02775
Geosynthetic Clay Liner	02777
CQA Manual	Attached

3. Reference Standards:

   The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the Geosynthetic Research Institute (GRI) are hereby made a part of these specifications.

ASTMD 413	Standard Test Methods for Rubber Property - Adhesion to Flexible Substrate.
ASTM D 1505	Standard Test Method for Density of Plastics by the Density-Gradient Technique.
ASTM D 1603	Standard Test Method for Carbon Black in Olefin Plastics.
ASTM D 3776	Standard Test Methods for Mass Per Unit Area (Weight) of Fabric.
ASTM D 4491	Standard Test Method for Water Permeability of Geotextiles by Permitivity.
ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
ASTM D 4716	Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products.
ASTM D 4751	Standard Test Method for Determining Apparent Opening Size of a Geotextile.

ASTM D 4833	Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
ASTM D 5035	Standard Test Method for Breaking Force and Elongation of Textile Fabrics (Strip Method).
ASTMD 5199	Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
ASTM D 5261	Standard Test Method for Measuring the Mass Per Unit Area of Geotextiles.
ASTMD 5321	Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.
GRI GC7	Determination of Adhesion and Bond Strength of Geocomposites

4. Quality Assurance:

   Quality Assurance during installation of GC will be provided by the Owner as described in the accompanying Project CQA Manual.

B. MATERIALS

1. General:

   The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

   Labels on each roll of GC shall identify the length, width, lot and roll numbers, and name of Manufacturer.

2. The Geonet shall be manufactured by extruding polyethylene strands to form a three dimensional structure to provide planer water flow.
3. A Type GT -S Geotextile shall be heat bonded to both sides of the Geonet. Heat bonding shall be performed by the Manufacturer prior to shipping to the site. The Type GT -S Geotextile shall be a nonwoven needlepunched synthetic fabric meeting the property requirements of Section 02240, Geotextiles, of these Specifications.
4. The Geonet shall contain UV inhibitors to prevent ultraviolet light degradation.
5. Physical properties of the GC shall be as shown in Table 1 of this section.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit one copy of a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the GC attesting that the GC meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample (4" x 6") of the GC to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.
2. Shipping. Handling. and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

3. Quality Control Certificates: For GC delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of GC. Each certification shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 2 of this section.

4. Furnish copies of delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

D. CONSTRUCTION

1. Shipping. Handling. and Storage:

   All GC shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing COA Material Control Tests:

   GC that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and quality assurance testing of GC supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Installation:

   a. GC shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, the GC shall be rejected, if it has defects, rips, holes, flaws, evidence of deterioration, or other damage.

   b. The GC shall be placed only on Geomembrane that has been approved by the Geomembrane Installer and accepted by the CQA Engineer.

   c. The GC shall be placed smooth and free of excessive wrinkles.

   d. The Contractor shall provide temporary anchorage of the GC at the top of perimeter and interior berms during installation to prevent movement during construction. Such anchorage may include sandbags and the like, as approved by the CQA Engineer. Permanent bonding to the Geomembrane shall be prohibited.

   e. Adjacent rolls of GC shall be overlapped a distance of at least 3 inches and secured using polyethylene ties. For GC placed on slopes, the ties shall be placed every 5 feet. For GC placed on the facility floor, tie spacing shall be every 10 feet.

      The overlying Type GT -S Geotextile, where applicable, shall extend at least 6 inches past the geonet seam and shall be permanently bonded to the Type GT -S Geotextile of the adjacent rolls by heat bonding or sewing as approved by the Engineer.

      All seams constructed on sloped surfaces ≥ 6H: 1 V or within 10 feet of the toe of a side slope shall be vertical seams, except where slope lengths exceed standard roll lengths and elsewhere as approved in advance by the Engineer. Where allowed by the Engineer, end seams on slopes shall be staggered a minimum of 5 feet between adjacent rolls and shall have ties placed every 2 feet.

f. Any GC that is torn, crushed, or punctured shall be repaired or replaced by the Contractor at no additional cost to the Owner. The repair shall consist of a patch of the same type of material, placed over the failed area and shall overlap the existing material a minimum of 12 inches from any point of the rupture. The patch shall be connected to the Geonet using polyethylene ties at 6 inch spacing.

g. Where applicable, the Contractor shall remove debris, including sediment to the degree possible, from the sump areas prior to placement of the GC. The sump areas shall be approved by the CQA Engineer prior to GC placement.

4. Cover Placement:

Placement of materials over GC shall be performed in a manner as to ensure that GC and the underlying geosynthetics are not damaged; minimal slippage of GC on the underlying geosynthetics occurs; no excess tensile stresses occur in the GC; and that no portion of the GC develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or GC that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

TABLE 1: REQUIRED GEONET COMPOSITE PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE
			6 oz
Transmissivity	ASTM D 4716	m^2/sec	1×10^{-4}
Ply Adhesion	ASTM D 413	lbs	1.0
Roll Width		ft	14
Roll Length		ft	200
Interface Shear Strength (Peak) 2,3 (Base Liner)	ASTM D 5321	psf	125 psf (Load=200psf) 1,000 psf (2,500 psf) 2,000 psf (5,000 psf) 4,000 psf (10,000 psf)
Net Properties			
Polymer Density	ASTM D 1505	g/cm^2	0.94
Carbon Black Content	ASTM D 1603	%	2.0
Thickness	ASTM D 5199	mil	250
Mass per Unit Area	ASTM D 5261	lbs/ft^2	0.256
Tensile Strength	ASTM D 5035/7179	lb/in	50
Transmissivity	ASTM D 4716	m^2/sec	2×10^{-3}
Geotextile Properties			
Fabric Weight	ASTM D 3776	oz	6.0
Grab Tensile	ASTM D 4632	lbs	160
Puncture	ASTM D 4833	lbs	95
Water Flow Rate	ASTM D 4491	gpm/ft^2	130
AOS	ASTM D 4751	US sieve	70

TABLE 2: REQUIRED MANUFACTURER'S QUALITY CONTROL TEST DATA

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Thickness (geonet only)	ASTM D 5199	50,000 ft^2
Density (geonet only)	ASTMD 1505	50,000 ft^2
Grab Tensile Strength (geotextile only)	ASTM D 4632	200,000 ft^2
Puncture Resistance (geotextile only)	ASTM D 4833	200,000 ft^2
Apparent Opening Size (AOS) (geotextile only)	ASTM D 4751	600,000 ft^2
Ply Adhesion	ASTM D 413/ GRI GC7	100,000 ft^2
Transmissivity	ASTM D 4716	100,000 ft^2 (See Note 4)
Interface Shear Strength	ASTM D 5321	(See Note 3)

Notes:

1. Base Liner:
   Conduct test for transmissivity at a normal compressive load of 8,000 psf and at a hydraulic gradient of 0.10 after a seating period of at least 100 hours. Boundary conditions are soil (sand) interface on the upper Type GT-S Geotextile and textured HDPE geomembrane against the lower Type GT -S Geotextile.

2. Test each interface to be used on this project using representative samples of materials to be supplied under normal loads indicated and using test parameters as specified by the Engineer. For this project, interfaces to be tested are:

   Base Liner:
   A. Textured HDPE-GM (40 mil) against subgrade soils;
   B. Geonet Composite against Textured HDPE-GM (40 mil);
   C. Geosynthetic Clay Layer against Geonet Composite;
   D. Textured HDPE-GM (60 mil) against Geosynthetic Clay Layer;
   E. Geonet Composite against Textured HDPE-GM (60 mil); and
   F. Protective Cover against Geonet Composite.

   If there are material differences in the surface of any of the geosynthetic materials from one side to the other, then all possible combinations of interfaces shall be tested. This testing shall be performed at Contractor cost by an independent GAI accredited laboratory and submitted to the Engineer for review prior to shipping.

   Upon review of test results, the Engineer may allow exceptions to the above criteria.

   For tests involving textured geomembrane, the laboratory shall also report the asperity height (GRI GM12) for the material samples used in the actual direct shear tests.

3. GC shall have adequate adhesion against adjacent materials under low normal loads to achieve the successful installation of overlying components without slippage.

4. The required Manufacturer's quality control testing for transmissivity may be reduced to one test per resin lot or one test per 500,000 ft2 (whichever provides the larger number of tests) if the minimum measured transmissivity is at least 50% greater than specified.

END OF SECTION

SECTION 02720
STORM WATER SYSTEMS

Storm Water Systems: Storm Water Systems shall include all piping, pipe fittings, flared end sections, and other appurtenances designated to convey stormwater.

A. DESCRIPTION

1. General:

   The contractor shall furnish all labor, material, and equipment to complete installation of Storm Water Systems in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Excavation	02222
Embankment	02223
Erosion and Sedimentation Control	02270
Rip Rap	02271
Concrete Work	03310

3. Reference Standards:

   The latest revision of the following standards of the American Society of Testing and Materials (ASTM), the American Association of State Highway and Transportation Officials (AASHTO), and the North Carolina Department of Transportation (NCDOT) are hereby made a part of these specifications.

ASTM C 76	Standard Specification for Reinforced Concrete Culvert, Storm Drain, and Sewer Pipe.
ASTM C 150	Standard Specification for Portland Cement.
ASTMD 1248	Standard Specification for Polyethylene Plastics Molding and Extrusion Materials for Wire and Cable.
ASTMD 2321	Standard Practice for Underground Installation of Thermoplastic Pipe for Sewers and Other Gravity-Flow Applications.
ASTM D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials.
AASHTO M 36	Specification for Corrugated Steel Pipe.
AASHTO M 252	Specification for Corrugated Polyethylene Drainage Tubing, 3 to 10 Inch Diameter.
AASHTO M 294	Specification for Corrugated Polyethylene Pipe, 12 to 36 Inch Diameter
VDOT	Road and Bridge Specifications.

B. MATERIALS

1. Corrugated Metal Pipe (CMP):

    a. Corrugated metal pipe and fittings shall be of the sizes shown or specified and shall conform to every aspect of AASHTO M 36.

    b. Corrugated metal pipe shall be fabricated from galvanized steel sheets. Corrugation profile shall be 2 2/3 inch crest to crest and 1/2 inch crest to valley, and sheet thickness shall be 16 gage/.064 inch minimum.

    c. Pipe sections shall be helically corrugated with each pipe end rerolled to obtain no less than two (2) annular corrugations.

    d. Coupling Bands: CMP shall be firmly joined by coupling bands in accordance with the manufacturer's recommendations. These bands shall be not more than two nominal sheet thicknesses lighter than the thickness of the pipe to be connected and in no case lighter than 0.052 inches.

    e. All CMP utilized for permanent installation shall have gasketed joints.

    f. Asphaltic or bituminous coatings shall be applied in conformance with the manufacturer's requirements, as applicable.

2. Corrugated Polyethylene (CPE) Pipe:

    CPE pipe and fittings shall be of the sizes and type shown on the Contract Drawings and shall conform to every aspect of AASHTO M 252 (3 to 10 inch diameters) or AASHTO M 294 (12 to 36 inch diameters). All Type S CPE pipe shall have watertight joints.

3. Flared End Sections:

    Flared end sections shall be reinforced and shall be fabricated from the same materials meeting the same requirements as the pipe to which they are connected. All reinforced concrete and corrugated metal flared end sections shall meet the requirements of the NCDOT. Corrugated polyethylene flared end sections shall be as recommended by the pipe manufacturer.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Submit a certification and summary of all required test results, prior to installation, that all Storm Water Systems have been produced in accordance with these Specifications.

2. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into construction.

D. CONSTRUCTION

1. All piping shall be installed by skilled workmen and in accordance with the best standards for piping installation. Proper tools and appliances for the safe and convenient handling and installation of the pipe and fittings shall be used.

2. All pieces shall be carefully examined for defects, and no piece shall be installed which is known to be defective. If any defective piece should be discovered after having been installed, it shall be removed and replaced at the Contractor's expense.

3. Excavation and backfilling of pipe trenches shall be as described in Section 02222, Excavation and Section 02223, Embankment, respectively, of these Specifications.

4. Following proper preparation of the trench subgrade, pipe and fittings shall be carefully lowered into the trench so as to prevent dirt and other foreign substances from gaining entrance into the pipe and fittings. Proper facilities shall be provided for lowering sections of pipe into trenches. No materials shall be dropped or dumped into the trench.

5. Water shall be kept out of the trench until jointing and backfilling are completed. When work is not in progress, open ends of pipe, fittings, and valves shall be securely closed so that no water, earth, or other substance will enter the pipes, fittings, or valves. Pipe ends left for future connections shall be valved, plugged, or capped, and anchored as required.

6. All piping shall be erected to accurate lines and grades with no abrupt changes in line or grade.

7. The full length of each section of pipe shall rest solidly upon the bed of the trench, with recesses excavated to accommodate bells, couplings, joints, and fittings. Before joints are made, each pipe shall be well bedded on a solid foundation. No pipe shall be brought into position until the preceding length has been thoroughly bedded and secured in place. Pipe that has the grade or joint disturbed after laying shall be taken up and relaid by the Contractor at his own expense.

8. The laying of reinforced concrete pipe shall conform to the applicable sections of the Concrete Pipe Handbook as published by the American Concrete Pipe Association.

END OF SECTION

SECTION 02775
HDPE GEOMEMBRANE

HDPE Geomembrane (HDPE-GM): The HDPE Geomembrane serves as the primary hydraulic containment barrier for the leachate to be developed in the landfill.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of HDPE-GM including all necessary and incidental items as detailed or required to complete the installation in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Geotextiles	02240
Protective Cover	02256
Drainage Aggregate	02710
Geonet Composite	02712
CQA Manual	Attached

3. Reference Standards:

   The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the Geosynthetic Research Institute (GRI) are hereby made a part of these Specifications.

ASTM D 638 — Standard Test Method for Tensile Properties of Plastics.

ASTM D 792 — Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement

ASTMD 1004 — Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.

ASTM D 1505 — Standard Test Method for Density of Plastics by the

Density-Gradient Technique.

ASTM D 1603 — Standard Test Method for Carbon Black in Olefin Plastics

ASTM D 4218 — Standard Test Method for Determination of Carbon Black Content in Polyethylene Compounds By the Muffle-Furnace Technique.

ASTM D 5199 — Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.

ASTM D 5321 — Standard Test Method for Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.

ASTM D 5397	Standard Test Method for Evaluation of Stress Crack Resistance of Poly olefin Geomembranes Using Notched Constant Tensile Load Test
ASTM D 5596	Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics
ASTM D 5820	Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes
ASTM D 5994	Standard Test Method for Measuring Core Thickness of Textured Geomembrane.
ASTMD 6392	Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods
GRI GM12	Asperity Measurement of Textured Geomembranes Using a Depth Gage

4. Quality Control:

The Geomembrane Installer will perform and document nondestructive and destructive Quality Control tests during installation of HDPE-GM as described in the accompanying Project CQA Manual.

5. Quality Assurance:

Quality Assurance during installation of HDPE-GM will be provided by the Owner as described in the accompanying Project CQA Manual.

6. Manufacturers Qualifications:

The Manufacturer shall have previously demonstrated his ability to produce the required HDPE-GM by having successfully manufactured a minimum of 10,000,000 ft2 of HDPE-GM for hydraulic containment purposes.

7. Installer Qualifications:

a. Installation of the HDPE-GM shall be performed by an Installer that has installed a minimum of 5,000,000 ft2 of the material within the past five (5) years in similar landfill installations.

b. All Installation Supervisors assigned to the Project shall have previously managed the installation of at least 2,000,000 ft2 of HDPE-GM using the same techniques to be used on site.

c. All welding machine operators shall have shown proven performance on previous HDPE-GM installations. All welding machine operators shall perform a demonstration of their welding technique and provide test data demonstrating the acceptability of the test welds which they have performed prior to performing any welding on the project.

8. Warranties:

a. General: Should a defect occur, which is covered under warranty, the Warrantor shall bear all costs for repair and/or relocation and replacement of the HDPE-GM.

b. Workmanship: The Contractor shall furnish the Owner a warranty from the Installer of the HDPE-GM which warrants their workmanship to be free of defects on a prorata basis for five (5) years after the final acceptance of the Work. This warranty shall include but not be limited to all field-welded seams, anchor trenches, attachments to appurtenances, and penetration seals, as applicable.

c. Manufacturer's Warranty: The Contractor shall furnish the Owner a warranty from the HDPE-GM Manufacturer for the materials used. The material warranty shall be for defects or failures related to manufacture on a prorata basis for five (5) years after the date of shipment.

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of new, first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes. The HDPE-GM and HDPE-GM Manufacturer shall be approved by the Engineer prior to the Contract award.

The HDPE-GM shall be supplied in rolls which shall have a minimum width of 22 feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest seams. However, no factory seaming of HDPE-GM panels shall be accepted. Labels on the roll shall identify the thickness, length, width, lot and roll numbers, and name of Manufacturer.

2. HDPE-GM Materials:

a. Resin Properties: The resin shall be high-density polyethylene (HDPE) and shall be new, first-quality, compounded and manufactured specifically for producing HDPE-GM. The resin shall not consist of mixed resin types. Recycled material reworked from the manufacturing process shall not exceed 5% by weight.

b. HDPE-GM Sheet Properties: The HDPE-GM sheeting shall be manufactured to meet the following requirements:

(1) Provide finished product free from holes, pin holes, bubbles, blisters, excessive gels, undispersed resins and/or carbon black, contamination by foreign matter, and nicks or cuts on edges.

(2) Physical properties of the HDPE-GM shall be as shown in Table 1 of this section.

3. Extrusion Resin/Typical Extrudate:

Extrusion resin/typical extrudate used for extrusion welding of HDPE-GM shall be high density polyethylene (HDPE). Physical properties shall be the same as the HDPE-GM sheet. The extrudate's additives shall be thoroughly dispersed throughout the rod or bead. The extrudate shall be free of contamination by moisture or foreign matter and shall be recommended for use with the associated sheet material.

4. Texturing:

Textured HDPE-GM, where required, shall be fabricated using co extrusion or impingement methods and not by lamination or embossing methods. Texturing applied to HDPE-GM using impingement methods shall be bonded securely to the parent HDPE-GM. All texturing shall be uniform in appearance and coverage on the finished sheet. Physical properties of textured HDPE-GM shall be as shown in Table 1 of this section.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

   Prior to HDPE-GM installation the Contractor shall submit the following:

   a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit one copy of a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the HDPE-GM attesting that the HDPE-GM meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample (6" x 8") of the HDPE-GM to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

   b. Qualifications:

      (1) Submit list of equipment and personnel proposed for the Project. Include equipment type and quantities. Include personnel experience on similar projects.

      (2) Submit resume and references of Installation Supervisor to be assigned to the Project, including data and duration of employment and pertinent experience information.

      (3) Submit resumes and references of installation welders who will perform seaming operations, including dates and durations of employment and pertinent experience information.

   c. Shipping. Handling. and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

   d. Delivery Date: Submit notification of the scheduled delivery dates for the materials.

   e. Installation Drawings. Procedures. and Schedules:

      (1) Submit installation (shop) drawings, procedures, and a schedule for carrying out the work. Shop drawings shall have HDPE-GM sheet layout with proposed size, number, position, and sequence of placing of all panels, and indicating the location of all field seams. Shop drawings shall also show complete details and/or methods for anchoring the HDPE-GM, making field seams, and making seals around pipes and structures penetrating the HDPE-GM. Following review, these drawings will be used for installation of the HDPE-GM. Prior to deviations from these drawings during construction, revised drawings must be submitted to and reviewed by the Engineer and CQA Engineer.

      (2) Installation procedures to be addressed shall include but not be limited to material unloading, storage, installation, repair, and protection to be provided in the event of rain or strong winds.

f. Quality Control Certificates: For HDPE-GM delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of HDPE-GM. Each certificate shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 2 of this section.

g. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of the HDPE-GM installation, the Contractor shall submit the following:

a. Certificate stating that the HDPE-GM has been installed in accordance with the Drawings, Specifications, and the Manufacturer's recommendations.

b. Completed Manufacturer's and workmanship warranties.

c. Record Information: Record information shall include but not be limited to: drawings showing the true panel dimensions; location and coordinates of all seams; panels with roll numbers; repairs; patches; destructive test locations; and pipe penetrations and other appurtenances. This information shall be accompanied by electronic data files of both plots and point listings which show X, Y, and Z and description for each point.

Finalization of payment for HDPE-GM installation shall not be made until the above submittals have been reviewed by the CQA Engineer.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

The HDPE-GM shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

HDPE-GM that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of HDPE-GM supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. Subgrade Preparation:

a. The surface of the subgrade shall be smooth, uniform, free from sudden changes in grade (such as vehicular ruts), rocks or stones greater than 1/2 inch in size, debris, and deleterious materials. During actual placing and seaming of the HDPE-GM, the subgrade shall be kept free of all standing water. If the subgrade below the HDPE-GM becomes excessively wet and unstable as determined by the CQA Engineer, it shall be dried and recompacted, and replaced if needed.

b. Before an individual panel of HDPE-GM is installed; the Contractor and Installer shall verify in writing and submit to the CQA Engineer:

(1) Lines and grades are in conformance with the Contract Drawings and Specifications.

(2) The surface area to be lined has been rolled and compacted, free of irregularities and abrupt changes in grade.

c. The Contractor shall not proceed with HDPE-GM installation until a complete report on all subgrade CQA testing has been submitted and approved by the CQA Engineer. If the Contractor proceeds with HDPEGM installation prior to completion of this testing, the Contractor will do so at his own risk. If any tests fail, the Contractor will be required to remove HDPE-GM and reconstruct the underlying components to specification requirements. All costs associated with such actions (including the costs of additional testing) will be paid for entirely by the Contractor.

4. HDPE-GM Placement:

a. Weather Conditions:

HDPE-GM placement shall not proceed at an ambient temperature below 40°F or above 100°F unless otherwise authorized, in writing, by the Engineer. HDPE-GM placement shall not be performed during precipitation, excessive moisture, in an area of ponded water, or in excessive winds. Any portion of HDPE-GM or subgrade damaged due to weather conditions shall be repaired at the Contractor's cost.

b. Method of Placement:

(1) Each panel of the HDPE-GM shall be installed in accordance with the approved shop drawings prepared by the Contractor. The layout shall be designed to keep field seaming of the HDPE-GM to a minimum, shall avoid seams parallel to and under leachate collection piping, and shall be consistent with proper methods of HDPE-GM installation.

(2) Panels shall be oriented perpendicular to the line of the slope crest (i.e. down and not across slope).

(3) The HDPE-GM shall be placed smooth and free of excessive wrinkles.

(4) HDPE-GM rolls shall be placed using proper spreader and rolling bars with cloth slings. If a sheet must be displaced a distance greater than its width, a slip sheet shall be used.

(5) The CQA Engineer shall inspect each panel, after placement and prior to seaming, for damage and/or defects. Defective or damaged panels shall be replaced or repaired, as approved by the CQA Engineer and as described in this section.

(6) The Installer shall avoid dragging the HDPE-GM on rough soil subgrades.

(7) All HDPE-GM shall be anchored as shown on the Contract Drawings and consistent with Manufacturer's recommendations.

(8) Personnel working on the HDPE-GM shall not smoke, wear damaging shoes, or involve themselves in any activity that may damage the HDPE-GM, in the opinion of the CQA Engineer.

(9) The HDPE-GM shall be properly weighted to avoid uplift due to wind.

(10) Vehicular traffic across the HDPE-GM shall not be allowed, except that four-wheel (or greater) all-terrain vehicles (ATVs) with low ground pressure may be allowed if approved in advance by the Engineer. The Contractor shall submit proposed equipment and procedures for use of ATVs to the CQA Engineer as part of his submittals. If ATVs are allowed by the Engineer, each ATV will be operated such that no sudden stops, starts, or turns are made.

(11) All damage shall be recorded and located on the record drawings.

(12) When tying into existing HDPE-GM, excavation of previously installed geosynthetics shall be performed in a manner that minimizes damage to the existing geosynthetics and as approved by the Engineer. All damage to the existing geosynthetics shall be repaired by the Geosynthetics Installer at the Contractor's sole expense.

(13) The HDPE-GM shall be kept free of debris, unnecessary tools, and materials. In general, the HDPE-GM area shall remain neat in appearance.

c. <u>Pipe Penetrations</u>:

All pipe penetrations through the HDPE-GM shall be as shown in the Contract Drawings. Alternative penetration details may be approved by the Engineer and CQA Engineer.

5. <u>Field Seams</u>:

a. Individual panels of HDPE-GM shall be laid out and overlapped by a minimum of 4 inches prior to welding. The area to be welded shall be cleaned and prepared in accordance with the Manufacturer's recommendations.

b. Single or double track hot wedge fusion welds shall be used for straight seams.

c. Extrusion welds shall be used for cross seam tees, patches, repairs, and penetration boots. To limit overgrinding, the amount of grinding exposed after an extrusion seam is completed should be less than 1/4 inch.

d. The welding equipment used shall be capable of continuously monitoring and controlling the temperatures in the zone of contact where the machine is actually fusing the HDPE-GM so as to ensure that changes in environmental conditions will not affect the integrity of the weld.

e. All seams shall have a seam number that corresponds with the panel layout numbers. The numbering system shall be used in the development of the record drawings. Seam numbers shall be derived from the combination of the two panel numbers that are to be welded together.

f. All fusion welded "T" seams (i.e., the result of panels placed perpendicular to each other) shall be double welded where possible. The extrusion process shall be used for the second weld.

g. All extrudate shall be free of dirt, dry, and protected from damage.

h. If an extrusion welder is stopped for longer than one minute, it shall be purged to remove heat-degraded extrudate. All purged extrudate shall be placed on a sacrificial sheet and disposed of.

i. Where horizontal seams are required on sloped surfaces, the panels shall be placed such that the "upstream" panel forms the upper panel and overlaps the "downstream" panel in order to minimize infiltration potential. All seams constructed on sloped surfaces ~ 6H: 1 V shall be vertical seams, except where slope lengths exceed standard roll lengths and elsewhere as approved in advance by the Engineer.

j. All vertical panels placed on side slope surfaces shall extend a minimum of 5 feet inward from the toe of slope or edge of trench.

k. All end seams shall be staggered a minimum of 5 feet in length between contiguous panels.

l. To prevent moisture buildup during fusion welding, it may be necessary to place a movable protective layer of plastic directly below each overlap of HDPE-GM that is to be seamed.

m. If required, a firm substrate shall be provided by using a flat board or similar hard surface directly under the seam overlap to achieve proper support.

n. All seams shall extend to the full extent of the anchor trench.

o. All seams (including repairs) shall meet seam strength requirements specified in Table 3 of this section.

p. No overlying material (i.e., leachate collection layer) shall be placed over the HDPE-GM until approved by the CQA Engineer.

6. Anchor Trench:

a. The anchor trench shall be constructed as shown on the Contract Drawings and as specified herein. The anchor trench shall be maintained by the Contractor.

b. Slightly rounded corners shall be provided in the trench to avoid sharp bends in the HDPE-GM.

c. The anchor trench shall be adequately drained to prevent water ponding and softening to adjacent soils. The anchor trench shall be backfilled with embankment material and compacted to 90% standard Proctor dry density (ASTM D 698).

d. If the anchor trench is located in a clay susceptible to desiccation, the amount of trench open at any time shall be limited to one day of HDPE-GM installation capacity.

7. Repair Procedures:

a. Any portion of the HDPE-GM exhibiting signs of defect or failing a nondestructive or a destructive test shall be repaired by the Geomembrane Installer. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be made by the CQA Engineer. The procedures available include:

(1) Patching - Apply a new piece of HDPE-GM sheet over, and at least 6 inches beyond the limits of a defect. The patch shall be extrusion seamed to the underlying HDPE-GM. This method should be used to repair holes, tears, destructive test locations, undispersed raw materials, contamination by foreign matter, dents, pinholes, and pressure test holes.

(2) Capping - Apply a new strip of HDPE-GM along the length of a delineated faulty seam. The cap strip shall extend at least 6-inches beyond the limit of the seam and the edges will be extrusion seamed to the underlying HDPE-GM. This method should be used to repair lengths of extrusion or fusion seams.

(3) Replacement - The faulty seam is removed and replaced.

b. In addition, the following provisions shall be satisfied:

(1) Surfaces of the HDPE-GM which are to be repaired will be abraded no more than one hour prior to the repair;

(2) All surfaces must be clean and dry at the time of the repair;

(3) All seaming equipment used in repairing procedures must be approved;

(4) The repair procedures, materials, and techniques will be approved in advance of the specific repair by the CQA Engineer; and

(5) Patches or caps will extend at least 6-inches beyond the edge of the defect, and all patch corners will be rounded.

8. Cover Placement:

Placement of materials over HDPE-GM shall be performed in a manner as to ensure that HDPE-GM and the underlying geosynthetics are not damaged; minimal slippage of HDPE-GM on the underlying geosynthetics occurs; no excess tensile stresses occur in the HDPE-GM; and that no portion of the HDPE-GM develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or HDPE-GM that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

TABLE 1: REQUIRED HDPE-GM PROPERTIES

<table>
<tr><th rowspan="2">PROPERTY</th><th rowspan="2">TEST METHOD</th><th rowspan="2">UNITS</th><th colspan="2">VALUE</th></tr>
<tr><th colspan="2">TEXTURED[1]
HDPE-GM</th></tr>
<tr><td>Thickness[2]</td><td>ASTM D 5994</td><td>mils</td><td colspan="2">40/60</td></tr>
<tr><td>Asperity Height (typ.)</td><td>GRI GM12</td><td>mils</td><td colspan="2">18/20
(See Note 3)</td></tr>
<tr><td>Density</td><td>ASTM D 1505/D 792</td><td>g/cm^3</td><td colspan="2">≥0.940</td></tr>
<tr><td>Carbon Black Content[4]</td><td>ASTM D 1603</td><td>%</td><td colspan="2">2.0-3.0</td></tr>
<tr><td>Carbon Black Dispersion</td><td>ASTM D 5596</td><td>category</td><td colspan="2">See Note 5</td></tr>
<tr><td>Tensile Properties:</td><td rowspan="5">ASTM D 638 Type IV
(See Note 6)</td><td colspan="3"></td></tr>
<tr><td>Tensile Strength at Yield</td><td>lb/inch</td><td colspan="2">≥90/≥126</td></tr>
<tr><td>Tensile Strength at Break</td><td>lb/inch</td><td colspan="2">≥75/≥90</td></tr>
<tr><td>Elongation at Yield</td><td>%</td><td colspan="2">≥12</td></tr>
<tr><td>Elongation at Break</td><td>%</td><td colspan="2">≥100</td></tr>
<tr><td>Tear Resistance</td><td>ASTM D 1004</td><td>lbs.</td><td colspan="2">≥32/≥42</td></tr>
<tr><td>Stress Crack Resistance</td><td>ASTM D 5397 (App.)</td><td>hrs.</td><td colspan="2">≥200</td></tr>
<tr><td rowspan="4">Interface Shear Strength (Peak) 7</td><td rowspan="4">ASTM D 5321</td><td rowspan="4">psf</td><td colspan="2">125 psf (Load = 200 psf)</td></tr>
<tr><td>1,000 psf</td><td>(2,500 psf)</td></tr>
<tr><td>2,000 psf</td><td>(5,000 psf)</td></tr>
<tr><td>4,000 psf</td><td>(10,000 psf)</td></tr>
</table>

Notes:

1. Textured HDPE-GM is textured on both sides.
2. For smooth HDPE-GM, the lowest individual thickness of 10 values = -10%.
   For textured HDPE-GM, the lowest individual thickness for 8 out of 10 values = -10%; the lowest individual thickness of any of the 10 values = -15%.
3. Or as otherwise required to satisfy interface shear strength criteria.
4. Other methods such as D 4218 (muffle furnace) or microwave methods are acceptable if an appropriate correlation to D 1603 (tube furnace) can be established.
5. Carbon black dispersion for 10 different views: - 9 in Categories 1 or 2 and 1 in Category 3.
6. Yield elongation calculated with a gauge length of 1.3 inches. Break elongation calculated with a gauge length of 2.0 inches.
7. Textured HDPE-GM shall have adequate adhesion against adjacent materials under low normal loads to achieve the successful installation of overlying components without slippage.

TABLE 2: REQUIRED MANUFACTURER'S QUALITY CONTROL TEST DATA

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Thickness	ASTM D 5199/D 5994	Every Roll
Asperity Height (Textured Only)	GRI GM12	Every Other Roll
Density	ASTM D 1505/D 792	200,0001b
Carbon Black Content	ASTM D 1603	20,0001b
Carbon Black Dispersion	ASTM D 5596	45,0001b
Tensile Properties	ASTM D 638 Type IV	20,0001b
T ear Resistance	ASTM D 1004	45,0001b
Stress Crack Resistance	ASTM D 5397 (App.)	1 Per Resin Lot (Smooth Sample)
Interface Shear Strength	ASTM D 5321	(See Note 1)

Notes:

1. Test each interface to be used on this project using representative samples of materials to be supplied under normal loads indicated and using test parameters as specified by the Engineer. For this project, interfaces to be tested are:

   Base Liner:
   A. Textured HDPE-GM (40 mil) against subgrade soils;
   B. Geonet Composite against Textured HDPE-GM (40 mil);
   C. Geosynthetic Clay Layer against Geonet Composite;
   D. Textured HDPE-GM (60 mil) against Geosynthetic Clay Layer;
   E. Protective Cover against Textured HDPE-GM (60 mil).

   If there are material differences in the surface of any of the geosynthetic materials from one side to the other, then all possible combinations of interfaces shall be tested. This testing shall be performed at Contractor cost by an independent GAI accredited laboratory and submitted to the Engineer for review prior to shipping.

   Upon review of test results, the Engineer may allow exceptions to the above criteria.

   For tests involving textured geomembranes, the laboratory shall also report the asperity height (GRI GMI2) for the material samples used in the actual direct shear tests.

TABLE 3: REQUIRED SEAM STRENGTH PROPERTIES

PROPERTY	TEST METHOD	MINIMUM VALUE
Bonded Shear Strength	ASTM D 6392	40 mil - 81 lb/inch and FTB1 60 mil – 121 lb/inch and FTB1
Seam Peel Adhesion	ASTM D 6392	40 mil 65 lb/inch and FTB! (Fusion Welds) 52 lb/inch and FTB! (Extrusion Welds) 60 mil 98 lb/inch and FTB! (Fusion Welds) 78 lb/inch and FTB! (Extrusion Welds)

Notes:

1. FTB = Film - Tear-Bond = Tearing in the membrane itself before ply separation of the seam.

END OF SECTION

SECTION 02777
GEOSYNTHETIC CLAY LINER

Geosynthetic Clay Layer (GCL): The GCL serves as a hydraulic barrier consisting of clay bonded to layer of geosynthetics.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of GCL including all necessary and incidental items as detailed or required to complete the installation in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Geotextiles	02240
Protective Cover	02256
Drainage Aggregate	02710
Geonet Composite	02712
HDPE Geomembrane	02775
CQA Manual	Attached

3. Reference Standards:

   The latest revision of the following standards of the American Society of Testing and Materials (ASTM) and the Geosynthetic Research Institute (GRI) are hereby made a part of these Specifications.

ASTM D 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
ASTM D 4643	Determination of Water (Moisture) Content of Soil by the Microwave Oven Method.
ASTM D 5084	Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.
ASTM D 5261	Stardard Test Method for Measuring Mass per Unit Area of Geotextiles.
ASTM D 5321	Determining the Coefficient of Soil and Geosynthetic or Geosynthetic and Geosynthetic Friction by the Direct Shear Method.
ASTM D 5887	Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter.
ASTM D 5888	Standard Guide for Storage and Handling of Geosynthetic Clay Liners.
ASTM D 5889	Standard Practice for Quality Control of Geosynthetic Clay Liners.

ASTM D 5890	Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners.
ASTM D 5891	Standard Test Mehod for Fluid Loss of Clay Component of Geosynthetic Clay Liners.
ASTM D 5993	Standard Test Method for Measuring Mass Per Unit of Geosynthetic Clay Liners.
ASTM D 6102	Standard Guide for Installation of Geosynthetic Clay Liners.
ASTM D 6243	Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method.
ASTM D 6496	Standard Test Method for Determining Average Bonding Peel Strength between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners.
ASTM D 6768	Standard Test Method for Tensile Strength of Geosynthetic Clay Liners.
ASTM E 96	Standard Test Methods for Water Vapor Transmission of Materials.

4. Quality Assurance:

Quality Assurance during installation of GCL will be provided by the Owner as described in the accompanying Project CQA Manual.

5. Manufacturers Qualifications:

The Manufacturer shall have previously demonstrated his ability to produce the required GCL by having successfully manufactured a minimum of 10,000,000 ft^2 of needlepunched GCL products.

6. Installer Qualifications:

a. Installation of the GCL shall be performed by an Installer that has installed a minimum of 5,000,000 ft^2 of the material within the past five (5) years in similar landfill installations.

b. All Installation Supervisors assigned to the Project shall have previously managed the installation of at least 2,000,000 ft^2 of GCL using the same techniques to be used on site.

c. The GCL lining Contractor shall demonstrate a minimum of 1,000,000 square feet of successfully completed multi-component composite liner installation experience or shall provide sufficient evidence of the appropriate level of installation experience and competence with other geosynthetics.

7. Warranties:

a. General: Should a defect occur, which is covered under warranty, the Warrantor shall bear all costs for repair and/or relocation and replacement of the GCL.

b. <u>Workmanship</u>: The Contractor shall furnish the Owner a warranty from the Installer of the GCL which warrants their workmanship to be free of defects on a prorate basis for five (5) years after the final acceptance of the Work. This warranty shall include but not be limited to all field-welded seams, anchor trenches, attachments to appurtenances, and penetration seals, as applicable.

c. <u>Manufacturer's Warranty</u>: The Contractor shall furnish the Owner a warranty from the GCL Manufacturer for the materials used. The material warranty shall be for defects or failures related to manufacture on a prorate basis for five (5) years after the date of shipment.

B. <u>MATERIALS</u>

1. The GCL product supplied to the project shall be in full accordance with the requirements of this section. The GCL shall be manufactured by mechanically bonding the Geotextiles using a needlepunching process to enhance frictional and internal shear strength characteristics. No glue, adhesives or other non-mechanical bonding process shall be used in lieu of the needlepunch process. Their use to enhance the physical properties of the GCL is permitted.

2. The GCL and its components shall have the properties shown in Table 1.

3. The GCL shall have 10,000 hours test data for large-scale constant-load (creep) shear testing for related products under hydrated conditions. The displacement shall be 0.13 in. (3.3 mm) or less at a constant shear load of 250 psf (12 kPa) and a normal load of 500 psf (24 kPa).

4. The GCL shall have seam test data from an independent laboratory showing that the seam flow with a grooved cut in one of the nonwoven geotextiles is less than 1 x 10-8 m3/m2/s at 2 psi hydraulic pressure.

5. The minimum acceptable dimensions of full-sized GCL panels shall be 150 feet (45.7 m) in length. Short rolls [(those manufactured to a length greater than 70 feet (21 m) but less than a full-length roll)] may be supplied at a rate no greater than 3 per truckload or 3 rolls every 36,000 square feet (3,500 square meters) of GCL, whichever is less.

6. A 6-inch (150 mm) overlap guideline shall be imprinted on both edges of the upper geotextile component of the GCL as a means for providing quality assurance of the overlap dimension. Lines shall be printed in easily visible, non-toxic ink.

7. All GCL rolls shall be packaged in moisture resistant plastic sleeves. The cardboard cores shall be sufficiently strong to resist collapse during transit and handling.

8. Prior to shipment, the manufacturer shall label each roll, both on the GCL roll and on the surface of the plastic protective sleeve. Labels shall be resistant to fading and moisture degradation to ensure legibility at the time of the installation. At a minimum the roll labels shall identify the following:

    a. Length and width of roll

    b. Total weight of roll

    c. Type of GCL material

    d. Production Lot number and Individual Roll number

9. The granular bentonite sealing clay used for overlap seaming, penetration sealing and repairs shall be made from the same material natural sodium bentonite as used in the GCL and shall be as recommended by the GCL manufacturer. Seaming of GCLs shall be conducted in accordance with the manufacturer’s guidelines for each particular GCL.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

   Prior to GCL installation the Contractor shall submit the following:

   a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit one copy of a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the GCL attesting that the GCL meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample (6" x 8") of the HDPE-GM to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

   b. Qualifications:

      (1) Submit list of equipment and personnel proposed for the Project. Include equipment type and quantities. Include personnel experience on similar projects.

      (2) Submit resume and references of Installation Supervisor to be assigned to the Project, including data and duration of employment and pertinent experience information.

   c. Shipping. Handling. and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

   d. Delivery Date: Submit notification of the scheduled delivery dates for the materials.

   e. Installation Drawings. Procedures and Schedules:

      (1) Submit installation (shop) drawings, procedures, and a schedule for carrying out the work. Shop drawings shall have GCL sheet layout with proposed size, number, position, and sequence of placing of all panels. Following review, these drawings will be used for installation of the GCL. Prior to deviations from these drawings during construction, revised drawings must be submitted to and reviewed by the Engineer and CQA Engineer.

      (2) Installation procedures to be addressed shall include but not be limited to material unloading, storage, installation, repair, and protection to be provided in the event of rain or strong winds.

   f. Quality Control Certificates: For GCL delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of GCL. Each certificate shall have the roll identification number(s), test methods, frequency, and test results. At a minimum, the test results and frequency of testing shall be as shown in Table 2 of this section.

g. Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

2. Post-Installation Requirements:

Upon completion of the GCL installation, the Contractor shall submit the following:

a. Certificate stating that the GCL has been installed in accordance with the Drawings, Specifications, and the Manufacturer's recommendations.

b. Completed Manufacturer's and workmanship warranties.

c. Record Information: Record information shall include but not be limited to: drawings showing the true panel dimensions; panels with roll numbers; repairs; patches; and other appurtenances. This information shall be accompanied by electronic data files of both plots and point listings which show X, Y, and Z and description for each point.

Finalization of payment for GCL installation shall not be made until the above submittals have been reviewed by the CQA Engineer.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

The GCL shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

GCL that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of GCL supplied as replacement for rejected material shall be performed by the CQA Engineer at Contractor's cost.

3. GCL Inspection Upon Delivery:

Each roll shall be visually inspected when unloaded to determine if any packaging or material has been damaged during transit. Repairs to damaged GCL shall be performed in accordance with this specification.

4. Geosynthetic Subgrade:

Prior to GCL deployment the geosynthetic surface as well as other underlying geosynthetics upon which the GCL material will be installed shall be inspected and approved by the CQA Engineer in accordance with the requirements of the project specification documents.

5. The GCL rolls should be delivered to the working area of the site in their original packaging. Immediately prior to deployment, the packaging should be carefully removed without damaging the GCL.

6. Equipment, which could damage the GCL, shall not be allowed to travel directly on it. If the installation equipment causes rutting of the subgrade, the subgrade must be restored to its originally accepted condition before placement continues.

7. Panel Deployment:

a. Deployment should proceed from the highest elevation to the lowest to facilitate drainage in the event of precipitation.

b. The GCL may be deployed on slopes by pulling the material from a suspended roll, or securing a roll end into an anchor trench and unrolling each panel as the handling equipment slowly moves backwards.

c. Deployment on flat areas shall be conducted in the same manner as that for the slopes, however, care should be taken to minimize “dragging” the GCL. Slip-sheet may be used to facilitate positioning of the liner while ensuring the GCL is not damaged from underlying sources.

d. Overlaps shall be a minimum of 6 inches and be free of wrinkles, folds or “fish-mouths”.

e. All GCL panels should lie flat on the underlying surface, with no wrinkles or fold, especially at the exposed edges of the panels.

f. The contractor shall only install as much GCL that can be covered at the end of the day. No GCL shall be left exposed overnight. The exposed edge of the GCL shall be covered by a temporary tarpaulin or other such water resistant sheeting until the next working day.

8. Anchoring:

As directed by the project drawings and specifications, the end of the GCL roll shall be placed in an anchor trench at the top of the slope or an equivalent runout design shall be utilized. When utilizing an anchor trench design, the front edge of the trench should be rounded so as to eliminate any sharp corners. Loose soil should be removed from the floor of the trench. The GCL should cover the entire trench floor but does not extend up the rear trench wall.

9. Seaming:

a. The GCL seams are constructed by overlapping their adjacent edges. Care should be taken to ensure that the overlap zone is not contaminated with loose soil or other debris.

b. The minimum dimension of the longitudinal overlap should be 6 inches (150 mm). If the GCL is manufactured with a grooved cut in the nonwoven Geotextile that allows bentonite to freely extrude into the longitudinal overlap then no bentonite-enhanced seam is required for this overlap. If the GCL does not have a grooved cut in one of the nonwoven Geotextiles in the longitudinal overlap, then bentonite-enhanced seams are required as described below.

c. End-of-roll overlapped seams should be constructed with a minimum overlap of 24 inches (600 mm). Seams at the ends of the panels should be constructed such that they are shingled in the direction of the grade to prevent the potential for runoff flow to enter the overlap zone. End-of-roll overlapped seams for all GCL seams require bentonite-enhanced seams as described below.

d. Bentonite-enhanced seams are constructed between the overlapping adjacent panels as follows. The underlying edges of the longitudinal overlap is exposed and then a continuous bead of granular sodium bentonite is applied along a zone defined by the edge of the underlying panel and the 6-inch (150 mm) line. The granular bentonite shall be applied at a minimum application rate of one quarter pound per lineal foot (0.4 kg/m). A similar bead of granular sodium bentonite is applied at the end-of-roll overlap.

10. Detail Work:

a. The GCL shall be sealed around penetrations and embedded structures embedded in accordance with the design drawings and the GCL Manufacturer.

b. Cutting the GCL should be performed using a sharp utility knife. Frequent blade changes are recommended to avoid damage to the Geotextile components of the GCL during the cutting process.

11. Repair Procedures:

a. Prior to cover material placement, damage to the GCL shall be identified and repaired by the installer. Damage is defined as any rips or tears in the Geotextiles, delamination of Geotextiles or a displaced panel.

b. Rip and Tear Repair (Flat Surfaces) – Rips or tears may be repaired by completely exposing the affected area, removing all foreign objects or soil, and by then placing a patch cut from unused GCL over the damage (damaged material may be left in place), with minimum overlap of 12 inches on all edges. Accessory bentonite should be placed between the patch edges and the repaired material at a rate of a quarter pound per lineal foot of edge spread in a continuous six inch fillet.

c. Rip and Tear Repair (Slopes) – Damaged GCL material on slopes shall be repaired by the same procedures above; however, the edges of the patch should also be adhered to the repaired liner with an adhesive to keep the patch in position during backfill or cover operations.

d. Displaced Panels – Displaced panels shall be adjusted to the correct position and orientation. The adjusted panel shall then be inspected for any Geotextile damage or bentonite loss. Damage shall be repaired by the above procedure.

e. Premature Hydration – If the GCL is prematurely hydrated greater than 30% moisture, installer shall notify the CQA Engineer for a site specific determination as to whether the material is acceptable or if alternative measures must be taken to ensure the quality of the design.

12. Cover Placement:

a. Precautions shall be taken to prevent damage to the GCL by restricting the use of heavy equipment over the liner system. Installation of the overlying geosynthetic component can be accomplished through the use of lightweight, rubber-tired equipment such as a 4-wheel all-terrain vehicle (ATV). This vehicle can be driven directly on the GCL, provided the ATV makes no sudden stops, starts, or turns.

b. If a textured Geomembrane is placed over the GCL, a slip sheet (such as 20-mil smooth HDPE) may first be placed over the GCL in order to allow the Geomembrane to slide into its proper position. Once the overlying Geomembrane is properly positioned, the slip-sheet shall be carefully removed paying close attention to avoiding any movement to the Geomembrane.

c. Cyclical wetting and drying of GCL covered only with Geomembrane can cause overlap separation. Geomembranes should be covered with a white Geotextile and/or operational layer without delay to minimize the intensity of wet-dry cycling. If there is the potential for unconfined cyclic wetting and drying over an extended period of time, the longitudinal seam overlaps should be increased based on the project engineer's recommendations.

d. To avoid seam separation, the GCL should not be put in excessive tension by the weight or expansion of textured Geomembrane on steep slopes. The CQA Engineer should be consulted about the potential for GCL tension to develop.

TABLE 1: REQUIRED GCL PROPERTIES

PROPERTY	TEST METHOD	TEST FREQUENCY	REQUIRED VALUES
Bentonite Swell Index[1]	ASTM D 5890	1 per 50 tonnes	24 mL/2g min.
Bentonite Fluid Loss[1]	ASTM D 5891	1 per 50 tonnes	18 mL max.
Bentonite Mass/Area[2]	ASTM D 5993	40,000 ft2 (4,000 m^2)	0.75 lb/ft^2 (3.6 kg/m^2) min
GCL Grab Strength[3]	ASTM D 6768	200,000 ft2 (20,000 m^2)	30 lbs/in (53 N/cm) MARV
GCL Peel Strength[3]	ASTM D 6496	40,000 ft2 (4,000 m^2)	2.5 lbs/in (4.4 N/cm) min
GCL Index Flux[4]	ASTM D 5887	Weekly	1 x 10^{-8} m^3/m^2/sec max
GCL Hydraulic Conductivity[4]	ASTM D 5887	Weekly	5 x 10^{-9} cm/sec max
GCL Hydrated Internal Shear Strength[5]	ASTM D 5321 ASTM D 6243	Periodic	500 psf (24 kPa) typ @ 200 psf

<u>Notes</u>:

1. Bentonite property tests performed at a bentonite processing facility before shipment to GCL production facilities.
2. Bentonite mass/area reported at 0 percent moisture content.
3. All tensile strength testing is performed in the machine direction using ASTM D 6768. All peel strength testing is performed using ASTM D 6496. Upon request, tensile and peel results can be reported per modified ASTM D 4632 using 4 inch grips.
4. Index flux and permeability testing with deaired distilled/deionized water at 80 psi (551 kPa) cell pressure, 77 psi (531 kPa) headwater pressure and 75 psi (517 kPa) tailwater pressue. Reported value is equivalent to 925 gal/acre/day. This flux value is equivalent to a permeability of 5 x 10^{-9} cm/sec for typical GCL thickness. Actual flux values vary with field condition pressures. The last 20 weekly values prior the end of the production date of the supplied GCL may be provided.

5. Peak values measured at 200 psf (10 kPa) normal stress for a specimen hydrated for 48 hours. Site-specific materials, GCL products, and test conditions must be used to verify internal and interface strength of the proposed design.

END OF SECTION

SECTION 02781
GEOSYNTHETIC RAIN COVER

Geosynthetic Rain Cover (GRC): The Geosynthetic Rain Cover is placed along the top of intermediate berms and is anchored in the Protective Cover.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to install GRC including all necessary and incidental items as detailed or required to complete the installation in accordance with the Contract Drawings and these Specifications.

2. Related Work:

Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Protective Cover	02256

3. Reference Standards:

The latest revision of the following standards of the American Society of Testing and Materials (ASTM) are hereby made a part of these Specifications.

ASTM D 4355 — Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).

4. Manufacturers Qualifications:

The Manufacturer shall have previously demonstrated his ability to produce the required GRC by having successfully manufactured a minimum of 5,000,000 ft^2 of GRC (or similar material).

B. MATERIALS

1. General:

The materials supplied under these Specifications shall consist of first-quality products designed and manufactured specifically for the purpose of this work, which shall have been satisfactorily demonstrated, by prior use, to be suitable and durable for such purposes.

The GRC shall be supplied in panels which shall be of maximum size to provide the largest manageable sheet for the fewest seams. Labels on the panels shall identify the thickness, length, width, lot and panel numbers, and name of Manufacturer.

2. GRC Materials:

a. GRC shall be manufactured to meet the following requirements:

(1) GRC shall be either a polyethylene, polypropylene, or polyvinyl chloride (PVC) based material. GRC shall be at least 20 mil thick for unreinforced material and at least 12 mil thick (measured across reinforcement) for reinforced geomembrane.

(2) Provide finished product free from holes, pin holes, bubbles, blisters, excessive gels, undispersed resins and/or carbon black, contamination by foreign matter, and nicks or cuts on edges.

(3) UV Resistance (500 hours) (ASTM D 4355) 2: 70%.

b. Approved GRC:

(1) Griffolyn TX-1200 as manufactured by Reef Industries, Inc. of Houston, Texas.

(2) Integra 12 BW as manufactured by Integra Plastics, Inc. of Madison, South Dakota.

(3) Cormier WP-1440 as manufactured by Cormier Textile Products, Inc. of Sanford, Maine.

(4) Any 20 mil unreinforced polyethylene, polypropylene, or PVC geomembrane approved by the Engineer.

(5) Approved equal material.

3. Seaming Materials:

Seams for reinforced GRC shall consist of a durable tape of a width as recommended by the Manufacturer. Seams for unreinforced GRC shall consist of hot-wedge or solvent-welded (PVC) seams or other method as approved by the Engineer. All seaming materials shall be approved by the Engineer prior to construction.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

Prior to GRC installation the Contractor shall submit the following:

a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit one copy of a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the GRC attesting that the GRC meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample (6" x 8") of the GRC to be used. The sample shall be labeled with the product name and be accompanied by the Manufacturer's specifications.

b. Shipping, Handling, and Storage Instructions: The Manufacturer's plan for shipping, handling, and storage shall be submitted for review.

c. Delivery Date: Submit notification of the scheduled delivery dates for the materials.

d. Installation Procedures and Schedules:

Submit installation procedures and a schedule for carrying out the work. Installation procedures to be addressed shall include but not be limited to material unloading, storage, installation, repair, and protection to be provided in the event of rain or strong winds.

Furnish copies of the delivery tickets or other approved receipts as evidence for materials received that will be incorporated into the construction.

D. CONSTRUCTION

1. Shipping, Handling, and Storage:

   The GRC shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Subgrade Preparation:

   a. The surface of the subgrade shall be smooth, uniform, free from sudden changes in grade (such as vehicular ruts), rocks or stones greater than 1/2 inch in maximum size (except for gravel columns), debris, and deleterious materials. During actual placing and seaming of the GRC, the subgrade shall be kept free of all standing water. If the subgrade below the GRC becomes excessively wet and unstable, as determined by the CQA Engineer it shall be dried and recompacted, and replaced if needed.

3. GRC Placement:

   a. Weather Conditions:

      GRC placement shall not proceed at an ambient temperature below 40°F or above 100°F unless otherwise authorized, in writing, by the Engineer. GRC placement shall not be performed during precipitation, excessive moisture, in an area of ponded water, or in excessive winds. Any portion of GRC or subgrade damaged due to weather conditions shall be repaired at the Contractor's cost.

   b. Method of Placement:

      (1) Each panel of the GRC shall be installed in accordance with the Manufacturer's recommendations.

      (2) The CQA Engineer shall inspect each panel, after placement and prior to seaming, for damage and/or defects. Defective or damaged panels shall be replaced or repaired, as approved by the CQA Engineer and as described in this section.

      (3) The Installer shall avoid dragging the GRC on rough soil subgrade.

      (4) Personnel working on the GRC shall not smoke, wear damaging shoes, or involve themselves in any activity that may damage the GRC, in the opinion of the CQA Engineer.

      (5) The GRC shall be properly weighted to avoid uplift due to wind.

      (6) Vehicular traffic across the GRC shall not be allowed.

      (7) The GRC shall be kept free of debris, unnecessary tools, and

      materials. In general, the GRC area shall remain neat in appearance.

4. Field Seams:

   a. Field seams shall be made according to the Manufacturer's recommendations.

   b. Individual panels of GRC shall be laid out and overlapped by a minimum of 4 inches prior to seaming. The area to be seamed shall be cleaned and prepared in accordance with the Manufacturer's recommendations.

5. <u>Repair Procedures</u>:

   a. Any portion of the GRC exhibiting signs of defect shall be repaired. Several procedures exist for the repair of these areas. The final decision as to the appropriate repair procedure shall be made by the CQA Engineer.

6. <u>Ballasting</u>:

   In addition to the anchoring the edges of the GRC within the Protective Cover (as shown on the Contract Drawings, the Contractor shall place sand bags (40 lb nominal) (or other ballast as approved by the Owner and Engineer) on top of the GRC on 15 foot centers along the entire length of the intermediate berm covered by the GRC.

END OF SECTION

SECTION 02930
REVEGETATION

Revegetation: Revegetation includes permanent Revegetation of all site areas disturbed by the Contractor whether inside the Contract Limits or not.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete Revegetation in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Embankment	02223
Erosion and Sedimentation Control	02270
Rolled Erosion Control Products	02275

3. Warranty:

   The Contractor shall be responsible for the satisfactory establishment and growth of a permanent stand of vegetation for a period of one year following the final seeding as judged by the Engineer. During this period, the Contractor shall be responsible for the maintenance items described in Section D.4 of this Specification.

B. MATERIALS

1. Limestone: Unless otherwise defined by specific soil tests, supply agricultural grade ground limestone conforming to the current "Rules, Regulations, and Standards of the Fertilizer Board of Control."

2. Fertilizer: Unless otherwise defined by specific soil tests, supply commercial fertilizer of 10-20-10 analysis, meeting applicable requirements of State and Federal law. Do not use cyanamic compounds of hydrated lime. Deliver fertilizer in original containers labeled with content analysis.

3. Grass Seed: Supply fresh, clean, new-crop seed as specified in Table 1 of this section. Do not use seed which is wet, moldy, or otherwise damaged. Deliver seed in standard sealed containers labeled with producer's name and seed analysis, and in accord with US Department of Agriculture Rules and Regulations under Federal Seed Act.

4. Mulch: Supply clean, seed-free, threshed straw of oats, wheat, barley, rye, beans, or other locally available mulch material.

   a. Do not use mulch containing a quantity of matured, noxious weed seeds or other species that will be detrimental to seeding, or provide a menace to surrounding land.

   b. Do not use mulch material which is fresh or excessively brittle, or which is decomposed and will smother or retard growth of grass.

5. Binder: Supply emulsified asphalt or synthetic binder.

6. Water: Supply potable, free of substances harmful to growth.

C. SUBMITTALS

The Contractor shall submit the following to the Engineer:

1. Results of soil tests performed and proposed modifications, if any, to the specified requirements.
2. Certificates for each grass seed mixture, stating botanical and common name, percentage by weight, and percentages of purity, germination, and weed seed. Certify that each container of seed delivered is fully labeled in accordance with Federal Seed Act and equals or exceeds specification requirements.
3. Copies of invoices for fertilizer, showing grade furnished and total quantity applied.

D. CONSTRUCTION

1. The Contractor shall establish a smooth, healthy, uniform, close stand of grass from the specified seed. Prior to Revegetation, the Contractor shall adequately test the soils to be revegetated to ensure the adequacy of the specified requirements. Any modifications to these requirements deemed necessary after the review of soil test results, shall be at the Contractor's sole expense. The Engineer will perform the observations to determine when successful Revegetation is achieved.
2. Soil Preparation:
   a. Limit preparation to areas which will be planted soon after preparation.
   b. Loosen surface to minimum depth of four (4) inches.
   c. Remove stones, sticks, roots, rubbish and other extraneous matter over three (3) inches in any dimension.
   d. Spread lime uniformly over designated areas at the rate specified in Table 1 of this section.
   e. After application of lime, prior to applying fertilizer, loosen areas to be seeded with double disc or other suitable device if soil has become hard or compacted. Correct any surface irregularities in order to prevent pocket or low areas which will allow water to stand.
   f. Distribute fertilizer uniformly over areas to be seeded at the rate specified in Table 1 of this section.
      (1) Use suitable distributor.
      (2) Incorporate fertilizer into soil to depth of at least two (2) inches.
      (3) Remove stones or other substances which will interfere with turf development or subsequent mowing.
   g. Grade seeded areas to smooth, even surface with loose, uniformly fine texture.
      (1) Roll and rake, remove ridges and fill depressions, as required to meet finish grades.
      (2) Fine grade just prior to planting.

3. Seeding:

a. Use approved mechanical power driven drills or seeders, mechanical hand seeders, or other approved equipment.

b. Distribute seed evenly over entire area at the rate specified in Table 1 of this section.

c. Stop work when work extends beyond most favorable planting season for species designated, or when satisfactory results cannot be obtained because of drought, high winds, excessive moisture, or other factors.

d. Resume work only when favorable condition develops, or as directed by the Engineer.

e. Lightly rake seed into soil followed by light rolling or cultipacking.

f. Immediately protect seeded areas against erosion by mulching or placing Rolled Erosion Control Products in accordance with Section 02275 of these Specifications, where applicable.

(1) Spread mulch in a continuous blanket at the rate specified in Table 1 of this section.

(2) Immediately following spreading mulch, secure with evenly distributed binder at the rate specified in Table 1 of this section.

4. Maintenance:

The Contractor shall be responsible for maintaining all seeded areas through the end of his warranty period. The Contractor shall provide, at his expense, protection of all seeded areas against damage at all times until acceptance of the work. Maintenance shall include, but not be limited to, the following items:

a. Regrade and revegetate all eroded areas until adequately stabilized by grass.

b. Remulch with new mulch in areas where mulch has been disturbed by wind or maintenance operations sufficiently to nullify its purpose. Anchor as required to prevent displacement.

c. Replant bare areas using same materials specified.

TABLE 1: SEEDING SCHEDULE

MATERIAL	SEED TYPE	MINIMUM SEED PURITY (%)	APPLICATION RATE1
Lime	-----	-----	4,000 lbs/acre
Fertilizer	-----	-----	1,000 lbs/acre
Seed	Kentucky 31 Tall Fescue	97	100 lbs/acre
	Red Top	94	2 lbs/acre
	Common Bermudagrass2	97	15 lbs/acre
	Sericea Lespedeza2	98	20 lbs/acre
	Seasonal Nurse Crop3	97	20 lbs/acre
Mulch	-----	-----	1,500 lbs/acre
Binder	-----	-----	150 gallons/acre

Notes:

1. Application rates and/or chemical analysis shall be confirmed or established by a soil test.
2. From May through October, use hulled seed.
3. Use seasonal nurse crop in accordance with seeding dates as stated below:
   February 1 - April 30
   May 1 - August 31
   September 1 - November 15
   November 16 - January 31

END OF SECTION

SECTION 03310
CONCRETE WORK

Concrete Work: Concrete will be used as ballast at leachate risers and pipe cleanouts, and for thrust blocking, valve footings, etc.

A. DESCRIPTION

1. General:

   The Contractor shall furnish all labor, material, and equipment to complete installation of all concrete including all necessary and incidental items, in accordance with the Contract Drawings and these Specifications.

2. Related Work:

   Related Contract Work is described in the following sections of the Specifications:

WORK	SECTION
Erosion and Sedimentation Control	02270
Precast Concrete Structures	02608
HDPE Pipe	02614

3. Reference Standards:

   The latest revision of the following standards of the American Concrete Institute (ACI) and the American Society for Testing and Materials (ASTM) are hereby made a part of these specifications:

ACI 301	Specifications for Structural Concrete for Buildings.
ASTM C 31	Standard Method of Making and Curing Concrete Test Specimens in the Field.
ASTM C 39	Standard Method of Test for Compressive Strength of Cylindrical Concrete Specimens
ASTM C 42	Standard Test Method for Obtaining and Testing Drilled Cores and Sawed Beams of Concrete.
ASTM C 94	Standard Specification for Ready Mixed Concrete.
ASTM C 143	Standard Method of Test for Slump of Portland Cement Concrete.
ASTM C 150	Standard Specification for Portland Cement.
ASTM C 172	Standard Method of Sampling Fresh Concrete.
ASTM C 309	Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete.

B. MATERIALS

1. Portland Cement:

   Cement shall be Portland cement Type II conforming to ASTM C 150, unless otherwise acceptable to the Engineer. Cement shall be proportioned in the mix for the specified class of concrete in conformity with the applicable provisions of ACI 301.

2. Water: Potable.

3. Class B Concrete:

Nonstructural concrete (Class B) may be used for fill concrete, thrust blocks, etc. Class B concrete shall conform to the following requirements:

Compressive Strength (28 day):	3,000 psi
Minimum Cement Content:	545 lbs/cy
Maximum Slump:	4 inches

4. Reinforcing Materials:

a. Reinforcing Bars:

ASTM A 615, Grade 60, deformed.

b. Welded Wire Fabric:

ASTM A 185, welded steel wire fabric.

c. Supports for Reinforcement:

Provide supports for reinforcement including bolsters, chairs, spacers, and other devices for spacing, supporting, and fastening reinforcing bars and welded wire fabric in place. Use wire bar type supports complying with CRSI specifications, unless otherwise acceptable.

(1) For slabs-on-grade, use supports with sand plates or horizontal runners where base material will not support chair legs.

(2) For exposed-to-view concrete surfaces, where legs of supports are in contact with forms, provide supports with legs which are plastic protected (CRSI, Class 1) or stainless steel protected (CRSI, Class 2).

C. SUBMITTALS

1. The Contractor shall submit concrete mix designs to the Engineer for approval at least 15 days prior to the first concrete placement.

2. Shop Drawings:

Submit shop drawings for fabrication, bending, and placement of concrete reinforcement. Comply with ACI 315 showing bar schedules, stirrup spacing, diagrams of bent bars, and arrangement of concrete reinforcement. Include special reinforcement required and openings through concrete structures.

D. CONSTRUCTION

1. Concrete shall be placed per the procedures specified in ACI 301.

2. Placing Reinforcement:

Comply with Concrete Reinforcing Steel Institute's recommended practice for "Placing Reinforcing Bars", for details and methods of reinforcement placement and supports, and as herein specified.

a. Clean reinforcement of loose rust and mill scale, earth, ice, and other materials which reduce or destroy bond with concrete.

b. Accurately position, support, and secure reinforcement against displacement by formwork, construction, or concrete placement operations. Locate and support reinforcing by metal chairs, runners, bolsters, spacers, and hangers, as required.

c. Place reinforcement to obtain at least minimum coverages for concrete protection. Arrange, space, and securely tie bars and bar supports to hold reinforcement in position during concrete placement operations. Set wire ties so ends are directed into concrete, not toward exposed concrete surfaces.

d. Install welded wire fabric in as long lengths as practicable. Lap adjoining pieces at least one full mesh and lace splices with wire. Offset end laps in adjacent widths to prevent continuous laps in either direction.

3. Inserted and Embedded Items:

Pipes, anchor bolts, steps, and other inserts, as indicated on the Contract Drawings or as required, shall be encased in concrete.

4. Concrete thrust blocks and valve footings shall be poured in-place and shall satisfy the minimum bearing surface requirements as shown on the Contract Drawings.

5. Structures shall be formed, chamfered, and finished in a workman-like manner.

6. Curing:

Curing shall be with curing compound conforming to ASTM C309, Type 2, Class A in two uniform thoroughly covering coats applied at right angles to each other.

END OF SECTION

Construction Quality Assurance Manual
International Paper Industrial Landfill
Cell 2 – Liner System
Riegelwood, North Carolina

Prepared for:

International Paper

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July 2010

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INTERNATIONAL PAPER INDUSTRIAL LANDFILL
CELL 2
RIEGELWOOD, NORTH CAROLINA

CONSTRUCTION QUALITY ASSURANCE MANUAL

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SECTION 1.0
GENERAL

1.1 INTRODUCTION

This Construction Quality Assurance (CQA) Manual has been prepared to provide the Owner, (Design) Engineer, and CQA Engineer the means to govern the construction quality and to satisfy landfill certification requirements under current solid waste management regulations.

More specifically, this CQA Manual addresses the soils and geosynthetics components of the liner system and the leachate collection & recovery (LCR) system. The liner system, as referenced herein, consists of a soil subgrade and a HDPE geomembrane liner. The LCR system consists of a layer of geonet drainage media with collection piping/stone.

The CQA Manual is divided into the following sections:

- Section 1.0 General
- Section 2.0 CQA Documentation
- Section 3.0 Earthwork CQA
- Section 4.0 Geomembrane CQA
- Section 5.0 Leachate Collection & Recovery System CQA
- Section 6.0 Geonet Composite CQA
- Section 7.0 Geotextile CQA
- Section 8.0 Geosynthetic Clay Liner CQA

1.2 DEFINITIONS RELATING TO CONSTRUCTION QUALITY

1.2.1 Construction Quality Assurance (CQA)

In the context of this Manual, Construction Quality Assurance is defined as a planned and systematic program employed by the Owner to assure conformity of the liner and LCR systems installation with the project drawings and the project specifications. CQA is provided by the CQA Engineer as a representative of the Owner and is independent from the Contractor and all manufacturers. The CQA program is designed to provide adequate confidence that items or services meet contractual and regulatory requirements and will perform satisfactorily in service.

1.2.2 Construction Quality Control (CQC)

Construction Quality Control refers to actions taken by manufacturers, fabricators, installers, and/or the Contractor to ensure that the materials and the workmanship meet the requirements of the project drawings and the project specifications. The manufacturer's specifications and quality control (QC) requirements are included in this CQA Manual by reference only. A complete updated version of each geosynthetic component manufacturer's QC Plan shall be incorporated as part of the Contractor's CQC Plan.

1.2.3 CQA Certification Document

At the completion of construction, a certification document will be prepared by the CQA Engineer and submitted to North Carolina Department of Environment and Natural Resources, Division of Waste Management. The certification report will include all QC testing performed by the Geosynthetics Manufacturers, all CQ testing performed by the Geosynthetic Installers, and all CQ testing performed by the CQA Engineer.

1.2.4 Discrepancies Between Documents

The Contractor is instructed to bring discrepancies to the attention of the CQA Engineer who shall then notify the Engineer for resolution. The Engineer has the sole authority to determine resolution of discrepancies existing within the Contract Documents (this may also require the approval of State Solid Waste Regulators). Unless otherwise determined by the Engineer, the more stringent requirement shall be the controlling resolution.

1.3 PARTIES TO CONSTRUCTION QUALITY ASSURANCE

1.3.1 Description of the Parties

The parties to Construction Quality Assurance and Quality Control include the Owner, Engineer, Contractor, Geosynthetics Manufacturer, Geosynthetics Installer, CQA Engineer, Geosynthetics CQA Laboratory, and Soils CQA Laboratory.

1.3.1.1 Owner

The Owner is International Paper, who owns and/or is responsible for the facility.

1.3.1.2 Engineer

The Engineer is responsible for the engineering design, drawings, and project specifications for the liner and LCR systems. The Engineer is an official representative of the Owner. The Engineer serves as communications coordinator for the project, initiating the meetings outlined in Section 1.7. The Engineer shall also be responsible for proper resolution of all quality issues that arise during construction. The Engineer is URS Corporation.

1.3.1.3 Contractor

The Contractor is responsible for the construction of the subgrade, earthwork and roadways, for placement of the liner and LCR systems, and erosion & sediment control practices. The Contractor is responsible for the overall CQC on the project and coordination of submittals to the CQA Engineer. Additional responsibilities of the Contractor are defined by the project specifications.

1.3.1.4 Geosynthetics Manufacturer

The Geosynthetics Manufacturer(s) is (are) responsible for the production of the geosynthetic components used in landfill construction. The Manufacturer(s) is (are) responsible for Quality Control (QC) during manufacture of the geosynthetic components, certification of the properties of the geosynthetic components, and field installation criteria.

1.3.1.5 Geosynthetics Installer

The Geosynthetics Installer(s) is (are) routinely a subcontractor of the Contractor and is (are) responsible for field handling, storing, placing, seaming, protection of (against wind, etc.), and other aspects of the geosynthetics installations. The Installer may also be responsible for transportation of these materials to the site, and for the preparation and completion of anchor trenches.

1.3.1.6 CQA Engineer

The CQA Engineer is a representative of the Owner, is independent from the Contractor, and is responsible for observing, testing, and documenting activities related to the CQA of the earthworks at the site, and the installation of the soil and geosynthetic components of the liner and LCR systems. The CQA Engineer may make field observations and review submittals for the Engineer and is responsible for notifying the Owner and Engineer of all quality issues that arise during construction. The CQA Engineer is also responsible for issuing a facility certification report, sealed by a Professional Engineer registered in The State of North Carolina.

1.3.1.7 Geosynthetics CQA Laboratory

The Geosynthetics CQA Laboratory is a party, independent from the Owner, that is responsible for conducting tests on conformance samples of geosynthetics used in the liner and LCR systems. The Geosynthetics CQA Laboratory service cannot be provided by any party involved with the manufacture, fabrication, or installation of any of the geosynthetic components. The services of the Geosynthetics CQA Laboratory are coordinated by the CQA Engineer and are paid for by the Owner.

1.3.1.8 Soils CQA Laboratory

The Soils CQA Laboratory is a party, independent from the Owner, which is responsible for conducting geotechnical tests on conformance samples of soils and aggregates used in structural fills and the liner and LCR systems. The services of the Soils CQA Laboratory are coordinated by the CQA Engineer and are paid for by the Owner.

1.3.2 Qualifications of the Parties

The following qualifications are required of all parties involved with the manufacture, fabrication, installation, transportation, and CQA of all materials for the liner and LCR systems. Where applicable, these qualifications must be submitted by the Contractor to the Owner and Engineer for review and acceptance.

1.3.2.1 Contractor

Qualifications of the Contractor are specific to the construction contract and independent of this CQA Manual.

1.3.2.2 Geosynthetics Manufacturers

Each Geosynthetics Manufacturer must satisfy the qualifications presented in the project specifications.

1.3.2.3 Geosynthetic Installer(s)

The Geosynthetic Installer(s) will be trained and qualified to install the geosynthetics components of the liner and LCR systems. Each Geosynthetics Installer must meet the requirements of the project specifications and be accepted by the Engineer. The Geomembrane Installer must be approved by the Geomembrane Manufacturer.

1.3.2.4 CQA Engineer

The CQA Engineer will act as the Owner's Quality Assurance Representative. The CQA Engineer will perform CQA testing to satisfy the requirements of this CQA Manual and will prepare the CQA certification document. The CQA Engineer will have experience in the CQA aspects of the construction and testing of landfill liner and LCR systems, and be familiar with ASTM and other related industry standards. The activities of the CQA Engineer will be performed under the supervision of a Registered Professional Engineer.

1.3.2.5 Geosynthetics CQA Laboratory

The Geosynthetics CQA Laboratory will have experience in testing geosynthetics and be familiar with ASTM, GRI, and other applicable test standards. The Geosynthetics CQA Laboratory will be capable of providing test results within 24 hours or a reasonable time after receipt of samples depending on the test(s) to be conducted, as agreed to at the outset of the project by affected parties, and will maintain that standard throughout the installation.

1.3.2.6 Soils CQA Laboratory

The Soils CQA Laboratory will have experience in testing structural fills, soil liners, and aggregates, and be familiar with ASTM and other applicable test standards. The Soils CQA Laboratory will be capable of providing test results within 24 hours or a reasonable time after receipt of samples depending on the test(s) to be conducted, as agreed to at the outset of the project by affected parties, and will maintain that standard throughout the installation.

1.4 SCOPE OF CONSTRUCTION QUALITY ASSURANCE MANUAL

The scope of this CQA Manual includes the CQA of the soils and geosynthetic components of the liner and LCR systems for Cell 2 of the subject facility. The CQA for the selection, evaluation, and placement of the soils is included in the scope.

1.5 UNITS

In this CQA Manual, all properties and dimensions are expressed in U.S. units.

1.6 REFERENCES

The CQA Manual includes references to the most recent version of the test procedures of the American Society of Testing and Materials (ASTM) and/or the Geosynthetic Research Institute (GRI). Appendix A contains a list of these procedures.

1.7 CQA MEETINGS

To facilitate the specified degree of quality during installation, clear, open channels of communication are essential. To that end, meetings are critical.

1.7.1 Geosynthetics CQA Meeting

A CQA Meeting will be held at the site prior to placement of the geosynthetics. At a minimum, the meeting will be attended by the Engineer, the CQA Engineer, the Contractor, and the Geosynthetic Installation Superintendent(s).

The purpose of this meeting is to begin planning for coordination of tasks, anticipate any problems which might cause difficulties and delays in construction, and, above all, review the CQA Manual to all of the parties involved. It is very important that the rules regarding testing, repair, etc., be known and accepted by all.

This meeting should include all of the activities referenced in the project specifications.

The meeting will be documented by the Engineer and minutes will be transmitted to all parties.

1.7.2 CQA Progress Meetings

Progress meetings will be held between the Engineer, the CQA Engineer, the Contractor, the Geosynthetic Installation Superintendent(s), and representatives from any other involved parties at the frequency dictated in the project specifications. These meetings will discuss current progress, planned activities for the next week, and any new business or revisions to the work. The CQA Engineer will log any problems, decisions, or questions arising at this meeting in his daily report. Any matter requiring action which is raised in this meeting will be reported to the appropriate parties. These meetings will be documented by the Engineer and minutes will be transmitted to affected parties during the next progress meeting.

1.7.3 Problem or Work Deficiency Meetings

A special meeting will be held when and if a problem or deficiency is present or likely to occur. At a minimum, the meeting will be attended by the Engineer, the CQA Engineer, the Contractor, and representatives from any other involved parties. The purpose of the meeting is to define and resolve the problem or work deficiency as follows:

- define and discuss the problem or deficiency;
- review alternative solutions; and
- implement an action plan to resolve the problem or deficiency.

The meeting will be documented by the Engineer and minutes will be transmitted to affected parties during the next progress meeting.

1.8 CONTROL VERSUS RECORD TESTING

1.8.1 Control Testing

In the context of this CQA Manual, Control Tests are those tests performed on a material prior to its actual use in construction to demonstrate that it can meet the requirements of the project plans and specifications. Control Test data may be used by the Engineer as the basis for approving alternative material sources.

1.8.2 Record Testing

Record Tests are those tests performed during the actual placement of a material to demonstrate that its in-place properties meet or exceed the requirements of the project drawings and specifications.

SECTION 2.0
CQA DOCUMENTATION

2.1 DOCUMENTATION

An effective CQA Manual depends largely on recognition of construction activities that should be monitored and on assigning responsibilities for the monitoring of each activity. This is most effectively accomplished and verified by the documentation of quality assurance activities. The CQA Engineer will document that quality assurance requirements have been addressed and satisfied.

The CQA Engineer will provide the Owner and Engineer with his daily and weekly progress reports including signed descriptive remarks, data sheets, and logs to verify that required CQA activities have been carried out. These reports shall also identify potential quality assurance problems. The CQA Engineer will also maintain at the job site a complete file of project drawings, reports, project specifications, a CQA Manual, checklists, test procedures, daily logs, and other pertinent documents.

2.2 DAILY CQA REPORT

The CQA Engineer's reporting procedures will include preparation of a daily report which, at a minimum, will include the following information, where applicable:

- A unique identifying sheet number for cross referencing and document control;
- Date, project name, location, and other identification;
- Data on weather conditions;
- A reduced-scale Site Plan showing all proposed work areas and test locations;
- Descriptions and locations of ongoing construction;
- Descriptions and specific locations of areas, or units, of work being tested and/or observed and documented;
- Locations where tests and samples were taken;
- A summary of test results;
- Calibrations or recalibrations of test equipment, and actions taken as a result of recalibration;
- Off-site materials received, including quality verification documentation;
- Decisions made regarding acceptance of units of work, and/or corrective actions to be taken in instances of substandard quality;
- Summaries of pertinent discussions with the Contractor and/or Geosynthetic Installers; and
- The CQA Engineer's signature.

The daily report must be completed at the end of each CQA Engineer's shift, prior to leaving the site. This information will be submitted weekly to and reviewed by the Owner and Engineer.

2.3 CQA PROGRESS REPORTS

The CQA Engineer will prepare a summary progress report each week, or at time intervals established at the pre-construction meeting. At a minimum, this report will include the following information, where applicable:

- A unique identifying sheet number for cross-referencing and document control;

- The date, project name, location, and other information;
- A summary of work activities during the progress reporting period;
- A summary of construction situations, deficiencies, and/or defects occurring during the progress reporting period;
- Summary of all test results, failures and retests, and
- Signature of the CQA Engineer.

The CQA Engineer's progress reports must summarize the major events that occurred during that week. Critical problems that occur shall be communicated verbally to the Engineer immediately as well as being included in the weekly reports. The CQA Engineer's weekly report must be submitted to the Owner and Engineer no later than the Monday following the week reported.

2.4 CQA PHOTOGRAPHIC REPORTING

Photographs shall be taken by the CQA Engineer at regular intervals during the construction process and in all areas deemed critical by the CQA Engineer.

These photographs will serve as a pictorial record of work progress, problems, and mitigation activities. These records will be presented to the Engineer upon completion of the project.

In lieu of photographic documentation, videotaping may be used to record work progress, problems, and mitigation activities. The Engineer may require that a portion of the documentation be recorded by photographic means in conjunction with videotaping.

2.5 DEFICIENCIES

The Owner and Engineer will be made aware of any significant recurring non-conformance with the project specifications. The Engineer will then determine the cause of the non-conformance and recommend appropriate changes in procedures or specification. When this type of evaluation is made, the results will be documented, and any revision to procedures or project specifications will be accepted by the Owner and Engineer.

2.6 DESIGN AND/OR PROJECT TECHNICAL SPECIFICATION CHANGES

Design and/or project specification changes may be required during construction. In such cases, the CQA Engineer will notify the Engineer. The Engineer will then notify the appropriate agency, if necessary.

Design and/or project specification changes will be made only with the written agreement of the Engineer, and will take the form of an addendum to the project specifications. All design changes shall include a detail (if necessary) and state which detail it replaces in the plans.

2.7 FINAL CQA REPORT

At the completion of each major construction activity at the landfill unit, the CQA Engineer will certify all required forms, observation logs, field and laboratory testing data sheets including sample location plans, etc. The CQA Engineer will also provide a final report which will certify that the work has been performed in compliance with the plans and project technical specifications, and that the supporting documents provide the necessary information.

The CQA Engineer will also provide summaries of all the data listed above with the report. The Record Drawings will include scale drawings depicting the location of the construction and details pertaining to the extent of construction (e.g., depths, plan dimensions, elevations, soil component thicknesses, etc.). All surveying and base maps required for development of the Record Drawings will be done by the Contractor's Construction Surveyor. These documents will be certified by the Contractor and delivered to the CQA Engineer and included as part of the final CQA (Certification) report.

It may be necessary to prepare interim certifications, as allowed by the regulatory agency to expedite completion and review.

At a minimum, the items shown in Table 2.1 shall be included in the Final CQA Report.

2.8 STORAGE OF RECORDS

All handwritten data sheet originals, especially those containing signatures, will be stored by the CQA Engineer in a safe repository on site. Other reports may be stored by any standard method which will allow for easy access. All written documents will become property of the Owner.

TABLE 2.1: FINAL CQA REPORT GENERAL OUTLINE

1.0 Introduction
2.0 Project Description
3.0 CQA Program
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  3.2 Personnel
4.0 Earthwork CQA
5.0 Geomembrane CQA
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Appendices

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SECTION 3.0
EARTHWORK CQA

3.1 INTRODUCTION

This section of the CQA Manual addresses earthwork (excavation and embankment) and outlines the soils CQA program to be implemented with regard to material acceptance, subgrade acceptance, field control and record tests, and resolution of problems.

3.2 EMBANKMENT MATERIAL ACCEPTANCE

All material to be used as compacted embankment shall be accepted in advance by the CQA Engineer. Acceptance is based upon successful completion of CQA control testing outlined below. Such testing can be performed either during excavation and stockpiling or from existing stockpiles prior to use.

3.2.1 Control Tests

The procedure for CQA testing during excavation and stockpiling (including existing stockpiles) is outlined below.

Each load of soil will be examined either at the borrow source or the stockpile area. Any unsuitable material will be rejected or routed to separate stockpiles consistent with its end use. Appropriate entries shall be made in the daily log.

During stockpiling operations, control tests, as shown on Table 3.1, will be performed by the CQA Engineer prior to placement of any compacted embankment.

3.3 SUBGRADE ACCEPTANCE

The CQA Engineer shall verify that the compacted embankment subgrade is constructed in accordance with the project specifications.

3.4 EARTHWORK CONSTRUCTION

3.4.1 Construction Monitoring

A. Earthwork shall be performed as described in the project specifications.

B. Only soil previously accepted by the CQA Engineer (see Section 3.2) shall be used in construction of the compacted embankment. Unsuitable material will be removed prior to acceptance by the CQA Engineer.

C. All required field density and moisture content tests shall be completed before the overlying lift of soil is placed. The surface preparation (e.g. wetting, drying, scarification, etc.) shall be completed before the CQA Engineer will allow placement of subsequent lifts.

D. The CQA Engineer shall monitor protection of the earthwork during and after construction.

3.4.2 Control Tests

The control tests, as shown on Table 3.1, will be performed by the CQA Engineer prior to placement of compacted embankment.

3.4.3 Record Tests

The record tests, as shown on Table 3.2, will be performed by the CQA Engineer during placement of compacted embankment.

3.4.3.1 Record Test Failure

Recompaction of the failed area shall be performed and retested until the area meets or exceeds requirements outlined in the specifications.

3.4.4 Judgmental Testing

During construction, the frequency of control and/or record testing may be increased at the discretion of the CQA Engineer when visual observations of construction performance indicate a potential problem. Additional testing for suspected areas will be considered when:

- The rollers slip during rolling operation;
- The lift thickness is greater than specified;
- The fill material is at an improper moisture content;
- Fewer than the specified number of roller passes are made;
- Dirt-clogged rollers are used to compact the material;
- The rollers may not have used optimum ballast;
- The fill materials differ substantially from those specified; or
- The degree of compaction is doubtful.

3.5 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies shall be properly documented by the CQA Engineer. The Contractor will correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer shall observe all retests on repaired defects.

TABLE 3.1: CQA TESTING PROGRAM FOR EMBANKMENT MATERIAL ACCEPTANCE

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
CONTROL TESTS:		
Visual Classification	ASTM D 2488	Each Soil
Moisture-Density Relationship	ASTMD 698	5,000 CY per Each Soil

TABLE 3.2: CQA TESTING PROGRAM FOR COMPACTED EMBANKMENT

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
CONTROL TESTS: (See Table 3.1)		
RECORD TESTS:		
Lift Thickness	-----	Each Lift
In-Place Density	ASTM D 2922[1]	1 test per 20,000 ft^2 per lift & 1 per 500 LF/lift of Berms (< 200 ft. base width)
Moisture Content	ASTM D 3017[2]	1 test per 20,000 ft^2 per lift & 1 per 500 LF/lift of Berms (< 200 ft. base width)

Notes:

1. Optionally use ASTM D 1556, ASTM D 2167, or ASTM D 2937. For every 10 nuclear density tests perform at least 1 density test by ASTM D 1556, ASTM D 2167, or ASTM D 2937 as a verification of the accuracy of the nuclear testing device.
2. Optionally use ASTM D 2216, ASTM D 4643, or ASTM D 4959. For every 10 nuclear moisture tests perform at least 1 moisture test by ASTM D 2216, ASTM D 4643, or ASTM D 4959 as a verification of the accuracy of the nuclear testing device.

SECTION 4.0
GEOMEMBRANE CQA

4.1 INTRODUCTION

This section of the CQA Manual addresses the geomembrane components of the liner and final cover systems and outlines the CQA program to be implemented with regard to manufacturer and installer acceptance, material acceptance, subgrade acceptance, field and laboratory control and record tests, repairs, and resolution of problems.

4.2 GEOMEMBRANE MANUFACTURER AND INSTALLER ACCEPTANCE

The Contractor shall submit the qualifications of the Geomembrane Manufacturer and the Geomembrane Installer, as described in the specifications, to the CQA Engineer for acceptance.

4.3 GEOMEMBRANE MATERIAL ACCEPTANCE

4.3.1 Geomembrane Product Data

The CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

4.3.2 Shipment And Storage

During shipment and storage, all geomembrane will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

4.3.3 Quality Control Certificates

Upon delivery, the CQA Engineer will:

- Verify that the Manufacturer's quality control certificates have been provided at the specified frequency and that each certificate identified the rolls or sheets related to it; and
- Review the Manufacturer's quality control certificates and verify that the certified properties meet the project technical specifications.

4.3.4 Material Control Tests

Samples for material control tests, as shown on Table 4.1, will be obtained by the CQA Engineer at the indicated frequencies upon delivery of the geomembrane. Alternatively, samples may be randomly obtained at the manufacturing site by the CQA Engineer or representatives of the Geosynthetics CQA Laboratory.

Unless otherwise specified, samples will be 3 feet long by the roll or sheet width. The CQA Engineer will mark the machine direction on the samples taken from rolls delivered to the site with an arrow.

All material control tests will be performed by the Geosynthetics CQA Laboratory.

All control test results must be available at the site prior to the deployment of all geomembrane. The CQA Engineer will examine all results from laboratory conformance testing for conformance to the project specification and this CQA Manual.

4.3.4.1 Material Control Test Failure

The following procedure will apply whenever a sample fails a material control test:

A. The Geomembrane Installer will replace the roll or sheet of geomembrane that is in nonconformance with the project specifications with a roll or sheet that meets project specifications.

B. The Geomembrane Installer will remove samples for testing for conformance to the specifications and this CQA Manual by the Geosynthetics CQA Laboratory from the closest numerical roll or sheet on both sides of the failed roll or sheet. These two samples must both conform to project specifications. If either of these samples fail, then the next numerical roll or sheet will be tested until a passing roll or sheet is found. This additional conformance testing will be at the expense of the Geomembrane Installer. If either of the two closest rolls or sheets fail, the Engineer will dictate the frequency of additional testing.

The CQA Engineer will document actions taken in conjunction with material control test failures.

4.4 GEOMEMBRANE INSTALLATION

4.4.1 Handling

The Geosynthetic Installer will handle all geomembrane in such a manner as required by the project specifications.

4.4.2 Earthwork

4.4.2.1 Surface Preparation

The Geomembrane Installer will certify in writing that the surface on which the geomembrane will be installed meets line and grade, and the surface preparation requirements of the project specifications. The certificate of acceptance will be given to the CQA Engineer prior to commencement of geomembrane installation in the area under consideration. The CQA Engineer will give a copy of this certificate to the Engineer.

To ensure a timely covering of the underlying surface, the Engineer may allow subgrade acceptance in areas as small as one acre. After the supporting soil has been accepted by the Geomembrane Installer, it will be the Geomembrane Installer's responsibility to indicate to the Engineer and CQA Engineer any change in the supporting soil condition that may require repair work. If the CQA Engineer concurs with the Geomembrane Installer, then the Engineer will ensure that the supporting soil is repaired.

4.4.2.2 Anchorage System

The CQA Engineer will verify that anchor trenches have been constructed and backfilled according to project specifications and design drawings.

4.4.3 Geomembrane Placement

4.4.3.1 Field Panel Identification

The CQA Engineer will document that the Geomembrane Installer labels each field panel with an "identification code" (number or letter-number consistent with the layout plan) agreed upon by the Geomembrane Installer and CQA Engineer at the Geosynthetics CQA Meeting (see Section 1.7.1).

The Geomembrane Installer will establish a table or chart showing correspondence between roll or sheet numbers and field panel identification codes. This documentation shall be submitted to the CQA Engineer weekly for review and verification. The field panel identification code will be used for all quality control and quality assurance records.

4.4.3.2 Field Panel Placement

4.4.3.2.1 Location: The CQA Engineer will verify that field panels are installed at the location indicated in the Geomembrane Installer's layout plan, as accepted or modified in Section 4.4.3.1.

4.4.3.2.2 Installation Schedule: The CQA Engineer will evaluate every change in the schedule proposed by the Geomembrane Installer and advise the Engineer on the acceptability of that change.

The CQA Engineer will record the identification code, location, and date of installation of each field panel.

4.4.3.2.3 Placement of Geomembrane: The CQA Engineer will verify that project specification related restrictions on placement of geomembrane are fulfilled. Additionally, the CQA Engineer will verify that the supporting soil has not been damaged by weather conditions.

4.4.3.2.4 Damage: The CQA Engineer will visually observe each panel, after placement and prior to seaming, for damage. The CQA Engineer will advise the Engineer which panels, or portion of panels, should be rejected, repaired, or accepted. Damaged panels or portions of damaged panels which have been rejected will be marked and their removal from the work area recorded by the CQA Engineer. Repairs will be made according to procedures described in this section.

As a minimum, the CQA Engineer will document that:

- The panel is placed in such a manner that it is unlikely to be damaged; and
- Any tears, punctures, holes, thin spots, etc. are either marked by the Geomembrane Installer for repair or the panel is rejected.

4.4.4 Field Seaming

4.4.4.1 Seam Layout

The Geomembrane Installer will provide the CQA Engineer with a seam layout drawing, i.e., a drawing of the area to be lined showing all expected seams. The CQA Engineer and Engineer will review the seam layout drawing and verify that it is consistent with the current industry standard of practice and this CQA Manual. In addition, no panels not specifically shown on the seam layout drawing may be used without the Engineer's prior acceptance.

A seam numbering system compatible with the panel numbering system will be agreed upon at the Geosynthetics CQA Meeting (see Section 1.7.1). An on-going written record of the seams and repair areas shall be maintained by the Geomembrane Installer with weekly review by the CQA Engineer.

4.4.4.2 Requirements of Personnel

The Geomembrane Installer will provide the CQA Engineer with a list of proposed seaming personnel and their experience records. This document will be reviewed by the CQA Engineer for compliance with project specifications.

4.4.4.3 Seaming Equipment and Products

Field seaming processes must comply with project specifications. Proposed alternate processes will be documented and submitted to the Engineer and CQA Engineer for their acceptance. Only seaming apparatus which have been specifically accepted by make and model will be used. The CQA Engineer will submit all documentation to the Engineer for his concurrence.

4.4.5 Field Seam Control Tests

4.4.5.1 Trial Seams

A. Prior to production seaming, after four (4) hours of continuous seaming, when significant changes in geomembrane or ambient temperature occurs, and any occurrence of full loss of power to the welding machine(s) the Geomembrane Installer shall make trial seams to verify that seaming conditions and procedures are adequate. Trial seams shall be performed by each operator of extrusion welders and by the primary operator of each wedge welder using seaming equipment to be used in production seaming.

B. Trial seams shall be performed for each welder to be used and by each operator of extrusion welders, and by the primary operator of each fusion welder. A passing trial seam shall be made prior to the beginning of each seaming period. Typically, this is at the start of the day and after lunch break.

C. Fusion welded trial seams shall be approximately 72" x 12" with the seam centered lengthwise. For extrusion welding, the trial seams shall be approximately 36" x 12" with the seam centered lengthwise. A minimum of four coupons will be tested in peel and shear (two each) (ASTM D 6392) by the Geomembrane Installer using a field tensiometer. The Geomembrane installer shall submit the the CQA Engineer the field tensiometer calibration certificate as evidence the tensiometer has been certified as calibrated less than twelve (12) months prior to the date of the beginning pf installation activities at this project. All coupons shall meet the minimum seam strength requirements as shown in the project specifications.

D. Each trial seam shall be assigned a number and the test results recorded in the appropriate log by the Geomembrane Installer. The CQA Engineer shall observe all trial seam welding and field testing, and shall compile all trial seam data.

4.4.6 Field Seam Record Tests

4.4.6.1 Nondestructive Seam Continuity Testing

The Geomembrane Installer shall test and document all seam welds continuously over their full length using one of the following nondestructive seam tests. This testing shall be performed simultaneously with geomembrane seaming as the work progresses and not at the completion of all field seaming.

A. Vacuum Testing for single track fusion and extrusion welded seams shall conform to ASTM D 5641 requirements.

B. Air Pressure Testing (for dual track fusion welded seam with an enclosed space) shall conform to ASTM D 5820 requirements and the requirements listed in Table 4.2.

The CQA Engineer shall observe the nondestructive testing on a full time basis to ensure conformance with this CQA Manual and the project specifications.

4.4.6.2 Field Destructive Seam Testing

A. The Geomembrane Installer will obtain 12" x 30" (or longer as needed) samples of field seams with the seam centered lengthwise, suitable for testing, at a maximum average frequency of one sample per 500 linear feet of weld. The sample shall be cut into two equal-length pieces, one to be given to the Geomembrane Installer for field destructive seam testing and one given to the CQA Engineer as an archive sample. The date, time, equipment, seam number, and seaming parameters will be marked on each sample and recorded by the CQA Engineer.

B. A minimum of five coupons each will be tested in peel and shear (ASTM D 6392) by the Geomembrane Installer using a field tensiometer. Four of five coupons shall meet the minimum seam strength requirements as shown in the project specifications.

C. The CQA Engineer or the Owner may require additional random samples to be taken for testing in areas which visually appear defective, where conditions differ from trial seam conditions, or areas that appear to differ from the project requirements.

D. All holes in the geomembrane resulting from destructive seam sampling shall be immediately repaired in accordance with repair procedures described in this manual.

4.4.6.3 Geosynthetics CQA Laboratory Destructive Testing

A. At the same location as the field destructive test location described in paragraph 4.4.6.2 the Geomembrane Installer will obtain 12" x 30" (or longer as needed) samples of field seams with the seam centered lengthwise, suitable for testing, at a maximum average frequency of one sample per day to confirm field destructive seam tests. The sample shall be cut into two equal-length pieces, both to be given to the CQA Engineer for laboratory destructive seam testing and as an archive sample. The date, time, equipment, seam number, and seaming parameters will be marked on each sample and recorded by the CQA Engineer.

B. Laboratory destructive test samples will be packaged and shipped to the Geosynthetics CQA Laboratory by the CQA Engineer in a manner that will not damage the test sample.

C. A minimum of five coupons each will be tested in peel and two coupons in shear (ASTM D 6392) and results shall be reported by the Geosynthetics CQA Laboratory. Passing results shall be determined as required by ASTM D6392 (i.e. four of five coupons shall meet the minimum seam strength required by the project specifications).

D. All geomembrane destructive test samples that fail to meet project specifications shall be saved and sent to the CQA Engineer for observation.

E. The CQA Engineer will review laboratory test results as soon as they become available.

4.4.6.4 Field Seam Record Test Failure

For noncomplying tests, the CQA Engineer will:

- Observe continuity testing of the repaired areas performed by the Geomembrane Installer;
- Confirm and record the location, date, test unit number, name of tester, and compile the record of testing provided by the Geomembrane Installer;
- Provide a walk-through inspection of all impacted seam areas and verify that the areas have been tested in accordance with the CQA Manual and project specifications; and
- Verify that the Geomembrane Installer has marked repair areas with the appropriate color-coded marking pencil.

4.4.6.5 Defining Extent of Field Seam Record Test Failure

All defective seam test failures must be bounded by acceptable destructive tests. Defective seams between the bounding acceptable tests must be repaired or replaced as determined by the CQA Engineer. The CQA Engineer will document repair actions taken in conjunction with all seam test failures.

4.4.7 Repairs & Verification

4.4.7.1 Repair Procedures

A. All repair procedures shall be in accordance with the project specifications. The CQA Engineer will observe all repair procedures.

B. All surfaces shall be clean and dry at the time of the repair.

C. After an extrusion weld is made, no more than 1/4 inch of abrasion shall be visible beyond the weld.

4.4.7.2 Repair Verification

A. Each repair shall be numbered and logged by the Geomembrane Installer.

B. Each repair shall be non-destructively tested by the Geomembrane Installer using the methods described above. Repairs which pass non-destructive testing shall be taken as an indication of an adequate repair.

C. Repairs more than 150 feet long may be of sufficient length to require destructive test sampling, at the discretion of the CQA Engineer. A failed test indicates that the repair shall be redone and retested until passing test results are achieved.

4.5 LINER SYSTEM ACCEPTANCE

The Geomembrane Installer and the Geosynthetic Manufacturers will retain all ownership and responsibility for the geosynthetics in the landfill unit until acceptance by the Owner.

The geomembrane component of the liner system will be accepted by the Owner when:

- The installation is finished;
- Verification of the adequacy of all seams and repairs, including associated testing, is complete;
- CQA Engineer provides the Engineer with a final copy of the nondestructive/destructive test documentation, seam and repair information, and as-built drawings, as submitted by the Geomembrane Installer.
- CQA Engineer furnishes the Engineer with a certification, submitted by the Geomembrane Installer that the geomembrane was installed in accordance with the Geomembrane Manufacturer's recommendations as well as the project drawings and project specifications;
- All documentation of the installation is completed including the CQA Engineer's final report; and

- Certification by the CQA Engineer, including Record Drawing(s), sealed by a Professional Engineer registered in the state in which the project is located, has been received by the Engineer.

The CQA Engineer will certify that the installation has proceeded in accordance with this CQA Manual and the project specifications for the project except as noted to the Engineer.

4.6 MATERIALS IN CONTACT WITH GEOMEMBRANES

The quality assurance procedures indicated in this subsection are only intended to assure that the installation of these materials does not damage the geomembrane. All reasonable measures to protect the geomembrane and provide additional quality assurance procedures are necessary to assure that systems built with these materials will be constructed to ensure proper performance.

4.6.1 Soils

Prior to placement, the CQA Engineer will visually confirm that all soil materials to be placed against the geomembrane comply with project specifications. The Geomembrane Installer will provide the CQA Engineer a written surface acceptance certificate in accordance with Section 4.4.2. All soil materials shall be placed and compacted in accordance with project specifications.

4.6.2 Sumps and Appurtenances

The CQA Engineer will verify that:

- installation of the geomembrane in appurtenance areas, and connection of the geomembrane to appurtenances have been made according to the project specifications;
- extreme care is taken while seaming around appurtenances since neither nondestructive nor destructive testing may be feasible in these areas; and
- the geomembrane or appurtenances have not been visibly damaged while making connections to appurtenances.

4.7 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies shall be properly documented by the CQA Engineer. The Contractor will correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer shall observe all retests on repaired defects.

TABLE 4.1: CQA TESTING PROGRAM FOR GEOMEMBRANE MATERIAL ACCEPTANCE

PROPERTY	TEST METHOD	TEST FREQUENCY
Thickness	ASTM D 5199/D 5994	200,000 ft^2 or 1 per Lot[1]
Density	ASTM D 1505/D 792	200,000 ft^2 or 1 per Lot[1]
Carbon Black Content	ASTM D 1603	200,000 ft^2 or 1 per Lot[1]
Carbon Black Dispersion	ASTM D 5596	200,000 ft^2 or 1 per Lot[1]
Tensile Properties:	ASTM D 638 (Type IV)	
Tensile Strength at Yield		200,000 ft^2 or 1 per Lot[1]
Tensile Strength at Break		200,000 ft^2 or 1 per Lot[1]
Elongation at Yield		200,000 ft^2 or 1 per Lot[1]
Elongation at Break		200,000 ft^2 or 1 per Lot[1]
Tear Resistance	ASTM D 1004	200,000 ft^2 or 1 per Lot[1]

Note:

1. Whichever provides the larger number of tests.

TABLE 4.2: AIR PRESSURE TEST REQUIREMENTS

MATERIAL	MIN. PRESSURE (PSI)	MAX. PRESSURE DROP (PSI) AFTER 5 MINUTES
40 Mil HDPE	30	3
60 Mil HDPE	30	3

SECTION 5.0
LEACHATE COLLECTION & RECOVERY (LCR) SYSTEM CQA

5.1 INTRODUCTION

This section of the CQA Manual addresses the leachate collection and discharge piping, sumps, valves, drainage aggregate, and the protective cover layer of the LCR system. By reference to Sections 6.0 and 7.0 of this CQA Manual, this section also addresses the geonet drainage media and geotextiles that are included in the LCR system. This section outlines the CQA program to be implemented with regard to material acceptance, construction monitoring, and resolution of problems.

5.2 LCR MATERIAL ACCEPTANCE

The CQA Engineer shall verify that the following are provided and installed in accordance with the project drawings, specifications, and this CQA Manual.

5.2.1 <u>High Density Polyethylene (HDPE) Pipe</u>

A. Receipt of Contractor's submittals on HDPE pipe.

B. Review of submittals for HDPE pipe for conformity to the project specifications.

C. Conduit lines external to the collection system are to be pressure tested as required by the project specifications and demonstrated to be leak-free.

5.2.2 <u>Sumps</u>

A. Receipt of Contractor's submittals on sumps.

B. Review of submittals for sumps for conformity to the project specifications.

5.2.3 <u>Valves</u>

A. Receipt of Contractor's submittals on valves.

B. Review of submittals for valves for conformity to the project specifications.

5.2.4 <u>Drainage Aggregate</u>

A. Receipt of Contractor's submittals on drainage aggregate.

B. Review of submittals for drainage aggregate for conformity to the project specifications.

C. Verify that drainage aggregate in stockpiles or at borrow sources conforms to the project specifications.

D. Conduct material control tests in accordance with Table 5.1.

5.2.5 <u>Geonet Composite</u>

The CQA program for geonet composite is presented in Section 6.0 of this CQA Manual.

5.2.6 Geotextiles (Verify for each type of Geotextile)

The CQA program for geotextiles is presented in Section 7.0 of this CQA Manual.

5.2.7 Protective Cover

A. Review the proposed source of protective cover for conformance with the project specifications.

B. Conduct material control tests in accordance with Table 5.1.

5.3 LCR SYSTEM INSTALLATION

The CQA Engineer will allow installation of the collection layer of the LCR system to proceed only after he has provided certification of the installed HDPE geomembrane.

The CQA Engineer will monitor and document the construction of all LCR components for compliance with the project specifications. Monitoring the construction work for the components of the LCR system includes the following:

- Monitoring the minimum vertical buffer maintained between field equipment and the geomembrane;
- Monitoring that the placement of the LCR components does not fold or damage the geomembrane or other underlying layers.

After the leachate collection lines have been installed the Contractor shall flush, clean and perform remote camera inspection of the system. The camera inspection must be videoed and submitted to North Carolina Department of Environmental Resources (NCDENR), Division of Waste Management. All leachate collection lines shall be cleaned at least once a year thereafter. After IP has successfully demonstrated three consecutive annual cleanings a request will be sent to NCDENR to increase the frequency between cleanings. Remote camera inspections of the leachate collection lines shall occur upon completion of construction and at least once every five years thereafter, and following the clearing of blockages.

5.4 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies shall be properly documented by the CQA Engineer. The Contractor will correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer shall observe all retests on repaired defects.

TABLE 5.1: CQA TESTING PROGRAM FOR LEACHATE COLLECTION SYSTEM AGGREGATES

COMPONENT	PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
CONTROL TESTS:			
Drainage Aggregate (Each Type):	Gradation	ASTM C 136	5,000 CY

	Carbonate Content	ASTM D 3042	1 per source
	Permeability (No. 78 Stone Only)	ASTM D 2434	10,000 CY
Protective Cover:	Visual Classification	ASTM D 2488	Each Load

SECTION 6.0
GEONET GEOCOMPOSITE CQA

6.1 INTRODUCTION

This section of the CQA Manual addresses geonet composite (GC) and outlines the CQA program to be implemented with regard to material acceptance, material control tests, repairs, and resolution of problems.

6.2 GC MATERIAL ACCEPTANCE

6.2.1 GC Product Data

The CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

6.2.2 Shipment And Storage

During shipment and storage, all GC will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

6.2.3 Quality Control Certificates

Upon delivery, the CQA Engineer will:

- Verify that the Manufacturer's quality control certificates have been provided at the specified frequency and that each certificate identified the rolls related to it; and
- Review the Manufacturer's quality control certificates and verify that the certified properties meet the project technical specifications.

6.2.4 GC Material Control Tests

Samples for material control tests, as shown on Table 6.1, will be obtained by the CQA Engineer at the indicated frequency upon delivery of the GC. Alternatively, samples may be randomly obtained at the manufacturing site by the CQA Engineer or representatives of the Geosynthetics CQA Laboratory.

Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Engineer will mark the machine direction on the samples taken from rolls delivered to the site with an arrow.

All material control tests will be performed by the Geosynthetics CQA Laboratory.

All test results must be available at the site prior to the deployment of all GC. The CQA Engineer will examine all results from laboratory testing for conformance to the project specifications and this CQA Manual.

6.2.4.1 Material Control Test Failure

The following procedure will apply whenever a sample fails a material control test:

A. The Geosynthetic Installer will replace the roll of GC that is in nonconformance with the project specifications with a roll that meets project specifications.

B. The Geosynthetic Installer will remove samples for testing for conformance to the specifications and this CQA Manual by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the failed roll. These two samples must both conform to project specifications. If either of these samples fail, then the next numerical roll will be tested until a passing roll is found. This additional testing will be at the expense of the Geosynthetic Installer. If either of the two closest rolls fail, the Engineer will dictate the frequency of additional testing.

The CQA Engineer will document actions taken in conjunction with material control test failures.

6.3 GC INSTALLATION

6.3.1 Handling And Placement

The Geosynthetic Installer will handle and place all GC in such a manner as required by the project specifications.

6.3.2 Stacking And Joining

When several layers of GC are stacked, care should be taken to ensure that stacked GC are placed in the same direction. Stacked GC will never be laid in perpendicular directions to the underlying GC (unless otherwise specified by the Engineer). The CQA Engineer will observe the stacking of GC.

Adjacent rolls of GC will be joined according to construction drawings and project specifications.

6.3.3 Repairs

Any holes or tears in the GC will be repaired in accordance with the project specifications. The CQA Engineer will observe any repair.

6.3.4 Placement Of Overlying Materials

All soil materials located on top of GC shall be placed in accordance with the project specifications.

6.4 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies shall be properly documented by the CQA Engineer. The Contractor will correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer shall observe all retests on repaired defects.

TABLE 6.1: CQA TESTING PROGRAM FOR GC MATERIAL ACCEPTANCE

PROPERTY	TEST METHOD	TEST FREQUENCY
CONTROL TESTS:		
Thickness (geonet only)	ASTMD 5199	200,000 ft^2 or 1 per Lot[1]
Density (geonet only)	ASTM D 1505	200,000 ft2 or 1 per Lot[1]
Ply Adhesion	ASTM D 413/ GRI GC7	200,000 ft: ^{2} or 1 per Lot[1]
Transmissivity	ASTMD 4716[2]	1 per Resin Lot

Notes:

1. Whichever provides the larger number of tests.
2. Conduct tests for transmissivity in accordance with the conditions given in the project specifications.

SECTION 7.0
GEOTEXTILE CQA

7.1 INTRODUCTION

This section of the CQA Manual addresses geotextiles and outlines the CQA program to be implemented with regard to material acceptance, material control tests, repairs, and resolution of problems.

7.2 GEOTEXTILE MATERIAL ACCEPTANCE

7.2.1 Geotextile Product Data

F or each type of geotextile to be used, the CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

7.2.2 Shipment And Storage

During shipment and storage, all geotextiles will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

7.2.3 Quality Control Certificates

Upon delivery, the CQA Engineer will:

- Verify that the Manufacturer's quality control certificates have been provided at the specified frequency and that each certificate identified the rolls related to it; and
- Review the Manufacturer's quality control certificates and verify that the certified properties meet the project technical specifications.

7.2.4 Geotextile Material Control Tests

Samples for material control tests, as shown on Table 7.1, will be obtained by the CQA Engineer at the indicated frequencies upon delivery of the geotextiles. Alternatively, samples may be randomly obtained at the manufacturing site by the CQA Engineer or representatives of the Geosynthetics CQA Laboratory.

Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Engineer will mark the machine direction on the samples taken from rolls delivered to the site with an arrow.

All material control tests will be performed by the Geosynthetics CQA Laboratory.

All test results must be available at the site prior to the deployment of all geotextiles. The CQA Engineer will examine all results from laboratory testing for conformance to the project specifications and this CQA Manual.

7.2.4.1 Material Control Test Failure

The following procedure will apply whenever a sample fails a material control test:

A. The Geosynthetic Installer will replace the roll of geotextile that is in nonconformance with the project specifications with a roll that meets project specifications.

B. The Geosynthetic Installer will remove samples for testing by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the failed roll. These samples must both conform to project specifications and this CQA Manual. If either of these samples fail, then the next numerical roll will be tested until a passing roll is found. This additional testing will be at the expense of the Geosynthetic Installer. If either of the two closest rolls fail, the Engineer will dictate the frequency of additional testing.

The CQA Engineer will document actions taken in conjunction with material control test failures.

7.3 GEOTEXTILE INSTALLATION

7.3.1 Handling And Placement

The Geosynthetic Installer will handle and place all geotextiles in such a manner as required by the project specifications.

7.3.2 Seams And Overlaps

All geotextiles will be seamed or overlapped in accordance with project specifications or as accepted by the CQA Engineer and Engineer.

7.3.3 Repairs

Any holes or tears in the geotextile will be repaired in accordance with the project specifications. The CQA Engineer will observe any repair.

7.3.4 Placement Of Overlying Materials

All soil materials located on top of a geotextile shall be placed in accordance with the project specifications.

7.4 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies shall be properly documented by the CQA Engineer. The Contractor will correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer shall observe all retests on repaired defects.

TABLE 7.1: CQA TESTING PROGRAM FOR GEOTEXTILE MATERIAL ACCEPTANCE

PROPERTY	TEST METHOD	TEST FREQUENCY
CONTROL TESTS:		
Grab Tensile Strength	ASTM D 4632	200,000 ft^2 or 1 per Lot[1]
Puncture Resistance	ASTM D 4833	200,000 ft^2 or 1 per Lot[1]
Trapezoidal Tear Strength	ASTM D 4533	200,000 ft^2 or 1 per Lot[1]

Notes:

1. Whichever provides the larger number of tests.
2. CQA testing is not required for geotextiles placed outside of the containment area.

SECTION 8.0
GEOSYNTHETIC CLAY LINER (GCL) CQA

8.1 INTRODUCTION

This section of the CQA Manual addresses geosynthetic clay liner (GCL) and outlines the CQA program to be implemented with regard to material acceptance, material control tests, repairs, and resolution of problems.

8.2 GCL MANUFACTURER AND INSTALLATION ACCEPTANCE

The Contractor shall submit the qualifications of the GCL Manufacturer and the GCL Installer, as described in the specifications, to the CQA Engineer for acceptance.

8.3 GCL MATERIAL ACCEPTANCE

8.3.1 GCL Product Data

The CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

8.3.2 Shipment And Storage

During shipment and storage, all GCL will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

8.3.3 Quality Control Certificates

Upon delivery, the CQA Engineer will:

- Verify that the Manufacturer's quality control certificates have been provided at the specified frequency and that each certificate identified the rolls related to it; and
- Review the Manufacturer's quality control certificates and verify that the certified properties meet the project technical specifications.

8.3.4 GCL Material Control Tests

Samples for material control tests, as shown on Table 8.1, will be obtained by the CQA Engineer at the indicated frequencies upon delivery of the GCL. Alternatively, samples may be randomly obtained at the manufacturing site by the CQA Engineer or representatives of the Geosynthetics CQA Laboratory.

Unless otherwise specified, samples will be 3 feet long by the roll width. The CQA Engineer will mark the machine direction on the samples taken from rolls delivered to the site with an arrow.

All material control tests will be performed by the Geosynthetics CQA Laboratory.

All test results must be available at the site prior to the deployment of all GCL. The CQA Engineer will examine all results from laboratory testing for conformance to the specifications and this CQA Manual.

8.3.4.1 Material Control Test Failure

The following procedure will apply whenever a sample fails a material control test:

A. The Geosynthetic Installer will replace the roll of GCL that is in nonconformance with the project specifications with a roll that meets project specifications.

B. The Geosynthetic Installer will remove samples for testing for conformance to the specifications and this CQA Manual by the Geosynthetics CQA Laboratory from the closest numerical roll on both sides of the failed roll. These two samples must both conform to project specifications. If either of these samples fail, then the next numerical roll will be tested until a passing roll is found. This additional testing will be at the expense of the Geosynthetic Installer. If either of the two closest rolls fail, the Engineer will dictate the frequency of additional testing.

The CQA Engineer will document actions taken in conjunction with material control test failures.

8.4 GCL INSTALLATION

8.4.1 Handling And Placement

The Geosynthetic Installer will handle and place all GCL in such a manner as required by the project specifications.

8.4.2 Seams and Overlaps

All GCL will be seamed or overlapped in accordance with project specifications. The CQA Engineer will observe any repair.

8.4.3 Repairs

Any holes or tears in the GCL will be repaired in accordance with the project specifications. The CQA Engineer will observe any repair.

8.4.4 Placement Of Overlying Materials

All geosynthetic liner system components located on top of GCL shall be placed in accordance with the project specifications.

8.5 DEFICIENCIES

The CQA Engineer will immediately determine the extent and nature of all defects and deficiencies and report them to the Owner and Engineer. All defects and deficiencies shall be properly documented by the CQA Engineer. The Contractor will correct defects and deficiencies to the satisfaction of the CQA Engineer. The CQA Engineer shall observe all retests on repaired defects.

TABLE 8.1: CQA TESTING PROGRAM FOR GCL MATERIAL ACCEPTANCE

PROPERTY	TEST METHOD	TEST FREQUENCY
CONTROL TESTS:		
Hydraulic Conductivity	ASTM D 5084/D 5887	200,000 ft^2 or 1 per Lot[1]
Bentonite Content	ASTM D 5993 (@ 0% moisture)	200,000 ft^2 or 1 per Lot[1]
Peel Strength	ASTM D 6496	200,000 ft^2 or 1 per Lot[1]

Notes:

1. Whichever provides the larger number of tests.

Appendix A

Reference List of Test Methods

APPENDIX A: REFERENCE LIST OF TEST METHODS

American Society American Society of Testing and Materials (ASTM):

ASTM C 136	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates.
ASTMD 413	Standard Test Methods for Rubber Property - Adhesion to Flexible Substrate.
ASTM D 422	Standard Test Method for Particle Size Analysis of Soils.
ASTM D 638	Standard Test Method for Tensile Properties of Plastics.
ASTM D 698	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft3).
ASTM D 792	Standard Test Method for Density and Specific Gravity (Relative Density) of Plastics by Displacement.
ASTM D 1004	Standard Test Method for Initial Tear Resistance of Plastic Film and Sheeting.
ASTMD 1505	Standard Test Method for Density of Plastics by the Density Gradient Technique.
ASTM D 1556	Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.
ASTM D 1603	Standard Test Method for Carbon Black in Olefin Plastics.
ASTMD 2167	Standard Test Method for Density and Unit Weight of Soil in Place by the Rubber Balloon Method.
ASTM D 2216	Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass.
ASTM D 2434	Standard Test Method for Permeability of Granular Soils (Constant Head).
ASTM D 2488	Standard Practice for Description and Identification of Soils (Visual-Manual Procedure).
ASTM D 2922	Standard Test Methods for Density of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).
ASTM D 2937	Standard Test Method for Density of Soil in Place by the Drive Cylinder Method.
ASTM D 3017	Standard Test Method for Water Content of Soil and Rock in Place by Nuclear Methods (Shallow Depth).
ASTM D 3042	Standard Test Method for Insoluble Residue in Carbonate Aggregates.
ASTMD 4318	Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
ASTM D 4533	Standard Test Method for Trapezoid Tearing Strength of Geotextiles.
ASTMD 4632	Standard Test Method for Grab Breaking Load and Elongation of Geotextiles.
ASTM D 4643	Standard Test Method for Determination of Water (Moisture) Content of Soil by the Microwave Oven Method.
ASTM D 4716	Standard Test Method for Constant Head Hydraulic Transmissivity (In-Plane Flow) of Geotextiles and Geotextile Related Products.

ASTMD 4833	Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products.
ASTM D 4959	Standard Test Method for Determination of Water (Moisture) Content of Soil by Direct Heating Method.
ASTM D 5084	Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.
ASTMD 5199	Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
ASTM D 5596	Standard Test Method for Microscopic Evaluation of the Dispersion of Carbon Black in Polyolefin Geosynthetics.
ASTM D 5641	Standard Practice for Geomembrane Seam Evaluation by Vacuum Chamber.
ASTMD 5820	Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes.
ASTM D 5994	Standard Test Method for Measuring Core Thickness of Textured Geomembrane.
ASTM D 6392	Standard Test Method for Determining the Integrity of Non-reinforced Geomembrane Seams Produced Using Thermofusion Methods.
ASTM 6496	Standard Test Method for Determining Average Bonding Peel Strength Between the Top and Bottom Layers of Needle-Punched Geosynthetic Clay Liners.
ASTM D 6693	Standard Test Method for Determining Tensile Properties of Non-reinforced Flexible Polyethylene and Non-reinforced Polypropylene Geomembranes.
ASTM D 6938	Standard Test Methods for In-Place Density and Water Content of Soil and Soil-Aggregate in Place by Nuclear Methods (Shallow Depth).

Geosynthetic Research Institute (GRI):

GRI GC7	Determination of Adhesion and Bond Strength of Geocomposites.